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Surface ocean biogeochemistry regulates the impact of anthropogenic aerosol Fe deposition on iron and iron isotopes in the North Pacific

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Long-range atmospheric transport and deposition of anthropogenically-sourced aerosol iron (Fe) affects surface ocean biogeochemistry far from the emission source. However, it is challenging to establish the integrated impact of anthropogenic aerosol Fe on surface ocean dissolved Fe (dFe) cycling, due to other Fe sources and in situ cycling processes. Previous work has used a distinctively-light Fe isotopic signature (δ^{56}Fe) associated with anthropogenic activity to track the contribution of anthropogenic Fe at the basin scale. However, this requires not only the determination of the δ^{56}Fe endmember of all potential Fe sources, but also the assessment of how upper ocean biogeochemical cycling modulates surface ocean dFe signatures ($\delta^{56}Fe_{diss}$). Here we accounted for dust, fire and anthropogenic Fe deposition fields in a global ocean biogeochemical model with an integrated δ^{56}Fecycle to quantify the impact of anthropogenic Fe on surface ocean Fe and δ^{56}Fe, with a focus on the North Pacific. The effect of anthropogenic Fe is spatially distinct and seasonally variable in our model, depending on the biogeochemical state of the upper ocean. In the subtropical regions where Fe is not limiting, anthropogenic Fe input leads to increased dFe levels and, at times, phytoplankton Fe uptake. $\delta^{56}Fe_{diss}$ declines due to the very light anthropogenic δ^{56}Fe endmember, most prominently in low dFe areas of the subtropical North Pacific gyre. In Fe-limited systems, such as the subpolar gyre, anthropogenic Fe stimulates both primary production and Fe uptake with little change to summertime dFe levels. Moreover, the decrease in $\delta^{56}Fe_{diss}$ is amplified as extra Fe dampens the impact of the fractionation effects associated with Fe uptake and complexation, whereby the overall $\delta^{56}Fe_{diss}$ often remains positive. Overall, it is important to account for biological parameters, such as primary productivity or Fe limitation, when assessing the oceanic impact of anthropogenic Fe.