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Spatiotemporal variability of carbon dioxide and methane in a eutrophic lake

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Lakes are important regulators of global carbon cycling and conduits of greenhouse gases to the atmosphere; however, most efflux estimates for individual lakes are based on extrapolations from a single location. Within-lake variability in carbon dioxide (CO_2) and methane (CH4) arises from differences in water sources, physical mixing, and local transformations; all of which can be influenced by anthropogenic disturbances and vary at multiple temporal and spatial scales. During the 2016 open water season (March – December), we mapped surface water concentrations of CO_2 and CH4 ∼weekly in a eutrophic lake (Lake Mendota, WI, USA), which has a predominately agricultural and urban watershed. In total we produced 26 maps of each gas based on ∼10,000 point measurements distributed across the lake surface. Both gases displayed relatively consistent spatial patterns over the stratified period but exhibited remarkable heterogeneity on each sample date. CO_2 was generally undersaturated (global mean: 0.84X atmospheric saturation) throughout the lake's pelagic zone and often differed near river inlets and shorelines. The lake was routinely extremely supersaturated with CH4 (global mean: 105X atmospheric saturation) with greater concentrations in littoral areas that contained organic-rich sediments. During fall mixis, both CO_2 and CH4 increased substantially, and concentrations were not uniform across the lake surface. CO_2 and CH4 were higher on the upwind side of the lake due to upwelling of enriched hypolimnetic water. While the lake acted as a modest sink for atmospheric CO_2 during the stratified period, the lake released substantial amounts of CO_2 during turnover and continually emitted CH4, offsetting any reduction in atmospheric warming potential from summertime CO_2 uptake. These data-rich maps illustrate how lake-wide surface concentrations and lake-scale efflux estimates based on single point measurements diverge from spatially weighted calculations. Both gases are not well represented by a sample collected at lake's central buoy, and thus, extrapolations from a single sampling location may not be adequate to assess lake-wide CO_2 and CH4 dynamics in human-dominated landscapes.