Scientific Projects

A word from the tutor

The project set up by the team covers the major themes of ocean studies, with a strong focus on Antarctica. Our oceans, and the polar zones in particular, are like a canary in a coal mine. The changes taking place there affect the world's populations directly and/or indirectly. Large uncertainties remain in the projections of large-scale models, such as rising sea levels and the capacity of the oceans to absorb the greenhouse gas CO2. The clusters contribute particularly to these uncertainties, given the logistical and budgetary challenges in obtaining field data. However, we have a crucial need for these data to be able to accurately assess the speed and magnitude of the changes taking place. The expedition is approached in this spirit, with a broad spatial coverage (north/south and east/west), punctuated by distinct oceanographic zones. The Antarctic Peninsula has a particularly interesting stake, given that environmental changes are more pronounced there than in the east of the Antarctic continent. The multidisciplinary scientific approach (physics, chemistry, cryosphere, microbiology, pollution and higher trophic levels) allows an adequate representation of a complex system. The balance between the joint project and individual subjects is an excellent example of a large-scale scientific mission, during which the aim is to maximise the set of samples and data collected by a small team, all in an extreme and confined environment. Of particular interest is the social approach to a scientific mission highlighted in the project, which will illustrate the team's learning of the different facets of the research world: collaborative approaches, logistics, pressure, budget and teamwork. Finally, through the film and the educational activities put in place, the expedition is an ideal platform to highlight the role of Antarctica in the collective consciousness.

Delphine Lannuzel - IMAS Institute for Marine and Antarctic Studies, Centre for Oceans and Cryosphere (UTAS) - delphine.lannuzel@utas.edu.au

Biogeochemistry and Microbiology

Introduction

About a quarter of annual CO2 emissions are trapped in the ocean and thus do not contribute to an increase in the greenhouse effect (Le Quéré et al. 2018). The Southern Ocean contributes almost half of this oceanic carbon pump. The pump works by simple chemical transfer (dissolution), but also by biological sequestration (production of organic matter by photosynthetic organisms), the latter contributing annually to the transfer of ~10 Gt-C-yr-1 of carbon as particulate organic carbon to the deep ocean (Passow and Carlson 2012; Boyd et al. 2019).

The solubility of CO2 in the ocean decreases with increasing temperature (Le Quéré et al. 2018), but the evolution of the biological pump due to climate change is still difficult to determine (Meredith et al. 2019). This is however a crucial question, in order to better constrain climate change models.

A number of metallic trace elements, such as iron (Fe), cobalt (Co), copper (Cu), zinc (Zn), molybdenum (Mo) or cadmium (Cd) are very important micronutrients as they partly condition the acquisition and assimilation of carbon, nitrogen and phosphorus by phytoplankton (Boyd and Bressac 2017; Morel and Price 2003; Sunda 2012). These elements, present in trace amounts in the ocean, structure the phytoplankton ecosystem. In addition, elements such as Fe or Cu are 99% complexed by organic ligands to maintain their solubility (Gledhill and Buck 2012).

Realization

In this project, the analysis of ligands and trace metals will make it possible to trace the resource acquisition strategies implemented by the various species making up the ecosystem. Different types of ligands can be produced depending on their nutrient uses (preventive intracellular storage, use as a biochemical catalyst, release into the environment, etc.) and the interactions at work with their neighbours (competition, collaboration, etc.) (Strzepek et al. 2011; Marchetti and Maldonado 2016; Seymour et al. 2017).

Analysis of the metatranscriptome of the present organisms, coupled with the characterisation of the ligands in solution, will shed light on the nature of the Fe ligands. Furthermore, the analysis of metagenomes and metatranscriptomes will enable us to understand which species are involved in this process (Shi, Tyson, and DeLong 2009; Hopkinson and Barbeau 2012; Marchetti et al. 2012; Creveld et al. 2016).

