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Size fractionation of particulate metals during a time series in East Antarctic fast ice

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The Southern Ocean is a high nutrient, low chlorophyll area where marine production is primarily limited by the micro-nutrient iron (Fe) (Martin and Fitzwater, 1988). While the rest of the Southern Ocean is Fe-depleted, there is now compelling evidence to demonstrate that sea ice is enriched in Fe and organic matter at a magnitude twice as high as underlying seawater (Lannuzel et al., 2010 and citations therein). Every year, when it melts, sea ice releases this reservoir of Fe and organic matter into the water column at a time ideal for phytoplankton growth, therefore producing large ice edge blooms observable from space. The sources of Fe to sea ice are multiple and include dust, glaciers, upwelling of sediment-rich waters, advection from the continental margins and remineralization processes. The magnitude of these fluxes may vary in space and time.

While several authors demonstrated that sediment contributes to the enrichment in lithogenic particles in coastal sea ice (Grotti et al., 2005; Hendry et al., 2009; Lannuzel et al., 2010), no studies have examined the size-spectrum of particles in this extreme environment. The partitioning of metals in the suspended solid phases is necessary for developing physically based models of metal transport in marine systems. Unlike the most common filtration method that only deciphers between the "dissolved" and "particulate" fractionation (0.2 μm), the present study was pursued to examine the seasonal distribution and sequential size fractionation of a suite of 15 elements (Al, P, Ti, V, Mn Fe, Co, Cu, Zn, Ga, Mo, Ag, Cd, Ba and Pb) onto 10 μm, 2 μm, 0.4 μm and 0.2 μm pore size filters. Sampling of snow, sea ice and seawater was carried out approximately 12 km northeast of the Casey Station (Australian East Antarctic sector) in seven occasions between 11th of November and 3rd of December 2009 on a 120 cm thick level ice sheet sitting 15 to 17 m above the seafloor. Our sampling site was 500 m offshore and enclosed in between islands from the Swain group. Concentrations of metals in large colloids (0.2 - 0.4 μm), small (0.4 - 2 μm), medium (2 - 10 μm) and large (> 10 μm) particles were measured by inductively coupled plasma – sector field mass spectrometry. The results were compared to physical (sea ice thickness, salinity, temperature), chemical (particulate organic carbon (POC) and macro-nutrients) and biological (Chlorophyll a (Chla)) parameters that characterize the sampled ice cover.

Our field study shows that large particles represent on average 72±13% of the total concentration metals in coastal sea ice, with 7-8% remaining in each of the smaller class sizes, all metals included. In coastal snow and seawater large particles (>10 μm) are also dominant and respectively represent on average 60±20% in snow and 49±14% seawater of the pool of particulate metals. Spatially, two concentration maxima are observed (one at 73 cm deep and one at the bottom) on the coastal sea ice profiles of the > 10 μm fraction for all elements but P and Cd. Intense convective mixing of the 17 m deep water column may have lead to the incorporation of particles >10 μm of sedimentary origin at 73 cm deep in autumn/winter, while sea ice algae would have mediated the incorporation of metals in the bottom of the ice cover in spring/summer, as confirmed by the basal enrichment in P, POC and Chla. The magnitude of the flux of metals from melting sea ice increases with the size of the particles. Based on the shortage of particles in the 17 m deep water column, about 80% of that flux seems to be lost to remineralization processes and/or rapid export to the seafloor, all size fractions and metals included.