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A 35-year hindcast for the Baltic Sea (1980-2014) - a statistical analysis

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The Baltic Sea is a semi-enclosed sea with limited water exchange. The most important process that leads to deep water renewal of the Baltic Sea are inflows of dense, saline North Sea water. These water masses have to pass narrow channels and sills in the Danish Straits and three basins with increasing depth. Along this path, the inflowing gravity currents are subject to entrainment, vertical and horizontal mixing. Thus, physical and numerical mixing are crucial for the proper propagation of these inflows. Additionally, a permanent halocline and a summer thermocline are challenging for state of the art ocean models. Moreover, Holtermann et al (2014) could show, that boundary mixing in the deep basins dominates the vertical mixing of tracers.

To tackle these challenges, we used the General Estuarine Transport Model (GETM) to give a state estimate for the Baltic Sea for the period 1980-2014. The setup has a horizontal resolution of 1 nm. In the vertical, terain following coordinates are used. A special feature of GETM is that it can run with vertical adaptive coordinates. Here we use an adaptation towards stratification. The minimum layer thickness is limited to 30 cm. We also include the effects of wind waves (by radiation stresses, and changes in the bottom stresses) into our simulations. The atmospheric forcing is taken from the global reanalysis of the NCEP-CFSR (Saha et al 2011) with a spatial resolution of 30 km and hourly values.

The model validation at selected stations in the Baltic Sea shows an average Bias of ± 0.15 psu and a RMSE of 0.4 psu. These values are similar to the data assimilation runs of Fu et al (2011) or Liu et al (2013). However, one has to note that our simulations are free runs without any nudging or data assimilation.

Driven by the good performance of the model, we use the model output to provide a state estimate of the actual climate period (1980-2010). The analysis includes a quantification and estimation of:

1. surge levels with a 30-year return period
2. temperature maxima with a return period of 30 years (in the surface and bottom waters)
3. duration of heat waves
4. warming and desalination trends
5. age of water masses with last surface contact

The presented model results might act as a reference to compare climate projections with the present state of the Baltic Sea. Moreover, the model system will act as inner core of a coupled hydrodynamic-biogeochemical model (ERGOM).

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