In concrete terms, about 500 surface water samples will be taken during the expedition (one every 5° lat. and at a higher resolution near the North African and South American margins and near the islands and Antarctic Peninsula in the Southern Ocean) and preconditioned on board for analysis on land on our return (nutrient concentration, cytometry, dissolved and particulate metals, organic speciation, metatranscriptomics on a selection of samples).
During the journey, measurements of the primary productivity of the surface communities and chlorophyll concentration will also be carried out continuously. These measurements will be compared to the estimates of these parameters obtained by satellite to better calibrate existing models and the measurement and monitoring strategies from space enabled by the new generations of ESA and NASA satellites.

The data thus produced will make it possible to better characterise the structure of the surface ocean ecosystem, which is the basis of the biological ocean carbon pump. This study will enable us to compare our data with those already produced locally in the different zones crossed.

A word from the supervisors

In addition to the innovative nature of the vessel on which this project will be carried out, the surface sampling of trace metals and organic speciation along the various proposed transects will make it possible to study contrasted biogeochemical provinces in terms of phytoplankton communities and nutrient inputs. Generally speaking, it will be possible to highlight the various sources of these trace metals at the surface, whether aeolian, basal or sedimentary.

More particularly, at the level of the West African coastline, the objective will be to differentiate wind contributions from contributions coming from upwelling and to possibly look into whether there is an anthropic impact. At the mouth of the Amazon, the focus will be more on river contributions. At Drake Passage and further south, near King George Island in Bransfield Strait, it will be possible to identify trace metal enriched surface currents, for example, between Clarence and Elephant Islands in the Ona Basin and see if this results in increased phytoplankton activity.

Thus, during this single transect, it will be possible to draw a parallel between the phytoplankton communities present and the potential co-limitation of trace elements and acquisition strategies.

Finally, these observations can be compared with data from major international programmes such as GEOTRACES (https://www.geotraces.org/) and SOOS (http://www.soos.aq/).

Hélène Planquette - LEMAR Laboratory of Marine Environment Sciences (UBO, IUEM, CNRS, IRD, IFREMER) - helene.planquette@univ-brest.fr
Ingrid Obernosterer - LOMIC Microbial Oceanography Laboratory (Sorbonne University, CNRS) - ingrid.obernosterer@obs-banyuls.fr
Christian Jeanthon - SBR Biological Station of Roscoff (Sorbonne University, CNRS) - christian.jeanthon@sb-roscoff.fr
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Climatology

Introduction

Understanding the causes of surface mass balance variations in Antarctica, where 90% of land ice is concentrated, is fundamental to assessing the impact of climate change on sea level change. In recent years, with accelerating iceberg breakup, continental ice loss in polar regions has become a key contributor to sea level rise (Rignot et al. 2019). The surface mass balance of much of Antarctica is controlled by a few extreme events, leading to high natural variability in this variable. Recent studies (Wille et al. 2019; 2020) show the primary role of the frequency of occurrence of atmospheric rivers on these variations.

Atmospheric rivers are air currents that form atmospheric filaments carrying warm, moist air from low to high latitudes. Although rare phenomena in Antarctica, atmospheric rivers have a major influence on the continent's mass balance; they generate extreme precipitation in East Antarctica (Gorodetskaya et al. 2014), 40% of the summer surface melt in parts of West Antarctica, and 40-80% of the total winter melt along many ice shelves (Wille et al. 2019).

Realization

The climatology section of Antarctique 2.0°C project is based on three research axes: the first one is a master's degree internship at the IGE (Institute of Environmental Geosciences) from February to July 2021. The second axis will be a two-month experimental approach on the Antarctic Peninsula from

January to February 2022 as part of the Antarctique 2.0°C campaign. The third level of study corresponds to a PhD thesis that will start in September 2022.

