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Insights into phytoplankton iron limitation in the Southern Ocean

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Southern Ocean net primary productivity, a major contributor to biological carbon export, is largely constrained by the supply of the essential micronutrient iron. Iron availability is a complex mix of concurrent biotic and abiotic processes, which are likely to be altered by anthropogenic forcing. Observational constraints on how phytoplankton respond to iron availability is crucial, and it is not possible to directly infer iron limitation from observed concentrations. Results from manipulation experiments of natural communities in bottle incubations over decades of research have highlighted the various responses in phytoplankton physiology to iron addition, however these long-term experiments pose problems in disentangling physiological versus ecological responses. Short-term experiments can not only resolve this but can also provide a higher spatial and temporal resolution for interpreting ecosystem level responses. The results from multiple cruises throughout the Atlantic and Indian sectors of the Southern Ocean highlight the role of various iron sources and the spatially and seasonally heterogeneity thereof. Phytoplankton in the Atlantic sea-ice zone showed no signs of iron limitation during autumn, when it was expected to be limited. Whereas the timing and magnitude of the deepest mixed layer in the Atlantic open ocean results in differential iron availability across the frontal zones. Finally, the sub-Antarctic islands in the Indian sector have variable longitudinal extents of iron supply constraining summer phytoplankton responses. The learning gained from these experiments, whilst important for understanding processes, remain limited in their spatial and temporal coverage. Autonomous platforms can fill these gaps, with the development of appropriate iron limitation proxies. We used the data from these short-term experiments to derive an iron limitation proxy that can be applied to fluorescence sensors on any platform. The application of the proxy allowed us to examine basin scale trends to determine climate driven impacts, with the results demonstrating unprecedented changes in phytoplankton physiology across the past few decades. The Southern Ocean is appearing to become more iron limited with time, resulting in potentially significant impacts on biological carbon export.