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PARLIAMENTARY OFFICE FOR THE EVALUATION OF SCIENTIFIC AND TECHNOLOGICAL CHOICES

REPORT

on

« France's position with regard to the international issues surrounding polar research : the case of Antarctica »

by

Mr. Christian GAUDIN, Senator

Filed with the Bureau of the National Assembly
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INTRODUCTION

"What's to explain the polar regions' strange attraction, at once so powerful and tenacious that, once returned home, one forgets the moral and physical fatigue and can't wait to return to them? What's to explain the incredible charm of these regions which are yet deserted and terrifying?"

Jean-Baptiste Charcot

Ladies and gentlemen,

"A century ago, exploring the polar regions was a heroic adventure, undertaken by poorly equipped men left to their own devices during solo expeditions. Little by little, scientists gave meaning to the support of fundamental research in these uninhabited zones, discovering - thanks to the development of international cooperation - the links that exist between the poles and our entire planet, as well as between the poles and the rest of the universe."

With these words, Bertrand Imbert and Claude Lorius, two great men of French polar research, bring to a close their presentation of the polar adventure in their book *Le grand défi des pôles*[11]. In this manner, they emphasize the deeply mysterious and spellbinding character of these regions to which, according to Commander Charcot, once discovered and despite their hostility, one can't wait to return. The poles, therefore, represent first and foremost adventure and a personal challenge. At the poles, one finds and leaves behind something of oneself.

Above all, they underline how the polar regions have gradually become an exceptionally rich research site; indeed, ever since 1959 the Antarctic continent has been reserved for peace and science – the only region of its kind in the world. While geography was the very first "polar science", all the other scientific domains were soon invited to locate the magnetic poles, describe new plant and animal species, and even observe the heavens. The very first International Polar Year was launched to study Venus and its movements, thereby marking the start of an exemplary collaboration.

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[1] *Découverte Gallimard, Paris, 159 p., 1st edition 1987, 2nd edition 2006.*

Today, the poles are once again sites of scientific adventure. They are emerging as outposts, testifying to the changes affecting our planet, such as global warming and the threat to biodiversity. The poles may provide answers to such fundamental cosmological questions as the origins of the universe, or such futurology questions as exploring the solar system. Like the African Rift Valley, the poles provide valuable clues to man's ancient history. 1.5 million years of climatic archives are available in the Antarctic ice. But there is also much older ice which, separated from its "timeline", has not yet provided scientists with subjects of investigation.

The polar environment therefore offers a particularly wide range of research areas: this was but the first surprise for those who expected to find only ice, penguins and polar bears.

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Your rapporteur felt this very same surprise and wonderment some four years ago, when he was charged by the Senate Commission on Economic Affairs with reporting on the transposition bill for the 1991 Madrid Protocol.

Your rapporteur had the immense privilege of being introduced to the polar regions via an on-site visit to the French and Italian scientific research centres in Antarctica (Mario Zuchelli, Concordia and Dumont d'Urville). Thanks to this mission, he was able to visit the research installations, take the appropriate means of transportation (C-130 and Twin Otter planes, a 1,200-km trek by snowmobile and the *Astrolabe* ship) and meet with the researchers. Your rapporteur remains greatly impressed by the necessary engineering for undertaking research in an extreme environment. Nothing is possible without effective logistics. He also remains greatly impressed by the personal confrontation with the glacial desert, this hostile, lifeless environment, by his meeting with Concordia's winter residents, completely separated from the outside world and without the possibility of assistance for almost 9 months, and by the comradeship of the supply-trekkers, as well as by the infinite relief upon regaining Australia of finally seeing a tree, some grass...

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This discovery then turned into a study when, on the instigation of the Senate Commission on Economic Affairs, the Office decided to launch an evaluation of France's role in the issues surrounding polar research on the eve of the International Polar Year.

For the Office, it was also a question of pursuing the same path as laid down in the report presented in December 1989 by Jean-Yves Le Déaut, Deputy. This report greatly contributed to the definition of France's position when President François Mitterrand decided, at Commander Jacques-Yves Cousteau's instigation, that our country would oppose the enforcement of the Wellington Convention on mining in Antarctica and proposed negotiating a new agreement that resulted two years later in the Madrid Protocol, making Antarctica a nature reserve dedicated to science and peace.

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In preparing this report, your rapporteur met with those in charge of French polar research, as well as the concerned authorities. He visited the research teams and their laboratories. What's more, your rapporteur began a direct dialogue with our main partners in the polar regions, both from within Europe (Germany, Italy and the United Kingdom) and from without (the United States, Russia and, during my trip to Antarctica, New Zealand and Australia).

When travelling abroad as a member of the French Parliament, your rapporteur was very happy to observe the extent to which our polar operators and researchers were appreciated for their skills and work. Regardless of the circumstances, during a scientific presentation or visit, French researchers and technicians were often cited as references in their respective fields or as essential partners for a successful collaboration or research.

These meetings would not have been possible without the effective, competent and often passionate support of the French ambassadors and of their embassies' science departments. Thanks is also due to the foreign polar operators who were ever generous with their time and attention when welcoming this member of the French Parliament.

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After first reviewing the main characteristics as well as the legal status of the polar environments and considering the question of Antarctic tourism, your rapporteur will present the issues surrounding the various polar research fields. He will then consider the organization of the French presence in the polar regions, the organization of research, and the development of partnerships at both the European and international levels.

I. THE POLAR REGIONS: AN URGENT NEED FOR PROTECTION

It seemed appropriate to your rapporteur to begin this report with a presentation of the polar regions, for they are often little known, as well as of the very specific legal system that applies to Antarctica and to finish this presentation with the various issues surrounding the development of tourism.

A. EXTREME BUT FRAGILE REGIONS

The polar regions are both harsh, because extreme, and fragile, due to greater climate changes at the poles and sensitive flora and fauna. Nevertheless, the two regions are very different: an ocean surrounded by land in the north and a continent surrounded by the sea in the south.

They share a common question: **where do the high latitudes start?** While not wanting here to enter into a particularly complex scientific debate, becoming aware of the relative limits that vary according to the chosen criteria in fact represents a first step towards understanding the regions' specificity and fragility[1].

The first and most often agreed upon criterion is that of latitude, the limit marked by the two polar circles: 66°33. At this latitude, the sun does not rise at winter solstice and does not set - but rather brushes the horizon - at summer solstice. It also marks the height of the sun at noon between 0° and 46°54.

But this limit is too rigid because too narrow in the north and south. In the north, because it excludes for example a part of the Greenlandic and Siberian icecap. In the south, because it doesn't take into account the maximum extension of the ice shelf in September, which can extend beyond the polar circle; what's more, it is not the legal limit set by the Antarctic Treaty, which instead sets the limit at 60° south.

The next possible criteria are **temperature-based limits**, on both land and sea.

On the oceans, it is possible to set the limit at the **maximum extension of the sea ice** which, in the south, extends beyond the polar circle in the eastern Antarctic, while not reaching the polar circle in the western Antarctic. It is also possible to set the limit at **an isotherm of 0°C in air temperature**. In the south, it can be seen that this criterion would set the limit beyond the farthest extension of the icecap. However, in the north in the summer, this criterion would only cover the central portion of Greenland and the area above 80° latitude.

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[1] *See Les milieux polaires, by Mr. Alain GODARD and Ms. Marie-Françoise ANDRÉ (Armand Colin, Collection U, Geography, Paris, 1999, 455 p., Chapter I).*

In the south, it is also possible to set the limit at the Antarctic convergence, which separates the cold southern waters from the warmer northern waters. This current, which completely surrounds the Antarctic, is undoubtedly the true physical and biological boundary. Nevertheless, its exact location varies considerably from year to year.

On the continents – and, therefore, essentially in the Arctic regions - it is also pertinent to set temperature-based limits. **An isotherm of 0°C for the warmest month** allows us to include these regions' vast ice-covered areas. **Average air temperature** is also a good criterion to shed light on those **areas with frozen soil** or permafrost. Permanent, continuous permafrost corresponds to an average annual temperature of -7 to -8°C, discontinuous permafrost to -4 to -1°C and sporadic permafrost to -1 to 0°C.

This criterion, marked principally by harsh winters, doesn't take into account very well the vigor of the summers and therefore the type of vegetation. That is why it is possible to **propose as a criterion a bioclimatic cleavage: the tree limit**. Indeed, while trees can withstand very cold temperatures, they require sufficiently warm summers to develop. Therefore, the tree limit depends upon the number of ice-free days, the possible duration of the vegetative period, as well as **the average temperature of the warmest month**. **The isotherm of 10°C**, or the "Köppen Line", seems to be one of the best markers. This line is very inclusive because in the northern hemisphere it lies very far south, as far as 51°, due to the continental climate of Canada and Siberia; however, it doesn't reach 60° in those areas more influenced by the ocean. Similarly, in the south, the line can be found as far north as 50°.

It is therefore particularly difficult to define the polar and subpolar regions, whose size varies depending on the season. The criteria used show that in the north the heart of these regions is rather limited in size and, what's more, that they may be influenced by fluctuations of only a few degrees that can significantly alter their climatic dynamics.

1. The Arctic Ocean

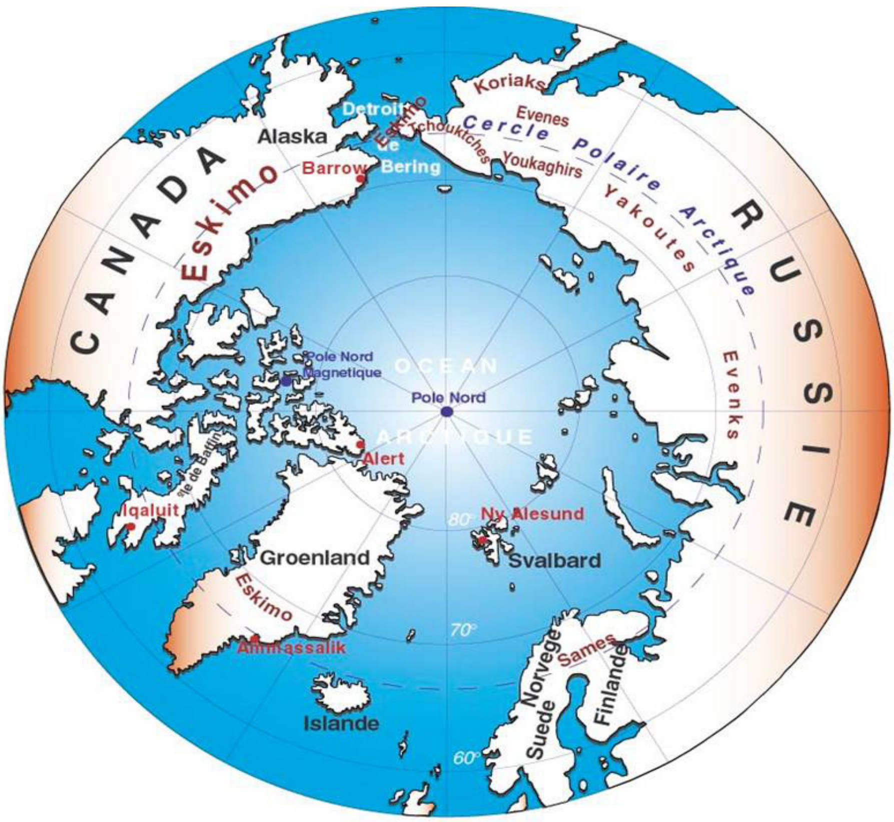
The North Pole is **an oceanic zone of 12 to 14 million km², a "Northern Mediterranean", almost completely surrounded by land**.

Its central area is covered by a permanent, multiyear ice shelf which in the winter can cover almost its entire surface and extend into the Pacific via the Bering Strait and into the Atlantic along the coast of Greenland. There are only three openings significant in size. The Bering Strait is the Arctic Ocean's opening to the Pacific.

80 km wide, it is only 38 m deep. The second opening is the Canadian archipelago, or the "Northwest Passage"; it does not allow for significant ocean traffic. The only real opening is to be found between Greenland and Norway, 1,500 km wide and marked by a furrow 3,000 m deep.

This geographic layout, marked by a single oceanic opening, structures the region's atmospheric circulation and sea currents and is key to understanding the great importance to the Arctic climate of the heat transfer that takes place between the Gulf Stream on the one hand and the Labrador Current on the other.

Arctic map



(*Source : IPEV)*

The legal status of the geographic North Pole

The North Pole's location in the centre of an ocean, not to mention the fact that the Arctic coast is little or not at all inhabited, would seem to make it especially difficult to appropriate. Due to its very weak occupation, the Permanent Court of International Justice was therefore called upon to confirm Denmark's effective possession of Greenland (ruling of 5 April 1932).

However, in 1909 – upon Peary's reaching the North Pole on 6 April 1909 – the president of the Canadian Supreme Court proposed applying the theory of sectors based upon the principal of contiguity. These sectors would be spherical triangles with the Arctic seaside of the adjoining nations as their bases, the east and west meridians of the coast's limits as their sides and the North Pole at 90° as their upper point. This idea was approved by the USSR in 1926. However, all the other bordering nations opposed this proposition, and the Arctic Ocean must be considered as being ruled by international maritime law, such as that defined by the Montego Bay Convention of 1982. The North Pole, therefore, is located in international waters.

The Svalbard Archipelago is subject to a specific system. The Paris Convention of 21 October 1920 recognizes Norwegian sovereignty, but allows free access to all parties to pursue scientific as well as economic activities (mining).

The Northeast and Northwest Passages are governed by more complex systems.

The Northeast Passage was first opened by the explorer Adolf Erik Nordenskjöld in 1878. Russia does not recognize the right to freely move about in this area. Authorization and the payment of a fee are necessary to join a convoy following in the wake of an icebreaker.

The Northwest Passage was first opened by the Norwegian Roald Amundsen in 1906. Following the passage of an American oil tanker on its way to Alaska in 1969, Canada adopted a specific law in 1970. This law requires ships to first obtain Canadian authorization to pass through a zone of 100 nautical miles[1] (environmental protection zone) due to the danger and environmental risks of such navigation, as well as the difficulty of providing assistance. In 1985, the United States, which did not accept this position, sent a Coast Guard icebreaker to the area without first notifying Canada. The resulting diplomatic crisis led to the Ottawa Agreement of 1988 by which the two countries agreed to cooperate on security and environmental-protection issues and the United States agreed to the system of prior authorization.

Finally, in 1992, Canada and Russia signed an agreement making the Arctic a special navigation and environment-protection zone, as set forth in Article 234 of the Montego Bay Convention.

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[1] *1 nautical mile = 1,852 metres.*

2. Antarctica

As opposed to the Arctic, Antarctica is a continent and not an ocean.

It was created by the breaking up of the Gondwana supercontinent 150 to 160 million years ago.

80 million years ago, during the Cretaceous Period, Antarctica was already centred on the South Pole. But its luxuriant flora and fauna, the fossils of which can still be found today, were tropical in nature. The first such fossils were found in 1902 by the Swede Otto Nordenjold. Antarctica remained connected to India and Australia for several tens of millions of years longer and up to 25 to 30 million years to South America.

Antarctica became further isolated with the formation of the Drake Passage. The Peninsula is now more than 1,000 km from Cape Horn and Adélie Land more than 2,700 km from Tasmania.

This isolation is the direct cause of a permanent east-to-west current in the ocean (the polar front) and in the troposphere which physically isolates Antarctica from the rest of the planet. This current can even be found in the stratosphere, but its direction varies according to the season. This sea current is 24,000 km long and 200 to 1,000 km wide and clearly separates the Antarctic from the other regions. Farther north, in a second circle, can be found the subtropical convergence marking the limit of the Antarctic Ocean, which covers a total of 76 million km^2. This system of circumpolar circulations divided into two concentric frontal structures forms a veritable natural boundary with the planet's three other great oceans (the Atlantic, Indian and Pacific Oceans). The polar front and the subtropical convergence mark the boundaries of two zones whose oceans and climates are clearly distinct and are therefore home to different flora and fauna.

The complete glaciation of Antarctica was a slow process. It began some 30 million years ago, eventually forming a complete icecap from glaciers or small pre-existing caps. The icecap's form has apparently changed little over the past 15 million years, though it may have been larger, extending farther out to sea, or smaller 3 million years ago; however, ever since then, the icecap has remained remarkably stable.

From a geologic point of view, the western and eastern portions of the continent are fundamentally different. The eastern portion is thick (30 to 40 km) and very old (pre-Cambrian, or 3 to 4 million years old). The western portion is younger, undulating and volcanic. It is also thinner (25 to 30 km). In addition, the two portions are separated by a rift with active volcanoes such as Erebus[1], located in eastern Antarctica near the American base of McMurdo.

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[1] *Named after the ship of its discoverer, James Clark Ross.*

Eastern Antarctica, in particular the coasts of Adélie Land and George V (250 km), is the subject of studies to locate very ancient portions of the earth's crust dating from the Archean (2.5 to 4 billion years ago). This is especially interesting for French researchers because there is no rock in France more than 600 million years old. This should allow scientists to better understand the formation of the earth's first crust which was much thinner at the time and behaved differently. It will also allow researchers to identify the points at which Antarctica was connected to Australia.

Besides Antarctica, the Antarctic zone is almost exclusively oceanic. Indeed, up to the 65th parallel, no 5° latitude section has more than 6.6% of its surface area above sea level.

Antarctica, from terra incognita to satellites

Antarctica was for many years the terra incognita *par excellence*, for it had been dreamed, imagined and calculated for several hundred years before finally being discovered. Indeed, in the 5th century B.C., it was imagined by the Pythagoreans to balance out their equations, just as it was starting in the mid-16th century, when the idea of a round earth was finally accepted.

It was named in opposition to the Arctic, land of the polar bear, either because it has no bears ("land without bears"), or because the Great Bear constellation cannot be seen from there, or simply because it forms the North Pole's counterpart.

During the 18th century, various explorers would attempt to discover this unknown continent which many still imagined as welcoming and home to extraordinary creatures. Maupertuis said, "I would prefer to spend an hour conversing with a native of terra australis incognita than with Europe's greatest scholar."[1]

Several explorers, such as Kerguelen, took various islands to be the headlands of a rich and prosperous continent. James Cook, who was the first to cross the Antarctic Circle on 18 January 1773 and to circumnavigate the Antarctic, pretentiously declared that since he was incapable of descending any further, either the continent didn't exist or it wasn't of any interest: "If any one should have resolution and perseverance to clear up this point by proceeding farther than I have done, I shall not envy him the honour of the discovery; but I will be bold to say, that the world will not be benefited by it".

It was not until 1820 that Antarctica was finally discovered by the Russian Fabian von Bellingshausen sailing aboard the *Mirny* and *Vostok*, although he didn't actually disembark.

[1] *See Le grand défi des pôles, Bertrand Imbert and Claude Lorius, 2nd Edition 2006, p.30.*

The Frenchman Jules Sébastien César Dumont d'Urville, sailing aboard the *Astrolabe* and *La Zélée*, was the first to set foot on the continent in January 1840 and named the land that he discovered Adélie Land after his wife. The expedition's hydrographer, Vincendon Dumoulin, located the magnetic South Pole. The South Pole would be precisely located by the Shackleton expedition of 1909. The first permanent weather station, Osmond House, which is still in service, was set up in the South Orkney Islands in 1903.

The Antarctic coast was gradually and slowly explored by Ross (1840-1842), Wilkes (1840), Filchner (1911-1912), de Gerlache, Scott and of course Amundsen, who conquered the South Pole on 14 December 1911. In 1912, the Australian Mawson discovered the first meteorite in Adélie Land.

The systematic exploration of Antarctica didn't truly get under way until after the Second World War, thanks to technological advances.

The American admiral Byrd conducted Operation High Jump, which allowed for the exploration of 3 million km² and the mapping of 60% of the coast. But the persistent lack of knowledge concerning Antarctica can be seen in the fact that at the time, a water route linking the Ross and Weddell Seas was still thought possible.

In 1947, the French Polar Expeditions (EPF) were created by Paul-Émile Victor in order to explore Adélie Land and reaffirm French sovereignty of the region.

The first station, Port Martin, was built for the 1949-1950 campaign and was occupied during the following three winters, up until 1952. Yves Valette and Bertrand Imbert were assigned the task of mapping the coastline.

The International Geophysical Year (IGY) of 1957-1958 marked a decisive stage in the still incomplete exploration of the continent, for it led to the establishment of numerous and important permanent bases that are still occupied to this day (in particular, the South Pole and Vostok stations). It was chosen both to commemorate the 25th year anniversary of the 2nd International Polar Year and because it was a year of very great solar activity and the objective was to make significant progress in the space sciences, particularly in the field of magnetism.

Under the direction of Bertrand Imbert, France built a new base, Dumont d'Urville, on the Adélie Land coast, to replace the Port Martin base that had been damaged by fire in 1952, and established the Charcot base 317 km inland at an altitude of 2,400 m. Jacques Dubois, Claude Lorius and Roland Schlich were the first to winter there, from February to November 1958.

The IGY of 1957-1958 also saw the first trans-Antarctic crossing between the Ross and Weddell Seas, undertaken by the team from Britain and New Zealand led by Vivian Fuchs and Edmond Hillary (99 days, 35 persons, 17 vehicles and 4 planes over 2,700 km), thereby realizing the dream that Shakleton was unable to fulfill in 1915 aboard the *Endurance*.

While today Antarctica has been completely mapped thanks to satellites, it has yet to be completely explored by man.

The Antarctic continent and its permanent, floating ice shelves represent a surface area of 14 million km^2, greater than the total surface area of Europe and one and a half times that of China and 8% of all above-sea-level land.

It's divided into two distinct parts lying east and west of the trans-Antarctic mountain chain that extends for more than 4,000 km and rises above 5,000 m (Mount Vinson = 5,140 m). To the west is the Antarctic Peninsula. The continent's most northerly portion extends beyond the polar circle (63° latitude). To the east lies the glacial plateau, a gigantic dome of ice rising to a height of 4,000 m.

Taking into account the entire continent, the average thickness of the ice is 2,200 m, though it can be over 4,000 m in areas. For instance, the ice is 4,776 m thick beneath the Charcot station in Adélie Land's Astrolabe Bassin. The greatest recorded thickness, 4,804 m, was measured between Concordia and Vostok.

Antarctica stores 30 million km^3 of ice: this represents 2% of the earth's water, 75% of its fresh water and 90% of its ice. The complete melting of Antarctica would raise the Earth's sea level by 60 to 70 m.

The colossal weight of the icecap (30 million billion tons) pushes the bedrock down some 700 m. This phenomenon is known as isostasy. Mapping has shown the bedrock to lie beneath sea level. This is especially true in the west, where the bedrock is often to be found at -1,500 m. Antarctica is therefore an archipelago. This characteristic could significantly impact the warming process of this continent since its ice is in direct contact with the oceans. More generally speaking, the bedrock's tortured and little understood morphology effects the flowing out of the ice, the dynamics of the icecap and even the formation of cold waters since the geography of the continental plateau is greatly marked by the oldest glaciers. In addition, it is especially striking to consider the fact that erosion seems to be insignificant in Antarctica, because of such ancient, stable and slow glaciers.

The floating ice shelves cover half of the coastline. Two are especially important: Ronne-Filchner in the Weddell Sea (473,000 km^2) and Ross in the Ross Sea (526,000 km^2), the second covering the same area as France. They play a fundamental role in the outflow of the icecap's ice, forming sorts of flying buttresses, and in the formation of cold, deep waters which feed the Earth's oceans. In the distant past, their formation was undoubtedly the key to the glaciation of the entire western part of the continent, transforming the archipelago into a single, unified icecap.

During the austral winter, our regions' summer, the ice shelf covers an extra 15 million km^2, brushing the geographic limit marked by the circumpolar current.

Antarctica is a continent of extremes. It is the coldest, windiest and most barren continent.

- **The cold**

The cold is due first and foremost to the inclination (the word "climate" comes from the Greek word "klima", meaning inclination) of the Earth, which in the winter results in long nights and in the summer in a rather feeble warming because of the slight impact of the sun's rays. There is also the "albedo" effect, by which the snow and ice reflect back into the atmosphere most of the sun's rays and therefore most of its heat.

Antarctica's continental structure also plays an important role, for it prevents the sea and air currents from coming to warm the continent; at the same latitudes, the difference in temperature between the Arctic and Antarctica has been estimated at 10°C.

One must also consider the continent's relatively high altitude. At 3,000 m, the temperature is some 20°C cooler than at sea level.

Indeed, the coldest recorded temperature was recorded in the heart of eastern Antarctica: - 89.6°C at Vostok, on 21 July 1983.

- **The wind**

Antarctica is also the world's windiest continent, because the air cools and condenses upon contact with the icecap. This phenomenon is explained by the impossibility of the air to escape by rising up due to the very low altitude of the temperature inversion layer. Therefore, it is forced to descend to the coast, creating the katabatic winds.

While these winds are rather weak on the plateau, they become much stronger when they arrive at the coast due to the difference in altitude. Indeed, they go from an average speed of 11.5 km/h at Concordia on Dome C to 22.3 km/h mid-route to 40 km/h at the French station of Dumont d'Urville. The world's wind record was recorded at Cape Denison (George V Coast) at 329 km/h. The former French station of Port-Martin recorded an average annual wind speed of 70 km/h; during eleven days, the winds there exceeded 180 km/h!

These winds play an important role in spreading and stratifying the icecap's snow. They also result in "sastruggi", small snow banks about a metre in height which render travel by snowmobile very difficult and are the cause of significant equipment breakage.

- **The barrenness**

Antarctica is also one of the world's most barren regions due to its extremely low rainfall: 2 to 3 cm in the centre, such as at the Concordia base, and only tens of centimetres along the coast.

In contrast, the plateau of Eastern Antarctica receives in one year the same rainfall as the Parisian basin receives in a single month: 5 cm of water.

The heart of Antarctica is completely void of any plant or animal life.

B. FRANCE'S RESPONSIBILITY IN THE ANTARCTICA TREATY

Antarctica is governed by a unique legal system which was established by the 1959 Treaty of Washington. It dedicates the continent to science and peace.

1. The origins of the treaty and the Antarctic system

- **The origins**

Following various discoveries, seven nations each successively claimed an angular portion of Antarctica: the United Kingdom in 1908, New Zealand in 1923, France in 1924 with Adélie Land, Australia in 1933, Chile in 1940 and Argentina in 1943.

For the United Kingdom, France and Norway, these claims were based on the principle of discovering lands under the sovereignty of no nation (*res nullius*).

However, Chile and Argentina based their claims on the theory of territorial contiguity. The Peninsula was seen as the continuation of their territories farther south, drawing a geologic analagoy between the Andes and the trans-Antarctic chain.

In the 1940s and 1950s, these claims gave rise to interstate conflicts. The British launched Operation Tabarin in 1943 in response to German activities. They established four bases which, at the end of the war, were placed under the authority of the Falkland Islands Dependencies Survey (FIDS), under the aegis of the Foreign Office. On 18 January 1949, the Argentines and Chileans exchanged fire on the Peninsula. What's more, the United Kingdom decided to take its territorial conflicts with these two countries before the International Court of Justice in 1955. The case would be removed from the Court in 1956.

But the conflicting claims of these nations seeking to appropriate various portions of Antarctica ran up against several important obstacles.

The Third World had just arisen - the Bandung Conference having taken place in 1955 – and refused to accept that the old colonizing countries share out amongst themselves this new continent.

More important still were undoubtedly the respective positions of the United States and the USSR, neither of which claimed any territory nor recognized any claim and both of which desired to be able to establish themselves there freely. They therefore imposed an "open door" policy which would allow them – in any case, the other countries would have been powerless to prevent them - to set up bases in Antarctica (South Pole, Palmer and McMurdo for the United States).

This philosophy would be firmly established during the International Geophysical Year of 1957-1958. During these 18 months, the principal permanent bases were established and the culture of international cooperation unique to Antarctica was forged.

- **The treaty**

The Antarctic Treaty was signed in Washington on 1 December 1959 by 12 nations. It came into effect on 23 June 1961. Today, it includes 46 parties, including 28 consultative parties.

It establishes *"a functional internationalization of the continent, founded upon both its use for peaceful purposes and the suspension of all territorial conflicts."*[1]

The treaty applies to all territories located south of 60° South.

It forever dedicates Antarctica to only peaceful activities.

Military activities, nuclear tests and nuclear waste are banned by Article 5, in the interest of all mankind.

These peaceful activities are science and international cooperation, as specified in the preamble and in Articles 2 and 3: "*Convinced that the establishment of a firm foundation for the continuation and development of such cooperation on the basis of freedom of scientific investigation in Antarctica as applied during the International Geophysical Year accords with the interests of science and the progress of all mankind.*"

The treaty also ensures the territory's internationalization. Article 4 "suspends" any territorial claims. The nations can maintain their claims, as nothing in the treaty can be interpreted as a renunciation of their rights. However, nothing in the treaty forces the other nations to recognize these claims. Those nations without possessions cannot make any claim.

The treaty assigns the management of Antarctica to a small group of nations: the consultative parties.

While the Antarctic Treaty is open to all countries, only certain nations are able to actively participate in the continent's management. These are the consultative parties. A nation **is considered a consultative party** as long as it "*demonstrates its interest for Antarctica by conducting substantial scientific research there, such as the establishment of a scientific station or the dispatch of a scientific expedition.*"

They gather together during the Atlantic Treaty's Consultative Meeting (ATCM). This body has the power of issuing recommendations which to date make up a body of some 200 documents and are the rules to be respected by the Antarctic operators.

[1] *Jean-René Dupuy, AFDI, 1960.*

The respect of the treaty is guaranteed by a system of observers with access to the bases. This clause of Article 7 is no longer applied in the spirit of the Cold War, but rather to encourage scientific cooperation. It amounts to evaluating the various countries' stations and their scientific potential. The French station of Concordia was evaluated in this manner during the austral summer of 2006-2007.

This "aristocratic" status has long been criticized by several Third World nations that would prefer that the management of Antarctica be transferred to the UN.

- **The "Antarctic system"**

The "Antarctic system" generally refers to all conventions and organizations – other than the Madrid Protocol - that have been added to the original treaty.

It consists of three conventions dealing with environmental protection:

- The Convention for the Conservation of Antarctic Seals

(CCAS) was signed on 1 June 1972 in London and came into effect in 1978. It forbids the hunting of seals.

- The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), signed in Canberra (Australia) on 20 May 1980, came into effect on 7 April 1982. It specifies the protected areas and ensures the management of marine resources. Its jurisdiction extends beyond 60° South.

- The Agreement on the Conservation of Albatrosses & Petrels (ACAP), signed in Cape Town on 2 February 2001, came into effect on 1 February 2004.

In addition to these conventions are various organizations dedicated to science in Antarctica. The two main organizations are:

- the Scientific Committee on Antarctic Research (SCAR), created in 1957 to coordinate the IGY. Its first president was Georges Laclavère, a member of the French Academy.

Its headquarters are in Cambridge and the Scott Polar Research Institute is in charge of its secretarial work. Its mission is to gather together the scientific community in order to define the main themes of scientific research in Antarctica. In addition, it now has its Arctic counterpart in the form of the International Arctic Scientific Council (IASC), created in 1990.

SCAR's scientific activities are organized around five international programmes:

– Subglacial Lake Exploration (SALE);

– The Antarctic and the Global Climate System (AGCS);

– The Antarctic Climate Evolution;

– Evolution and Biodiversity in the Antarctic (EBA);

– Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR).

- The Council of Managers of National Antarctic Programmes (COMNAP) was created in 1988. It gathers together the directors of polar institutes from 29 countries, who coordinate their activities and organize their cooperation. Its current president is Mr. Gérard Jugie, director of IPEV (French polar Institute-Paul-Emile Victor).

Finally, the temporary offices set up to organize the international polar years can also be considered of importance. The defining of themes and the selection/certification of programmes which play a role in the structuring of research and maintaining the spirit of cooperation unique to Antarctica.

The International Polar Years and the 2007-2008 Polar Year

The International Polar Year is a major scientific event. It only occurs every 50 years or so.

The first took place in 1882-1883. It was inspired by an initial, successful international collaboration in 1874-1875 between France, the United Kingdom, Germany and the United States to observe the passage of Venus from the sub-Antarctic islands. The Austrian explorer and geophysicist Karl Weyprecht therefore put forward the idea of organizing an international polar year to study geophysical and astronomic phenomena. Twelve countries agreed to organize fifteen simultaneous expeditions, thirteen to the Arctic and two to the Antarctic (South Georgia and Tierra del Fuego).

One objective was to once again observe the passage of Venus (6 December 1882). On the heels of this new success, the International Physics Congress held in London in 1895 decided to organize a polar year every 50 years.

The World Meteorological Organization launched the second IPY in 1932-1933 to study the planetary implications of the newly discovered jet streams. More than 40 countries participated, which allowed for important progress to be made in the fields of meteorology, geomagnetism, the atmospheric sciences and the cartography of ionospheric phenomena. 114 observation stations were established in the Arctic, and the first station in the Antarctic interior was built by the American admiral Byrd, who wintered there alone on the Ross Ice Shelf. France established a winter station at Scoresby Sund in Greenland.

The last IPY was the International Geophysical Year of 1957-1958, which gathered together 61 countries. Three high-atmosphere physicians were largely responsible for its organization: Lloyd Berkner, Sydney Chapman and Marcel Nicollet.

They wanted to take advantage of the radars that had been perfected during the Second World War, as well as of the future satellites during a year of exceptional solar activity. An international research programme was therefore established to collect data on the high atmosphere, the icecaps and continental drift, as well as on the volume of fresh water in the form of Antarctic ice, seismology and meteorology. 45 research stations were set up in Antarctica and the sub-Antarctic islands.

Indeed, during this IGY, the physicist Van Allen demonstrated that solar wind particles are channeled in the polar regions by the magnetic field's lines of force and it is the shock of these high-energy particles colliding with our atmosphere that results in the formation of aurora australis and borealis.

The 2007-2008 International Polar Year will therefore be a very important event. At an especially critical time in the world's history, considering the current climate change, a principal objective of the IPY will be to better understand the polar regions' role in global equilibriums through the organization of an intense research campaign.

The IPY enjoys the support of more than 60 countries and nearly twenty international research organizations, including the International Council for Science (ICSU) and the World Meteorological Organization (WMO). The IPY is managed by the British Antarctic Survey in Cambridge and its director is Prof. Chris Rapley. At the French level, the IPY is organized by the Academy of Sciences and IPEV, under the direction of Claude Lorius and Yves Frénot. More than 200 research projects have been selected.

Six main themes have emerged:

- **Inventory:** Determining the current environmental situation of the polar regions. What is the status of the circulation and the oceanic composition in the high latitudes? How do the polar ecosystems vary in time and space? To what extent can these variations be explained by anthropogenic impacts? How is the climate changing?

- **Evolution:** A quantification and understanding of the natural, environmental and social evolution, past and present, in the polar regions, as well as a fine-tuning of future projections. How does the polar regions' biodiversity respond to climate changes in the long term? How does the planet respond to successive glacial cycles? What are the polar regions' cooling factors?

- **Planetary interactions:** A better interpretation of the connections and interactions that exist between the polar regions and the rest of the world. What role do the polar regions play in the global carbon cycle? How stable are the large bodies of ice and what impact do they have on sea level? What are the North-South interconnections?

- **New frontiers:** Study the limits of science in the polar regions. What are the characteristics of the deep oceans and sub-glacial ecosystems?

- **A privileged position:** Utilization of the polar regions to create Earth-based observatories to study the sun and cosmos.

- **The human dimension:** The durability of circumpolar societies.

2. Mining a suspended issue

Ever since the 1980s, the economic exploitation of Antarctica has become an ever more important issue, in particular with regard to mining.

The handful of explorations undertaken at the time and the knowledge acquired on continental drift would suggest that Antarctica harbors immense mineral resources. Indeed, considering the links that exist between Antarctica and the Andes, South Africa and Australia, it's not difficult to imagine the combined mineral riches of these three zones awaiting discovery in Antarctica. In addition to these mineral resources, the continent could harbor oil and gas reserves due to the existence of sedimentary plateaus.

To open Antarctica to oil and mineral exploration and development, the signatories to the Antarctic Treaty negotiated during six years **the Wellington Convention, which was signed on 2 June 1988**. This convention regulates in a very strict manner these activities and was seen by many as being a lesser evil than uncontrolled development.

This failed to take into account the mobilization undertaken by Commander Jacques-Yves Cousteau, who led the Antarctic and Southern Coalition international campaign.

Under these circumstances, in June 1989, the Bureau of the National Assembly commissioned the Parliamentary Office for the Evaluation of Scientific and Technological Choices to evaluate the economic issues and ecological risks related to mining research and development. Mr. Jean-Yves Le Déaut, Deputy, was chosen as the commission's rapporteur and was able to attend the ATCM of October 1989 in Paris.

In June 1989, the President of France, François Mitterrand, after having received the report that he had requested from Commander Cousteau, decided to submit to the French Government his proposal to make Antarctica a nature reserve in which mining would be completely banned. Soon afterwards, the Prime Minister, Michel Rocard, announced that France would not ratify the Wellington Convention.

In August 1989, France was joined by Australia. In December 1989, the Parliamentary Office rendered its conclusions public. In 1990, Italy and Belgium joined France and Australia; together, these four countries favoured negotiating a new agreement. **Two years later, on 4 October 1991, the Madrid Protocol was signed. It came into effect on 14 January 1998.**

This protocol named Antarctica a "nature reserve dedicated to peace and science" (Article 2).

It forbids any mining activity for 50 years (Article 7), and this ban can only be lifted by a unanimous vote of all parties.

All activities on the continent must first be approved by the competent authorities of each signatory nation (Article 8). For France, the TAAFs are assigned this responsibility. In addition, a Committee for the Polar Environment was created under the auspices of the treaty system.

Specially protected zones can be established for the flora and fauna.

The Madrid Protocol was integrated into French law by Act No. 2002-347 of 15 April 2003 and Decree No. 2005-403 of 29 April 2005. These texts have been included within Title VII of the French Environmental Code.

The system of prior authorization suffers from important limits: every national authority is qualified to make rulings in its specific claim zone with respect to not only its own nation's citizens, but also the citizens of the other "possessioned" nations; this means that it is possible to seek the approval of those domestic or foreign authorities deemed to be the most flexible. Above all, it amounts to only a **procedural obligation**. There are no common, fundamental rules governing the decision-making process. Most of the consultative parties cannot prevent one of their number from pursuing an environmentally-harmful activity.

Indeed, this is the case with regard to Russia's desire to penetrate the sub-glacial lake of Vostok, or at the very least to provoke an upwelling of water to be withdrawn once frozen. The scientific community strongly doubts that Russia has perfected a method that poses no risk of **contamination**. Despite statements to this effect formulated by various parties, the Russians are going ahead with their programme, convinced of the harmlessness of their method and the scientific interest of such sampling and they refuse to transfer this activity to another, smaller lake located more on the continent's periphery.

Indeed, this lake, of **nearly the same size as Corsica, is the largest known sub-glacial lake in Antarctica**[1]**.** Many researchers feel that it should be preserved and that the samples of frozen water will be of little scientific interest; the threat of contamination posed by such sampling is even greater now that it is believed that the lakes form an interconnected network linked together by channels of melted water beneath the icecap.

Indeed, the heat of the bedrock combined with the pressure of the moving ice results in the bottom of the icecap melting. This water can, depending on the relief, be concentrated to form sub-glacial lakes which, along with their tributary channels, contribute to the process of the glaciers flowing out to the sea. Many believe that they play an important role in the speed of the outflow and therefore in the overall state of the Antarctic ice mass.

But what draws the attention of the Russian researchers on Vostok and motivates this sampling is the existence of unknown life forms. What life can exist 3,500 m below the ice? How did it develop? How old is the water?

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[1] More than one hundred lakes have been discovered. Vostok Lake has a surface area of 14,000 km².

The first hypothesis was that the lake's water was more than 400,000 years old, because the Vostok ice core enabled scientists to go back that far. This would have meant that the lake was effectively sealed and that any life it contained would have been at least as old, even going as far back as the Antarctic glaciation. However, the most recent studies tend to call this hypothesis into question. The water would appear to be very old, certainly more than 100,000 years, but the lake is not a closed environment.

