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Physical responses of small temperate lakes to variation in dissolved organic carbon concentrations

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Abstract

We used a mechanistic physical model to examine the effect of variability in dissolved organic carbon (DOC) concentrations on the physical properties of small temperate lakes. The model was validated on eight small (6×10^{-4} to 3.8×10^{-2} km^2) lakes in Wisconsin and Michigan, with a standard error $< 1^{\circ}$C for seven of eight lakes. Attenuation of photosynthetically active radiation (400–700 nm) in these lakes was regulated by DOC concentrations and was important in the vertical structuring of water temperatures. Heat exchange below the surface mixed layer was near the molecular rate, increasing the importance of water clarity as a control on the heat content of deeper waters. To understand the thermal effects of changing DOC concentrations, we applied scenarios of a 50% increase and 50% decrease in DOC concentrations for one lake (Trout Bog) and found water temperatures to vary in response, with the seasonally averaged temperatures in the increased DOC scenario being $> 2^{\circ}$C colder than the reduced scenario. We found a nonlinear relationship between DOC and temperature, with clearer (lower DOC) simulations being more sensitive to climate variability, suggesting that DOC may act as a buffer against a warming climate. Our model showed that DOC also influenced epilimnetic depths, as nocturnal mixing (related to the vertical partitioning of heat) was more important than wind-driven mixing. Small lakes are globally important regulators of biogeochemical cycles and are structurally different from larger lakes. Important feedbacks to physical processes must be accounted for when understanding the effects of changing DOC and climate on small lakes.