This English version of the activity report is shorter than the French version.
A mixed year of joys and hardships

EDITORIAL

The time has come to present the new activity report for the French Polar Institute, which covers the 2019 calendar year as well as the 2019-2020 austral summer campaign. The results are mixed, with both highs and lows.

Let’s start with the high points, the ones that will remain in the Institute’s history because, fortunately, memories are selective and tend to remember the positive. The spotlight is on the research projects, the “raison d’être” of the Institute that supports them. Among the ongoing 74 projects and 108 field campaigns in the various Arctic, Subantarctic and Antarctic regions, three of them, which much more ambitious than usual, were implemented in the southern hemisphere this fiscal year. First we have the French-Norwegian PALAS 2 project in the Subantarctic area, which plans to collect sediment cores in several lakes that are quite difficult to access, located in the western sector of the Kerguelen islands. Second, in Antarctica, glaciology took centre stage with the setting up of a core drilling camp at the Little Dome C site (located roughly 40 km from the Concordia station) for the new European Beyond EPICA project. And third, the EAIST scientific traverse into the unexplored sector separating Concordia from the South Pole.

In all three cases, the missions were a complete success. The PALAS 2 team managed to extract a total of 127 m of lake cores, obtained from 6 different lakes and 16 coring sites. Their analyses will provide an exceptional look at the climatic and environmental evolution of this poorly documented sector of the planet. For the Beyond EPICA project, it was possible to install the main elements of the camp. This is an immense logistical challenge because it must be possible for a team of approximately fifteen people to live there and to be completely self-sufficient during close to 60 consecutive days each season and for 5 consecutive summer campaigns, one after the other. Last, the EAIST scientific traverse continued to help revive the great scientific exploration expeditions in the best way possible; the Polar Institute fortunately had its toll separating Concordia from the South Pole.

In addition, one of the high points of this past fiscal year was to have been able to bring the Minister of Research, Frédérique Vival, as well as the CEO of the CNRS, Antoine Petit, to discover the mythical white continent and some of our infrastructures. This was a first for a Minister in charge as well as for the head of the flagship of French research. On this occasion, an action plan was discussed in favour of research, infrastructures and national logistics at the poles. I hope that this will become a reality in the coming months because the Institute is currently understaffed, placing a burden on French aspirations.

2019 was also a year of internal and external initiatives. A few examples of this include: the development of a ‘Forward-looking management of jobs and skills’ solution and a review of the functionality of the Institute, the creation of an innovation department that made it possible to initiate numerous industrial contacts as well as to launch the Institute’s ‘Carbon footprint©’ programme (a first for a polar operator), the application of the new graphic charter and the creation of new institutional films, in addition to the management of the Archipôles national archives platform, the establishment of a bilateral archives committee with the European Space Agency, and the organization of the general assembly of the European Polar Board in Brest.

The main setback was the damage caused to the L’Astrôle, discovered by the ship - the French Navy - in mid-November 2019 when it was leaving Hobart in Tasmania to carry out its first mission to support our Antarctic logistics. The ship ended up being sent to an Australian shipyard for repairs, and we are grateful to the Australians who stepped in and saved the Polar Institute’s campaign and our two Antarctic stations at the same time; our counterparts from the Australian Antarctic Division agreed, at a moment’s notice, to provide their own icebreaker to ensure the supply run, delaying their own campaign by two weeks. A tremendous display of solidarity among polar operators! The fact that the collateral damage caused by this technical mishap was as limited as possible is also due to our highly skilled operational teams: they were able to reorganize several hundred tons of freight within a few hours, they immediately changed the routes for personnel, they organized three lightning-fast rotations for the Astrolabe in the second half of the season once the ship had been repaired, etc. However, international solidarity and the skills of our agents were not enough. Against this exceptional background, the Polar Institute fortunately had its fair share of good luck with the exceptionally good weather and sea ice conditions during the stopovers at Dumont d’Urville. Obviously, this is not something that can be counted on each year.

In June 2021, France will chair the annual meeting of the Antarctic Treaty in Paris, 32 years after the last time. It is my personal hope that with this geopolitical perspective, we will be able to collectively inspire a new national momentum in favour of research in polar environments. Anyone who reads the following pages should be convinced that this is a necessity because France should be very proud of the work we’re carrying out there. As it stands, in the words of former minister Herve Gaymard, France will not remain a ‘polar power’ unless our decision-makers engage in strong and long-lasting commitments.
**Antarctic**

14 millions Km²

**Subantarctic islands**

Archipel de Crozet

Île aux Cochons
Île de l'Est
Île de la Possession

ARCHIPEL DE KERGUELEN

Station de Port-au-Français

47°27' - 50°03' S
60°27' - 70°35' E
1800 m d'altitude (Piton Rossa)
1er hivernage en 1949

Environ 25 hivernants
et jusqu'à 50 personnes en été

Îles Amsterdam et Saint Paul

Base Martin-de-Viviès

53°06' - 77°13' S
881 m d'altitude (Mont de la Dives)
1er hivernage en 1950

Environ 25 hivernants
et jusqu'à 50 personnes en été

Station Concordia

75°06' - 123°21' E
3200 m d'altitude
1er hivernage en 2005
12 à 15 hivernants
et de 50 à 70 personnes en été

**Station Dumont d'Urville**

et la station annexe de Cap-Prud'homme

66°40' - 140°01' E
30 m d'altitude
1er hivernage en 1952
25 à 35 hivernants
et jusqu'à 100 personnes en été

**Arctic**

Station arctique AWIPEV

Bouvet (78°1 - 77°5)
Temperatures moyennes
en été : +4°C
en hiver : -12°C

**Subantarctic**

**Archipel de Kerguelen**

Station Concordia

75°06' - 123°21' E
1800 m d'altitude
1er hivernage en 2005

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**Antarctic**

14 millions Km²

Le plus grand continent du monde.

**Subantarctic**

1,4 fois plus grand que l'Europe,
25 fois plus étendu que la France.

Annual report 2019-2020
The Institute provided support for 10 French scientific projects in marine biology, ornithology, glaciology, ionospheric science and atmospheric physical chemistry.

**Support for Scientific Projects**

**Installation of the electric winch on the Jean Floc’h vessel:**

The winch and hydraulic crane on the Jean Floc’h are quite often used for all operations at sea. This combination is very practical for putting somewhat heavy loads to sea, but lacks flexibility and speed for small sensors or light sampling systems. As it has already been shown that the electric winch on AWIPEV’s second boat is perfect for this use, the same model was installed on the Jean Floc’h. As a result, we now have two winches and a more suitable profile speed for the body of water.

**Installation of a stabilization ballast on the Goupil electric vehicle:**

After a few years of use of this vehicle, the Goupil has a better grip on the ice and snow when loaded. As a result, ballast was placed on the chassis of the vehicle to improve passenger safety during use.

**Installation of a compressed air system in the scooter garage workshop:**

The general mechanical workshop called the ‘scooter garage’ now has a compressed air system equipped with a 150L compressor (to clean mechanical parts, inflate tyres, etc.). It also has a bench grinder and a welding machine (TIG steel/stainless steel/aluminium and coated electrodes).

**Installation of a new load regulation system for the Corbel wind turbine**

In 2018, a new wind turbine was installed at the Corbel station. It worked for several months on the old battery electric charging regulation system. But at the beginning of this year, the system broke down. Therefore, a new charging system was purchased from the manufacturer of the wind turbine and installed during the fall campaign.

**Creation of a special window and installation of a staircase**

This year, the researchers wanted to install scientific equipment to measure the auroral radiation at the Corbel station. Given that this equipment is very sensitive to stray light (extraneous light), the Corbel site in winter is an ideal location as there is no light pollution. In order to install this equipment, a window had to be created in the laboratory/workshop building. It is tilted towards the sky and has optical quality glass with an anti-frost system. An external staircase was also manufactured so as to be able to reach the roof platform safely in order to take a series of measurements using the 360° instrument.
At the start of the season, this 2019-2020 summer campaign was generally characterized by good environmental conditions with mild weather and negotiable pack ice less than 35 km from Dumont d’Urville. The first air arrivals to Dumont d’Urville and Dome C landed on the agreed-upon dates, 2-8 November, which meant that the stations could be opened and the EAIST and logistics traverses were able to depart on time.

However, the weather changed for the worse starting in January with 16 days of snowfall, two times the normal seasonal values, making it much more dangerous to carry out all of the operations.

The major difficulty encountered this season was the damage to the submerged bearings of the Astrolabe’s shaft lines right before the first rotation (R0). This breakdown had a long-lasting impact on the summer campaign and meant that all arrivals and departures as well as logistical and technical provisional schedules had to be reorganized.

Fortunately, the chartering of the polar vessel Aurora Australis on December 11 to Dumont d’Urville and the three express rotations of the repaired Astrolabe organized between late January and early February made it possible to deliver the priority cargo, i.e. food, spare parts, fuel and the essential fluids needed to maintain the stations.

In addition to the impact on the scientific programmes, the damage to the Astrolabe resulted in significant repercussions on several logistical and technical positions.

With regards to energy, it was not possible to deliver 300 m³ of SAB fuel (Special Antarctic Blend, the fuel used in Antarctica). Stations will still be able to be self-sufficient up until early January 2021, however the safety stock was not built up. There was a shortage of 30 m³ of aircraft fuel, i.e. the overall supply contained 23% less fuel. One of the direct results of this shortfall this season was that the locap airborne project was curtailed in order to save energy. And last, 50% of the fuel supply for the vehicles could not be delivered. Broadly speaking, all of the stations’ SAB fuel safety stocks were used to cover the consequences of the Astrolabe damage.

With regards to the work projects, the repair of the Concordia supply store and the work on the southern helipad field camp had to be postponed because the equipment could not be delivered. Because the equipment needed to repair the cladding on machinery hangar No. 97 at Dumont d’Urville was only delivered during R4, this project had to be postponed. In addition, work on the Prud’homme store (covering it with cladding), was also postponed until later in the season.

Following the cancellation of R0, and thus the arrival of the scientific personnel, the technical team had to help out with the scientific work during the month of November and in early December. As a result, certain work projects were slowed down.

The handover between inbound and outbound winterting personnel took place in one and a half days instead of 7 days (the average). Certain more specific handovers requiring more time (telecommunication-radio, glaciology, power plant), which normally take place over a two-week period, did not happen. This meant that the handover of the necessary information needed for the incoming team was less efficient. This made it more difficult for incoming personnel to take up the post and the on-site handover (polar environment) was limited.

The Institute operated with the new helicopter company (Canadian Helicopters - HHN) that won the tender last year. A helicopter was on site throughout the entire season and a second machine arrived with the Aurora Australis vessel to facilitate the unloading as well as the R4 rotation. The collaboration with this company is highly satisfactory and it was shown that the investment in the company’s equipment was worthwhile.

Despite the delay in deliveries, it was possible to carry out repair work at the station and at Cap Prud’homme using materials that had been delivered during the previous campaign. The main project was to completely cover the spare parts store for the Cap Prud’homme traverse.

The campaign also included numerous projects that were smaller in scope but still quite important as they ensured the proper technical management of the site: the sides of building 25 laboratory No. 1 were covered, the boiler room in building 31 living room-recreation room was renovated, the tunnel under the road used to pass pipes and electric cables was replaced in the southern end of Petrelis Island.

The technical office’s missions are divided between ensuring the handover to incoming overwintering personnel, facility maintenance and upkeep, logistics (exception, dispatch, handling, distribution and storage of packages), assisting scientific operations and overseeing work sites and new work projects.

The EAIST traverse required significant support during their two visits to Concordia; however, the work orders had been anticipated. Last, the Samba glacier project also figured prominently during the first part of the season.
The main mission of the French Polar Institute in the southern islands is to ensure the scientific and logistical organization for the winter camps and summer campaigns. Due to weather conditions, these field missions are deployed between the months of November and March.

Specifically, the French Polar Institute provides supplies and maintenance to the field camps, 50 potential sites, where scientists and civic service volunteers stay throughout the year. Primarily helicopters and barges are used to drop off scientific materials, food and equipment at the sites.

In 2019, supplies were delivered via helicopter during the Marion Dufresne's November and December rotations. Scientific equipment and tools (logistics) are recovered during the March-April rotation (OP1).

By the end, the logistics team from the French Polar Institute replenished the food, energy and scientific equipment supplies at the following field camps and isolated sites:

**CROZET**: La Pérouse, Baie américaine, Pointe basse
**KERGUELEN**: Pointe Suzanne, Estacade, Ratmanoff, Pointe Mome, Val Stüyer, Baie Charrier, Pointe Morne, Val Studer, Baie Charrier, Cap Noir, Cap Cotter, Cataractes, Sourcils noirs, Phonolite, Bossière, Port Elisabeth, Gazelle, Port Couvreux.

**AMSTERDAM**: Entrecasteaux and Del Cano

**DELIVERING SUPPLIES TO THE FIELD CAMPS**

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**WORK PROJECTS AT REMOTE SITES**

**CROZET**

During the 2019 campaign, a logistics team was deployed to carry out a renovation project at the Pointe Basse field camp. The main objective of the project was to repair the ageing parts of the structure so as to ensure the safety of users and the durability of the structure in particular. The most important part involved reinforcing the structure of the raft foundation, which supports the field camps, and the traffic zones. The storage and work spaces in the red French Arbec Hut, located next to the field camp, were reorganized, maximizing the available space.

The Baie Américaine field camp was inventoried this year in anticipation of a renovation project in the next few years. However, some improvements were made such as temporarily securing the awning and routine maintenance, as well as sorting out and fully cleaning the field camp.

**KERGUELEN**

The interior of the Estacade field camp has been renovated so that a team of 4 scientists can live there over long periods of time with, in particular, the installation of solar panels so that the field camp is now self-sufficient in energy. In addition, the field camp was furnished with 4 beds, a kitchenette and a workshop for scientific activities.

The Pointe Mome field camp was completely renovated with the installation of exterior cladding over the entire refuge and the installation of a new roof. Rainwater collection systems and autonomous photovoltaic solar systems were also installed.

Continuation of the multiannual project at the Studer field camp; after having thoroughly cleaned up this site, which dates back to the 1980s, and furnishing the inside with sleeping and storage fixtures, major work was carried out to solidify the foundations and to maintain the field camp.

The old scientific workshop at the Île Verte field camp was demolished and fully cleaned up. A new module was brought to the island by helicopter and set up by the logistics team.

**LOGISTICS IN THE SUBANTARCTIC ISLANDS**

The main mission of the French Polar Institute in the southern islands is to ensure the scientific and logistical organization for the winter camps and summer campaigns. Due to weather conditions, these field missions are deployed between the months of November and March.

**Authors**

Yann LE MEUR, Romuald BELLEC

**Logistic Subantarctic**

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The Korrigan Field camp was prepared for winter because there are no plans for personnel to overwinter there in 2020.

The two Fillods (prefabricated metal constructions) for the Mortadelle field camp were given a waterproof coating in order to make the field camp permanent. The weather station was inspected by civic service volunteers from the Polar Institute’s IT department and data were sent for an ICEx science project.

On the nearby glacier, the forward base for the Mortadelle field camp was dismantled and then evacuated during Marion-Dufresne’s OP1 (port operation 1) because it was no longer in use.

New remote sites were established so that scientific projects could be set up on new sites.