Exchanges exist with the icecap. A process of melting and regelation exists. There is a circulating current. There may also be openings to other lakes. The life that exists within the lake is indeed very old, but it must be better understood to have a more precise idea of its age. Researchers believe that these life forms can yield important information regarding the origins of life on Earth and perhaps the type of life that may exist beneath the icecaps of other planets.

These hypotheses are based on the discovery in the regelation ice at the bottom of the Vostok sample of a thermophile bacterium, *Hydrothermophilus thermoluteolus*, which lives on hydrogen. This bacterium is only found in three places on Earth (Japan, the United States and Australia). Do similar hot springs exist at the bottom of Vostok Lake? How is this bacterium related to the other known bacteria? What else awaits discovery?

In addition, these mechanisms must be accompanied by measures to deal with **ecological emergencies** linked to such accidents as the January 1989 shipwreck of the Argentine tanker Bahia Paraiso, whose 700 tons of oil polluted 100 km^2. Likewise, it took 17 years to completely eliminate the consequences of the 1972 cooling-system leak of the McMurdo nuclear reactor built in 1962.

3. Tourism: a new peaceful threat?

In Antarctica, the growth of tourism has become a subject of concern. In 2005, an estimated 23,000 tourists visited Antarctica, as compared to only 6,700 in 1992.

Tourism on the continent is growing exponentially. The first tourist flight to Antarctica was an overflight in 1956 from Chile. The first cruise to Antarctica took place in 1957-1958. In 1990, the 50,000th tourist visited Antarctica, but the 100,000th arrived in 1998 and the 200,000th most likely set foot on the continent in 2006.

A worrying parallel can be drawn with the Falkland Islands. The arrival of ships carrying more than 1,000 passengers greatly opened these islands to tourism. In 1994-1995, only 5,000 persons visited these islands each year; in 2000, there were almost 40,000 visitors.

The same trend could today take place in Antarctica, with important consequences on the continent's flora and fauna. Indeed, the time of basic cruises for a very limited number of passengers is over. There are an ever greater number of ships with more than 3,000 passengers sailing to Antarctica, which allows operators to offer cruises for as little as €5,000.

This trend runs counter to the recommendations of the International Association of Antarctica Tour Operators (IAATO), created in 1991 upon the initiative of the NSF[1] and American tour operators. This organization tries to limit tourism's impact by pursuing an educational policy, respecting biological non-proliferation measures (foot baths), and respecting the continent's animal life (preventing visitors from getting too close to the animals).

Tour operators also have a real interest in preserving the wild character of these cruises, by never having more than one boat at the same site and limiting the number of disembarking tourists via rotations.

Nevertheless, most of the tourist activity is concentrated around some fifty sites on the Peninsula where the continent's animal life can be easily observed, thereby creating inevitable problems.

Today, there are real causes for concern. There is a strong temptation to increase the passenger capacity of the tourist ships. However, the greater the number of passengers, the more difficult it will be to carry out any sort of regulation. A certain growth is inevitable: several boats at the same site, an increase in the number of disembarked passengers, an artificialization of the sites for their protection (footbridges, etc.), even the construction of a permanent tourist infrastructure and in all likelihood of hotels. What consequences will all of this have on the flora and fauna and on the scientific research? The Australians have already demonstrated that Adélie Land's penguins have been contaminated with viruses by their contact with the bases.

Scientists operating on the Peninsula are increasingly concerned by the influence tourism may have on their bases' activities, because it necessitates specific measures in order to manage visits and avoid disturbances. During accidents, logistical means meant for research must also be mobilized. Getting about in Antarctica is obviously complicated, costly and often dangerous.

So far, France has been relatively protected from this influx of tourists thanks to Adélie Land's isolated location.

The sub-Antarctic islands are accessible via the *Marion Dufresne* during its annual rounds. Tourism remains very limited and its growth is undoubtedly restrained by the tediousness of moving about in the area, with all journeys taking place by sea.

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[1] *The National Science Foundation of the United States (equivalent to France's CNRS) – Office of polar programmes.*

Nevertheless, the situation is quite unique, with a public authority playing the role of tourist operator, at the risk in certain cases of assuming the financial consequences. This was notably the case in 1999-2000, when a millennial cruise that had been organized turned out to be a complete failure. Indeed, as related by the Controller and Auditor General in its 2005 public report, only 4 passengers (among 38 available seats) had reserved and paid for their trip. "Most of the passengers were already connected to the territory in some manner and the great majority didn't have to pay for the cruise." The total cost of this operation came to €730,000 of the taxpayer's money! Happily a one-off event, such a situation shows the limits of a tourist operation organized by a public authority rather than by a private operator acting at its own risk.

The question now concerns the **development of tourism in Adélie Land**. Tourist cabins are being planned for the *Astrolabe*, as is a "tourist-scientific tour" at the Dumont d'Urville station, with the active participation of the researchers present in an open-door, educational programme.

Your rapporteur is firmly opposed to any such projects, should they be proposed.

First of all, such projects are simply **unrealistic**, considering the great discomfort of a two-week, round-trip journey on the *Astrolabe*, in very rough seas, in a vessel with a flat bottom because of the ice!

It is shocking to want to make changes - to the Astrolabe and the Dumont d'Urville base - **for the safety or comfort of tourists, when such changes would be first and foremost necessary for the researchers.**

Likewise, **it doesn't make sense to give a few tourists - rather than the scientists - priority access to the limited logistical means available** for the carrying out of scientific work at sea or far from Dumont d'Urville (in other words, the Astrolabe and its helicopter).

It is also **shocking to want to transform a scientific base into a tourist attraction**, by obliging the scientists to give tours of their living areas and laboratories and even to allow the tourists to participate in their work. No laboratory in France is subjected to such an obligation.

Finally, if one persists in wanting to open this station to tourism and to impose such a change on the scientists, one must then consider **the great consequences that such a decision would have on our credibility within the Antarctic system**, even though our country was at the origin of the continent's total protection.

Clearly, the development of tourism should not be completely excluded from Adélie Land. However, should the local government be organizing tourist activities using logistical means originally meant for scientific research?

In the opinion of your rapporteur, the answer is clearly no, it should not.

II. THE POLES: THEIR KEY ROLE IN UNDERSTANDING CLIMATE CHANGE

Climate change has become a major scientific and political concern, but few are aware of the extent to which polar research has contributed and will continue to contribute in the coming years to predicting - and perhaps preventing - climate change. There are three major domains: ice coring, oceanography and the dynamics of the large frozen zones (the North Pole, Greenland and Antarctica).

A. UNDERSTANDING PAST CLIMATES TO UNDERSTAND THE FUTURE CLIMATE

The great inlandsis of Greenland and Antarctica are extraordinary in that they constitute climatic archives.

Fallen snow accumulates and slowly turns into ice due to the temperature and the snow's ever greater weight, because it becomes increasingly dense. During this process, it definitively traps a few air particles and dust from the surrounding environment. In this manner, invaluable information on the world's climate can be found in the form of successive layers of ice. The "seal" is never broken, because the temperatures are always several tens of degrees below zero.

In Antarctica, this sealing takes place at a depth of 100 m, when the density reaches 0.84. When the accumulation is very low, the snow takes a few thousand years to turn into ice and the imprisoned air is therefore younger than the ice. At Vostok, this difference in age has been estimated at 4 to 7 thousand years.

To analyze the ice samples, it is therefore necessary to carry out advanced studies on the photochemistry of the layers of snow, on the chemistry of the snow and on the trapped particles, as well as on the metamorphism of the snow, because over time a transformation occurs which disturbs the signal that is then detected in the ice.

The ice is stratified, with winter and summer layers. In the summer, the layers are less dense, because the particles are larger due to warmer temperatures. The winter layers are denser and are sometimes crusted due to the wind.

These are the first elements which allow for an analysis of the superficial zone and to discover the meteorological conditions of past years.

Over time, all of this ice moves from the top to the bottom of the icecap and from the centre to the coasts.

The speed of this vertical outflow is a few centimeters per year at the surface, depending on precipitation. This speed can vary considerably from site to site. For instance, in Antarctica, even though the two sites are less than 600 km apart, the Vostok ice core – even though its longer (3,650 m) than that of Concordia (3,270) – only goes back 420,000 years, compared to more than 800,000 years for the Concordia core.

This movement is also very slow horizontally: less than 1 m per year on the Plateau and some one hundred metres for the outgoing glaciers. This movement results in a progressive thinning of the successive layers. This distortion can be modeled to enable dating. The weakness of the movements is essential for a long, undisturbed timeline.

In total, the fallen snow in the centre of the continent can take several hundred thousand years to reach the coast. It is this process that makes the Greenlandic and Antarctic icecaps archives of the world's climate.

The science of ice analysis first appeared in the 1950s. The French scientist Claude Lorius explains how the idea came to him to analyze the air bubbles contained in the ice by watching an ice cube in a glass of whiskey: "By observing the bursting [of the air bubbles] when an ice cube melted in a glass of whiskey, I suspected they might represent unique, reliable witnesses of the atmospheric composition, which we then went on to prove over the coming years."

The first deep core samples were taken in Greenland at Camp Century in 1966 and in Antarctica at Byrd in 1968 and Vostok starting in 1970. The first deep sampling (900 m) by the French was undertaken on Dome C in 1978, where the first glaciology studies had been carried out in 1974.

1. Recent ice cores from Greenland

A European programme, the Greenland Ice Core Project (GRIP), carried out a sampling at the top of the inlandsis in 1989; its objective was to sample the glacier's entire depth (3,027 m). A similar American project, the Greenland Ice Sheet Project 2 (GISP 2), produced an ice sample of 3,053 m and a bedrock core of 1.55 m 28 km from the European site. These samplings allowed scientists to reconstruct the climate of the past 105,000 years, beyond which time the samples proved to be of lesser quality.

A new sampling series – this time under Danish direction and with European, American and Japanese partners - was carried out 300 km farther north (North GRIP). The sampling began in 1996 and the bedrock was reached in 2003. The base was closed in 2004.

The recently published results (10 June 2004 in *Nature*) show that this **3,085 m sample, the deepest made in this region, goes back farther than the last ice age (115,000 years)**. At that time, Greenland's climate was warm and stable.

The cores taken from Greenland will therefore allow scientists to reconstruct the entire climate cycle starting from the last warm period similar to our own.

2. Ice cores from Antarctica

The glacial ice cores from Antarctica, **which go back 850,000 years, had a huge impact on our understanding of the world's climate.**

The ice cores make it possible **to reconstitute**:

- **The temperature**, by using the "isotopic thermometer": in other words, different atoms present in the ice and, in particular, the variations between the isotopes 16 and 18 of oxygen.

- **The composition of the atmosphere**; in particular, the presence of **greenhouse gases** (methane and carbon dioxide) by analyzing air bubbles.

- The **atmospheric circulation**, by analyzing dust particles present in the ice.

- Inter-seasonal variations, by analyzing salinity. In the winter, the ice's salinity is a tenth of its salinity in the summer, because the winter ice shelf doubles the total surface area of the Antarctic and the icecap is distanced considerably from the sea. It allows dating over some one hundred years.

Of course, the scientists must date these layers of ice. They do this, particularly for the more recent period, by referring to volcanic eruptions and nuclear tests. Because these important events affected the entire planet, they allow scientists – when the events are well known – to precisely date a given layer and serve as reference points.

This is the case with important volcanic irruptions: Laki (1783-1784), Krakatoa (1883), Santamaria (1903), Agung (1963) and Pinatubo (1991).

The same is true for atmospheric nuclear tests from the 1940s to the 1970s.

While these events don't allow for dating in the distant past, they allow scientists to evaluate the accumulation rate of snow and the burial speed, and then to extrapolate for older periods, at least during the Holocene.

The researching of these various elements is shared out within the "Ice Cores – France" group, created in 2005, which allows for the specialization of the four associated laboratories:

- LGGE: gas, dust, chemistry, rheology, heavy metals, dating and geophysics;

- LSCE: water isotopes, permanent gas isotopes;

- CEREGE: beryllium-10;

- EPOC: krypton-81.

This work allows scientists to reconstruct the fundamental elements of climate. The most well-known tool is the relative abundance of oxygen isotopes. Isotopes are different forms of the same atom, varying according to the number of neutrons they contain. Oxygen has two main isotopes: oxygen 16 (8 neutrons) and oxygen 18 (10 neutrons). However, their average abundance in water (99.76% for oxygen 16 and 0.2% for oxygen 18) varies according to the ambient temperature. This was demonstrated by Willi Dansgaard following a storm in Copenhagen on 22 July 1952.

As the temperature cools, oxygen 18 decreases. This fundamental principle is the same for the other isotopes: identification and interpretation of variations according to the average natural abundance.

They increasingly help explain climate changes. Beryllium 10 should allow scientists to reconstruct insolation variations that are believed to be the cause of natural climate changes. Sulphur 33 will explain the influence of large volcanic irruptions (LGGE – the University of San Diego, *Science*, 5 January 2007).

• The results from the Vostok ice core

The results provided by the Vostok core have allowed for **spectacular scientific progress** to be made. They were obtained for the most part by French teams from the LGGE (Laboratory of Glaciology and Environmental Geophysics) led by Claude Lorius and the LSCE-CEA (Climate and Environmental Sciences Laboratory) led by Jean Jouzel, in cooperation with Russian and American scientists.

They have been able to reconstitute **the Earth's climate over the past 420,000 years**.

First considering the history of the climate, it was not until the beginning of the 19th century - when the Swiss Louis Agassiz put forward his hypothesis that moraines are not the result of any downpour, but rather the debris left behind by successive glaciers advancing or falling off – that the idea of a succession of glaciations and warmer periods was generally accepted.

Up until the publication of the Vostok ice core results, the scientific community believed in the existence of only four prior glaciations, which Albrecht Penck named after the Danube's four German tributaries: the Gunz (320,000 to 400,000 years ago), the Mindel (240,000 to 300,000 years ago), the Riß (140,000 to 230,000 years ago) and the Würm (15,000 to 120,000 years ago).

But in fact, between 1.8 million years ago and the beginning of the quaternary period, there were 20 successive glaciations.

The Antarctic ice cores allowed scientists **to prove the veracity of the theory put forward by the Serbian mathematician Milutin Milankovitch in 1924, which attributed climatic variations to variations in the position of the Earth in relation to the Sun** throughout history, according to various cycles:

- **Excentricity** (degree of flattening of the ellipse of the Earth's trajectory around the Sun). It varies from 0% (circular orbit) to 6%. Today, this figure is 1.7%, meaning the Earth is closer to the Sun in December than in July. It varies according to two cycles of 400,000 and 100,000 years;

- **Obliquity** (the degree of the Earth's North-South axial tilt in relation to its orbital path). This figure can vary by up to 2°, according to a 41,000-year cycle. It varies between 22° and 25°. The current obliquity is 23°27', which results in mild seasonal differences;

- The **precession of the equinoxes** (the changing date on which the equinox occurs in relation to the Earth's orbit). This means that for any given date, the Earth is not to be found in the same location of its annual trajectory around the Sun from one year to the next. It results in a seasonal insolation variation of up to 20% and varies according to two cycles of 19,000 and 23,000 years[1].

Previously, atmospheric forcing was the principal cause of climate change, because four regular glaciation cycles have been discovered.

However, the Milankovitch Theory leaves several important questions unanswered:

- the transition of 40,000 to 100,000-year cycles 800,000 years ago;

- the very great transition that occurred some 400,000 years ago without any major change in insolation;

- the near absence of any glaciations in the northern hemisphere before 1.8 million years ago.

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[1] *See Le climat : jeu dangereux, Jean Jouzel and Anne Debroise, Paris, Dunod, collection: Quai des sciences, 2004, 212 pages.*

The Vostok results also **demonstrated the very close connection that exits between temperature and two greenhouse gases - carbon dioxide (CO_2) and methane (CH_4) - and therefore their essential role in the amplification of** climate changes.

Finally, the results showed that **concentrations of greenhouse gases are currently the highest they have ever been for the past 420,000 years, shining light on the impact of man's activities.**

- **The EPICA ice core results**

The Europeans - in particular, the French and Italians – managed to extract the world's oldest ice from Dome C as part of the EPICA programme (European Project for Ice Coring in Antartica).

This project was begun in 1995 and included two sites: Dome C (123° east / 75°06' south) and Kohnen (00°04' east / 75°00' south). **850,000 years of climatic archives** were extracted from the ice, which is more than twice as old as those obtained at Vostok and the Fuji Dome in 2003 (350,000 years).

Over the past 850,000 years, the Earth has known **eight climatic cycles, with alternating glacial and warmer, interglacial periods.**

The Concordia results have largely confirmed the Vostok results:

- perfect data coherency;

- confirmation of the determining role of atmospheric forcing,

- confirmation of the role played by rising greenhouse gases and their correlation with the temperature;

- confirmation that the current concentrations are the highest they've ever been, even though a climate as warm as the present one once existed naturally.

3. Ocean core samples: the transpolar link.

The EPICA programme is coupled with an oceanic programme (EPICAMIS for Marine Isotopic Stages).

The principal interests of oceanic samples are the following:

- they allow scientists **to go back several million years**;

- they furnish the "oceanic signal"; in other words, **the manner in which the oceans have evolved throughout the various climatic periods (for example, their temperature)**;

- they enable scientists to discover **how the large sea currents have changed**;

- finally, they allow scientists **to reconstruct the link connecting the two poles and therefore how the global climate mechanism functions in the north and in the south**.

However, they are less precise.

The various oceanic, Greenlandic and Antarctic samples are able to be compared thanks to specific events. Some of these events are astronomic. Others are physical and can be explained by the history of the last ice age's gigantic icecaps.

Indeed, between 15,000 and 120,000 years ago, the Earth underwent a period of heavy cooling. This led to the creation of the Laurentide (North America) and Fenno-Scandian (Europe) ice sheets, which together were 80 million km^3 in size and rose to 3,800 and 2,500 m respectively. The sea level was 120 m lower.

In all likelihood, these ice sheets resulted in gigantic calvings in the ocean which had a very great and very rapid effect on the Earth's climate. They led to a very great rise in temperature and then, just as rapidly, a renewed glaciation. They were discovered thanks to the moraines and striations present at the bottom of the Atlantic Ocean. They are known as the Heinrich events, after their discoverer. They are part of the 24 Dansgaard-Oeschger events which marked the Earth's climate in cycles of approximately 1,000 years.

Less marked manifestations have been discovered in Antarctica and in the oceans, allowing for a correlation to be made between these three series of events.

This synthesis was recently completed as part of the EPICA programme, thanks in large part to help from the German scientists of the Alfred Wegener Institute. This synthesis was the subject of an article published in *Nature* in 2006.

4. The future of glacial core sampling

The question that is now being raised concerns the principal directions which glacial core sampling research should now take. What information do the researchers need in order to understand how climate works?

This questioning has been pursued since 2004 at the instigation of the Americans and British within the framework of the International Partnerships in Ice Core Sciences (IPICS) programme. **Four main areas of research** have been established:

• **Reconstitute the Earth's climate farther back than a million years**

The first area of research is concerned with delving farther back into the past. Indeed, oceanic samples demonstrate that **up until 800,000 years ago, the great climatic cycles were 40,000 rather than 100,000 years in length**.

Explaining this change is essential for at least two reasons:

- Is it connected to varying, long-term levels of greenhouse gases provoking a noticeable difference in the climate's sensitivity to changes in insolation? What role do natural reserves of greenhouse gases play? This would open up a field for analysis of great importance for understanding the future climate.

- Why does a small change in insolation have such an important impact on the climate? This is still not well understood.

To answer these questions, scientists would like to obtain a sufficient series of 40,000-year cycles. They are currently seeking a location in Antarctica where it would be possible to go as far back as 1.2 or 1.5 million years. Ideally, they would carry out two such samplings in different locations so as to maximize their chances of success and to have highly reliable data not subject to local variations.

The scientific community is therefore searching for appropriate sites in the eastern Antarctic.

One site will most likely be Dome A, where the Chinese would like to set themselves up. They already carried out a 110-metre sampling during the last ice-coring project and would like to reach 500 m during the International Polar Year.

France has long collaborated with the main Chinese laboratories in the sector. It is greatly in France's interest to participate in this operation, the details of which have yet to be decided.

• **Try to understand our future by studying the Eemian.**

It is generally believed that **the period most similar to our own in terms of climate** was the Eemian, 125,000 years ago, between the Würm and Riβ Ice Ages. **The climate was warmer and the sea level was some 6 to 7 metres higher.**

Taking into account ice core sampling results from Greenland and estimations of the icecap's mass, as well as of the sea level, it appears that during this period **the Greenland icecap had largely melted**.

One major question is: did the Greenland icecap completely melt away and what was the volume of any remaining glaciers? This calculation is essential for measuring the impact of today's global warming. How great an effect will it have? What effect will it have on oceanic circulation, sea level and the climate in general?

To try and answer these questions, a new sampling site in Greenland must be found, one that will allow scientists to reach unmixed ice layers that haven't been subjected to melting, layers that are older than those discovered so far and, if possible, older than the last interglacial period. Very old ice has already been found, but such samples have not been usable for climate reconstruction. Several scientific teams, especially the Danes, are convinced that such ice exists and can be found and used.

This is the second most important research area of the IPICS programme, which is aimed at obtaining an ice core that will allow scientists **to reconstruct the past 140,000 years of the northern hemisphere's climate**.

Much progress has already been made in the identification of sampling sites. The University of Copenhagen has identified two in the northwest of Greenland, in cooperation with the University of Kansas. They used radar soundings to obtain profiles of the icecap. These profiles have revealed different layers that are perfectly identifiable with those of the GRIP and NGRIP ice samples. The first site (NEEM1) is 2,542 m deep with an accumulation rate of 0.23 cm of ice per year; some 80 m would be usable for the **Eemian**. The second site (NEEM2) is deeper (2,756 m) with a lower accumulation and some 100 m for the Eemian. But at the second site, there are uncertainties concerning the bedrock, which could have the effect of jumbling the bottom of the sample. Therefore, the first site will most likely be chosen.

The sampling should take place during the International Polar Year.

• Better understand climate variability by studying the past 40,000 years

The last 40,000 years cover the transition from the last great ice age to today's climate, during which time sudden changes took place marked by rapid warmings and coolings (Dansgaard-Oeschger events).

This is the best-documented period for climatic reactions to great changes resulting from natural variations.

These climatic changes and the reactions in time and space can help us understand the future climate, with today's climate undergoing an extremely rapid forcing due to the actions of man.

The idea, therefore, is to obtain a series of ice cores providing scientists with the information they need to construct as precise a panorama of these changes as is possible.

Already existing samples from the Antarctic and Greenland would be used, from both coastal regions and from the centre of the inlandsis. This programme should also necessitate new samples: WAIS, Talos Dome, James Ross Island, Neumayer Hinterland (in Antarctica), the Greenland coasts, in the Canadian Arctic islands (Agassiz, Devon, Penny, Prince of Wales) and in Alaska (Mt. Logan).

Certain samplings will be carried out during the International Polar Year, with more to follow.

- **Clarify what we already know about the past 2,000 years.**

The fourth objective of IPICS is concerned with the past 2,000 years. Data is particularly insufficient and unreliable when one goes back farther than 400 years. There are many uncertainties regarding the functioning of the northern-hemispheric climate, in particular for determining the frequency and amplitude of the Arctic oscillation and for determining whether the climate warming that affected Europe during the Middle Ages was a regional phenomenon or something more widespread. Granted, the various scientific methods that have been used up until now[1] have provided scientists with a certain amount of information, but this information remains imprecise and localized.

The objective, therefore, is to **collect and study more than 200 ice cores** to have as detailed an image as possible of this period. These samplings will be carried out in both the polar regions and on mid-latitude glaciers.

B. THERMOHALINE CIRCULATION

In addition, polar research allows for a better understanding of the ocean's effect on climate, due to the central role played by the polar regions in the world's thermohaline circulation. It also raises the question of the ocean's capacity to serve as a carbon sink.

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[1] *Dendrochronology, historic documents (grape-harvesting dates, etc.), lacustrine sediments, etc. See* Histoire du climat depuis l'an mil*, Emmanuel Le Roy-Ladurie, Paris, Flammarion, 1983.*

1. The general circulation system

Henri Poincaré once explained to the members of one of Charcot's expeditions: "The great atmospheric movements, upon which all of meteorology depends, are largely governed by polar phenomena. The Earth is like an immense thermal machine with a hot and a cold source".[1]

The poles are this cold source. There are several explanations (the polar night, the angle of the sun's rays), but these elements can be partially compensated for by the thinner atmosphere[2] and, in certain regions, by the absence of cloud cover.

Indeed, the lack of warming in the polar regions is due to the layer of fresh, white snow that sends 80-90% of the sun's heat back into the atmosphere, resulting in a negative radiation balance during a large portion of the year. This negative balance is compensated for by the positive balance of those regions close to the equator, which together make up the hot source.

These two sources govern the atmospheric and oceanic circulations. In this very schematic manner, the poles play their fundamental role in balancing the world's climate by acting as a cold source.

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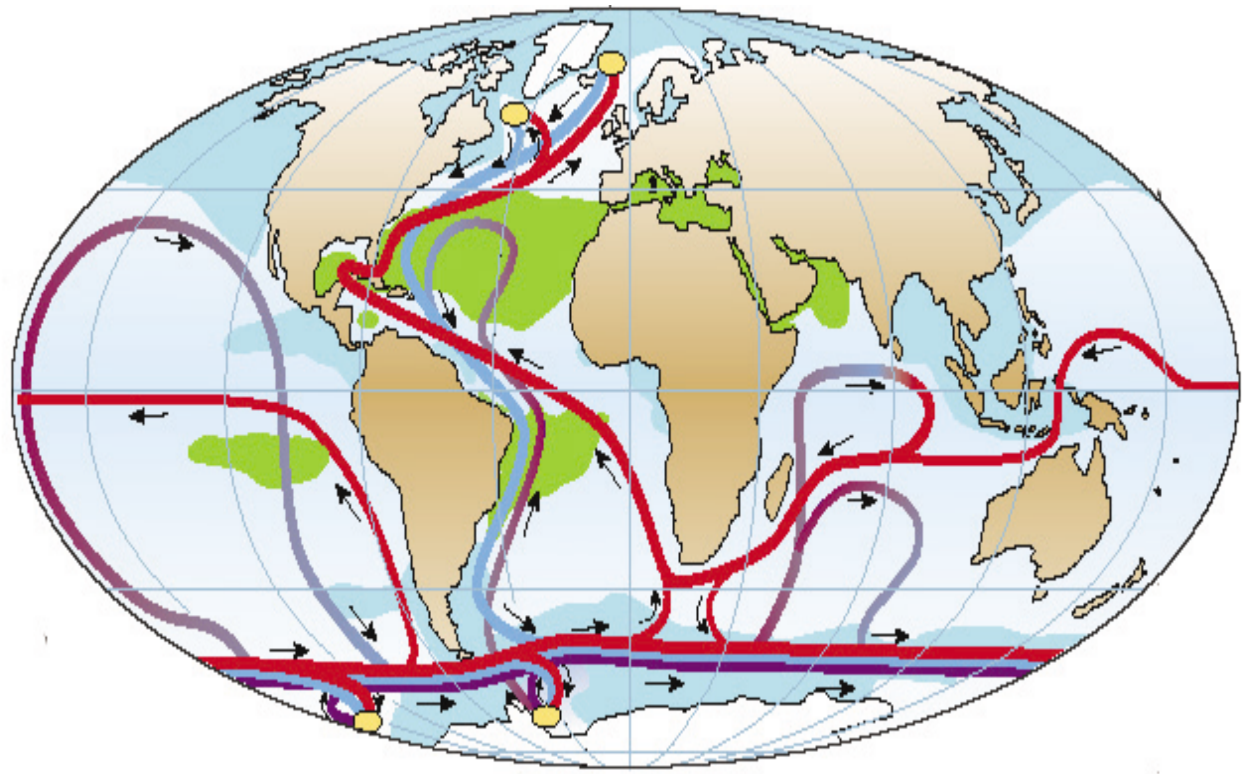
[1] *Cited by Frédérique Rémy in L'Antarctique, la mémoire de la Terre vue de l'espace, CNRS Editions, 2003, p. 20.*

[2] *The troposphere is only 7 km thick at the poles, as compared to 20 km at the equator.*

The oceanic circulation



Red: warm surface currents.
Blue/Purple: cold deep currents (2,000 to 4,000 m).
Yellow dots: areas where cold deep waters form
(Source: IPSL-LSCE-Paleoceanic Teams)

In the oceans, the most important point to consider in the functioning of the general oceanic circulation is that the two poles play an essential role in the creation or disappearance of the great sea currents. This is especially the case with regard to the Arctic's effect on the Gulf Stream.

The Antarctic Ocean plays a singular role, because the circumpolar current is a veritable driving belt; it's the only such current to be largely open to the Earth's three major oceans: the Atlantic, Indian and Pacific Oceans. It absorbs the warm currents and redistributes the cold waters.

For Europe, the most important of these great sea currents is the Gulf Stream. Its presence explains the fact that Europe, up to a very high latitude, enjoys a mild climate that greatly differs from those of the North American and Asian regions subject to the continental influence or cold currents.

Climatic archives tend to show that in the past the oceanic circulation in the Atlantic Ocean was greatly disturbed by global warming during either the Dansgaard-Oeschger events or the Eemian.

Therefore, several researchers believe that, taking into account current global warming, the Gulf Stream will once again be affected and some argue that it could even stop.

Taking into account various studies brought to the attention of your rapporteur during his research that didn't deal precisely with this point, it would seem that the scientific community is divided and that more data is needed to determine whether or not the Gulf Stream has already decreased in speed, how great this decrease could be, and what affect it could have on Europe's climate. The estimations are from 1 to 5 from now until 2150.

2. The importance of the creation of cold, deep waters

A key role played by the polar regions in the oceanic circulation is the formation of cold, deep waters.

Indeed, a few specific polar regions allow for their formation. They must combine climatic conditions (cold, wind) and bathymetric conditions (depth, intermixing of waters). There are two well-identified regions in the Arctic, to the east and west of Greenland. In the Antarctic, the Ross and Weddell Seas are the main regions, but the region of Adélie Land seems to play a more important role than has been thought up to now.

The objective of the Albion programme (Adélie Land Bottom Water Formation and Ice Ocean InteractioNs) is to study the Adélie Land coast. The functioning of this polynya coastal region is not very well understood.

Adélie Land's coastal waters form a 20,000-km^2 polynya which produces 100 km^3 of ice per year, the second largest amount in Antarctica. This polynya could be responsible for up to 25% of the Antarctic's deep water formation. However, its existence is closely linked to the protection offered by the arm of the Mertz glacier, an emissary glacier reaching far out to sea and which could break. This protection, combined with the region's especially violent katabatic winds, prevents the formation of a continuous and homogeneous ice shelf and maintains a favourable polynya by the heat exchanges it provokes upon the formation of deep waters.

This research programme is part of the international SASSI (Synoptic Antarctic Shelf-Slope Interactions) programme studying the Antarctic Plateau.

It is the fruit in France of a wide collaboration, in particular between the oceanographers at LOCEAN (IPSL-UPMC) and paleoclimatologists specialized in sediments (the EPOC laboratory in Bordeaux), as well as satellite observations (LEGOS in Toulouse) and even biologists from Chizé thanks to data they've collected on the environment of "diving" animals, in particular elephant seals.

3. The Antarctic Ocean, a carbon sink

A third important area of oceanographic research has to do with the role played by the polar oceans – the Antarctic Ocean, in particular - in the carbon cycle.

The oceans play a very important part in the carbon cycle, because phytoplankton and the entire trophic chain progressively stock a significant amount of carbon in the oceans' depths. There are also the mechanical exchanges linked to the formation of deep waters.

An ocean's primary production of phytoplankton varies depending on the season. This variation is very great in the Antarctic Ocean, due to the absence or very low level of sunshine during a large part of the year. Nevertheless, the Antarctic Ocean is very productive because it is rich in nutritive salts.

As for mechanical action, the Antarctic Ocean can be seen as a "veritable window to the abyssal waters", in the words of Paul Treguer, from UBO-IUEM in Brest, due to the intermingling of the different waters and their dive towards the ocean bottom.

The scientific community debated the role of the Antarctic Ocean in 2002. This led to a decreased estimation of its contribution as a carbon sink, estimated at **18% of the global oceanic sink**. However, south of the polar front, its contribution is very low. Furthermore, the global assessment is liable to reverse itself during the El Niño phenomenon. In addition, the ocean's warming should diminish its capacity to absorb CO_2.

However, **certain researchers believe that it is possible to stimulate the ocean's primary production in order to increase its ability to stock carbon**. In particular, by increasing the ocean's iron content, thereby stimulating the production of phytoplankton. First put forward in 1931 by Gran, this idea was again taken up in 1988 by John Martin with his famous line: "Give me a half tanker of iron and I will give you an ice age." The iron content of shallow waters depends both on wind (aeolian contribution) and the contribution of the deep waters and of the continental plates. However, the Antarctic Ocean has a deficit of iron.

This hypothesis has since been the subject of several important experiments. The first was carried out in the Weddell Sea in 1988 in bottles of surface water, then ten out at sea: 2 in the Equatorial Pacific (1993 and 1995), 5 in the Antarctic Ocean (1999, 2000, 2002 and 2004) and 2 in the sub-Arctic Pacific (2001 and 2002). All of these experiments were relatively conclusive, since the addition of iron to iron-poor areas leading to a strong growth in plankton and an absorption of CO_2.

In 2005, French researchers carried out a larger-scale experiment off the Kerguelen Islands by studying a zone naturally supplied with iron by the erosion of the continental plateau. This study should help scientists understand the impact of additional iron over time and over large areas.

Today, **the addition of iron has proved its effectiveness in increasing the ocean's primary production; however, the consequences of such an experiment carried out on a large scale are unknown**, because primary production does not lead automatically to a long-term stocking of CO_2 in the sediments and above all can have the inverse effects of sterilization and the reemission of greenhouse gases.

C. THE POLAR REGIONS AT THE HEART OF GLOBAL CLIMATE CHANGE

The increased climate change at the poles - with the high latitudes warming two to three times more rapidly than the temperate regions - is liable to provoke the progressive disappearance of the frozen zones: the Arctic summer ice shelf, the Greenlandic inlandsis and the Antarctic icecap.

1. Will the Arctic ice shelf disappear in the summer?

World public opinion has been greatly aroused about the risk of **the Arctic ice shelf progressively disappearing during the summer over the next fifty years**.

This concern is the result of **a combination of factors**, which the researchers presented to your rapporteur:

- The ice shelf's **diminishing surface area**. Since 1979, the frozen surface has decreased by 9% every ten years.

- **The diminishing age of the ice**. In the Arctic, a portion of the ice shelf remains frozen from year to year. Permanent in appearance, this ice is in fact mobile and there is hardly any sea ice more than 4 or 5 years old in these regions.

The surface area of this several-year-old ice is also diminishing by 8-10% per year. Simulations based on satellite images show that the average age is constantly decreasing, even that of the perennial ice, which is becoming younger and younger.

- The **diminishing thickness**. The ice shelf is normally 2.5 to 3 metres thick, on average. However, recent soundings carried out by both American military submarines and scientific ships tend to show a very marked decrease in thickness, of around 40% over the past thirty years.

This important data is confirmed by the eyewitness accounts of professionals working in the Arctic, who are noticing marked changes in their normal working conditions.

However, great uncertainties remain regarding the collected data and the forecasts.

For this reason, the European Commission is supporting the **DAMOCLES (Developing Arctic Modeling and Observing Capabilities for Long-term Environmental Studies) scientific programme**. This international programme, which will last from 2005 to 2009, gathers together a great many research centres. It is coupled with the American SEARCH programme. It is directed by the French researcher Jean-Claude Gascard. Its objective - thanks to the installation of new autonomous sensors throughout the Arctic basin - is to precisely measure a great many factors: atmospheric pressure, currents, salinity, water and air temperature, etc.

It should allow scientists to model the Arctic environment and predict its future evolution. **After 2009, it will most likely take the form of a European observatory to study climate change in the region.**

2. Will Greenland melt completely?

The geometry and volume of the icecaps is governed by the balance between the amount of fallen and evacuated snow.

With a surface area of 1.7 million km^2 and an average thickness of 2,000 m, Greenland contains 9% of the Earth's ice.

Its latitude is much lower than that of Antarctica and much of Greenland is located south of the Polar Circle.

Scientists know that historically Greenland has been subjected to brutal climate variations and that its icecap has undoubtedly disappeared - if not entirely, than at least to a great extent.

The icecap's dynamics is very different from that of the Antarctic, because precipitation in Greenland is much greater in proportion to the surface area. There is also much more melting in the summer, resulting in the evacuation of at least half of the precipitation.

Based on observations, it is believed that the Greenlandic icecap is today in disequilibrium. It is losing volume due to melting and the accelerated outflow of its glaciers. What's more, its general profile is becoming more sloping.

Recent studies of Greenland[1] have shown a significant weakening of the icecap, between 1992 and 2002, which appears to be accelerating. Over this ten-year period, Greenland has lost 80 km^3 of ice per year, for a total volume of 3 million km^3. Should more than 20% of the ice be lost, this trend would become irreversible. The melting of Greenland has raised the Earth's sea level by 15 mm over the past 15 years. The point of no return would be reached with a global warming of 3°C, which is probable before the end of the 21st century.

These evaluations have given rise to important debates within the scientific community for two main reasons:

- There is **insufficient data concerning Greenland's natural state during a warm period such as ours**, which is why additional core samplings are necessary. We must have more information on the state of the Greenlandic icecap some 120,000 years ago.

- Researchers **agree over the general meaning of the current evaluations: Greenland is in the process of shrinking. But the exact magnitude and speed of this loss are hotly debated**, due to the present **lack of satellite-based means**. Indeed, space-based data remains relatively imprecise and incomplete, and there are no long series of data. This situation should soon change thanks to data collected during two combined missions, one calculating **Greenland's gravity and therefore mass (GRACE-NASA), the other the volume of its ice, including its sea and coastal ice (Cryosat-ESA)**.

Gravimetry consists of measuring terrestrial gravity, which depends on the distribution of masses between the Earth's surface and its centre. The heavier these masses are and the closer they are to the surface, the greater the gravity. Gravity is measured by taking into account natural variations in the gravitational field linked to the diameter 21 km shorter between the poles than at the equator and to surface heterogeneities such as mountains, oceans, ice, etc. This results, therefore, in an ellipsoid indicating a greater force of gravity at the poles than at the equator. For a long time, gravity was only measured by disturbances in the satellites' orbits, but this method was imprecise. Initial progress, with measurements four times as precise, was made possible by the Champ (Challenging Minisatellite Payload for Geoscience and applications) satellite, launched in 2001, which allowed scientists to identify the effects of gravity.

Recently, the GRACE (Gravity Recovery and Climate Experiment) satellites launched by NASA have allowed for a precise measurement of the gravitational field. By comparing measurements made during their successive transits, the satellites will allow scientists to evaluate the increase or decrease in the ice mass, thereby allowing for a more precise assessment.

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[1] *Philippe Huybrechts, Université Libre (Néerlandophone) de Bruxelles, Nature and Geophysical Research Letter.*

Cryosat's mission is to monitor the thickness of the continental and sea ice masses, so as to better understand the link between the melting polar ice and the sea level in correlation with climate change.

The Cryosat mission is scheduled to last three years. The satellite will be positioned at an altitude of 700 km, enabling it to make observations up to 88° north and south latitude.

The measurements are made by a highly sophisticated radar altimeter (Synthetic Aperture Interferometric Radar Altimeter or SIRAL), assuring a very precise positioning of the satellite and therefore allowing scientists to monitor any change in the surface's altitude and thereby monitor variations in ice thickness (continental and sea ice).

Sea and shelf ice is relatively thin - a few metres at the most. All the same, this ice great influences the climate because of its effect on oceanic temperature and the circulation of warm and cold waters. Cryosat will also be able to detect and precisely measure variations in ice thickness throughout the year and from one year to the next.

It should therefore be possible to provide a precise answer in 5 to 10 years.

3. Can a diagnosis be made concerning the assessment of Antarctica's mass?

In the case of Antarctica, public opinion was also greatly aroused with the breaking off of gigantic icebergs over the past 10 years.

This phenomenon is still not very well understood. In several cases, it is most likely to be explained by the natural dynamics of the Antarctic icecap, which regularly gives birth to tabular icebergs. In other cases - in particular, in the Peninsula, with the dislocation of the Larsen B ice shelf – it is to be explained rather by climate change.

