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Modelling density-driven currents in Lake Constance

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In deep monomictic Lake Constance, vertical mixing has a great influence on the distribution of substances and therefore on biological and chemical processes. Besides convective overturn in winter, density currents of cold or turbid water can bring surface water with high oxygen content into the hypolimnion of the lake. In times of climate change, when hibernal total circulation is likely to become more seldom, this source of hypolimnetic oxygen might become more important.
Cold density currents can be caused by differential cooling, when in winter shallow littoral parts of the lake cool faster than the pelagic zone. Measured profiles of temperature, oxygen, phosphorus and silica at the deepest point of the lake indicate several differential cooling events during the last 20 years.
Turbidity currents, in which the increased density is induced by high concentrations of suspended solids due to flood flows in the tributaries, occur mainly during summer. A well documented example is the flood flow in the Alpine Rhine and the Bregenzer Ach in august 2005. Due to heavy rain in the Alps the discharge in the Alpine Rhine reached 2600 m^3/s, which corresponds to a 100-year flood. The Institute for Lake Research realised a large measurement program to document the effects of the flood flow on the lake: the fluvial water covered a distance of at least 20 km and reached the deepest point of the lake in 254 m depth, where it was detected as an increase of temperature from 4.3 °C to 8 °C only a few hours after the peak inflow. Several days after the event, the fluvial sediments were detected as increased turbidity at the drinking water outtakes around the lake.
Increased concentrations of suspended solids can also be caused by resuspension of fine material from the lake bottom. This can be either wind induced due to currents and surface waves in the littoral zone, or caused by the density currents, which by resuspension can experience amplification.
The three dimensional hydrodynamic and water quality model ELCOM-CAEDYM is able to model both cold and turbid density currents. The suspended solids module of the model accounts for the impact of the sediment load on water density. Settling is considered using Stokes Law, and resuspension can also be included.
By comparing model output with measured data, the model system can be evaluated with regard to integrating the effects of density currents in climate change scenario simulations.