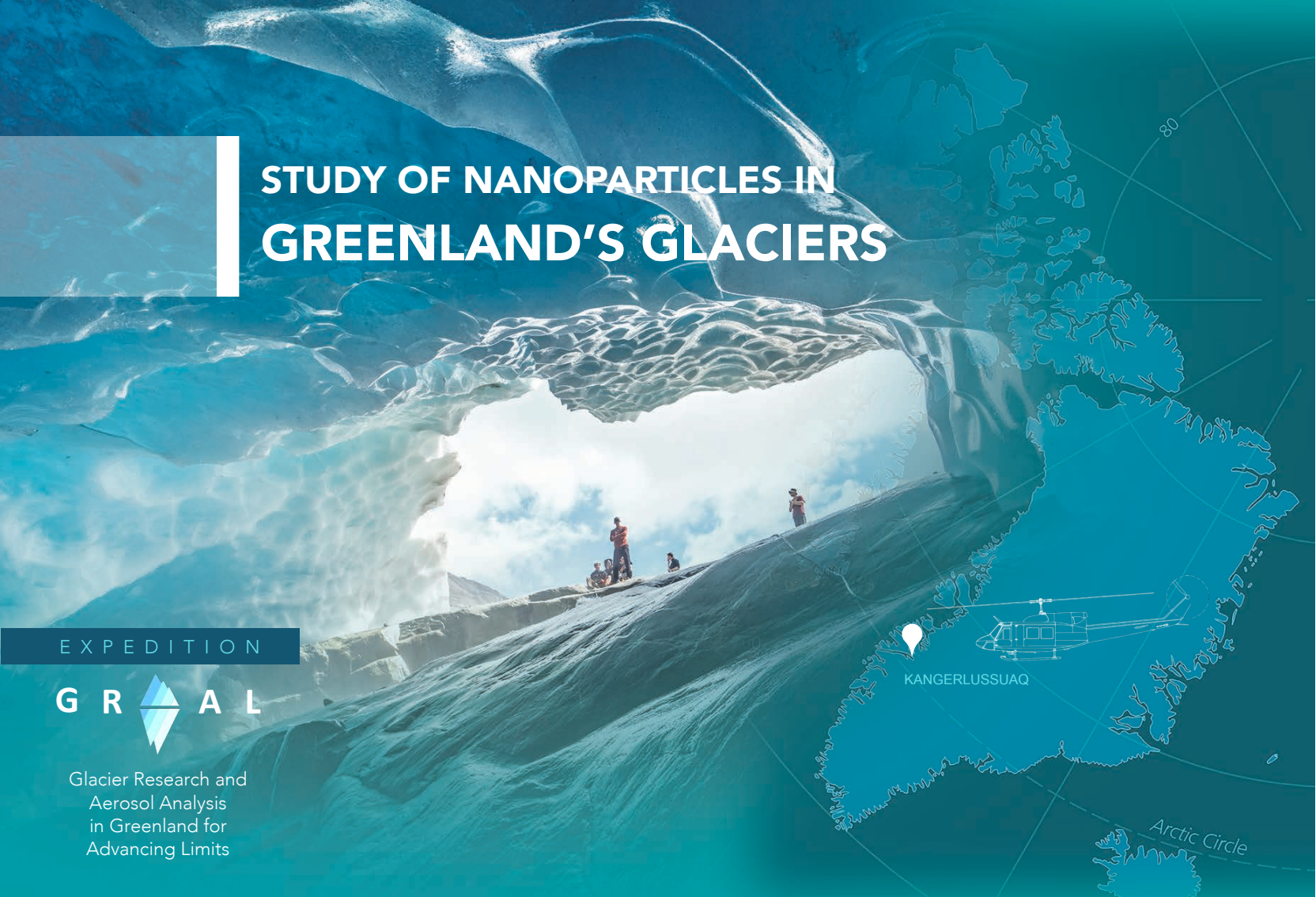
STUDY OF NANOPARTICLES IN GREENLAND'S GLACIERS



EXPEDITION

GRAAL

Glacier Research and Aerosol Analysis in Greenland for Advancing Limits

Nanoparticles:
Great Travelers

For a long time, climativ and geological phenomena were the primary drivers of transformations on Earth's surface. In the Anthropocene era, global changes caused by human activity are now the predominant forces shaping natural environments. In this context, the study of the biogeochemical cycles of metallic elements and their evolution under human influence has become a growing focus for scientist.

metallic contaminants are sometimes emitted into the air, water, and soils in nanoparticulate form through natural processes (volcanic activity, erosion) or human activities (traffic emissions, fossil fuel combustion, mining operations, metal refining, asbestos, and lead). It has already been demonstrated that these activities produce nanoparticles capable of traveling great distances.

