doi.org/10.22498/pages.26.2.92

The role of dust in climate change: A biogeochemistry perspective

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Las Cruces, Chile, 8-10 January 2018

Mineral-dust aerosols are critically important components of climate and Earth system dynamics as they affect radiative forcing, precipitation, atmospheric chemistry, surface albedo of ice sheets, and marine and terrestrial biogeochemistry, over significant portions of the planet. Dust-borne iron is recognized to be an important micronutrient in regulating the magnitude and dynamics of ocean primary productivity and affecting the carbon cycle under past and modern climate conditions. Paleodata suggest large fluctuations in atmospheric dust over the geological past. However, dust-transport models struggle to reproduce observed spatial and temporal dust-flux variability. In addition, observational and modeling studies based in the current climate suggest that not all iron in dust is equally available to continental and ocean biota. Iron solubility varies dramatically, depending on mineralogy and state of soils, as well as atmospheric processing by acids. Modeling studies, however, still mostly assume constant solubility.

The PAGES Dust Impact on Climate and Environment (DICE) working group held its first workshop on *The Role of Dust in Climate Change: A Biogeochemistry Perspective*. Twenty-seven experts from nine different countries came together at the Coastal Marine Research Station of the Catholic University of Chile in Las Cruces for the three-day workshop that was jointly supported by PAGES and the Chilean Comisión Nacional de Investigación Científica y Tecnológica. About half of the participants were early-career researchers or scientists from developing countries. The workshop format combined keynote talks with shorter thematically matching pop-up talks, followed by discussion and brainstorming of future research avenues among all participants.

This workshop was a highly interdisciplinary effort to better quantify and simulate biogeochemical impacts of dust deposition. It gave observationalists and modelers the chance to combine perspectives on the role of dust in ocean biogeochemical cycles and the greater carbon cycle. The specific goal of the workshop was to more precisely quantify the effects of mineral dust, and specifically iron, during various climate states, and to strategize how to further foster this relationship in future work.

The major themes of the keynote presentations followed the pathways of dust emissions, from geochemically identifying and tracing source regions to deposition in the surface ocean. Participants discussed the effects on the solubility and bioavailability of iron at each of these stations in the dust cycle, including the influence of dust source and mineralogy on dust solubility and bioavailability, the role of atmospheric processing in dust solubility, and the importance of organic ligands and aggregation to iron lifetime in the mixed layer of the ocean for bioavailability in modern and past oceans.

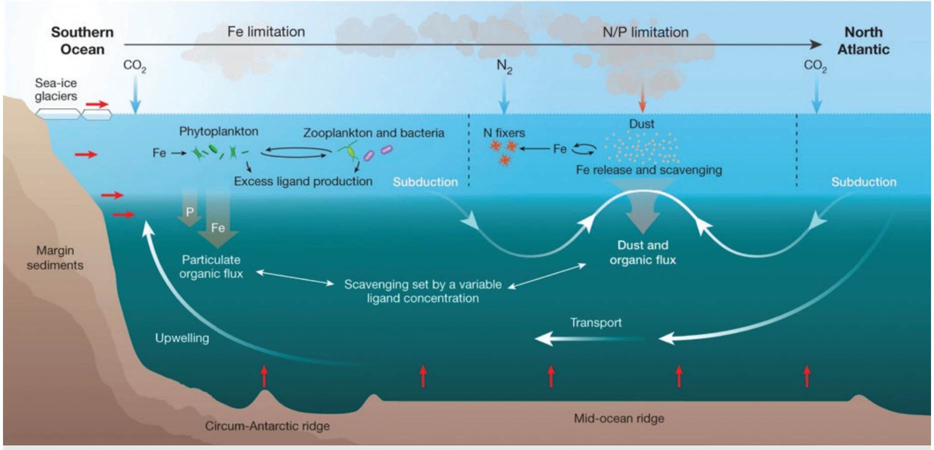

Figure 1: Representation of the major processes in the ocean iron cycle from Tagliabue et al. 2017. Reprinted by permission from Springer Nature.

Halfway through the workshop, participants split into three breakout groups for extended discussion on the following three avenues of future research (1) Ocean iron sources (aeolian versus others), (2) Iron solubility past, present, future, and (3) Dust particles: shape, size and composition.

As a direct interdisciplinary outcome of the workshop, participants are developing a model that evaluates the relative importance of atmospheric processing, mineralogy, size fraction, settling rate, and ligand-mediated dissolution on the solubility of dust-borne iron that reaches the ocean (Fig. 1). This is in an effort to combine experimental and modeling results to improve the estimates of iron solubility in biogeochemical models – moving beyond the assumptions of constant iron solubility. The group plans to combine observational data on dust-source mineralogy, dust deposition, atmospheric processing, and ligand concentrations and strengths with kinetic models of dust dissolution in the water column. Such a model can be applied to both modern as well as past dust sources that may have been more highly impacted by glacier physical weathering, and have been shown to have a different mineral composition as a result. The goal of this effort is to combine the highly varied range of expertise to better quantify the bioavailable iron in different dust sources across space and time.

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