For the Palas scientific project (see insert below), a total of 6 drop-off sites for scientific and living equipment were used: 5 wooden living and sleeping modules, 5 wooden sleeping and storage boxes and 4 tents and coring equipment.

For Talisker, a camp with 2 modules that can be transported by helicopter was positioned in the northern Presqu’ile de la société de Géographie area.

The B17 logistics platform of the French Polar Institute at the Port-aux-Français station received a new roof and by moving and re-installing the workshop, the workshop was able to tidy up, sort and reorganize the workshop.

For the Palas project, in addition to ordering the large modules, 2 small storage modules were manufactured in wooden box format to be transported by helicopter.

**Supports and Specific Means of Support for Scientific Activity**

Over the past few years, in a joint charter with TAAF, the Polar Institute has been deploying a 25 m vessel, La Curieuse, to carry out both scientific projects and prospecting activities and to maintain remote coastal sites over the entire Kerguelen district.

This year, La Curieuse enabled numerous scientific missions to be carried out around Kerguelen. The vessel was on-site during the first period of the year from January 1 to January 24 and then from November 26 to December 31, 2019.

It ensured a security support mission for the Palas mission and enabled the deployment of the land missions across Kerguelen for the Enviker, Bingo, Talisker, Cycloëphe, Salmevol, Subanteco projects as well as the monitoring of the marine environment with the Proteker project which involves scuba diving around Kerguelen and in the Gulf of Morbihan.

As part of the ten-year maintenance plan for the Superdarn Project, a certified observation project, an 18 m articulated boom lift was installed in 2019 and enabled the scientific teams to carry out the rejuvenation plan and guarantee the operational continuity of this tool.

**Palas 2 Project**

During this 2019 campaign, the logistics team set up the Paleoclimate from Lakes sediments on Kerguelen Archipelago 2 (Palas 2) project in the northern part of the Kerguelen Archipelago. The objective was to collect lake sediment samples in order to reconstruct past climatic fluctuations at high resolution.

Its deployment around the glacier lakes in the northern area of Kerguelen required a substantial logistical investment on a scale that has never been seen in the past two decades.

- A self-sufficient mission was set up for a team of 6 scientists comprised of 4 French and 2 Norwegians over a period of one month. In order to guarantee the safety of the mission, new communication procedures were used with GPS allowing messages to be sent even if there is no network coverage.

- New field camps were installed at 6 remote sites near the lakes selected to carry out lake coring operations. These field camps were built, furnished and then temporarily set up on site for the duration of the mission.

- In total, the logistics (field camps, food, energy, etc.) and scientific (coring barge, sonar, etc.) equipment weighed 77 tonnes. 37 helicopter loads. This required the exceptional deployment of a B3-type Ecureuil (or Squirrel) helicopter for the recovery.

In particular, the main difficulty of this operation was that there was only a very short operational window available to install the personnel, samples and equipment during OP3, and then to recover everyone and everything during OP4 over a large geographical area. Approximately 3 days of helicopter time (roughly 10 hours/day) were needed: 1.5 days for drop-off + 1.5 days for recovery. This duration is equivalent to or greater than that needed to deploy an operation at Crozet or Amsterdam, all operations combined (TAAF, French Polar Institute, Nature Reserve) during the Marion Dufresne’s supply rotations.

A lot of preparation was needed beforehand between the scientific and logistics team to complete this project.
Science

Mission
PALAS 2 20
Palaeoclimate from lake sediments on the Kerguelen Archipelago

EAIIST 34
East Antarctic International Ice Sheet Traverse
INTRODUCTION

The Kerguelen Archipelago is located at 49°S, i.e., in the Antarctic Polar Front Zone which separates the cold polar waters from the temperate waters of the Subantarctic regions. Today, this zone, also known as the ‘Antarctic Convergence’, oscillates between a latitude of 48° and 61° depending on the season. It is characterized by very strong westerly winds that are found in the northern hemisphere. In the southern hemisphere, these winds are particularly violent given that there are no continents to slow them down (Figure 1). Navigators call these strong winds the famous ‘roaring forties’ and ‘furious fifties’; for climatologists, they require special study because of the essential role they play in regulating the Earth’s climate. They isolate Antarctica from the warmth of the lower latitudes, stimulate global ocean circulation via the Antarctic Circumpolar Current (ACC) system and regulate the absorption of CO₂ in the Southern Ocean. This position in the Antarctic Convergence Zone makes the Kerguelen Islands a key site for understanding the global climate system and its evolution. Even though this band of latitudes plays a major role in regulating the climate on a global scale, we have very limited knowledge about past climate changes. This is explained by the high proportion of ocean compared to continents, making it difficult to acquire climate records. A few records have been obtained via marine cores, as well as from continental records, primarily in Patagonia followed by Tasmania, New Zealand and South Georgia. In the French Southern and Antarctic Lands (TAAF), the first studies on the continental records are quite recent. At Amsterdam, for example, analysis of the flux and origin of dust trapped in peat has made it possible to reconstruct the glacier fluctuations during the Holocene and the climatic changes that controlled them, which are still poorly known in this very remote region.

The PALAS 2019 mission was designed to improve our knowledge about past glacial and climatic fluctuations in this region of the world. To do this, the goal was to collect as many lake sediment records in connection with the Cook Ice Cap as possible (Figure 2), so as to be able to indirectly study (i.e., via glacial processes) the dynamics of the westerly winds. Lakes fed by glaciers have a high potential for recording the glacial signal over time, since a large part of their sedimentation comes from the production of glacial flour. In order to validate these reconstructions and to better constrain them in space, the moraines and other glacial landforms around the lakes were mapped and sampled during the mission for cosmogenic isotope dating purposes.

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The PALAS 2019 mission was designed to improve our knowledge about past glacial and climatic fluctuations in this region of the world. To do this, the goal was to collect as many lake sediment records in connection with the Cook Ice Cap as possible (Figure 2), so as to be able to indirectly study (i.e., via glacial processes) the dynamics of the westerly winds. Lakes fed by glaciers have a high potential for recording the glacial signal over time, since a large part of their sedimentation comes from the production of glacial flour. In order to validate these reconstructions and to better constrain them in space, the moraines and other glacial landforms around the lakes were mapped and sampled during the mission for cosmogenic isotope dating purposes.

The Kerguelen Archipelago is located at 49°S, i.e., in the Antarctic Polar Front Zone which separates the cold polar waters from the temperate waters of the Subantarctic regions. Today, this zone, also known as the ‘Antarctic Convergence’, oscillates between a latitude of 48° and 61° depending on the season. It is characterized by very strong westerly winds that are found in the northern hemisphere. In the southern hemisphere, these winds are particularly violent given that there are no continents to slow them down (Figure 1). Navigators call these strong winds the famous ‘roaring forties’ and ‘furious fifties’; for climatologists, they require special study because of the essential role they play in regulating the Earth’s climate. They isolate Antarctica from the warmth of the lower latitudes, stimulate global ocean circulation via the Antarctic Circumpolar Current (ACC) system and regulate the absorption of CO₂ in the Southern Ocean. This position in the Antarctic Convergence Zone makes the Kerguelen Islands a key site for understanding the global climate system and its evolution. Even though this band of latitudes plays a major role in regulating the climate on a global scale, we have very limited knowledge about past climate changes. This is explained by the high proportion of ocean compared to continents, making it difficult to acquire climate records. A few records have been obtained via marine cores, as well as from continental records, primarily in Patagonia followed by Tasmania, New Zealand and South Georgia. In the French Southern and Antarctic Lands (TAAF), the first studies on the continental records are quite recent. At Amsterdam, for example, analysis of the flux and origin of dust trapped in peat has made it possible to reconstruct the past dynamics of westerly winds over the past 6,600 years. In particular, it highlights alternating phases of strengthening and/or shifting winds towards the equator and phases of weakening and/or shifting winds towards the poles. A study carried out on the geomorphology of glaciers on Kerguelen have allowed us to track major glacier fluctuations over the past 24,000 years. In addition, using a modelling approach (integrating instrumental data from the Port-aux-Français station), this same team showed that the poleward shift towards the polar front, which resulted in decreased precipitation on Kerguelen, explained to a large extent the dramatic retreat of the Cook Ice Cap since the 1960s. Thus, there is a relationship between polar front fluctuations and the westerly winds, and the fluctuations of the Kerguelen glaciers, via precipitation.

The PALAS 2019 mission was designed to improve our knowledge about past glacial and climatic fluctuations in this region of the world. To do this, the goal was to collect as many lake sediment records in connection with the Cook Ice Cap as possible (Figure 2), so as to be able to indirectly study (i.e., via glacial processes) the dynamics of the westerly winds. Lakes fed by glaciers have a high potential for recording the glacial signal over time, since a large part of their sedimentation comes from the production of glacial flour. In order to validate these reconstructions and to better constrain them in space, the moraines and other glacial landforms around the lakes were mapped and sampled during the mission for cosmogenic isotope dating purposes.
Furthermore, to determine the role of temperature and precipitation in the Cook Ice Cap fluctuations, a multi-indicator approach will be used on cores as part of the 'Southshere' project, led by Jostein Bakke from the University of Bergen (Norway). The target indicators are hydrogen isotopes for tracking precipitation and lipid biomarkers for temperature. Sedimentological and geochemical analyses will be used to track glacier fluctuations. Analyses will also be performed on terrestrial plant remains, pollen and plant DNA to study fluctuations in plant cover, in terms of extent and composition, in relation to climate change. If exotic pollens are found, they can be used as indicators of changes in the position of the westerly winds. Finally, at Lake Cartographie, a second core (Figure 3B), offset in depth, is planned to carry out DNA analyses of mammals and plants in order to track the dynamics of invasive species and their impact on the environment in this area which is actually quite far from their point of introduction.

Figure 2. Distribution of the coring sites and lengths of the core sampled during the PALAS 2019 mission.

Figure 3. Illustration of the applied coring techniques.

A) Photos of the coring platform used at Guynemer and one of the core samples collected using the Nesje corer. The corer diagram illustrates the piston corer system developed by Niederrieter and used at Guynemer as well as to collect cores > 6 m long in sections measuring 2 or 3 m.

B) Core diagram provided by the Corebook application. When this application is used in the field, it is possible to enter the coordinates of the cores and to mark the position of each section in real time. This makes it possible to assess how much sediment is lost and thereby helps the person catching up the corer to obtain the entire sediment settling sequence (i.e. a correct recovery rate of 100% between the sections).

https://svs.gsfc.nasa.gov/3723

Lipid biomarkers are specific organic molecules that can be used to identify the origin of organic matter.

1. METHODS

1.1. LAKE BATHYMETRY, SEDIMENTARY INFILLINGS AND CORE ASSESSMENT

In order to determine the zone(s) where sediment core samples will be taken, it is necessary to know the lake bathymetry. In addition to the morphology of the lake basin, it could be interesting to determine the thickness of the sediment infilling and to study how the deposits are organized. In order to do this, sedimentologists use seismic reflection equipment which, through the various propagation speeds of the waves based on the materials encountered, makes it possible to show the layers of sediment. Palaeo-environmentalists/climatologists often prefer the deeper, flat and remote areas of deltas. In fact, these areas are the least affected by sublacustrine landslide deposits coming from the slopes of the basin. These instantaneous deposits may be quite thick and may have eroded some of the previous deposits. In addition, these areas have reduced sediment accumulations, which allows to maximize the temporal depth covered by the record.

During the PALAS 2019 mission, three different core drilling techniques were used. On each of the lakes, ‘short’ gravity cores (UWITEC core drill), mostly involving hammering so as to increase the thickness of the sediment collected, were sampled. This coring technique is used to take sediment samples without disturbing the interface and therefore provides essential records that can be used to properly document the recent sedimentation. In Lake Guynemer, the objective was to sample the longest sequence possible. In order to do this, we used a platform and an UWITEC stationary piston corer developed by Richard Niederrieter (uwitec.at). This type of corer (Figure 3A) can be used to sample the sediment in sections measuring 2 (90 mm Ø) or 3 m long (63 mm Ø). The principle consists of lowering the corer from the platform to the desired depth and then locking the piston in order to be able to start the coring by hitting it using hammers. Once the 2 or 3 m tube is filled with sediment, the corer is raised to the surface using winches and the core is recovered. Then, the corer is sent 2 or 3 m further down in order to sample the next section and so on. A hydraulic core catcher system or an orange peel is installed at the base of the corer to prevent the loss of sediment while raising the core. Even if these systems work correctly, sediment corresponding to the space taken by the stationary piston is lost between each section. In order to make up for this loss and obtain 100% of the sedimentary sequence, a second core (Figure 3B), offset in depth, is sampled right next to the first (Hole A). The core diagram is built in real time in the field using the Corebook application developed at the EDFYTEM Laboratory (Figure 3B). The third coring system used is the one developed by Atle Nesje6. This is also a stationary piston system that is used to collect samples by hammering up to 6 m of sediment at once. It has been used in all of the lakes.

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6 Nesje, 1992

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12. GEOMORPHOLOGICAL MAPPING AND SAMPLES TAKEN FOR DATING ANALYSES

Past glacier extensions are identified through a combination of observations and the mapping of glacial landforms and formations. Observations are carried out at several spatial and temporal scales. Prior to the field mission, satellite imagery is used to perform these observations. Since 2017, the resolution of the images available on Google Earth have been satisfactory; however, the easternmost part of our study area (Guynemer Peak) is completely whitewashed because it is covered by an image from August 2006. This resource made it possible to identify several moraines that have been there for a while but only recently became more visible, especially in the Guynemer sector. Given the cloudy and snowy conditions in this region, we only acquired Pléiades tri-stereo coverage on January 16, 2019, almost one year after it was ordered from Airbus DS as part of the ISIS programme (Access to SPOT images for Science/Initiation à l'utilisation de l'information géographique globale). Thus, from this perspective, the postponement of the PALAS mission by one year to the 2019 OP3 was welcomed: the DEM (digital elevation model) and orthophotography produced from these satellite images helped us with our preliminary observations for the mission. Numerous moraines were identified, as well as areas with roches moutonnées with their abundant erratic boulders, and potential glacial drainage channels, which helped guide the organization of the field mission. Given that this area does not have any footpaths whatsoever and is also characterized by numerous rivers that cannot be crossed on foot, these images were used to identify possible routes in the field. In fact, this geometric resource formed the basis of the Geographic Information System (GIS) in which the field observations were reported daily as in a geomorphological map (see Inset 1) — which also incorporated very high-resolution images acquired by drone in several sectors.

The goal of geomorphological mapping is to create a spatial reconstruction of the Holocene or even Tardiglacial glacial extensions*. The frontal and lateral moraines illustrate the 2D geometry of the glacier (and its temporal variations). It was possible to model the volume of this glacier from this geometry as well as from the derived glaciological parameters — therefore, the altitude of the glacial equilibrium line and its evolution are palaeoclimatic indicators. A roches moutonnées sector indicates minimal extension of the glacier in terms of length and altitude; an erratic boulder, one position of the glacier during a retreat phase.

The principle of this mapping is to represent all landforms (e.g. moraines, scree, etc.) and formations (e.g. till, glacial-lacustrine infilling, etc.) found within a study sector, by associating them to the processes that generated them (e.g. glacial, periglacial processes, etc.) while integrating the chronology (at least relative) of their establishment.

