Contribution ID : **218**

Type : **Oral**

Linking upwelling, export production and nitrogen cycling processes in the OMZ waters of the ETSP

Tuesday, 4 September 2018 17:15 (15)

Upwelling of nutrient-rich water fuels high surface productivity and the resultant export of organic matter stimulates strong microbial respiration in the subsurface waters. Combined with poor ventilation, O2-deficient waters called oxygen-minimum-zones (OMZs) develop. Under these low oxygen conditions fixed nitrogen is lost as N2-gas via the anaerobic processes of anammox and denitrification. Although constituting only ~1% (O2≤20 µmol kg-1) of global ocean volume, OMZs account for ~20-40% of the global oceanic N-loss. Thus, processes removing fixed nitrogen in OMZ waters partly regulate the availability of nutrients for primary production in the photic zone. As the organic matter exported from primary production is the main source of substrates for N-loss processes, there is a tight coupling between the physical processes bringing nutrients to the surface waters and microbially driven nitrogen cycling in the underlying OMZ waters.

The eastern tropical South Pacific (ETSP) OMZ is one of the ocean's largest sinks of fixed nitrogen where one-third of nitrogen loss occurs in productive shelf waters stimulated by organic matter export as a result of eastern boundary upwelling. Further off shore mesoscale eddies have been suggested to enhance vertical nutrient transport and thereby regulate primary productivity and organic matter export. For offshore mesoscale eddies, both depth-integrated chlorophyll content and anammox activity increase at the periphery, relative to the eddy center; suggesting enhanced organic matter export along the periphery supports nitrogen loss activity. In the central ETSP-OMZ, the formation of eddies, as a result of a topographic bend on the shelf edge, can also influence the coastal currents and transport coastal waters towards the open ocean OMZ with important implications for the fixed nitrogen budgets.

Futhemore, the physical processes causing upwelling of nutrients to the surface waters can also bring oxygen into the OMZ waters and thereby support microaerobic processes. The occurrence of aerobic processes in waters seemingly devoid of free oxygen is supported by the high presence of obligate aerobic microbes and gene transcripts in OMZ water. In the upper part of the OMZ waters, microaerobic respiration was shown to be the dominant source of the ammonia which sustains fixed nitrogen loss by anammox. The co-occurrence of aerobic and anaerobic N-cycling processes under low oxygen conditions has been described in several studies. However, the production of N2O, an important greenhouse gas, in direct comparison to other N-cycling products like N2-gas under these conditions has been less systematically studied.

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Session Classification : 05 Major Upwelling Systems

Track Classification : 05 Major Upwelling Systems