Oceanographic studies of the Baltic Sea with emphasis on sea ice and mixing processes.

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Doctoral Thesis in Oceanography

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Abstract

This thesis comprises of model estimates of the water and heat budgets, re-estimating of the budget of deep-water mixing energy, model studies of generation mechanisms for internal waves, sea ice dynamics and finally sea ice monitoring. Common site for all the studies are the Baltic Sea.

A Baltic Sea model was used as a tool for synthesizing available data to be able to analyze the Baltic Sea water and heat balances. The accuracy in the long-term water and heat balances was quantified, while the accuracy of the individual terms is still unknown. The study illustrates the possibility of negative precipitation minus evaporation rates. The calculated inter-annual variability of the heat loss between atmosphere and Baltic Sea indicates large variations (± 10 Wm^{-2}). Despite an atmospheric warming no trend was seen in the annual mean water temperature.

Computations suggest that breaking internal waves, generated by wind forced barotropic motions, contribute significantly to the diapycnal mixing in the deep water of the Baltic Sea. Similar computations have previously been performed for tides in the World Ocean. However, the primary driver of barotropic motions in the Baltic Sea is the local weather. This causes the generated internal waves to have periods well above the inertial period. The stochastic forcing and the complex topography imply that the described energy transfer can be quite efficient even though the waves have super inertial periods. The diffusivity due to the dissipation of the barotropic motion conforms to earlier estimates and this mechanism also explains observed seasonal and spatial variations in vertical diffusivity.

Ice motion and ice thickness in the center of the Bothnian Bay was monitored with a bottom mounted ADCP for an entire winter season. The ice motion was primarily driven by the wind but with a clear influence of internal ice stresses and ice thickness. A rough force balance computation gave compressive ice strength 4 times larger than normally used in numerical ice models. The ridges made up 30-50% of the total ice volume showing that dynamical processes are important for the total ice production.

The development of a dynamic ice model includes a novel viscous-plastic approach where a memory of weak directions in the ice cover were stored. The model computes the ice motion, the ice deformation and the associated dynamic ice production and the results shows good agreement when compared with measurements of ice velocity from the ADCP. The results also show that the dynamic ice production typically increases the ice volume with 80% over the simulation period.

Key words: Baltic Sea; Water and Heat budgets; Deep-water mixing; Internal Wave-drag; Dynamical Sea Ice production; Sea Ice dynamics