The topic of our study explains that emphasis was placed on geomorphological markers of glacial dynamics — only a few non-glacial landforms/formations have been mapped when they can be used to recognize/glacial forms (e.g. gullying and associated deposition affecting a moraine, or an abutting rockfall deposit).

This figure shows part of the moraine complex of the Agassiz glacier. Three sets of moraines can be distinguished in the photo taken by the drone (top; authorization 2019-158). By cross-checking satellite (bottom) and drone images with field observations and photos, it was possible to map these moraines in detail as seen by the large number of ridges [N.B.: the moraines are not listed in order based on their sizes]. The footprint and distribution of the wide drainage channels provide evidence for the extensive reworkings that have affected this moraine complex on at least two occasions. The wind fetch induced by the size of the lakes, which see frequent and intense winds, and the seasonal variations in their water level explain the development of beaches on their shores.

*Jomelli et al., 2017

**DEM** (Digital Elevation Model) is a representation of land elevation. Orthophotography are images of the earth’s surface (satellite or aerial) whose geometry has been rectified so that they can be superimposed on a flat map.

**Dendrochronology** is a dating method based on counting and analysing the morphology of growth rings in trees.

**Fetch** is the time and undisturbed distance travelled by and over a body of water. At the end of this momentum zone, the water will rise to form a wave; the greater the fetch, the higher the wave.

**Orthophoto**: Pléiades satellite, 16/01/2019

**Isohypse contour interval**: 50 m
**SCIENCE**

**2019-2020**

**COSMOGENIC ISOTOPES DATING BY IN SITU-PRODUCED**

< 5% except for very young surfaces (past few centuries).

This ratio is then converted into a concentration, from which an exposure age is calculated using an online calculator, along with an uncertainty (analytical and on the production rate) that is generally 5% except for very young surfaces (past few centuries).

**SAMPLES COLLECTED FOR COSMOGENIC DATING**

![Image 1](image1.png)

**2. RESULTS**

**2.1. BATHYMETRY AND SEDIMENTARY INFILLING**

The bathymetry of Lake Guynemer is relatively simple as there is a single basin that is quite deep (90 m). Conversely, the bathymetry of Lake Hera and the other Mythos lakes is much more complex as they are made up of several basins and sometimes contain ‘hummocky’ structures that can be seen on the seismic profiles (Figure 5A). This complexity is probably related to sediment inputs from the various glaciers (Agassiz, Chamonix and Pointu) connected to the lakes in the past and to subaqueous slides. Within this sedimentary context, we understand why sediment equipment is needed to identify the most appropriate coring areas, i.e. areas with undisturbed sedimentation (preservation of the chronological order of the deposits and without hiatus), and thus to be able to address our scientific question.

**SAMPLES COLLECTED FOR COSMOGENIC DATING**

This spatial dimension of the palaeo-glaciation shown by the map must be combined with a relative and absolute chronometric calibration. In most mountain massifs, the presence of wood layers in the moraines has made it possible to establish chronologies for the glacial fluctuations using dendrochronology and radiocarbon dating. As there are no trees on Kerguelen, dating using in situ cosmogenic isotope (see Inset 2) products was used (see Inset 2). For this, samples were taken from the moraine complexes, areas with roches moutonnées and on erratic boulders. It will also be possible to use these dates to track the past dynamics of the various glaciers (Guynemer, Agassiz and Chamonix).

In total, two glacial deposits, 10 roches moutonnées surfaces, 23 erratic boulders and 75 boulders on moraines were sampled using an angle-grinder and a hammer and chisel (Figure 4). These 110 samples, weighing 1 to 2 kg, were collected from basaltic (100), in which 36Cl is produced from calcite, and from quartz veins and gneisses (10) in order to measure the 10Be concentration.

**DATING BY IN SITU-PRODUCED COSMOGENIC ISOTOPES**

Primary cosmic radiation interacts with components of the atmosphere creating cosmogenic nuclides which then adsorb onto the surface of the minerals in the rocks, resulting in nuclear reactions. As a result, cosmogenic nuclides (14C, 26Al, 36Cl, 10Be) then start to be produced there, in situ. The measurement of their concentration provides an estimation of how long the rocky surface has been exposed, taking into account the nuclide production rate (which depends on time, altitude, etc.), the local topography (shading) and the rate of possible erosion of this surface. Cosmogenic nuclide surface exposure dating requires collecting samples with a maximum thickness of 3-5 cm, preferably at the centre of large flat boulders or on the ridge for moraines, and as stable as possible, and recording their dimensions, their altitude and the topographic shading (Figure 4). The sample then undergoes mechanical preparation followed by chemical preparation in the laboratory, which takes a long time for 10Be: the steps include grinding and sieving, purification, separation and dissolution with hydrofluoric acid (HF), then substitution of HF and last, beryllium oxide (BeO) extraction — a much faster preparation for 36Cl. The isotope ratio can then be measured by Accelerator Mass Spectrometry (AMS). In France, on the national ASTER instrument (LN2C, CEREGE). This ratio is then converted into a concentration, from which an exposure age is calculated using an online calculator, along with an uncertainty (analytical and on the production rate) that is generally 5% except for very young surfaces (past few centuries).

**Figure 4. Collecting basaltic samples for surface exposure dating using 36Cl. a: collecting samples on an erratic boulder located on a roche moutonnée on Mont Fauve (515 m). b: a: collecting sample on a boulder located on a roche moutonnée (515 m) on Pointu (1088 m), c: collecting sample on a boulder located on the ridge of the Agassiz complex (75 m); d: sample taken from a roche moutonnée on Mont Fauve (515 m).**

**2.2. OVERVIEW OF THE SAMPLES, FIRST RESULTS AND OUTLOOK**

At Guynemer Lake, 10 m of sediments in 3 m-long sections and from 3 holes (A, B and C) were collected (Figure 3B). In addition, three other cores measuring 140 cm, 240 cm in length were collected using the Nesje coring system. The cores will be studied in Bergen and Chambery starting in June 2020. However, it was already possible to make a few observations. As an example, approximately fifteen centimetres of well-preserved and laminated sedimentation was brought up on the anchors used to stabilize the coring platform during coring, indicating by yellow stars. B) Seismic profile corresponding to the SW-NE transect in orange on the bathymetric map of Hera. In particular, it highlights a small perched basin with undisturbed sedimentation inputs from the various glaciers (Agassiz, Chamonix and Pointu) connected to the lakes in the past and to subaqueous slides. Within this sedimentary context, we understand why sediment equipment is needed to identify the most appropriate coring areas, i.e. areas with undisturbed sedimentation (preservation of the chronological order of the deposits and without hiatus), and thus to be able to address our scientific question.
Rabbits were introduced to Observatory Bay in 1874 by British navigators from the HMS Volage. This was done in order to ensure a food resource on this mammal-free island, especially in the event of a shipwreck. The introduction was successful in the sense that the rabbits proliferated. However, it also resulted in a major ecological crisis. During the subsequent scientific missions, the very first signs of this crisis were seen on the endemic flora, with the almost-complete disappearance of the Kerguelen cabbage (Pringlea antiscorbutica), followed by the replacement of the Azorella Selago carpets with Acaena Magellanica, and then the effect of plant cover degradation on soil erosion. Even though the impacts of the introduction of this invasive species have been described many times, we still only have limited knowledge about the temporal dynamics of the invasion and ecosystem responses. Lake sediment records are the only way to go back in time to retrace these dynamics.

During the previous PALAS mission in 2014, sediments from a core sample taken from Lac de la Poule were subjected to plant and mammal DNA analyses (Fig. A). These analyses have made it possible to pinpoint the arrival of rabbits in the watershed towards the late 1940s, i.e. approximately 70 years after they were introduced on the island, roughly ten kilometres away as the crow flies (Fig. B). This presence is confirmed by the observation of coprophilic fungi spores (Sporomiella sp.) that grow on herbivore faeces. The rabbit invasion very quickly caused an erosion crisis that lasted until the mid-1960s. Although erosion has become less of a problem since the 1960s, the change in the plant community, i.e. the gradual disappearance of Azorella in favour of Acaena, still exists today. Given that the Azorella population started to decline as soon as the rabbits arrived, it is most likely to be explained by the massive degradation of those cushion plants due to the construction of burrows (and then the rains could easily move the plant fragments). In the mid-1950s, the high rabbit mortality suggested by the data (decreased sporomiella concentration and DNA spike due to cadavers), may reflect the introduction of myxomatosis in 1955-1956. A second phase of significant mortality was recorded in 1975. This could have been caused by the virus, decreased food resources or another reason. It is interesting to note that the decrease in erosion occurs before this significant decline in the rabbit population, but it is concurrent with the decrease in precipitation. The erosion crisis observed when the rabbits arrived could also have been exacerbated by the increase in rainfall (Fig. B).

Around Guynemer Lake and the Mythos lakes, only a few living or dead rabbits were observed during our PALAS 2019 mission. Kerguelen cabbage is still relatively abundant there and so are Azorella cushions. However, near the Cartographie lakes or on the coast of the Baie du Repos, further away from the Cook Ice Cap, we were able to observe large rabbit populations. How long did it take for the rabbits to colonize this very remote area of Observatory Bay? What is the scale of the impact on erosion and vegetation? What are the temporal dynamics of the responses of the ecosystem as well as the rabbit populations (are we in a phase of decline as around Lac de la Poule?)? The use of DNA analyses on the sediments of Lake Cartographie will provide answers to these questions.
23. MAPPING THE MORAINES AND TAKING SAMPLES FOR DATING: PRELIMINARY RESULTS ON THE GUYNEMER PROGLACIAL MARGIN

The current Guynemer Glacier is divided into four unequal parts, with a total surface area close to 1.4 km². The two lower sectors (0.25 km²) are found 100 to 250 m below the upper sectors from which they are separated by non-glaciated walls; their fronts descend to an altitude of 340 and 395 m.

The part of the Guynemer moraine complex located upstream from the cone-delta is quite complex: in addition to the three main lateral-frontal moraines (Mg-4 to 6) downstream from the upper lake, between which less-continuous ridges are found, numerous ridges surround this lake, especially on its north shore, marking the glacial retreat since 1963; the inner flank of the largest of these moraines, the visible part of which overlooks the 30 m lake, is subject to active runoff (Figure 7a). A few perched ridges > 300 m on the south shore are possibly connected to the Mg4-6 set.

Three moraines are present around the lower Lake Guynemer: Mg-3 on the intermediate bench on the west shore, between 165 and 200 m in altitude, Mg-2 at its northern end, a few m above the lake, and Mg-1 on a bench on the east shore, at an altitude of 190 m.

Forty samples were collected to carry out cosmogenic dating on Mg-1 (2), Mg-2 (3), Mg-3 (3), Mg-4 (7), Mg-5 (8), Mg-6 (5) and on 12 erratic boulders distributed at various altitudes (max 305 m) around the lower lake including at the limit, at an altitude of 150 m, between Lake Louise and Guynemer Lake.

The same mapping and sampling approach was applied in the proglacial margins of Agassiz (Figure 7b) and Chamonix. Samples were also taken from roches moutonnées and boulders along a 500 m altitudinal transect between Lake Athena 2 and the summit of Mont Fauve (Figures 2 and 7c). This work will help document the extension phases of the Agassiz and Chamonix glaciers.

The work of the five core cutters and three geomorphologists during a one month period in the field and the logistics put in place by the French Polar Institute meant that an incredible amount of samples could be collected: 127 m of sediment and 110 rock fragments.

The preliminary results of this mission have already resulted in a map of the glacial formations in the study area, located between the Cook Ice Cap and the Presqu’île de la Société de Géographie. The first analyses performed on two short cores from Lake Guynemer already show recent changes in the sedimentation dynamics and raise questions about the potential recording of seismic activity linked to volcanism. Answers to these questions will be found by dating these cores. Cosmogenic isotope analyses to date the ice formations are currently underway and the study on the remaining cores will begin in June 2020. Therefore, we will soon have the reconstructions of the glacier and palaeoclimatic fluctuations.


Fletcher, M.E., Moreno, P.J., 2011. Zonally symmetric changes in the strength and position of the Southern Westerlies drove atmospheric CO2 variations over the past 14 k.y. Geology 39, 419–422. https://doi.org/10.1130/G31807.1


A SHORT AND RATHER INCOMPLETE HISTORY OF LAND TRAVERSE IN ANTARCTICA.

Introduction

All ‘Polar’ people know the incredible story of the Endurance, this epic monument to survival in a hostile polar environment, and the unbelievable crossing by boat between the inhospitable and ice-covered Elephant Island and South Georgia. This journey was a feat (an inspiring story of survival under Shackleton’s command) within a failure (the Antarctic crossing itself never took place).

It was almost fifty years later and during the third International Polar Year (1957-1958) that the first overland traverse of the Antarctic continent would take place over 99 days and 3300 km. The British explorer Vivian Fuchs and his team set out from the Weddell Sea on Tucker Sno-Cat and Bombardier Muskeg vehicles and became the first to cross Antarctica. Their support team was led by the illustrious Sir Edmund Hillary, who mapped out the final section of the journey between the Ross Sea and the South Pole.

Two years later, after overwintering at Charcot station in 1957, the French glaciologist Claude Lorius – invited by an American team for the Victoria Land Traverse – carried out a mechanised traverse and co-discovered a mountain range that was not mentioned in the topographical surveys of the time. On the strength of his polar experience, Claude Lorius pioneered the International Antarctic Glaciological Project (IAGP) with Russian, American, Australian and British colleagues. This glaciology programme, which ran from 1969 to 1980, aimed to study and understand the history, evolution, flow, surface and bedrock topography of the East Antarctic polar ice cap through overland traverses and airborne soundings. This programme was the first to use overland traverses as a research rather than an exploration tool, with a complete scientific programme including geodesy, geophysics, seismology, analysis of the physical and chemical properties of ice, and a drilling programme. The data acquired during the IAGP determined, among other things, the location of the deep drill holes at D47 and Dome C (drilling Dome C 7B, EPICA) and consequently the location of the Concordia research station.

Many traverses followed, not all of which will be detailed here, but it is worth noting that 10 years after the end of the IAGP programme, the International Trans-Antarctic Scientific Expedition (ITASE) initiative was relaunched in France, Grenoble, bringing together 20 nations. This international programme, which lasted until 2010, enabled several scientific traverses to be carried out that aimed to spatialize climatic, meteorological, geophysical and chemical data. It is within the ITASE framework that France resumed scientific traverses. With the benefit of 20 years of experience in logistical traverses supplying the Concordia research station and following the renewal of part of its vehicle fleet, the French Polar Institute Paul-Emile Victor (IPEV) had gained new capacities for scientific traverses. It now had, 30 years after the IAGP programme, a life caravan, energy caravan, mobile laboratories and sleds.

This means that since 2010, scientists have been able to carry out scientific traverses such as the VANISH programme (Concordia-Vostok round trip traverse), ABN (French-Australian Dumont d’Urville-Aurora Basin North traverse) or ASUMA (coastal traverse around Dumont d’Urville). All have more or less followed an identical scientific programme close to IAGP’s recommendations. A scientific traverse, although less expensive than an oceanographic or airborne campaign, still represents a considerable financial cost, so everyone strives to maximize the scientific experience gained in order to make the most of the investment. The EAIIST traverse of the 2019-2020 summer campaign was not immune to this constraint. Here is the story.
In line with previous projects and in the absence of surface data on a section of Dome C-South Pole, which corresponds to the shift in the ice flow towards the western part of Antarctica, the idea arose to conduct a scientific traverse in this section. While visiting McMurdo station in 2012, I spoke with the then-director of the National Science Foundation’s (NSF) glaciology programme, Julie Palais, to see what she thought about a Dome C-South Pole traverse in collaboration with American teams. With her encouragement, the first contacts were established with Italian and American teams and later with Australian researchers.

