Compound marine heatwaves and biogeochemical extremes explain regional patterns in coral bleaching severity in the Red Sea

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Coral bleaching events have increased in the Red Sea since it experienced a sudden rise in temperature in the mid-90s. However, the northern Red Sea remains unaffected by severe bleaching despite experiencing many intense marine heatwaves (MHWs). Furthermore, bleaching has been observed in the central Red Sea in the absence of MHWs. While temperature extremes are predominantly responsible for mass bleaching, other environmental factors can influence the suscpetibility of corals to bleach. This study investigated the combined impacts of MHWs and multiple biogeochemical extremes on Red Sea coral bleaching severity across four distinct regions. Using in-situ data from the Global Coral Bleaching Database and a Red Sea-tuned coupled physical-biogeochemical model, we examined seasonally-varying anomalies in temperature, salinity, oxygen, chlorophyll, nitrate, phosphate, iron, and pH wihtin the 3 months leading up to coral bleaching events, through the upper 50m of the water column. We find that in the northern Red Sea regions, deoxygenation, acidification, and salinity drops influence bleaching more than MHWs. Nutrient limitations were also crucial, with low anomalies increasing coral sensitivity to heat stress, while positive anomalies alleviated stress. In the southern Red Sea regions, MHWs played a significant role in moderate and severe bleaching, a signal most pronounced in the southernmost region, suggesting a north-to-south gradient in their contribution to severe bleaching. Phosphate and iron also emerged as crucial factors, influencing the severity of bleaching events. Mild bleaching in both southern regions seemed related to cold stress with low salinity and nitrate. Overall, this study provides a comprehensive analysis of the diverse factors influencing coral bleaching severity in the Red Sea, emphasizing the importance of considering multiple environmental variables beyond temperature alone. Understanding these intricate interactions is essential for effective coral conservation strategies in the face of ongoing climate change.