

The role of atmospheric dust deposition in supplying Fe to oceanic surface waters and the limitations of current modeling approaches.

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An important factor moderating the biological productivity of the surface ocean is the availability of the micronutrient Fe. A required component of many crucial biochemical pathways, dissolved Fe is in limited supply in the surface oceans as a result of the extreme insolubility of its oxidised form. During the remineralisation of organic matter exported from surface waters there is fractionation between the solubility-limited Fe and the soluble macronutrients N and P. Upwelled waters therefore are always deficient in the amount of dissolved Fe required to enable the biological removal of the accompanying macro nutrients. Thus, there must always be an external source of Fe to oceanic waters when nutrients are brought into the photic zone by upwelling, deep mixing or simple diffusion. While this Fe may be supplied by sedimentary sources in shallow coastal regions, in the open ocean only eolian deposition can supply the required Fe. Thus the deposition of Fe-containing mineral dust to the surface ocean is a vital part of the biogeochemical cycle that couples carbon and nutrient cycling.

In the contemporary ocean we have already identified several regions where, apparently, the deposition of eolian Fe is insufficient to support macronutrient removal. These High Nutrient Low Chlorophyll (HNLC) regions appear to generally coincide with oceanic regions that receive minimal dust loads. Specific dust deposition rates range from $> 10 \text{ g m}^{-2} \text{ yr}^{-1}$ in the Atlantic Ocean downwind of the Sahara to $< 0.01 \text{ g m}^{-2} \text{ yr}^{-1}$ in the waters around Antarctica. These estimates are based on converting measured suspended dust loads collected at various land-based sampling stations (e.g., islands) into deposition rates using settling velocities and scavenging ratios. The derived values, therefore, are subject to significant uncertainty for a variety of reasons. For example, scavenging ratios used to estimate wet deposition in the North Pacific and the North Atlantic differ by a factor of 5. Estimation of suspended loads is also complicated by the high frequency temporal and spatial nature of dust deposition events and the sparsity of oceanic island sampling sites. Thus, despite the best efforts of large numbers of people, even the finest data-based dust deposition maps, such as that produced by Duce et al. (1991), are based on extrapolation of spatially limited data sets. In addition, these deposition estimates cannot be validated in the remote ocean by direct aerosol sampling programs from short duration oceanographic cruises. This means that there are no ground-truthed dust deposition data over the open ocean, only estimates extrapolated from adjacent land-masses.

Thus, a crucial component of biogeochemical models, namely the adequacy of atmospheric Fe supply to contemporary oceanic surface waters, is completely unvalidated. We cannot expect to develop realistic models that provide meaningful insights into climate change and yield accurate prognostications of future climate variations until the temporal and spatial pattern of dust deposition to the surface of the contemporary ocean are delineated and its geochemical effects are understood. On going approaches using dissolved Al and Fe in oceanic surface waters to delineate the magnitude and geochemical effects of dust deposition and the opportunity to extend this validation process to large oceanic regions in collaboration with repeat global hydrography projects will be discussed.