The second research axis is part of the YOPP-SH 2022 campaign, which sets in the international initiative "Year of Polar Prediction" within the Polar Prediction project, and of the PROPOLAR (Portuguese Polar Program) APMAR project led by Irina Gorodetskaya in collaboration with Raul Cordero at the Escudero base. The objective is to study the physical functioning of atmospheric rivers. The study site is the Chilean base Escudero on King George Island. This base has already hosted measurement campaigns (Bromwich et al. 2020) studying atmospheric rivers, which will serve as a support for future campaigns. The on-base study begins in early January 2022, and lasts 3 weeks. It will track atmospheric rivers with isotopic measurements of snow precipitation and radiosondes during the special measurement campaign of the YOPP-SH program. In terms of fieldwork, this will involve setting up protocols to be carried out later during the winter, installing an automatic weather station that will remain in place until the next campaign, and taking snow samples. The snow sampling and radiosonde program are managed by the APMAR project, and all environmental and logistical authorizations have already been obtained. In addition, if a river passes by during the time we are on site, a sounding balloon release will be used to characterize its atmospheric profile. The various sensors required for snow sampling are provided by Météo France. The IGE provides the meteorological station. Antarctique 2.0°C expedition will also help Raul Cordero's group to carry out measurements at the Escudero station (including radiosonde launches). Discussions are underway to develop the sampling protocols from the ship.

The climatology component of Antarctique 2.0°C proposes a close collaboration with members of the ANR ARCA (IGE, LSCE, LOCEAN) and with Irina Gorodetskaya, member of the ATLACE and APMAR projects, supported respectively by the FCT (Foundation for Science and Technology) of Portugal in the framework of the CIRCNA operational program, and by the Portuguese Polar Program and the Chilean Antarctic Program. The ARCA and APMAR projects aim to describe atmospheric rivers in the polar regions, and Antarctique 2.0°C project proposes measurements and field support in the Antarctic Peninsula to obtain the information needed to understand extreme events in Antarctica.

A word from the supervisors

The surface mass balance (SMB) of much of Antarctica is controlled by a few extreme events, leading to high natural variability in this variable. Extreme moisture intrusions related to atmospheric rivers (ARs) flowing through the Southern Ocean lead to intense snow accumulations, but also to extreme Antarctic surface heat and melt events. Yet, these ARs are currently neglected in Antarctic climate change impact studies.

In the framework of the ARCA project, coordinated by IGE, LSCE, LOCEAN, we propose to assess the impact of atmospheric rivers on the Antarctic surface mass balance and to explore to what extent past atmospheric river activity can be recovered from ice core records. In order to do this, we need to collect meteorological and isotopic data in the snow to characterize the isotopic signature of atmospheric rivers. We also need to characterize the structure of the atmosphere during these particular events, using radiosondes and radar measurements (Micro Rain Radar). The measurements, which will be carried out by Niels Dutrievoz on King George Island, are part of our collaboration with Irina Gorodetskaya in the ARCA project. During the same period, we will carry out similar measurements on the Dumont d'Urville and Davis bases, in collaboration with a team of Australian researchers. This collaboration is part of the special measurement campaign of the SCAR (Scientific Committee on Antarctic Research) YOPP-SH international program, from which we expect important spin-offs. Niels' initiative in the field, which should be continued in his thesis, will allow to concretize an important collaborative effort with many teams.

Vincent Favier - IGE Institute of Environmental Geosciences (Grenoble Alpes University, CNRS) - vincent.favier@univ-grenobles-alpes.fr
Irina Gorodetskaya - CESAM Centre for Environmental and Marine Studies (University of Aveiro) - irina.gorodetskaya@ua.pt
Cécile Agosta - LSCE Laboratory of Climate and Environmental Sciences (Paris Saclay University, CNRS) - cecile.agosta@lsce.ipsl.fr
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Microplastics

Introduction

Pollution in micro (0.3-1mm) and nano (<0.1mm) plastics is a global problem affecting all oceans, including the most remote areas (Cozar et al. 2014). For example, plastic particles have been found trapped in the Arctic (Peeken et al. 2018) and Antarctic (Kelly et al. 2020) sea ice. Even more worryingly, analyses of fresh snow in the Alps and the Arctic (Bergmann et al. 2019) suggest the presence of atmospheric micro and nano plastics in these isolated regions.

