Nutrient and CO_2 dynamics in the northern Benguela

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Abstract

Physical upwelling in the Benguela Upwelling System (BUS) fertilises the ecosystems on the shelf and in the adjacent ocean with nutrient elements that support massive phytoplankton production and a rich and productive ecosystem. The origin of the upwelling water masses, their nutrient, oxygen and CO_2 heritage, and internal biogeochemical cycles also determine the oxygenation state of the system. The overall oxygenation state in turn governs several key sources and sinks of nutrients: mineralisation of nutrients in organic matter, reflux of phosphate from sediments, cycling of fixed nitrogen (nitrification versus denitrification/anaerobic ammonia oxidation, anammox), sequestration of organic matter in sediments, and its decomposition by microbial processes. All of these processes potentially alter the masses and ratios of nutrients available for assimilation by phytoplankton, and thus affect the fertility of the system. Changes in external forcing (acting to alter the mixture of feed waters) are expected to lower the overall redox state of the near-seafloor water masses, with internal processes (oxidation of abundant reduced carbon and sulphur) modulating that baseline. Physical forcing and internal biological and chemical oxygen demand thus jointly set the stage for ecosystem structures and functioning via biogeochemical cycling.

Biogeochemical work in GENUS project has provided analyses of nutrient concentrations of surface waters in high temporal and spatial resolution during 3 expeditions with the online multi-analysis instrument FerryBox. These data illustrate an extreme variability in space and time, albeit with an underlying pattern of low N:P ratios (<16) suggesting losses of reactive N (nitrate, ammonium) in the suboxic sectors and periods of the shelf system. We quantified the anomalies and presumed sources by flux and mass balance investigations coupled with analyses of the two stable N-isotopes in reactive N. Initial work has also shown that the flux of phosphate across the sediment-water interface contributes to low N:P ratios.

Both nutrients and CO_2 in sub-thermocline upwelling water often derive from remineralisation of sinking organic matter and thus are stoichiometrically balanced. But there are water masses such as the East South Atlantic Central Water in which high phosphate concentrations coincide with low CO_2 concentrations; this is due to their origin in areas where CO_2 has equilibrated with the atmosphere, but phosphate has not been quantitatively removed by assimilation. These are so-called preformed nutrients, and their ratio to remineralised nutrients is key to the balance between CO_2 emission and sequestration in the

BUS. Data from six expeditions demonstrate that the southern sector of the upwelling system is a CO_2 sink fuelled by abundant supply (and phytoplankton assimilation) of pre-formed PO_4^o imported with sub-antarctic mode upwelling water not laden with metabolic CO_2. The northern sector is a source of CO_2 acquired from mineralization of sinking organic carbon. Because the outgassing CO_2 is stoichiometrically balanced by phosphate (from remineralisation of organic matter) in the northern sector, the CO_2 released during outgasing is subsequently re-captured by phytoplankton assimilation in the periphery of the upwelling system.

Our new data suggest that all processes that change water-mass composition are of prime importance to biogeochemical cycles and the CO_2 balance of the Benguela System. Unravelling and quantifying these processes will be the central target of GENUS in its phase III.