A first workshop was organised in Grenoble in September 2014, followed by the drafting of a white paper which included scientific questions, participants, route, financial plan and a planned timetable. Given the distances to be covered in a two-month traverse, this journey (3300 km round trip) could only be completed in two seasons: Dome C-South Pole in year 1 with winter storage of vehicles at the South Pole and the return journey in year 2. This set-up was the best match for the distance that needed to be covered, with the double benefit of crossing specific topographic structures such as megadunes or ‘glazed’ surfaces, and it enabled us to set up a series of experiments on the visited sites that could be recovered the following year when returning to Concordia. Therefore, logistical support was needed (fuel, winter storage of vehicles, maintenance) from the South Pole station. Unfortunately, a major difficulty that is common in this type of project very quickly emerged: coordinating the logistical and financial support from several nations who all have different means, procedures and structures for financing their polar research.

Over time, for internal reasons, the NSF became increasingly reluctant to host the South Pole traverse. Moreover, the American project systematically received poor assessments from the project selection committee on which the NSF relies for funding. This resulted in a long process of application submission and rejection for the Americans that finally led to the withdrawal of the US teams in 2018 and the participation of the Australians but with no involvement on the ground. With the Italians having obtained funding through their National Antarctic Research Programme (PNRA) and the French from the National Research Agency (ANR), the BNP-Paribas Foundation and French Polar Institute Paul-Emile Victor (IPEV), two workshops in October 2018 and 2019 and numerous exchanges with the polar institutes laid the traverse’s foundations: the route (round trip to the Mid Point Concordia-South Pole), research activities and traverse participation.

**During the first meetings, three scientific questions were identified.**

The first was the mass balance in Antarctica, which directly affects sea level rise. Projections from the IPCC’s Special Report on the Ocean and Cryosphere\(^1\) indicate a sharp rise in sea levels of between 20 and over 100 cm by 2100. This wide range is largely due to uncertainty about the mass balance in Antarctica. However, if coasts continue to lose increasing amounts of ice, the question arises of what fate awaits the Antarctic Plateau. In a warmer climate, the atmosphere will contain more moisture and snowfall is expected to increase on the Antarctic continent, which, if not reversed, could slow down the rate of sea-level rise. A 1% loss of mass from the Antarctic continent represents a 70 cm rise in sea level. With 10% of the world’s population living less than 10 m above sea level, the consequences would be catastrophic for societies and marine biodiversity. It is therefore essential to measure the evolution of snow accumulation rates over the central parts of Antarctica and to place them in a historical context over the last few thousand years in order to obtain the best possible future projections.

The second question concerns the quality of the glaciological record contained in the ice. At deep drilling sites such as Vostok or Concordia, the accumulation of snow during the ice ages was about half of the levels in warm periods. In the hyper-ard zones of Antarctica, however, very specific surface structures can form. These include megadunes, where snow accumulation is highly variable (loss on the leeward and gain on the windward side of the dune) and can lead to biases in the recording of climatic and chemical signals. Going to study these areas of megadunes and other surfaces where snow accumulation has been impacted by ablation processes enables us to set foot on a terrain similar to what might have happened during an ice age at Vostok or Concordia and to see how the signals are recorded.

The final issue addressed by EAIST concerns the representative nature of the measures currently being taken near research stations such as Concordia. The activity of a station running on fuel-based power inevitably generates local snow pollution, the consequences of which are sometimes difficult to assess: contamination of the snow, thermal structure of the snowpack, redistribution of the snow by wind, lack of zone marking for sampling areas, passage of non-listed vehicles, and so on. Conducting experiments in virgin ground makes it possible to assess the impact and biases that a station’s activity can generate.

Finally, EAIST is now YOPP (Year of Polar Prediction) endorsed, a program of the World Meteorological Organization to promote international cooperative research for the development of improved meteorological and environmental prediction services for the polar regions, on time scales ranging from hours to seasons. EAIST therefore plans to make all its meteorological data available to the community.

**The project has brought together around twenty teams, with the participation of the Laboratory of Climate and Environmental Sciences (LSCE), European Centre for Research and Teaching in Environmental Geosciences (CEREGE), Strasbourg Institute for Earth Physics (IPSGS) and Institute of Environmental Geosciences (IGE) for France, the National Institute of Geophysics and Volcanology (INGV), National Research Council of Italy (CNR), Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), and the universities of Venice, Bologna and Florence for Italy, and the Australian Antarctic Division (AAD) for Australia. To these we must, of course, add the French Polar Institute Paul-Emile Victor (IPEV) and the National Antarctic Research Programme (PNRA) for the logistical aspects. The traverse participants will be selected from these teams.**
THE CHOSEN ROUTE

Having adjusted for the fact that the Americans were no longer project participants, a new route was defined with the constraint of having to make the round trip in the same season since there was no longer any support available at the South Pole. Seeking to protect the project’s initial objectives, it was finally decided to travel as far as the megadunes area, around 640 km from Concordia. The distance of this round trip meant that it could be made in one season, but it also meant that it was possible to recover, by air or over land, some of the scientific equipment that the traverse had left on site to cover a full year’s worth of recordings. On the basis of the scientific questions and satellite maps, five locations were defined (Table 1).

On the strength of this scientific programme, differing working meetings made it possible to establish a chronogram, the configuration of the traverse, allocation of tasks and staff rotation. A season on the Antarctic plateau corresponds to only around sixty days of scientific activities in summer. Taking into account the necessary preparations, fifty traverse days were finally available to carry out EAIIST. On top of these fifty days on the Antarctic plateau, 2 x 10 days of driving were required to bring the vehicles from the coast to Concordia and back down again. In order to allow all the scientific experiments to be carried out, there was a staff rotation system for the megadunes area which meant that 15 people could participate, even though the traverse has only 10 beds. The convoy set-up was designed by the Polar Institute to accommodate staff, ensure a high level of security and be capable of transporting all the equipment.

ORGANISATION

Geophysics

- Surface radar to determine snowpack layers and to spatially monitor accumulation changes
- Seismic stations to make soundings of glacier movements and thickness
- GPS stations to determine flow directions and speeds

Atmospheric Physics

- Temperature, humidity, pressure, wind speed and direction, solar radiation, accumulation for the bilan de masse et la météorologie

Atmospheric Chemistry

- Water vapour isotopes for air-snow transfer functions
- Mass and size distributions of aerosols for comparison with Concordia and in-snow transport functions
- Aerosol collection for comparison with Concordia and air-snow transfer functions
- Nitrogen oxides for comparison with Concordia and air-snow transfer functions

Snow Chemistry

- Snow pits for measuring surface glaciological records
- Surface snow for spatial variability of the records
- Drilling for accumulation measurements and spatial and historical variability of the records

All these tasks are unevenly distributed depending on the site visited.

SCIENTIFIC PROGRAMME

As mentioned above, the organisation of a scientific traverse in a hostile, isolated environment that is restrictive for both machines and people, involves significant costs that have to be optimized by maximizing the possible scientific returns, while at the same time answering scientific questions. In accordance with this principle, the planned scientific activities were as follows:

Snow Physics

- Spectral albedo for energy budget
- Snow structure and surface roughness for energy budget and comparison with satellite microwave measurements
- Snow density for energy and accumulation budgets
- Thermal gradients and light penetration into the snowpack for energy budget
- Deployment of beacons to measure accumulation

Snow Chemistry

- Snow pits for measuring surface glaciological records
- Surface snow for spatial variability of the records
- Drilling for accumulation measurements and spatial and historical variability of the records

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There are five Challenger C65 tractors, sleds, fuel tanks, a snow groomer, life caravan (kitchen, office, beds, communication), energy caravan (mechanical workshop, bathroom facilities, shower, generator, food supply) and two CLIMCODE mobile laboratories (one hot, one cold). Because, in previous years, the transport of equipment and staff had come up against difficulties caused by sea ice-related hazards, the shipment of heavy equipment was brought forward to year n - 1. This turned out to be a critical choice. Beyond gaining flexibility and being able to work independently of the sea ice conditions, the damage to the Astrolabe vessel at the beginning of the 2019 season would have dealt a fatal blow to the traverse project now considering the COVID-19 related issues that also arose.

THE TRAVERSE

THE TEAM AND HUMAN FACTORS

Selecting a team for an isolated traverse in quasi autonomy is not a task to be taken lightly. While it is always difficult to predict the dynamics of a group that will be living in very close quarters, it is worth attending to this aspect before setting out. The initial requirement was to have on board a competent and experienced technical team consisting of a traverse leader, two mechanics and a doctor. That left six places for scientists, who needed to be experienced and familiar with the terrain and its difficult conditions, adaptable and able to multi-task. There also had to be both French and Italian contingents in the traverse. I also wanted as many women as possible to be involved so as to have varied and complementary viewpoints on subjects that may arise during the 70 days of voluntary confinement.

The technical team was established by the French Polar Institute. It was composed of Anthony Vende, traverse leader, Alexandre Leluc and Quentin Celle, mechanics, and Nicolas Rombauts, part-time emergency physician and designated cook.

As for the scientists, the various meetings had made it possible to compose a complementary and experienced team consisting of Joël Savarino (IGE), scientific coordinator and chemist, Nicolas Caillon (IGE), chemical engineer, Pete Akers (IGE), post-doctoral chemical researcher, Mathieu Casado (AWS), post-doctoral chemical researcher, Andrea Spolaor (U. Venice), chemical researcher, Craziano Larocca (INGV), geophysics engineer, Emmanuel Le Mœur (IGE), geophysics senior lecturer, Fanny Larue (IGE), post-doctoral chemical researcher, Laurent Arnaud (IGE), physicist, Mohammed Souil (IHA), French and Italian contingents in the traverse. The traverse went almost without a hitch. The only real technical problems encountered were the malfunctioning of a hydraulic power station, which had no impact on the traverse, and an engine failure on a Challenger that required the loads to be redistributed. Fortunately, this happened on the return journey and only 100 km from Concordia. If it had happened earlier it would have caused serious problems. Some other incidental issues that were taken care of without delaying the traverse’s progress were a broken tiller, the replacement of a sled runner axle, breakage of a snow groomer’s window, as well as other mechanical problems. The positive atmosphere that prevailed throughout the traverse was also the result of this excellent progress. Returning to the coast with no pressure and ahead of schedule, we made a detour to a site visited by the ASUMA traverse in 2017 to repair a broken weather station.

Figure 2 shows the GPS track of the route followed by the EAIIST traverse with the evening stops and the visited sites (Table 1). We were able to follow the planned route exactly. Staff changeovers were seamless and took place on the agreed days. The traverse went almost without a hitch. The only real technical problems encountered were the malfunctioning of a hydraulic power station, which had no impact on the traverse, and an engine failure on a Challenger that required the loads to be redistributed. Fortunately, this happened on the return journey and only 100 km from Concordia. If it had happened earlier it would have caused serious problems. Some other incidental issues that were taken care of without delaying the traverse’s progress were a broken tiller, the replacement of a sled runner axle, breakage of a snow groomer’s window, as well as other mechanical problems. The positive atmosphere that prevailed throughout the traverse was also the result of this excellent progress. Returning to the coast with no pressure and ahead of schedule, we made a detour to a site visited by the ASUMA traverse in 2017 to repair a broken weather station.
The mission

906 METRES OF CORES

3657 km of traverse

158 ISOTHERMAL BOXES BROUGHT BACK

5 SNOW PITTS

installation and operating autonomously

weather stations

Ancillary activities

Continuous measurements

Fixed and ad hoc devices

Drilling

Pits

Surface

Problems (Pb) Repairs (Rep)

<table>
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<tr>
<th>PREPARATION</th>
<th>Loading of materials</th>
<th>Loading of GPS station</th>
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All of the cores could be taken. No major problems threatened the smooth execution of the scientific programmes. Once again, like the logistics, the science had only minor problems to deal with that had no consequences for the experiments. For example, a malfunction of the particle counter caused by very low temperatures led to no data being obtained during the Prudhomme - Dome C pre-routing. Once transferred inside the CLIMCOR hot laboratory, however, the counter worked without a hitch. The loading of the NOx monitor on the Prudhomme - Dome C portion ensured a minimum of data for this task. Unfortunately, an on-site breakdown of the UV lamp at Concordia prevented us from taking it on the EAIIST traverse as the replacement UV lamp did not arrive until the end of the summer season.

Given the difficulty of operating the FELICS core drill in the CLIMCOR cold laboratory by staff without the proper experience, it was decided to take on board a master driller (Philippe Possenti) at the start of the expedition. This turned out to be a decisive choice for the success of the drilling programme. The rapid execution of some of the drillings saved precious time. Each project manager’s experience was deployed in the field and they will all now have that success.

By way of illustration, Figure 3 shows the first meteorological data transmitted by the megadune station and analysed by Laurent Arnaud. In view of the results of the data and samples acquired, I consider that all the scientific objectives set for the traverse have been achieved and even, in some cases, exceeded.

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Table 2: All the experiments conducted at different points during the EAIIST traverse.

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<td>1. Temperature 10m</td>
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<td>1. Density/size 8m</td>
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Once again, I would like to offer my sincere thanks to all of the teams who enabled this traverse to be carried out, regardless of whether they participated in the field or not. I thank our financial supporters, the French National Research Agency (agreement ANR-16-CE01-0011-01) and the BNP-Paribas Foundation (sponsorship agreement 2017-6639), without whom this traverse could not have taken place. I also thank all the French Polar Institute teams and the PNRA, management, administration, communications, logistics and technical services that make polar research possible and who have worked countless hours to achieve the results. I would also like to express my gratitude again to our supervisory authorities, CNRS and Grenoble Alpes University for their support in kind. My final words go to the entire EAIST team, from the overwinners to the technical and research teams. This experience was enriching and a remarkable achievement made possible through great teamwork.

CONCLUSIONS
AND PROSPECTS

Taking stock of such an operation, a great deal of scientific work remains to be done, but it is evident that the amount of effort that was needed on all levels is astounding. Nearly 8 years of preparation were necessary, a period marked by countless meetings, failures, exchanges, and also crises (an emotional experience). Yet, despite the meticulous preparation, there is also a certain amount of luck involved. Had the engine breakdown occurred in the middle of the scientific programme, it would have been a completely different story. And what about the emergence of a pandemic, the type the world has not witnessed since the Spanish flu? The need to prepare this type of complex project well in advance goes without saying because of the type of terrain, how the scientific programme is structured, and the safety of all staff involved. However, luck must also be on your side. What this experience has shown is that long and meticulous preparation work carried out well beforehand and by seasoned and experienced staff is a sine qua non for the success of such an undertaking. Yet this is not enough, as even though it reduces the risks, it cannot eliminate them. I am also aware of the sheer effort and amount of work required to prepare for and to implement such a traverse. The interdependence of people with different profiles is probably what best embodies this type of project.

