2nd BioGeoScapes -France Meeting

9-10 December 2021 LEGOS-OMP, Toulouse, France

The main aim of the meeting was to continue and broaden the discussion started within the French community in December 2020 (1st French BioGeoScapes meeting, online), and thereby to foster the French national BioGeoScapes community and to provide novel opportunities for national and international networking.

The meeting was organized by Ingrid Obernosterer (LOMIC), Catherine Jeandel (LEGOS), Damien Cardinal (LOCEAN), Ludwig Jardillier (ESE), Marion Gehlen (LSCE) and Urania Christaki (LOG) and received financial support from the French national funding agency CNRS-INSU-LEFE-CYBER.

A total of 38 research scientists from 17 laboratories participated to the meeting. A full list of participants is provided at the end of this document. The following report aims to provide a summary of the main points of discussions, including the feedback from the 3 break-out groups and the plenary meetings. Each break-out group had a heterogeneous composition of scientists with different backgrounds (bio-geochemistry, biology, and working with different approaches including field, laboratory and modelling experiments).

A few main points are summarized below.

The need for a clear overarching question to which BioGeoScapes aims to respond was raised during the meeting. In this context, the term 'ocean metabolism' was lively discussed, as the understanding of this term/concept varied among research scientists. The meeting gathered scientists from two fields of ocean research with very different advancements in intercalibration and intercomparison exercises. The discussions between scientists with expertise in Geotraces-like approaches and those with –omics-methodologies highlighted that a better understanding of what is achievable by each of the techniques is key for a successful cross-disciplinary integration of the results. The need for a glossary and complementary training became evident as the definitions of terms can differ between disciplines and chapels. The question of the definition of what is a future BioGeoScapes-like project was closely linked to the priorization of core parameters. Geochemical: which chemical elements? Biogeochemical: Which stocks and fluxes? Biological: Which group of organisms? What level of description of ecosystems?

<u>What science questions are most important to scientists in France within the broad scope of Biogeoscapes on a 10-year timeframe?</u>

Metabolic processes and possible adaptation to a changing environment. Which environmental conditions will affect ocean metabolism and nutrient cycling? For which metabolic processes can adaptation take place, which ones will be replaced?

Regulation and processes involved in these regulations. How do metabolic processes respond to different environmental stressors? At what level does the regulation of a given metabolic process to an environmental stressor take place, the molecular, cellular or population level?

Processes of acclimation and adaptation. What are the underlying mechanisms of acclimation to immediate and short-term changes in the environment, and of adaptation to longer-time scale changes (i.e., evolutionary processes)? How different are these among species?
Individual or connected nutrient cycles. What are the interactions and inter-dependencies between nutrient cycling pathways? How do biological processes affect the isotopic fractionation of trace elements? How can we improve our understanding of the cycling of organic substrates across the size-continuum and their link to the involved taxa?

Magnitude and distribution of metabolic processes in the ocean. Is each metabolism everywhere? What are the rules (e.g. environmental selection) of their structuring? Which metabolisms can coexist? Are taxonomically diverse organisms involved in these metabolisms? How stable through time is a biological structure carrying out a metabolism and what are its responses to perturbations?

The issue of scales. An integrated view from the molecule to the ecosystem, from the sea-surface to surface sediments is required, and a panel of high resolution techniques in –omics, imaging, chemistry and process studies exist, but how can we link processes occurring on different spatial and temporal scales? How can we extend from the microenvironment surrounding a single cell to large-scale processes? How can we improve our understanding of the complexity of the ecosystem, e.g. mixotrophy, symbioses, viruses, and more generally the interactions between microorganisms in trace elements and nutrient cycling?

Which science questions require a coordinated effort between different disciplines in oceanography?

- How can we better consider biological complexity and interactions in models of nutrients cycling?
- Can we identify similar concepts in different disciplines, and how can we bridge them? E.g., can we link the cell surface area relationship to genomics scaling laws to better understand the bioavailability of elements from -omics knowledge?
- Can we identify omics-based proxies (e.g. biosensors) at the gene, species and community level to measure/predict i) nutrient bioavailability and ii) functional traits?
- Can we derive biogeochemical rates from -omics data?
- How can we integrate information from elemental isotopes to better mine and understand -omics data, and vice-versa?

What are potential barriers to interdisciplinarity and how can we address them?

Different temporal and spatial scales – For the design of relevant process studies, we need to identify the spatial and temporal resolution required to appropriately address geochemical and biological questions of interest. E.g., diel cycles are key in microbial processes, and can be reflected in metatranscriptomics results, but this temporal scale might not be the most relevant in geochemistry. Can we identify common key ocean regions that are of particular interest to different disciplines, or that will provide the more suitable environment for major advances in the context of BioGeoScapes? This and other scientific reasons render the simultaneous and exhaustive sampling for geochemical and –omics analyses during cruises challenging. One logistic issue is the large water requirements. There is a need for the development/deployment of new tools and/or dedicated cruises.

Cooperation could be encouraged if missing links between disciplines are defined and a complementary approach, requiring analyses from both fields of research, is needed to address them.

E.g., what are the methodological limitations within a given discipline that hamper the full understanding of a process, and how could complementary approaches help advance?

How to improve the preliminary BioGeoScapes mission statement?

The evolutionary aspect is not well considered, but molecular evolution and adaptation can be useful to understand how the system formed and adapted, in order to understand and predict how it may evolve in the future.

Emerging points that need to be discussed within the larger BioGeoScapes community.

