BioGeoSCAPES: Ocean metabolism and nutrient cycles on a changing planet

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Abstract

Greater understanding of the oceans is critical to the sustainability of human society. The importance of ocean microbes in marine food webs and as essential drivers of planetary biogeochemical cycles has long been recognized, yet our understanding of the dynamics and controls of these cycles remains limited. Recent major advances in DNA sequencing, mass spectrometry, and bioinformatics have advanced the field to the point that a more complete integration of molecular biology and geochemistry is now possible in the ocean. At the same time, our predictive capacity is greatly increasing as a result of the integrative potential of new modelling platforms, artificial intelligence/machine learning, and robotic sampling. A coordinated global microbial biogeochemistry program, in which genomic surveys and process studies are combined with sophisticated, high-resolution geochemical measurements, could transform our understanding of the ocean's microbiome. BioGeoSCAPES will improve our understanding of the functioning and regulation of ocean metabolism and its interactions with nutrient cycling. Through a multi-disciplinary and multi-dimensional approach built on international collaboration, BioGeoSCAPES strives to provide significant and transformative advances in our knowledge at multiple space and time scales that will contribute to understanding the oceans and their role in influencing climate on a changing planet.

BioGeoScapes
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New Technologies Come of Age: 'Omics and Micronutrients

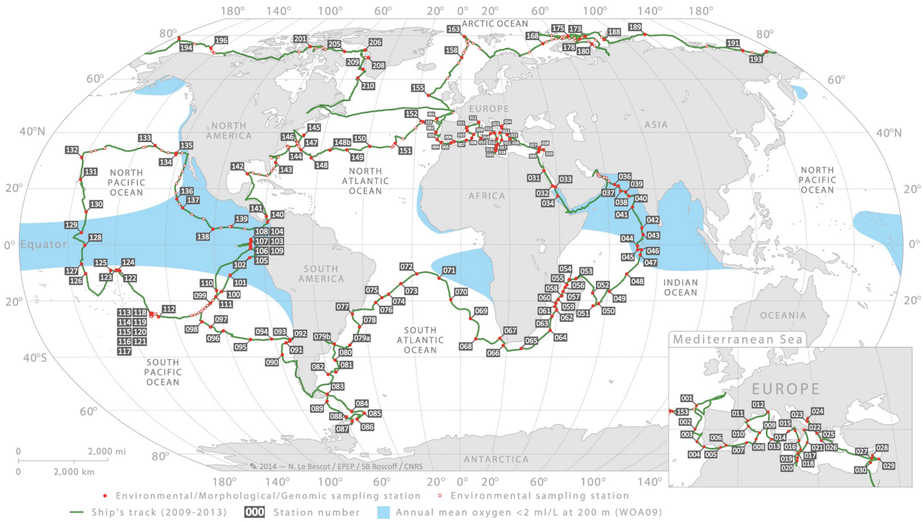
'OMICS REVOLUTION

- The use of new biological "omics" methods has transformed our understanding of biological communities and their activities.
- **Genomic**, **transcriptomic**, **proteomic**, **metabolomic**, and **lipidomic** measurements are now routinely made, but often not simultaneously.

MICRONUTRIENTS

- Significant advances have enabled the quantification of metal micronutrients in seawater
- This has led to significant insights into biogeochemical controls on biology.

Despite these advances, rarely are these new measurements conducted simultaneously.



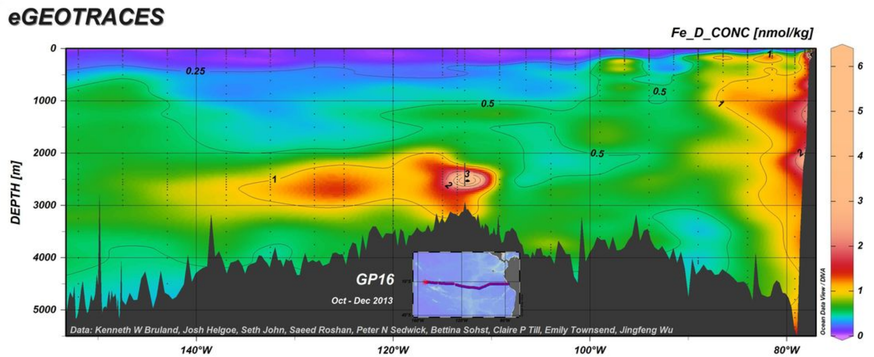


Figure 1. Revolutions in 'omics (top) and trace metal measurement technology (bottom) has enabled major ocean discoveries within recent decades. (Pesant et al., 2015; Resing et al., 2015)