Generally speaking, it is very difficult to provide an assessment of Antarctica's mass. In 2003, Frédérique Rémy (LEGOS, book cited above) noted an uncertainty of some 20-30%. Numerous mechanisms are still not understood and cannot yet be modelled.

As is also the case for the Arctic, the scientific community believes that satellite observations will greatly help them to understand and measure the present phenomena.

The past can also help us understand the future.

For example, this is the case with the functioning of the Antarctic during the last ice age 18,000 years ago. The climate was 10°C cooler and precipitation was half as great. The eastern and western areas reacted differently.

The west was greater in volume and had a larger surface area than it does today.

Indeed, the volume of the ice and the form of the icecap are greatly influenced by sea level. When the sea level is lower, the ice can rest upon the bedrock, cover a greater area and support a greater volume further up. Its altitude was 80 m higher than it is today, as shown by the Byrd sample.

On the other hand, in the east, the altitude was some 200 m lower, because in this truly continental - rather than archipelagic - zone, the icecap's volume depends essentially on the lower precipitation during the ice age due to the drying-up of the atmosphere. This would suggest that the opposite mechanism is also possible: a thinning and reduction in surface of the western icecap at the same time as the floating ice shelves weaken, as well as a thickening of the eastern icecap due to greater precipitation.

However, due to the continent's isolation and thermic inertia, global warming cannot have a rapid impact on Antarctica. Indeed, during the last deglaciation, most of the melting occurred in the north: the American and Asian icecaps completely disappeared, while Antarctica underwent relatively little change. Only 10 m of the 120-metre rise in sea level was linked to Antarctica. Certain glacial retreats and the fossilized remains of a few penguin-colonies (such as those found near Terra Nova Bay) would indicate that real changes did indeed occur, but these were limited in scope at the continental level.

Therefore, the most likely hypothesis, based on our current knowledge and the observations made, is that **the Antarctic Peninsula continues to undergo rapid warming, though this will not affect the general equilibrium of the continental masses anytime in the near future due to the development of the eastern icecap**. However, the glaciers of the sub-Antarctic islands are rapidly retreating.

For your rapporteur, three factors must be emphasized:

- The great importance of this research, which is aimed at answering fundamental questions concerning our planet's future, and therefore the need for the French research teams to fully participate;

- **The absolute need to help finance the research teams**, which must remain at the highest international level, even in the face of increasing competition. **The glaciology teams** in particular need the means to automatically carry out the traditional analyses, as well as to make progress in new fields of research. They need computing power. They need to be able to welcome young researchers working on their doctorate or post-doctorate. Their on-site means (logistics and sampling system) must also allow them to be ideally positioned in the international programmes. In the end, it is all of these factors together that will provide our scientists with the raw material to analyze and allow them **to be the first to publish their results in the main scientific journals**;

- **The need to establish, at least at the European level, long-term observatories for the polar regions.** The observation programmes must be continued beyond an initial PCRD or ESA mission.

III. FRANCE'S FIRST-CLASS BIOLOGICAL RESEARCH

French biological research in the polar environment is not always given the respect it deserves, because it is often eclipsed by research carried out on the ice or oceans, which requires greater funding and is more concerned with global warming.

This traditional assessment is unfounded. If one considers IPEV's database of scientific publications appearing in journals with an international readership and indexed by the Journal Citation Report (JCR) and stemming from IPEV-supported programmes, it can be seen that since 1998 the life sciences represent half of all publications. This erroneous impression undoubtedly has something to do with the fact that since 2000 the sciences of earth and astronomy have accounted for a greater number of publications in *Nature* (10 vs. 5) and *Science* (9 vs. 3). However, the life sciences seem to publish articles in a greater array of journals that are often of a higher caliber than those of the sciences of earth and astronomy.

These excellent results are to be explained by an exceptional scientific heritage, innovative research and the development of research topics suited to the most important scientific questions.

A. AN EXCEPTIONAL HERITAGE

French polar biologists benefit first and foremost from an exceptional scientific heritage linked to the history of French operations and research in these regions.

1. A unique geographic situation

The most important asset for French researchers is their access to exceptional research sites.

Your rapporteur would here like to discuss the location of our various bases in the sub-Antarctic islands and in Adélie Land.

The sub-Antarctic islands form an exceptional gradient of territories lying at different latitudes, from the Kerguelen Islands at the edge of the polar front to the islands situated in more temperate zones at the level of the subtropical convergence. This represents the foundations of the first comparative studies concerned with the adaptation of either a single species or of related species.

All the superior predators of the Antarctic Ocean are concentrated in these islands, because they are the only bodies of land several thousand kilometres in circumference. Therefore, there is a very high concentration of different species. Colonies of several hundred thousand individuals are not rare. As a researcher asserted to your rapporteur: "The real treasure of these islands is their biomass."

The animals are very accessible, because they have never known terrestrial predators and therefore have developed no wariness vis-à-vis man. Their behaviour has not been modified by the few periods of hunting.

There are 52 species of bird[1]. The Crozet archipelago is, in terms of the number of species, the richest in the world, with 38 different species. Ile aux Cochons ("Pig Island") is home to the world's largest colony of king penguins, with more than 550,000 couples in the beginning of the 1990s. Such large colonies must be counted with the help of satellite imaging. Indeed, average colony density can be calculated according to the rule by which the king penguin will sit on a single egg at a distance safe from the beaks and wings of its neighbours, or 65 cm (equivalent to two wing-tip lengths). Therefore, it is possible to determine a given colony's population from the surface area it covers.

These regions are rich in endemic species. Several examples are especially telling. Your rapporteur would like to discuss two such examples from among the insects: the Kerguelen weevils (*Ectemnorrhinines*) are only found in these islands. No close species exists anywhere else on Earth, so it is supposed that this insect is a relic of the animal life present in Antarctica a long time ago and that these weevils migrated to warmer land when the continent became too cold. A second example consists of the wingless or apterous flies and butterflies. Scientists believe that this adaptation – abandoning the ability to fly – allows them to build fatty reserves that make up 40-45% of their weight and which take the place of wing muscles, allowing them to better deal with the harshness of their climate.

The Dumont d'Urville base in Adélie Land is exceptionally well located to study the region's animal life. It is the closest Antarctic station to a colony of emperor penguins, first discovered in 1950.

This colony is truly unique. It is accessible by foot, while most penguin colonies are located rather far off and researchers must use heavy logistical means to visit them. This proximity is especially valuable for making observations during the winter, when moving about is difficult. The extraordinary animal documentary *March of the Penguins* could never have been filmed without this proximity.

[1] *Throughout this section, your rapporteur is referring to* Les 40^{e} rugissants, un sanctuaire sauvage*, by Charles-André Bost, Christophe and Dominique Guinet, Benoît Lequette and Henri Weimerskirsh, Gerfaut, 2003, 208 pages.*

Indeed, it should be pointed out that there are only 35 emperor penguin colonies in Antarctica, for a total estimated population of 135,000 to 175,000 couples[1].

The Dumont d'Urville base also provides access to other species emblematic of Antarctica, such as the Adélie penguin and various species of Pinnipedia.

There are other species with extraordinary features. For example, the Antarctic midge can survive the continent's extreme temperatures by accepting the presence of ice particles within its body. Other continental insects are able to survive thanks to a very high level of glycerol, alcohol or sugar in their blood. As for plant life, one must mention the endolithic lichens which survive thanks to the light which infiltrates certain rocks which also serve to protect them from the cold.

The list wouldn't be complete if one didn't mention Antarctica's marine life, of which Dumont d'Urville also provides a good cross-section and which provides scientists with a deeper understanding of how animals adapt to extreme conditions.

2. 40 to 50 years of continuous observations

These exceptional sites could have remained under-exploited by the researchers. Such has not been the case.

French biological research in these regions benefits from nearly 50 years of continuous work with the same colonies. Indeed, from the very beginning, French researchers have progressively compiled a database for the various populations of species present. For example, the database takes into account homogeneous data over a 40-year period for the emperor penguin in Adélie Land and the great albatross in Crozet. 27 species of seabird and Pinnipedia are monitored on a yearly basis.

The database gathers together population countings over time for each colony in the different locations. The number of couples, the reproduction rate, the survival rate of the young and mature, and their physical conditions are, of course, precisely monitored. All of this data can be correlated with meteorological observations. This database also includes information on individual subjects. Most species of superior predators present in these regions are long-lived animals which live several decades and reproduce slowly. This specificity is explained by the animals' slow metabolism due to the cold, as well as by the necessity to adapt to the quantity of prey.

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[1] *The penguins living in the Antarctic are birds which have lost their ability to fly. They are in no way similar to the 23 species of penguin living in the Arctic and which can fly*

While it remains constant in the mid-term, it can vary widely from year to year. Predatory species must therefore be able to give priority to the survival of their adults over reproduction. For example, the black-browed albatross is reproductively mature at the age of 10. Couples have one chick per year. As for the great albatross, it can live up to 70 years, with couples having one chick every two years. The same individuals have therefore been monitored over several decades in some cases, which is obviously exceptional. It is not rare for the same great albatross to be studied by two or three generations of researchers!

This continuous 40 to 50-year database is today managed by the Chizé laboratory. It is completely computerized and is capable of making readouts according to the wishes of the researchers.

Very few countries have such precise information at their disposal.

The French researchers can only be compared to their British counterparts of the BAS who have been present during a comparable amount of time in the Falklands, in South Georgia, in the South Sandwich Islands and in Rothera on the Peninsula (from the north to the south).

This data is clearly indispensable for any long-term analysis of the interactions between the populations of different species and their environment and to study the species themselves, considering their longevity.

B. ADAPTING TO GLOBAL CLIMATE CHANGE AND EXTREME ENVIRONMENTS

Two main research areas have been developed: the adaptations of animals to climate change and the specific mechanisms they have developed to survive in these extreme environments.

1. Adapting to climate change

Due to the polar regions' much more rapid warming compared to the rest of the planet, their flora and fauna are subject to much more intense pressure. They therefore represent important control subjects.

Looking first at fauna, a principal tool is the long-term demographic database. This has already allowed scientists to **demonstrate a change in the climatic regimen between the late 1960s and the mid-80s linked to a rise in temperature**. Demographic changes are quite distinct for the emperor penguin, the king penguin, the Adélie penguin, the rockhopper penguin, several species of albatross, the fulmar, the sea elephant and the fur seal. What is probably most surprising is that the changes are not unequivocal.

For example, the populations of several species are declining: the emperor penguin, the rockhopper penguin, the black-browed albatross and the sea elephant. On the other hand, other species seem to be profiting from the current climate change, with their populations increasing: the king penguin, the Adélie penguin and the fur seal. Finally, a few species, such as the fulmar, don't seem to be much affected. It is very interesting to note that it is quite useful to compare data for the same species from several different islands, because the intensity of change varies.

An article published in *Nature* in 2001 dealt with the changing population of the emperor penguin. The Chizé researchers demonstrated that over a 4-5 year period (1975-1980), the number of reproducing birds had abruptly fallen from 5 to 6 thousand to some 2 to 3 thousand individuals. This change is explained by an excess mortality of adults linked to a decrease in the surface area of the sea ice which led to decreased amounts of krill[1]. This excess mortality rate is even greater among males who go without food during 3 ½ months in the winter to ensure the brooding of their young and can thereby lose up to 30% of their body weight.

On the other hand, this reduction in sea ice seems to have favoured the Adélie penguin, even though this trend is undoubtedly deceiving, because continued warming would certainly lead to a decrease in the population of Adélie penguins.

This mechanism also explains in large part the changing populations of other birds, because they feed in the polar front, the location of which varies according to the temperature. The colder it is, the farther north the polar front is to be found, and vice versa.

Plant life is also subject to climate change. There is very little flora specific to Antarctica. There is more plant life in the sub-Antarctic islands, with a high rate of endemism.

The main risk for plant life is the invasion of outside species due to global warming. Indeed, Antarctica's flora was previously subject to the invasions of plants imported (voluntarily or not) by the men and women working at the scientific bases; however, the harsh climate prevented their spread. For example, a plant or animal could not survive outside the greenhouse used to provide the base with fresh food. Over the past several years, however, a wild environment of escaped species has been discovered. These are often very common and very resistant species from our regions which find an environment favourable for their growth. Provided with a more active metabolism than the local species, they tend to take their place.

For example, in the Kerguelen Archipelago, where the average temperature has risen by 1.3°C in 50 years, the bluebottle fly of our regions,

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[1] *Krill is a pelagic shrimp which plays a central role in the entire food chain of the Antarctic Ocean. In the winter, it lives beneath the ice shelf which serves as protection.*

Calliphora vicina, began to colonize the main island, moving out from the base, in the 1980s and is putting ever greater pressure on the local, wingless fly species (see above). In those environments already greatly degraded by man through the introduction of foreign fauna (cats, rats, sheep, cows, rabbits) and flora (for example, the dandelion), the removal of one element can have an aggravating effect on the environment - for example, getting rid of the rabbits which eat the dandelions.

Another example is that of the introduction of cows to the islands of Saint Paul and Amsterdam to provide passing vessels with fresh meat.

When first discovered, these islands were covered with a very dense, shrubby vegetation up to an altitude of 250 m, made up mostly of Phylica arborea (endemic shrub 3-4 m in height). This vegetation has almost completely disappeared due to overgrazing, fires and ships stopping for wood. Today, this vegetation is entirely protected thanks to enclosures and a replanting programme.

Therefore, the ideal solution remains increasing preventive measures against invasions, in particular by the tourists (footbaths, special clothing)**, and a precise understanding of the environment in order to attempt their restoration.**

2. Understanding the adaptation to extreme environments

The adaptation of animals to extreme environments is another great area of research.

The Antarctic continent's penguins and fish must live and reproduce in conditions which normally would preclude any form of life.

This is especially true for **fish** living off the coast of Adélie Land. Research carried out since 1996 seeks to inventory the species present and to study in the long-term the pelagic conditions and the functioning of the food chain. **Living in water temperatures which should freeze them**, the species of fish present must have adopted certain adaptations. **Two important changes have been discovered: the decrease, even the total disappearance, of haemoglobin in the blood and the secretion of an antifreeze protein.**

The same is true for **the penguin species**. Penguins are endothermic, meaning they are warm-blooded animals which maintain their constant, elevated internal temperature independent of any variations in the ambient temperature, as opposed to ectothermic or cold-blooded animals, whose internal temperature – and thus their physical activity - is dependent upon fluctuations in the ambient temperature. The emperor penguin has an internal temperature of 38°C.

It must produce enough heat to maintain this temperature while dealing with ambient temperatures well below zero and must make long dives in water close to freezing, which increases by 190% its loss of body heat.

The list of adaptations employed by the penguins is long: a reduced heat-exchange surface, a very insulating covering, a very unique cardiovascular system, group protection (huddling together) or burrowing in the snow (the Adélie penguin), specific growth mechanisms for juveniles, etc.

This research on the energy functioning of polar animals is directly linked to human-based studies. Indeed, the study of these energy-use mechanisms – and, therefore, the animal's storage of lipids, carbohydrates and proteins – can be quite useful for treating certain human illnesses, such as obesity. Penguins are birds which, like humans, do not have brown adipose tissue, which allows mammals to withstand the coldest temperatures. **Following studies of penguins, human-based studies will be carried out at Concordia.**

In addition, within the framework of their adaptation to these environments, a common characteristic shared by most of these species is **their reproduction on land being carried out several hundred kilometres from their feeding areas. The mating couples must therefore take turns first brooding and then feeding their young and withstand long periods without eating**: the period of brooding and feeding their young, combined with the length of the trip to the fishing zone, usually located in the polar front several hundred kilometers from the colony. They have therefore developed unique mechanisms to control their digestion and utilize their energy, so as to be able to not eat during several weeks while they feed their young. This mechanism is even more active during the El Niño phenomenon. For example, the male king penguin must be able to wait during a longer period of time for its female partner to return while the egg is hatching. This unique phenomenon has led to **the discovery of a very powerful peptide in the male's stomach: spheniscine (from the latin name for penguins, Spheniscus). It allows the food to remain well preserved during the final two or three weeks of brooding. In this manner, the male can feed the young chick while awaiting the return of the female. There are numerous biomedical applications possible for this peptide.**

C. INNOVATIVE RESEARCH

The polar environment and the specificities of the species studied have forced scientists to innovate. Researchers have developed instruments far removed from the naturalist's more traditional tools and which allow them to observe the animals during their movements at sea.

What's more, they are developing leading-edge technologies for physiological and genetic analysis, allowing to propose certain changes in the organization of this sector to increase even more the research effort.

1. The equipment of animals

In these regions, researchers are mostly interested in the superior predators - birds, mammals and large fish – because, occupying as they do the summit of the ecosystems, they serve as reliable indicators. The quality and productivity of the entire environment affect the health and population sizes of the predators. They are also the most accessible animals on land.

But dry land, where reproduction takes place, is clearly not the principal environment of animals entirely dependent on the sea for their food. They find no nourishment on the islands. There is a marked spatial segregration. Therefore, the land-based study of these animals offers only a limited field of observation. It was necessary to find ways to observe them at sea.

Sailors have long known that albatrosses cover immense distances. For example, the 13 survivors of the Tamaris, a French three-masted vessel shipwrecked in the Crozet Islands on 4 August 1887, attached an iron plate on which they had engraved their location to the neck of an albatross, to serve as a sort of messenger pigeon or message in a bottle. 5,000 km and 45 days later, the albatross was found dead on an Australian beach. Help was organized, but it was too late. Upon their arrival, the castaways had disappeared without a trace.

Researchers at Chizé were the first to install a tracking device to birds. **The first tracking by satellite of the great albatross was carried out in 1989** and made the cover of Nature in 1990. For the first time ever, it was possible to know where the birds went at sea. It was now possible to measure the very long trips made by these animals in search of food – 5 to 7 thousand km on average and up to 16,000 km over a period of 15 to 20 days – and to locate their diverse feeding areas. Since this initial experiment using an Argos tag weighing some 200 g, much progress has been made in the techniques employed. Satellite tracking now uses tags weighing around 20 g and GPS, allowing scientists to monitor smaller birds and to receive a signal every second and precise to within one metre, as compared to one signal every two hours for a precision of some 350 m.

In particular, this technique allowed scientists to understand why a certain species of albatross at Crozet was threatened with extinction since the 1970s due to the very great decrease in the number of females.

The researchers demonstrated that, as opposed to the males, outside the reproduction period, the females flew to the subtropical zones of the Indian Ocean, 1,000 km to the north, where they were the accidental victims of drop-line fishing. An effective policy for their protection was able to be proposed.

However, knowing where the animals go is no longer enough. Researchers wanted to know where, when and how much they fed. That is why they developed a stomach probe coupled to a GPS tag. Each time the fish dove in the water to feed, the probe detected a decrease in temperature, which was then transmitted. This research carried out on the great albatross was published in *Science* in 2003. This study revealed that these birds, which weigh 10 kg for a wingspread of 3.5 m, could capture cuttlefish of up to 2 kg, the researchers estimating the weight of the prey according to the amount of time it took the bird's stomach to return to its initial temperature of 39°C. The same studies also allowed researchers to understand how the great albatross is able to cover such great distances. This was explained through the combination of a GPS transmitter, a heart-rate monitor and a transmitter attached to one foot of the bird to know if it was flying, on water or on land. The researchers were thereby able to show that the great albatross flies in zigzagging glides, carried by the wind, allowing it to not use any more energy during these flights than while at rest in its nest. Taking flight and flying by beating its wings are the two phases requiring the most energy.

This type of instrument also allows scientists **to monitor changes in the feeding zones over the years. The tagging of petrels, birds with an exceptional sense of smell, has allowed scientists to better understand how they locate their feeding areas and relocate their nests. It appears that they are able to detect the molecule dimethyl sulphate – which has a strong sulphurous smell – emitted by zooplankton feeding on phytoplankton several tens of km away by flying and hunting into the wind. A similar experiment was carried out on the king penguin between 1992 and 2001 during the El Niño phenomenon** (El Niño South Oscillation, ENSO). In 1993, the penguins only had to cover 338 km on average (one way trip) to reach the polar front for their fishing and in 1996, 437 km. This was once again the case in 2000, with an average distance of 366 km. But during the ENSO, the king penguins had to cover 526 km in 1997 and 642 km in 1998, which obviously had a great impact on their reproduction.

More-advanced monitoring equipment has been developed and attached to penguins, allowing scientists **to monitor the depths to which the fish feed**. Thanks to this new instrument, it is possible to monitor the success of their fishing in relation to the depth of their dives during the penguins' trip to the polar front and back. The studies have yet to be published.

An experiment on equipping **sea elephants** is also currently being carried out within the framework of an international programme. The sea elephants are equipped with tags capable of measuring ambient pressure and therefore the depth of the animal's dive, as well as temperature and conductivity, and therefore a certain number of ambient characteristics.

The studies are being carried out on animals living in the Kerguelen Archipelago and which in fact feed off the coast of Antarctica! The results are very important, because they have shown that the sea elephants dive as far down as 1,500 m once a day on their way to the continent. Nearly 7,000 oceanic profiles of temperature and salinity have been established, which, along with the information they furnish biologists, will be transmitted to oceanographers.

For all of these animal studies, a request must be made to the **Ethics Committee of the CNRS** of the Midi-Pyrénées region and they must also obtain prior approval by the IPEV's Scientific Council. For Spitzberg, a Norwegian authorization is necessary, and in the TAAF an authorization by the prefecture is required. These studies must always be justified and proportionate, must not disturb the animals and must not induce abnormal behaviour which would not be in the scientists' best interest. They play an important role in our understanding of these species and their environment, as well as in their conservation.

However, researchers are questioning the necessity to maintain all of these different filters and the need to re-request each year the same authorizations for the same programmes on the same animals. Indeed, shouldn't a lightening of these regulations be considered, one which would not be harmful to the protection of these species, but which would take into account the routine character of certain operations and the trust we can legitimately have in our scientific personnel within the framework of multi-year programmes?

2. Hormonal, molecular and genetic research

Biological research in the polar regions makes increasing use of extremely sophisticated scientific equipment to study metabolism from the inside and to explain certain adaptations. It calls upon specific hormonal, molecular and genetic research.

Research on **the role of hormones in adaptation mechanisms** is being carried out at Chizé, in particular within the framework of studies carried out in the Arctic on the black-legged kittiwake. This Franco-Norwegian programme is aimed at understanding why this bird common to our coasts is two to three times less fertile in the Arctic (a single chick instead of two or three). Of course, the answer lies in the particular climatic situation and the general environment, but the researchers want to understand the energy-use and hormonal mechanisms that affect the level of reproduction, the date at which the eggs are laid and the regulation of the population. The kittiwakes could, in fact, lay just as many eggs as in our latitudes, but suffer heavy losses among the chicks. To do this, the scientists must therefore have the necessary means for the characterization of these hormones.

As regards molecular research, a good example can be seen in **the research carried out in Lyon by the Laboratory of Integrative Cellular and Molecular Physiology on the penguin's adaptation to the cold**. As your rapporteur already pointed out above, birds – and, therefore, penguins – have no brown adipose tissues in which mitochondria[1] produce heat. In these tissues, thermogenesis is provoked by a decoupling of oxidations linked to the presence of a particular protein known as UCP1. Penguins have developed other thermogenic mechanisms, located principally in the musculus skeleti. A protein homologous to UCP1 has there been characterized. The laboratory has been able to demonstrate that this protein is the result of an adaptation mechanism linked to the necessity for juvenile penguins to prepare for their adult life at sea, where thermal stress is much greater. Following muscular biopsies, it was possible to demonstrate that it is indeed successive immersions that provoke the production of this UCP. The presence of this protein is detectable by molecular biology techniques such as RT-PCR (reverse transcription polymerase chain reaction) which is correlated with the increase in messenger RNA codifying the protein. This research also suggests that another protein of the mitochondria's internal membrane (ANT - adenylic nucleotide transporter) plays an important role.

Genetic research is increasingly utilized to study polar animals. The objective of sequencing their DNA is to understand the **genetic particularities which, for instance, explain their resistance to cold**. This is particularly the case with regard to certain species of fish.

Genetic analysis also allows scientists **to understand the history of a species**, comparing those members of the same family which remained north of the polar front and those now located south of the front and which needed to become acclimatized to their new climatic conditions. It can also provide scientists with **information regarding the evolution of the polar front**. At one time, the polar front was most likely located much further north, which explains why certain species of fish have genetic adaptation mechanisms even though they now live north of the front.

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[1] *Mitochondria are cellular organelles about a micrometre in length. They stock energy in the form of ATP following an oxidation process. ATP (adenosine triphosphate) is a molecule used by all living organisms to produce energy. It is used in the synthesis of RNA.*

Genetics is also a powerful tool for population studies, considering the fact that in this immense ocean with very few landmasses, the same species are to be found on islands or on the coast several hundred or thousand kilometres from one another, even though they are philopatric and therefore have a low dispersal rate. For example, genetics has recently shown that **the rockhopper penguin is not one but two species of penguin**, one living along the polar front, the other at the subtropical convergence (there is a difference in water temperature of 10° C between the two locations).

Until then, this genetic distinction was only a hypothesis stemming from observations made by French researchers (Pierre Jouventin) who had noted differences in the size of the birds' yellowish-orange crests above the eyes and in their singing, event though the other biometric characteristics traditionally utilized by taxonomy remained similar. The scientists took advantage of the gradient of the French territories. Indeed, the southern rockhopper penguin is characteristic of the Kerguelen Islands and Crozet, while its northern cousin is to be found on Amsterdam Island. Thirty years were needed to transform this hypothesis into a scientific fact, following the genetic analysis of blood and feather samples taken from various specimens.

The data thus obtained doesn't just allow for the determination of separate species, it also allows scientists to hypothesize on **the history of these populations and the evolution of the polar front**. It is believed that the early group of rockhopper penguins separated in two during the transition from the Pliocene to the Pleistocene, which resulted in the polar front moving 7° farther north 1.8 million years ago. This isolated the southern islands and provoked a process of speciation in the north. Afterwards, in the north, the rockhopper penguins from the island of Gough in the South Atlantic colonized the island of Amsterdam following its formation 690,000 years ago. In the south, the rockhoppers from the Kerguelen Islands and Crozet (in the Indian Ocean) colonized the Falklands (in the South Atlantic) during a recent period. These migrations would therefore be quite exceptional, following the direction of the polar front (from east to west) over several thousand kilometers.

The likelihood of these migrations is strengthened by other known cases that are comparable. For example, the phanerogams (flowering plants) in Crozet and the Kerguelen Archipelago, which are native to Tierra del Fuego, located 15,000 km away.

3. The implications for the organization of research

All of these new instrumentation and analysis techniques at the service of the life sciences have several important implications for the laboratories. Your rapporteur can identify **at least seven**: the cost of research, the teams' multi-disciplinary character, the critical size of the laboratories, the cooperation with the French and foreign teams, the economic impacts and the social issues.

• The cost of research

The days when all the naturalist needed to carry out his research were a good pair of hiking shoes, a backpack, some paper, some pencils and a few tags are long since over. **Today, the study of polar flora and fauna is a leading edge research necessitating extremely sophisticated technical means: computers, miniaturized equipment, satellites, genetic sequencing, etc.**

These technical means, indispensable to research at the international level, are clearly much more expensive. Making available adequate funding for this new reality is therefore an unavoidable issue.

• The teams' multi-disciplinary character

The mobilization of all this know-how is also only possible in teams or multi-disciplinary research centres which, in addition to traditional knowledge on the polar environments and species, have access to the necessary technical (for the equipment) and scientific competences to carry out new research in these regions.

• The critical size of the laboratories

Significant financial means and a marked, multi-disciplinary character necessarily imply laboratories either of a certain critical size or integrated into larger research centres, so as to be able to pay for the expensive scientific equipment and have the technical capacity for managing and supporting their research. This dimension is also indispensable for the development of international cooperation.

• Cooperation at the national level

During the hearings, your rapporteur heard most of the researchers express **their disappointment concerning the absence of a more active policy of national cooperation, in particular via the research zone** created some fifteen years ago. Several researchers also argued that the monitoring of species via the database should be **the object of an ORE (Environmental Research Observatory) recognized by the CNRS**.

More generally, they expressed their desire for **a better coordination between IPEV and the financing research bodies**, in particular the CNRS and its new department dedicated to the environment and sustainable development (EDD).

One can also hope for **greater and better-coordinated funding**.

• Cooperation at the international level

In both the Antarctic and Arctic, the geographic conditions strongly encourage international collaboration to progress in our understanding of the species and of their environments.

Following a period marked by the study of colonies and species present in the vicinity of national research stations, we can now expect to see a new period of exchange between scientists of different nationalities working on the same species. Whether for long-term monitoring or genetic population studies, the usefulness of comparing French data with data collected by our foreign counterparts is obvious. **Adapting to a changing climate and the preservation of biodiversity are international issues.**

• The economic impacts

This research also has a significant economic impact, at two very different levels.

The first level is that of **fish management**. Antarctic fishing is an important economic issue. It poses management and conservation problems in which the scientists, whatever their speciality, play a major role by providing a vision of the state of the ecosystem and by proposing suitable technical solutions for the preservation of species.

The second level is that of **uncovering and making economic use of proteins and molecules that can be used for medical or veterinary ends**. This dimension is often glossed over, but in the future it could represent an area of significant research development and a closely related source of funding.

• Societal issues

Finally, **biological research in the polar environment has become symbolic of such important societal issues as climate change and the preservation of biodiversity.** To the regret of some, the public readily identifies with the polar bear and the emperor penguin, perceiving threats to the animal as threats to mankind. This perception also engenders increased ethical requirements for the study of animals. Beyond this rise in awareness, the accentuated climate change at the poles makes these species early indicators and increases the societal demand for research.

IV. OBSERVING THE EARTH, OBSERVING THE UNIVERSE

The polar regions, particularly Antarctica, are extremely important places for the observation of both the Earth and outer space.

A. OBSERVATORIES FOR THE EARTH AND THE UPPER ATMOSPHERE

France maintains several observatories in the polar regions and carries out regularly-scheduled missions.

1. Seismology

Seismological observations are carried out by the University of Strasbourg I, under the direction of Michel Cara.

In Adélie Land, for the past 40 years, in the Kerguelen Archipelago since 1983, in Crozet and in Amsterdam, these activities are carried out by an ORE (environmental research observatory).

The objective is to make very-wide-frequency-band and wide-dynamic-range measurements of ground movements. These observations are carried out continuously. Their stability and homogeneity are essential for their scientific utility.

The observatories are part of an **international network** and the collected data is made available to the international scientific community.

These stations are also extremely valuable in providing **early warnings of tidal waves in the Indian Ocean**.

The French Atomic Energy Commission (CEA) also maintains observatories as part of the Nuclear Non-Proliferation Treaty, so as to be able to detect any nuclear testing.

The current objective is to install an international seismology station at Concordia, so as to complete the network in an area in which very little data is available. This station should allow scientists to increase their understanding of the Earth's structure and earthquakes. An antenna of seismometers will be installed to observe seismological phases of little energy. Indeed, Dome C is particularly interesting to study the propagation of seismic waves along the North-South axis, because it is more rapid than along the equator due to the action of the Earth's core.

In addition, these stations would study - in partnership with Australia and the United States within the framework of the GAMSEIS project - the bedrock and, in particular, the Gamburtsev sub-glacial mountain chain, because the glaciers perhaps originated from this zone 25 to 30 million years ago.

To this end, the Australians and Americans would set up 25 autonomous stations, to be extended by some ten more stations towards Concordia. They must, of course, be sufficiently energy efficient to continue functioning during the winter months, which is technically very difficult. They could therefore be equipped with small wind turbines.

2. Measuring gravity and terrestrial magnetism

The University of Strasbourg I is also responsible for the monitoring of terrestrial magnetism and gravity.

In the Kerguelen Islands, Crozet, Amsterdam and Adélie Land, absolute measurements are carried out of the terrestrial magnetic field and of its variations. These measurements are made so as to better understand our planet's interior. They are **transmitted around the world via the Intermagnet network**. Dumont d'Urville is located near the magnetic pole, where the terrestrial field lines are vertical. In addition, the magnetic pole is moving rather rapidly north (it was located in the continent's interior in the middle of the 19th century). It is therefore very interesting to monitor it, given the fact that the magnetic poles have already been reversed several times in the Earth's history.

A station should be constructed on Dome C and used in collaboration with the Instituto Nazionale di Geofisica y volcanologia (INGV) in Rome. The objective is to have an **international** station that can be integrated into the Intermagnet network.

A temporary research programme is also aimed at measuring the absolute gravitational field in the sub-Antarctic islands and Antarctica thanks to a portable absolute gravimeter. This should allow for maregraphic measurements to be made and contribute to our understanding of the local geoid[1]. It should also allow for a better appreciation of inter-annual variations and their comparison to measurements made from space.

[1] The geoid is a more precise representation of the Earth's surface than the spherical or elliptical approximations. As an equipotential surface with a specific weight, the geoid serves as a reference point for precise measurements.

3. Studying the stratosphere and monitoring the ozone layer

The discovery of the hole in the ozone layer in 1985 at Halley Bay by Joe Farman, Brian Gardiner and Jon Shanklin (see Farman et al, *Nature*, 1985) opened up an entire field of research, seeking both to measure this hole and to understand the mechanisms in ever greater detail.

• Quantifying the hole in the ozone layer

Since 1985, the hole in the stratospheric ozone layer[1] has been a recurring, seasonal (austral spring) phenomenon. The ozone layer can decrease by 60-70% above the Antarctic.

The mechanisms resulting in the ozone-layer hole are now well known:

- a rise in the concentration of halogenated products in the stratosphere over a long period of time;

- polar masses isolated in the wintertime because of the vortex (see the Vorcore project below);

- an intense cooling (temperatures below - 80° C);

- the activation of chlorine-containing compounds;

- a 4-5% loss per day of ozone starting in September, leading to the total or near-total disappearance of ozone at an altitude of between 14 and 22 km.

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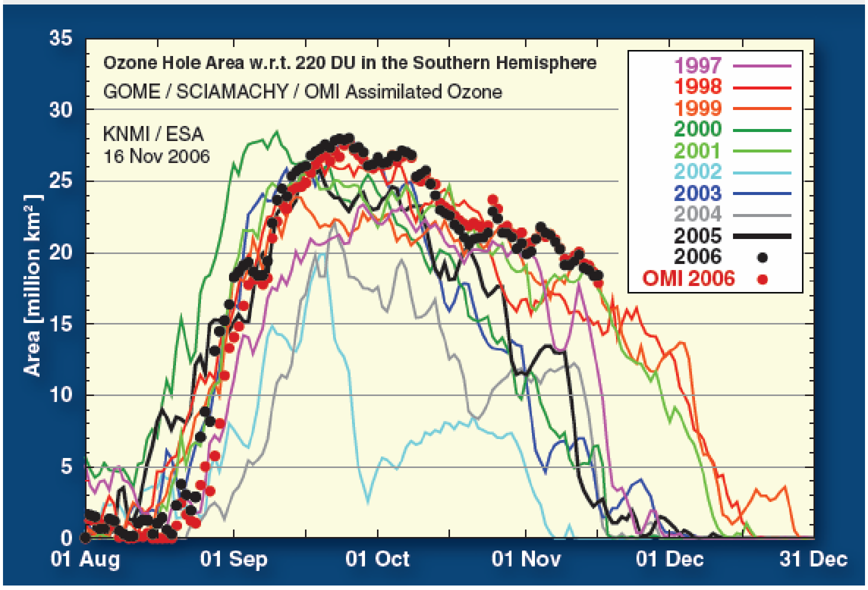
[1] *The problem with stratospheric ozone is not connected in any way with the ozone-peak phenomena observed in heavily polluted, urban areas. The ozone located at ground level is not connected to that located in the stratosphere. This is best understood by taking into account the different layers of the atmosphere:*
- the troposphere: 0-12 km in altitude.
- the stratosphere: 12-45 km in altitude
- the mesosphere: 45-90 km in altitude.
- the ionosphere: over 90 km in altitude.

Inter-annual variability in the ozone-layer hole



Source: Sophie Godin-Beekmann (IPSL-SA, CNRS-UMPC-UVSQ)

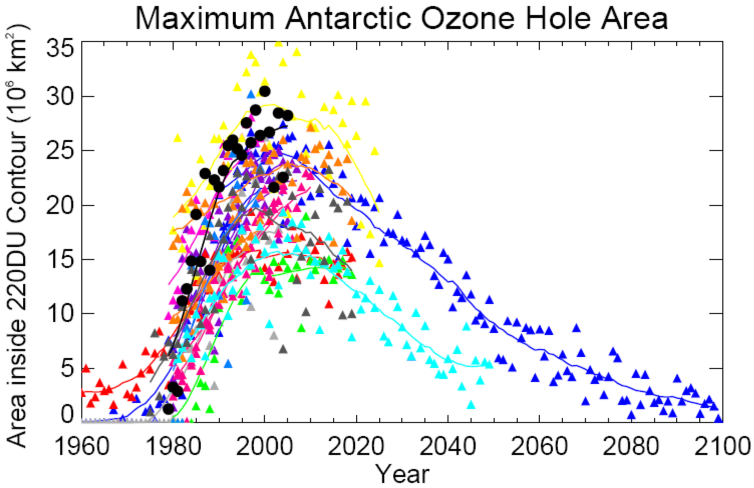
France is part of the **international surveillance network** via an ORE (environmental research observatory) placed under the direction of the Service d'Aéronomie (IPSL-UPMC-CNRS). This scientific network was created following the signature of the **Montreal Protocol in 1987**, which organizes the return of CFC[1] emissions to their natural level.

The hole in the ozone layer can have an important impact, because it provokes an increase in the amount of UV rays that reach Earth, causing skin cancers, cataract, immunitary problems and damage to all living organisms.

The measures carried out by the researchers, therefore, seek to monitor the evolution of this phenomenon and anticipate its reduction. They must allow scientists to measure the impact of the Montreal Protocol and, taking into account its success, the other international agreements which strengthened it.

[1] *Chlorofluorocarbon.*

Expected evolution in the ozone-layer hole over the Antarctic



Source: Sophie Godin-Beekmann (IPSL-SA, CNRS-UMPC-UVSQ)

- **Understanding the mechanisms**

The Vorcore project is a major research project carried out in France on the lower Arctic and Antarctic stratosphere using long-lasting sounding balloons.

The objective of the Vorcore project is to study the dynamics of the Antarctic vortex using sounding balloons to understand the formation of the ozone hole during the austral spring, by measuring the impermeability of the polar vortex and therefore its small-scale porosity.

It is a **good example of the complementarity of Arctic and Antarctic research**. A series of tests was carried out in the Arctic between 2000 and 2002 and a measurement programme was carried out in September 2005 from the McMurdo American research station.

Therefore, it is also a good example of **international cooperation** and the quality of relations maintained between several partners. Indeed, the NSF accepted to bring nine French researchers to the American base during the first rotation at the end of September. Eight other stations accepted to carry out balloon launches coupled with the passing of the Vorcore balloons to complete the measurements.

The Arctic programmes of 2000 to 2002 were carried out from the Swedish Kiruna base. They had difficulty in obtaining the necessary authorizations for flying over the different territories.

27 balloons where launched from 5 September to 25 October, the last of which was destroyed on 1 February. They flew an average of 63 days and collected 150,000 observations.

4. Observing the ionosphere

The polar regions - and, for our country, the Antarctic bases – are important locations for observing the connections between the Earth and the sun, in particular the ionosphere.

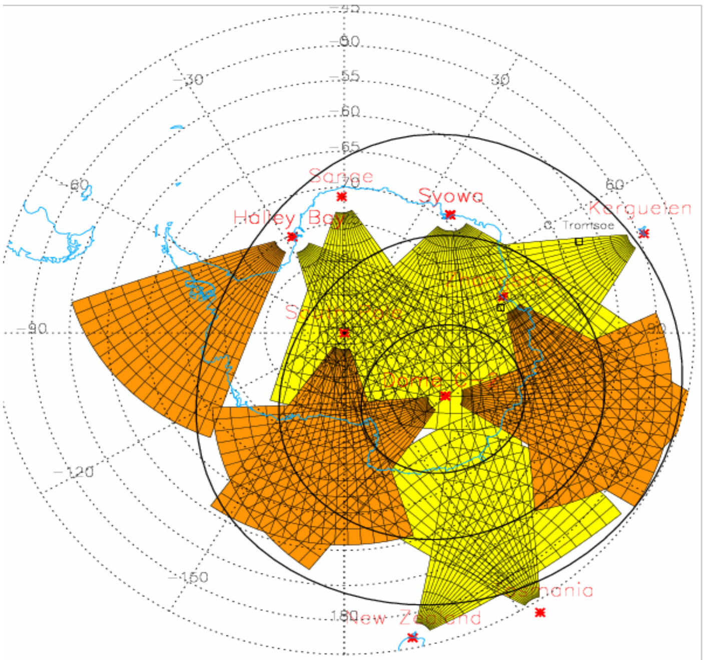
The ionosphere is located at an altitude of over 90 km and forms a charged zone under the effect of the sun. It has significant meteorological and technological effects: **magnetic storms** can provoke gigantic power failures, especially in North America where the magnetic pole is located within Canada.

