Chesapeake Bay acidification: relative impacts of long-term local and global stressors

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Multiple anthropogenic stressors have been impacting the Chesapeake Bay carbonate (CO_2) system over the past several decades. These include global-scale increases in atmospheric temperature and CO_2 concentration, and local-scale changes in riverine nutrients and alkalinity. Because these stressors impact physical and biogeochemical processes, the Bay CO_2 system is likely to undergo complex long-term changes that are challenging to study via analysis of in-situ data alone. Historical pH data collected since 1996 showed surface pH has been decreasing with rates of up to -0.08 pH unit decade^{-1} from May to September. Global increases in atmospheric CO_2 concentration are expected to decrease pH by -0.02 pH unit decade^{-1}; however, it is difficult to quantify the impacts of other stressors (e.g. changing nutrients) on pH trends. We examine and identify the primary drivers of this long-term trend in Chesapeake Bay CO_2 system using a 3D physical-biogeochemical estuarine model. A reference simulation is conducted from 1985-1989. Sensitivity simulations conducted from 2015 to 2019 are used to study the global vs. local stressors that are responsible for the changes in CO_2 system over 30 years. Model results indicate that global increases in atmospheric CO_2 concentration and local reductions in nitrogen loading are two primary stressors causing similar long-term changes in Chesapeake Bay CO_2 system. Increased atmospheric CO_2 and temperature together reduced surface pH and aragonite saturation state (Ω) by 0.2 units and 0.4 over 30 years, respectively. Reduced riverine inorganic and organic nitrogen concentrations result in similar decreases in surface pH and Ω, indicating that nutrient management efforts in the Bay watershed may be exacerbating acidification in surface waters; however, nutrient reduction may improve bottom pH in the deep mainstem due to decreased respiration. In comparison, long-term increases in riverine alkalinity and dissolved inorganic carbon inputs, together, barely impact surface pH while increase surface Ω by 0.1. This work suggests that a complex combination of global and local anthropogenic stressors are responsible for observed long-term CO_2 system changes in estuarine systems.