Finally, on a more forward-looking aspect, scientific tractor traverses are still fantastic exploration tools, but are also heavy infrastructures that are not very agile, and lack flexibility and adaptability. While this approach is perfectly suited to traverses where scientific operations require a large payload, their ‘laziness’ can also become an impediment. The Institute is currently working with scientists to find ways of providing a lighter infrastructure capable of covering large areas in a short space of time while guaranteeing safety and autonomy. Having such an infrastructure would make a significant contribution to the study of the strong gradients of altitude, accumulation, temperature, wind, humidity and flow observed along the Dumont d’Urville - Concordia axis.

Finally, it was a shame that there was no film crew on the traverse as initially planned to make a EAIST documentary, as this will now have to be done with amateur footage and with a different form of narration. Nevertheless, with luck on our side (favourable weather, good snow, few worries), EAIST remains a great success both scientifically and logistically and is fully in keeping with the IAGP approach.
The French Polar Institute is a public organization responsible for bringing to fruition French research operations in the polar regions of the globe.

Access and living conditions in these zones of the world are difficult. The French Polar Institute deploys substantial resources and specially adapted, technologically advanced systems to research sites. The Institute also employs people with the special knowledge and skills required for top quality scientific research in extremely harsh polar conditions.

**Mission**

The French Polar Institute participates in international consultations on scientific, logistical and environmental considerations and often represents France in that capacity.
**Scientific Council**

- **Isabelle Delacroix**, Commission du Gouvernement
  - French representative on the International Arctic Science Committee Council, en videoconference
  - March 2020
- **Christiane Laurent-Monpret**, Ministre de l'Outre-Mer
  - Committee for the Protection of the Environment (CPE) and Committee of Managers of National Antarctic Programmes (COMNAP) in Plovdiv
  - July 2019
- **Clémence Renévier**, Caroline Semichon
  - Réunion «les enjeux de l’Arctique» à Reykjavik
  - April 2019
- **Fatima Lagouzin**, Personnalité étrangère (CNRS–INSU)
  - Ny-Alesund Science Managers Committee (NySMAC) in Arkhangelsk
  - May 2019
- **Paris**
  - Committee of Scientific Operators in Ny-Alesund (NySMAC) in Arkhangelsk
  - May 2019
- **Switzerland**
  - Committee of Scientific Operators in Ny-Alesund (NySMAC) in Arkhangelsk
  - May 2019
- **Portugal**
  - General Assembly and Symposium of the Council of Managers of National Antarctic Programmes (COMNAP) in Plovdiv
  - September 2019
- **Italy**
  - Meeting with the Alfred Wegener Institute (AWI) in Hamburg
  - February 2020
  - Committee of Scientific Operators in Ny-Alesund (NySMAC) in Arkhangelsk
  - May 2019
Australia and France have long enjoyed a warm relationship in Antarctica and the sub-Antarctic. These close ties were evident this summer when the French Antarctic Program called for assistance, after its icebreaker became unserviceable, due to a damaged propeller. The Australian Antarctic Division (AAD) was able to resupply the French Antarctic station, Dumont D’Urville, and transport a new team of wintering expeditioners south.

While Australia’s icebreaker, Aurora Australis, delivered expeditioners, cargo and 250,000 litres of fuel to the station, the AAD also flew 14 French passengers to the joint French/Italian station, Concordia.

Such assistance is part of the spirit of cooperation that exists in Antarctica, but it also reflects the long and close relationship between Australia and France.

As original signatories to the Antarctic Treaty, we have a strong, shared history, including as lead proponents of the Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol), which indefinitely bans mining in Antarctica. Our two countries are also geographical neighbours in Antarctica, and we have adjacent Exclusive Economic Zones (EEZs) on the sub-Antarctic Kerguelen Plateau.

As a result of our scientific collaborations on marine ecosystem and fisheries research on the Kerguelen Plateau, we have adopted complementary approaches to toothfish stock assessments in our EEZs. This approach has been welcomed by the Commission for the Conservation of Antarctic Marine Living Resources – the key body responsible for the conservation of marine ecosystems and fisheries management in the Southern Ocean.

The AAD and the French Polar Institute Paul-Emile Victor (IPEV) also work closely together under various agreements that demonstrate our shared commitment to good governance, environmental protection and scientific excellence.

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Scientific programmes supported

Scientific programmes supported in Arctic 58

Scientific programmes supported in Antarctic and Subantarctic Islands 79
In the framework of the ORNITHO-ENDOCRINO research program, we will study the physiological and fitness effects of poly- and perfluorinated alkyl substances (PFASs) exposure in Svalbard Black-legged Kittiwakes. PFASs are surface-active agents used in a multitude of manufactured and consumer products and are nowadays the most abundant contaminants in many Arctic seabirds, but their effects remain poorly known. We will:

- Investigate in depth the influence of PFASs on key endocrine mechanisms underlying reproductive decisions and parental effort (corticosterone, LH, prolactin)
- Explore via the study of telomeres dynamics the impact of PFASs contamination on the rate of ageing of individuals
- Assess the consequences of PFASs exposure on fitness traits like reproductive success and survival.

The aim of this research program is to examine the response of animal populations to environmental variability at different spatial scales. The study system is a host-parasite system at three levels, involving Arctic seabirds as hosts, the tick Ixodes uriae as their ectoparasite and microparasites such as Lyme disease agent Borrelia burgdorferi and arboviruses. The role of the variability in host phenotypic responses (immunology and behaviour) and of the coevolution between the hosts and the vector tick for the ecology and evolution of such interactions at different scales will be studied. In addition to laboratory analyses, the approach combines field experiment to the analyses of data recorded in a spatialised context.
The Arctic region is warming more rapidly than any other region on Earth, and predicting the response of biodiversity to climate change (CC) has become an extremely active field of research. Most studies of the impacts of CC on biodiversity have so far focused on individual responses, mainly on phenology, physiology or range shifts. However, it is increasingly apparent that biotic interactions drive key ecological and evolutionary processes and mediate ecosystem responses to CC. Thus, predicting the effects of CC is dependent upon identifying the interactions between species that are most vulnerable to changing climate and are key determinants of the structure and function of a community.

Predator-prey interactions (PPI) play a determinant role in structuring Arctic terrestrial vertebrate communities, and understanding how the strength of these interactions varies under the constraints of CC is crucial to assess ongoing changes in Arctic biodiversity.

If PPI is primarily seen as the direct trophic (lethal) interactions between prey and predator species, at a community level it can also take many different forms. Thus, PPI can be non-trophic/non-lethal when predators induce antipredator responses (risk effects) in preys, hence not necessarily impacting their current abundance but rather their long-term survival and/or their breeding performances.

This project is the continuation of our “INTERACTIONS–1036” program funded by the French Polar Institute-IPEV between 2011 and 2014 and extended during 2015-2018. In our previous programmes, we have deepened our understandings of the direct and indirect interactions between lemmings, shorebirds and their shared predators. The new INTERACTIONS program (2019-2022) will now aim at capitalizing on this expertise in order to broaden the picture to far more complex inter-specific interactions, and involving two aims:

Observations at larger time scale on the previously studied site in order to better appreciate the effect of yearly fluctuation;

Extension to the study of individual responses of predators and prey to the intensity of their interactions.

The originality of our new program consists in the mutual study of the behavioural responses of the prey and the predators to the variations of intensity of their interactions, and the consequences for the dynamics and distribution of the different populations. Better understanding of the evolution of the predator-prey interactions in Arctic terrestrial ecosystems could have strong implications in our ability to understand the effects of CC on biodiversity and evolution.

It is essential to reach a better understanding of ecological processes in the Arctic, as this ecoregion is hit severely by the consequences of global change. In this context, we study the ecophysiology of little auks (Alle alle), which are the most abundant seabirds of the Arctic, and acknowledged ecological indicators of changing marine ecosystems in this polar region. Via a long-term study of little auks breeding in East Greenland (Liverpool Land), in place since 2005, but also through specific experimental and modelling approaches, as well as through a panarctic network of collaborations, we test the following hypotheses:

- Arctic climate change is impacting the trophic status, the foraging ecology, the reproductive output, the body condition and the multi-annual survival of adult little auks during the breeding season.
- Ongoing climate change impacts the migratory ecophysiology of little auks in the North Atlantic.
- Flight and diving energetics condition the functional ecology of little auks - among the world’s smallest diving marine homeotherms.
- Climate change is generating thermal stress for arctic seabirds, with impacts on their reproductive performances.
- Environmental contamination impacts little auk ecophysiology, behaviour and breeding success, with long-term population effects.
- The pan-arctic seabird community functions as a natural monitoring network for both legacy and emerging contaminants. All of our work participates in the Circumpolar Biodiversity Monitoring Programme (CBMP) of the working group Conservation of Arctic Flora and Fauna (CAFF) of the Arctic Council, and therefore corresponds to the expectations of arctic peoples in terms of environmental research.
The west coast of Svalbard is one of the most impacted area in the world due to global warming, as Atlantic, Arctic and glacial waters converge and mix there. As a result, the Kongsfjorden is a very impacted area in the world due to global warming, as Atlantic, Arctic and glacial waters converge and mix there. As a result, the Kongsfjorden is a very
Arctic ecosystems are far removed from the direct effects of the soaring human population because they are remote and sparsely inhabited. However, ironically, trends in recent decades suggest that Arctic ecosystems may undergo the fastest and most radical changes on the planet as a consequence of human activities. This is in particular because of their sensitivity to current anthropogenic changes in global climate. These climate induced changes in Arctic ecological conditions have rightfully attracted the attention of the research community. However, this focus comes at the expense of research on other forms of anthropogenic disturbance in the Arctic. One of the most dramatic examples is the explosion of arctic-nesting snow geese populations. Their numbers soared from less than 100,000 individuals to possibly over 1 million in only a small number of decades. This resulted from changes in agricultural practices and of the ability of these species to shift their wintering grounds to these novel, man-made habitats. The focus of this proposal is to repeat detailed, ground-based data collection carried out 22 years ago, to evaluate the cascade of changes in habitats and avifauna that have occurred, and the role played in these changes by changes in the intensity of goose grazing and climate.
Permafrost covers over 20% of landmasses in the Northern hemisphere. Its thawing due to global warming could release tens of Pg of carbon in the form of CO₂ and CH₄ to the atmosphere, representing a major positive feedback to warming. Permafrost thawing also impacts Northern communities and on the development of the Arctic. This project aims at improving:

- Our prediction of the evolution of the thermal regime of permafrost;
- Our understanding of the exchanges of carbon between the permafrost and the atmosphere.

Regarding the first question, the emphasis will be placed on snow-vegetation interactions, and in particular on the physical processes induced by vegetation growth and which modify snow thermal conductivity, in order to pursue and complement the breakthroughs of the past 4 years.

Regarding the second question, the emphasis will first be placed on the Umiujaq site, where the ground in carbon-poor and where vegetation growth has allowed recent carbon uptake. Subsequently, the carbon-rich Bylot site will be studied.

Climate assessments consistently reproduce zonal mean surface temperature warming in Arctic latitudes exceeding the global average. This Arctic Amplification was initially attributed to snow/ice albedo feedbacks, but progressing climate modeling revealed several other feedbacks playing a role as well. These include effects due to modified thermal properties of sea ice or changes in poleward energy transport and associated shifts in storm tracks, vapor and clouds. These findings are mostly based on climate modeling, but their validation by observations as well as the assessment of the relative importance of inherent processes remains difficult and is still quite controversially discussed.

Based on this background, this project seeks to investigate the role of long-term snow developments and of inherent feedbacks due to e.g. changes in snow structure and snow albedo in Arctic Amplification in more detail. Albedo changes are at least partly related to the incorporation of light absorbing impurities and, thus, the chemical composition of the snow. Therefore, a second objective is related to a better understanding about chemical interactions between the atmosphere and the snow including pollutant wet/dry deposition and pollutant recycling at the snow/ice-atmosphere interface.
In its first phase, the AWIPEV-CO2 project set-up a time-series of carbonate chemistry parameters at Ny-Ålesund. It is the first (and only) such series in the Arctic Ocean. These data are required to estimate air-sea CO2 fluxes, the rate of ocean acidification, and plan future perturbation experiments following those conducted in 2009 and 2010. An ERC project has been submitted. Four instruments have been set-up as part of the AWIPEV Underwater Observatory: pCO2 (2015), total alkalinity (2016), in situ pH (2017) and pH in the Ferrybox (2017). Beside IPEV, these activities have been financially supported by the AWI and the European project INTAROS. Discrete samples are collected weekly (dissolved inorganic carbon and total alkalinity) as well as monthly (pH) to calibrate the sensors and perform quality-control. The data are available in near-real-time (http://www.obs-vlfr.fr/~gattuso/data/awipev-CO2_web.html). We are seeking the continuation of this time-series.

The Arctic is undergoing the most rapid changes among all regions on the Earth. These changes, including the rapid sea ice decrease and air temperature warming, are affecting the Arctic ecosystems in terms of functioning, geographical distribution and communities. They are also suspected to influence the Northern Hemisphere atmospheric circulation and the European Climate. Increasing in-situ observing capacity in the Arctic has become a major challenge owing to the current lack of data, mostly due to the difficulty in accessing these remote and harsh environments. The INTAROS-Svalbard aims at strengthening the observing capacity in a very important region of the Arctic with regards to ongoing changes, the Svalbard region. This initiative is part of a wider scope of the Arctic with regards to on-going changes, the Svalbard region. This initiative is part of a wider INTEGRATED ARCTIC OBSERVATION SYSTEM (INTAROS) project. The ocean around Svalbard is a key-region for the Arctic climate, as it is a major pathway for the warm Atlantic water entering the Arctic Ocean, an area of intense ocean-ice-atmosphere exchanges. In Kongfjorden, passive acoustic signals recorded by hydrophones and measurements by accelerometers which will be installed on benthic bivalves will be used to monitor the biological activity. The separation of the acoustic signals between its biological and abiotic origins will allow to understand the biological activity in relation to the sea ice evolution and other environmental parameters. Wave-sea ice interactions will be investigated from the acoustic records and high resolution SAR imagery.
Mercury is toxic to both wildlife and humans and is transported to arctic ecosystems via air, rivers and oceans. During recent ERC, CAF, and H2020 projects we have made new and critical observations on arctic mercury cycling, including the first seasonal observation on russian river inputs, on open Arctic Ocean mercury speciation and distribution and on tundra uptake of atmospheric mercury. These results are stimulating a rethink of arctic mercury cycling and the development of a new generation of numerical models that help understand how arctic warming affects mercury cycling and exposure. One key observation, the elevated summertime atmospheric elemental Hg levels, remains ill-understood. The main objective of the MESSI project is to make novel observations on arctic mercury cycling, including the mercury isotope signatures of the summertime peak, in order to understand its origin (terrestrial, marine, sea ice?). In addition we will revisit seasonal atmospheric reactive mercury (HgII) dynamics by intercomparing novel sampling methods to current mercury monitoring instruments. The new observations should help better parameterize coupled 3D models of the arctic mercury cycle.