The effects of these plastic particles are diverse, but still little known: in addition to their accumulation in the digestive systems of marine fauna, these particles transport organic additives (Campanale et al. 2020) and microorganisms (Dussud et al. 2018) to the different marine ecosystems of the globe.

Many sample collection campaigns have been undertaken, but data is still too sparse and suffers from a lack of unity in the protocols, which makes it difficult to compare different data sets. Some initiatives to harmonise data collection and classification have been proposed, which would allow a closer synergy between the different studies carried out (Hartmann et al. 2019).

Realization

Our study will focus on the 3 main environments encountered during the expedition:
[1] Sea water : this will be the main part of the study. Seawater samples will regularly be collected to analyse their micro/nano plastic content in all the marine areas crossed: Atlantic and Southern Oceans. The Antarctic coastal waters will also be inspected. We will try to see if a change in the distribution of plastics between the coastal waters and the open ocean is noticeable, and if these concentrations are linked to physical processes (presence of eddies, ocean currents/front, rivers) or biological processes (biofouling: a plastic sink. see diagram in ((Van Sebille, Spathi, and Gilbert 2016)).
[2] Sea ice (pack ice) : The mechanism of incorporation of plastics into ice is still unknown, but is suspected to be similar to that of incorporation of biological matter. We will take sea ice cores, separate the different horizons and analyse the plastic and chlorophyll (biomass marker) content. We will then be able to compare the occurrence of the two to see if there is a correlation, which would allow us to better understand the mechanism of plastic incorporation in ice.
[3] Fresh snow : This will be an opportunity to complete the sampling points of (Bergmann et al. 2019) and to find out whether or not there are atmospheric microplastics in a region as remote as Antarctica. We will collect fresh snow to assess its microplastic content.

The identification of the collected microplastics will be carried out using FT-IR and SEM measurements available in the Mediterranean Institute of Oceanology (MIO) at the Luminy campus in Marseille. The analyses will be carried out by Olivier Smith as part of a 6-month internship upon return from the expedition.

Passive samplers will also be used in parallel to collect additives present on the surface of marine microplastics, throughout the itinerary. The samples will be analyzed mainly by Vincent Fauvelle, from the Mediterranean Institute of Oceanology.

In conclusion, this is a study on the Atlantic and Southern Oceans generating a large dataset from the same protocol and the same experimenter, which makes comparison possible. We will also rely on the interdisciplinary aspect of the project: data from other projects will allow us to look for trends in relation to ocean currents, weather, biogeochemistry and biology of the studied environment.
These studies are based on existing expertise in the literature. They will tell us a lot about Atlantic and Southern plastic and will raise awareness of the ubiquitous nature of plastic pollution.

A word from the supervisors

Pollution of marine environments by microplastics is a current societal and scientific issue. Despite the large number of papers in the field, it is a very young research field with unstable methodologies and analysis routines. Together with our partners, we are contributing to the effort to standardize measurement methods in order to enable the comparison of results. The accumulation of standardised data will make it possible to draw up maps of existing pollution and to carry out its modelling in order to analyse the impact of pollution on ecosystems and human health. Today, data on pollution by microplastics are unevenly distributed and not widely available for large maritime areas. The exploration of the Antarctique 2.0°C mission will make it possible to contribute to this international effort by sampling - with a standardised protocol - the marine pollution of a north/south axis of the Atlantic Ocean, in areas close to dense human populations, areas of accumulation of plastics and far from human habitats.

