Uranium Isotopes as the Storytellers of Swaying Oxygen Minimum Zones

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The need to accurately recreate how Oxygen Minimum Zones (OMZs) changed through time requires a combined use of classic and novel proxy approaches. Proxy qualities of U are usually attributed to authigenic enrichment during early diagenesis. Evidence from modern OMZs show that U authigenesis can occur in the water column adding significant amounts of particulate U to marine basins. Here we apply the novel toolbox of U isotopes to sedimentary material from the Eastern Tropical North Pacific (ETNP) OMZ with two main goals: (1) comparing $\delta^{238}U$ composition of settling particles to that of the underlying laminated sediments, while (2) unscrambling productivity-triggered OMZ variability from long-term global variations in oceanic O_2 due to change in solubility and ventilation.

Our extensive dataset of classic redox (Fe/Al, Fe_{HR}/Fe_T, Mo, V) and productivity (C_{org}, bio-SiO_2, Ni, Zn) reconstructions from the Gulf of California (ETNP) show that the OMZ achieved its peak strength during warm sea-level highstands (MIS5, MIS3 and Holocene) exposed by high Mo, V and authigenic U (U_{auth}). Contrastingly, the cold sea-level lowstands (MIS4, LGM) often manifested as higher than expected U_{auth} in marine sediments despite abundant bottom water O_2 at that time. Furthermore, U_{auth} display stronger correlation with C_{org} and micronutrients (Ni and Cd) than with typical redox indicators (Mo, V and Fe_{HR}/Fe_T).

By coupling our existing data with newly produced $\delta^{238}U$ values for settling particles and marine sediments of the ETNP we propose a pathway by which particulate U_{auth} can be exported into the sediments. The mechanism invokes a direct manifestation of high primary productivity that cause the formation of abundant marine snow aggregates. These settling particles have their own redox microenvironments that allow U to escape the water column (even if not severely oxygen-deficient) and reach bottom sediments. This process is confirmed by elevated values of U (up to 40 mg/kg) in sediment trap material, while the maximum reported for the sedimentary record of the last 100 kyr only reached 23 mg/kg.