CliOMZ Nitrification rates

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Data Type: Cruise Results
Version: 1
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Project
» Collaborative Research: Underexplored Connections between Nitrogen and Trace Metal Cycling in Oxygen Minimum Zones Mediated by Metalloenzyme Inventories (CliOMZ)

Contributors	Affiliation	Role
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Abstract
These data include nitrification and nitrite oxidation rates measured during oceanographic expeditions on R/V Roger Revelle from San Diego to San Diego, USA in June 2021 and on R/V Atlantic (CliOMZ AT50-10 expedition) from Golfito, Costa Rica to San Diego, USA in May-June 2023. Instruments used were a CTD profiler and an isotope ratio mass spectrometer.

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Coverage

Location: Eastern Tropical and Subtropical Pacific Ocean
Temporal Extent: 2021-06-12 - 2023-06-09

Methods & Sampling

Water samples were collected during cruises RR2104 and AT50-10 in the eastern tropical and subtropical Pacific Ocean. Discrete water samples were obtained using a CTD rosette sampler equipped with 24 x 10 L Niskin bottles. Different depths were sampled ranging from 35 meters to 300 meters.

Nitrification and nitrite oxidation rates were determined using 15N isotope tracer methods. For oxygenated depths, incubations were conducted in 1L or 250 mL polycarbonate bottles (Nalgene) and for depths with low in situ O2 concentrations (≤ 20 µM), incubations were conducted in 500 mL Tedlar bags (Restek) equipped with a septum injection port and three-way stopcocks, following the procedures described previously (Santoro et al. 2021). Each bottle or bag was spiked with [15N]-tracer (99 atm% 15NH4Cl or 98 atm% Na15NO2-, Cambridge Isotope Laboratories) to a final label concentration of 70 to 200 nM (depending on the depth and productivity region the sample was collected from), and incubations were conducted as close to in situ temperature conditions as possible (±1.5°C). Phenylacetylene (10 µM) dissolved in dimethylsulfoxide (DMSO, 0.01%) was used to some bottles to test its efficiency in inhibiting ammonia oxidation activities. At timepoints of 0, 12, and 24 h, 50 mL samples were drawn from each bottle or bag, 0.2 µm syringe-filtered into a 20 mL HDPE bottle, and frozen at -20ºC. Frozen samples were transported to the laboratory, thawed, and prepared for δ15NNO2+NO3 analysis using the ‘denitrifier method’ (Sigman et al. 2001). For nitrite oxidation rate samples, the added 15NO2- tracer was removed using sulfamic acid addition and subsequent neutralization with NaOH prior to sample preparation (Granger et al. 2006). Samples were analyzed on a custom purge and trap system interfaced to a Thermo Delta Plus XP isotope ratio mass spectrometer (McIlvin and Casciotti 2011). δ15NNOx values were calibrated against NO3- isotope reference materials USGS 32, USGS 34, and USGS 35, analyzed in parallel.

Data Processing Description

Nitrification and nitrite oxidation rates were calculated using the basic equations of Dugdale and Goering (1967).

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Related Publications

Taylor,B. D., Keep,C. F., Hall,R. O., Koch, B. J., Tronstad, L. M., Flecker,A. S. & Ulseth, A. J. (2007). Improving the fluorometric ammonium method: matrix effects, background fluorescence, and standard additions. Journal of the North American Benthological Society 26(2), 167-177. doi:10.1899/0887-3593(2007)26[167:ITFAMM]2.0.CO;2
Methods

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Parameters

Parameters for this dataset have not yet been identified

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Instruments

Dataset-specific Instrument Name	Thermo Delta Plus XP isotope ratio mass spectrometer
Generic Instrument Name	Mass Spectrometer
Dataset-specific Description	d15N values were measured on a Thermo Delta Plus XP isotope ratio mass spectrometer.
Generic Instrument Description	General term for instruments used to measure the mass-to-charge ratio of ions; generally used to find the composition of a sample by generating a mass spectrum representing the masses of sample components.

Dataset-specific Instrument Name	Rosette Sampler equipped with 24x10 L Niskin Bottles
Generic Instrument Name	Niskin bottle
Dataset-specific Description	Discrete water samples were collected using a rosette sampler equipped with 24×10 L Niskin bottles.
Generic Instrument Description	A Niskin bottle (a next generation water sampler based on the Nansen bottle) is a cylindrical, non-metallic water collection device with stoppers at both ends. The bottles can be attached individually on a hydrowire or deployed in 12, 24, or 36 bottle Rosette systems mounted on a frame and combined with a CTD. Niskin bottles are used to collect discrete water samples for a range of measurements including pigments, nutrients, plankton, etc.