Vincent Fauvelle - MIO Mediterranean Institute of Oceanology (Aix-Marseille University, Toulon University, CNRS, IRD) - vincent.fauvelle@mio.osupytheas.fr
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Social Sciences

Introduction

Few scientific research expeditions include sociologists on board. However they embody one of the forms of contemporary scientific activity, especially with regard to the preservation of ecosystems; they also bear witness to the reconfiguration of the scientific field concerning the logics of financing, media coverage and the relationship between science and society (Faugère and Pascal 2011; Comby 2008). Moreover, Antarctica is an emblematic territory of contemporary research at the crossroads of scientific discoveries, international relations and environmental policies (Aykut and Dahan 2015; Elzinga 1993). It has become one of the most emblematic research areas on the planet in terms of the study of climate change, but it is also one of the most threatened (Gaudin 2007b; 2007a). Although it has been the subject of numerous publications in history and geopolitics, it remains poorly studied from an ethnographic perspective. The apprehension of the stakes of preservation of the marine environment in terms of public policies also offers particularly rich perspectives of analysis and action.

The contribution of the social sciences to the Antarctique 2.0°C project is, on the one hand, to take scientific activity as an object of inquiry. It offers a unique opportunity to analyze the logic of environmental knowledge production in a variety of configurations: within a scientific mission, as well as on the scale of a scientific base in the Antarctic Peninsula during austral summer. Sociology of science has addressed the issue of scientific activity in polar environments in the wake of its founding works on the functioning of research laboratories (Latour and Woolgar 1996; Callon and Latour 2016; Vinck 2007). Contemporary works aim to shed light on the "internationality" of scientific activity in Antarctica concerning the issues of data production and sharing, campaign financing or even the logistics of daily life on the bases (Gingras 2002; Walton 2013; Jouvenet 2016). They also highlight the power of scientists' expertise in Antarctic governance and environmental policies (O'Reilly 2017; Oppenheimer et al. 2019; Crespy and Jouvenet 2020).

The second part of the social science project will focus on the legal constructs related to environmental issues, and in particular the regime of marine protected areas. France and Chile have developed them in parallel (Bonnin and Velut 2008); they constitute a good angle of attack for questioning conflicts of use (Queffelec et al. 2021; Strobel and Tétart 2007), and comparative modes of management of oceanic environments with regard to environmental issues (Cicin-Sain and Belfiore 2005; CHAUMETTE et al. 2019; Charvolin 2003). They also allow us to question the collaboration between researchers and managers (Cibien 2006), the effectiveness of such measures (Sciberras et al. 2015) as well as their sustainability (Wright et al. 2019; Jordan and Moore 2020).

Realization

The research project is divided into three parts: [1] the first is an ethnography of scientific and international cooperation in the Fildes Peninsula (King George Island); [2] the second is a reflexive approach of the expedition and the practice of field science; [3] the third is a cross-analysis of legislation related to marine environmental protection. Daily and long-term participant observation will be complemented by interviews as well as documentation and archival work (Beaud and Weber 2010; Hine 2007).

[1] Since its inception, the Washington Treaty ('Antarctic Treaty' 1959) has dedicated the continent to scientific activities and international cooperation, particularly on climate and environmental issues (Howkins 2011; Grevsmühl 2019). The nature and place of scientific activity, however, have undergone profound transformations and now represent a subject of debate regarding governance of Antarctica. However, still few works that document these issues through a field survey analyzing the concrete configurations at work in Antarctica. Moreover, the areas and bases that have been studied are primarily anglo-saxon (O'Reilly 2017). The Fildes Peninsula, located in the southwestern part of King George Island, offers an exceptional field of study in this regard. Indeed, it comprises one of the highest concentrations of scientific bases as well as one of the only villages in Antarctica, Villa Las Estrellas, under Chilean administration. The Peninsula is also one of the main areas for the development of southern tourism (Strobel and Tétart 2007). Thus it crystallizes the main governance issues Antarctica is facing today: international scientific cooperation, political administration of its territory and the effects of anthropization at work.
An ethnographic study of the Fildes Peninsula thus offers a unique opportunity to document the complex network of actors, activities and objectives that shape the experience of everyday life in Antarctica. The objective will be to document the mechanisms of cooperation and exchange (scientific, logistical, but also social and informal) between the Escudero base and its counterparts in order to analyze the practical governance operating on the peninsula. The aim is also to understand how the diversity of actors in situ position themselves with respect to the preservation and regulation of the austral environment in their daily experience in Antarctica. Finally, this work will allow us to question the production of territorial and professional identities inherent to the governance of the southern continent. This line of study is thus at the crossroads of international relations studies and sociological work focused on scientific work.

