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Global modeling studies of aerosol iron deposition to marine ecosystems in the Anthropocene

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Human species has been evolved through rapid consumption of fossil fuels and mineral resources. Industrial activities without effective emission control substantially co-emit large amounts of metals and acidic species. Atmospheric depositions of bioaccessible iron (Fe) from anthropogenic (fuel combustion and metal smelting), lithogenic (wind-blown dust), and pyrogenic (open biomass burning and pyro-convective dust) aerosols represent important external sources of micronutrients to the open ocean, which could affect marine ecosystems and climate through marine biogeochemical feedbacks. However, significant uncertainties remain in the source fluxes and their apportionment to specific sources. This review paper summarizes the progress in research on how bioaccessible Fe in aerosols affects marine biogeochemistry and ecosystems from atmosphere (emission, transformation, and deposition processes) to post-deposition (leaching into seawater as dissolved Fe). We will focus on interdisciplinary research of field observational, laboratory experimental, and numerical modeling studies.

Observations of Fe stable isotopes have been used to constrain the anthropogenic Fe contribution in fine parciels predicted using the atmospheric Fe model over the western North Pacific Ocean (Kurisu et al., *Atmos. Chem. Phys.*, 2021). However, for coarse particles, the atmospheric Fe model overestimated contribution of anthropogenic Fe. Furthermore, higher Fe stable isotope ratios were observed in the coarse particles than in natural crustal sources over the oceans. Indeed, high values of Fe stable isotope ratios were measured for coal fly ash and heavy oil fly ash, which were distributed as standard samples of source materials (Mead et al., *Geophys. Res. Lett.*, 2013; Li et al., *Sci. Total Environ.*, 2022). These results suggest that coarse particles are emitted in the combustion process at lower temperatures than in the evaporation process of Fe, and that the stable isotope ratio of Fe may be close to that of the raw material and thus higher than the natural crustal Fe. Therefore, model predictions are expected to be improved by implementing source-specific isotope ratios in size-segregated aerosols measured near the source into the model. We will discuss the use of Fe isotopes in models for more accurately predicting the contribution of anthropogenic sources.