Summary of proposals for the planning Russian BioGeoSCAPES for the International BioGeoSCAPES community

Introduction. The proposals for the planning Russian BioGeoSCAPES were prepared through a local meeting in Moscow (September 26, 2023) by Dr. Marina Kravchishina and Prof. Mikhail Flint (Shirshov Institute of Oceanology, Russian Academy of Sciences, IO RAS) and personal communication with experts in marine biogeochemistry, microbiology, hydrobiology, genomics, biophysics and ecology. In total, 12 participants from various academic institutes and universities took part in the discussion. The aim of the meeting and personal communications was to obtain feedback from Russian scientists on four questions (A–D) proposed by workshop participants in Woods Hole, MA, USA, in November 2018 for discussion at the national meeting.

A) Thoughts on the preliminary mission statement of BioGeoSCAPES: "*To improve our understanding of the functioning and regulation of ocean metabolism and its interaction with nutrient cycling within the context of a hierarchical seascape perspective*".

Russian researchers propose to consider the following options for the mission statement of BioGeoSCAPES:

- *Advancing research on understanding of ocean metabolism and elemental cycling on a changing planet using a system approach: creation of new integrated methodology, analytical methods and technologies, and development knowledge of environmental effects.*
- *To intensify the research on ocean metabolism and deeper understanding of elemental cycling on a changing planet*: *fostering methodologically robust approach,* sensitive *methods, technologies, and knowledge of environmental effects.*

B) How would your nation best contribute to BioGeoSCAPES efforts? – e.g. fieldwork, laboratory work, modelling, intercalibration efforts, project coordination, data management, bioinformatics.

According to Russian researchers, our contribution to the international activities of BioGeoSCAPES should be based on scientific competences and many years of experience in the following areas:

- Ongoing Arctic research programs in collaboration with various academic institutes and universities across Russia: (i) European Arctic: A Geological Record of Environmental and Climate Change, led by Dr. Marina Kravchishina (IO RAS); (ii) Ecosystems of the Seas of the Siberian Arctic, led by Prof. Mikhail Flint (IO RAS, full member of the Russian Academy of Sciences).
- Automatic Deep-Water Sedimentary Observatories – mooring systems equipped with sediment traps, current meters and a suite of sensors to study of vertical particle fluxes and fluxes of particulate elements.
- Development of a national system for monitoring of climatic changes of hydrophysical and biogeochemical characteristics and fluxes of climatically active substances using marine observatories, ship-based and shore-based observations, which will provide prompt, reliable and publicly available data sets on the dynamics of climatic characteristics and greenhouse gas fluxes, including rapid reanalysis, in the Subpolar North Atlantic, Northwest Pacific Ocean and Russian seas. The project is carried out by seven academic institutes and universities across Russia under the leadership of Prof. Sergey Gulev (IO RAS, Corresponding Member of the Russian Academy of Sciences).
- Cruises to areas of critical gateways of ocean circulation patterns: (i) the Barents Sea and Fram Strait (Arctic) – "northern sinking" pathway of warm Atlantic waters into the Arctic; (ii) the Nordic Seas and Greenland-Scotland Ridge (Subpolar North Atlantic) controls exit of dense polar waters from the Nordic seas to the Atlantic; (iii) the Bering Sea – narrow seaway connecting the Arctic and Pacific Oceans; (iv) the Vema Channel (southwestern Atlantic) – a pathway of Antarctic Bottom Water flow to the north and some other critical areas.

- Laboratory work: study of element cycles, rates of microbial processes (sulfate reduction, methanogenesis, etc), phylogenetic analysis of the microbial communities, primary production, biodiversity, etc.
- Participation and assistance in intercalibration works.

Russian researches plan to participate in BioGeoSCAPES surveys in the Eurasian Arctic, subpolar North Atlantic, and Northwest Pacific. Our ongoing system investigations represent promising opportunities for sampling and international collaboration and intercalibration efforts.

C) What science questions are most important to your nation within the broad scope of BioGeoSCAPES on a 10-year timeframe?