The main objective of the ALPACA (Alaskan Pollution and Chemical Analysis) project is to gain new insights into the processes governing the formation and distribution of aerosol originating from local pollution sources in the Arctic during wintertime and early spring. For this purpose, this project makes a major contribution to, and benefits from, a major international field campaign being planned in Fairbanks, Alaska during winters 2019/20 and 2020/21 as part of the International programme ALPACA (supported by IGAC/IASC PACES). A combination of field data collection, chemical composition analysis in the laboratory, analysis of observations and atmospheric modelling will be used to better understand and simulate Arctic aerosol sources, interactions between chemical and dynamical (boundary layer) processes influencing aerosols, and the impacts of aerosols from local anthropogenic sources on climate relative to remote sources of pollutants transported from mid-latitudes (Arctic Haze). This project brings together 7 complimentary French groups working on atmospheric chemistry and dynamics together with geochemists working on isotopes. This project requires support for the field campaigns in Alaska.

The project EXTREMEVENT is conducted through the problematic of global warming that would have as supposed impacts, an increase of the frequency and/or intensity of storm events at medium and high latitudes. In that context, the study of coastal morphodynamic processes on the peninsula of Reykjanes (SW Iceland) is proposed. It is based on the annual monitoring of a dozen coastal sites corresponding to rocky coast where cliff-top storm deposits (cTSDs) are accumulated, and accumulation forms such as boulder beach and dunes. Therefore, cTSDs carrying, transport and accumulation, and boulder beach and dunes erosion by giant storm waves are interpreted as proxy of extreme events on the dynamics of the Icelandic coasts. Comparisons with the dynamics observed on the lower latitudes of Brittany are realized through the French Service National d’Observation SNO-DYNALIT funded by the CNRS-INSU. The survey is based on topo-morphological measurements using KAP and UAV aerial images, and DGPS field measurements; it is also based on hydrodynamic analysis using wave and tide measurements. This project was completed over a period of 4 years - 10 days of field campaign during spring period (mid-May 2019, 2020, 2021, and 2022), to accommodate the longest survey period. Staff travel, material transport, consumable (car location), and field and running costs for 3 persons (researchers and engineers) are requested to IPEV for a total amount of €350 euros per year. Original scientific outputs (i.e. articles and conferences) on aspects that are not studied in Iceland yet, and scientific and educational strengthening collaboration with the University Centre Of The West(Jors), are expected.

The decline of Arctic sea ice extent is one of the most spectacular signatures of global warming, and studies converge to show that this decline has been accelerating over the last 4 decades, with a rate that was not anticipated by forecasting models. In order to improve these models, relying on comprehensive and accurate field data is essential. While sea ice extent and concentration are accurately monitored from microwave imagery, we are still lacking an accurate and comprehensive measure of its thickness. In addition, models could benefit from including other observables related to the ability of the ice cover to resist cracking and to heal when cracking occurs. The ICEWAVEGUIDE project introduces a methodology based on seismic waves propagation to meet these needs, and aims at completing current knowledge so far acquired mostly from Radar and Sonar data. Based on continuous, passive recordings of seismic ambient noise at an array of geophones, the ICEWAVEGUIDE project will demonstrate that propagation of leaky seismic waves guided in the thickness of the ice can be measured. Guided waves being sensitive to the geometrical and mechanical properties of the waveguide, the measures will be inverted to recover important markers of ice mechanical resistance, such as thickness, elastic properties and damage level. This new methodology was successfully tested on data acquired in a lab-scale experiment. The experiment consisted in leaving a water tank in a cold room so as to grow an ice layer at its surface. While its thickness was increasing, ultrasonic guided waves were generated in the ice with a piezoelectric source, and measures were subsequently inverted to monitor the thickness and mechanical properties of the ice. The goal of the proposal is to extend this proof of concept on actual geophysical data acquired on a frozen lagun in Svalbard (Norway) during winter 2019.
The Arctic is warming at twice the global mean rate and shows acute visible signs such as the retreat of summertime sea-ice. The predictive capability of Arctic response to climate change is severely hampered by a lack of understanding on key processes related to clouds. Observations suggest that boundary layer mixed phase clouds (MPC, mixture of liquid droplets and ice crystals) are ubiquitous in the Arctic and persist for several days under a variety of meteorological conditions. The strong impact of MPC on the energy budget stems from their persistence and peculiar microphysical properties which result from a complex web of interactions between local microphysical, radiative, dynamical processes and larger scale environmental conditions and processes. Within the (MPC)² project, we plan to provide and analyse high quality cloud data to quantify the impact of the microphysical properties of MPC on the surface energy budget and to better understand the life cycle of the mixed phase. The proposed work mainly relies on the statistical analysis of the in-situ cloud microphysical and optical measurements collected during ACLOUD 2017, AFLUX 2019 and MOSAIC 2020 airborne arctic campaigns in the vicinity of the Svalbard Archipelago. State of the art in situ instrumentation (cloud and aerosol) along with airborne remote sensing devices will be used to characterize the spatial distribution of cloud microphysical properties as a function of large scale meteorological and surface conditions as well as aerosol concentrations. We can expect to collect comparable dataset of cloud properties during summertime and springtime to study the influence of environmental properties on the vertical profile of microphysical properties. This new dataset will contribute to the development of cloud parameterizations for models and satellite retrievals and to increase our process level understanding of cloud microphysics.

Our project will focus on tracking the genetic, epigenetic, and microbiota changes experienced by the Sakha people (Yakuts) in Far Eastern Siberia, following contact with Russians from 1632. Prior to Russian contact, native Yakuts had never been exposed to germs such as smallpox and tuberculosis. The arrival of Russians in the region resulted in massive epidemiological outbreaks, which decimated the population. Likewise, the Yakut traditional diet was transformed to include more carbohydrates, derived from the newly introduced cereals and potatoes. Therefore, Russian contact kick-started, as early as the 17th century, a series of deep transformations in the Yakut society, which continued in the following centuries with the rise of the Soviet Union in the early 1900s and the emergence of antibiotics after 1950. Our project associate: (i) The excavation of frozen grave from periods and/or sites which has never been excavated before and that we expect that they will furnish unexpected results about the history of population of this part of the world. (ii) The study of biological modifications experienced by human groups following population contact and change in lifestyle at three levels, genomic, epigenetic and microbial level. The samples that will be studied include the human sample excavated from 2002 to 2015 and the new ones that we excavate and which are susceptibility to change the history of the population of this part of the world and of the arctic.
The ENCHAINEC project is focused on vulnerability, resilience and adaptation of northern societies facing global change. The rapid current warming of Arctic climates has already created many changes in the social, economic and cultural behavior of the populations inhabiting these regions and more changes are expected to come. These changes disturb the fragile balance between human and the environment. Populations of these areas have to face these challenges, and in this context, looking at the past provides the opportunity to explore the complex relationships between climate, ecology and human societies, which may help to suggest scenarios about some situations according to the forecasts. The chronological frame of the project encompasses the last millennium, a pretty well documented period. The study area concerns North-Eastern Canada (Nunavik, and Labrador-Nunatsiavut). Around 1000 years cal. AD, hunters/gatherers/fishers lived by the Nunavik and Labrador coasts. Within these study areas, our aim is to document 1000 years of interactions between Thule/Inuit (last Dorset pro parte) people, and their environment, through an interdisciplinary approach exploiting different kinds of natural archives. The use of pedo-sedimentary archives (lake and peat deposits, cryosols, anthrosols) and palaeoenvironmental multiproxy analyses will give useful information about landscape evolution, climatic and anthropogenic forcings upon ecological processes. Archaeological sites, and more specifically archaeological soils, ecofacts and artefacts, will give precious information about the nature of these interactions. In parallel when possible, an anthropological/cultural approach through open interviews will focus on human memory of Inuit elders, perception and prospects of environmental and social changes. Several modes of communication have already been identified, adapted to the different audiences and partners involved in the project: academics (presentations at conferences and publications in international journals), local communities and local authorities. It is a priority for us to circulate the results of our field work and analyses to a non-specialist audience, especially youths of the Inuit communities, by a website featuring the innovative interactive platform and the Facebook page.

The ALSI project is aiming at consolidating the basin of the Austre Lovén glacier as a long-term observatory. Such observatories are scarce in the Arctic and the data they provide are therefore all the more valuable. While the first observations in this basin were conducted in the 1960’s, a renewed effort has been undertaken by our team amounting this year to a decade of data. This work consisted for some part in applying standardized protocols for glacier mass balance measurements, and for another part in instrumental experimentations and developments such as automatic cameras. As of today, recurrent measurements led on the glacier are now part of the national SOERE CRYOBS-CLIM, recently integrated in the newly created IR OZCAR, and at the international level part of the World Glacier Monitoring Service (WGMS) database. The observation network is now operational in the field and benefits of the 10 years of experience our team holds. Keeping these measurements going can be done at minor human and financial costs. We are encouraged by our international scientific community to continue our efforts as the Austre Lovén glacier basin holds specific characteristics that makes it of particular interest in a global glaciological and hydrological approach.
Reindeer herders today face many challenges, including climate change (resulting in later springs and colder summers), high rates of predation on young calves, and restricted access to land due to increased encroachment (by mining, wind farms, hydroelectric dams and tourism). Given these concerns about their future, they wish to better understand how the cumulative effects of these changes are currently affecting the reindeer-herding economy and lifestyle, the land, as well as their future impact on Saami reindeer-herding culture and language.

When they finish school, young Saami students have to make choices based on what they believe the future holds. Would their best prospects be in mining, tourism, or other jobs combined with reindeer herding?

To address these issues, a proposal for an initial research project was drafted in July 2017 during a series of workshops with the Jåkkåkaska Sameby at the reindeer-marking camp in Arasluokta. The project, aimed at exploring options and possible future scenarios, will be led by Sameby members and students at the Saami school in Jokkmok, working with a team of researchers from universities in Sweden, Norway, Finland and France. The project, supported by a series of workshops with the Jåkkåkaska Sameby, will bring together local expertise and scientific knowledge in order to better understand the magnitude of changes, to analyze their impacts, and to envision the scenarios for the future.

The Saami of Sapmi seek an overall view of the changes taking place rather than dealing with one question at a time. BOAZU stands for ‘reindeer’ in Saami.
This research project aims to study the conditions of admission and academic success of Greenlandic students in migratory situations, mainly through qualitative research. Focusing on the conditions of their mobility (about the way people change location as part of their studies and about its impacts), the study will rely on a two-fold methodology: participant observation field-notes on the one hand, analysis of a corpus of interviews on the other.

To identify how the double process of subjectivation and emancipation at work in education related mobility, we will investigate the journeys and experiences of Greenlanders who have moved to Copenhagen to study. As keys to better appreciate their stories, special attention will be given to a historical situation of colonial domination that still pervades Greenlandic society, where race and culture are central issues, as well as to the global context in which such mobility takes place today - commodification of higher education in relation with the rise of the “economy of knowledge” and a high variability of migrants’ social inclusion according to their country of origin. We will examine how students resist norms foreign to them, open spaces for their own fulfilment, rely on social and political networks to support their educational trajectories.

Hence, this research will draw a social geography of access to a University diploma for minority groups that are such both in their own country and in the academic world.

Fieldwork will be conducted both in Copenhagen, where Greenlanders come to study, and in Nuuk (Greenland), where they depart from and return to. To put this study into perspective, a secondary and minor research will consider the Canadian Inuit situation. Mainly based on an analysis of already available quantitative data, it will also include a limited case study based on in-depths interviews with those who choose to study at Whitehorse Yukon College.

The Nenana valley near Healy, Alaska, has been the site of many decades of prehistoric archaeological research focused on the late Pleistocene and early Holocene records, thus documenting the initial settlements of humans in the New World. New research at the Little Panguingue Creek site (HEA-038) will provide us with important information about Pleistocene-Holocene human activities in the Nenana valley foothills. This multi-component site is located on a Healy-aged glacial-outwash terrace, overlooking Little Panguingue Creek. A new multi-year excavation program, began in 2015, revealed a c. 9,600 cal yr BP knapping workshop (hammerstones, cores, preforms, cortical spalls, tools, debitage, etc.) with a major microblade component dating from the final phase of the Denali Complex, along with an older component dating to c. 11,150 cal yr BP. The on-going research at the site will further our understanding of human technological, subsistence, and settlement organization in the Nenana valley (and beyond) during the Pleistocene/Holocene transition. One of the main objectives of this project is to develop a paleoethnological approach to this site. In other words, not simply understanding the chrono-cultural complexes present, but understanding this campsite in detail. In order to do this, we have planned extensive excavations, new surveying techniques (GPR, magnetic, etc.), and the application of specific disciplines (lithic technology, raw materials provenience, use-wear analysis, spatial analysis, refitting, etc.).
The program uses seabirds and marine mammals as indicators of global changes in the marine ecosystems of the southern ocean. Through a network of 4 observatories from the Antarctic to sub-tropical biomes, the populations of 25 species of marine top predators and their distribution at sea are monitored since 50 years. These individually based long term information, combined with shorter term studies carried out on an annual base, especially on the foraging ecology of the species, are used to understand the processes through which climate affects marine ecosystems, and to make predictions on the effects of future changes in these ecosystems, as well as to propose conservation measures to limit the impact of fisheries on populations.

Our research program ECONERGY is devoted to the study of the physiological, energetic and evolutionary aspects of the so-particular adaptations exhibited by adults and king penguin chicks (Aptenodytes patagonicus) to their ashore living stages. These are characterized either in chicks by their extraordinary long growth period and the irregular feeding rates during the winter or in adults by their long-term fast during reproduction or molting. To answer our questions we realized studies via the study of the animal in his environment with an ecophysiologist approach.

Because they have optimized the bioenergetic processes essential for their survival, marine birds from the polar and subantarctic regions are of outstanding interest. By an integrative physiological approach from the entire animal to gene expression, the deciphering of the adaptive energetic mechanisms developed by polar species at each critical steps of their living (reproduction, hatching, thermal emancipation) could improve our understanding and reveal potential targets for metabolic diseases.

The subantarctic islands are amongst the most isolated islands from any continental landmass and contain a number of the limited terrestrial habitats present at these latitudes. Interestingly, our knowledge of the subantarctic biodiversity, autoecology and effects of climate changes and biological invasions still contain many gaps. In parallel, accurate assessments of the sensitivity and vulnerability of polar organisms must be achieved in order to reliably predict species and community trajectories. In addition to climate changes, alien insects and plants can represent significant drivers of community structure and functional diversity in general. Changes in plant communities have strong bottom-up effects on multitrophic interaction networks with subsequent effects on above-ground animal communities in terms of abundance, taxonomic and functional diversity. In this project, we are investigating the spatio-temporal patterns of the subantarctic biodiversity, biological invasion processes, the effects of changing environments and multi-stress on the species physiological ecology and the perception of the biodiversity in a non-market context.
Assessing the ongoing and future adaptive capacities of populations to cope with global changes is a major challenge. Relying on multi- and trans-disciplinary expertise, P137 has selected three main animal models (and phylogenetically related top-predators): king penguins Aptenodytes patagonicus, Adélie penguins Pygoscelis adeliae, and emperor penguins Aptenodytes forsteri, to investigate the impact of climate on Southern Ocean ecosystems. Our unique database, without the biasing effects of flipper bands, allows us to study two contrasting, but nonexclusive, mechanisms that can explain their population responses to environmental variability (natural and anthropic): Phenotypic plasticity responses and microevolutionary processes.

