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## Modelling the main factors leading to ice formation on lakes

Marco Toffolon (1), Luca Cortese (1,2), and Damien Bouffard (2)

(1) University of Trento, Department of Civil, Environmental and Mechanical Engineering, Trento, Italy (marco.toffolon@unitn.it), (2) Eawag, Department Surface Waters Research & Management, Kastanienbaum, Switzerland

The process of formation of the ice sheet at the lake surface in winter is governed by two main factors: the heat loss related to the atmospheric cooling and the mixing of the surface layer produced by the wind. The two factors play an opposite role in determining the time required for the ice formation: more intense wind increases the thickness of the mixed surface layer, increasing the heat capacity of the volume directly reacting to the external cooling, and hence reducing the rate of decrease of water temperature. Conversely, an increased wind could enhance the heat exchange at the lake surface, thus increasing (with the same air temperature) the cooling effect. The dynamics is even more complex because it depends on several atmospheric variables, possibly correlated with each other, and because the sequence of cold and warm days, i.e. the history of the system, controls the actual realization of the process.

The focus of this work is the period of inverse stratification in dimictic lakes that goes from the fully mixed condition at the temperature of maximum density, around 4°C, to the freezing of the surface. A minimal model was developed to simulate the water temperature dynamics in this period, based on the change of thermal energy due to cooling, which is associated with the change of potential energy in stratified conditions, and the mixing energy provided by the wind. Such a simple model allowed us to analyse the statistics of a large number of morphological cases and different histories of the systems, leading to a probabilistic characterization of varying lakes and climates. As a verification, the results of the minimal model were checked against the behaviour of five Swiss lakes, as reconstructed on the basis of available measurements and numerical results obtained using the one-dimensional model Simstrat. The main advantage of the simplified approach lies in the possibility to perform uncertainty analyses easily, whereby we can show that some general dynamics can be identified also for this complex process.