The future of marine heatwaves and biogeochemical extremes in the California Current System

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As a hotspot for future change, the California Current System (CalCS) is expected to undergo drastic changes in the frequency and intensity of marine extreme events, such as marine heatwaves (MHWs), high acidity, or low oxygen extremes. Yet, most existing projections of future extreme statistics are limited in skill, as they rely on relatively coarse resolution global coupled model simulations that do not fully resolve mesoscale variability, which is an important driver for many extremes. In this study, we investigate how extreme events in the CalCS will change towards the end of the 21st century under strong global warming, using kilometer-scale simulations conducted with the coupled regional ocean-atmosphere model (ROMSOC). To do so, we perform a control hindcast for the present day (2011-2021) and replicate this simulation by adding a climate change delta corresponding to the high emission future scenario (SSP585). In this pseudo-global warming approach, we derive the climate change delta from the MPI-ESM-1.2-HR model at the end of the 21st century (2070-2099 average). From the daily output of the high-resolution simulations, we detect extremes by applying a seasonally varying 90th (10th) percentile across the upper water column. We find that the frequency and intensity of surface MHW days increases drastically in the coastal CalCS (about 6 times more MHWs in the SSP585 scenario than in the present day run), although to a lesser degree than in the offshore Northeast Pacific, where MHW days occur up to 10 times more frequently. While the mean duration of surface MHWs in the coastal CalCS remains relatively unchanged between present day and future conditions, offshore MHW durations increase more than tenfold, with conditions tending towards a near-permanent extreme state in the future. These results indicate that the highly variable coastal upwelling along the US west coast can partially mitigate the rise of surface MHWs driven by long-term ocean warming. Interestingly, we find that the increase in MHW days shows a generally reversed cross-shore behaviour in the subsurface. For instance, at 200m depth, we find a 10-fold increase in coastal MHW days, which is about 30% more pronounced than the increase in offshore MHW days. As a generalising result, we find that the local multiplicative increase in extreme days scales to first order with the local ratio between the long-term warming signal and the standard deviation of the present day deseasonalized temperature variability (Pearson's $r > 0.8$). Our analyses, which also include biogeochemical variables, offer relevant insights for ecosystem management into future extreme conditions in the CalCS, contingent upon the chosen anthropogenic carbon emission scenario.