On a global scale, human sources of nanoparticles contribute to the global cycles of toxic elements; However, the proportions, origins, and temporal evolution of these contributions remain largely unknown due to the challenges of tracking them.

Greenland:
An Ideal Experimental Site

The GRAAL expedition aims to overcome this challenge by distinguishing between geogenic (natural) and anthropogenic (human-produced) nanoparticles transported atmospherically and accumulated in Greenland's ice, in regions thought to be remote and pristine.

The expedition will take place in Greenland, home to the only ice sheet (polar cap) in the Northern Hemisphere and uniquely situated equidistant between the European megacities (London-Mila axis) and the North American megalopolis (BosWash corridor, Boston-Washington).

The new knowledge gained through this project will be crucial not only for studying and understanding human impacts on major natural cycles but also for informing and protecting the public regarding nanoparticle sources. In the long term, these findings could support regulations and laws aimed at mitigating human emissions of particles.

Moulin Ice Caves:
A Unique Sampling Opportunity

This mission will allow scientists to collect samples of ice at various depths, as well as meltwater and sediments, to determine the chemical and isotopic composition (variations in atomic mass of the same element) of nanoparticles deposited over time in successive ice layers. The goal is to link this composition to natural or human sources following atmospheric transport and deposition (via snow, rain, wind).

Unlike traditional scientific expeditions where samples are taken from the surface down, researchers will descend directly into « moulin »-crevasses widened by meltwater-with the assistance of speleologists and high-altitude guides. Small horizontal cores, 20 cm in length, will then be extracted to access the different ice layers.

Moulins:
A Unique Subject of Study in Glaciology

Recent boreholes in the target exploration area will provide a valuable point of comparison with these vertical, deep cavities. This comparison is essential for establishing correlations regarding glacial stratifications, basal water levels, and ancient cryoconite deposits (dark-colored fine particles that accelerate surface melting).

During the exploration of moulins and contact cavities, several parallel studies will be conducted. These include measuring the piezometric level of meltwater and recording basal water pressure variation throughout the expedition. A complex brut critical objective is dating the different ice layers within the glacial moulins. The team will also use 3D scanners to quantify cavity valumes and study their evolution over time.

Practical Details of the Expedition

GRAAL will take place on the ice cap approximately 70 km east of Kangerlussuaq, an area well-suited for the formation of glacial moulins.

The expedition is scheduled for autumn 2024, when summer meltwaters have receded, leaving dry and accessible streambeds and moulins before snowfall blankets the ice cap and obscures them.

Led by **Serge AVIOTTE**, Expedition Leader of the Ppélé'Ice Exploration Association, and inspired by the polar expeditions of French explorer and ethnologist Paul-Émile VICTOR, the team, spearheaded by **Yann SIVRY**, will include scientists from the Institut de Physique du Globe de Paris – Université Paris Cité, glacial speleologists (glacionauts), and a filmmaker from the French and Italian associations « Spélé'Ice Exploration » and « InsidetheGlaciers. »

The Exploration Phase

From Kangerlussuaq, researchers will reach the expedition zone by helicopter, which will also transport the ton of equipment needed to establish a base camp for one week, explore the discovered cavities, and conduct scientific studies in the field.

- **Option 1**: A single camp on the glacier.
- **Option 2**: Two consecutive camps, one on the moraine and the other on the glacier.
- **Option 3**: Two simultaneous camps, one on the moraine and the other on the glacier.

The final choice will be determined following an aerial reconnaissance flight from Kangerlussuaq to identify the main moulin exploration area and a suitable location for the base camp.

The Analysis Phase

The samples will be analyzed at the IPGP using some of the most advanced innovative tools, including plasma-source mass spectrometry in single-particle mode (spICP-Tof-MS) for nanoparticle measurement or multi-collection mode (MC-ICP-MS) for stable isotope analysis, as well as asymmetric flow field-flow fractionation (AF).

This project is not only one of the first studies dedicated to distinguishing between anthropogenic and geogenic nanoparticles in environmental systems but also the first to combine these three cutting-edge tools to understand, quantify, and predict the fate of nanoparticules on a large scale.

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