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Iron and manganese colimitation in the Southern Ocean examined with a proteomic allocation model

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Iron (Fe) limits primary productivity in a large part of the ocean; but recent geochemical profiles and bottle incubation assays indicate that manganese (Mn) can also limit primary productivity in the Southern Ocean. Fe and Mn can interact to influence primary productivity, but the extent to which these elements colimit phytoplankton in the Southern Ocean is uncertain. In addition, current models are insufficient to assess colimitation as they assume a single, most scarce, resource. In order to examine Fe and Mn colimitation in phytoplankton, we developed a modeling framework to predict proteomic profiles under varying Fe, Mn, and light conditions. In our model, proteins are optimally allocated to various coarse-grained cellular pools, governed by environmental conditions. We predict that Fe controls cellular Mn quotas, largely because of paired stoichiometry within photosynthetic machinery. Our model suggests that the diffusion-limitation paradigm of Fe should be revisited, as diffusive flux of Fe does not appear to be limiting. We then use our model to explore various cellular mechanisms leading to phytoplankton Fe limitation. Lastly, using Fe and Mn biogeochemical model output, we predict regions in the Southern Ocean where Fe/Mn colimitation is most likely to occur.

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