SOLAS Open Science 2015 Discussion session report on "Atmospheric deposition, ocean biogeochemistry and climate change"

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Circa 30% of the world's surface oceans are high-nitrate low chlorophyll systems featuring iron limitation, with most of the remaining low-latitude oligotrophic systems being nitrogen limited (or in places co-limited by nitrogen and phosphorus) (Moore et al., 2013). Atmospheric deposition provides additional nutrients to the surface ocean, which affects the budget and stoichiometry of nutrients in these waters (Krishnamurthy et al., 2010). The atmospheric supply therefore determines primary productivity, di-nitrogen fixation and microbial community structure and thus the carbon and nitrogen cycles (Law et al., 2013). Major progresses have been made in our estimates of natural and anthropogenic atmospheric inputs of nutrients and trace elements to the ocean and the response of ocean biogeochemistry and plankton community to such inputs in recent years (Schlosser et al., 2014; Ussher et al., 2013; Paytan et al., 2009; Tan et al., 2013). However, there are still major uncertainties concerning the sources and delivered amounts of total and soluble iron and phosphorus and organic nitrogen, in atmospheric deposition as well as in the interaction of atmospheric deposition, ocean biogeochemistry and the climate system. Three key topics were discussed in this session.

1. Potentially bioavailable Fe deposition from dust, biomass burning, coal combustion, shipping, and volcanic eruption

Dissolved iron is usually presumed to be bioavailable. However, there is no consensus on the methods (leaching solutions) to measure dissolved iron derived from atmospheric inputs. Large uncertainties in iron solubility (dissolved relative to total iron), and bioavailability, hamper accurate simulations of the effects of bioavailable iron deposition on marine productivity and thus the carbon cycle. Different approaches can be envisaged to mimic dissolution processes occurring at low ionic strength and pH values on aerosols and in rain, and at high ionic strength and pH in seawater. It was suggested during the discussion session that we develop a common method to leach dissolved iron and other elements and compounds. A further workshop to discuss this matter was recommended.

Both measurement and process-based modeling studies suggested that relatively high iron solubilities in aerosols (e.g., >10%) are associated with combustion sources, but specific emissions sources and their contributions to deposition fluxes largely remain uncertain. The role of aerosol organics and humic-like substances in the complexation and dissolution of iron minerals over a wide pH range has received considerable attention in recent years. Continuous monitoring of soluble Fe together with a number of other tracer species will be useful to constrain the contribution from specific sources.

Participants recognized that community efforts are needed to establish a well-defined and affordable measurement technique for time series measurement of both the deposition flux of bioavailable and total nutrients and ocean biogeochemical parameters at a number of strategic sites around the world. Inorganic nitrogen data from acid deposition networks have been used to contrain global models on nitrogen deposition (e.g., Lamarque et al., 2013). Such networks may be extended for use for nutrients such and iron, phosphorus and organic nitrogen measurement. It has been recommended that a data sharing mechanism should be established to enable a global synthesis and continual evolution of deposition datasets. This is however challenging considering the difficulty in data validation and in obtaining agreement from data owners. An inter-laboratory comparison would probably an essential way forward.

Combined efforts from SOLAS and other programmes, particularly GEOTRACES may significantly advance our understanding of the impact of atmospheric deposition on ocean biogeochemistry. The development of a range of SOLAS aerosol standards to improve the accuracy and intercomparability of measurements is needed. A workshop to develop such standards was recommended. GEOTRACES data on dissolved iron and aluminum in the surface ocean may offer an important constraint on atmospheric deposition flux of dust and dissolved iron. In the meantime, continuous improvement in emission inventory of soluble nutrients (bottom up approach) and quantitative source apportionment of aerosol soluble nutrients (top down approach) would be required to better quantify anthropogenic perturbation to ocean nutrient budget and its impact on biogeochemistry.

2. Overall impact of atmospheric depositions on ocean ecosystems

Nutrients in atmospheric deposition may stimulate the growth of plankton and thus enhance primary productivity. However, there are also species in the deposition that may be toxic, as has been suggested for Cu (Paytan et al., 2009). The overall impact of atmospheric deposition on primary productivity, and microbial community structure is critical to understand the overall impact of atmospheric deposition on ocean biogeochemistry. Remote sensing techniques may be useful to track the impact of anthropogenic pollution, including ship's emissions, on primary productivity in the surface ocean.

3. Climate feedbacks of atmospheric deposition to the ocean

Atmospheric deposition to the oceans in cold high latitude regions remains highly uncertain due to limited understanding of Fe sources and their dissolution under pristine conditions. In response to global warming, ice retreat on Iceland, Greenland, Antarctica and in other areas is likely to increase dust emissions from these regions. Also, potential increase in biomass burning emissions in the future may also provide addition nutrients that may impact ocean biogeochemistry. Further research in this area is needed.

References

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