EGU2020-22197
https://doi.org/10.5194/egusphere-egu2020-22197
EGU General Assembly 2020

Dynamic carbon-oxygen interactions over minute to annual time scales in an experimentally-oxygenated reservoir

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Oxygen dynamics in lakes and reservoirs are changing worldwide due to human activities. Changing hypolimnetic oxygen conditions will substantially alter carbon cycling in aquatic ecosystems, as oxygen dynamics near the sediment-water interface regulate whether carbon inputs will be buried, respired as carbon dioxide, or respired as methane. At the decadal scale, warming temperatures and increased nutrient loads are increasing the prevalence and duration of anoxia. Conversely, at the daily scale, mixing due to more powerful storms may periodically increase hypolimnetic oxygen availability. It remains unclear, however, how carbon quantity and quality will respond to these changes in oxygen at different time scales. Our team used unprecedented whole-ecosystem manipulations of hypolimnetic oxygen concentrations in a eutrophic reservoir to identify how changes in oxygen at different time scales (i.e., weeks to months) alter freshwater carbon processing, burial, and greenhouse gas emissions. Against the backdrop of multiple-week shifts between oxic and anoxic conditions in the bottom waters of the experimental reservoir over multiple years, we observed that the dominant scale of variability in dissolved organic matter (DOM) concentrations was predominantly at the daily scale in the summer and monthly scale in the winter. At the monthly time scale, dissolved oxygen concentrations controlled DOM; at the daily time scale, water temperature and photooxidation controlled DOM. Modeling and field results show that intermittent week-long oxic conditions mineralized “legacy” carbon that had accumulated over years of sedimentation and changed the dominant terminal electron acceptor pathways used for mineralization on the daily scale. Building off of this work, future oxygenation experiments will examine the role of alternate electron acceptors in carbon release from sediments on the daily scale, the impact of carbon quality on carbon processing under varying oxygen conditions at the daily to week scale, and the effects of future oxygen scenarios on carbon cycling in lakes and reservoirs around the world on the annual to decadal scale.