[2] Antarctique 2.0°C mission appears to be a hybrid object that puts at stake considerations that are intrinsically scientific, financial, political, logistical and relational. The opportunity to follow all the phases of the project, from its preparation to the publication of the expedition's results, offers a remarkable occasion to document a contemporary scientific expedition (Faugère 2019; 2018). Involvement in the multiple dimensions of the project allows us to shed light on a tangle of networks and actors, while promoting the observation of "scenes of everyday life" during the expedition. Antarctique 2.0°C also

appears to be an example of interdisciplinary study, which has become a structuring principle of contemporary research (Prud'homme and Gingras 2015). In doing so, it arouses epistemological and practical reflection on the relationship between experimental and social sciences and about their research approaches (Passeron 1991; Kohler 2002).

[3] The territories crossed by the expedition are diverse but have in common that they share oceanic zones. Throughout the expedition and the people we met, from the preparation to the realization, we will question the way relationship to the sea is visible in the various legislations and how it has evolved over the last decades (Bonnin and Velut 2008; Gauchon and Huissoud 2010; Jordan and Moore 2020). Through examining the respective roles of scientific, economic and cultural actors, we will seek to explore the networks of stakeholders at work in these maritime territories and to track the emergence of contemporary legal concepts that structure them today in a more or less homogeneous manner, in the national laws of sovereign states and within the major international treaties (High Seas and Antarctica) (Bonnin et al. 2006; Bonnin 2008).

A word from the supervisors

The research project presented by Margot Legal falls within the field of science studies. Mixing sociology, history and ethnography, it is promising in several respects. To begin with, Margot Legal's participation in the "Antarctica 2.0° C" expedition allows her to benefit from a rare opportunity for "participant observation", at the heart of an adventure carried out for the benefit of environmental sciences. Although these sciences have gained much visibility in recent years, little work has yet been done to shed light on the way their actors work and produce knowledge. They sometimes do so by relying on the participation of lay citizens, and as such, the analysis of how a student project fits in with those of science professionals should be particularly interesting. Beyond this association, the observations that Margot Legal will conduct on the ocean and in the Antarctic will provide her with unique material to nourish a sociology of science "in action" and in situations that promise to be highly original. In particular, it will have the opportunity to contribute to a very dynamic stream of science studies, focusing on "field" sciences. Finally, and more generally, such a project should also enable Margot Legal to work on questions that are always central for the human and social sciences, on ways of analysing and connecting lines of activity that take place in various temporalities: those of environmental sciences and their "whistleblowers", those of the research institutions on which the polar bases depend, those of the researchers' projects, that of the "Antarctique 2.0°C" expedition, etc. All this makes Margot Legal's project a personal and collective adventure that it is important to support, and which I have agreed to follow as a mentor.

The Antarctique 2.0°C project is extremely convincing in many ways. It combines a strong interdisciplinary approach with scientific commitment and a central concern for citizens. Moreover, it strongly combines these three dimensions, interdisciplinarity being the guarantee of a more scientific investigation, which in turn determines the quality of the consequences for citizens and politicians that can be drawn from it.
Very early on, I was approached by part of the Antarctique 2.0°C team as director of studies in the social sciences department of the ENS. The instigators of the project wanted to add a sociologist to their team and hoped that I could guide them. It was one of the best students in the department who responded positively to this request.
She has developed an ethnographic research protocol that is as ambitious as it is exciting.
The interdisciplinary combination is strengthened because the sociological project is not overhanging the course of the expedition, but is not diluted in the project either: it is literally anchored and encapsulated in the whole project.

