Transport and mixing in Lac Léman

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Lake Geneva (Lac Léman) is the largest freshwater body in Western Europe. It is a deep peri-alpine lake whose importance stems from being not only an essential freshwater source in the region, but also a major tourist destination, a fishery and a waterway. Its dynamics have been the subject of long-term monitoring and study, and its response patterns to wind forcing (the major forcing) are relatively well understood (e.g. Lemmin et al. 2005). On the other hand, the large-scale organisation of the water circulation is less well known; the associated transport properties are even less clear.

The interest in the transport of water parcels inside the lake is linked to the inflow of sediments and pollutants from the tributaries, in particular from the Rhône River, the major one in terms of water and sediment discharged into the lake. Most of the sediments entering the lake through the Rhône are believed to sink in the eastern part of the lake (Giovanoli, 1990). More recently, Halder et al. (2013) traced, using stable isotopes, water parcels from the Rhône River in the entire lake basin. This study demonstrates that the water entering the lake from its main tributary has a complex distribution inside the whole basin. How this distribution is established and evolves in time is, however, mostly unknown.

The Ecological Engineering Laboratory of EPFL is trying to shed further light on this issue, by combining observational and numerical modelling tools. In particular, up to 6 Acoustic Doppler Current Profilers (ADCP's) have been simultaneously deployed at various locations inside the lake. This data, together with available historical data, is being used to validate a hydrodynamic model of the lake, implemented using Delft3D code.

Various passive-tracer release experiments were conducted using the numerical model, investigating the relative importance of wind-forcing, depth of release, stratification, and the Rhône discharge rate, for the spreading and mixing of the tracers. The preliminary numerical results confirm that the northern and southern coastal regions are preferred initial pathways for the transport of the Rhône discharge. More interestingly, the numerical simulations unmistakably show that the transport of the Rhône River water inside the lake is highly inhomogeneous in space, and highly intermittent in time, even ignoring the discharge variability itself. This intermittency should be taken into account, in particular when interpreting point measurements, isolated in time. From a practical point of view, this is likely to have an important effect on the nutrient and oxygen availability, as well as on the concentration of pollutants. From a more fundamental point of view, this study contributes to further understanding the mixing processes in rotating, stratified flows at length scales where rotation is an important but not the only dynamic process (Rossby number small but non-zero).
Figure 1. Filled-contours plot (logarithmic scale) of the simulated concentration of a passive tracer released from the Rhône river mouth (south-eastern end of the basin). The figures shows the results approximately 4 months after the beginning of the numerical simulation.

REFERENCES