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Deployments

RR2104

Website	https://www.bco-dmo.org/deployment/948513
Platform	R/V Roger Revelle
Start Date	2021-06-12
End Date	2021-07-01

AT50-10

Website	https://www.bco-dmo.org/deployment/916122
Platform	R/V Atlantis
Report	https://www.rvdata.us/search/cruise/AT50-10
Start Date	2023-05-02
End Date	2023-06-09

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Project Information

Collaborative Research: Underexplored Connections between Nitrogen and Trace Metal Cycling in Oxygen Minimum Zones Mediated by Metalloenzyme Inventories (CliOMZ)

Coverage: Eastern Tropical Pacific

NSF abstract:
Though scarce and largely insoluble, trace metals are key components of sophisticated enzymes (protein molecules that speed up biochemical reactions) involved in biogeochemical cycles in the dark ocean (below 1000m). For example, metalloenzymes are involved in nearly every reaction in the nitrogen cycle. Yet, despite direct connections between trace metal and nitrogen cycles, the relationship between trace metal distributions and biological nitrogen cycling processes in the dark ocean have rarely been explored, likely due to the technical challenges associated with their study. Availability of the autonomous underwater vehicle (AUV) Clio, a

sampling platform capable of collecting high-resolution vertical profile samples for biochemical and microbial measurements by large volume filtration of microbial particulate material, has overcome this challenge. Thus, this research project plans an interdisciplinary chemistry, biology, and engineering effort to test the hypothesis that certain chemical reactions, such as nitrite oxidation, could become limited by metal availability within the upper mesopelagic and that trace metal demands for nitrite-oxidizing bacteria may be increased under low oxygen conditions. Broader impacts of this study include the continued development and application of the Clio Biogeochemical AUV as a community resource by developing and testing its high-resolution and adaptive sampling capabilities. In addition, metaproteomic data will be deposited into the recently launched Ocean Protein Portal to allow oceanographers and the metals in biology community to examine the distribution of proteins and metalloenzymes in the ocean. Undergraduate students will be supported by this project at all three institutions, with an effort to recruit minority students. The proposed research will also be synergistic with the goals of early community-building efforts for a potential global scale microbial biogeochemistry program modeled after the success of the GEOTRACES program, provisionally called "Biogeoscapes: Ocean metabolism and nutrient cycles on a changing planet".

The proposed research project will test the following three hypotheses: (1) the microbial metalloenzyme distribution of the mesopelagic is spatially dynamic in response to environmental gradients in oxygen and trace metals, (2) nitrite oxidation in the Eastern Tropical Pacific Ocean can be limited by iron availability in the upper mesopelagic through an inability to complete biosynthesis of the microbial protein nitrite oxidoreductase, and (3) nitrite-oxidizing bacteria increase their metalloenzyme requirements at low oxygen, impacting the distribution of both dissolved and particulate metals within oxygen minimum zones. One of the challenges to characterizing the biogeochemistry of the mesopelagic ocean is an inability to effectively sample it. As a sampling platform, we will use the novel biogeochemical AUV Clio that enables high-resolution vertical profile samples for biochemical and microbial measurements by large volume filtration of microbial particulate material on a research expedition in the Eastern Tropical Pacific Ocean. Specific research activities will be orchestrated to test the hypotheses. Hypothesis 1 will be explored by comparison of hydrographic, microbial distributions, dissolved and particulate metal data, and metaproteomic results with profile samples collected by Clio. Hypothesis 2 will be tested by incubation experiments using 15NO2- oxidation rates on Clio-collected incubation samples. Hypothesis 3 will be tested by dividing targeted nitrite oxidoreductase protein copies by qPCR (quantitative polymerase chain reaction)-based nitrite oxidizing bacteria abundance (NOB) to determine if cellular copy number varies with oxygen distributions, and by metalloproteomic analyses of NOB cultures. The demonstration of trace metal limitation of remineralization processes, not just primary production, would transform our understanding of the role of metals in biogeochemical cycling and provide new ways with which to interpret sectional data of dissolved and particulate trace metal distributions in the ocean. The idea that oxygen may play a previously underappreciated role in controlling trace metals due not just to metals' physical chemistry, but also from changing biological demand, will improve our ability to predict trace metal distributions in the face of decreasing ocean oxygen content.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1924512

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