Counting Beddies (Baltic Sea eddies)

Counting eddies in the Baltic Sea - physical assessment and biological implications

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In Short

- Counting eddies in the Baltic Sea
- Quantification of mass transport
- Eddy driven nutrient transport

Eddies are a typical flow structure in the ocean. Their distribution and impact has been studied both in the global ocean and on regional scales. These studies are based on measurement campaigns, satellite data, or on eddy-resolving ocean model output. More precisely, eddies' lifetimes, propagation distances, sizes or Rossby numbers are studied to characterise the detected eddies. Most of the studies are based on two-dimensional velocity fields. However, an eddies' vertical extent strongly influences the estimate of transported volume and vertical transport processes inside the eddy. Therefore, three-dimensional eddy studies are necessary for a precise understanding.

A precondition for reliable detection of eddies is an applicable mathematical definition and a suitable automatic identification algorithm. This algorithm can be either based on flow geometry (Eulerian measures) or Lagrangian measures. The Eulerian measures are based on an eddy definition by circular or spiral streamlines around the core of an eddy calculated from the velocity field. A variation of this concept is the winding angle method. It is taking changing directions along the streamlines into account. Additionally, anomalies regarding the sea surface height or the sea surface temperature are used for the Eulerian eddy definition.

Lagrangian measures are a very diverse group. Nonetheless, all of them are based on the dynamical system theory to detect organising structures in the ocean flow. These organising structures are so-called Lagrangian coherent structures (LCS). They are distinguished curves or surfaces which influence the behavior of all nearby fluid trajectories for a given period and lead to the formation of fluid (trajectory) patterns. The repelling or attracting properties of these LCS, and their evolution in time, are very useful for the definition of eddies.

Recent studies showed a strong impact of eddies on plankton patches' development by isolating water masses and thereby triggering or suppressing algal blooms. These studies described such

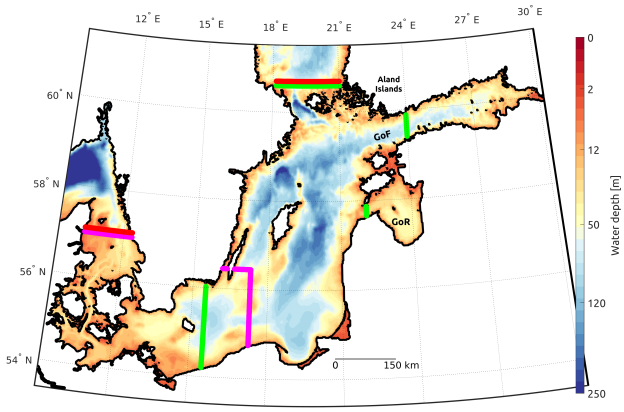

Figure 1: Waterdepth of the Baltic Sea. The magenta lines mark the boundary of the western Baltic Sea setup, the green line the central Baltic Sea setup and the red line the merge of both.

effect not only on local but also on global scales. In a nutrient-plankton-zooplankton modeling study it could be shown that this inhomogeneous nutrient distribution favors the plankton's inhomogeneous dominance patterns. The inhomogeneity in nutrients is produced due to the hydrodynamical motion like in an artificial vortex street. This effect is dependent on the match of hydrodynamical and biological time scales, as well as on the entrainment of the nutrient within the eddy. Additionally, mesoscale eddies and turbulent flows are one candidate to explain the paradox of plankton and biodiversity pattern formation. The paradox of plankton is the coexistence of more competitive species than the number of limiting resources.

To study eddies' impact on the ecosystem, especially on algal blooms, a water body suffering from recurring algal blooms and high nutrient loads is of particular interest. An example of such a water body is the Baltic Sea, which is, on the one hand well assessed concerning the ecological status but, on the other hand lacking information on eddy distribution and dynamics. The nearly-tideless, semi-enclosed Baltic Sea is topographically characterised by limiting sills, steep slopes, deep basins and topographic wakes. The combination of limited water exchange with the North Sea through the Danish strait and the basin structure result in a stratification of the Baltic Sea. Diverse layers are of interest in this context. Most important is a halocline in 40-80 m depth (in shallower parts even less) and a seasonal summer thermocline in 15-25 m depth, decoupling the warm, well mixed, low saline summer layer and deeper layers. Furthermore, a cold intermediate layer called winter water is a final remain of the upper layer in

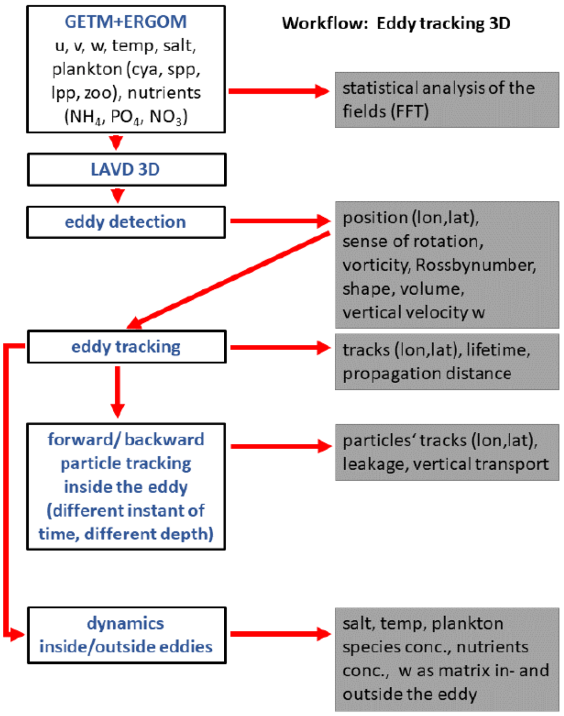

Figure 2: *Schematic sketches of the eddy data analysis pipeline. White boxes denote calculation steps and grey boxes indicate output.*

winter and can be found in 30-50 m depth between the summer thermocline and the halocline. Occasionally occurring major Baltic inflows can interrupt limited water exchange with the North Sea by large inflow events of saltier water in the bottom layer.

Our study's general scope is to study eddies' effects on the Baltic Sea physics and biogeochemistry. Since this is already a challenging task, we limit ourselves to the dynamics of the Gulf of Finland, the central Baltic Sea, and the western Baltic Sea. With our study, we aim at answering four main questions.

1. What is the three-dimensional shape of eddies?
2. How pronounced is the vertical transport within three-dimensional eddies?
3. Which influence do three-dimensional eddies have on biological processes?

In previous studies, we used separate setups for the western Baltic Sea (Gräwe et al. (2015), magenta line Fig. **??**, mvk00080) and the central Baltic Sea (Holtermann et al. (2014), green line Fig. **??**, mvk00053). Both have a spatial resolution of 1/3 nautical mile (approx. 600m). During the studies of Vortmeyer-Kley et al. (2018a) and Vortmeyer-Kley et al. (2018b), we realised that, especially in both setups' overlap regions, boundary artefacts were present. To avoid those effects and improve the dynamic representation of inflows into the central Baltic Sea, we combined both setups. Additionally, we added the remaining part of the Gulf of Finland and the Gulf of Riga. Now, we have a numerical setup covering the entire Baltic Sea, except the Gulf of Bothnia. Since we kept the original resolution of 600 m, the newly created setup is still eddy-resolving. At present, this will be the largest setup used so far at IOW. It will have a size of 2300×1400 grid points. After successful calibration, it will mainly be used for annual or multi-annual simulations. The numerical ocean model, used in this study, will be the General Estuarine Transport Model (GETM, https://getm.eu).

WWW

https://www.io-warnemuende.de

More Information

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Project Partners

University of Oldenburg

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