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OCEAN METABOLISM – at the heart of the planetary support system

Intracellular processes

Organisms & assemblages

Ecosystem-scale cycling and feedbacks

Mission Statement: To improve our understanding of the functioning and regulation of ocean metabolism and its interactions with nutrient cycling within the context of a hierarchal seascape perspective.

Why? To constrain biological feedbacks on a changing planet

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Vision

- An integrated approach combining 'omics approaches (genomics, transcriptomics, proteomics, lipidomics and metabolomics) and chemical measurements (nutrients, micronutrients, metabolites)
- Global-scale quantification of microbial communities
- Understanding ocean metabolism and its influence on ecosystem health and biogeochemical cycles.

BioGeoSCAPES

- International, community-driven effort (www.BioGeoSCAPES.org)
- Full-depth, basin-scale ocean sections, time-series, process studies
- Rich biological and chemical datasets and improved integration between observations and models

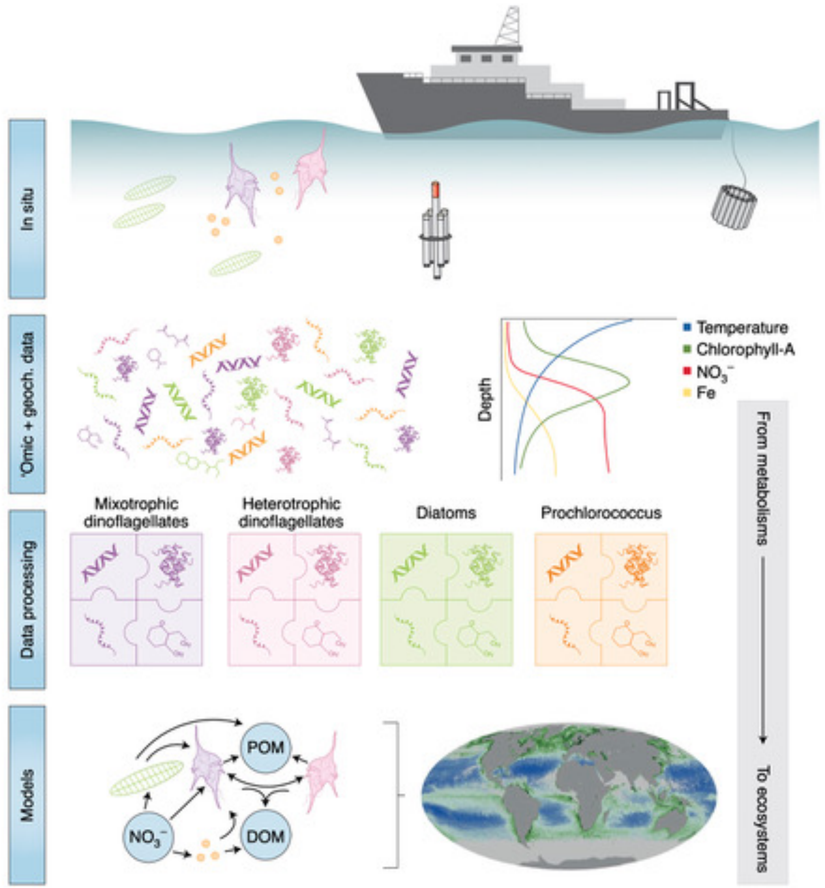

Figure 2. BioGeoSCAPES will integrate *in situ* 'omic and geochemical observations with data science and models to transform our understanding of ocean microbial biogeochemistry. From Levine and Leles, 2021.