Aurora borealis and australis are undoubtedly its most beautiful manifestation. They are best observed at the geographical poles, because they are closer to the magnetic poles which concentrate the ionized particles emitted by the sun.

To measure these phenomena, SUPERDARN radars are used. They are the subject of an **international cooperation programme** to cover the North and South Poles.

In the southern hemisphere, France already uses one radar in the **Kerguelen Islands. At Concordia, two trans-horizon HF radars** will be installed for the longitudinal sectors between the Kerguelen and Tasmania and between New Zealand and the British Halley Bay base. They will function in pairs, one with a radar from the South Pole base and the other with the Chinese Zongshan base. They will be built and used within the framework of the programme of Franco-Italian cooperation at Concordia.

The international Superdarn network in Antarctica



(*Source: IPSL-CNRS-UVSQ-Research Centre for Terrestrial and Planetary Environments)*

The scientific objectives of the programmes for making optical measurements in the visible of the aurora australis at Dome C (Auroral Light Fine Analysis - ALFA) are:

- studying the energy and material exchange in the transpolar arcs;

- fine analysis of light emissions in the ionosphere (between 150 and 300 km in altitude);

- the interaction between high–energy electrons and the ionosphere;

- the formation of density irregularities in the regions of electron precipitation;

- the movements of plasma linked to the electrical currents aligned with the magnetic field.

B. ANTARCTIC ASTRONOMY: A NEW FIELD

Since July 2006, SCAR has recognized astronomic research as an important field of research in Antarctica. This research is in full expansion, of which the United States is already well aware as can be seen at their South Pole base, while France and Italy have a major asset in the form of the Concordia station.

1. Recognizing this fast-growing discipline

Reflections on the development of astronomy in the Antarctic began in the early 1990s and the first series of tests at the South Pole base took place between 1993 and 1994.

Ever since then, major projects have been developed at the American base.

Your rapporteur will here discuss two which seem to him to be particularly significant for the scientific influence: studying cosmic background and detecting neutrinos.

- **Studying the universe's cosmic background**

Measuring the universe's fossil radiation is a fundamental scientific and philosophical area of research, because it seeks to understand the state of the primordial universe and to get as close as possible to the moment of its birth, the Big Bang.

The first measurements were made by NASA's **COBE satellite** in 1992. This discovery allowed the American researchers John Mather and George Smoot to obtain **the Nobel Prize in 2006**. They carried out the first precise observations of the cosmic background, the luminous radiation that appeared 300,000 years after the Big Bang. Fossil radiation had been accidentally discovered in 1964 by Arno Penzias and Robert Wilson at the Bell Laboratory. But at the time, it was impossible to measure this radiation from the Earth; this led to the COBE satellite project. For the authors, the main results of these observations were the confirmation of the Big Bang Theory (an expanding universe from an initial starting point) and the publication of a map of the cosmic background radiation revealing the temperature variations (anisotropies). These results would allow scientists to understand why the universe is not homogeneous, but rather made up of vacuums and islands of matter.

More recently, the measurements made by **the WMAP (Wilkinson Microwave Anistropy Probe) satellite** have been very largely disseminated. This satellite provides a new image of the early universe, one that is infinitely more precise than that provided by COBE. It shows a polarization and orientation of light. It allows scientists to specify the universe's distribution of matter: 4% of ordinary matter, 22% of dark matter and 74% of black energy. It allows scientists to clarify the formation scenario for the first stars and galaxies.

The Antarctic appears extremely complementary to research carried out in space. Indeed, the Antarctic's very specific conditions allow for work to be carried out of a precision equivalent to that undertaken in outer space. It also offers the advantage of allowing researchers to use the latest, most advanced equipment that can also be rapidly repaired.

Several experiments were carried out from the South Pole base, particularly in 2000 (Boomerang), from a measurement balloon.

In addition, within the framework of a collaborative programme between the United Kingdom and the United States, the QUEST (Q and U Extra-Galactic Survey Telescope) was deployed in 2004-2005 on DASI, an interferometer for measuring anisotropies of temperature and polarization.

In this field, on Concordia, within the framework of Brain, a Franco-Italian team installed bolometers. These sensors consist of a crystal whose temperature varies according to the energy of the particles that hit it. They are placed within a cryostat which cools them to a temperature close to absolute zero.[1]

At the time, these experiments allowed scientists to produce images of the cosmic background much more rapidly, much less expensively, and – taking into account the use of the most advanced technological equipment – much more precise than had been the case with the COBE satellite during its several years of use.

Today, this research is carried out on-site, so as to continue to clarify the measurements, under the personal direction of one of the two Nobel Prize winners, in preparation for the launch of the European Planck mission in 2008. What's more, the satellite's technology was tested in the Arctic from a balloon (the Archeops Mission) launched from Kiruna, Sweden.

- **Searching for neutrinos: the Ice Cube Project**

Another example of the importance of astronomical research carried out in the Antarctic is the international programme for the detection of neutrinos.

Under the direction of the United States and on the initiative of the University of Wisconsin at Madison (Prof. Francis Halzen), a very important research programme is underway on neutrinos. It receives $295 million in funding from the National Science Foundation (NSF), in association with several countries: Sweden, Belgium, Germany, the United Kingdom and the Netherlands.

This construction for this programme, known as **Ice Cube**, should be completed in 2009.

Neutrinos are elementary particles with almost no mass created by nuclear reactions. The sun and other astronomical phenomena produce low-energy neutrinos, while cosmic cataclysms such as black holes, supernova or the Big Bang produce high-energy neutrinos. Scientists are searching for the latter.

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[1] *Absolute zero: 0 kelvin (K) = -273.16°C.*

Once generated by these cataclysms, the neutrinos move at the speed of light and do not stop. Having virtually no mass, they very rarely interact with other particles, allowing them to move in a straight line all the way to the outer limits of the universe, passing through any celestial bodies - stars, planets and magnetic fields – on their path, as though they didn't even exist. In this manner, trillions of neutrons pass through Earth every nanosecond. However, for astrophysicists, each of these particles is a potential messenger carrying information on its origin.

However, neutrinos are extremely difficult to detect. They can only be detected when they collide with a molecule. The collision disintegrates the nucleus and the neutrino is transformed into another particle called a muon. The muon continues on the same trajectory as the neutrino, but can be detected thanks to the cone of blue light it creates (Cherenkov radiation), similar to the airwave produced by a bullet.

In order to successfully detect muons, one must observe a vast amount of a perfectly transparent substance in total darkness.

In the early 1980s, the United States attempted to create a detector off the coast of Hawaii in the depths of the ocean. However, the instable weather and sea conditions prevented this experiment from being a total success. Antarctica's ice would appear to be much more promising. A first generation already exists: the AMANDA (Antarctic Muon and Neurtino Detector Array).

The new generation is represented by the **Ice Cube**, which will consist of **5,000 photomultiplier detectors set in 1 km^3 of ice, at a depth of between 1,400 and 2,400 metres below the South Pole**. It will therefore be possible to take advantage of Antarctica's darkness and crystal-clear ice. These detectors will serve to multiply the signal some 100 million times and to send it to the surface, where it will be processed by computer. In this manner, it will be possible to determine the particles' direction and origin, and therefore to study the cosmic event that created them.

This experiment is linked to other programmes abroad: Auger in Argentina, Antares off of Toulon, and Nemo and Nestor in southern Italy.

These research programmes carried out in Antarctica **are also linked to one of today's most advanced domains in fundamental physics.**

What's more, Raymond Davis was awarded the Nobel Prize in physics in 2002 for his research on neutrinos. He was one of the first, in 1968, to construct a basin filled with 600 tons of chlorine-rich solvent which was then buried 2,300 m below ground in the Homestake mine in the United States in order to detect neutrinos emitted by the sun.

Not finding all the neutrinos that he expected to find, he put forward the hypothesis of their oscillation; these results were confirmed in 1998 by the Japanese "Super Kamikande" experiment, which used a much larger detector.[1]

Neutrino research is not only derived from particle physics; **certain researchers speculate that following the Big Bang, a background of neutrinos was present alongside the cosmic background already detected.**[2]

2. Concordia: the best site in the world for astronomic observations?

For the Concordia station, two questions arise: Is the site as good as is hoped? What are the development projects for astronomy?

- **Qualifying the site**

Concordia Dome appears to be one of the best locations in the world for astronomy.

The Franco-Italian site would seem to combine all the ideal conditions for an astronomical observatory: clear, cold, dry, clean, dark, low precipitation, little wind, little turbulence, little seismic activity, accessible, climatic stability and the possibility of carrying out continuous measurements.

The atmosphere is very stable due to an altitude of 3,300 m, far from any pollution.

The little wind there is – less than 2.5 m/sec – blows in a constant direction. Its results are clearly superior to those of the great Chilean sites. This also represents a major difference when compared to the South Pole site, which is subject to katabatic winds due to an altitude of only 2,830 m, while Concordia is located at the summit of a dome.

A temperature of always less than -30°C should allow for increased performance in the use of infrared.

During the austral summer, image stability is less than 0.5 arc-seconds for 4 hours, or two times better than the best known terrestrial site, Cerro Paranal in Chile, where the European VLT is located. The scintillation is very low, offering a coronal sky.

During the austral winter – in other words, at night – the sky is clear 95% of the time.

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[1] *Jean Orloff, Université Blaise-Pascal Clermont-Ferrand, La Recherche, No. 402, November 2006.*

[2] *Julien Lesgourges (CNRS), La Recherche, November 2006, No. 402.*

However, between 0 and 30 m, the site is not as good and prevents any work from being carried out. These disturbances (0-150 m) are caused by the temperature inversion layer, with maximum disturbance between 0 and 30 m.

These turbulences must be made clear, in particular to determine if they are stable throughout the year in terms of altitude and thickness. If this is the case, they would not constitute a major handicap.

Indeed, the large instruments are built above this turbulence.

Therefore, the question is knowing if these supposedly excellent conditions do indeed exist and could lead to the installation of one, or even several, large instruments. We should have the answer to this question very soon.

- **Defining a strategy for astronomy at Concordia**

The prefiguration of European astronomy in the Antarctic is the object of a European network: ARENA (Antarctic Research, a European Network for Astrophysics). It is coordintated by Nicolas Epchtein, at LUAN (the University Laboratory of Astrophysics at Nice).

This network, registered at the 6th PCRD, enjoys a budget of €1.3 million over 36 months between 2006 and 2008. France receives 36% and Italy 31%. This network is largely open, because, in addition to the two leader countries at Concordia, the following countries are also present: Germany, Spain, Belgium, Portugal, the United Kingdom and Australia, gathering together 15 laboratories and 120 scientists. Japan and New Zealand also sent representatives to the first annual conference in Roscoff.

Numerous projects are emerging from this reflection. They should be classified by priority, but demonstrate the scientific community's very great interest in this site: wide-range imaging, high angular resolution, precise photometry, interferometry, etc.

For your rapporteur, it is clear that looking beyond this question of the site's qualification, a credible strategy needs to be formulated for strengthening Concordia scientifically and logistically, by taking into account all the engineering constraints (energy, communications, transport, robotics, environment).

Therefore, we must **first turn towards projects of a high scientific level but that are compatible with the current logistics, so as to then develop larger projects that could, in 10 to 15 years time, rival the Andean sites**.

This strategy must also take into full account the desire of the Chinese to set themselves up on Dome A in a permanent manner, starting during the IPY of 2007-2008. Inspired by the Franco-Italian dynamics at Concordia, China would like to not only carry out very deep ice coring, but also develop an astronomical station taking advantage of the site's higher altitude (4,083 m) and enjoying similar, if not better, conditions than those of Dome C.

Today, there isn't cause to dramatize competition from China, but it should be taken very seriously. Indeed, last year, expedition to Dome A encountered a serious incident necessitating emergency assistance on the part of the Americans and the evacuation of one of the expedition's members. In addition, Dome A is undoubtedly one of the least accessible sites on the planet and significant, dependable logistics need to be put in place before a permanent station can be built in which researchers could winter. Several years of observation are also needed to validate the site's astronomical quality and start research.

Having said that, **in the opinion of your rapporteur, competition from China engenders five proposals:**

- The Concordia station must first and foremost demonstrate its scientific potential in astronomy.

- In particular, a consideration must be made of the **its scientific contribution compared with that of the South Pole base**, at which considerable material means are already available.

- It must then **demonstrate a growing logistical capacity**, perhaps by considering new routes.

- **Europe must also define a political strategy** to position its research at the highest international level.

- There is **a limited amount of time** to deal with all of these points.

- **The scientific projects at Concordia**

The scientific projects are gathered together within the Stella Antarctica project. IPY-certified, it is coordinated by Eric Fossat at LUAN. It distinguishes **two important scientific subjects**: the exoplanets and the early moments of the universe.

The first **exoplanet** was discovered less than 10 years ago. Since then, more than 100 planetary systems have been discovered. But no exoplanet, nor any planetary system similar to our own, has been directly observed. These planets are small, cold, dark and close to their suns. The observation instrument must therefore be specific and extremely precise. This research requires great angular resolution in the infrared. This would suggest using a network of Earth-based interferometric telescopes.

Following qualification, this project would be developed in two stages: an initial project of limited size to validate the project's potential and study via spectroscopy the nature and composition of the atmospheres of the already known exoplanets, allowing for the exploration of the disks of dust and gas in which the planets are formed. A much larger project could then be set up to make an inventory of the exoplanets.

The second big research subject is **the polarization of the Big Bang's fossil electromagnetic radiation**. It has a very weak component (type B modes) that corresponds to the imprint left by the gravity waves. It is very difficult to measure, because of its weak intensity and the large angular size of what is looked for in the sky. It necessitates a very stable microwave sky background, as is the case at Dome C.

The closest projects are the ASTEP (Antarctic Search for Transiting Extrasolar Planets) instrument, to be installed at Concordia in 2008. This 40-cm-in-diameter instrument will be used to detect exoplanets. This qualification instrument could be followed in 2012 by a larger one: Ice-T, coordinated by Germany.

In 2008, an Italian infrared telescope will also be installed: the International Robotic Antarctic Infrared Telescope (IRAIT).

As regards stellar seismology, France would like to carry out the SIAMOIS (Seismic Interferometer Aiming to Measure Oscillations in the Interior of Stars) experiment. This should allow scientists to understand the internal structure of stars, via a longterm and very precise photometric observation and in coordination with the Corot satellite. These conditions are to be found at Concordia, because the sky can be observed 90% of the time during several consecutive months. SIAMOIS will pay particular attention to shining stars of little mass detected by Corot. The programme should be carried out over 6 winters starting in 2010, for a cost of €860,000.

In addition, in preparation for the Darwin space mission to discover exoplanets and search for life, French researchers are planning an Alladin mission, based on the principle of black-fringe interferometry. Its objective would be to demonstrate on Earth Darwin's expected technical functioning and to validate the scientific concepts. It will contain two telescopes within a tool 40 m in diameter, simulating the formation flight in space of the Darwin mission satellites.

Scientists imagine for the future a gigantic infrared interferometer consisting of 36 telescopes covering an area of 1 km^2, the cost of which would be similar to the large Andean instruments.

3. Searching for meteorites in Antarctica

Although the first meteorite was discovered in 1912, it was not until 1969, following the simultaneous discovery of four meteorites, that Antarctica was recognized as being a formidable hunting ground. Indeed, meteorites statistically imprisoned in the ice[1] are progressively concentrated by the large glaciers and later resurface in certain areas, in particular when terrain features push up the ice.

Two thirds of all meteorites were discovered in Antarctica!

At Concordia, it's not only a question of collecting as many as possible, but, on the contrary, of discovering new types of meteorites. Indeed, the Concordia site is subject to very little horizontal movement, which is why it was chosen for ice coring.

This characteristic, already taken advantage of for ice core dating, is also a great asset for measuring the abundance of meteorites and their composition over time on our planet; it could also allow for the discovery of variations.

The Concordia site also provides scientists with access to meteorites that were only a little transformed during their fall through the atmosphere, due to the atmospheric particularities at the poles.

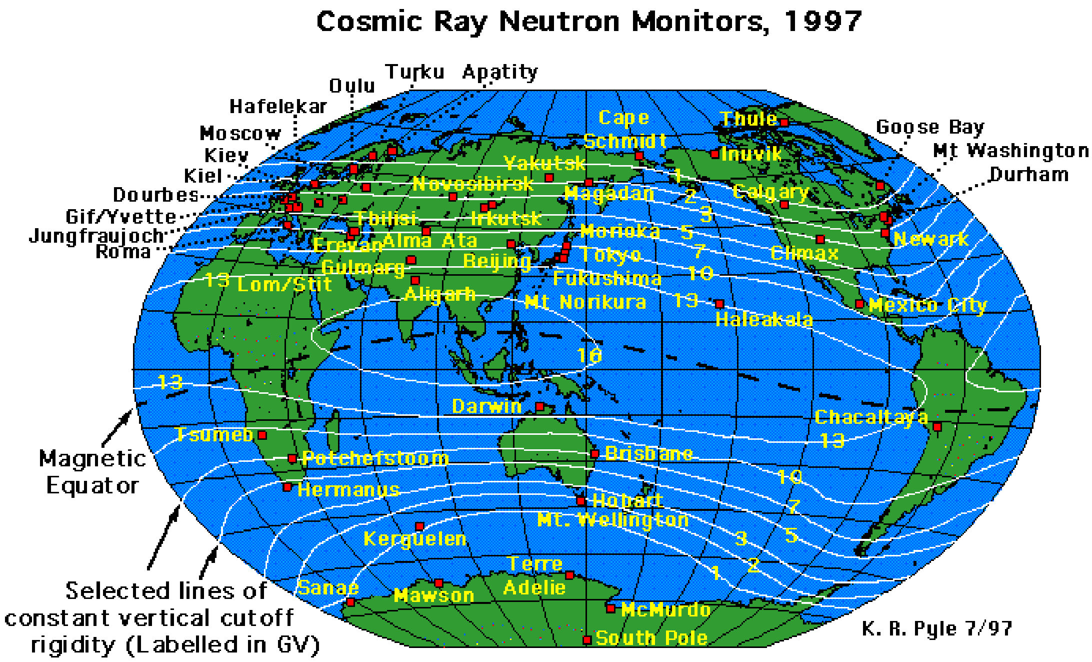
The programme carried out in the summer of 2006 was a great success, with 1,500 particles **20-50 micrometres in diameter** having been collected.

Finally, the purity of this exceptionally well preserved site allows scientists to locate very small meteorites – submillimetric and micrometric – because the collection area is made up entirely of snow. These meteorites are also exceptionally well preserved considering the amount of time spent on Earth, because they are not contaminated by other dust particles, thanks to Concordia's great distance from any dust-carrying currents. The French research team, directed by Jean Duprat, hopes to be able to demonstrate the existence of cometary micro-meteorites or meteorites from the external solar system. They should provide information on the conditions of planetary formation, 4.5 billion years ago.

[1] *Every year, 5 to 6 thousand tons of meteorites fall on Earth.*

4. Measuring cosmic radiation

France has installed **neutron monitors in the Kerguelen Islands since 1964 and in Adélie Land since 1968**, with a break in the latter location from 1977 to 1982. These monitors measure high-energy particles emitted by the sun and other stars. These observatories are part of an **international network** (the International Space Environment Service - ISES).



(Source: the Paris-Meudon Observatory – LESIA)

At the national level, the objective would be to make them an ORE to stabilize the research activity.

Instruments placed at the French bases are used to count the particles, allowing scientists to monitor their source and energy.

The primary particles of cosmic radiation (85% of protons) do not reach the ground. Their collisions with atmospheric particles create secondary particles - nucleonic components consisting of protons and neutrons. They can be detected on the ground if the kinetic energy of the original particles is over 0.5 GeV.

Before reaching the atmosphere, cosmic rays are deflected by the Earth's magnetic field, which forms a "geomagnetic break" limiting a particle's capacity to reach the ground. The least-energized particles only reach the surface in the high latitudes.

Each station is also characterized by an "asymptotic direction", or the deviation of the particle - according to its energy – in arriving vertically at the station. For example, the low-energy particles that arrive vertically in the Kerguelen Islands come from areas of the celestial sphere located above Brazil. Their propagation is so complex that two nearby stations such as McMurdo and Dumont d'Urville have opposite asymptotic directions.

These neutron monitors provide valuable information on solar activity, because cosmic radiation depends greatly upon solar activity. Strong solar activity provokes a reduction in cosmic radiation, due to a phenomenon of repulsion provoked by the heliospheric magnetic field (a timescale of one year), a temporary reduction due to particle ejections (a timescale of one day) and, finally, by the production of certain relativistic particles during certain irruptions (a timescale of a few minutes).[1]

These magnetic observations are **applied directly to human health, because exposure to natural radiation is now monitored, in particular the exposure of the airlines' flight personnel**. This monitoring is organized by European directive no. 96-29 EURATOM of 13 May 1996 on exposure to ionizing radiation.

In France, this data is stored in the SIEVERT (Computerized System for the Evaluation During Flight of Exposure to Cosmic Radiation among the Airlines) system. This service, established by the DGAC (Department of Civil Aviation) for professionals, is also made available to the general public as an informative measure and teaching tool. The most exposed air routes are those passing over the Far North - in other words, flights to North America or Asia from Europe. The occupants of the polar bases are also exposed.

In the future, measuring radiation will also be important to **protect planes from experiencing power failures**.

In a more fundamental manner, understanding variations in solar radiation and measuring the isotope 10 of beryllium (^{10}Be) in the ice cores should allow for progress to be made in the reconstruction of past solar activity.

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[1] *Your rapporteur is here referring to an article by Pierre Lantos and Christophe Marqué (CNRS, the Paris-Meudon Observatory, Laboratory of Solar and Heliospheric Physics) and a presentation by Karl Ludwig Klein of LESIA.*

Thus, Antarctica is proving to be an exceptional zone for scientific observation. This leads your rapporteur to make the following **three conclusions:**

- It is desirable to **support and perpetuate the observation activities at our bases**, because they are essential for understanding our planet. Wasn't the hole in the ozone layer discovered by accident thanks to routine stratospheric measurements? **What's more, these activities only make sense if they are permanent, without interruption and carried out at an international scientific level allowing for their integration into the computerized networks.**

- Our country must fully participate in the scientific research being carried out on stratospheric ozone in the polar regions, because **the success of the Montreal Protocol, which will celebrate its 20th anniversary during the IPY, makes it a model for the shared handling of global problems.**

This is symbolized by its objective of returning emissions to their natural levels. It should serve as inspiration in our handling of climate change.

- Finally, France and Italy must **become fully aware of the exceptional qualities of the Concordia site for astronomy and develop a two-phase strategy for strengthening their position: programmes targeting scientific excellence but requiring little in the way of logistics, followed by a positioning of the station to welcome large European instruments with the necessary logistics in 10 to 15 years time, while taking into account the opportunities already offered by the South Pole base and possible competition from the Dome A site.**

V. PREPARING THE SPACE MISSIONS IN ANTARCTICA

Due to Antarctica's extreme conditions and the organization of the bases, it can be used to prepare for the space missions. It is also necessary to carry out in the polar regions operations to prepare and verify the satellite-based and robotic missions.

A. PREPARING AND VALIDATING THE SATELLITE MISSIONS

1. Space and the polar regions: preparation complementarity

Your rapporteur has already shown above the importance of the complementarity between Antarctica and outer space in terms of astronomic research and scientific space missions.

What is true for astronomy is equally true for the preparation of observation missions. Antarctica's extreme climatic conditions and, in particular, the cold and electromagnetic environment make this continent a very useful zone for the testing of equipment - robotic or otherwise - destined for space or for other planets. Indeed, this equipment must be able to withstand extreme conditions similar to those of Antarctica. Equipment that doesn't function in Antarctica has little chance of functioning in space.

Therefore, IPSL is currently carrying out, via the Centre d'études des environnements terrestres et planétaires (Research Centre for Terrestrial and Planetary Environments), a **long-term test on the stability of a triaxial, flux-valve magnetometer** destined to be installed on the surface of Mars. The magnetometer is subjected to thermal variations of between –70 and –30°C, comparable to those it can expect to encounter on Mars. In addition, these performances can be compared to those recorded at the observatory, which is located in a much more stable environment.

Within the framework of the Arena network, French researchers have also proposed **measuring the frozen particles and electric field in Dome C's boundary layer to predict the impact of these phenomena on equipment sent into space**. The measurements would be made using AIRS electric antenna of the vertical electric field, the atmosphere's electrical conductivity, and the dispersal and distribution of charged ice particles.

2. Validating on the ground observations made from space

Despite the spectacular progress made in satellites, projects for the preparation and validation of the collected information must still be carried out. This is particularly true regarding the evaluation of ice, whether inlandsis or sea ice. Your rapporteur would like to here cite two examples characteristic of this work in preparation for the launch of the Cryosat satellite.

- **Calibrating Cryosat on sea ice**

The Electromagnetic Bird (E-M Bird) instrument of the Alfred Wegener Institute (AWI) will be deployed during the International Polar Year, during the mission carried out by Jean-Louis Etienne at the North Pole.

This instrument is designed to be placed between 15 and 20 m above the ice shelf, in order to furnish a continuous profile of its thickness. It consists of a laser altimeter that can be used to measure the distance between the instrument and the upper surface and of an electromagnetic transceiver which, via low-frequency induction, allows scientists to measure the sub-surface depth.

In addition to the centre of scientific interest consisting of studying the changing extent and thickness of the boreal ice shelf, the objective of this mission is to establish a reference value that could then be compared to that obtained by the Cryosat satellite via its laser altimeter, whose principle innovation will be its taking into account all the discontinuities in the ice to produce a much more precise mass assessment.

- **Calibrating Cryosat on continental ice**

This mission was partially carried out by a German team of the AWI. It used an airborne radar: the Airborne SAR Interferometric Radar Altimeter System (ASIRAS). One point calling for clarification was the impact of discontinuities in the snow (in particular those of the upper layer) on the radar echo. The instrument's calibration was carried out on a perfectly familiar terrain, a runway, to allow for a precision of some 2 cm.

Several missions were carried out from March to the end of September 2004 at Svalbard and in Greenland. These missions allowed scientists to obtain a profile of the Greenlandic icecap in two areas and to a depth of some 20 m. As a reference point, a reflective corner was installed such as those used for satellites. A British team confirmed the measurements on the ground via a sledge-mounted instrument pulled by a man.

This calibration programme will be continued by a Svalbard mission in 2007, then in Antarctica in 2008. There will then follow verification missions after the launch of Cryosat in 2009 or starting in 2010.

B. PREPARING MANNED SPACE FLIGHTS AND MOON OR MARS-BASED STATIONS

The conditions of isolation experienced by the personnel of the Antarctic stations are the most similar on Earth to those encountered in space: complete isolation of up to 9 consecutive months; night; extreme cold and therefore confinement; living in small communities or even, for Concordia, an organization similar to that planned for a moon or Mars-based station. Therefore, the bases offer a rare opportunity to carry out research programmes which otherwise would have to be carried out in caissons.

1. Concordia – a unique research site

In this respect, **Concordia is truly the world's most valuable station for the space agencies.** While the permanent coastal stations' climate, geographic location and organization (scattered buildings, at times high number of winter residents) certainly make them interesting locations for carrying out behavioral research, their conditions are still very different from what we could expect to encounter onboard a space vessel or station. In addition, several of these Antarctic stations must deal with a growing number of tourists.

The only other permanent stations located in the Antarctic interior – Vostok and South Pole – are not as interesting for such research. Indeed, the main disadvantage of the South Pole station is its great size. It is therefore not comparable to what could exist in the near future - it rather resembles what could exist on the moon in a few decades. As for Vostok, this station suffers from a certain rusticity which makes this type of research difficult. Both of these bases also have the disadvantage of being old stations which no longer allow for contamination studies set at a level of 0 contamination.

However, Concordia has **all the necessary conditions: a layout similar to what could exist in space; a reduced personnel limited to 15 persons; a multi-national team (Franco-Italian); and a recent station**, in which medical and biological studies have been carried out since its opening.

2. Studying behaviour in an extreme environment

The first field of study is that of human behaviour in conditions of confinement.

An initial research programme studies the psychosocial adaptation of a multi-cultural group in a closed, isolated environment: strategies for "coping"; the influence of the environment; group dynamics; and leadership phenomena. The delicate equilibrium of these stations can rapidly deteriorate.

The team can become obsessed with a relatively small event, leading to a deterioration of the station's atmosphere for a much longer period of time than normal given the absence of more important events liable to divert the team's attention. Similarly, as regards leadership, the scientific teams at the Antarctic stations behave very differently than the military crews of nuclear submarines. Hierarchy, discipline and task distribution at the stations is much less rigid, which can complicate the exercise of authority.

A second programme specifically studies body language, or ethology. The ethological approach focuses on the co-adaptation process of the members of the research team, whose socializing is restrained by extreme conditions. It studies how the individuals occupy space in the collective activity areas by monitoring changes in such behaviour over time. It sheds light on critical moments during the mission and cycles of behavioural change that can be identified by typical behaviour.

In addition to having theoretical repercussions, **this research should help prevent serious crises from appearing within the teams by predicting such problematic situations and aiding in their resolution by referring to model-data.**

These are based on various methods for gathering information, from questionnaires to cameras, which are used very sparingly. **Indeed, the teams are reluctant to take part in studies that are too intrusive and which do not respect their privacy and are difficult to deal with** in a context of confinement, where one major type of behaviour in the middle of the austral winter is that of withdrawing into a reconstructed private space and reducing one's interactions with the other team members. This undoubtedly explains why the biggest celebration in Antarctica is that of mid-winter, which has always been a cause of great rejoicing.

The particularly delicate nature of such research also explains why the directors of several foreign research stations have opposed such studies. They fear that such studies could have serious consequences on their teams, especially as outside intervention is impossible during the austral winter. They therefore prefer to rely on very strict procedures for selecting their teams' members and on their own experience as directors, rather than the integration of teams of specialists in psychology or behavioural studies.

3. Physiological studies

In addition to behavioural studies, the Concordia station allows for the carrying out of several important physiological studies on populations subjected to very particular conditions.

First and foremost, studies on **biological contamination** are carried out at Concordia; these studies seek to understand how pathogens develop in a closed environment, based on an initial situation of zero contamination. Concordia is an excellent site for such research, because nothing - or almost nothing - can survive outside the station due to the extreme temperatures. Thus, **a parallel can easily be drawn between Concordia and long-term space flights or space-based stations**, in which, from an initial "virgin" situation, a new living environment would also develop due to contamination. This research is therefore of great interest.

Another example of research carried out at Concordia is studying the adaptation over time to conditions unique to the site. Indeed, Dome C is located at an altitude of more than 3,000 m, equivalent to an altitude of more than 4,000 m in a very dry and cold atmosphere. It is therefore possible to carry out studies on the adaptation to **hypoxia** in both the first days of wintering and during this entire period.

C. TESTING EXPLORATION MATERIAL

Similarly, the space agencies have recognized the interest of using either the environment or the research stations in Antarctica to test equipment destined for space-exploration missions.

1. American examples and projects

NASA and the NSF have for many years recognized the interest of using Antarctica to test materials liable to be used in exploring the solar system.

Indeed, the McMurdo station is located near a few dry valleys in Antarctica. These valleys are absolutely exceptional sites for a continent covered on average by 2,000 m of ice.

This situation is explained by the sites' morphology and climate. They are completed protected - even over-flights are prohibited without express permission. A few, in particular the high Beacon Valley, have glaciers covered with blocks of rock, producing formations that are very unique on Earth and are somewhat similar to sites on Mars (the Mars Crater Wall).

These sites were used for the testing of lunar rovers. More recently, they have been used to test Mars rovers.

One of NASA's planned futuristic projects will use sub-glacial lakes in Antarctica to test in near-real conditions a cryobot/hyrdobot capable of penetrating the ice covering Europa, one of Jupiter's satellites, or the icecaps of other celestial bodies in the solar system.

All the necessary conditions have yet to be met, because the researchers do not yet have the technology to allow them to avoid any risk of contaminating these lakes.

2. European perspectives

For Europe, as well, Antarctica can offer new opportunities for testing materials before they are sent into space, in particular towards Mars.

Today, the most important experiment is **Concordia's water-treatment system**. Indeed, the station's similarities with a **space station,** or the conditions of isolation similar to those of a **long-term space flight**, have attracted the **attention of ESA**. Another similarity is Concordia's obligations concerning the treatment of waste generated by polar operators, who must remove their waste from Antarctica. They also would like to determine the most effective *in situ* solutions, to save on logistics.

An effective solution must also be found for the production of drinking water. Contrary to popular opinion, water is a problem in Antarctica, because most bases do not have an easily accessible source of fresh (liquid) water. The usual techniques consist of producing fresh water from ice, using either a melting machine or a well. The well technique consists of drilling down to the level at which snow becomes ice and then injecting warm water to melt the ice. But this necessitates often changing the pumping site. The melting-machine technique consists of making a daily collection of snow according to the level of consumption; this can become a real chore, because 4 to 5 m^3 of snow is needed to produce 2 m^3 of water. A system for the recycling of water is therefore a very interesting alternative.

Concordia's water-recycling system is based on the **separate treatment of its "grey" and "black" wastewaters**. The grey wastewater includes water used for both cleaning (body, ground, dishes, clothing) and cooking.

The black wastewater includes organic waste (human excrement, leftovers from meals, expired food) and sludge produced by the grey wastewater. To ensure their separation, two vacuum wastewater collection systems have been installed.

The tests also allowed for the identification of soaps and cleaning products suited to the recycling system, as well as the correct doses. Therefore, Concordia doesn't offer a choice of shower gels!

All types of waste have been modeled according to the population liable to be present at the station: from 15 to 70 persons. 2.4 m^3 of grey wastewater must therefore be treated.

The treatment of grey wasterwater is carried out in a tank that can contain one day's wastewater. The wastewater is continually stirred. The water is passed through four filters, from coarse to ultra-fine filters (ultrafiltration – nanofiltration), then two stages of reverse-osmosis remove the salts from the treated products. **After ultrafiltration, 90% of the water is recovered. The remaining 10% is treated with the black wastewater.**

This system was put into service in March 2005. It had first been tested at a secondary school with a boarding school in the spring of 2004. Its design was completed in July 2002 and its construction was finished at the end of 2003.

The system for treating black wastewater also uses a tank capable of containing up to one day's waste production (1.5 m^3). The water is continuously stirred and is also filtered to eliminate any abrasive particles liable to damage the membranes. An anaerobic reactor is then used to avoid any exchange with the outside environment, such as injections of air and ejections of unpleasant-smelling vapour into the atmosphere. The reactor consists of three levels: liquefaction (3 days), methanogenization and nitrification (1.5 days). The water produced by the system is sent to the grey wastewater system, while the remaining product is frozen, sent to the coast and scattered at sea.

Via these different examples, **your rapporteur would like to underline**:

- the growing complementarity between space-based research - with regard to its scientific and technological components - and research in a polar environment;

- the development of a new body of research and activities;

- their serving as precursors for solar-system exploration programmes.

Thus, **these programmes – at once complementary, innovative and ground-breaking – merit real support, because they are also essential for the success of our space missions.**

VI. FRANCE'S PRESENCE IN THE POLAR REGIONS

France has long been present in the polar regions. French sailors were among the regions' first explorers, including Bouvet and Kerguelen in the 18th century, Dumont d'Urville in the 19th century and Charcot in the 20th century, to cite only the most famous names. The French were therefore among the first to come into contact with the Arctic peoples, after Paul-Émile Victor and Jean Malaurie.

With the age of exploration and first discoveries over, France must establish a permanent, scientific presence in the polar regions to carry out research in these extreme environments.

In this regard, the French presence can be seen to be very unequal at the two poles, necessitating a certain re-equilibrium.

A. DEVELOPING FRANCE'S PRESENCE IN THE ARCTIC, STRENGTHENING ITS PRESENCE IN ANTARCTICA

For essentially historic and territorial reasons, France's presence is very different at our planet's two poles.

1. Developing France's Arctic presence

France is little present in the Arctic.

This is to be explained by the region's geopolitical situation. Ever since its abandonment of Canada, France has never claimed sovereignty over any Arctic territory. However, all the territory located above the polar circle is today under the control of a small number of nations: the United States, Canada, Iceland, Norway, Sweden, Finland and Russia. Therefore, it is not possible to set up a scientific base there, without a prior international agreement. Only a few nations benefit from an exception to this rule; for example, Germany has been able to retain the Arctic base it was conceded by Russia during the Cold War.

The establishment of scientific stations by third-party nations is only possible in the **Svalbard Archipelago**, which was partially internationalized by the Treaty of Paris in the 1920s. While this treaty grants Norway the right to act as the islands' sovereign power, it also allows the other signatory nations to freely set themselves up there and to develop scientific and economic activities exempt from Norwegian taxation.

France is present in Svalbard via its **scientific bases of Charles Rabot**, in the village of Ny-Ålisund, and **Jean Corbel** (named after the scientist who led to the first French presence starting in 1963), 6 km to the southeast.

Norway installed the first permanent base in 1968, which then served to welcome a veritable international research village.

Following a rapid development centered around the personality of Jean Corbel, French activity greatly declined before again progressively increasing starting in 1974. In 1982, an Arctic research group was created, which later became part of the IFRTP, today's IPEV.

The Charles Rabot base is a two-storey building with a surface area of 250 m^2 in the village, while the Jean Corbel base is a summertime-only installation capable of welcoming some ten persons. The Corbel base is a "clean" station, whose energy is entirely furnished by renewable, nonpolluting sources to allow it to specialize in delicate chemical studies of the atmosphere.

France also benefits from the support of other countries in carrying out certain research, including in the United States (Alaska), Canada, Greenland and Sweden (Kiruna). All told, France carries out some twenty research programmes in the Arctic.

This presence is rather small in comparison to that of other countries such as Germany, let alone the United States and Russia.

This weakness is detrimental for three main reasons:

- A great many research areas carried out at one pole have their counterpart at the other. This is particularly true with regard to glaciology, but it is also the case for the fields of oceanography and biology. Indeed, a few species of bird, such as the Wilson Petrel, migrate every year from the sub-Antarctic islands to Alaska and Greenland.

- For Europe, the main political and economic issues linked to climate change are located in the Arctic: the evolution of the Gulf Stream; the weakening of the ice shelf; the moving fish stocks; the extinction of species; the opening up of new oil and gas exploration areas; new communication routes; and threats to the peoples of the Far North.

- The equilibrium of our partnerships, which are founded on an exchange of means and knowledge, would justify our greater presence – comparable to that of our principal partners - in the Far North, as a natural extension of our successes in the Antarctic.

Despite the scientific and political interest in pursuing such a development, your rapporteur must here point out the budgetary and human constraints. Indeed, IPEV is currently incapable of funding a greater French presence, with an ever-greater portion of its means being absorbed by the chartering of the *Marion Dufresne*. What's more, in human terms, the interested research teams also lack recruits to develop – as far as is possible and desirable - new studies.

Nevertheless, we will have to strengthen our presence if we want to play a permanent driving role in polar research and if we want to give substance to our participation in the Arctic Council, the political body comprised of those countries bordering the Arctic.

The Arctic Council was created in 1996. It gathers together the eight nations bordering the Arctic: Canada, Denmark, the United States, Finland, Iceland, Norway, Sweden and Russia. Since 2000, five other countries act as observers: Germany, France, Great Britain, the Netherlands and Poland; they were joined by Spain in 2006. Some fifteen NGOs and international organizations, as well as six associations of northern peoples also participate as observers. Its objective is to protect the Arctic environment and promote better living conditions for the indigenous peoples.