- Definition of the term/concept '**Ocean metabolism**'. E.g., Ensemble of biochemical reactions and processes, mediated and catalysed by enzymes, that shape biogeochemical cycles.

- **Common vocabulary and cross-training**. The establishment of a glossary with definitions of terms to facilitate communication between disciplines is one option. This basic glossary could be extended to a number of concepts that are key in BioGeoScapes and eventually also include some technical aspects related to key points of different disciplines. E.g., What is a gene? How can a gene be defined and what is its signification in –omics analyses? Is the number of genes in a metagenome comparable to a number of molecules in a volume of seawater?

- **Linking biogeochemical and –omics data**. The deposition of data into different repositories as fast as possible is required for coordinated sample analyses. Depending on the question to be addressed, the type of data can be heterogeneous (e.g. absolute vs relative values) and will determine the minimum amount of common data required. Computational approaches to integrate heterogeneous data presently exist. Design a sampling strategy that resolves both biogeochemical and omics aspects (diel, seasonal, vertical/horizontal resolution/ water masses/ biogeographic provinces/time series). What kind of models do we need to address these challenges?

- **Keep an eye on the organisms**. Maintain and develop further our abilities to observe the organisms of interest. Microscopic observations, associated with isotopic labelling techniques, and high frequency in situ imaging are powerful tools to identify species, their traits and contribution to elemental cycles, and to quantify their abundance in the environment.

- Establish a list of **core parameters** for BioGeoScapes-like studies, similar to what has been done in Geotraces. Which genomic data would be most relevant and which other complementary data are needed? Will metabarcoding data (microbial diversity analyses) be key for BioGeoScapes or should our focus be on the functional aspect (meta-omics)? The access to meta-omics data is still more costly, thus funding availability is a potential barrier for labs participating to BioGeoScapes. But the increasing amount of sequencing data from almost all ocean regions will allow the re-analysis of publicly available data sets with a BioGeoScapes perspective. A key future challenge is to maintain the expertise in the optical determination of species and their traits (size, morphology, etc.). Clear sample management (e.g. one data = one "barcode") for standardization of data is required. Data management: prior, during and after the cruise so that samples can be tracked easily.

- Intercalibration and Intercomparisons for core parameters. Are -omics data quantitative? Which of the -omics techniques are quantitative? What is the aim of an intercalibration for non-quantitative data? What can be compared among studies, and what cannot? A list of priorities of common procedures is suggested. These could include sampling procedures (e.g. size fractionation, types of filters used, storage of samples), extraction kits, types of primers for metabarcoding, sequencing depths, bioinformatics pipelines for initial steps. A dedicated international intercomparison exercise is to be planned. At the European level, protocols from TARA-oceans and EMOBON (sediment) have been adopted by a large community. These could be starting points. Can we gain insights from the more advanced gut microbiome research community?

How would France best contribute to BioGeoScapes efforts – e.g. fieldwork, laboratory work, modelling, intercalibration efforts, project coordination, data management, bioinformatics?

The French scientific community is co-leader in GEOTRACES and TARA-oceans, it has strong expertise in environmental genomics and ecophysiology, process studies, and modelling. For its contribution to BioGeoScapes it is now key to bring these communities (and possibly also others) together; this 2nd meeting was clearly an important step in this direction.

France co-ordinates the long-term observation (> 20 years) of the coastal ocean through 21 times-series sites (Atlantic Ocean, English Channel and Mediterranean Sea). Some of these sites could become extended observatories, including BioGeoScapes-like core parameters.

Which previous or on-going research/coordination activities in France could be a good starting point/example for a Biogeoscapes-like project?

French scientist led a number of interdisciplinary cruises in the past years that collected BioGeoScapes -like data. Can we take advantage of these already existing (or under construction) datasets to attempt links between chemical and –omics data? Some very recent cruises are SWINGS (Southern Ocean), TONGA (South Pacific Ocean), PERLE (Mediterranean Sea), and some upcoming cruises are APERO (North-Atlantic Ocean) and BIOSWOT (Mediterranean Sea). What type of data exist already, which ones are in progress? Is there a potential for exploration or are we entirely dependent on new data acquisition? Some already existing French networks (e.g. Si, N) should be included for a common effort of protocol standardization.

Which training opportunities, at different levels, can the French community offer?

Several opportunities already exist, such as the EBAME course (https://maignienlab.gitlab.io/ebame6/; OMICS approaches), TARA course (https://en.qlife.psl.eu/actualite/winter-school/course-quantitative-ecological-genomics-tara-ocean; OMICS, modelling), summer schools like Geotraces and silica school (from the field to data analysis and modelling). To increase these opportunities, it is suggested to set up a catalogue of existing French training modules, to cross-compare, and design new transdisciplinary programmes and provide feedback to University and Master programmes, to train the BioGeoSCAPES scientists of tomorrow. In parallel, a catalogue of labs/platforms/people with specific skills, will facilitate contacts and collaboration is suggested to be set up.

What will happen next in France?

The BioGeoScapes workshop clearly identified the need for a common language between research scientists of different disciplines and a better understanding of each others' basics concepts. It is planned to organize a few webinars to address this issue.

Get in contact with international colleagues to exchange on progress made in intercalibration and intercomparison exercises on –OMICS data. This is should be a common, international effort. A first exchange between I. Obernosterer and Adrian Marchetti took place in January 2022. They agreed on co-ordinating an on-line meeting once the report of the US workshop on Nucleic Acids 'Omics is published on the Ocean Carbon and Biogeochemistry website.

Keep the French BioGeoScapes community informed about international ongoing activities through regular updates via messages to a French mailing list.

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