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Iron, primary production and an oxygen minimum zone feedback mechanism

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In regions bordering productive eastern-boundary upwelling systems, extensive O_2 minimum zones (OMZs) develop along the ocean shelf. Enhanced sedimentary release of Fe and PO_4 under these low O_2 conditions could drive enhanced N_2-fixation and primary production in the ocean, thus ultimately increasing O_2 consumption, and potentially creating a positive feedback to ocean deoxygenation. A similar feedback loop has been identified in shallow and enclosed coastal regions such as the Baltic where primary production is controlled primarily by N and P bioavailability, but it is unclear to what extent a similar mechanism operates at a larger scale in the open ocean where productivity is proximally constrained by Fe and/or N availability. This is largely because of uncertainties in the fate of the Fe released from shelf sediments.

Here we present extensive Fe measurements from a series of 5 cruises and a mesocosm experiment on the Peruvian shelf which combined extensive measurements of Fe distribution with an inert tracer release experiment, to quantify off-shelf transport, and N_2 fixation rates. As expected for a region with among the highest reported benthic Fe fluxes in the world, dissolved Fe concentrations were generally elevated along the inner-Peruvian shelf reaching >60 nM. Whilst concentrations rapidly declined across the shelf, reaching as low as 0.01 nM after the shelf break, 'pockets' of 1-2 nM elevated Fe concentrations were evident in some transects suggesting a significant role of eddies in off-shelf transport which was verified by the results of our CF_3SF_5 tracer release experiment. Never-the-less, benthic Fe release was rapidly attenuated close to the sediment interface, with the vast majority of Fe loss occurring on timescales of <1 day and spatial scales of <1 km. Evidence of Fe limitation was even found at some stations on the Peruvian shelf questioning the efficiency with which Fe released from sediments is able to positively influence marine primary production. Despite an excess of P across the region with respect to biological requirements, and extremely high inner-shelf Fe concentrations, N_2 fixation rates remained consistently low across the region (0-0.8 nmol N L^{-1} d^{-1}). Furthermore, the maximum lateral transfer of Fe was de-coupled spatially from maximum benthic Fe release, limiting the potential for a P/Fe-fueled positive feedback loop to OMZ expansion.