Russian scientists outline the range of scientific tasks for the 10-year perspective:

– The processes of sedimentation and transformation of organic matter in the Arctic seas are closely related to global climate change and formation of fossils. As the active phase of oil and natural gas exploration continues in the Barents and Kara seas, the interdisciplinary research is not only of fundamental importance, but also becomes particularly relevant for the ecological monitoring of the marine environment. The study of the structure, functioning and protection of Arctic ecosystems is necessary due to the development of intensive shipping and the exploitation of fossil resources in the Arctic seas.

– We consider the study of biogeochemical cycles of C, S, N and related trace element cycles as one of the most important questions in the Arctic marine ecosystems. Differences in estimates of the oceanic methane flux to the atmosphere are due to limited knowledge of the oceanic methane cycle. Understanding the Arctic methane cycle is a topical scientific problem that has often been neglected in carbon cycle research to date. The study of the methane cycle which carries out under strictly anoxic (methanogenesis and anaerobic methane oxidation) and under oxic (aerobic methane oxidation) conditions provide new insights into the carbon cycle in marine sediments. The activities of methanogens and methanotrophs are linked to the biogeochemical cycle of sulfur. As for the biogeochemical cycle of nitrogen, ammonia- and nitrite-oxidizing microorganisms are often abundant in the upper oxic layers of sediments, and nitrate-reducing bacteria and archaea can oxidize sulfide. Thus, the sulfur biogeochemical cycle is linked with the anaerobic oxidation of methane and the nitrogen cycle, which includes the oxidation of ammonium to nitrate in the oxic layers and denitrification coupled to the oxidation of sulfide in the deeper layers of sediments. Therefore, to study the phylogenetic composition and metabolic capabilities of marine microbial communities depending of different physicochemical conditions in the environment is of key importance. Testing of the hypothesis about the possibility of methane generation in the oxic water column of the Arctic shelf seas as a byproduct of methylphosphonate decomposition in phosphate-depleted waters.

– The fluxes of settling particles and their composition are closely related to current climate changes in the Arctic, where dramatic changes in the ocean and atmosphere have occurred. Particle fluxes in the ocean are one of the main characteristics of sedimentation, which makes it possible to study particle transformation during their passage through the water column to the seafloor and makes it possible to estimate the quantity and determine the composition of sinking particles.

– To assess the long-term variability of macro nutrient concentrations in the Arctic and to provide a retrospective of research in this area over the past 30 years. The Arctic Ocean receives high freshwater inputs, and annual freshwater flows from the large Arctic river systems have increased in recent decades. The main contribution to the fresh water budget on the Siberian shelf comes from the melting of sea ice and glaciers on archipelagos and the runoff of large rivers (Ob, Yenisei, and Lena). This process affects the structure of water masses on the shelf and modifies the large-scale freshwater cycle in the Eurasian Arctic Basin and freshwater outflow to the North Atlantic by the Transpolar Drift. The physical effects of freshwater input are accompanied with

increases in riverine and permafrost-derived inputs of carbon, nutrients, and related trace elements, which are still poorly understood.

– Development of multi-component databases of energy fluxes, climatically active gases and related biogeochemical characteristics for the Russian seas and assessment of the changing role of individual seas in the formation of the carbon balance of the ocean and the Earth's carbon balance.

D) Are there any impediments that the international community could seek to mitigate via training or collaboration?

There is a clear need for international co-operation in the study of ocean metabolism. Russian scientists would like to be optimistic about the continuation of international co-operation in ocean research, despite the ongoing negative global political processes, such as, the culture of dialogue in international affairs is degrading and the effectiveness of diplomacy as a means of peaceful dispute settlement. We believe that the international community will stay out of the ongoing negative processes in politics and will not allow them to penetrate into the scientific field. We hope in the future to revive international programmes/expeditions in the ocean and in the Eurasian Arctic with the participation of Russian scientists.

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- Several colleagues from different universities involved in the discussion wished to remain unnamed.