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Enhanced atmospheric solubilization of iron due to anthropogenic activities

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Atmospheric deposition of soluble iron (Fe) to the ocean has an impact on oceanic primary productivity, thus on carbon dioxide uptake. Understanding how anthropogenic activity influences the atmospheric Fe cycle is key to project ocean biogeochemical cycles and has been barely explored.

In this study, we assess past, present, and future soluble Fe deposition to the ocean, accounting for natural and anthropogenic sources, using an advanced atmospheric Fe cycle module implemented into the EC-Earth3 Earth System Model. This version of the model considers primary emissions of insoluble and soluble Fe forms associated with dust minerals, and anthropogenic and biomass burning combustion aerosols. Fe solubilization processes in the atmosphere include 1) proton-promoted, 2) oxalate-promoted (with oxalate calculated on-line), and 3) photo-reductive Fe dissolution. We run time-slice simulations using the atmosphere-chemistry model configuration constrained by past, present, and future ocean states. The necessary sea surface temperature and sea ice concentration climatologies are obtained from EC-Earth3 CMIP6 coupled model experiments. Future projections rely on three CMIP6 scenarios representing different socio-economic pathways and end-of-the-century forcing levels: SSP1-2.6, SSP2-4.5, and SSP3-7.0.

Our setup allows us to estimate the soluble Fe deposition into the ocean while quantifying the contribution from dust, biomass burning, and anthropogenic combustion sources separately under a range of scenarios. Our preliminary results suggest nearly a 50% increase in soluble Fe deposition for the present time since the industrial revolution, attributed to increased atmospheric acidity and oxalate concentrations that result in a more efficient atmospheric processing. Future projections of soluble Fe show a high correlation between anthropogenic activity and solubility of deposited Fe, scenarios with higher anthropogenic emissions consistently yield a higher fraction of soluble over total deposited Fe. Our results also suggest diverging trends for the different ocean basins. Disentangling the factors that drive those differences in regions

where Fe is known to be the limiting nutrient, such as the North Pacific or the Southern Ocean, is fundamental to improve our understanding of the atmospheric Fe cycle and its consequences for the ocean biogeochemistry.