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Underflows in Lake Constance – Numerical Modeling, Instrumental Observations and Sediment Data

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A torrential rain event in the western Alps in August 2005 caused high flood flows in the rivers Alpine Rhine and Bregenzer Ache which are the main tributaries into Lake Constance. The discharge of the Alpine Rhine reached 2200 m^3/s, which is little below a centennial flood event. Discharge of the Bregenzer Ache was estimated to 1350 m^3/s which statistically occurs every 100 yr but with a 1000 yr frequency in selected smaller tributaries. The high concentration of suspended solids in the fluvial water increased its density and created an underflow with considerable influence on the lake's hydrodynamics and water quality.
Consequences within the lake were directly registered by a mooring (equipped with thermistor chain, sediment trap, current meter, oxygen sensor). Spatial data of the path and form of suspended matter cloud within the lake were gathered using echo sounder and probe measurements (turbidity, temperature, salinity). An underflow with a temperature of 14°C flew with 1.4 km/h some 20 km into the lake. Several days after the event, the fluvial sediments were detected as increased turbidity at the drinking water outtakes around the lake.
Sediment cores recovered from the lake bottom show the distribution pattern of the sediments while sidescan data give a picture from proximal sediment structures originating from this event.
Further, we modelled this underflow using the three dimensional hydrodynamic and water quality model ELCOM-CAEDYM. 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. The simulation of the August 2005 flood event and comparison with measured data impressively showed the ability to reproduce the most important effects of the flood flow on the lake. Comparative simulations with and without consideration of the coriolis effect indicate an influence of the coriolis force on the flow path of the density current.