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Evaluating marginal sea ice as a reservoir and source of iron in the Atlantic sector of the Southern Ocean

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Large parts of the Sub-Antarctic and Antarctic Ocean suffer from dissolved iron (dFe) concentrations as low as 0.01 nmol/kg and below, which often limits phytoplankton growth. In contrast, in such regions, the annual formation and melting of Antarctic Sea ice has the potential to serve as a source of iron (Fe). Despite its ecological significance, Fe biogeochemistry of the Antarctic marginal ice zone (MIZ) remains poorly understood due to limited data. While previous studies primarily focused close to ice shelf and during the productive summer season, this study investigates seasonal variations in dFe and particulate Fe (pFe) within the sea ice and snow sampled around the zero meridian between 57.32 and 59.47° S, approximately 1300 km from the Antarctic shelf. Using 53 dFe and 19 pFe measurements from winter and spring sea ice, we report dFe concentrations ranging from below detection to 9.53 nmol/kg, with an average concentration of 0.66 ± 1.51 nmol/kg, and pFe concentrations ranging up to 9.78 nmol/kg, with an average concentration of 3.46 ± 2.57 nmol/kg. Measured Fe concentrations are significantly lower than previously reported values from sea ice (dFe: 0.20 – 109 nmol/L and pFe: 0.04 - 6828), with unique pFe/pAl signatures. While no significant seasonal differences in Fe concentrations were detected, vertical and longitudinal profiles revealed site-specific variability in Fe distributions, with pFe concentrations often higher in sea ice than in underlying seawater. The physical speciation showed that while pFe is more abundant than dFe in sea ice, it remains less bioavailable as inferred by their low pFe/pAl ratios (0.04 – 0.17). We posit that the melting of sea ice has a negligible effect on biological processes, while the reductive dissolution of pFe controls the rate of primary productivity in this Fe-limited system.