Spatial and temporal dynamics of pCO$_2$ and CO$_2$ flux in tropical Lake Malawi

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Numerous studies have documented CO$_2$ dynamics in temperate lakes, but only a handful of such studies have been conducted on tropical lakes. In this study, spatial and seasonal variation of air and water pCO$_2$, along with supporting limnological and meteorological variables, were measured along the north-south axis of Lake Malawi aboard a vessel of opportunity. These measurements were used to estimate annual net lake-air CO$_2$ flux and infer mechanisms regulating it. Lake surface pCO$_2$ and CO$_2$ flux varied significantly with season and location. Temporally, the lake was CO$_2$ undersaturated during the rainy season (December–March) and the mixing season (July–September), while it was CO$_2$ supersaturated at the onset of the mixing season (May) and during the stratified season (October). Concurrent measurements of lake thermal structure, weather conditions, phytoplankton biomass and seston $\delta^{13}$C suggest that increased nutrient supply due to vertical mixing and allochthonous nutrient inputs promotes high phytoplankton growth rates and net CO$_2$ uptake during the mixing and rainy seasons. Unlike the rest of the lake, the southernmost region of the lake was usually CO$_2$ supersaturated, even though phytoplankton productivity is highest in this region. While the upwelling of hypolimnetic water at the southern end of the lake is a major source of nutrients that drive phytoplankton photosynthesis and CO$_2$ uptake, the CO$_2$ introduced in upwelled water appears to overwhelm the photosynthetic capacity of the lake, especially at the onset of the mixing season. Over an annual cycle, the lake appears to be a net CO$_2$ sink with a mean CO$_2$ flux from the atmosphere to the lake of $1,005\pm99$ mmol C m$^{-2}$ yr$^{-1}$. This contrasts with observations for many temperate lakes and may be due to the efficiency of phosphorus recycling in Lake Malawi.