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UN Challenges addressed

- 'Omics methodologies are particularly well-suited for studying the effects of multiple stressors on ocean ecosystems under changing conditions (**Challenge 2**)
- Building our capacity to monitor changes in marine microbial distributions and measure their responses to stressors on regional to global scales will assist in understanding and protecting marine ecosystems and fisheries (**Challenge 3**)
- Providing novel data sets documenting the metabolic status of the global ocean will contribute to our understanding of the ocean-climate nexus (**Challenge 5**)
- The global mission and multi-omic technology behind BioGeoSCAPES will form the foundation of a global ocean observing system for monitoring marine ecosystem health and providing evidence of human impacts on critical marine ecosystems to better inform "humanity's relationship with the ocean." (**Challenges 7 and 10**)
- The ability to visualize ocean microbial populations and their genetic and biochemical information to the ocean's full depth and across basin-wide BioGeoSCAPES sections will contribute to "developing a comprehensive digital representation of the ocean, including a dynamic ocean map" with "free and open access" to stakeholders. (**Challenge 8**)
- BioGeoSCAPES will provide "capacity development and equitable access to data, information, knowledge and technology across all aspects of ocean science and for all stakeholders." (**Challenge 9**)

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Connections to existing infrastructure, technology, and partnerships

- BioGeoSCAPES will connect with the development of both biogeochemistry and biomedical infrastructure and technology development.
- The study of trace metal micronutrients and ‘omics in ocean environments are active fields in the US and beyond.
- Infrastructure includes multiple sampling modes: Trace metal rosette and winch, submersible filtering pumps, autonomous underwater vehicle, analytical sequencers, and mass spectrometers.
- **Intercalibration** and **data science** initiatives needed for implementation

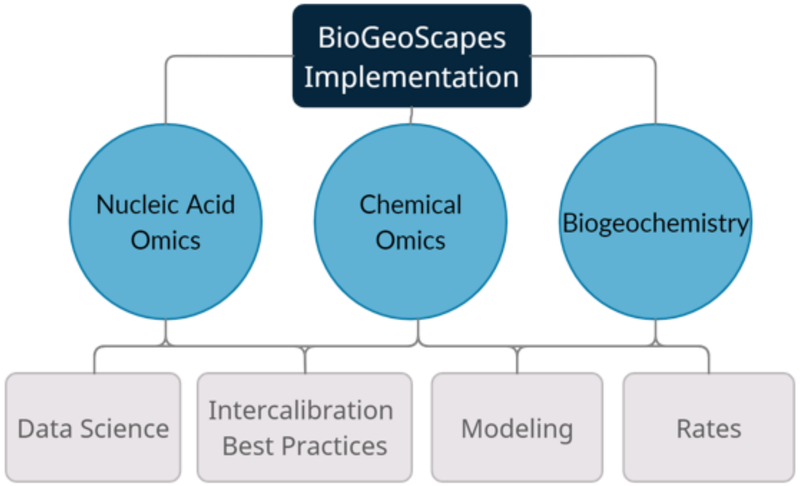

Figure 3. Three examples of science domains (blue) that will be integrated into BioGeoSCAPES science, relying on four enablers (grey).

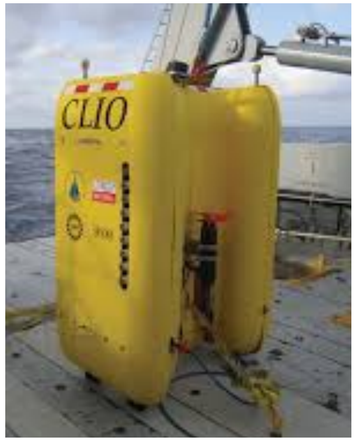

Figure 4. The autonomous underwater vehicle CLIO designed for biogeochemical sampling on global ocean basin scales.

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Opportunities for international collaboration and capacity-building

- BioGeoSCAPES is a larger effort than any nation can accomplish alone.
- An international community is being organized to plan and implement a coordinated suite of global expeditions.
- To date, representatives have been identified in 21 nations.
- National meetings have occurred or are planned in seven countries.
- The resulting scientific community and massive datasets will together promote ocean research and education internationally. Planning efforts began in 2018 with a meeting of international participants tasked with organizing national communities.
- **Join the email list: Contact info@biogeoscapes.org**
- **www.BioGeoSCAPES.org for further information.**