Cédric Moreau de Bellaing - LIER-FYT Laboratoire Interdisciplinaire d'Etudes sur les Réflexivités - Fonds Yan Thomas (EHESS) / ENS - cedric.moreau.de.bellaing@ens.fr

Morgan Jouvenet - PRINTEMPS Profession, Institutions, Temporalities (UVSQ, CNRS) - morgan.jouvenet@uvsq.fr
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Population Biology

Introduction

Antarctica is a particular ecosystem because of the climatic conditions that prevail there. The fauna that manages to develop there is particularly adapted to these conditions making the local species very sensitive to the variations of these conditions. Global warming generates many pressures on local penguin populations. One of them is the modification of their breeding habitats. If the stocks of food resources of penguins are theoretically monitored, the terrain of breeding habitats is an equally important issue for the reproductive success of penguins.

Objective: To anticipate the risks linked to global warming on the future of penguin populations.

In the southern region, penguin nesting sites are limited by topographic features of the terrain and by intra- and interspecific competition. Climate change modifies the space available for breeding colonies. For example, it is common to find breeding colonies on beaches and along the coast. The current rise in sea level (Frederikse et al. 2020) could therefore lead to a loss of suitable nesting sites for penguins, forcing them to migrate. These migratory flows generate a reorganization of territory sharing between penguins of the same species or of different species, leading to new selection pressures. Such events are already remarkable, we observe today movements of populations of penguins towards the Antarctic Peninsula in response to global warming.

Realization

Our aim is to carry out for the first time a spatial analysis of the breeding habitat of penguin populations in relation to current sea level. This analysis will enable us to better anticipate the consequences of the sea level rise projected by scientists (Frederikse et al. 2020). Using drones equipped with LiDAR and GPS-RTK, we will attempt to locate and map penguin colonies of different species (Shah et al. 2020): we will evaluate the 3D surface occupied by the colonies, the topography of the nesting area, the tidal limits (high/low), ... The lower limit of glaciers will also be mapped. Overflight of the colonies by UAVs will be done at a minimum height of 50m to limit disturbance of the colonies (Rümmler et al. 2018).
These data will be compared with satellite data for the mapped sites. Once calibrated, our ambition is to generalise our analysis to the whole Peninsula.

A word from the supervisors

In Antarctica, global warming is generating a lot of pressure on the local penguin populations. One of these pressures results from the modification of their breeding habitats.
Although sea level rise is one of the obvious signs of climate change, the consequences of this rise on penguin breeding sites have not yet been studied. However, many colonies are established on the coasts of the white continent and the southern islands.
The study carried out during the "Antarctique 2.0°C" project will therefore be the first to look into the loss of breeding habitat of Antarctic animal populations due to the sea level rise. Innovative means, such as the use of onboard LiDAR, will enable the precise analysis of the location and topography of colonies of different penguin species at the visited sites. These analyses will make it possible to anticipate the consequences of sea level rise on the loss of breeding habitat for these species, and to assess the impacts on reproductive success, population dynamics, and the ability of these populations to adapt through mechanisms such as dispersal and colonisation of new available sites.

By integrating these data into global models (initially on the scale of the Antarctic Peninsula, and then on the scale of Antarctica), this study will make it possible to put into perspective the selection pressures likely to impact Antarctic penguin populations and to project their extinction risks in the context of expected future climate change.

Céline Le Bohec - Monaco Scientific Centre, IPHC Institut Pluridisciplinaire Hubert Curien (University of Strasbourg, CNRS) - celine.lebohec@iphc.cnrs.fr
Daniel Zitterbart - WHOI Woods Hole Oceanographic Institution - dzitterbart@whoi.edu
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Partner Laboratories

The researchers with whom we work on the elaboration of scientific projects and experimental protocols, and who help us in the design of the scientific layout of the boat, are not all mentioned in the previous descriptions but come from the following laboratories.

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