In addition to determine and monitor the flexibility and plasticity of numerous phenotypic traits (morphological, physiological, phenological and behavioural; accounting for sex, age, experience, condition, etc.), we also study the spatial structuration of the colonies according to different constraints (social structure, parasitism, predation, local meteorological conditions, etc., but also phylogenetic constraints). We also aim to evaluate the genetic basis of phenotypic traits and their plasticity, and assess genetic diversity and gene flow between colonies within and between archipelagos to gauge their adaptive capacities. The development of new predictive models of population responses to ecosystem changes (models integrating individual-based models within demographic-selection modelling framework, based on scenarios forecast by the IPCC 2014) will be precious tools for population conservation measures and ecosystem management. As never done before, we also propose to develop cutting edge technological innovations to minimise experimental disturbances and resulting scientific bias, such as mobile Radio Frequency Identification antennas on remote-operated vehicles (ROVs), automatic weighing and camera-tracking systems, or networked implanted micro-loggers. In return, it will open new opportunities for science, bringing new research questions that could not have been addressed without these innovations.

Individuals are programmed to survive, mate, and optimise their fitness. To accomplish these tasks they interact with conspecifics, other organisms, and other elements of their environment. Behaviour thus is the baseline of all animal activities and is continuously modified by cues and clues coming from their environment. Our project, merges animal behaviour and sensory ecology, and aims at studying those cues and clues influencing seabirds’ behaviour. Signals coming from other individuals broadcast important information for communication. We are particularly interested in the process of mate choice. This behavioural process in penguins may use their orientation an acoustic landscape formed by all individuals calling in the colony. In this case, what is used by an individual it is not the information directly broadcasted between two individuals, but the constant noise that all the information broadcasted forms in the environment. To test this hypothesis, we aim to study how this acoustic landscape forms and whether it is actually used to orient. However, in penguins not only cues coming from other individuals may be important for orientation and positioning. Positioning in the colony and thus survival depend also from predators and other environmental features (waves, temperature, rain, flooding etc.). Ultimately the colony structure may reflect how the birds respond to all the inputs coming from their surroundings. We therefore also need to understand colony formation and dynamics to understand movements of individuals in crowded environments.

The objectives of this proposal are to study the foraging strategies and energetics of the main diving birds of the Southern Ocean (especially penguins) that play in major role in food webs through a pluri-disciplinary study involving ecologists, physiologist and oceanographers and using bio-logging developments. We want to determine

- Their foraging strategies
- Their at-sea energetics, from the individuals to the population
- To evaluate the consequences of environmental changes on diving birds ecology.

The applied issues concerns the determination of important at-sea bird areas and the use of penguins as indicators of the impact of climatic variability, at short and long term, on some poorly known food webs of the South Indian ocean.
In the current context of climate change, variation of sea surface temperature and salinity, sea level rise and latitudinal shifts of currents and hydrological fronts are expected to affect marine biodiversity of the sub-Antarctic Islands, particularly in coastal areas, in which many species have limited regulatory abilities. Characterizing the impact of climate change on marine communities implies that environmental data must be continuously recorded for interpreting ecological changes, predicting their potential impacts on marine life, and setting up relevant management plans. Such objectives can only be achieved by implementing a long-term and cross-disciplinary observing system. For this purpose, the IPEV program PROTEKER was conceived as a multidisciplinary approach including oceanographic measurements, benthic dynamics survey, as well as genetic, trophic, and eco-physiological analyses. The main objective of the program is to establish a base line for assessing the impact of climate change on coastal marine ecosystems. The program also aims to contribute to the international network of nearshore observing systems in the Southern Ocean (SCAR ANTOS Expert and IASA Action Groups, IDEAL Center in Chile).

In partnership with the WWF, these data will be included in the databases of international programmes of eco-regionalization (Census of Antarctic Marine Life, SCAR, CCAMLRI). Comparisons with Adélie penguins’ performance in other regions of the East Antarctic sector will be conducted, in collaboration with colleagues from Australian and Japanese polar institutes. Following the recommendations of the aforesaid international institutions, the program will put a special emphasis on the examination of possible outbreaks. In order to do so, we will combine complementary methodological approaches from different fields, involving notably laboratory analyses of biological samples gathered in the field on identified individual birds, the parallel development of modelling approaches. Modern molecular techniques as well as tracking devices will be used to address specific questions. The project aims to provide nature reserve managers and decision makers with scientific criteria for protection and conservation of coastal marine ecosystems. The program also aims to contribute to the international network of nearshore observing systems in the Southern Ocean (SCAR ANTOS Expert and IASA Action Groups, IDEAL Center in Chile).
Links between personality and energetic and behavioural adjustments of Southern elephant seals in response to environmental condition variations during their life cycle.

Climate and environmental changes influence the dynamics and structure of marine ecosystems, which affect the distribution and the abundance of marine species. Southern elephant seals (Mirounga leonina) may be particularly affected by such spatiotemporal variability, since they alternate between foraging periods at sea and fasting time on land. Different foraging strategies at sea may impact the efficiency with which animals forage, which is the key to their reproduction and moult on land. This work aims to 1) link natural conditions and energetic constraints of a marine predator during its life cycle, alternating foraging and fasting periods; 2) explore whether individual strategies related to personality traits would impact on foraging success, moult speed, and ultimately on energetic and fitness components and 3) extend the environmental and seal behaviour data set through the SO-MEMO program. By exploring both proximate parameters (i.e. physiological, behavioural, energetic strategies) and ultimate (i.e. foraging success, reproductive success, moult speed) of individuals, this work will substantially increase our understanding of how environmental stressors such as ocean warming may influence energy expenditure, energy intake and therefore energy balance of this deep diving predator and how this could be mediated by personality traits.
The 5 permanent magnetic observatories (Amsterdam, Crozet, Dumont d’Urville and Kerguelen) are located in remote and isolated locations. They are therefore of great significance for the observation of the internal magnetic field but also for the study of phenomena generated by the solar wind at the surface of the globe (geoeffectivity). These 5 observatories meet the highest international standards and norms thanks to the development of specific procedures and acquisition chains. The Earth’s magnetic field is recorded continuously with sampling rates of 1 second. Absolute manual measurements of the magnetic field components are also made daily throughout the year. Data processing and dissemination at the Central Terrestrial Magnetism Office (Bureau Central de Magnétisme Terrestre SNO-BCMT) and at world geophysical data centres (WDC for geomagnetism - World Data Centers, INTERMAGNET) are carried out every 12 hours UT thanks to the acquisition system integrating expedition protocols. The continuity, quality, stability and homogeneity of these observations are of prime importance for their continuous use by the both Solid Earth and Astronomy-Astrophysics scientific communities. Our goals are to maintain or improve the quality of the data, to improve the robustness of the data recording and distribution procedures, and to increase their national and international utilization.

The objectives of the 209 program “NDACC Antarctic” consist in long term monitoring associated to process and climatological studies on both the particle population (aerosols, cirrus, Polar Stratospheric Clouds – PSC) and chemical composition (including stratospheric ozone) of the Upper Troposphere / Lower Stratosphere. The global thematic is the stratospheric ozone chemistry and depletion, in a changing climate context. Consequences on UV-B radiation on ground, as well as ozone interactions with climate, especially concerning the impact of green house gases increases are also investigated. A set of instruments dedicated to the measurements of clouds occurrence and physical characterization, and ozone, along with the parameters involved in its chemical equilibrium is currently implemented on the French stations Dumont d’Urville and Kerguelen. These instruments are: UV-Visible spectrometers, UV-B broad-band detector, balloon ozone soundings and lidar (Rayleigh/Mie/Raman). The observed variables are ozone, total column and vertical profiles, aerosols and PSC profiles, temperature, nitrogen dioxide and erythemal UV-B. This observatory program is part, at the French level, of the Observing Service NDACC-France.

Continuous observation of the nucleonic cosmic ray component:
- As the French contribution to the international network of neutron monitors and to the NMDB database
- To study relativistic proton acceleration in solar eruptive events, and solar particle events in general
- To provide the data for, and to improve the models used by the Sievert system (DGAC-French civil aircraft authority; IRSN - French institute for radioprotection and nuclear safety).
The radial flux of charged particles from the sun called the solar wind is responsible of the existence of a cavity where the Earth’s magnetic field is confined, the magnetosphere. Inside the magnetosphere, the dynamics of the ionised gas (plasma) results from the interaction of the solar wind with the magnetosphere at its outer boundary. Because magnetic field lines in plasma are highly conducting, processes occurring at the magnetopause and in the outer magnetosphere map down along the Earth’s magnetic field lines, to the high-latitude ionosphere where their signatures can be observed by radars.

At high frequencies (HF), a radar signal transmitted to the ionosphere is refracted and partly backscattered by the small-scale electron density irregularities. The Doppler shift of the backscattered signal is a measure of the radial velocity of the plasma. SuperDARN (Dual Auroral Radar Network) radars can thus monitor the plasma convection over large areas (53° in azimuth and 3500 km in range). SuperDARN is also included in major magnetospheric research and space weather programmes.

Several coupling mechanisms occur at the boundary between the solar wind and the magnetosphere. The primary response of the magnetosphere to this interaction is plasma convection at various spatial and temporal scales and constitutes the main objective of SuperDARN. Global oscillations of the magnetosphere, magnetic conjugacy between hemispheres, reconnection in the tail and magnetospheric substorms, estimation of ionospheric electron density belong also to the scientific objectives of SuperDARN. The processes by which the energy from the Sun is transferred to the ionosphere and ultimately to lower altitudes in the atmosphere can thus be studied. Because of its global coverage and realtime data analysis, SuperDARN is included in major magnetospheric research and space weather programmes.
The MINERVE project (Mesures à l’Interface Eau- aïr de la Variabilité des Echanges de CO2), based on oceanographic cruises, aims to observe and understand seasonal variabilities of CO2 partial pressure (pCO2), Total Dissolved Inorganic Carbon and Total Alkalinity of surface seawater, in association with hydrological and in-situ biogeochemical measurements, and also using remote sensing data (temperature, seawater color). Logistical routes of the Astrolabe lead to poorly known areas and allow to collect information in order to understand processes involved in the mesoscale spatio-temporal variability of pCO2 in the austral oceanic regions. Data collected during these cruises will be used as a background to estimate interannual and averaged variability (trends) of the CO2 net flux through the air/seawater interface. Measurements collected during the MINERVE project will be used also by other colleagues to constrain atmospheric models and validate biogeochemical models coupled with circulation models in order to simulate the carbon cycle for the next decades and centuries.

The main objective of the SURVOSTRAL project is to MONITOR different physical parameters in the AUSTRAL Ocean with long-term hydrological measurements. SURVOSTRAL started in 1992-1993, and since then the ocean heat content in the first 800 m and the surface salinity have been measured regularly on a repeated line (6-10 times a year) between Tasmania and Antarctica. These measurements form the longest time series of seasonal and interannual variations of these parameters in the Southern Ocean, and are therefore a key value for quantifying oceanic changes in this key climate region.

The overall objectives are as follows:

- A monitoring of the seasonal, interannual and decadal variability of the heat content of the Southern Ocean and its response to changes in atmospheric heat fluxes.
- A study of surface salinity and its relationship with the freshwater balance in the Southern Ocean.
- Study of the transport and structure of the Antarctic Circumpolar Current (ACC).
- Study of the variation of the different thermal and haline fronts.
- Study of the role of oceanic eddies in the flow of mass, heat and salt through the CCA.

The SURVOSTRAL project uses the regular rotations of the supply vessel ASTROLABE between Hobart and Terre Adélie. This transit enhancement project is based on high spatial resolution XBT and thermostalinograph measurements. Participating in this project supported by IPEV: LEGOS (France), CSIRO (Australia) and the Scripps Institution of Oceanography (USA). SURVOSTRAL is currently integrated into CLIVAR and the scientific valorisation is financed by TOSCA (CNES).
HAMSTRAD

H2O ANTARCTICA MICROWAVE STRATOSPHERIC AND TROPOSPHERIC RADIOMETERS

The HAMSTRAD radiometer is a genuine state-of-the-art microwave instrument dedicated for the detection of 1) the 60-GHz oxygen line to measure tropospheric temperature profile, and 2) the 183-GHz water vapour line to get tropospheric H2O (profile and precipitable water). It has been installed at Dome C in 2009 and is running normally since 2010. The initial aim of the HAMSTRAD project was to measure the trends in water vapour and temperature profiles from the lower part of the troposphere to the lower part of the stratosphere and their links with climate change. Coupled with other instruments operating at Dome C (e.g. aerosol Lidar), the HAMSTRAD project also intends to study the genesis of thick clouds and diamond dust (ice particles) above the Dome C station by using the information coming from measurements (in situ and remote sensing at the station, satellites) and meteorological analyses of different parameters: temperature, water vapour, ice, precipitation, AOD, radiation, particles, etc. To date, the project has produced 12 peer-reviewed papers.

CALVA

IN SITU DATA FOR THE CALIBRATION AND VALIDATION OF METEOROLOGICAL AND CLIMATE MODELS AND SATELLITE REMOTE SENSING, FROM THE COAST OF ADÉLIE LAND TO DOME C.

The aim of CALVA is to gather series of in situ observations in Adélie Land and at the Dome C, which are needed to better evaluate and improve Antarctic meteorological models and global climate models over Antarctica. The observations also aim to contribute to improve remote sensing methods. In Adélie Land, CALVA focuses on precipitation, extreme dynamic atmospheric boundary layer (catabatic winds) and drifting and blowing snow. At Dome C, CALVA also focuses on precipitation and clouds, and on the boundary layer, which is extreme here in terms of temperature and inversions and exchange fluxes with the snow surface. These are poorly known aspects of the Antarctic meteorology and climate, which are consequently poorly represented or simply ignored (blowing snow) in the models used for IPCC climate change predictions. The observations thus aim to improve those predictions, in particular those of the surface mass balance of the ice sheet and impact on sea-level.

GMOSTRAL 3

OBSERVATIONS MONDIALES SUR LE MERCURE : SURVEILLANCE DE L’ATMOSPHÈRE ET ÉTUDES DES PROCESSUS ATMOSPHÉRIQUES DANS LES RÉGIONS SUBANTARCTIQUES ET LES TERRES ANTARCTIQUES

Mercury (Hg) is a potent neurotoxin that is globally dispersed in the atmosphere. Humans are mostly exposed to mercury by eating seafood. In 2017, the Minamata Convention has come into force, which aims to limit the use, emissions and health impacts of mercury globally. The Convention’s effectiveness will have to be evaluated. How does the scientific community can contribute to assess the effectiveness of the convention and the government policies ? GMOSTRAL-3 proposes to work at improving process knowledge and decision tools such as models through:

- A continuous survey of atmospheric mercury (since 2012) at key sites of the Southern Hemisphere (Concordia Station and Amsterdam Island)
- The development of alternative strategies to monitor Hg (and other contaminants) at lower cost
- A better parameterization of oxidation pathways of Hg using innovative approach (Hg isotopes, oxidized Hg speciation)
- Coordinated campaigns on atmospheric oxidants (as halogens)
SCIENTIFIC PROGRAMMES SUPPORTED IN ANTARCTIC AND SUBANTARCTIC ISLANDS

Annual Report 2019-2020

DYNAMICS OF COASTAL OUTLET GLACIERS AND IMPLICATIONS ON THE OVERALL MASS BALANCE OF THE EAST ANTARCTIC ICE SHEET

The Astrolabe glacier serves as a test zone for measuring and understanding the dynamics of East Antarctic outlet glaciers. It is part of the more general observatory CRYOBS-CLIM (https://cryobsclim.osug.fr) which aims at understanding the links between the environment (essentially climate forcing) and resulting glacier changes. These links operate at two principal levels:

- Climate changes induce surface mass balance changes which indirectly impact the environment.
- Surface mass balance changes constitute the principal boundary conditions in the dynamic evolution of ice masses.