Our country would like to participate more fully in this organization and encourages the creation of a new status, that of "associated member", which would allow it to fully participate in the workgroups. There are six such workgroups:

- Arctic Council Action Plan (ACAP) – the elimination of pollutants in the Arctic (dioxin, mercury, pesticides);

- Arctic Monitoring and Assessment Programme (AMAP) – the identification and evaluation of pollution problems (oil and gas activities and acid precursors);

- Conservation of Arctic Flora and Fauna (CAFF) – biodiversity conservation and the use of living resources;

- Protection of the Arctic Marine Environment (PAME) – protection against terrestrial and maritime activities, in particular evaluating the impact of increased sea traffic;

- Emergency, Prevention, Preparedness and Responses (EPRS) – the prevention of pollution, control measures for urgent environmental situations in the Arctic;

- Sustainable Development Working Group (SDWG) – the connection between pollution and the health of the indigenous peoples.

Your rapporteur approves of this political orientation, which is in accordance with our diplomatic, economic and scientific interests.

2. Strengthening our presence in the southern regions

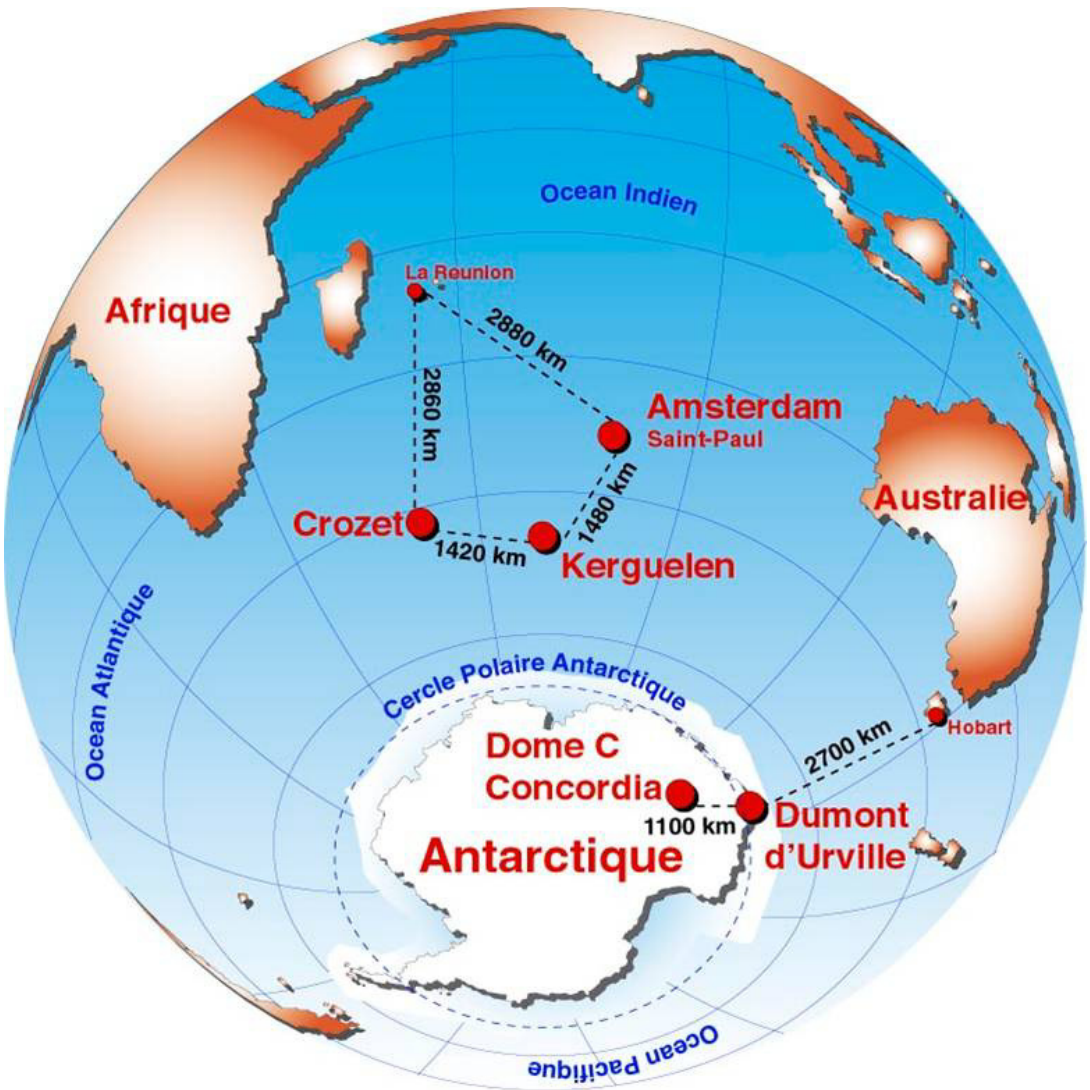
As opposed to the situation in the Arctic, France benefits from desirable positions in the Antarctic and Antarctic Ocean.

Indeed, for reasons that are also historic, France controls several islands and archipelagos: the Kerguelens, Crozet, Saint-Paul and Amsterdam.

It also claims a portion of the Antarctic continent: Adélie Land.

Very few countries can boast such possessions. Only the islands and bases of Great Britain, Australia, New Zealand and South Africa are comparable in certain respects.

For the past fifty years, France has established scientific bases on each of these territories, carrying out observation activities that are world famous in both the life and earth and astronomy sciences.



(Source: IPEV)

The French sub-Antarctic bases and the Marion Dufresne:

- Kerguelen – The Port-aux-Français base – 49°S-70°E

The Kerguelen Archipelago is the largest French sub-Antarctic archipelago, with a surface area of 7,215 km^2, comparable to that of Corsica. The main island is La Grande Terre, on which Mont Ross rises to 1,850 m. Rainfall in the islands is heavy and there are violent winds. The first permanent installation was set up in 1949 around the meteorological station. Today, all of the installations cover a total surface area of 9,000 m^2, accommodating more than one hundred persons in the summer and 60 persons in the winter. The CNES has been present there since 1994, with a satellite-monitoring station.

- Crozet – The Alfred-Faure base – 46°S-51°E

The Crozet Archipelago is made up of two groups of islands some 100 km apart. The main island of La Possession has a surface area of 140 km^2. The Alfred-Faure base was installed there in 1964. It accommodates 15 persons in the winter and some thirty persons in the summer. Rainfall there is very heavy (2.5 m/year).

- Amsterdam – Saint-Paul – The Martin-de-Viviès base – 37°S-77°E

Amsterdam Island has a surface area of 58 km^2. The Martin-de-Viviès base was installed there in 1950. It allows for the wintering of some fifteen persons.

- The *Marion Dufresne* II:

The *Marion Dufresne* is a ship that makes the rounds of the austral districts four times a year. During the rest of the year, it is used for scientific missions. It is 120 m long, 20 m wide and has a displacement of 10,380 tons. It was built in 1995.

It belongs to the TAAF and is commissioned by CMA-CGM.

This ship is all of the following:

. A passenger ship – 110 passengers – scientists and tourists;

. A cargo ship, with a cargo area of 4,600 m^3 (2,500 t) and 5 cranes, including two 25-ton cranes;

. An oil tanker used to supply the bases;

. A heliport;

. A research vessel with 650 m^2 of laboratory space, a lateral coring apparatus capable of extracting the world's longest sedimentary samples (65 m), and a multi-beam sounder. While suitable for sailing in the Antarctic Ocean, the ship is not equipped to sail through ice. Therefore, it cannot access Antarctica, except under exceptional circumstances. Its zone of logistical action is strictly limited to the islands.

As a research vessel, it is equipped with tools for the automatic collection of data during its repetitive annual routes; it is also used for a number of scientific missions in the southern seas. But this austral scientific activity is very marginal in the field of oceanography.

In addition, our country, in cooperation with Italy, is only one of three nations with a permanent base in the Antarctic interior. The other countries are the United States, with its South Pole base, and Russia, with its Vostok base. All of the other stations located in the continent's interior are summer installations, which only function a few months during the year.

The French bases in Antarctica:

Adélie Land forms a triangular sector of 432,000 km^2 between the 136th and 142nd meridians of east longitude. Its summit is the geographic South Pole and its base the 350 km of coast between the two meridians.

- The Dumont d'Urville base in Adélie Land – 66°S-140°E

The Dumont d'Urville base is located on Ile des Petrels in the Pointe Géologie Archipelago, 5 km from the Antarctic continent. The French have been permanently installed on the island since 1956. It was built during the International Geophysical Year in the territory claimed by France and near the magnetic pole, which is today located in the ocean off the Antarctic coast.

The base's living conditions aren't very comfortable due to the age of its buildings and the site's violent katabatic winds.

The buildings cover a total area of 5,000 m^2. Some thirty persons can winter there. During the austral summer from November to March, some one hundred persons can operate at the station.

An annexe was built on the continent at Cap André Prud'homme. It is the starting point of annual three treks allowing for the transport of freight to Concordia (a minimum of 350 t per year). This same trek allowed for the transportation of the 3,800 t necessary for the construction of Concordia.

- The Concordia base – Dome C – 76°S-123°E

The Concordia base is the fruit of a glaciological research activity that began in 1974 under the instigation of Claude Lorius. The construction project for a permanent base was finalized by the Franco-Italian agreement between IPEV and PNRA (National Programme for Antarctic Research) signed 9 March 1993.

It is the third permanent base in the Antarctic interior. It is located more than 1,000 km from the coast at an altitude of 3,233 m. The nearest Antarctic base is Vostok, 560 km away.

It consists mainly of two three-storey cylindrical buildings built on the ice. Its total surface area is 1,500 m^2. It can accommodate some 15 persons, including 9 scientists, for a 9-month wintering period, and 30 persons during the summer.

The site's climatic conditions are extreme: -51°C on average (record: -84°C), but with very little wind and rainfall (less than 10 cm).

Besides the tri-annual treks, Concordia is accessible via small Twin Otter planes, carrying up to 1 ton of cargo each. These planes are essentially used to transport people. Some 40 flights are made each year.

This gives an idea of our country's privileged, well-affirmed position.

It is necessarily very costly to maintain our presence in these far-off lands, due to our having to provide access to these bases, maintain their equipment and infrastructure, and take advantage of them through the development of research activities. It is therefore subject to the permanent risk of a loss of interest and disengagement on the part of metropolitan France, where it can be difficult to be fully appreciate the sites' isolation and harsh climate.

Crozet Island is 2,850 km from Réunion and the islands of Amsterdam and St-Paul 2,880 km away. The Kerguelen Islands are even more isolated, because they lie 1,420 km from Crozet and 1,480 km from St.-Paul. The Dumont d'Urville station is located 2,700 km from the closest port, that of Hobart in Tasmania. Concordia is 1,100 km from the Antarctic coast and the bases of DDU and Casey (Australia) and Mario Zuchelli (Italy, 1,200 km).

One must also consider the climate which for most of the year makes it extremely difficult or even impossible to visit these stations due to the cold, wind and violent seas. Finally, none of these bases have a runway allowing for the landing of large transport and long-haul planes.

Therefore, it hardly seems possible to cooperate with another partner for the logistic service of these islands. In Antarctica, the situation is somewhat different, given the cooperation with Italy, but it is also necessarily complex due to the geographic isolation of our bases.

In addition to these costs that it would be difficult to reduce, there is the cost of maintaining the bases themselves, which take a real pounding from the climate. In Antarctica, where the wintering teams are left without any means of assistance during several months, security cannot be neglected.

Finally, in addition to this intangible data for this part of the world, it must also be added that, as is also the case for the Arctic, international interest in Antarctica is growing. More and more countries would like to set themselves up there, on a temporary or permanent basis.

For instance, China would like to install a permanent base at the least accessible and highest site on the Antarctic continent: Dome Argus, at an altitude of 4,083 m.

The isolation of the French bases means that our country is little confronted with this phenomenon in its zone, but this trend is quite marked on the Peninsula and even in that part of Antarctica close to South Africa. In the sub-Antarctic zone, it is clear that several countries would be immediately interested in our bases if we were to no longer use them.

More generally, **France must be mindful - by strengthening its already-acquired positions – of remaining in the forefront of the Antarctic nations**, while, at the same time, a greater number of nations is active in the region.

Your rapporteur therefore recommends strengthening the French position in the Antarctic Ocean and on the continent, and pursuing the concomitant development of our Arctic activities in cooperation with our partners, thereby pursuing a certain re-equilibrium.

B. IPEV (THE FRENCH PAUL-ÉMILE VICTOR INSTITUTE), AN AGENCY OF MEANS

IPEV was **set up as a GIP (public interest group) following the signing of its constitutive contract on 2 April 1992.**

The objective of this new institute was to increase the visibility and coherency of the French presence in the polar regions. Indeed, IPEV took over the management of the French infrastructures in Adélie Land, previously placed under the authority of the EPF (French Polar Expeditions, the non-profit making organization created by Paul-Émile Victor). It also took over the research activities in the TAAF, which were previously carried out by the research programme for the Antarctic Territories. At this time, the Institute also expressed its desire to successfully set up the continental station on Dome C and took over the oceanographic missions.

The GIP was **extended for twelve years, until 2014**, by the ministerial order of 8 December 2001, which came into effect on 8 January 2002.

Let us now discuss the naming of the Institute. It dropped its original name, Institut français pour la recherche et la technologie polaires – Expéditions Paul-Émile Victor (the French Institute for Polar Research and Technology - Paul-Émile Victor Expeditions) – for its current name, Institut polaire français – Paul-Émile Victor (Paul-Émile Victor French Polar Institute). This simpler name marks the Institute's evolution and progressively increased autonomy. The Institute's mission is no longer strictly limited to the TAAF and Antarctica. The Institute also distances itself from the era of "expeditions", carried out under the direction of the charismatic Paul-Émile Victor.

The success of IPEV led to the renewal of its GIP status, as is underlined in its preamble: "Considering the fact that, since its creation, the group has managed to carry out logistical operations in the polar and sub-polar zones benefiting research programmes leading to **major scientific breakthroughs of great international influence**.

"Considering the interest of the group's renewal, in so far as it guarantees an increased visibility for the polar research and technology programmes carried out by France, as well as an improved monitoring of the means allocated to these programmes."

IPEV defines itself as a national agency of means and competences serving research in the polar environments of the Arctic and Antarctic, whose isolation and climate necessitate suitable technological sophistication. Therefore, it is not a research body.

Its objective is defined by Article 2 of the constitutive convention:

. It operates in a specific geographical zone: the polar regions of the Arctic and Antarctic, and the sub-Arctic and sub-Antarctic zones.

. Its role is to:

"coordinate, support and implement – in its role as an agency of means – national/international, scientific and technological programmes, and to select and support scientific and technological projects;

"organize and run scientific expeditions" (recruit scientific and technical personnel; charter ships to carry personnel and materials to the sites; general organization of the missions, from metropolitan France to the polar regions);

"participate in the international dialogue on science and logistics in the polar regions, by maintaining permanent relations with its foreign counterparts;

"encourage the development of scientific and technological knowledge and arouse public interest in these regions;

"assemble and manage an open documentation for these domains;

"set up and ensure the proper functioning of research observatories;

"also, to carry out oceanographic programmes via ships placed under its control;

"It helps develop European cooperation in its fields of competence."

It therefore provides the scientific bases operating in these regions with the following services: construction; management and maintenance of bases and buildings; acquisition and maintenance of scientific equipment.

The GIP gathers together all the main actors involved in polar research. Since the renewal and the withdrawal of the Overseas Ministry and the adhesion of both the Ministry of Foreign Affairs and the CEA (Commission on Atomic Energy), IPEV includes – in addition to the latter two bodies - the following actors:

. The Ministry of Research,

. The TAAF,

. The CNRS,

. The CNES,

. Météo-France,

. Ifremer,

. The French polar expeditions.

Their rights and obligations are organized in the following manner:

. The Ministry of Research – 49%

. The CNRS – 36%

. The CEA – 5%

. Ifremer – 5%

. The others: 1% each, in particular for the TAAF.

The financial contributions made to the Institute are not exactly proportional to the above shares.

The administrative council (Article 17) is made up of members appointed by the GIP parties, in addition to those serving a consultative role appointed by the Ministry of the Budget, the Ministry of the Environment and the Overseas Ministry, as well as the government commissioner appointed by the Ministry of Research, the State Regulator, the IPEV director and two qualified personalities.

The administrators serve four-year terms. This position is non-remunerated and carried out on an individual basis.

One of the two exterior personalities – today, Jean Jouzel - is appointed as president of the administrative council.

The make-up of the administrative council as of 31 December 2005:

- Jean-Paul MONTAGNER, the Ministry of Research,
- Christian THIMONIER, the Ministry of Foreign Affairs,
- Sylvie JOUSSAUME, the CNRS,
- Jean-Yves PERROT, Ifremer,
- Yves CARISTAN, the CEA,
- Geneviève DEBOUZY, the CNES,
- Jean-Pierre MAC VEIGH, Météo France,
- Michel CHAMPON, the TAAF,
- Jacques SOYER, the EPF.

Participants with a consultative role:

- Jean-Pierre GUARDIOLA, the Overseas Ministry,
- Laurence PETITGUILLAUME, the Ministry of the Environment,
- Florence GOURGEON, the Ministry of the Budget,
- Philippe IMBERT, Government Commissioner,
- Jean-Claude MOREL, State Regulator,
- Jean JOUZEL, President,
- Jacques DESCUSSE, exterior personality,
- Gérard JUGIE, Institut Director.

The administrative council meets at least twice a year. It is responsible for making all important decisions concerning the Institute.

In particular, it appoints the director to a 4-year, renewable term. **The director** ensures the proper functioning of the Institute, under the authority of the administrative council. He/she has the power of committing the Institute to third parties (Article 18).

The Institute also has a **Council on Scientific and Technological Programmes for the Poles** (Article 19).

This council plays a very important role in the carrying out of research, because it puts forward opinions and recommendations on:

. the implementation of scientific programmes and the ocean and land-based projects entrusted to the Institute;

. the Institute's scientific and technical actions,

. the Institute's policy of scientific and logistical cooperation at the international level.

It also has the power of proposing new research areas.

In addition, it must be kept informed of the means brought into play for the processing of the scientific data and ensuring the diffusion of the research results.

Finally, it makes sure that the organizations proposing new programmes have the sufficient means, in terms of equipment and personnel, to successfully carry out in metropolitan France - with the Institute's support, if need be - the preparation, interpretation and publication of the scientific and technological data collected.

It is made up of 16 members organized in the following manner:

. The president of the polar environment committee,

. Five members appointed by the CNRS, Ifremer, Météo-France, the CNES and the CEA,

. Ten nominated by the Ministry of Research, including five foreign nominees.

They serve four-year terms that can be renewed one time and are non-remunerated.

Make-up of the Council on Scientific and Technological Programmes:

- Edouard BARD, President, Collège de France,
- Eric BRUN, Météo France,
- Dorthe DAHL-JENSEN, University of Copenhagen,
- Patrick DUNCAN, the CNRS-CEBC,
- Thérèse ENCRENAZ, the CNRS-Paris Observatory,
- Françoise GAILL, the CNRS-University of Paris VI,
- François GUYOT, the CNRS-University of Paris VI,
- Jeronimo LOPEZ, the Autonomous University of Madrid,
- Valérie MASSON-LAMOTTE, the CNRS-CEA,
- Jean-Robert PETIT, the CNRS-University of Grenoble I,
- Jason PHIPPS MORGAN, Geomar Forschungszentrum,
- Victor SMETACEK, the Alfred Wegener Institute,
- Jorn THIEDE, the Alfred Wegener Institute,
- Paul TREGUER, Vice-President, the CNRS-UBO-IUEM,
- Nigel G. YOCCOZ, the Norwegian Nature Institute,
- Alain PUGET, President of the Regional Ethics Committee on Animal Testing of the CNRS-Midi Pyrénées.

Finally, the articles touch upon issues relative to **patents and the use of results** (Article 21). The measures are not very detailed, but do mention that work carried out within the framework of the Institute or with outside partners must be the subject of conventions specifying the ownership of the results and that specific contracts will be concluded allowing for the use of this data.

VII. INTERNATIONAL COOPERATION: A NECESSITY AND A GOAL

Polar research, at least in the Antarctic, is clearly characterized by international cooperation. It is the philosophy behind and the raison d'être of the 1959 treaty.

The state of mind remains heavily influenced by the period of exploration and scientific adventure. Indeed, a heavy human toll was paid in the discovery and exploration of the polar regions. A great many explorers lost their lives in these regions during scientific expeditions or while attempting to assist explorers in difficulty. Therefore, the bases and researchers are still obligated to demonstrate a certain solidarity. Today, this obligation for cooperation is essentially felt by those operators with the heaviest and most numerous logistical means.

Polar research, despite national rivalries and competition between researchers, has also been lastingly influenced by the last three International Polar Years of 1882-1883, 1932-1933 et 1957-1958. The scientific progress and discoveries made through cooperative work in these regions have imposed international cooperation as both a principle and an efficient work method.

These three aspects unique to the polar regions powerfully reinforce the culture of international cooperation already present in all of today's scientific domains.

For your rapporteur, in addition to these general elements, France must commit itself to two main themes of international cooperation: encouraging the development of a European process and organizing international partnerships.

A. HOW TO ENCOURAGE A EUROPEAN PROCESS?

The European dimension of our country's actions is fundamental, and polar research doesn't escape this principle.

It is both the expression of a political will to be affirmed and an absolute material necessity. However, it is indispensable to correctly determine the framework of cooperation, its objectives and limits, and to devise a strategy.

1. The European Union: a sufficient framework?

Of course, it is within the framework of the European Union that an organized programme for cooperation in polar research should be implemented.

Most European partners are already EU members, excepting Norway and Russia.

The PCRD is a powerful vector for the financing and federation of research via such important programmes as EPICA for ice coring and now DAMOCLES for modeling the Arctic Ocean and its impact on climate.

It also furnishes tools for prefiguring the future by allowing for the formation of networks such as ARENA for European astronomy in the Antarctic.

Finally, the European Union provides a framework for the presentation, selection and validation of the major research infrastructures at the European level, as is currently the case for the project of a German polar icebreaker, the *Aurora Borealis*.

Cooperation at the EU level is therefore essential, but perhaps insufficient.

Indeed, in addition to cooperation in terms of research, one awaits – perhaps, above all - a sharing of the logistics and infrastructure costs. However, as your rapporteur was able to discover during meetings with the European Commission in Brussels, the Commission would rather steer clear of these topics.

The Commission is opposed to the creation of a **European Polar Agency**. Just mentioning it provokes a chorus of protests. Indeed, the Commission doesn't want to see a new dismemberment preventing it from carrying out the necessary arbitration and reallocation of means. It is true that the idea of transforming the European Polar Board, which gathers together the directors of the various European polar institutes, into an agency might appear attractive, it is still too early. Neither today's frames of mind, nor the current on-the-ground cooperation allows us to take this step. Therefore, **your rapporteur, without rejecting this idea in the long-term, believes that it is unrealistic to want to pursue this transformation starting today. Such a move would be premature and undoubtedly counter productive.**

In addition, the polar operators are used to functioning at a research station according to what each one is capable of contributing. This situation increases, therefore, the differences in means between the big countries - or those with a strong polar tradition - and the other nations. The polar zones are not freely accessible, either because they are controlled by sovereign nations (as is the case in the north), or because the engendered costs make the continent accessible to a limited number of operators (as is the case in the south). What's more, this is the functioning principle behind the Antarctic

Treaty, which, while being open to all comers, only allows those nations that are both interested and capable of intervening to manage the continent.

Today, it is up to the large polar agencies to promote by themselves a process of European cooperation.

Your rapporteur believes that France could pursue a European strategy at different levels:

- **Fully play the game centered around those EU mechanisms seeking to coordinate and organize research around unifying projects.** In this respect, it would appear **absolutely necessary that IPEV become the agency of skills and means for managing those European projects under French direction**. Indeed, it's not right that certain large programmes for which we make a determining scientific contribution aren't managed by France and that researchers who manage to win a European proposal do not benefit from the support they naturally expect from their laboratories or universities. In reality, it's up to IPEV to play this role and to maintain and make available the means suitable to following these programmes through, at the financial, technical and political levels.

- **Promote our strongpoints and open our bases to the new EU members.** They are genuinely interested and they have knowledge and know-how, but they often lack the necessary financial means. No country should be excluded from a process of European cooperation.

- **Give ever greater European coherency to bilateral partnerships.**

2. The practical and political limitations of cooperation

European cooperation in the polar domain will only grow if the practical and political limits to its development are taken into account from the very beginning. Otherwise, France risks being deceived and discouraged.

First and foremost, at the political level, one should take into account those missions accorded to the various polar operators by their governments, because, for most of our partners, the objective of polar research is not just scientific.

For example, ever since the Falklands War and Argentina's contesting certain austral possessions of the United Kingdom, this country has decided to give important means to the British Antarctic Survey, to the detriment of the nation's historic organization in the region, the Scott Polar Research Institute (SPRI). However, the BAS must work almost exclusively in that portion of Antarctica claimed by Great Britain. It is not allowed to use a certain proportion of its means for research carried out outside this zone or in the

Arctic. As for SPRI, it has seen its means greatly diminish and has had to focus on the Arctic.

As for Germany, following reunification, the government asked the Alfred Wegener Institute to actively cooperate with Russia in the polar domain.

This cooperation has first and foremost been developed within the framework of a study on the Laptev Sea, gathering together more than 150 Russian and German researchers. This zone is extremely interesting, because it's an important location for the formation of the ice shelf and Arctic drift due to the out-flowing of several rivers. The German-Russian research programme includes studies on permafrost (its evolution and the evaluation of its role as a carbon sink and source of greenhouse gases), the effects of environmental changes (biogeochemical dynamics and the reaction of the Arctic ecosystems), terrestrial and marine interactions along the coast, and environmental changes in the recent (100 years) and distant (5 million years) past.

Following the success of this initial collaboration, Germany opened a laboratory at AARI in Saint Petersburg, via the AWI and the Institute of Marine Sciences in Kiel. This laboratory, named after the Russian scientist Otto Schmidt, was created in 2000. Its main objective is to train young Russian scientists via grants in the fields of meteorology, oceanography, marine chemistry, biology and the geosciences. A summer school and professor-exchange programme are also organized. The grants are underwritten by the German Ministry of the Sciences, for a renewable period of twelve months. Over the past six years, 150 scientists from 16 Russian research bodies have benefited from these grants.

The success of this programme encouraged the Norwegian Polar Institute to join. The resulting bilateral Norwegian-Russian laboratory was named Fram, after the ship on which Fritjof Nansen carried out the first transpolar drift at the end of the 19th century. The laboratory is dedicated to the study of climat change in the Arctic. Its functioning principle is the same as that of the Otto Schmidt laboratory, which it is almost an integral part of, since the two laboratories share the same site.

What's more, the Russian, German and Norwegian officials clearly indicated to your rapporteur that the site still has two free rooms of the same size as those occupied by the Norwegians and that they would very much like for France to set up operations there. In the opinion of your rapporteur, the answer is obvious: **we need to follow up on this proposal**. Indeed, it is surprising and regrettable that we have not yet been able to offer the Russians any real collaboration.

Since 2002, the University of Saint Petersburg has offered a Masters programme in English to some twenty Russian students on the polar and marine environmental systems (POMOR), in partnership with the above-mentioned German institutes, the University of Bremen and the research institute on the Baltic Sea. The first semester is dedicated to in-class studies, while during the second semester, the students have the possibility of pursuing a 1-month internship at one of the German institutes. Upon completion of the programme, the students receive a double-diploma from the Bremen and Saint Petersburg Universities.

Germany also gives much greater importance to the Arctic, out of tradition and because of its cooperation with the Scandinavian countries.

Norway, Denmark, Sweden and Finland are also strongly present and have their own particular priorities due to their strong polar and marine tradition and to their geography.

Denmark's connections with Greenland result in Denmark's strong presence in the ice-coring that is carried out there. For Denmark, it is a "national priority" to find old ice showing the state of the Greenlandic icecap at the moment at which it could have completely disappeared, 120 to 125 thousand years ago.

At a practical level, one must then take into account the geography of the installations and the scientific traditions.

From a logistical point of view, on the Antarctic continent - which is larger in size than Europe - it is impossible to enact a programme of cooperation on principal between European countries. The installations are too distant from one another to imagine implementing a generalized sharing of resources. It is completely impossible to serve the western bases using the same logistical means as for the eastern bases. Therefore, no logistical cooperation is possible, for example, between France and the United Kingdom in this regard; the same is true for Germany. Similarly, the pooling of naval means is subject to specific constraints. The German icebreaker the *Polar Stern* cannot dock at Dumont d'Urville because of its draught and the base's insular location; the same is true for the American icebreakers serving McMurdo and operating in the Ross Sea.

However, these difficulties should not preclude a common reflection on equipment and materials, even the creation of a sort of trading group. Just the same, it is striking to observe the different operators acquiring small amounts of equipment which are often identical and designed for the same purposes, when group purchases would undoubtedly result in substantial savings. This is particularly true for the most expensive materials, the cargo tractors serving the continental stations, with each operator building a few prototypes with their own specificities based on a different base model. Wouldn't it be possible to develop a generic model, given the fact that these vehicles are all designed to carry out the same tasks in similar zones?

On Spitzberg, the situation is completely different, because the archipelago is easily accessible by air and sea and all the scientific bases share the same location.

Finally, in scientific terms, the programmes for cooperation can only be carried out if pertinent scientific sharing can take place. Each country excels in one or more domains and we must work with the existing synergies and complementarities. Therefore, it is unrealistic to pursue a programme of scientific cooperation covering the entire spectrum of polar research. Rather, it is preferable to pursue flexible partnerships adapted to the particular interests and competences of their members. In the realm of science, cooperation cannot be an objective in and of itself.

3. Towards an Italian-German-French engine?

These considerations and recent developments lead your rapporteur to **propose that we concentrate our efforts on combining the Franco-Italian and Franco-German partnerships, so as to encourage a European-based process.**

The Franco-Italian partnership is rather obscure in the scientific world. However, as regards polar research, this partnership is particularly important, because it was thanks to a Franco-Italian initiative that the Concordia base - the only permanent European base in the Antarctic interior - was able to be built and today functions. This cooperation has been undertaken on an equal basis by both partners, who are rightfully very proud of the result.

The costs and scientific work are shared - in particular, all the recurring observation activities - so as to avoid any overlapping means.

Logistics are also pooled and are divided into two different routes: Dumont d'Urville and the supply trek on the one hand, and Mario Zuchelli and the C-30 plane on the other.

This partnership was the subject of a bilateral draft agreement on 4 October 2005 on the organization of the scientific relations between the two partners. The agreement just recently took effect on 9 January 2007, the two countries' having completed their internal formalities for approval in November and December 2006. This agreement can now be implemented.

As regards the Franco-German partnership, it has essentially been developed on Spitzberg. Indeed, France and Germany have decided to combine their research bases and encourage the development of cooperative programmes. While this programme represents a limited financial engagment, it nevertheless has symbolic importance, because France and Germany are the only two countries to have taken such a step in Ny-Ålesund. What's more, in this little village of researchers, the partnership has had an important impact, with certain partners visibly struggling to consider them truly united and accept such a demonstration of European-level cooperation.

This process also questions certain habits, because, as at Concordia, it naturally becomes inconceivable to carry out the same measures twice.

Today, our two partners are open to the creation of a Rome-Berlin-Paris triangle for polar research. For Germany, this would mean progressively setting itself up at Concordia and taking advantage of this permanent infrastructure. For their part, the Italians would like to join the Franco-German base on Spitzberg.

Indeed, they have been on the island since 1997. This plan arouses real interest and for certain components already benefits from the official support of the Research Ministers.

However, to carry out this plan, much remains to be done and several obstacles must be overcome. Your rapporteur has identified three principal prerequisites to ensure its success:

- The **necessity for a high-level scientific project**, the only means of justifying in the long-term an enlarged presence at the two sites, combined with real complementarities and cooperation between the partners;

- **Real savings** thanks to a sharing of means and, at Concordia, a clear convention allowing for the participation of a third permanent partner. In the case of Dome C, this would translate as a sharing of the operating costs, rather than asking Germany to buy a share of the capital corresponding to the cost of construction - a solution that would not be acceptable to Berlin;

- A **process of cooperation which is open** and, therefore, politically acceptable to the other partners. This is an important point. As your rapporteur has already pointed out, these two partnerships are already unique in each hemisphere - adding a third partner would have a much greater political impact that will bother several countries. They could complicate its being carried out. This is particularly the case with regard to Norway, which is not favourable to the development of a European research body on Spitzberg (because it would escape Norway's control) and which prefers to maintain bilateral connections. We must also be careful of the reactions of those partners that cannot participate, at least in the short-term, such as the BAS or other European countries that could feel marginalized.

While this Franco-Italo-German plan must be favoured, it must not be incompatible with other forms of cooperation which, indeed, it could give rise to. The first country concerned by this plan could be Spain, which has expressed its strong interest in participating scientifically and operationally at Concordia. Spain represents a good example of a third party capable of strengthening the European presence in Antarctica.

This trilateral process is today under way, thanks to the signing of an initial agreement for the creation of a tripartite research programme at Concordia. While the details have yet to be worked out and while the agreement represents only a first step in this direction, it is clearly suggestive of future developments.

This project is part of the international TAVERN programme. It is aimed at quantifying the tropospherical aerosols and the variability of thin cloud cover in order to precisely establish the radiation balance of the eastern Antarctic plateau.

Carried out under the aegis of the AWI, it includes the University of Bologna (Italy). It will lead to the installation of a radome 4 metres in diameter and a stellar photometer at Concordia. They will be installed starting in 2009; an AWI technician will then winter there to carry out the experiment during the austral winter.

For these basic reasons, **your rapporteur would like for the development of European cooperation to be more clearly indicated in IPEV's missions**.

B. WHAT INTERNATIONAL COOPERATION FOR FRANCE ON THE EVE OF THE IPY?

Polar research is, by nature and tradition, international. What is the level of this cooperation today? What effect can we expect the International Polar Year, which begins in March 2007, to have in this domain?

1. Excellence, proximity and longevity: three key criteria for cooperation.

For a country such as ours, which cannot be present at the highest level in every sector of research and which does not have the means to carry out a policy of systematic cooperation with all the countries present at the poles, your rapporteur believes that it is desirable to pursue a three-part strategy founded upon excellence, geographic proximity and long-term cooperation.

- **Excellence**

This entails, first and foremost, giving priority to those domains in which France makes a real scientific contribution. Your rapporteur has already discussed several such domains: in particular, glaciology, biology and astronomy. France has a genuine interest in strengthening its globally recognized position by taking the lead in its partnerships. As has also already been emphasized, this also entails the material means and personnel necessary for both the scientific research and the logistics and management of the cooperative programme.

- **Geographic proximity**

The partnerships must also - at least in Antarctica and for logistics - meet certain criteria regarding proximity. The United States, Italy, Australia and New Zealand are the four countries whose bases are the closest to our own. These four countries must be favoured, without our necessarily maintaining a special approach toward them. While your rapporteur observed an excellent level of cooperation with the first two countries, cooperation with the latter two was less evident. Therefore, with regard to Australia and New Zealand, we should consider the subject of logistics, even if New Zealand would be in little need of assistance considering the proximity of its Scott base to the American McMurdo base. However, Australia's Antarctic logistics are located at the same site (Hobart) as France's.

It could also be scientifically interesting to include them in the development of Concordia, in particular with regard to the station's astronomical research.

A lack of scientific integrity thwarted an experiment carried out with an Australian team, but this unfortunate experience shouldn't discourage all cooperation.

Cooperation with the United States has greatly increased over the past few years. The current IPEV director played an important role in this development. He managed to impose our country vis-à-vis those "Anglo-Saxon" partners discouraged by certain events in the past. Today, our bilateral relations are characterized by mutual confidence and esteem. It is striking to note the laudatory mentions made of French research, as much by the National Science Foundation as by the laboratories. At the logistical level, France can benefit, under certain conditions, from American logistical means - in particular, seats on the Christchurch (New Zealand) – McMurdo air link. France furnishes the United States with technical aid in certain areas - for example, ice-coring techniques for setting up the Ice Cube experiment.

France also cooperates with the United States in Alaska, where certain French researchers can successfully carry out research programmes.

However, as far as your rapporteur knows, this rich relationship has yet to be formalized by any general cooperation agreement or by the creation of a shared laboratory acting as the cement for a lasting collaboration, whatever the future may hold. Yet this is an approach that could be pursued in several scientific areas, considering the links that already exist between France and the United States, in particular in the field of glaciology. Closer partnerships could also be set up in the biological domain, where the French positions are especially strong.

- **Longevity**

Finally, the longevity of cooperation – in other words, its stability and lasting quality – is an important element for developing useful connections. In this regard, **the links that have been developed with Russian researchers in the field of glaciology would seem to be a good example for us to follow.**

They all resulted from the strong personal connections that united Claude Lorius with several Vostok researchers in his field of research.

It was via these connections that the record depth of 3,623 m was reached in 1998, which allowed for the reconstitution of the Earth's climate and atmosphere over the past 420,000 years, covering four complete glaciation cycles. This ice core also allowed researchers to discover Vostok, a sub-glacial lake the size of Corsica. It was possible to progressively transform these experiments into a lasting link - that extended beyond mere personal relationships - between the LGGE in France and the AARI in Russia, in the form of a European research group (GDRE).

It was created in December 2004 by the CEA, CNRS, LGGE and IPEV. Its main objectives are:

- continue the studies on the climatic records of the Vostok ice core;
- develop and carry out geophysical and microbiological measurements in the already existing coring holes.

In these two domains, the GDRE has already obtained important results. A new dating method, based on the amount of trapped air, has been the subject of high-level publications. Indeed, this method allows scientists to determine with great precision the local insolation and the exact date via astronomical calculations. It furnishes a never-before-seen level of precision in the analysis of these ice cores.

As regards microbiology, much work has been carried out on the regelation ice of Vostok Lake. Initial analyses have shown that this ice contains very little biomass, but that the bacteria contained therein are thermophilic.

2007 is an important year, marking the 50th anniversary of the Vostok base (16 December 1957) and **the renewal of the GDRE.**

Your rapporteur greatly hopes that the GDRE is renewed, considering the great interest of the shared research carried out there.

Today, AARI is requesting a larger, structured cooperation with France.

Your rapporteur is favourable to this development. It would mean both developing our links in Antarctica – but with other bases than those of Vostok (Mirny which was cited as a possibility) – and to set up a partnership in the Arctic.

In particular, it was proposed that France participate in the German-Norwegian-Russian laboratory covering the region of the Laptev Sea: the coastal system, the formation of the trans-Arctic drift, and studying the ice shelf.

This participation **would also be coherent with France's technical participation in the *Aurora Borealis* icebreaker project.** For the time being, only Russia has really committed itself financially to this project, alongside Germany. France is expected to furnish the technology for long oceanic ice-coring developed on the *Marion Dufresne*. This contribution is important, because one of the ship's main objectives is to be able to carry out sedimentary sampling in the Far North.

However, your rapporteur regrets that France has not been able to assert a greater commitment alongside Germany. Justifiable on the scientific level, such an action would have a symbolic effect, with the Germans waiting for a significant participation on our part with regard to their large, European-level research infrastructures.

The financial situation of polar research does not allow, given our current means, to free funds, what with other areas having the priority.

However, within the framework of the new five-year period and the global reevaluation of the Franco-German relationship by the next President of the French Republic, your rapporteur would like for this dossier to be re-examined. Our relations with Germany and Russia - especially in the scientific domain - and the importance of being significantly more present in the Arctic - a strategic zone that is increasingly accessible, particularly in those scientific areas in which France predominates - are important arguments to be weighed.

Germany's objective is also to make the *Aurora Borealis* an infrastructure of federative research at the European level, by using it as a floating university. This is in line with our own objectives as regards European cooperation.

2. Developing a network for the stations

In addition to bilateral and multilateral cooperation, either one-off or over several years, there is the question of creating a network for the observatories and research data in the polar regions.

This issue would appear particularly topical on the eve of the International Polar Year, especially as several research domains are already organized at the world level to collect and make available their data.

In particular, this is the case with regard to several geophysical networks: seismic, terrestrial and spatial magnetism, monitoring of the ozone layer.

