

## **Summary of the German BioGeoSCAPES scoping workshop “Ocean Metabolism and Nutrient Cycles on a Changing Planet”**

The scoping session for the German BioGeoSCAPES project was organised on July 10th at the Institute for Advanced Study (HWK) in Delmenhorst. The workshop was supervised by Martha Gledhill from GEOMAR, Sinikka Lennartz from ICBM (Uni Oldenburg), and Kristin Bergauer from GEOMAR. A group of researchers from multiple universities and institutions in Germany, possessing a range of expertise in physical oceanography, biogeochemistry, quantitative biology/microbiology, biogeochemical modelling and bioinformatics, collaborated to analyze and provide feedback on the initial BioGeoSCAPES Mission Statement and research plans. This collaborative effort aimed to address four primary questions that arose during an initial international meeting held in Woods Hole, USA, in November 2018.

Four keynote speakers addressed the following topics

- i) **Tom Browning** (GEOMAR): ‘Oceanic nutrient limitation: current observations and looking forward to BioGeoSCAPES’
- ii) **Wiebke Mohr** (MPI): ‘The role of nitrogen-fixing microorganisms in element cycling’
- iii) **Frank Oliver Glöckner** (AWI): ‘News from PANGAEA – Data Publisher for Earth and Environmental Science’
- iv) **Christoph Völker** (AWI): ‘What can modelling contribute to Biogeoscapes?’

Here we offer a concise overview that addresses the four primary inquiries:

1. The preliminary mission statement is ***‘To improve our understanding of the functioning and regulation of the ocean metabolism and its interaction with nutrient cycling within the context of a hierarchical seascape perspective’***. Workshop participants felt the mission statement generated some confusion, particularly the ‘hierarchical seascape perspective’. Furthermore, the phrase ‘improve our understanding’ was perceived as too broad. Alternative suggestions: i) ‘role of nutrients’ instead of ‘interaction with’, ii) ‘ocean metabolism’ (divided feedback), iii) ‘provide a mechanistic and quantitative understanding’ instead of ‘improve our understanding’, iv) ‘biogeochemistry and energy cycle’ or ‘energy and material cycling’. Overall, participants suggested to include the keywords ‘global’ and ‘underpin’ and to **expand the statement to two or three sentences, emphasizing an endpoint and purpose** and to maybe follow the example of the C-CoMP mission statement (<https://ccomp-stc.org>), describing how the goals will be achieved.

***‘To provide mechanistic and quantitative understanding of the functioning and regulation of the ocean’s metabolism, linking microbial diversity with biogeochemical processes across the ocean’s seascapes.’***

2. **How could Germany best contribute to BioGeoSCAPES efforts** (e.g. fieldwork, laboratory work, modelling, intercalibration efforts, project coordination, data management, bioinformatics)?

Ship-based research (ship infrastructure; new RV Meteor) was identified as a major resource, as well as having expertise in coastal time-series (Boknis Eck station, Helgoland, Hausgarten), and oceanographic transects/large expeditions following a common sampling strategy. Furthermore, participants mentioned interdisciplinary research, data management/bioinformatics, collaboration, and biogeochemical models/modelling. German research is likewise strongly involved in polar research, micronutrients, pelagic imaging, climate models, artificial intelligence, chemical oceanography, greenhouse and volatile gasses, rate measurements, microbial ecology, and sensor technology. Germany also possesses

expertise in biogeochemical modelling, especially in the topics of isotopes (nitrogen cycle), dissolved organic matter and microbial interactions as well as trace metals and ligands, using global modelling frameworks such as ERSEM and UVic.

### **3. What science questions are most important to Germany within the broad scope of BioGeoSCAPES on a 10-year timeframe?**

The utilization of multiOMICs technologies in conjunction with **physiological** investigations has been recommended to be highly advantageous and constructive. The integration of culture-independent and culture-dependent methodologies will be essential for the progression and integration of ocean metabolism and large-scale patterns, as well as the understanding of microbial community structure and functions, and rate measurements at many levels of biological organization, ranging from individual cells to entire ecosystems.

The scientific community has recognized numerous issues that may be regarded as potential areas of exploration as BioGeoSCAPES continues to develop. Two main topics/research questions emerged from the discussion:

- How resilient are marine ecosystems and their services in the face of global change? This question focuses on the stability of microbial communities against multiple stressors, and their connection to ocean biogeochemistry. This question sets an emphasis on populations and variations of characteristics, embracing the diversity of microorganisms and organic molecules as well as their interactions, rather than average measurements on the bulk level. The question touches on functional redundancy and the factors limiting microbial growth and turnover of elements.
- Which climate feedbacks do we expect on ocean's energy flux and productivity? Understanding feedbacks requires a comprehensive picture of the ocean system, making a large-scale effort like BioGeoSCAPES an ideal venue. This question aims to link living (microbial) and non-living (physical, chemical) systems and their relation to the climate system with respect to productivity and carbon sequestration through the lens of energy fluxes. It requires rate measurements in addition to bulk measurements of microbial uptake and transformation of compounds as well as the resulting carbon export.

It was highlighted that a hypothesis driven approach, rather than purely exploratory approaches, was favoured, that allows moving from correlation to causality. Equally, a comprehensive approach including biogeochemical, microbial and physical measurements was seen as desirable.

### **4. Are there impediments that the International program could seek to mitigate via training or collaboration?**

Intercalibration and intercomparison efforts are essential for several applications, such as 'omics' technologies, rate measurements, and bioinformatic workflows. There is a need for the development of a Best Practise guide within the BioGeoSCAPES community. A platform facilitating collaborative endeavours and knowledge sharing, could prove beneficial in promoting project development. Importantly, facilitating the exchange across disciplines was seen as a huge opportunity in order to develop a 'common language' by working interdisciplinary towards a common goal. In addition, the desirability of support and benefits sharing, such as in the case of the Nagoya Protocol, is evident.