Drivers of surface ocean acidity extremes in an Earth system model

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Oceanic uptake of anthropogenic carbon causes acidification, a process that describes the increase in hydrogen ion concentrations ([H$+̂$]) and decrease in calcium carbonate mineral saturation states (Ω). Of particular concern are ocean acidity extreme (OAX) events, which pose a significant threat to many calcifying marine organisms. However, the mechanisms driving such extreme events are not well understood. Here, we use high-frequency output from a fully- coupled Earth system model of all processes that influence the surface ocean temperature and carbon budgets and ultimately [H$+̂$] and Ω anomalies to quantify the driving mechanisms of the onset and decline of high [H$+̂$] and low Ω extreme events. We show that enhanced temperature plays a crucial role in driving [H$+̂$] extremes, with increased net ocean heat uptake being the dominant driver of the event onset in the subtropics. In the mid-to-high latitudes, decreased downward vertical diffusion and mixing of warm surface waters during summer, and increased vertical mixing with warm and carbon-rich subsurface waters during winter are the main drivers of high [H$+̂$] extreme event onset. In the tropics, increases in vertical advection of carbon-rich subsurface waters are the primary driver of the onset of high [H$+̂$] extremes. In contrast, low Ω extremes are driven in most regions by increases in surface carbon concentration due to increased vertical mixing with carbon-rich subsurface waters. Our study highlights the complex interplay between heat and carbon anomalies driving OAX events and provides a first foundation for more accurate prediction of their future evolution.