Differential coupling of oceanic nutrient cycles controlled through maximum biotic uptake ratios

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Biological cycling controls the overall concentrations and distributions of multiple nutrient elements in the ocean, while oceanic productivity is reciprocally dependent on the availability of multiple nutrients, including a number of trace metals. The complexities of stoichiometric plasticity in biological nutrient uptake have confounded development of a generalised understanding of this multi-nutrient ocean. Directly considering how the intercellular quotas of both limiting and non-limiting nutrients vary as a function of their availability, we develop a simple theoretical prediction of how biotic stoichiometry might be expected to operate in the multi-nutrient ocean. We emphasise how differences in maximum elemental uptake ratios between various nutrients are crucial determinants of their coupled cycling from local through to global scales. Using this insight we develop a framework which, when applied within idealised ocean box models, can simultaneously reconcile the overall oceanic inventories and residence times of multiple nutrient elements, alongside the roles of both macronutrients and trace-metals in limiting productivity. Implementing the same framework within realistic ocean general circulation models we further demonstrate how such concepts may explain many aspects of differential nutrient distributions as, for example, revealed by observed micro- and macro- nutrient interrelationships within the global datasets being produced by the GEOTRACES programme.