The idea of setting up a network for the Antarctic stations has also made much progress in the domain of atmospheric analysis, as was recently shown by the Vorcore programme, which consisted of carrying out measurements from a balloon touring the continent within the vortex. Not only were the balloons launched from the American McMurdo station - which gave them top priority and ensured their implementation at the very beginning of the season -, but the French researchers were afterwards able to benefit from the competition of other stations along the coast, which launched balloons to carry out complementary measurements during the French instrument's transit.

Could this concept be applied to other research domains – in particular, biology?

Each country has benefited from its position to study those animals found either in its territory or near its base, thereby creating a national tradition of observing certain species. This has been the case for France, whose researchers have had access to an exceptionally rich biodiversity. The Dumont d'Urville base's exceptional proximity to a colony of emperor penguins is now well known to the general public, but the French possessions offer, almost without exception, exceptional working conditions for biologists. A similar process can be observed in other countries possessing austral islands: the United Kingdom (South Georgia and the South Sandwich Islands), Australia (Macquarie Island), New Zealand (Campbell, Auckland and Bounty Islands) and South Africa (Prince Edward and Marion Islands).

However, in several cases, those species present on an island or in a coastal colony can also be found somewhere else, despite the distances which separate them and their generally philopatric nature. It would therefore appear to be of great interest, with several species threatened by climate change, to set up an enlarged observation network to include the principal countries concerned.

It should here be pointed out that Antarctica is one and a half times the size of Europe, with a maximum population of only 5,000 researchers working at some fifty stations.

France should, if it provides itself with the necessary means, play an important role in this domain, because its database is undoubtedly the oldest (40-50 years), the most precise and the largest in terms of the number of species observed in the Antarctic Ocean.

These considerations could be applied to the Arctic Ocean, which also forms a rather homogeneous ecosystem.

VIII. THE RAPPORTEUR'S CONCLUSIONS AND PROPOSALS

1. Strategic regions

The polar regions are of strategic importance for both our country and Europe for two main reasons:

. They are at the centre of great climatic changes that will determine our future and allow for very sophisticated research that is likely to change our way of life and view of the world.

. Because of global warming and technological progress, these regions are becoming increasingly accessible for the development of economic activities. The northwest and northeast passages, as well as the natural resources of the Arctic and Antarctic regions are important issues.

2. Regions to protect

The polar regions are particularly fragile, because they are subject to increased climatic changes. Certain of their defining characteristics, as well as their flora and fauna are threatened.

The exploitation of resources, as well as tourism in these regions must be regulated.

While the Washington Treaty and the Madrid Protocol will protect the Antarctic from mining for another 40 years, they can do nothing to prevent a rapid rise in tourism.

Our country, which played a decisive role in 1989 in the protection of the Antarctic, must oppose an unregulated growth in tourism marked by the use of ships with over 3,000 passengers and the construction of permanent, land-based infrastructure.

Your rapporteur is also opposed to the growth of tourism in Adélie Land, which would use for commercial purposes the logistical means currently reserved for research and would force the scientists to participate in tourist-based activities.

3. Essential regions for understanding climate change:

The polar regions, via the glacial ice cores carried out at Vostok and at Concordia by EPICA, have already had a great effect on our understanding of climate change, by allowing researchers to recreate the Earth's changing climate over the past 850,000 years and by demonstrating mankind's effect on climate. This data is also the standard metre of climate models aimed at predicting future climate change.

We must continue to strongly support climatic research in the polar regions, because it will surely allow for important discoveries:

- **Through ice coring**, allowing scientists to study the earth's climate for over the past 1.2 million years and to recreate critical periods - both ancient (the Eemien) and more recent - in order to understand the future variabilities of the Earth's climate;

- **Through oceanography**, allowing scientists to understand the determining factors of the world's oceanic circulation - in particular, the formation of deep cold waters and the ocean's ability to absorb carbon;

- **Through monitoring the large glacial regions**, in order to predict their future evolution and the consequences this will have on climate and biodiversity.

It is essential that our understanding progresses in all of these domains.

4. Life in the polar regions: of great value to humanity

The biological polar research carried out by France is among the most sophisticated in the world. It was possible to develop this research by taking advantage of France's network of research bases, which forms an exceptional climatic gradient - extending from the Antarctic to the subtropical regions and incorporating the polar front - and which is ideal for the study of the region's flora and fauna. This research has also led to the creation of a database covering over 40 years of research, which today enables scientists to pursue studies of great interest.

The two main research areas that are the adaptation to climate change and the adaptation to extreme environmental conditions are of great interest, as much for future biodiversity as for human health. They are therefore at the center of important societal issues and have a real economic potential.

Today, this innovative research is increasingly turned towards the most advanced technologies, closely related to the biomedical techniques.

Its financial means and organization (more multidisciplinary teams) must therefore be appropriate. This research must also establish stronger national synergies, so as to develop its international partnerships.

5. The polar regions: an observatory for the Earth

A great many geophysical observatories have been set up in the polar regions, either in order to complete the world-wide network or because the two poles offer unique conditions for observation (for example, for studying Earth-Sun relations or monitoring the ozone layer).

These observation activities are symbolic of the scientific community's networking and the collaborative spirit for observing physical phenomena of great size.

Therefore, France must fully support these activities in order to maintain them, in the long-term, at the international level.

6. Strongly support the development of astronomy at Concordia

Astronomy has become the new frontier for French polar research. Scientific and political officials alike must realize that Concordia could rapidly be considered one of the planet's top astronomical sites, in competition with or to complement the space-based sites.

Indeed, the United States, at its South Pole station, has taken this direction and supports fundamental ground-breaking research, such as studying the universe's cosmic background and the detection of neutrinos (two research areas awarded the Noble Prize in 2006 and 2002, respectively).

Our country, in cooperation with Italy, must therefore develop a scientific and logistical strategy that takes into account the activities already carried out at the South Pole station, as well as those that could be developed at Dome A once the Chinese have constructed a permanent base there.

Your rapporteur proposes, first of all, that we develop projects of great scientific added value – but that are realistic, given the current infrastructure - in order to, secondly, place Concordia in a position to welcome large international instruments with the appropriate logistics.

7. Take advantage of the polar regions' complementarity with the space missions

Today, many space missions need to be prepared or validated by work carried out in the polar regions.

The Antarctic is increasingly recognized as a favorable site for the preparation of both men and materials for long-duration missions to explore the solar system.

This scientific and technological dimension is truly promising, although the exploration programmes' scheduling does not make it a current priority.

8. Strengthen France's presence in the polar regions

France must increase its presence in the polar regions, due to their strategic importance.

Historically strongly present in the south, our country has built for itself an internationally-recognized scientific legitimacy in the austral region, which should serve to strengthen our positions.

France has again started to develop its research activity in the Arctic region, where traditionally it has been less present. This change of strategy must be significantly strengthened, considering the scientific and political importance of these regions, as well as the bi-polar nature of most research areas and international partnerships.

9. Reorganize France's presence in the polar regions

The bi-polar dimension of France’s presence in the polar regions suffers from a lack of direction and permanency.

Therefore, your rapporteur proposes that we appoint a coordinator for the French presence at the two poles, by assigning this mission to either the French Polar Institute – Paul-Émile Victor or the Ministry of Foreign Affairs through the naming of an ambassador-at-large in charge of polar-related issues.

In the southern regions, France suffers from disagreements between the two main players: the TAAF and IPEV. Following the example of the national audit office, your rapporteur proposes a better separation of the two missions (particularly in terms of logistics) while, at the same time, we bring their objectives closer together (taking advantage of the polar territories via research, sustainable resource management, and defending French interests in these regions).

10. Better coordinate polar research

Your rapporteur also proposes that we better coordinate polar research.

While the polar-institute model, an agency of skills and means, seems appropriate to both the French research environment and our objectives, it must, in the future, be provided with real means and real organizational powers.

It must be the site where our priorities are developed and from which the coherency of our research project stems with regard to its means – both at the national level and in its partnerships at the international level.

It must help to train young researchers, even while its American counterpart is already busy selecting its postdoctoral researchers.

Finally, it must act as a reservoir of human resources for the management of European and international programs.

11. Solve the problem of insufficient funding for polar-research logistics

While it may not be possible to put a figure on French funding of polar research, considering the organization of such research, it is nevertheless clear that France under-finances polar logistics.

IPEV is in the process of becoming more of an oceanographic, rather then polar-based, institute, specialized in deep ice-coring due to the rising cost of the *Marion Dufresne*. If this change were to be confirmed, the institute would progressively lose its polar specificity.

Despite significant funding by the Ministry of Research, this oceanographic ship weighs heavily on the entire IPEV budget. It is today urgent to find a coherent solution, with the principal role of Ifremer in the management of France's scientific fleet.

This financial burden prevents IPEV from beginning the urgently needed renovation of the Dumont d'Urville station, many of whose buildings are decrepit.

On this occasion, we must pursue a long-term scientific and logistical consideration of our presence at Dumont d'Urville, taking into consideration the opening of Concordia.

Finally, it also prevents the realization that, among the great Antarctic nations, France suffers from the weakest logistics, having neither a real icebreaker nor an airplane.

12. Define a French strategy for European and international cooperation

Finally your rapporteur believes that it is essential to formulate a cooperation strategy at both the European and international level.

A European strategy is essential for a fundamental research domain that is particularly costly in terms of logistics and covers vast geographic areas. It is also essential because as isolated countries, the European nations cannot compete with the great polar powers that are the United States, Russia and, tomorrow, China.

If the idea of establishing a European agency must be abandoned in the mid-term due to opposition from the European Commission and the current level of cooperation, it is still possible to formulate a three-part strategy.

Firstly, we should take advantage of the synergies that can be expected from the large European programmes (EPICA, DAMOCLES). Secondly, we should take fully into account the constraints and political, logistical and scientific imperatives of our main partners. Thirdly, the process of Italo-Franco-German bipolar cooperation should be intensified by keeping it open to other European countries.

In this regard, your rapporteur recommends that the new French President reconsider our country's decision to participate only marginally in the German project for a European icebreaker, the *Aurora Borealis*.

At the international level, your rapporteur thinks that France should have two main priorities. On the one hand, France must give priority to structured, long-lasting relationships which are the most likely to offer important opportunities for collaboration by focusing on the more important partners. On the other hand, France should be able to exercise its leadership in those domains in which it excels at the international level – the fields of glaciology, biology and, perhaps tomorrow, astronomy come particularly to mind.

APPENDICES

SPEAKERS

I. IN FRANCE

A. THE POLAR CIRCLE ASSOCIATION

. Mr. Stéphane HERGUETA

. Mr. Marc LACHIÈZE-REY

. Mr. Laurent MAYET

. Mr. Stanislas POTTIER

B. THE EUROPEAN CENTRE FOR RESEARCH AND ADVANCED TRAINING IN SCIENTIFIC COMPUTATION (CERFACS)

. Mr. Jean-Claude ANDRÉ

C. CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)

. Ms. Catherine BRÉCHIGNAC, President

. Mr. Arnold MIGUS, Managing Director

. Mr. Arnaud BENEDETTI, Director of Communications

. Mr. Bernard DELAY, Director of the Environment & Sustainable Development Department

. Mr. Jacques DESCUSSE, Advisor to the President

. Mr. Jean-Jacques GAGNEPAIN, Advisor to the President

. Mr. Pierre JOUVENTIN, Research Director

. Mr. Dominique LE QUÉAU, Director of the Institut National des Sciences de l'Univers (National Space Science Institute)

. Ms. Monique ROYER, Cabinet Director to the President

D. THE CHIZÉ BIOLOGICAL RESEARCH CENTRE (CEBC)

. Mr. Patrick DUNCAN, Director

. Mr. Vincent BRETAGNOLLE, Assistant Director

. Mr. Henri WEIMERSKIRCH

. Mr. Yves CHÉREL

. Mr. Charles-André BOST

. Mr. Olivier CHASTEL

. Mr. Christophe GUINET

. Mr. Christophe BARBAUD

. Ms. Dominique BESSON

. Ms. Karine DELROT

. Ms. Catherine CLEMENT-CHASTEL

E. CITÉ DES SCIENCES

. Mr. Jean-François HÉBERT, President

F. COLLÈGE DE FRANCE

. Dr. Yannick Giraud-HERAUD, Laboratory of High-Energy Particulate Physics and Cosmology

G. THE EARTH SCIENCES SCHOOL AND OBSERVATORY (EOST)

. Mr. Michel CARA, Director

H. ETHOSPACE

. Ms. Carole TAFFORIN, Director of Scientific Affairs

I. THE PAUL-EMILE VICTOR FRENCH POLAR RESEARCH INSTITUTE

. Mr. Gérard JUGIE, Director

. Mr. Yves FRÉNOT, Assistant Director

. Mr. Patrice GODIN

. Mr. Yvon BALUT

J. THE HUBERT CURIEN MULTIDISCIPLINARY INSTITUTE

. Mr. Yvon LE MAHO, Assistant Director

K. THE PIERRE-SIMON LAPLACE INSTITUTE (UNIVERSITY OF VERSAILLES)

. Mr. Jean JOUZEL, Director

The Laboratory for Climate and Environmental Sciences (LSCE)

. Mr. F. VIAL, LMD

. Mr. H. de FÉRAUDY, Research Centre for Terrestrial and Planetary Environments

. Mr. RAMONET, Atmospheric Network for Measuring Greenhouse Gas Compounds

. Mr. G. HOFFMANN, polar ice coring

. Mr. C. WAELBROECK, sedimentary coring

Aeronomy Department

. Ms. Sophie GODIN-BEEKMANN

. Ms. Florence GOUTAIL

. Ms. Christine DAVID

. Mr. Gérard ANCELLET

. Ms. Marie-Lise CHANIN

Laboratory of Oceanography and Climatology: digital-technology experimentation and approaches

. Ms. Marie-Noëlle HOUSSAIS, Albion Project

. Mr. Jean-Claude GASCARD, DAMOCLES Project

. Ms. Claire LO MONACO, CARAUS Project

L. THE UNIVERSITY ASTROPHYSICS LABORATORY IN NICE (LUAN)

. Mr. Nicolas GLEICHENHAUS, Vice-President of the University of Nice-Sophia Antipolis

. Mr. Farrokh VAKILI, Director of LUAN

. Mr. Nicolas EPCHTEIN, Scientific Coordinator for the ARENA-EC network, CNRS Director

. Mr. Eric FOSSAT, Astronomer

. Mr. Jean VERNIN, CNRS Director

. Mr. Karim AGABI, CNRS Research Engineer

M. THE EUROPEAN OCEANIC INSTITUTE – UNIVERSITY OF WESTERN BRITTANY

. Mr. Paul TREGUER, Director

N. THE RESEARCH LABORATORY FOR SPACE-BASED GEOPHYSICS AND OCEANOGRAPHY (LEGOS)

. Ms. Anny CAZENAVE, Director

. Ms. Frédérique RÉMY, Midi-Pyrénées Observatory

O. MERCATOR (OPERATIONAL OCEANOGRAPHY)

. Mr. Pierre BAHUREL, Director

P. MÉTÉO FRANCE

. Mr. Jean-Pierre MACVEIGH, Director of the Overseas Departments

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. Mr. Francis LEFÈVRE, Advisor on Agriculture, Forestry, Fishing and the Environment

. Mr. Stéphane JUVIGNY, Advisor on Parliamentary Relations

U. THE NATIONAL MUSEUM OF NATURAL HISTORY

. Ms. Catherine OZOUF-COSTAZ, Systems and Evolution Department

V. THE PARIS OBSERVATORY

. Mr. Jean-Louis BOURGERET

. Mr. Karl-Ludwig KLEIN

. Mr. Vincent COUDÉ DU FORESTO

. Mr. Daniel ROUHAN

W. SEPTIÈME CONTINENT

. Mr. Jean-Louis ETIENNE

X. TARAWAKA

. Mr. Etienne BOURGOIS, Co-Founder

. Mr. Bernard BUIGUES, Director

Y. FRENCH AUSTRAL AND ANTARCTIC TERRITORIES (TAAF)

. Mr. Michel CHAMPON, Prefect

. Dr. Claude BACHELARD, Head of the Medical Department

Z. JOSEPH FOURIER UNIVERSITY IN GRENOBLE – LABORATORY OF GLACIOLOGY AND ENVIRONMENTAL GEOPHYSICS

. Mr. Michel FILY, Director

. Mr. Jérôme CHAPPELAZ, Assistant Director

. Prof. Roland DOUCE, J-P Ebel Institute of Structural Biology

. Mr. Claude LORIUS, Presdent of the Science Committee for the International Polar Year, LGGE

. Mr. Jean-Robert PETIT

. Mr. Florent DOMINÉ

. Mr. Gehrard KRINNER

. Ms. Marie-Antoinette MELIERES

. Mr. Joël SAVARINO

. Mr. Robert DELMAS

. Mr. Jean-Marc BARNOLA

. Mr. Jérôme WEISS

. Mr. Dominique RAYNAUD

. Mr. Olivier ALEMANY

. Mr. Olivier MAGAND

AA. LITTORAL UNIVERSITY

. Mr. Philippe KOUBBI, Director of LIMUL (Laboratory of Marine Ichtyo-Ecology)

BB. PROF. CLAUDE DUCHAMP, DIRECTOR

. Prof. Jean-Michel PEQUIGNOT, Director of the Research Unit

CC. THE UNIVERSITY OF SAINT-ÉTIENNE

. Mr. Jean-Yves COTTIN, Laboratory of Geology and Petrology

. Mr. René-Pierre MÉNOT, Research Director

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. Dr. BIEBOW H. FISHER

. Dr. GERSONDE

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. Dr. HAAS

- Dr. HELMS
- Dr. HERBER
- Dr. HORMES
- Dr. KLAGES
- Dr. NEUBER
- Dr. NIXDORF
- Dr. Manfred REINKE
- Dr. STEINHAGE
- Dr. WILHELMS
- Ms. Catherine AUDEBERT, in charge of European Relations

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- Mr. David BOUCARD, Science Representative

C. ASTRIUM

- Mr. MALLOW
- Dr. SCHRÖTER

D. UMWELTBUNDESAMT (UBA)

- Dr. Heike HERATA, Director of the Environmental Protection Department for Antarctica
- Mr. Fritz HERTEL, Ecologist
- Dr. Hans H. JANSSEN, Doctor in Biology

E. BUNDESMINISTERIUM FÜR BILDUNG UND FORSCHUNG (BMBF)

- Mr. Hartmut GRÜBEL, Director
- Dr. Klaus SCHINDEL.

III. AUSTRALIA

. Mr. Antoine GUICHARD, Executive Secretary of the Council of Managers of National Antarctic Programs (COMNAP)

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. Prof. Hugo DECLEIR, President of the National Belgian Committee on Antarctic Research

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. Mr. Johan BERTE, Director of the Antarctic-base project

. Mr. Nighat F.D. JOHNSON-AMIN, Director of International Affairs

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. Ms. Elisabeth LIPIATOU, Director of the Environment and Climatic System Unit, General Director of Research

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. Mr. Tore GRONNINGSAETER, Research Advisor

V. THE UNITED STATES

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. His Excellency Mr. Jean-David LEVITTE, Ambassador
. Mr. Michel ISRAEL, Advisor on Science and Technology
. Mr. Philippe JAMET, Science and Technology Attaché
. Ms. Elodie PASCO, Assistant Science Attaché

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. Mr. Kim L. SILVERMANN, Program Manager Antarctic & Writer Programs, Office of Polar Programs

. Mr. Larry RUDOLPH, General Counsel, Office of the General Counsel (OGC)

. Ms. Noëlle MILLARD, Space Policy Analyst

F. PENNSYLVANIA STATE UNIVERSITY

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. Mr. Michael E. MANN, Associate Professor

. Dr. Sridhar ANANDAKRISHNAN

. Dr. Eric BARTON

G. THE US HOUSE OF REPRESENTATIVES

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. Mr. Jim COSTA, Representative

. Mr. Frank M. CUSHING, Staff Director, Committee on Appropriations

. Mr. Mike RINGLER, Staffer

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. Mrs. Devon FLEMING, International Program Specialist, Office of External Relations

J. THE "SCIENCES AT THE POLES" SEMINAR

. Mr. Donald MANAHAN, University of Southern California

. Mr. Andrea MORELLI, Instituto Nazionale di Geofisica e Vulcanologia

. Mr. Jean DUPRAT, CNRS

. Ms. Stéphanie PFIRMAN, Barnard College

. Mr. Michael TURNER, University of Chicago

. Mr. Francis HALZEN, University of Wisconsin

. Mr. Paolo de BERNARDIS, Università La Sapienza di Roma

. Mr. Guido di PRISCO, CNR

. Mr. Didier SCHMITT, ESA

. Mr. Michael KRAUSS, University of Alaska

. Ms. Sylvie JOUSSEAUME, Director, Space Science Institute, CNRS

. Ms. Kathie OLSEN, Assistant Director of the National Science Foundation

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- Ms. Genevieve LITTOT
- Mr. Paul DULSON
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C. THE SCOTT POLAR RESEARCH INSTITUTE

- Dr. Peter CLARKSON
- Prof. Liz MORRIS

VII. ITALY

A. THE FRENCH EMBASSY

- Mr. Jean FAVERO, Scientific Advisor

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- Mr. Carlo-Alberto RICCI, President
- Mr. Paolo PERFETTI
- Mr. Claudio QUARESIMA

D. THE MINISTRY OF RESEARCH

- Mr. Luciano MODICA, Parliamentary Under-Secretary for Research
- Mr. Domenico GIORGI, Plenipotentiary Minister, Advisor to the Minister

E. THE SENATE

- Ms. Vittoria FRANCO, Senator, President of the 7th Commission

VIII. THE RUSSIAN FEDERATION

A. THE RUSSIAN ACADEMY OF SCIENCES

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- Prof. Vladimir PAVLENKO, Assistant to the Vice-President
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- Mr. Thierry VAUTRIN, First Secretary

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. Ms. Helena PERROUD, Director

F. THE GEOGRAPHIC INSTITUTE

. Prof. Arkady A. TISHKOV, Assistant Director

G. THE ARCTIC AND ANTARCTIC RESEARCH INSTITUTE (AARI)

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. Mr. Valéry LUKIN, Director of the Antarctic Expedition

. Dr. Serguey PRIAMIKOV, Director of International Scientific Cooperation

. Mr. V. Y. LIPENKOV

H. THE OTTO-SCHMIDT GERMAN-RUSSIAN LABORATORY

. Dr. Heidemarie KASSENS, Director of the Paleo-Oceanography Department

. Ms. Tatiana ALEXEEVA

. Mr. Serguey KIRILOV

. Prof. Leonid A. TIMOKHOV, Research Director

I. ROSYDROMET

. Mr. Alexandre BEDRITSKI, Director

PROCEEDINGS OF THE 1 MARCH 2007 SEMINAR:

"OPENING OF THE INTERNATIONAL POLAR YEAR IN FRANCE"

PART ONE:
LUNCH-DEBATE

I. MR. HENRI REVOL, PRESIDENT OF THE OPECST

Your Serene Highness,

Honourable Ambassadors,

Madam President,

Mister Secretary-General,

My fellow Members of Parliament,

Ladies and Gentlemen,

It is with great pleasure that I welcome you here today to the solemn opening of the 2007-2008 International Polar Year.

The International Polar Year is a rare and important event. Every fifty years, it gathers together the men and women from many different countries who share the same goal of making progress in our understanding of the poles and of our planet.

2007-2008 appears to be a year of transition, a year that international public opinion has been waiting for.

Threats to the world's climate and biodiversity, as well as to certain indigenous peoples require that we become aware of these issues and make decisions.

The research being carried out is therefore *political*, in the original sense of the word - in other words, it directly concerns life in the cities.

That is why today, it is the duty of the Senate - and, in particular, the Parliamentary Office for the Evaluation of Scientific and Technological Choices – to commit itself to this research. We wanted to give this day a particularly solemn nature, but we also wanted to use it as an opportunity for exchanges between the researchers and political leaders.

*

I have expressed my feelings and my commitment.

I would also like to express my humility, at seeing gathered here such high-ranking and exceptional personalities.

I would like to express my particular thanks to His Serene Highness Prince Albert II of Monaco, whose presence among us throughout this day symbolizes the great personal commitment and the passion for research carried out in these regions.

We are also extremely fortunate to have among us two pioneers of French polar research.

I would first like to welcome Mr. Bertrand IMBERT, who led the French Antarctic expeditions during the International Geophysical Year of 1957-1958, laying the foundations for the Dumont d'Urville station and opening the way to so many others.

I would next like to welcome Mr. Claude LORIUS. This internationally renowned glaciologist participated in the very first French scientific wintering in the Antarctic interior at the Charcot base during the International Geophysical Year of 1957-1958. He also made a decisive contribution to science by reconstructing the Earth's climate via glacial records.

It is an honour and a privilege to be among you, gentlemen.

*

This day will be divided into two parts: this lunch-debate, and then the official opening of the International Polar Year for France this afternoon.

The lunch-debate will also be divided into two parts:

The starter and the main dish will first be served. Then, at the end of the main course and while the service continues, we will hear the eyewitness account of the explorer Jean-Louis Etienne. We should have more than three-quarters of an hour for discussion.

Our debates will be chaired throughout the day by Bruno Rougier, science journalist for France-Info.

In the spirit of dialogue and openness that I mentioned earlier, we asked Jean-Louis Etienne to share with us his experience on the subject of: "Adventure, art and science: intersecting perspectives". Because, in our opinion, these are not parallel or divergent perspectives, but rather experiences which can converge and even intermingle when science becomes art or adventure and when adventure and art serve science. I hope his account will lead to many others.

I thank you for your attention. *Bon appétit.*

II. MR. JEAN-LOUIS ÉTIENNE

Ladies and gentlemen, it is a very great honour for me to be able to say a few words of welcome to the Senate on the occasion of the launch here in France of the International Polar Year.

A tribute to the commitment of men

I would first of all like to pay tribute to the commitment of men, by trying to shed some light on the following enigma: why this attraction to such inhospitable regions?

In this sensory-poor universe, where grey alternates between blue and white, in this odourless universe, without any sound other than that of the wind, man, freed from the world's constraints and stimulations, loses his bearings and has no other choice but to learn to tame himself. Forced to spend time with oneself, one never returns unchanged from a long journey through the great winter. This is perhaps a key to understanding the paradox of the irresistible attractiveness of the polar regions.

This meeting with oneself is generally expressed through writing or painting. The polar explorer fills his diary with the passing time, his feelings, his observations. One can paint or sketch, one can write in and tell anything to one's logbook, one's "trip confidant". In this manner, the first explorers brought back their watercolours from an until-then-unknown world, at a time not very long ago when photography and film were still in their infancy.

Often plagued by cold and hunger and an uncertain tomorrow, these pioneers found the courage to write some of the most beautiful pages expressing the until-then-unsuspected heroism of human nature. They taught us that one discovers, rather than pushes back, one's limits.

Thus, the polar regions have produced their heroes, painters and writers, and it is in this manner that this icy world entered the popular imagination, with igloos and bears still furnishing childhood's most beautiful dreams.

The North and South Poles: differences and similarities

In popular culture, these extremes are mixed up and combined in the same clichés, while they are in fact quite different. In the north, a deep ocean surrounded by land and covered by an icecap a few metres thick. In the south, the Antarctic continent: an immense ice sheet 3 km thick and 28 times the size of France, surrounded by the Antarctic Ocean and its legendary winds.

The ecosystems of these two poles are different, but the species which live there share a remarkable adaptation to the climate, to the winds, to the distances they need to cover to access the necessary resources, to the bareness of their reproduction areas open at all times to the weather and predators, and to the short summer which forces them to rapidly raise their young before the sudden arrival of winter. Throughout the millennia, these polar species have won the biological bet of being able to successfully establish themselves at the frontiers of life, frontiers which today we are transgressing.

Careful – in these powerful lands, the species are fragile.

A treaty for the Antarctic

For long *terra incognita*, the poles were the last regions to reveal their secret. Lost at the ends of the Earth, they practically never appear on world maps – and yet, they arouse our desire.

At the end of the Second World War, Antarctica was the distant centre of diplomatic tensions, fueled by territorial claims: Chile, Argentina, Australia and New Zealand claimed the continuation of their coasts onto the "white continent", while England, France and Norway emphasized their Antarctic discoverers; the United States and the Soviet Union claimed no territory, but reserved all the rights.

Within the framework of the International Geophysical Year, the third International Polar Year was decided. Twelve nations - including France, motivated by the French polar expeditions led by Paul-Émile Victor – set up permanent scientific bases in Antarctica. As part of this great federating impulse, all the researchers from all of the countries which in 1957-1958 set off on this adventure were ordered to share their results. In the very heart of the Cold War, free from all national ambitions, this remarkable international cooperation led to the signing of the Antarctic Treaty, making the austral continent a land of peace dedicated to science. The main objective of this treaty was to ensure, for the future generations, that Antarctic remain forever occupied for pacific ends and never again be the subject of disagreement. Since its signature and its renewal in 1991, the territorial claims have been frozen, all military and nuclear activities have been forbidden, and researchers have been obliged to share their results. The Madrid Protocol on environmental protection forbids the exploitation of Antarctica's potential mineral and oil resources until 2048.

There you have, ladies and gentleman, what the previous International Polar Year bequeathed to mankind: a peace treaty, an exemplary model of management at the world-level, and this founding act was only made possible by its having been the fruit of a united scientific community.

As climatic indicators and actors, the poles call for planet-wide protective measures

Today, the state of the world has changed and the polar regions are at the forefront of the ever-increasing threat posed by climate change. In our understanding of the phenomenon, the polar regions are no longer only distant indicators of global warming, but also actors in the climatic disharmony which will progressively weigh on our future and the future of all the world's ecosystems. Because everything that affects the poles affects the world, and vice versa.

The International Polar Year that is now opening will allow for an inventory to be made of the human, geopolitical, biological and environmental impact of our civilization - an impact which is unfortunately already known to us, particularly in the Arctic.

Strengthened by this expertise which will have an impact around the world, let us hope that following the example of the previous International Polar Year - which resulted in the Antarctic Treaty - the scientific community, strengthened and united behind this report and supported by the latest IPCC report, let us hope that the scientists will manage to develop, under the banner of the International Polar Year, a solemn call that will serve to convince all the decision-makers - both industrial and political - of the urgent need for each of them to carry out, in their respective fields of action, the necessary environmental measures, that fears for their sector-based and national interests are no longer appropriate, and that by immediately taking these measures, the future will prove them right.

It's a great challenge that this International Polar Year can take up, by relying on the universality of the poles, these points of convergence where the meridians of all the nations meet.

Mr. Christian GAUDIN, Senator for the Maine-et-Loire département, and Mr. Gérard BAILLY, Senator for the Jura département

Ms. Catherine PROCACCIA, Senator for the Val-de-Marne département, with Dr. Claude BACHELARD, senior physician at TAAF-IPEV, and Mr. Michel FILY, Director of LGGE

Mr. Marcel-Pierre CLÉACH, Senator for the Sarthe département, Mr. Bernard d'ALESSANDRI, the Monaco Yacht Club de Monaco, and His Excellency Claude LAVERDURE, Ambassador of Canada

Ms. Catherine BRÉCHIGNAC, President of the CNRS, and Mr. Jean-Louis ÉTIENNE, explorer

His Serene Highness Prince Albert II of Monaco and Mr. Christian GAUDIN

Mr. Henri REVOL, Senator for the Côte-d'Or département, President of the OPECST, and Mr. Claude LORIUS, member of the French Academy of Sciences

His Serene Highness Prince Albert II and Ms. Nelly OLIN, Minister of the Environment and Sustainable Development

Mr. François GOULARD, Minister for Higher Education and Research

Ms. Joëlle GARRIAUD-MAYLAM and Mr. Christian COINTAT, Senators for French expatriates, and Mr. Yvon LE MAHO, member of the French Academy of Sciences.

Mr. Christian PONCELET, President of the Senate, and Mr. Michel JARRAUD, Secretary-General of the World Meteorological Organization.

Ms. Valérie MASSON-DELMOTTE, LSCE, CEA.

Mr. Gérard JUGIE, Director of the Paul-Émile Victor Institute.

Ms. Joëlle ROBERT-LAMBLIN, anthropologist,

PART TWO: OFFICIAL OPENING SESSION

Introduction by Bruno ROUGIER, journalist

The opening of the fourth International Polar Year (IPY) is a major scientific event. During the first IPYof 1882-1883, geophysical and astronomical phenomena were studied. The second IPY of 1932-1933 was dedicated to meteorology, geomagnetism and the atmospheric sciences. During the third IPY of 1957-1958, various data on the atmosphere, the icecaps and continental drift was collected.

Now it is time for the fourth International Polar Year, which, just like its predecessors, in fact covers a period of two years. That won't be too much time to carry out the 209 IPY-certified projects, 45% of which deal with the environment and sustainable development, 45% with the space sciences and 10% with the social sciences.

I would now like to hand over to Christian Gaudin, Senator for the Loire Valley region, the first and only member of the French parliament to have visited Antarctica. Mr. Gaudin is the rapporteur of the study carried out for the Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST) on evaluating French polar research, which was presented only last week. I therefore risk a poor play on words by pointing out that this report is perfectly "fresh".

I. INTRODUCTION

A. MR. CHRISTIAN GAUDIN, SENATOR, RAPPORTEUR FOR THE OPECST

Your Serene Highness,

Honourable Ambassadors,

Madam President,

Mister Secretary-General,

My fellow members of Parliament,

Ladies and gentlemen,

It is a great honour for me to open this afternoon's solemn session during which Mr. Christian Poncelet, President of the Senate, will officially open for France the International Polar Year of 2007-2008.

In this opening talk, I would like to take the opportunity to share with you three convictions that I acquired during my parliamentary work on the polar regions. First of all, I would like to tell you of the exceptional nature of these regions. I would then like to testify to the excellence of French polar research. Finally, I would like to emphasize the necessity for stronger European and international collaboration.

Senate rapporteur for the 1991 Madrid Protocol transposition law, I was immediately made aware of the necessity to protect the Antarctic and, more generally, the poles.

These regions must be protected, because they play an essential role for our planet.

They act as indicators and evidence of major changes in our planet's climate and biodiversity and even in our societies.

It is our responsibility to collect this information, and to then interpret and learn from it. Placed at the disposal of both scientists and ordinary citizens, it's an invitation for us to exercise our responsibility freely, but with full knowledge of the facts.

Men once thought that the wealth of the poles lay in the unlimited exploitation of its natural resources. In concrete terms, the hunting of seals and whales came to a halt following the near-extinction of these species – a sad example of our capacity for destruction.

Antarctica, the only continent set up as a nature reserve to serve humanity, peace and science, is a precious heritage. It's also a fragile heritage, because, let's be honest, its protection greatly depends upon its inaccessibility.

But it's science that reveals to us the true wealth of these regions.

In this regard, the year I just spent preparing my report for the Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST) by meeting with the scientists and by visiting with our international partners after travelling myself to Antarctic, as Bruno Rougier pointed out, has made me certain of the excellence of the French research teams and of the logistical support they are provided with.

In several major domains, such as climatology and biology, our researchers are among the very best in the world.

However, French polar research is not limited to these two flagship fields – far from it. Whether in the study of the Earth and of the universe or in anthropology, this research is extraordinarily rich.

The French bases, with the support of both the TAAF (French Austral and Antarctic Territories) and the Paul-Emile Victor Institute (IPEV), are extremely valuable places for researchers in the Antarctic Ocean, as on the continent or in Svalbard.

I wrote it in my report and I'm repeating it to you today: to remain excellent, our research needs better support.

Finally, in these regions that are so vast and difficult to access, it is undoubtedly impossible to imagine any more work being done without strong international collaboration. This collaboration is already an integral part of everyday life in the realm of polar research.

I would particularly like to underline the fact that France has led the way in developing a closer European cooperation by building, in partnership with Italy, the Concordia research base and by fusing with the German base in Svalbard. Today, these two processes must be combined to serve as a centrifugal force for European cooperation. As Jean Monnet pointed out, in the polar domain as well, Europe is built on concrete interdependences. It is both pragmatic and necessary, but it also represents a clear political commitment.

James Cook, who failed to discover Antarctica in 1773, once wrote: "If any one should have resolution and perseverance to clear up this point by proceeding farther than I have done, I shall not envy him the honour of the discovery; but I will be bold to say, that the world will not be benefited by it."

Several generations of scientists have already proven him wrong. The International Polar Year that opens today will demonstrate, I believe, just how important the evidence from the poles still is for mankind.

I thank you for your attention.

Bruno ROUGIER

Honourable Senator, we thank you for your speech. I now propose that we listen to Catherine Bréchignac, member of the Academy of Sciences, specialist in aggregate physics, President of the Centre National de la Recherche Scientifique (CNRS), President of the Board of Directors for the Palais de la Découverte and, as of next year, President of the International Council for Science (ICSU).

B. MS. CATHERINE BRECHIGNAC, PRESIDENT OF THE CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)

Your Serene Highness,

Ladies and gentlemen, senators and deputies,

My dear colleagues and friends,

This International Polar Year is in keeping with the previous IPYs. As has already been pointed out, the first International Polar Year was held in 1882 to study the climate and magnetism at the poles. Twelve countries participated in carrying out thirteen projects in the Arctic and two in the sub-Antarctic.

Fifty years later, in 1932, the second International Polar Year was dedicated to meteorology and magnetism, as well as to studying the ionosphere. Indeed, it had been discovered during the First World War that the ionosphere garbled radar emissions. Therefore, one wanted to better understand these phenomena.

The third IPY was launched not fifty by 25 years later, in 1957. This year was basically dedicated to geophysics, due to the particularly heavy solar activity at the time.

Fifty years later, 63 countries are participating in this new International Polar Year. Those of you who attended this morning's ceremony for the world opening of the IPY at the Palais de la Découverte were able to observe firsthand the necessity for all of these countries to work together.

Scientists work continuously, rather than every fifty years. I would like to remind you of what Jean-Louis Etienne and Claude Lorius pointed out during lunch: scientists need a lot of time to collect data and make progress. Taking a long-term view has allowed us to reach our current level of understanding: this is the message that should permeate this new International Polar Year.

Six themes have been chosen for 2007-2009:

- the poles themselves;

- the pertinence and understanding of the data, which entails worldwide cooperation;

- the connections between the poles and the rest of the planet;

- biodiversity;

- the observatories, which allow us to make progress in the accumulation of data;

- the social sciences – in other words, the lives of the polar region populations.

This project necessitates very strong logistics and organization and the use of leading-edge technology. At the world level, two organizations have joined forces in support of this effort: the International Council for Science (ICSU) and the World Meteorological Organization (WMO).

Next, each country implements its own coordination: in France, this is the responsibility of both the Comité de l'Année Polaire (Polar Year Committee), headed by Claude Lorius under the aegis of the Academy of Sciences, which has always supported our work, and the Paul-Émile Victor polar Institute (IPEV). In this regard, I would like to thank Gérard Jugie, who has handled all the logistics of cooperation on French territory. We must also thank the various research bodies, as well as the scientists; it's thanks to their work that progress is made in our understanding of climate.

Indeed, there is a definite "climate connotation" to this International Polar Year: we must take great care of our ice, because it contains our planet's climate records.

Lastly, I would like to thank the Senate and, in particular, Senator Gaudin, who welcome us here today. This afternoon will be dedicated to scientific presentations.

I thank you for your attention.

Bruno ROUGIER

Thank you, President Brechignac. This International Polar Year will be a new, wonderful opportunity to attract the public's attention to global warming. In this regard, it is therefore particularly important to welcome Michel Jarraud, Secretary-General of the World Meteorological Organization.

C. MR. MICHEL JARRAUD, SECRETARY-GENERAL OF THE WORLD METEOROLOGICAL ORGANIZATION

Your Serene Highness,

Honourable Ministers and Members of the Senate and of the National Assembly,

Ladies and gentlemen,

My dear colleagues and friends,

On behalf of the World Meteorological Organization, it is a great honour and pleasure to be invited to speak here today, on the occasion of the launch of this International Polar Year in France, which has as its theme: "The poles: indicators and evidence for mankind".

I would first like to thank Mr. Poncelet, the President of the Senate, and through him Senator Gaudin, as well as Mr. Revol, for having invited us to participate in this important event.

Indeed, the WMO supports all efforts whose aim is to promote this exceptional scientific initiative, which it got going with the International Council for Science.

