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Freezing of lakes on the Swiss Plateau 1865-2100: combining long-term observations with modelling

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The frequency of lake freeze-up on the Swiss plateau is a sensitive indicator of changes in central European winter climate. Whereas smaller and more shallow lakes are reported to completely freeze in more than 50% of the winters, large and deep lakes like Bodensee and Zurichsee only froze one to very few times during the 20th century. The ice cover lasted between some days and up to three months. The periodic freezing of lakes on the Swiss plateau exerts considerable public attraction and is, in some cases, even an economic factor.

In this study, we rely on an exceptional data set presented by Hendricks-Franssen and Scherrer (2008) providing complete series of freeze-up events for a dozen lakes on the Swiss plateau since 1901 based on direct observations. A new physically-based 1-D model for the energy balance and the thermodynamics of lake ice is presented and validated against the long-term observations. The model is driven with measured meteorological data as well as with results of 10 regional climate models. We apply the model to compute continuous series of freeze-up events between 1865 and 2100 for 14 Swiss lakes. In addition, the model calculates the time evolution of the ice thickness and the corresponding bearing capacity.

We discuss the potential of the model for simulating lake freeze-up events over the last century in connection with the direct observations and simplified approaches for estimating lake ice formation. Changes in freezing frequency are analysed over a period of more than 200 years extending from the beginning of the instrumental record into the future. Until 2050, freezing is still possible even for medium-sized lakes in extreme winters. Towards the end of the 21st century, however, lakes on the Swiss plateau are unlikely to freeze during winter with the exception of rare events on small lakes. For an additional study site located at higher elevation in the Alps the model predicts annual freezing until 2100 but with strongly reduced duration and ice thickness.