If the first aspect is principally covered by the GLACIOCLIM Observatory (IPEV program 411), the aim of the present proposal is to tackle these ice dynamics mainly driven by surface mass change and, to a lesser degree, by direct climatic inputs (essentially temperature) and as such, appears fully complementary to the GLACIOCLIM one. Since the ice discharge in Antarctica is by more than 80% drained by outlet glaciers from the eastern ice sheet, understanding their dynamics and being able to model their present and future behaviour is crucial when addressing the sea level issue. The proposed approach is double by first proposing a comprehensive survey of the selected test glacier in order to capture the specific dynamics of marine outlet glaciers and feed relevant ice flow models.

Corresponding results will then in a second time be applied to the modeling of the large outlet glaciers of the Wilkes-Terre Adélie land sector of east Antarctica whose contribution to sea level is major and needs to be constrained. The core of the activities detailed in the proposed program concerns the first task implying field work on the Astrolabe glacier. As for the second part, it is carried out through an international collaboration of our program with the University of Texas under the form of several airborne geophysical campaigns. These measurements allow for assessing the environment settings of these large glaciers (bedrock and surface topographies, outlining of respective grounded and floating parts,) necessary for conducting the modeling of their future behaviour.

Exoplanets are now discovered on a daily basis thanks to many astronomical surveys. These surveys require additional follow-up observations for validation or for joint observations at different wavelengths. This need will become even more important with the launch of TESS and JWST. In this domain, the potential of robotic medium size (30-80 cm) telescopes has been demonstrated by TRAPPIST in Chile with its successful confirmation and characterization of more than 90 exoplanetary systems. In parallel, recent results obtained on the characterization of the delta Scuti oscillations of beta Pictoris, with ASTEP 400, a photometric 40cm telescope, have demonstrated that a very accurate photometry can be obtained with an automated telescope operated from the Concordia station with minimal human interventions. We propose to continue operating ASTEP in 2019 and beyond. The core of the ASTEP+ project requires only maintenance work to keep the mount, telescope and support system operational and limit the failures during the year. Minor adjustments are proposed to improve the image resolution and for a more complete remote control of the instrument. ASTEP+ will be operated in coordination with TRAPPIST. It will observe stars with exoplanets detected in radial velocimetry to check for possible planetary transits, confirmed transiting planetary systems to characterize them, and as generally any target of opportunity that is of high scientific interest. ASTEP+ will also follow up the southern hemisphere planet candidates to be discovered by NASA/TESS space mission.

Kerguelen corresponds to a unique geodynamic context and geological history, with no current equivalent on Earth, a contemporary analogue of the formation of the first continents 4 billion years ago. The study of the productions, the migrations and the emplacement of differentiated magmas in an oceanic context, the characterization of alteration processes (serpentinization) and mantle fertilization, the distinction in the micro-tectonics between local magmatic causes and regional incidences of the oceanic plate dynamic as well as the geometry of the different parts of the lithosphere and fluids circulations between them allow to provide constraints to clarify the current geodynamics and the scenario of the formation of the first continents on Earth. The current geographical situation is also strategic to constrain the climatic evolution of the last millions of years by studying the dynamics of erosion of the rocks of the archipelago and matter transfers towards the ocean.

Terre Adélie

Le Meur Emmanuel

Guillaume Damien

Concordia

TALISKER

FLUIDS AND MAGMAS TRANSFERS ACROSS THE LITHOSPHERE OF KERGUELEN

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Kerguelen

Subantarctic

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The CHINSTRAP project aims at installing a high-energy extended neutron spectrometer at the Concordia station in Antarctica. The particularities of this location are unique (high-altitude and proximity to the geomagnetic pole) and allow long-term measurements dedicated to the study of the atmospheric natural radiative environment dynamics for Space Weather applications. These data will complete the ones already obtained at the Pic-du-Midi in France and in the Pico dos Dias in Brazil, near the South Atlantic Anomaly. The project includes two phases: the first consists in installing and operating the HERMEIS in the station; the second consists in investigating the data then in combining their analyses to those from other measurement sites.

This project aims to maintain the AERONET measurements at Amsterdam Island. These measurements provide optical and microphysical properties of aerosols in the atmospheric column. Very few «clean marine» stations are currently in operation in the AERONET network. Observations initiated since 2002 at Amsterdam Island thus represent an important component of AERONET and will continue in this new IPEV project. Most of the work on site concerns for the installation (once / year) and monitoring (maintenance, data) of the measurements provided by a sunphotometer CIMEL. Data is shared and publicly accessible in near real time in the AERONET database. This project was previously managed by the IPEV program AEROTRACE (415) led by Jean Sciare (LSCE).
Italian, French and US scientists unite their knowledge and capability to study the interior of the Antarctic plateau between the French-Italian Concordia station (75°S, 123°E) and the US South Pole station (90°S). The scientific objectives of EAIIST are to study the icy terrain of the Antarctic continent in its driest places. These areas are largely unexplored and unknowns and offer unique and extraordinary morphological characteristics: presence of mega-dunes, glazed ice surface, and thermal cracks, structure probable analog to glacial age on deep drilling sites such as Dome C or Vostok. A consortium of scientists from three nations, Italy, France and US is built around the idea to explore and study the geophysical (snow physics, surface mass balance, density, temperature, seismicity, etc.), geochemical (impurities, aerosols, air-snow transfer, water isotopes, etc.) and meteorological dimensions (AWS, atmospheric dynamic, air mass transport, etc.) of these most inhospitable, remote and unknown regions of the planet by the means of a scientific traverse.

The CAPOXI 35-75 project aims to document the oxidative capacity of the southern hemisphere following a North-South latitudinal gradient, from the Amsterdam Island (37°S) to the Concordia station (75°S), including the Dumont d’Urville coast station (67°S). The program will specifically be dedicated to solve few inconsistencies observed these past few years in Antarctica. If the high oxidative capacity of the Antarctic plateau atmosphere is a well established phenomena, induced by the snow emission of nitrogen oxides, it is however difficult to reconcile our current knowledge of the oxidation schemes with the ground observations. Such discrepancies strongly limit our capacity to understand to ice core records. In this program, we propose to revisit some of the key parameters governing of the oxidation state of the atmosphere. By managing scientific stations from 37 to 75°C, IPEV offers the unique opportunity to study the oxidative capacity in very contrasting environments that will ease to reveal the different interaction between reactive species. The project will focus on the nitrogen oxides and halogen species in direct link with the ozone budget and will benefits from international collaboration to access specific instrument and modeling tools not available in our group.

The southern Ocean is a key player for the control of atmospheric CO2 and therefore climate. However, the biological pump of CO2 in this ocean is severely limited by the availability of iron for phytoplankton. But a few oasis exist where enhanced biological activity results from natural iron fertilization. These regions are excellent natural laboratories and the Plateau of Kerguelen and the waters extending eastward are a good example. BINGO aims to investigate a so far unexplored issue in this region: the role of glacier melting as iron source for the ocean. BINGO proposes a study focused on the Cook Ice Cap. The challenge will be to detect iron nanoparticles in the melting water of the glacier and to evaluate their bioavailability for phytoplankton. BINGO relies on an expedition at Kerguelen where we will first collect the particles in the vicinity of the Glacier Ampère and second we will test the availability of these particles for iron limited phytoplankton at Port aux Français. Investigation conducted both from a geochemical and biological perspectives will provide original results that will contribute to better understand the future of Southern Ocean considering accelerated melting of ice caps.
Due to their geographical position, under the influence of the Southern Hemisphere westerly winds and under the influence of the Antarctic Circumpolar Current, Kerguelen archipelago, in the sub-Antarctic, is a perfect natural experimentation site for the record of recent environmental changes. The testate amoebae have been studied in Antarctica and the subantarctica islands through about a hundred studies. In the islands of Kerguelen, they are described in four rather extensive studies in 1904, 1908, 1912 and 1981. These studies reveal the presence of cosmopolitan species with a few rare of a more restricted distribution. The proportions of the different species and the composition of the communities depend on the hygrometric degree, the pH, the temperature and the biogeographical factors. On the other hand, the skeletons of these amoebae are preserved and are therefore witnesses of past environments. Thus, by characterizing the environmental constraints of testate amoebae communities within modern environment and by defining indicator species of all identifiable sub-environments, it is possible to reconstruct recent paleoenvironments and model the important changes operating in recent decades. This project focuses on the Kerguelen islands. In the BE-OI reconnaissance boreholes, during these two seasons, before their deployment, we will deploy all possible analyzes. In addition, tests of new logging tools (notably a sonic logger) in the EPICA boreholes are anticipated during these two seasons, before their deployment in the BE-OI reconnaissance boreholes.

BE-OI is a H2020 European project (Coordination and Support Action, IPEV, INPBA and CNRS being official contractors) to locate in Antarctica optimal sites where a deep drilling operation could be conducted during the decade 2020. The aim is to recover a stratigraphically-ordered sequence of climate and atmospheric/environmental conditions going back to 1.5 million years before present, overlapping the so-called mid-Pleistocene transition when the pacing of glacial-interglacial cycles dramatically changed from 40 to 100 kyr periodicities. Ultimately, the main question lies in the role played by greenhouse gases in this major change. On the French and Italian side, the focus reconnaissance work of BE-OI takes place at Concordia and its vicinity. In 2016/2017, the site of “Little Dome C”, located about 40 km west from Concordia along the ridge toward Vostok station, has seen extensive radar survey, a first series of phase radar measurements, GPS positioning as well as a first test drilling with the British RAID rapid access drill. At Concordia itself, the first test campaign of the highly innovative SUBGLACIOR reconnaissance probe was conducted. 2017/2018 will see a second test season for SUBGLACIOR (if logistics permits it), a second deployment of RAID, as well as GPS and phase radar measurements. The BE-OI component presented here covers the follow-up of the 2018/2019 and 2019/2020 field seasons: the SUBGLACIOR deployment at the optimal site of Little Dome C, a site defined during the field season 2017/2018, as well as additional deformation measurements and the first field deployment of the Swiss rapid access tool RAADIX. 2019/2020 will either see a reiteration of the above activities, or the start of camp buildup anticipated for the following deep drilling operation. In addition, tests of new logging tools (notably a sonic logger) in the EPICA boreholes are anticipated during these two seasons, before their deployment in the BE-OI reconnaissance boreholes.
MANAGEMENT OF THE EPICA-DC ICE CORE STORED AT CONCORDIA

The EPICA ice core, drilled at Dome C is 3260 m long and allows to record climatic changes over the last 800,000 years. It is therefore a particularly valuable archive. A quarter of the ice core (over the entire length) has been kept in an ice cave dug into the snow, where the average annual temperature is -55°C. The reason for this on-site storage is indeed to keep the ice at very low temperatures as required by certain measures. The rest of the ice core was either distributed to EPICA’s various partners or kept in cold rooms at -25°C, near Grenoble. The objective of this project concerns the management of the archive remaining in Concordia. The tasks are:

- Respond to sampling requests from various national or international groups (once endorsed by EPICA’s Steering Committee)
- Finish the repacking of the bags (if it is not finished in 2017-2018)
- Prepare the specifications for the future EPICA cave, taking into account the interactions with the “ice memory” storage project.

This project is thus a service to the ice core community more than a scientific proposal by itself.

Quantification of fluxes of snow and water vapor at the Antarctic surface as well as links with climatic variations is a major challenge for projections of climate and water cycle organization in this region. Still, large uncertainties prevent such quantification. On the one hand, precipitation amount is difficult to estimate because of the influence of wind, a process particularly important on the coastal areas because of the strong katabatic winds. On the other hand, it is particularly difficult to quantify the direct snow exchanges with atmosphere (sublimation / condensation) because of badly constrained processes within the boundary layer (blowing snow, supersaturation, turbulence influence, ...). Finally, climatic variations over the last decades to centuries are often bad documented because of a lack of instrumentation in this region.

Water isotopic measurements on shallow ice or snow cores in Antarctica is currently one of the best tools to reconstruct the climatic variability (temperature, accumulation) in the absence of weather station instrumentation. Indeed, because of isotopic distillation from low to high latitudes, it is possible to link temperature to the snow isotopic composition at the seasonal and intrannual scale. However, the snow isotopic composition is also sensitive to other effects during snow formation and deposition (e.g. kinetic fractionation, re-evaporation of falling or blowing snow) and after deposition (diffusion, sublimation and hoar deposition). These effects increase the complexity for direct interpretation of snow isotopic composition in term of temperature but also permit to retrieve other information on the snow deposition conditions and water fluxes at the ice sheet surface. Within the ADELISE project, we propose to perform continuous isotopic measurements on the water vapor, precipitation, blowing snow and surface snow at Dumont d’Urville over 2 consecutive years. The isotopic measurements will complement the measurements performed on the LIDAR, RADAR and pluviometers already in place at this station in order to characterize water cycle processes in the atmospheric column and at the snow surface. The isotopic measurements will be combined with long-term chemistry measurements on aerosol filters within the CESOA program (and following program from 2020) and will permit to better interpret the isotopic and chemistry records obtained on shallow cores drilled recently in Adélie Land within the ASUMA project. Finally, a parallel system of continuous measurements of water vapor isotopic composition will be installed over the same period at Dome C, within the NIV02 project. Combination of the two records with back-trajectories will permit to better understand the isotopic transfer function between the coast and East Antarctica hence improving our interpretation of water isotopes in the Dome C deep ice core.

This project also includes a significant part of modeling through the atmospheric regional model MAR already largely applied for Adélie Land. MAR is also currently being equipped with water isotopes. This project will thus permit the validation of the MARiso model as well as its use for interpretation of shallow ice cores recently drilled in Adélie Land.
Introduction: Short-duration space flight induces circulatory blood volume alterations known as “space flight anemia” and characterized by decreases in red blood cell volume (RCV) and plasma volume (PV). Such hematological alterations may persist during long-duration space missions, potentially impacting the astronauts’ health, however this aspect remains unexplored. On the other hand, during long-duration space missions the use of hypoxia is envisaged for technical reasons, but the safety of hypoxia must be first verified since this environmental condition provokes numerous physiological alterations in humans. In particular blood volume changes potentially interacting with the hematological effects induced by space flight. Objective: Using Antarctic confinement as a high fidelity Earth-based analogue for long duration sleep space missions, we hypothesize that:

- Confinement at sea level reduces blood volume by concomitantly decreasing RCV and PV.
- Chronic hypoxia counterbalances the decrease in RCV but exacerbates the decrease in PV induced by confinement.

Methods: Using an innovative, automated carbon-monoxide rebreathing technique usable by the wintering staff, blood volumes will be repeatedly measured in two groups of subjects overwintering at Dumont d’Urville (DDU) (sea level group) or Concordia (3200m, altitude group).

This study will focus on the evaluation of (1) visual, (2) olfactory, (3) gustatory, (4) tactile, (5) auditory individual perceptions and (6) proprioception and body scheme, on an triple investigative pattern “at the beginning”, “during” “at the end” of the stay/mission in ICE/EUE.