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Variability in response of lakes to climate change explained by surrounding watersheds

Love Råman Vinnå (1), Alfred Wüest (1,2), Damien Bouffard (1,2)

(1) Physics of Aquatic Systems Laboratory, Margaretha Kamprad Chair, École Polytechnique Fédérale de Lausanne, Institute of Environmental Engineering, Lausanne CH-1015, Switzerland, (2) Eawag, Swiss Federal Institute of Aquatic Science and Technology, Surface Waters Research and Management, Kastanienbaum, Switzerland

The consequences of climate change for inland waters have been shown to vary extensively not only globally, but also on a sub-regional scale [O'Reilly et al., 2015, GRL]. Local factors affecting heating include morphology [Toffolon et al., 2014, LO], irradiance absorption [Williamson et al., 2015, SR], local weather conditions and onset of stratification [Zhong et al., 2016, LO] as well as ice conditions [Austin and Colman, 2007, GRL]. However, inland waters are often a complex web of rivers, streams, lakes and reservoirs. Thereby, to correctly assess and predict future changes in lakes/reservoirs due to climate change, it is important to consider the changes occurring in the surrounding watersheds and how they affect downstream waters.

Here we evaluate the impact of climate change on rivers originating in the Swiss Alps (Aare and Rhône) and downstream located perialpine lakes (Lake Biel and Lake Geneva). We use regional predictions for air temperature increase and the subsequently expected shift in river discharge regime under the A1B emission scenario [Bey et al., 2011, CH2011; Federal Office for the Environment FOEN, 2012, CCHydro]. Focus is on predicting the changes in water temperature, particle content, stratification and deep water renewal rate using the 1D SIMSTRAT [Goudsmit et al., 2002, JGR] and Air2Stream [Toffolon and Piccolroaz, 2015, ERL] models. We show that the effect of tributaries on the reaction for downstream lakes to climate change are inversely proportional to the hydraulic residence time of the systems. We furthermore include known changes in anthropogenic thermal emissions, which in Lake Biel correspond to $\sim$2 decades of climate induced warming. Our results are put into context with future water utility plans in Lake Biel.