Ladies and gentlemen, you are undoubtedly familiar with Pytheas, the sailor, explorer and geographer who lived in the Greek colony of Massilia between 380 and 310 BC. His legendary voyages of exploration took him very close to the "roof of Europe". He most probably circled Great Britain and observed the midnight sun, the aurora borealis and polar ice. He can probably be considered one of the very first polar explorers, as well as a very early example of European cooperation, between Gaul and Greece.

Starting in the 16th century, French sailors went adventuring in the far south - for instance, Jean-Baptiste Charles Bouvet de Lozier, who in 1739 discovered the island that was later named after him. However, the isolated observation of natural phenomena does not necessarily result in a global vision. As Henri Poincaré said: "Science is built upon facts, as a house is built with stones. An accumulation of facts is no more a science than a pile of stones is a house." Only interdisciplinary work coordinated at the international level can increase our knowledge: this is the objective of this new International Polar Year.

The first international meteorological congress, which was held in Vienna in 1873, gave birth to the International Meteorological Organization (OMI), the precursor to the WMO. The OMI made the important decision to organize the very first International Polar Year.

During the second congress, which was held in Rome in 1879, first eleven and then twelve countries agreed to participate in this project by establishing polar stations, two of which were set up in the southern hemisphere. France was one of these countries: it sent a sloop, *La Romanche*, to Tierra del Fuego. This polar mission established a base in Orange Bay, where some thirty men spent the winter and carried out a scientific programme on meteorology, magnetism and astronomy. The active phase of this International Polar Year covered two years, from 1882 to 1883.

The second International Polar Year, as Ms. Bréchignac pointed out, was held fifty years later, in the same spirit of international cooperation and with a complete sharing of all data, which Jean-Louis Etienne mentioned during lunch. Once again, it was the OMI that launched this project, which was also aimed at strengthening and expanding the meteorological and magnetic observation networks set up in the polar regions. Naturally, France participated in this project, with Greenlandic and Arctic missions. During this International Polar Year, Commander Charcot, the doctor and explorer, played a major role with his ship, the *Pourquoi pas?*

In 1957-1958, the WMO, which had succeeded the OMI in 1950, joined the International Council for Science in organizing the International Geophysical Year. This was probably one of the greatest examples of international cooperation in the scientific domain. The observations, studies and activities were much more complete than during the precedent International Polar Years. They also included a wider range of disciplines. It was during this International Geophysical Year that the first artificial satellite was launched. The programme concentrated its efforts on the Antarctic, where twelve countries, including France, set up stations. Unfortunately, the death in Adélie Land of the French meteorologist André Prud'homme cast a shadow over this IPY.

Ladies and gentlemen, upon the launch of this International Polar Year, the World Meteorological Organization is pleased to renew its collaboration with the International Council for Science. At the world level, the WMO has at its disposal a scientific infrastructure operational in its 188 member-countries and which will be put at the service of the IPY's objectives - because the weather, climate and water cycle know no political or economic boundaries.

Finally, I would like to point out that by taking part in this coordinated effort in the polar regions, the WMO also hopes to reach a better understanding of these regions' influence on the entire climate system, as well as the other regions' influence on the climate of the polar regions.

I once again thank you for your invitation and I propose that we meet once again in 25 years, for the 150th anniversary of this event, or perhaps in 50 years, for the next International Polar Year.

I thank you for your attention.

Bruno ROUGIER

As Michel Jarraud has just reminded us, France boasts a great tradition of Antarctic research, which goes all the way back to the discovery of Adélie Land in 1840 by the Frenchman Jules Sébastien César Dumont d'Urville. It can be said that, ever since then, France has maintained close ties with this region of the world via its polar stations: Port-Martin in 1949, Charcot, Dumont d'Urville and, most recently, Concordia.

What is France's current programme, in particular in the Kerguelen, Crozet, Saint-Paul and Amsterdam archipelagos? François Baroin, Minister for the Overseas Territories, had meant to answer this question for us; however, as you are well aware, the minister has been busy dealing with the catastrophe that recently hit the island of Réunion. Mr. Baroin has only just recently returned and much work remains to be done. Therefore, Senator Christian Cointat has agreed to take his place at this meeting. Mr. Cointat represents French citizens living abroad and presides over the Arctic, Antarctic and TAAF task force, which gives him full legitimacy to speak for François Baroin.

D. MR. CHRISTIAN COINTAT, SENATOR, PRESIDENT OF THE ANTARCTIC AND ARTIC STUDY GROUP

In the absence of Mr. François Baroin, Mr. Christian Cointat, Senator representing French citizens living abroad, reads the Minister's speech.

Your Serene Highness,

President of the Senate,

Honourable Ministers,

Honourable Members of Parliament,

Ladies and gentlemen,

As has just been explained, I will be speaking to you on behalf of François Baroin. I am also Overseas Rapporteur for the Commission on Senate Laws, and it was for this reason that he chose me as his representative. This is a very great honour and pleasure for me. Therefore, by my voice, Mr. Baroin addresses you directly.

« First of all, I would like to say that it would have been a great pleasure for me to be with you today to open the International Polar Year.

2007 has a special significance, for it marks the one-hundred-year anniversary of the birth of Paul-Emile Victor.

I would therefore like to take this opportunity to draw attention to the work carried out by the Paul-Emile Victor Institute and by its director, Mr. Gérard Jugie, who, thanks to his remarkable work, continues the French tradition of excellence and innovation in the domain of polar research. I salute the presence of His Serene Highness Prince Albert II of Monaco, who accomplished the feat of being the first head of state to reach the North Pole and who, thanks to the Albert II of Monaco Foundation, has helped to raise international awareness of environmental issues, which are crucial for the polar regions. I would also like to express my gratitude to Senator Christian Gaudin for his work carried out for the Parliamentary Office for the Evaluation of Scientific and Technological Choices concerning France's position in the international issues surrounding polar research.

France's presence in the austral and polar regions dates back to the great scientific expeditions which began in the 18th century, those of Marion-Dufresne, Charcot and Dumont d'Urville. For many years after their discovery by Yves Joseph de Kerguelen de Trémarec, the archipelago that today carries his name was known as the Islands of Desolation. Up until the beginning of the 20th century, the occupation of these islands was marked by the massacre of it terrestrial and aquatic animals.

Today, Kerguelen and all the other austral and Antarctic territories governed by France represent a formidable research potential. It is our responsibility to pay particular attention to their protection. This approach by France to its territorial holdings is in line with the philosophy of the explorers and pioneers who gave these lands their names.

I would here like to salute Jean-Louis Etienne and Nicolas Hulot, for both their competence and their talent as educators. Both men are in keeping with this prestigious tradition. While France may have inherited its presence in the Antarctic, it also inherited the responsibility of ensuring the reasonable development of certain economic activities, as well as these regions' research conditions and the preservation of these unique ecosystems.

French sovereignty in these territories guarantees the carrying out of both these missions. This sovereignty translates as the maintenance of law and order in these areas, as the installation of logistics and infrastructure to make these territories habitable, and, finally, as the maintenance of international relations. It's up to the Ministry of Overseas Territories to ensure that the international agreements are respected and to allow the researchers from all the different countries to carry out their work in the best possible conditions. To do this, it is essential that the Ministry of Overseas Territories, in partnership with all the ministerial departments and public bodies, sees to the respect of our sovereignty and ensures our presence in this zone.

To that end, France has created a specific government service for these regions, whose acronym you are all familiar with: the TAAF (French Austral and Antarctic Territories). A prefect, a senior administrator, directs state services, ensures the maintenance of law and order, and watches over *the general interests of these territories. This rather particular service will evolve: the law on statutory and institutional measures for the overseas territories, recently passed by Parliament and promulgated by the President of the French Republic, modernizes the law of 1955 on the status of the TAAF. In this perspective, I set up a task force to reflect upon the TAAF and the means assigned to them, in partnership with the ministries and various other bodies which are active in these territories.*

The relations between the TAAF and the Paul-Emile Victor Institute are of fundamental importance for the French presence in the austral regions. The new convention that unites these two bodies, signed on 27 December, defines and above all perpetuates each actor's role. Thus, the Institute is in charge of selecting and running the research programmes, while the TAAF is in charge of providing logistical support.

The actions of the two emblematic vessels that are the Astrolabe and the Marion Dufresne is a deciding factor in guaranteeing the French sovereignty of those polar zones under French protection. The first vessel provides access five times a year to the Dumont d'Urville station in Adélie Land. The second vessel acts as a passenger ship, a cargo ship, an oil tanker, a heliport and a scientific research vessel and sees to the provision of the TAAF. Together, they symbolize the important means dedicated by the French government to these regions.

The seas under French control are natural treasures that must be managed in a sustainable manner within the framework of a reasonable exploitation. In this regard, fighting illegal fishing is a government priority and is carried out in the southern Indian Ocean, in partnership with the fishing industry. A surveillance system using two satellites, Radarsat and Envisat, was set up by Réunion's Regional Operational Centre for Surveillance and Sea Rescues. This system allows for a monitoring of illegal fishing throughout the French exclusive economic zone, as well as in the Australian zones of Heard and MacDonald. The French navy, thanks to its patrol boat the Albatross, dedicates 250 sea days per year to surveillance activities in this area, alongside Osiris, which carries out 150 surveillance days.

The subject of illegal fishing demonstrates the particularity of the French presence in these areas: national means are made available to international objectives. It is by a shared objective, as well as by shared means, that we will arrive at a sustainable development of the means for exploiting and developing the marine resources of these especially rich areas.

In our fight against illegal fishing in our exclusive economic zone, we are sometimes criticized for simply pushing this predatory behaviour outside our areas of control. In reality, this testifies to the quality and effectiveness of our activities, and encourages us to continue and extend efforts at international cooperation in this domain. Strengthened cooperation and consultation between countries is essential to ensure permanent service to *these lands which are so difficult to access. I am pleased to observe that the Paul-Emile Victor Institute is currently seeking international partners capable of ensuring the continued service of the Astrolabe after March 2007.*

Antarctica is the only region on Earth that is truly international.

Governed by the 1959 Treaty of Washington - initially signed by twelve countries, but today including 40 member nations – Antarctica is an important region with regard to France's global presence.

The objective of our presence is not simply to underline our territorial claims, but rather to preserve through our action this demilitarized and denuclearized region dedicated to scientific research. However, we must not only see the TAAF as a sterilized sanctuary.

The freedom to come and go must respect certain conditions: in delimited and regulated areas, it is important not to close all doors to the development of certain activities linked to these territories' resources or attractiveness as tourist sites. However, it is our responsibility to make preliminary plans for their supervision via the objectives for a sustainable, reasonable development that we apply today in all public policy.

France can be rightfully proud to possess these territories, because it places our country in control of undeniable geo-strategic, economic and scientific assets.

I would like to conclude by sharing with you both my concern and my passion for the austral and polar regions. These parts of the world – whose living conditions for man have ever made them lands for scientific missions and pioneers - are home to a fragile, but grandiose, nature. As the recent meeting in Paris of the IPCC once again demonstrated, this nature is the most exposed to climatic changes that we are aware of today. These areas remind us that it is our responsibility to do everything in our power to fight the ecological catastrophe which would inevitably occur if the polar ecosystems were to disappear.

In its austral territories, France has provided itself with the means to preserve these unique areas. In particular, I'm thinking of the TAAF Nature Reserve, by far the largest in France, with its 700,000 hectares covering certain parts – both on land and at sea - of the Crozet, Saint-Paul, Amsterdam and Kerguelen archipelagos. However, this effort must be planet-wide and France – in particular, thanks to the actions of the French President - is one of the countries to have done the most to place these issues in the limelight.

The coming years will be especially important in the fight against global warming. Scientific research must therefore pay particular attention to the poles. Indeed, it is in these regions, which are subject to the greatest climatic disruptions, that we can grasp the seriousness of this phenomenon and find the keys to solving and adapting to this problem.

The International Polar Year, therefore, plays a fundamental role. It must help to raise global awareness of these dangers, by calling upon the international community's conscience and sense of responsibility. It is high time that an unprecedented mobilization finally manifest itself. Each one of us - citizens, scientists, researchers, political leaders - must take advantage of this IPY to strengthen our efforts, in order to alert and convince everyone of the urgency of the situation.

The International Polar Year will effectively lend momentum to this movement. In this time of globalization, this realization and public mobilization clearly cannot be achieved independently of one another. It is our responsibility, each in his or her own domain, to find a citizen-based and global answer. »

That was the message François Baroin asked me to give you.

Bruno ROUGIER

Thank you very much. It is now time for us to welcome the President of the Senate, Christian Poncelet, who will officially announce the opening of the International Polar Year.

II. OFFICIAL OPENING OF THE INTERNATIONAL POLAR YEAR IN FRANCE BY MR. CHRISTIAN PONCELET, PRESIDENT OF THE SENATE

Your Highness, and, I would like to add, my dear friend,

Honourable Ministers,

President of the Parliamentary Office for the Evaluation of Scientific and Technological Choices, my dear colleague and friend,

Honourable Members of Parliament,

President of the CNRS and of the International Council for Science,

Addressing all of you without distinction, let me say simply and sincerely, my dear friends,

I would like to offer all of you the warmest of welcomes to the Senate of the French Republic. It is my pleasure to welcome you here on behalf of the entire Senate. I hope you look back with the fondest of memories to your participation in this event and your visit to the Senate.

It is an honour and a pleasure for me to now solemnly open here in France an event of great scientific consequence: the fourth International Polar Year, which will come to an end on 1 March 2009.

A place for projections and dialogue between political, scientific and economic representatives, our High Assembly, the very incarnation of political power, is pleased to gather together here for the very first time such a learned gathering of scientists, researchers, personalities and experts directly concerned with research at the poles, where most of the questions the world is currently asking itself with regard to its changing environment are to be found.

The extreme quality of this assembly confirms the realization of the importance of studying our planet's poles with regard to such urgent and fundamental societal issues as climate change, the evolving ozone layer and the modification of biodiversity. Progress in the polar sciences is greatly indebted to this succession of International Polar Years - which, you should remember, began in 1882.

A veritable turning point in the history of scientific research, these events gave birth to and later reinforced the spirit of international cooperation. Thus, the second IPY, which was held from 1932 to 1933, allowed for progress to be made in the fields of meteorology, geomagnetism and the atmospheric sciences, as well as in the mapping of ionospheric phenomena.

However, excepting perhaps the exploits of Captain Cook, there has been no event of greater significance in the history of polar research than the

International Geophysical Year of 1957-1958, which gathered together no less than 61 nations.

It allowed American physicists to measure the potential of radar and other technologies developed during the Second World War. It also allowed for the setting up of an international research programme for the collecting of data on such diverse subjects as the upper atmosphere, the ice caps and the theory - for a long time controversial - of continental drift. It met with such success that it led to the drawing up of first the Antarctic Treaty, signed in 1959, and then the 1991 Madrid Protocol for the protection of this exceptional environment.

The planning of this fourth International Polar Year, which we are inaugurating today, has found a great echo at a particularly critical moment in the Earth's history, due in particular to the emergence of global warming. It should generate large-scale international programmes, as much in the northern as the southern hemisphere. All of the sciences, including the social sciences, are concerned by this set of issues.

An Inuit circumpolar conference gathers together the various populations of the Arctic regions, for the native populations of Alaska, Canada, Greenland, Scandinavia and Russia are the first victims of climate change, the effects of which are greater above the polar circle.

Thus, for the very first time, an International Polar Year will be devoted to better understanding social and human specificities. Whether for climate change or the conservation of biodiversity, the polar regions are exceptional research sites which considerably amplify what can be felt in our lower latitudes. It is at the poles that our planet's archives are to be found: their evolution anticipates future changes for the rest of the planet.

In the coming months, under the aegis of the ICSU and the WMO, various events will place the poles, as well as the men and women studying them, in the news.

In addition to these geophysical considerations, the polar regions - both terrestrial and marine, areas of the most amazing contrasts and superlatives - have long fascinated man, whether for their grandiose, icy landscapes or for the emblematic animals that live there.

For its part, the Senate couldn't let such an opportunity pass it by. That is why the railing of the Luxembourg Gardens - a privileged site for outdoor art exhibitions, that I had the opportunity of inaugurating for the first time - could exhibit, I hope, in 2008, wonderful images and photographs of the poles thanks to Nicolas Mingasson.

Just as opportunely, the Parliamentary Office for the Evaluation of Scientific and Technological Choices - currently presided over by my colleague and friend, Senator Revol - has just published the excellent report on polar research prepared by our friend Christian Gaudin. Christian Gaudin, it should be remembered, is the first member of the French Parliament to have visited the Antarctic continent.

I would therefore like to take this opportunity to pay particular tribute to the quality of the work carried out by this office common to both the National Assembly and the Senate and to warmly congratulate its coordinators, to whom we also owe the initiative for today's meeting.

I'm particularly delighted at the link that has thus been established between the political world and the diffusers of scientific culture, at this alliance between the French Republic and its scientists that I have hoped and prayed for ever since I became President of the Senate in 1998. Finally, this International Polar Year provides the various research fields with an exceptional showcase, through numerous exhibitions, books, films, conferences and debates throughout France.

France has always managed to occupy an important place in the scientific and technological research of the polar regions. It has had, in the recent past, its famous explorers: Dumont d'Urville, Charcot and, even more recently, Paul-Emile Victor. Its presence in the austral and Antarctic lands of Adélie Land allows scientists to work in the best possible conditions at permanent bases well suited to the carrying out of their research, in particular thanks to the regular service to these sites provided by our large ships, such as the *Marion Dufresne*.

In the coming months, our country will participate in 55 of the 200 scientific projects selected by an international committee. The CNRS and IPEV are called upon to play a decisive role in this early-21st-century adventure. In addition, thanks to their know-how, acquired over decades of on-site expeditions, this indispensable "spotlighting" directed by the polar-based activities has an excellent chance of shedding light on such emerging research fields as astronomy (in particular with regard to infrared observations) or the behavioural study of researchers in a confined environment (in preparation for future space missions).

The international scientific community can therefore realistically hope to make a considerable leap forward during this period that opens today, here at the Senate. We are indeed proud to be able to host this event.

Meaningful and productive exchanges should also be prompted by this afternoon's conference, which Prince Albert II of Monaco, whom I very respectfully salute once again, was eager to honour with his presence. I would like to offer him the warmest of welcomes and present him with my sincerest thanks.

We thank you, Your Highness, for your presence here today and for your having renewed your family's great tradition that was begun by your great-great-grandfather Albert I, a pioneer of modern oceanography, with a passion for the social sciences and anthropology - the very incarnation of an ecological conscience well before its time. It should be pointed out that from the very beginning of your reign, you have personally committed yourself to protecting the environment. The expedition you led from Barneo to the North Pole in April 2006 is a lesson in humility and respect. Therefore, allow me to conclude my speech with a quote by Your Highness: "Man must not go against the forces of Nature, but rather draw from it his strength".

Ladies and gentlemen, my dear friends, I solemnly declare open in France, here at the Senate, the fourth International Polar Year. May it allow for much progress to be made and may it be rich in those values common to all of Earth's inhabitants.

Thank you for your kind attention.

Bruno ROUGIER

Thank you, Mister President, to have officially opened this International Polar Year with your habitual good humour. I am sure that the scientists present at this assembly have been deeply touched by the favour you have done us by coming here to open this IPY.

Now that this IPY has been officially opened, let us begin the scientific portion of this meeting. We will now welcome the Minister of Ecology and Sustainable Development, Nelly Olin, who, by way of an introduction, will explain to us the main issues of this International Polar Year, in particular with regard to climate change and biodiversity.

III. THEMATIC DEBATE - THE POLES: INDICATORS AND EVIDENCE FOR MANKIND

A. MS. NELLY OLIN, MINISTER OF ECOLOGY AND SUSTAINABLE DEVELOPMENT

President of the Senate,

Your Serene Highness,

President of the Parliamentary Office for the Evaluation of Scientific and Technological Choices, my dear friend,

Senator Gaudin, my dear friend Christian,

Honourable Members of Parliament,

Honourable scientists,

Ladies and gentlemen,

The poles are special places which play a key role in the global system of our planet.

They act as catalysts for international cooperation.

Alone, it is impossible to comprehend these regions geophysical phenomena, and no one can appropriate them.

Since 1882, each International Polar Year has thus been an opportunity to reaffirm the necessity for a multi-thematic mobilization to make progress in our understanding of the phenomena at stake.

The momentary concentration of our research and communication efforts should result in our making faster progress with regard to our overall understanding of our planet.

In the past, during the Great Depression of 1932-1933, this scientific mobilization allowed for a justification of the important grants made to research.

This was during the second IPY, which studied the planet-wide implications of the newly-discovered Jet Stream.

More important still, this same scientific cooperation leant support to arguments in favour of a freeze of territorial claims in Antarctica, eventually validated by the Antarctic Treaty signed in 1959 at the close of the third International Polar Year.

Antarctica, set aside as a world heritage site, nevertheless remains the target of largely-economic attempts at appropriation, for which France remains ever vigilant.

This fourth International Polar Year will undoubtedly prove itself useful for the same reasons.

The issues which today justify international scientific cooperation have nevertheless changed.

As Professor Le Maho I'm sure agrees, it is no longer a question of seeking to understand the stable dynamics of a system in which we include our actions, but rather to better understand the dynamics partially resulting from our own actions.

The poles are privileged locations for the carrying out of this research, for they act as indicators of our actions and of the consequences of these actions.

Once distant, exotic lands, the frontiers of the known world and the objects of expeditions in which national pride went hand-in-hand with the scientific approach, the poles today serve as our most valuable indicators and evidence - at once close, because directly linked to the consequences of our actions, and reliable, because they scrupulously retain the traces of these same actions.

The poles testify to our past. They retain records of the variations in climate and in the chemical composition of the world's atmosphere.

In an ice core, it is possible to read certain events in the history of mankind: nuclear tests, the international Montreal Treaty (from which date the atmospheric concentration of CFCs has declined), the introduction of unleaded fuels, etc. One day, I hope to be able to read the effects of the Kyoto Protocol.

These archives cannot be falsified - that is, as long as they exist.

The poles also serve as privileged testimony for the present.

They have ringside seats to climate change, exposed as they are to tangible climatic developments.

Thus, the poles send back to us an honest picture of the present consequences of human activities.

As will be discussed by Valérie Masson-Delmotte, Yvon Le Maho and Joëlle Robert-Lamblin, climate change affects the equilibrium of these regions as much as it affects their unique biodiversity and the peoples who inhabit them.

Today, the polar regions are the site of significant changes, whose developments are amplified and accelerated at the poles.

Average Arctic temperatures have risen almost twice as fast as the world average over the past one hundred years. In general, the temperatures at the top of the Arctic permafrost have increased since 1980 (up to 3°C).

The frozen regions' maximum seasonal surface area has decreased by around 7% since 1900 in the northern hemisphere, with a spring decrease of up to 15%.

The paleoclimatic data confirms the hypothesis that the global warming of the past half-century is atypical, for at least the past 1,300 years.

The last time that the polar regions were significantly warmer than they are today for a long period of time (around 125,000 years ago), the reduced volume of polar ice led to a rise in sea levels of between four and six metres.

For the next one hundred years and for all the scenarios studied by the IPCC, the simulations predict a decrease in sea ice in both the Arctic and the Antarctic.

According to certain simulations, the ice will almost completely disappear in the Arctic at the end of summer in the second half of the 21st century.

The impact of climate change on the polar regions is both uncertain and potentially considerable.

Could the Greenlandic icecap collapse? If so, what would the consequences of this collapse be?

Will the northern sea route between Europe and Asia open up? If so, what would be the economic, ecological and geopolitical consequences of this new passage?

Faced with these changes that can be observed at the global level and for the study of which we support the international scientific mobilization effort, the local behaviour of the Arctic peoples is especially informative.

These societies, which are intimately connected with their environment, do not benefit from the same distance and global vision as we do. As a result, climate change, felt locally, is not always perceived as a threat in the case of certain Siberian groups. On the other hand, it is very much a reality for a number of settlements in Alaska. These groups have had to adapt. However, the ability of these once nomadic and now sedentary peoples to adapt is reaching its limit.

Because we benefit from the necessary distance and are aware of the future impacts of climate change, we are accountable - before both these peoples and future generations - for our efforts to understand, anticipate and control the consequences of human activities on the ecosystems.

For this reason, it is a good idea to underline the direct impact of human activities on the biodiversity specific to the polar regions.

The image of the drowning polar bear - exhausted after swimming tens of kilometers and incapable of getting back to the ice shelf, after having been carried too far off by a small ice floe in its effort to catch fish - certainly attracts media attention, but oh how unbearable it is to watch!

I would here like to emphasize the seriousness and importance of biological research. While it is true that media exposure of the biodiversity crisis has generated public awareness of the threats to biological diversity, this media coverage - let's be honest - is not equal to the gravity of the situation.

It is only through biological research that we will be able to consider the adaptability of ecosystems, anticipate biological invasions, prevent the potential impacts of a growing tourist industry, and assist bio-exploration.

I would here like to congratulate French biological research in the sub-Antarctic regions. This research, I am proud to point out, is ranked number one in the world (according to a study conducted by the Paul-Emile Victor Institute) and has developed numerous innovations which are now widespread.

Faced with all of these scientific and human challenges, the Ministry of Ecology and Sustainable Development intends to play its part in the international mobilization effort for the IPY and, more generally, through its policy on polar research and the management of the polar territories.

With regard to polar issues, the French community and the Ministry of Ecology are making a great effort.

Evidence of this mobilization can be seen in the unprecedented effort of the French scientific community to develop climate scenarios. These scenarios are presented in the fourth evaluation report of the IPCC.

The work thus carried out by the French computation centres (IDRIS, CEA, the Météo-France centre) has allowed for all the components of the climatic models to be improved and their precision to be increased. This project represents more than 20,000 computation hours for the Pierre-Simon Institute and Météo-France.

This institute is currently setting up a scientific interest group on the impacts of climate change, which I proudly support.

To complete our understanding of climate by drawing lessons from the past, French researchers are concentrating heavily on - and are famous in - the field of paleoclimatology. This was once again shown by the work carried out on the glacial records frozen within the polar icecaps and which allowed scientists to confirm the link between climate change and greenhouse gases.

French involvement in such international programmes as the Antarctic ice coring provides us with new pieces to complete the very complex puzzle of global climate.

I would also like to emphasize France's strong commitment to the preservation of biodiversity, as evidenced by the creation last October of the nature reserve of austral territories.

This reserve, it should be pointed out, covers 700,000 terrestrial hectares and 1.6 million sea hectares, between the sub-Antarctic zone and the subtropical zone, including the Crozet, Kerguelen, Saint-Paul and Amsterdam islands. Very isolated, located at more than 2,000 kilometres from the nearest continent, this reserve represents a unique sanctuary which must be preserved indefinitely.

This reserve is also an exceptional site for carrying out quality research on the living environments of the sub-Antarctic regions.

I intend that this nature reserve be managed in synergy with the research projects.

Regarding specifically the International Polar Year, the programme of scientific research and interdisciplinary observations, launched in a coordinated manner, has two objectives.

Firstly, it seeks to improve our understanding of the polar processes, as well as their links, by considering both the Arctic and the Antarctic and by coordinating heavy logistical means, such as ships and satellites.

Secondly, it seeks to inform and raise the awareness of the general public, the media and decision-makers regarding the importance for society of work carried out in these extreme zones.

Among the 209 projects recognized at the international level, 55 have a French component and five are directed by a French scientist. The Ministry of Ecology is extremely attentive to work carried out within the framework of the IPY, considering the importance of the environment for these zones.

Concerning this matter, I would like to point out my ministry's role in maintaining a strong French position on protecting Antarctica from any unreasonable economic development; in particular, this means forbidding the installation of any long-term infrastructure for tourism, as well as strengthening legislation and the power of the police.

Finally, I would like to conclude with the Tara Arctic expedition - a fine example of scientific collaboration meant to raise awareness among the general public.

This drifting expedition in the Arctic, led by Etienne Bourgois, is a scientific and human adventure, whose aim is to raise awareness among the world's population of the importance of ecological balances.

This scientific expedition lies within the framework of the International Polar Year through the European DAMOCLES programme, whose aim is to observe, understand and quantify climate changes in the Arctic.

My ministry is, of course, associated with this expedition, by helping to bring into play practices for reducing energy consumption and by supporting the expedition's efforts to raise awareness among the general public.

There you have it, ladies and gentlemen - that's all I wanted to say. I thank you for your kind attention.

Bruno ROUGIER

Thank you, Minister Olin. Following the exposition of the scientific importance of this International Polar Year and before moving on to the next three talks, I would like to address Senator Gaudin. Mr. Gaudin, in your report, you emphasized that the research programmes must last several years.

Christian GAUDIN

Indeed, all research implies the accumulation of a given potential. For example, in the field of animal biology, the study of certain species over the past fifty years has allowed us to create a database that is the envy of the world. We are able to trace the adaptations of these species to both changes in climate and their life in an extreme environment.

Today, it is important to provide the necessary means for the continuation of this research, in areas that are very difficult to access and where the scientists' living conditions are rather uncomfortable. To provide the necessary logistics, we need to pursue a mutualization via a coming together of the EU member countries. France cannot act alone; it needs this European group in order to act on the world stage at a time when numerous countries - in particular, the emerging nations – are well aware of the strategic importance of this research.

Bruno ROUGIER

Thank you, Senator Gaudin. We will now learn about a few of the studies currently under way, via three themes: the ice and the information contained therein, biodiversity, and the Arctic peoples.

We will start with the Antarctic ice, a veritable climatic archive. A sampling carried out in Greenland has allowed for climate reconstructions going back as far as 123,000 years - in Antarctica, scientists have gone as far back as 800,000 years.

Valérie Masson-Delmotte, who will present this subject to us, is a paleoclimatologist and heads the Glacios team at the Laboratoire des Sciences du Climat et de l’Environnement (Laboratory of Climate and Environmental Sciences), a mixed CEA-CNRS research team connected to the University of Versailles-Saint-Quentin and the Pierre-Simon Laplace Institute (IPSL). Via this enumeration, I would like to salute all the organizations working in this sector.

In 1997, you carried out ice corings over a period of two months. Since then, you have participated in numerous projects, both in France and abroad. Therefore, I would like to ask you to tell us our history, via the ice.

B. MS. VALÉRIE MASSON-DELMOTTE, CLIMATOLOGIST, CEA

The poles: indicators and actors of climate change

Thank you. Unfamiliar with all the subtleties of protocol, I will simply say "Hello, ladies and gentlemen" and I would particularly like to address those of you interested in the poles.

The image of the Concordia station illustrates the impression one has in the polar regions of being far from the tumultuous world. There, one can find the slow components of the climatic machine: in the polar seas are formed the deep waters which carpet the depths of the oceans, while the polar ice records, year after year, the history of the climate. Those persons who have visited Concordia have therefore walked on ice that is 800,000 years old.

Far from the tumultuous world, certain polar regions are nevertheless subjected to extremely rapid changes. Thus, in the Arctic, the ice shelf has shrunk by two million square kilometers. Since 1975, the observation of the poles by satellite has allowed for an improved observation of the changes at the poles. We have thus discovered a significant decrease in the extension of the sea ice, as much in winter, with a shrinkage of 4.5% per decade, as in summer, particularly over the past few years.

To this shrinkage must be added significant variability from one decade to the next. Our ability to distance ourselves from these variations, via the data obtained by satellite, remains slight. That is why we also make use of climatic models, which allow us to predict the impact of human activity on the ice cover. Thus, the Météo-France model predicts that the Arctic ice shelf will disappear by 2060, while the IPSL model predicts the same result for the year 2080. If the next International Polar Year is held in fifty years, the ice cover over the Arctic will therefore have almost completely disappeared. This amounts to a global warming of 3.5°C, corresponding to a continuation in the release of greenhouse gases at the present rate - in other words, based on an increase of 25% since 1990.

In Antarctica, we have observed a shrinkage of the minimal sea-ice extension of around 25%, with important consequences for the ecosystems which have adapted to this cover.

Changes in temperature have been measured since the International Geophysical Year of 1957-1958, which saw the installation of numerous weather stations in these zones. Temperature records from before this time are very rare. We have therefore been able to measure a general increase of 0.6°C since 1958, which has had very different effects on the various polar regions:

the Antarctic Peninsula and certain Arctic regions have undergone a warming of more than 2°C, while in other regions, the great ten-year variability, as well as the atmospheric and oceanic circulation which redistributes the planet's heat, have reduced this warming trend.

No matter what we do, the average temperature will continue to increase: global warming will amount to 2°C if we do everything in our power to curb this trend, but it will surpass 3.5°C if greenhouse-gas emissions continue at their present rate.

Therefore, the scientific community is certain of some things: in particular, it expects a further increase in greenhouse-gas emissions, which will accelerate climate warming in the Arctic. However, considerable uncertainties remain: a global warming of 3.5°C represents an uncertainty of almost 3°C at the world level, with a factor of two in the Arctic. It is urgent to reduce this uncertainty and the dispersion between the climatic models. The answer is to systematically test them by the yardstick of their capacity to represent the great climatic changes of the past.

The following elements are responsible for the climatic specificities of the polar regions:

- magnifying mechanisms;

- the melting ice shelf;

- the link between the atmospheric and oceanic circulation and the extension of the sea ice;

- the link between the carbon cycle, with carbon contained in the permafrost, and the Antarctic Ocean plays a critical role in the overall assessment of carbon dioxide;

- the possibility of ruptures, in these regions with a slow time-constant, as can be seen in the extension of the sea ice in the summer;

- the lack of meteorological records over the long term, despite our increased level of knowledge.

To go further, intensive observation programmes must be combined in order to map out the changes currently under way in the polar regions, and these meteorological series must be interpreted using the history of the climate as recorded in the ice.

The two ice samples presented here were made during the EPICA ice-coring project at Dome C in Antartica. This is the result of both an international partnership gathering together ten countries and logistical, technological and scientific know-how.

The oldest ice cores – 123,000 years for the North GRIP site in Greenland and 800,000 years for the Dome C site in Antarctica – lie within the framework of a project to develop a 10-year research strategy, whose objective would be to go further back into the past and to map out, in both time and space and using different time scales, the evolution of the climate in the polar regions.

This graph, therefore, retraces 800,000 years of temperature change in the Antarctic. The natural rhythm shows a succession of ice ages and warm periods, with a transition period in the region of 10,000 years. The amplitude of a glaciation is 10 degrees in the Antarctic and 25 degrees in Greenland, with a global average of 4 to 7 degrees. In the past, due to the Earth's position in its orbit around the sun, the poles have known warmer periods than the present.

During the last interglacial period, which more or less corresponds to the appearance of our species, the temperatures at the two poles were some 5°C warmer than they are today. This is the maximum climate warming recorded on these time scales. Sea levels were four to six metres higher than they are today. For natural reasons, a persistent warming at the poles can have an effect on the overall mass of the polar ice caps and, consequently, on the sea level, as well.

A direct link can also be seen between the changing temperatures in Antarctica and the concentrations of carbon dioxide. In the past, natural variations of this concentration, a major amplifier of these glaciations, were responsible for half of the amplitude between the glaciations and the warm periods. Thus, one can measure the extent of the human disturbance, over the past 150 years, since the beginning of the industrial period, which represents the radiative equivalent of past natural changes between the warm and interglacial periods.

The climate's natural rhythm has therefore been broken: in the past, the Earth's orbit governed glaciations, which were amplified by the concentrations of greenhouse gases. Today, it's greenhouse gases that are driving the climatic system. Therefore, we no longer have any analogy for understanding the effects of these emissions on the climate. However, we can use periods of climate warming observed in the past to test the ability of our climate models to represent these great changes.

I mentioned earlier the sea levels. In its 2007 report, the IPCC presents the current state of our knowledge on this subject. Between 1993 and 2003, observations made by satellite revealed an increase in sea level of some 3 mm per year, an important contribution made by the melting of the smaller glaciers and the thermal expansion of the ocean, as well as a significant role played by Greenland and Antarctica. However, for the latter case, the uncertainties remain great, because it is difficult to assess the ice cap's mass. Most satellite-based observations of the altitude of this ice cap go back less than ten years, with the gravimetric observations going back only three years. In these conditions, it is difficult to correct for annual or ten-year variations.

Long-term estimations can result from a combining of, on the one hand, on-the-ground expeditions planned for the IPY, superficial sampling and measuring past variations in the accumulation and outflow of ice, and, on the other hand, satellite-based measurements offering a larger-scale coverage.

To give you some rough estimates, we have observed a 20-centimetre rise in sea level over the 20th century, while the estimated risk for the 21st century is between 19 and 58 cm. One must take into account the great uncertainties regarding the polar icecaps, the accumulation of snow and the effects of outflow.

Finally, the poles are both indicators and actors of climate change. There are two parts to the scientific community's strategy:

- understand the past climatic variability and the reaction of the polar icecaps via ice coring;

- map the climate change currently under way at the poles and its processes at the level of the atmosphere and oceanic circulation, the melting of the Arctic ice shelf and the reaction of the polar icecaps, by bringing together on-the-ground programmes and remote-sensing programmes.

Both parts of this strategy are essential in order to improve the climate and polar-icecap models, the only tools we have to predict and adapt to the future of the poles. A double linking is therefore necessary: first of all, between the various facets of climate research, and secondly, between these long-term studies and major societal issues.

In my opinion, the International Polar Year presents us with the opportunity to establish a pact between science and society, to show the young generations that it is possible to carry out science conscientiously, to understand the world and make oneself useful. Perhaps such a pact will give rise to new vocations. Thank you.

Bruno ROUGIER

Thank you, Valérie Masson-Delmotte. We will now turn our attention to the animals that live on the ice shelf. We know that the polar regions' biodiversity is threatened by climate change. One of the ice shelf's emblematic animals, the emperor penguin, has two surprising characteristics. First of all, the male emperor penguin can go without food for up to four months in order to look after its egg, while the female penguin searches for food. Secondly, a biological process sends the male a signal when the time has come for it to once again feed, abandoning if need be its egg. Even more surprising is the fact that this signal takes into account the amount of time necessary to search for food.

I know, Mr. Le Maho, that you will not limit your talk to the emperor penguin. Nevertheless, it is one of your favourite subjects. I should point out that you are a biologist at the CNRS, the assistant director of the Hubert Curien Interdisciplinary Institute, a member of the Council on Scientific and Technological Programmes at the Polar Institute, and a member of the French Academy of Sciences.

C. MR. YVON LE MAHO, BIOLOGIST, CNRS

Biodiversity at the poles: a treasure under threat

Your Serene Highness,

Honourable Minister,

President of the CNRS,

Secretary-General,

Honourable Members of Parliament,

Dear colleagues,

Dear friends of the poles,

Faced with these two major issues for the future generations, which are climate change and the preservation of biodiversity, there is no choice but to except that they are dealt with differently by the media. Climate change is beginning to be taken seriously, but, as Jean-Louis Etienne once said to me with his usual subtlety, one has the impression that, in the discourse on climate issues, the various forms of life are at best part of the scenery. Society has yet to fully grasp - excepting, perhaps, with regard to the polar bear - the seriousness of the extinctions caused by man. Set against our socioeconomic concerns, the preservation of biodiversity often seems like little more than a subject of interest.

Ever since the winter I spent in Adélie Land, how many times have I been told with a smile: "But of what use is the study of penguins? Are there not more serious research subjects, such as the genome?" Is climate, then, a serious research area for scientists, and ecology a subject for explorers, film-makers and photographers?

Far be it from me to minimize the role of Jean-Louis Etienne, Yann Arthus-Bertrand, Jean-Jacques Annaud, Jacques Perrin or Nicolas Hulot. Without them - in particular, Nicolas Hulot – there would have been no such spectacular realization of the importance of environmental issues during the presidential campaign. However, my objective here today is to show you that ecology is a perfectly genuine scientific domain. In particular, I would like to show you how the work carried out by the teams from the CNRS and the

National Museum of Natural History - within the framework of the Paul-Emile Victor Polar Institute and in collaboration with teams from Great Britain, the United States, Japan, Australia and elsewhere – is at the forefront of research on the impact of climate change on biodiversity, which together, as we have seen, are the two principal themes of the International Polar Year.

For both the film-maker and the scientist, the actor remains the same: the emperor penguin. However, while the film-maker seeks to cause tears to fall and tongues to wag all over the planet, the aim of the scientist is to understand by which mechanisms the animal copes with its environmental constraints.

