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Ocean Acidity Extremes Altered by Variability Changes

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The uptake of anthropogenic CO_2 by the ocean reduces the increase in atmospheric CO_2, but causes ocean acidification, i.e. a decrease in both pH and calcium carbonate saturation. On top of this secular change, recent studies suggest that the seasonal cycle in ocean acidity will strongly change over the 21^{st} century because of the nonlinearity in carbonate chemistry of the ocean seawater. An increase in variability potentially leads to more frequent and intense short-term ocean acidification extreme events.

Here, we use daily output from global warming simulations with a comprehensive fully coupled Earth system model (GFDL ESM2M) to quantify the impact of changes in daily, seasonal and interannual variability in ocean acidity ([H^+]) on changes in different extreme event characteristics. The impact of variability changes on extremes is isolated by adding the mean shift of the distribution from the secular change to the preindustrial threshold (the 99^{th} percentile). We show that an increase in the variability of [H^+] leads to a strong increase in the occurrence of extreme events and to large changes in their characteristics at the global scale. The number of days with extreme [H^+] conditions for surface waters more than doubles by the end of the 21^{st} century compared to present day under the RCP4.5 greenhouse gas emission scenario. At the same time, the duration and maximal intensity of individual events increase by about 50%. At subsurface, where extreme events tend to be longer lasting and more intense, similar trends in duration and intensity are simulated, but the model projects a six-fold increase in the number of extreme event days. In addition, the volume extent of individual extreme events in the upper 200m of the water column triples over the 21^{st} century. We show that the increase in the [H^+] seasonality is the dominant driver of changes in [H^+] extreme events at the surface, whereas changes in interannual and daily variability are of similar importance at 200m depth. Present day in-situ [H^+] observations are analysed to constrain the model's capability of representing short-term variability in seawater acidity. An increase in variability and extreme events in ocean acidity under future global warming will probably increase the risk of severe and detrimental impacts on marine organisms, especially on those that are adapted to a more stable environment.