

Chemical Geology

Winter and summer distributions of Copper, Zinc and Nickel along the International GEOTRACES Section GIPY05: Insights into deep winter mixing

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Abstract

First measurements of labile dissolved copper (LdCu) and dissolved zinc (dZn) and nickel (dNi) in the Atlantic sector of the Southern Ocean in winter are compared with summer data at reoccupied stations in order to better understand the winter reset state and supply of these trace metals to support productivity. In summer, vertical profiles of zinc behaved similarly to silicate (Si) and increased from sub-nanomolar surface concentrations to 8 nmol kg⁻¹ in bottom waters. Copper profiles also resembled Si and were typically 1 nmol kg⁻¹ in surface waters and increased to 3 nmol kg⁻¹ at depth. First summer nickel data reported from this transect displayed comparatively higher surface concentrations of ~4.6 nmol kg⁻¹ increasing more rapidly to local intermediate depth maximums between 6.5 and 7.0 nmol kg⁻¹, similar to phosphate (PO₄). Trace metal seasonality was most apparent in the mixed layer where the average of winter concentrations within the mixed layer exceeded summer values by approximately 0.2 nmol kg⁻¹ for LdCu, 1.2 nmol kg⁻¹ for dZn and 0.3 nmol kg⁻¹ for dNi owing to low utilization under unfavourable growth conditions for phytoplankton. In an effort to estimate the winter reserve, two scenarios were considered. Scenario 1 accounted for in-situ mixed layer depths (MLD) where the winter reserve inventory was calculated by subtracting the summer depth integrated metal inventory (surface to summer MLD) from the winter equivalent (surface to winter MLD). Scenario 2 assumed a constant mixed layer (taken as the depth of the maximum winter mixed layer) where summer depth integrated metal inventories (surface to maximum winter MLD) were subtracted from the winter equivalents (surface to maximum winter MLD). Results for scenario 1 were predominantly dependent on the mixed layer depth which varied spatially and seasonally. Scenario 2 showed a southwards increase in the winter reserve inventory suggesting a greater role for entrainment at higher latitudes in this region. This is however heavily dependent on other physical processes controlling vertical trace metal supply e.g. diapycnal diffusion, Ekman upwelling/downwelling. Zinc ($R^2 > 0.75$) and copper ($R^2 > 0.73$) were strongly correlated with Si throughout the study implicating diatoms as strong controllers of their biogeochemical cycling. Nickel was more strongly correlated with PO₄ in the upper water column ($R^2 > 0.75$), as compared to the whole water column ($R^2 > 0.52$), while in the deep ocean nickel appears to correlate with Si although more deep ocean data is needed to confirm this. Trace metal to major nutrient ratios were higher in winter suggesting reduced micronutrient requirement relative to macronutrients under stressed but low productivity conditions. This article is part of a special issue entitled: “Cycles of trace elements and isotopes in the ocean – GEOTRACES and beyond” - edited by Tim M. Conway, Tristan Horner, Yves Plancherel, and Aridane G. González