Detailed hydrodynamics of cold density currents generated by differential cooling along the sloping bed of Lake Geneva

François Mettra, Rafael Sebastian Reiss, Ulrich Lemmin, David Andrew Barry

Ecological Engineering Laboratory (ECOL), Institute of Environmental Engineering (IIE), Faculty of Architecture, Civil and Environmental Engineering (ENAC), Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne

Corresponding author: francois.mettra@epfl.ch

Deep water ventilation and mixing are of great importance for large lake ecosystems. Relevant processes include cold density currents due to differential cooling, inter-basin exchange and upwelling. At present, a good understanding of these processes in large lakes under realistic external forcing is still missing, which prevents, for example, to assess their relative contribution to and their evolution with climate change. Cold density currents bring cold surface water with oxygen and potential pollutants from coastal regions to the deep layers of the lake along the sloping boundaries. Earlier hydrodynamic studies allowed determination of the general behavior of those currents in Lake Geneva (Fer et al., 2001, 2002). With the recent advances in instrument capabilities, we were able to collect more detailed field data in the bottom boundary layer. In this study, we present preliminary results on the hydrodynamics of cold density currents generated by differential cooling using a unique high spatial and temporal resolution dataset.

Acoustic Doppler Current Profilers (ADCPs) and vertical thermistor lines were deployed during the winter season on the northern shore of Lake Geneva on the shallow shelf and along the sloping lakebed. In addition, CTD (Conductivity-Temperature-Depth) profiles were taken during periods of strong cooling in order to obtain a broader view of the temperature field along a cross-shore transect. After a cold, calm night, strong differential cooling forms between the shallow shelf and the open lake, initiating cold dense water from the shelf that flows as pulses along the sloping lakebed. Analysis of the velocity profile shows that the maximum velocity is relatively close to the bed, as would be expected for a density current. However, the height above the lakebed of this maximum velocity fluctuates depending on the stage of the flow (accelerating or decelerating). During the accelerating stage, i.e., at the beginning of a new pulse, the flow is thick enough to elucidate details of the velocity profiles close to the boundary – the measured profiles are logarithmic, as expected for a boundary flow (e.g., Kneller et al., 1999). Moreover, this new dataset enables us to determine the stability of the flow and the entrainment of the ambient water into the density current.

REFERENCES

Fer, I., Lemmin, U., & Thorpe, S. A. 2001: Cascading of water down the sloping sides of a deep lake in winter. Geophysical Research Letters, 28(10), 2093-2096.

Fer, I., Lemmin, U., & Thorpe, S. A. 2002: Winter cascading of cold water in Lake Geneva. Journal of Geophysical Research: Oceans, 107(C6), 13-1.

Kneller, B. C., Bennett, S. J., & McCaffrey, W. D. 1999: Velocity structure, turbulence and fluid stresses in experimental gravity currents. Journal of Geophysical Research: Oceans, 104(C3), 5381-5391.