The March of the Penguins marvelously popularized the image of these males that, to look after their eggs, go without eating in the heart of the Antarctic winter in a cold that is extreme for man. After viewing the film, we come away with the idea that these males spend days, even weeks, tightly huddled together in order to survive four months without food. A moving image in the film is of these packs of emperor penguins breaking up, with the males overexcited by the return of the females to take over looking after the eggs. Naturally, as you may well expect, they're late!

On our side, we demonstrated some ten years ago that emperor penguins, by huddling together, are capable of lowering their energy expenditure, thereby reducing their metabolism by 25%. How is this done? Is it a sort of hibernation, in which the metabolism decreases with the internal temperature?

Thanks to progress made in microelectronics and microcomputing – which demonstrate the future interdisciplinary nature of ecology – miniature data-gathering systems of this type, known as "loggers", have allowed us answer this question. Indeed, we equipped emperor penguins with loggers that included temperature and light sensors. The light sensors are sensitive enough to allow us to obtain a signal even during the polar night; its disappearance means that the bird is in a very tight pack. In this manner, we were able to observe that the packs are continuously breaking apart and reforming, lasting on average only an hour and a half. Observing changes in the ambient temperature allows us to understand why: the temperature rises very quickly, to above 35°C.

Thus, we were able to observe how the mechanism by which the huddling emperor penguins save their energy reserves differs from hibernation. Their internal temperature is maintained at 37°C, allowing them to incubate their eggs at 36°C, and their reduced energy expenditure is linked to the decreased body surface exposed to the cold while closely huddling together. But the penguins are well-insulated and it quickly becomes very hot within the huddle: they paradoxically create a tropical environment and it is precisely for this reason that the packs quickly break apart and reform. In fact, it has nothing to do with the late arrival of the females. We are currently studying how the hatchlings, thanks to a similar mechanism, manage to reduce their energy expenditure and thereby accelerate their growth. Far from the cold being the principal problem, work carried out by our Chizé colleagues suggests that the halving of Adélie Land's penguin colony in the early 1970s is linked to a reduction in the surface area of the ice shelf due to warming.

Let us now consider the emperor penguin's closest relation: the king penguin. Here we are in Crozet, in what we call the French Galapagos, due to the many seabird colonies that find shelter there. The fact that the reproducing penguins do not huddle together, rather maintaining a territorial distance due to the some 1,500 pecks and pinion blows per day, is to be explained by the milder temperatures of the sub-Antarctic zone.

The temperature rarely falls below freezing in the 40°s and 50°s south latitude. Nevertheless, we will see that climate variations still have a significant impact. However, we must stop thinking – and I agree with Valérie Masson-Delmotte on this point – that the effect of climate is limited to temperature. Indeed, it is above all through its impact on marine resources that its influence is critical.

Thanks to loggers fitted with sensors, we can discover at what depth the birds feed (about one to two hundred metres down), as well as their speed, acceleration and hunting techniques. Thanks to other sensors monitoring how far they open their beaks, we can also monitor when they feed. The French teams, along with those from the British Antarctic Survey, were pioneers in this domain, as they were by equipping the birds with miniature Argos tags in order to track their movements about the oceans.

What have we learned? We discovered that the king penguins from Crozet, during their reproduction period, go to feed in the so-called "polar front" zone, while their partners remain with their eggs at the colony. Their trip is short – in other words, some 300-400 km – when the sea level is low, but longer – up to more than 600 km – when the sea level is high. However, sea level corresponds to the ocean's degree of dilatation, and therefore to its temperature. During warm years, the sea level is high, and, naturally, the level is low during cold years. Work carried out by our colleague at the Natural History Museum, Young-Hyang Park, has shown that these warm years, which result in longer sea trips for the penguins, are essentially linked to the El Niño phenomenon, which, after a certain time-lag, is transmitted from the Pacific to the Antarctic Ocean.

What are the consequences for the birds in the middle of reproduction?

Let us consider the male, that normally ensures the final three weeks of incubation, and the female, that after a fishing trip at sea, usually returns at the time of hatching to feed the chick. During a cold year, the female's short trip at sea allows it to return before the egg hatches. However, she comes back too late during a warm year. Yet, we discovered that the chick survives, because it is fed by the male, even though he has remained in the colony for two or three weeks.

Indeed, we have shown that, depending upon when he arrived, the male is capable of retaining between 400 g and 1 kg of food in his stomach. He is able to keep this food intact, without modifying the reproduction cycle, even though the temperature in his stomach is 37°C.

We were therefore interested in the penguin's food-preservation mechanism. Thanks to support from the Ars Cuttoli Committee, then presided over by Hubert Curien at the Fondation de France, following three years of research in analytical chemistry and molecular biology, we were able to identify a small protein associated with the preservation of fish in the king penguin's stomach. After having synthesized this protein, we demonstrated *in vitro* its great effectiveness against pathogenic bacteria and fungi, in particular those associated with nosocomial diseases. We are considering a biomedical development of this molecule.

Let us return to the case of the emperor penguin, which ensures the survival of its chick by regurgitating the food it has kept in its stomach. However, it doesn't wait indefinitely to do this. We discovered that an internal signal provokes the abandonment of the chick by the adult penguin so that it can go feed, after a twelve-day walk – in the same manner as a blinking light on the dashboard warns us when it is time to fill up. After having demonstrated that we can generalize the existence of this mechanism in the animal world, we discovered that it is linked to the secretion in the brain of a certain molecule, neuropeptide-Y, which makes the animal increasingly hungry. As you know, after a long period of not eating, it is dangerous to start eating again too quickly, because the intestine has become atrophied. Quite remarkably, because there has not yet been any ingestion of food, we have observed a cellular proliferation at the base of the intestinal villi and, what is even more extraordinary, an interruption of the apoptotic process - in other words, the dying-off of cells - at the extremity of the intestinal villi, thereby producing sorts of growths. Ordinarily, apoptosis appears during cancer. Consequently, these two mechanisms allow for an early, accelerated restoration of the intestinal villi.

Obviously, we were then interested in knowing if the penguins are completely protected from the effects of the polar climate by such survival mechanisms. To answer this question, we developed a new type of observatory, in which thousands of penguins have been automatically identified since 1998 thanks to microchips weighing less than 1 g planted under the skin. They are identified via the electromagnetic field created by antennas buried at the natural point of passage between the colony and the sea. Within the framework of the International Polar Year, we are coordinating an international project to develop these biology-based observatories.

What have we already learned? Despite their remarkable adaptations to climatic variations and the consequences of these variations on the marine resources, an increase of only 0.3°C in the sea's temperature results in a decrease of around 10% in the average annual survival rate for the emperor penguins.

Naturally, during the IPY, we must try to learn more about the emperor penguin's population dynamics, in particular the survival rate of the young. Nevertheless, *a priori*, this decreased survival rate for the adults is enough to engender a decrease in their populations and even their complete disappearance, should the rise in temperatures persist.

You would be right to point out that the environment is not limited to penguins. Therefore, I would like to speak to you about the work carried out by our colleagues in Rennes and Paimpont, which is interested in the consequences for the micro-fauna of climate warming and the lack of precipitation that has been observed since the mid-1970s in the eastern Kerguelen Islands.

As a result, there are now a sufficient number of days during which the temperature rises above 5°C to allow for the life cycle of the blue-bottle fly, or *Calliphora*. This fly, probably brought to the islands by boat from Réunion, has therefore succeeded in establishing itself in the archipelago and is now competing with the populations of the endemic, wingless fly, *Anatalanta*.

However, it would be overly-simplistic to limit man's impact to the indirect effects of climate change. In the austral islands, man has also introduced animals – cats, rabbits, rats, mouflon and mice - which today we are able to get rid of only on the small islands. Work carried out by research teams from the National Museum of Natural History and the CNRS at the University of Rennes demonstrates the impact of rabbits on an island in the Kerguelen Archipelago: Ile Verte (Green Island). Of the original vegetation - in particular, the Kerguelen cabbage and Azorella - essentially only one species remains, Acaena, and the island's soil has been badly eroded.

What happens when the rabbit is eliminated from the island? Restoration ecology is just as important as the study of the genome, or other scientific disciplines. Due, most likely, to climate warming, it is not the original endemic plants that are getting the upper hand of Acaena, but rather dandelions, an invasive plant introduced by man and which has colonized the entire island. All these phenomena add up, to the extent that today we are witnessing the disappearance of the original biodiversity and a homogenization of the environment.

I think you have understood that, looking beyond just images, the preservation of the polar regions' biodiversity is of major scientific importance and the International Polar Year represents an exceptional opportunity to meet this challenge. In collaboration with numerous international research teams, the French teams are at the forefront of an approach that is, I'm sure you have also understood, interdisciplinary in nature. It's a misconception that researchers are only interested in studying molecules. We are deeply moved by the beauty of the polar landscapes and the surprising spectacle of polar life in the high latitudes. I thank you for your attention.

Bruno ROUGIER

Thank you. After having touched upon the themes of ice and biodiversity, we will now consider the Arctic peoples. Some 3,750,000 persons, for the most part immigrants, live in these regions. The native populations have remained in the majority only in Greenland and in Nunavut, an autonomous Inuit territory created in 1999 in the Far North of Canada.

This talk will be presented by Joëlle Robert-Lamblin, ethnologist, anthropologist and member of the Laboratoire Dynamique de l'Evolution Humaine (Dynamic Laboratory on Human Evolution) of the CNRS. She has carried out research on the native peoples of the Arctic since 1966, studying in particular man's adaptation mechanisms to Arctic environments.

D. MS. JOËLLE ROBERT-LAMBLIN, ANTHROPOLOGIST, CNRS

The Arctic peoples: the "First Nations" and the first persons confronted with climate warming.

First of all, I would like to emphasize the fact that for the first time ever, an International Polar Year includes the human aspects (socioeconomic, cultural and political questions) in its research programme. It is precisely this human and social aspect of climate change in the Arctic that I will here discuss, in a somewhat simplified form, during my short talk.

Who are the Arctic's "First Nations"?

With regard to their origins, languages, lifestyles, cultural choices and political situations, the native peoples of the Arctic are characterized by a great diversity. However, they all live in close symbiosis with an extremely-harsh environment (intense cold, winter darkness, absence of arable land, etc.), making the most out of its resources.

These populations live spread out over vast territories encircling the Arctic Ocean. The areas in which they carried out their traditional activities have been considerably reduced by the influx of nonnative populations, which arrived during the 20th century to participate in the militarization or industrial exploitation of these regions.

Today, the demographic weight of the native Arctic peoples is weak. Now minorities in their own ancestral lands, they number less than 500,000 individuals, while the immigrants in their regions are nearly eight times as numerous. However, two territories are exceptions: Greenland and Nunavut, which became autonomous in 1979 and 1999, respectively, and whose populations are over 85% Inuit.

It will here be useful to provide you with a few demographic precisions regarding these populations placed under the sovereignty of seven countries.

Numbering some 140,000 individuals, the Inuit and the Yupik are divided between four countries: Denmark (for Greenland), Canada, the United States (for Alaska) and Russia.

The Aleuts, who belong to the same linguistic family, number around 12,500 individuals. For the most part, they are to be found in Alaska, but a few live in Siberia.

The Amerindians of Alaska and northern Canada - who belong, for the most part, to the Athapaskan group - number less than 26,000. To these can be added around 11,400 Tlingit and only 50 Eyaks.

In northern Europe, the Sami, or Laplanders, represent a community of some 70,000 persons divided between four countries: Sweden, Finland, Norway and Russia.

Finally, the "small" peoples of northern Russia, some twenty ethnicities, number barely 187,000 individuals. The largest community is that of the Nenets, with more than 41,000 members, but the smallest groups number only a few hundred individuals. Their ethnonyms are: Nenets, Enets, Khanty, Mansi, Dolgnas, Nganasans, Evenki, Eveny, Yukaghir, Chukchi and Koryaks, to name but a few.

It should be pointed out that the Sakha or Yakuts, who represent an important Turkic people numbering some 430,000 individuals, are not considered a native minority of Arctic Russia, even though they occupy a portion of this region.

Traditionally leading nomadic or semi-nomadic lives, all of these peoples have adapted to our planet's most extreme conditions, drawing all of their subsistence from an ecosystem which they do not consider inhospitable.

Some have adapted to the marine environment, such as the Eskimos (Inuit and Yupik), who have perfected their methods for hunting marine mammals.

Others, living in the tundra or taiga, have specialized in first hunting and then raising reindeer (this is the case of the Sami and various communities in Siberia), or the capture of animals with pelts and river-fishing, as practiced by numerous Siberian and North Amerindian peoples.

What impact can global warming have on the Arctic societies?

Even though a few managed to undergo an extraordinary socioeconomic transformation during the second half of the 20th century, the Arctic peoples remain closely connected to their polar environment and its ecosystems, whose equilibrium is particularly fragile and vulnerable. To illustrate this fragility, it can be pointed out that lichen, the principal food source for reindeer and caribou, only grow a few millimeters per year.

A significant and long-lasting climate change could greatly disrupt, even threaten, the cultural diversity - and, in certain cases, the very existence - of the Far North's native minorities.

For the time being, the impact of global warming varies according to the region, but the lifestyles of the Arctic peoples have already been affected. "Silaa Nalagavok", "Climate is king": this common saying in Greenland underlines northern man's great dependence on climate.

The hunters of mammals and the traditional fishermen must adapt their activities to major changes linked to the ever-shorter winter, modifications in game-animal behaviour, even the disappearance of certain ancestral resources. The shrinking ice shelf engenders an increasing scarcity of the hunted species (seals and polar bears) which is already perceptible and necessitates an adaptation of hunting practices, in particular the placing of nets beneath the sea ice and the hunting of game in the midst of ice floes. In addition, the thinning ice constitutes a permanent danger for hunters moving about by snowmobile or dog sled.

For their part, the nomadic breeders of reindeer, the Sami and Siberians, dread the hotter summers, which tire out their herds and result in a proliferation of insects. Similarly, they are witnessing greater snowfall in the winter, which disrupts their seasonal migrations and makes it more difficult for the animals to feed.

Finally, on ground that is wet, sudden changes in temperature result in the formation of a layer of ice that is an even more formidable danger for the herbivorous animals.

In a few communities in the north, the warming of the permafrost and the erosion of the coasts and riverbanks threaten the villages, as can already be seen in northeastern Siberia, as well as in northwestern Alaska. The relocation of entire villages is being considered, but the human and financial cost will be too great. For the Siberian communities, already in a very precarious situation since the fall of the Soviet Union, the difficulties are piling up with the recent appearance of these climatic disturbances.

At the political level, the local governments and the organizations that defend the collective rights and interests of the native peoples - such as the Inuit Circumpolar Conference, the Sami Council, the Association of Indigenous Peoples of the North, and the Aleut International Association - are perfectly aware of the environmental problems linked to global warming. They are also aware that the climatic changes rendering their underground resources more accessible are also encouraging an international race for their regions' energy and mineral riches. In fact, requests for the exploration and off-shore exploitation of oil and gas are increasing, while the potential opening of the north Siberian sea route, as well as of the Northwest Passage, is also arousing envy.

What impact will this have on the small societies bordering these sea routes? Will it represent an opportunity for these societies to end their isolation and improve their economic situation, or, on the contrary, will it represent a terrible threat to these peoples' cultures and ways of life, which will not withstand this economic and cultural shock? One must also consider the major ecological risks that this new situation could engender, in particular in the case of an oil spill.

Can the past shed light on the future?

During prehistory, temperature variations provoked major changes in the Arctic cultures, as shown by archeology. This diagram (Fig. 1) compares past climatic changes and the diverse cultures which have succeeded one another in Greenland. In particular, one notices that the beginning of the long period during which this territory remained uninhabited corresponds to the peak in observable cooling, around the year 200 B.C. The presence in Greenland of the Vikings, who arrived from Europe, as well as their disappearance, can also be correlated with the changing climate.

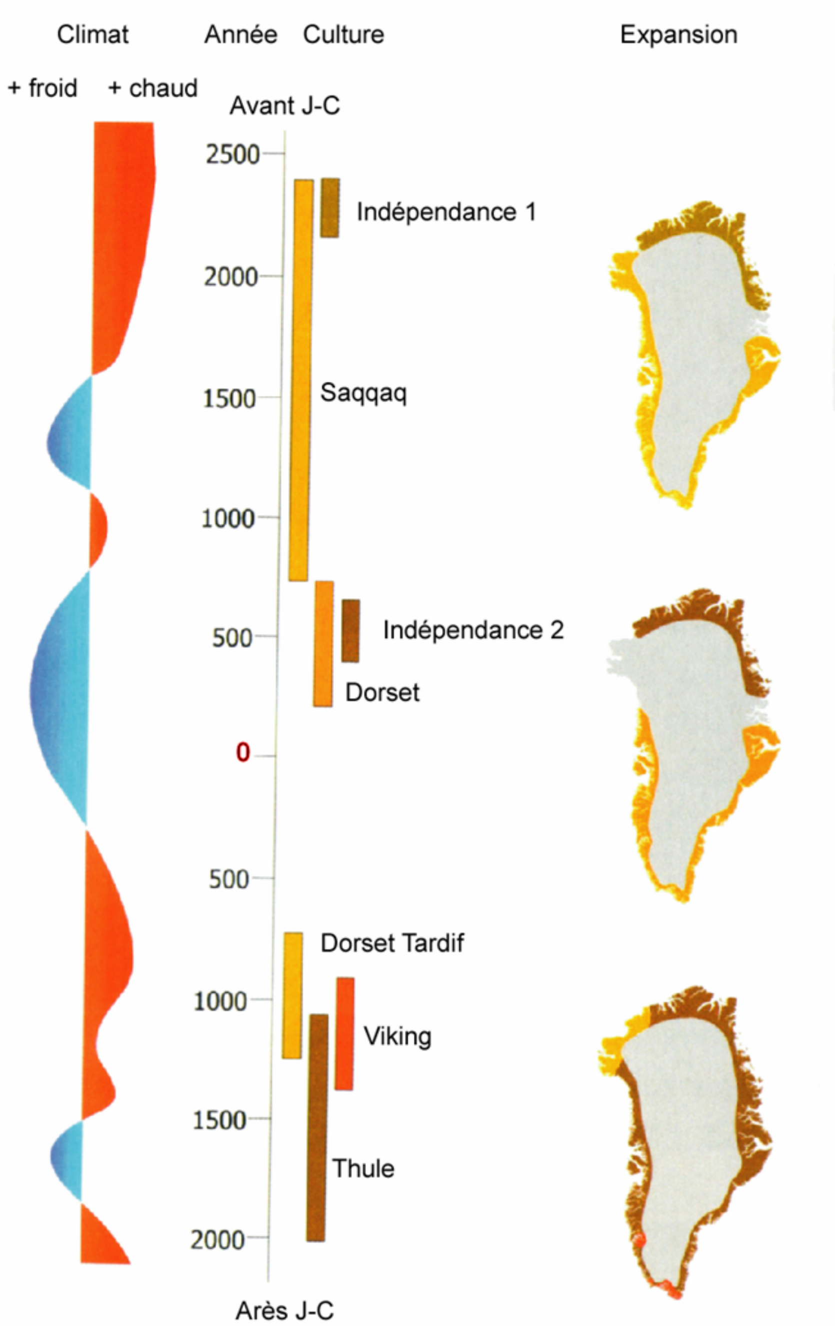
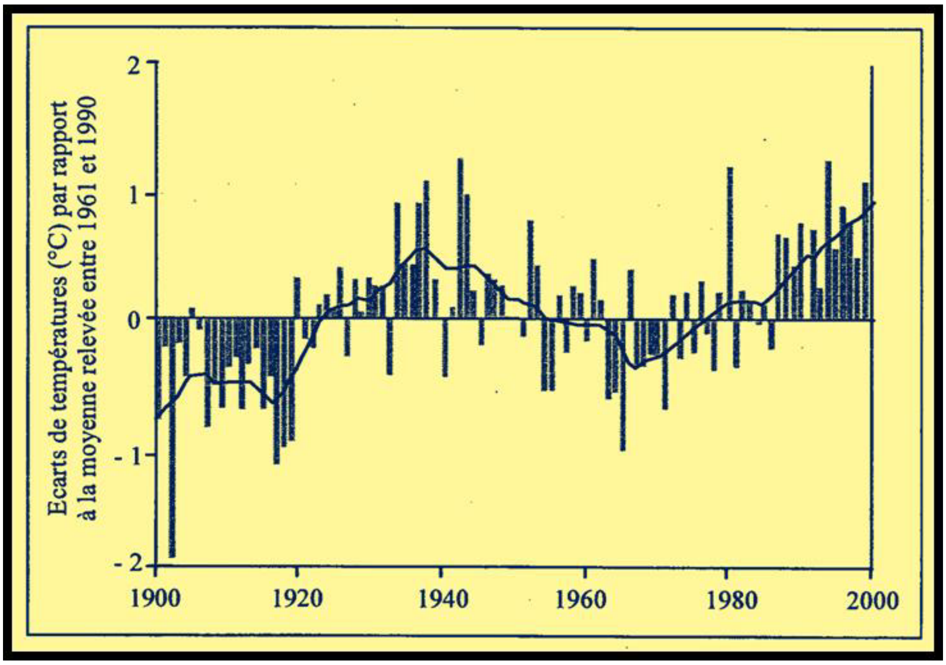
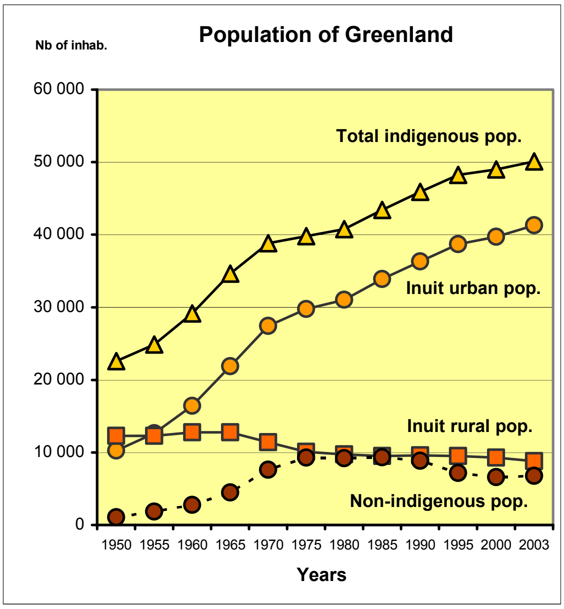


Fig.1- Cultural history of Greenland illustrated in time and space related to climatic change
(fig. H.C. Gullöv, in *Grönlands forhistorie*, Gyldendal, Köpenhavn 2005, p. 22).

Considering a more recent case, a warming of the sea waters during the first half of the 20th century had a considerable effect on the activities of the Greenlandic communities, which had previously depended almost entirely upon the hunting of marine mammals. A sudden influx of cod near the coastline had a significant socioeconomic effect on these societies: changes in their activities and lifestyles, the development of urban centres around the fisheries and port installations, and the sedentation and grouping together of settlements that previously had been very widely dispersed (Fig. 2). As a result, more than 80% of the Greenlandic population today lives in town, with a quarter living in the capital, Nuuk. However, this new abundant fish stock turned out to be short-lived. Cod-fishing was therefore replaced by shrimp-fishing, engendering new economic adaptations. Similar observations can be made in Siberia, Alaska and Canada.



Legend: Differences in temperature (°C)
compared to the average recorded between 1961 and 1990.



Legend: The territory of Greenland.

Fig. 2 – Correspondence between climatic variations and socioeconomic changes.

a/ Evolution of the average temperatures in the Arctic: from the Little Ice Age to contemporary global warming (Diagram: M.-F. André, in *Le monde polaire. Mutations et transitions*, publisher: Ellipses, Coll. Carrefours, Paris, 2005, p.12).

b/ Evolution of the Greenlandic population and urban growth, from 1950 to 2003.

A large proportion of the Arctic peoples are now part of the modern world. Many of these regions' inhabitants now have salaried jobs, in the administrative sector, the service industry and construction. However, while they are no longer directly dependent upon the resources of their environment for their survival, their ways of living, thinking and governing are still largely based upon the special relationship they continue to maintain with nature - a fundamental link that nourishes the culture and representations of all of these peoples.

Throughout their history, the Arctic peoples have had to face a succession of challenges, most often engendered by climatic changes. It is their exceptional ability to adapt that has allowed certain groups, despite their low numbers, to overcome these crises and survive up until the modern era.

The new episode we are today confronted with will probably have a different impact, because it is combined with the effects of globalization. The survival of these northern peoples no longer depends on their ability to adapt. Indeed, the environmental and geostrategic stakes are now so high that circumpolar cooperation has become indispensable.

This cooperation takes place, in particular, within the framework of the Arctic Council, created in 1996, which gathers together the eight circumpolar countries and the organizations representing the native peoples. Its mandate is to protect the Arctic environment and improve the economic, social and cultural well-being of the Far North's indigenous peoples.

Human and social-science research in the Arctic

While global warming has already had perceptible effects, it is really only after several years of systematic studies among these populations that the trends and conclusions will be able to emerge. Anthropologists and ethnologists are seeking to collect the knowledge of the native peoples, knowledge founded upon a close observation of their environment and its evolution. For this reason, accounts provided by the oldest generations, the inheritors of a long and rich oral tradition, prove to be an extremely valuable source of information.

What's more, research carried out in the fields of archeology and paleogenetics can tell us much about the past of the populations living in the northern regions, so as to better understand the former human and social mechanisms for adapting to the boreal environment. Nevertheless, researchers interested in the future of the Arctic populations don't limit themselves to observing and analyzing the changes engendered by climate warming. They also study demography, economic development at the local and regional levels, the political evolution that goes hand in hand with a strong cultural identity, etc.

In addition to these aspects, one can cite among the subjects studied by the researchers working in these fields:

- the phenomena of family and social destruction affecting these communities often suffering from alcoholism and suicide;

- diet and health confronted with the appearance of new diseases and the effects of chemical pollution on traditional food resources;

- issues related to education and professional training, which condition the emergence or development of a native administration for these territories;

- the analysis of both traditional and recently introduced rituals and beliefs, in particular in Siberia following the collapse of the Soviet Union;

- the study and rescue from oblivion of endangered languages, which has emerged as an obligation in order to preserve our planet's cultural diversity, already greatly impoverished .

Taking into account these various issues, research programmes are now carried out in close cooperation with the concerned communities and involve the participation or training of native researchers.

Therefore, we are today opening up a vast research area. Pursued in an interdisciplinary spirit of international cooperation, its aim is to contribute to the knowledge and preservation of the peoples, ways of life and cultures found in this unique environment that is the Arctic.

Thank you.

E. DEBATE

Bruno ROUGIER

Thank you very much. You can now ask Valérie Masson-Delmotte, Yvon Le Maho and Joëlle Robert-Lamblin your questions, before we move on to a two-part conclusion.

I would like to ask you the first, very simple question: what type of programmes will your teams be working on within the framework of the International Polar Year?

Yvon LE MAHO

I am coordinating a project that I presented to you during my talk. We are monitoring thousands of birds thanks to antenna buried underground. A system has already been installed in Crozet and we plan to install another one in Adélie Land, which unfortunately I cannot take care of myself.

Valérie MASSON-DELMOTTE

We are involved in carrying out small ice corings. Starting in May, we will search for a new deep-sampling site in the northwest of Greenland, with the aim of characterizing the climatic variations over the past 140,000 years, in particular the stability of the last warm period. We are also planning, in partnership with the Glaciology Laboratory in Grenoble, to participate in an Antarctic ice-core study, in up-until-now unexplored regions of the continent.

Joëlle ROBERT-LAMBLIN

I am indirectly involved in a linguistic and ethnolinguistic project to collect native knowledge. The human and social sciences are the poor relation of Arctic research, but a team of young and experienced researchers is working in Greenland, Siberia, Nunavut and Alaska. The resources exist, but organization is lacking.

Bruno ROUGIER

Your greatest wish would be to involve these populations.

Joëlle ROBERT-LAMBLIN

Indeed, the native communities have always collaborated with our research, but we have been endeavoring to train native researchers and to involve them in our work, in order for them to take over from us in a few years time.

From the audience

I would like to know if your interest in these projects is to be explained by their being financed by Prince Albert of Monaco or by a real concern for public health issues. I would also like to understand why Mount Kilimanjaro and Mount Everest, both of which are concerned by climate problems, are not the subject of research.

Valérie MASSON-DELMOTTE

I can only answer your second question. It is true that the Chinese consider Everest the third pole. Numerous studies deal with the future of the glaciers, in particular the tropical glaciers which are essential water sources. Those of Tibet are the subject of studies not lying within the framework of the IPY: certain French teams, such as the Glaciology Laboratory in Grenoble and the Institut de Recherche pour le Développement (Research Institute for Development), are monitoring certain glaciers in Tibet and in the Andes.

Regarding Mount Kilimanjaro, we are analyzing ice brought back by an Austrian team, in order to characterize very recent climate variations. Indeed, the varying volume of its icecap reflects the evolution of its temperature and rainfall, which we are endeavoring to isolate.

However, these two zones do not lie within the framework of the IPY programmes.

From the audience

Allow me to present myself: my name is Jacques Peignon and I have carried out four expeditions by sailboat along the Antarctic Peninsula and around the continent. I would like to know if a programme is planned to clean the waste leftover from the 1958 International Polar Year and if you plan on reducing this type of waste this time around.

Yvon LE MAHO

A programme has been begun by the TAAF, as well as by the Polar Institute. This task will take several years. The work is progressing, but it is very difficult to clean up all the waste in Antarctica.

Bruno ROUGIER

The vestiges of past expeditions can, in the future, serve as testimony.

Yvon LE MAHO

Research is being carried out on the rehabilitation of whaling installations, as well as certain installations for the salvaging of sea-elephant fat.

Bruno ROUGIER

Today, researchers pay more attention to this problem. For example, at the Concordia base, waste water is partially recovered.

Yvon LE MAHO

In addition, everything considered waste is brought back home.

Gérard JUGIE, IPEV Director

Within the framework of the Madrid Protocol, the objective in Antarctica is to achieve zero waste. I would like to point out that the Peninsula, which has welcomed no less than 30,000 tourists and a total of 50,000, is the most visited part of the continent. In their construction of Concordia, France and Italy did everything they could to achieve this objective. For example, 83% of "grey" waste water is treated and then reinjected into the water-use cycle. We go beyond what is required by the Antarctic Treaty, which authorizes the burying of waste. France and Italy have committed themselves to leaving no waste at Concordia.

In addition, as Latin countries, we are carefully watched by the Anglo-Saxon countries, which encourages us to make greater-than-average efforts. I just finished making an inspection tour, in accordance with a clause of the Antarctic Treaty which allows all countries to visit foreign bases. We therefore visited the American South Pole base and Concordia. Both bases are exemplary, insofar as their installation only corresponds to scientific objectives and their waste treatment has been considerably improved. However, we must take into account the fact that, fifty years ago, environmental issues were not given as much importance as they are today.

Bruno ROUGIER

Thank you very much. I would like to know how climate change is affecting the biodiversity of the polar regions.

Yvon LE MAHO

I mentioned the example of Kerguelen's microfauna, by discussing the ability of a fly to establish itself on the island. The number of species is in fact increasing, but these are nonendemic species. We are therefore witnessing a homogenization of the environment, with, for example, the invasion of dandelions, and the disappearance of magnificent landscapes.

Bruno ROUGIER

How far back can we go in climate history?

Valérie MASSON-DELMOTTE

Other climate records, such as marine sediments, can shed light on climate history. Ice provides us with certain elements on the local climate, the composition of both the regional and world atmosphere, via the greenhouse gases. Therefore, we understand what is potentially at stake in going back as far as possible.

Modeling of the Antarctic icecap shows that it is possible to go back more than one million years, perhaps as far back as 1.3 million years, in the driest regions. I pointed out the close relationship between climate and the natural concentration of greenhouse gases.

Up until one million years ago, glaciations occurred every 40,000 years and were of a limited intensity. How did a major change affect the intensity of glaciations? How did the relationship between climate and the carbon cycle play a driving role in this transition? Only by studying the oldest ice will we be able to answer these questions, in particular via the ice samplings carried out at Dome A. Talks are currently underway with our Chinese contacts, for a project to allow us to go back as far as 1.2 million years. Jérôme Chappellaz, present here today, is the French coordinator of this project.

The ice corings are increasingly difficult, because the concerned regions are very far from the bases, which means that various countries must combine their efforts. We can resort to the technology developed for EPICA, along with the know-how of the Glaciology Laboratory in Grenoble.

Bruno ROUGIER

Is climate warming already disrupting the Arctic populations' way of life? Joëlle Robert-Lamblin, you mentioned the danger of the weakening ice for persons moving about by snowmobile, as well as the displacement of certain populations.

Joëlle ROBERT-LAMBLIN

Displacement concerns those villages threatened with destruction by sea storms or the recurring flooding of certain rivers. This is the case on the western coast of Alaska. We're talking about small communities, though they nevertheless have infrastructures which need to be moved. This is a very difficult situation for the populations, especially as it disrupts their hunting and fishing activities, as well as their connection to the land.

From the audience

As part of my work at Météo France, I recently became interested in the problem of the melting ice shelf at the North Pole. I learned that Jean-Louis Etienne, in cooperation with the Wegener Institute, was planning an expedition to measure its depth. How does this project lie within the framework of the International Polar Year?

Bruno ROUGIER

The thickness of the ice shelf will be measured from a Russian-made airship, which should be finished in June or July. The expedition will take place next year.

From the audience

My name is Michel Fily and I'm director of the Glaciology Laboratory in Grenoble. Jean-Claude Gascard directs the DAMOCLES project, which studies the Arctic basin and sea ice. The measurements made by Jean-Louis Etienne can be considered a contribution to this body of work.

Jean-Claude GASCARD

The DAMOCLES project, funded by the European Union, studies the current evolution of the Arctic ice shelf under the effect of the atmosphere and of the ocean. It focuses on ice, though it includes numerous ramifications. The average thickness of the ice has dropped from more than 3 m to less than 2 m in twenty years. 45 laboratories in Europe, including the Alfred-Wegener Institute, are involved in this programme.

It is very difficult to measure the thickness of the ice, in particular due to the presence of ice reefs. Satellites, sonar-equipped submarines, AUVs and floats are all used. We are faced with a logistical problem: it is impossible to carry out this type of measurement using classic means. Helicopters and airplanes have a limited autonomy. That is why Jean-Louis Etienne came up with the idea of carrying out measurements from a sweeping airship, this means of transport having already been used some one hundred years ago in the Arctic.

Today, the thickness of the ice seems to be decreasing by 10 to 15 cm per year in the centre of the Arctic. Maps from the month of September 2006 show rather large areas of open water from the islands of Spitzberg and François-Joseph to near the pole. The forecasting models for ice evolution indicate a certain delay. For example, Tara is drifting twice as rapidly as predicted. These phenomena, which we are endeavouring to understand, could be explained by a fluidification due to the thinning of the ice.

Bruno ROUGIER

Thank you. Yvon Le Maho, during your presentation, you mentioned an antibacterial, the "spheniscine", found in the stomach of the emperor penguin and capable of helping us fight nosocomial diseases. Do you think that we can find useful molecules for research in these *a priori* inhospitable regions?

Yvon LE MAHO

Each species represents an irreplaceable innovation. The disappearance of any species can therefore represent the loss of a particular molecule. For instance, penguins are particularly sensitive to aspergillosis, caused by the development of a pathogenic fungus in the lungs. This can explain the effectiveness of the protein which we identified, a defensin, in fighting this disease. Defensins have also been discovered in saprophytic fungi, mussels and oysters. The defensin, which possesses a gene one billion years old and which is produced by our body, allows us to fight not only bacteria, but also viruses and pathogenic fungi, as opposed to antibiotics. It therefore represents a very interesting subject for medical research, especially considering that the difficulty once connected to sulphide bridges has just been solved, thereby lowering the cost of molecular production.

The different species also present interesting biological mechanisms: I mentioned that which pushes penguins to once again start feeding. To take another example, Professor Hervé Barré, of the University of Lyon, has shown by studying the penguin's heat-production mechanisms that these birds constitute a better model than laboratory animals, due to their similarities to man.

In parallel with all the genetic strains developed in the laboratory, the study of animal species therefore represents an area of research that is just as interesting, although it currently receives less funding.

Bruno ROUGIER

Valérie Masson-Delmotte, you discussed the role of human activities in global warming. Have you identified other factors?

Valérie MASSON-DELMOTTE

The study of concentrations of greenhouse gases or the temperature of the ice demonstrates man's influence not on the climate, but on the composition of the atmosphere. The tool which allows us to identify the cause and effect is the modeling of interactions between the composition of the atmosphere and the evolution of the climate. By studying polar ice, we have access to several factors that influence climate at different time scales (the Earth's orbit, the frequency of volcanic irruptions, solar activity), but whose global impact remains unknown. It is possible to characterize their past variations in the ice by then using climate models to quantify the cause-effect relationship.

Bruno ROUGIER

Can we quantify the contribution of human activity to global warming?

Valérie MASSON-DELMOTTE

Thanks to climate models, we are capable of asserting that the global warming of the past thirty years cannot be explained by natural factors. In the polar regions, the situation is contrasting. In Greenland, we remained within the natural variability up until some ten years ago, when temperatures began to surpass those of the warm period of the 1930s and 40s, and even those of the climate warmings of the Middle Ages. For the time being, no significant warming has been detected in central Antarctica, but the climate models do not allow us to simulate it. The effects of climate change vary according to the region.

Bruno ROUGIER

Thank you. It is now time for us to close this solemn opening ceremony for the International Polar Year with two speeches. The first speaker will be François Goulard, Minister for Higher Education and Research.

IV. CLOSING SPEECHES

A. MR. FRANÇOIS GOULARD, MINISTER FOR HIGHER EDUCATION AND RESEARCH

Your Serene Highness,

Honourable Members of Parliament,

Honourable Presidents, representatives of the scientific community here gathered,

Allow me to salute you, Your Serene Highness, for your presence and extremely active participation in this opening day, and to tell you just how much we appreciate your commitment, as well as the long-standing commitment of your family, which has allowed for progress to be made in the sciences. We are well aware just how famous Monaco is for its oceanographic and polar research. I wanted to take this opportunity to tell you this, very simply, but with great warmth.

I would also like to salute the Members of Parliament, who are very committed to these scientific issues, such as President Revol, in particular those concerning the poles, such as Senator Gaudin, one of the many persons in this room familiar with the polar regions. Although I haven't had the privilege myself, I know, from having read it many times, that the poles exert a fascination on those who have discovered them. From this point of view, I am also aware of the fact that the International Polar Year is a unique event, with a power to move that is quite exceptional. The International Polar Years are rare and represent important events in and of themselves.

The international nature of any scientific event must be highlighted: science belongs to all of humanity, with the men and women of science working for all of mankind. We sometimes have the opportunity to celebrate this gathering of scientific forces in large projects: we had the pleasure of hosting here in France the ITER project, which brings together exceptional means, allowing us to perhaps discover the energy of tomorrow. Each time the international community gathers together for a scientific objective is grounds for an intense feeling of satisfaction. We know that together we are more effective. All of these countries coming together for a scientific end also has symbolic power.

When we talk of the poles, this international cooperation has even greater symbolic power, for the same reason that I just mentioned - namely, this extraordinary power to move – but also because there exist specific statutes, in particular in Antarctica, with particularly protective international agreements which we need to develop and extend. When the international community, spurred on by the men and women of science, admits that certain territories need to be preserved, protected and dedicated to science – territories where our nationality identities must give way before issues that are beyond us - because they belong to all of humanity, one can there see signs that are particularly important and positive.

This International Polar Year is certainly different in nature from its predecessors. I mean to say that the explorers, the geographers, those who before were simply trying to understand our planet in all of its aspects have today given way to a scientific community.

Polar research not only concerns polar specialists, it also covers entire scientific fields. It is no longer only a question of better understanding the poles; scientific considerations of great amplitude are at stake. You mentioned the issues of climate change and biodiversity: in this domain, a community of interest is emerging between the research carried out in our different countries and that which has polar research as its advanced base. They are thereby imparted with both a new dimension and special importance.

The interest of the general public, the fascination that I mentioned earlier allow us to make this International Polar Year an opportunity to attract the attention of our contemporaries to the great scientific questions. We must take advantage of this unique opportunity to highlight today's important scientific subjects, to treat them in a manner that is likely to interest the general public, to consider them from various scientific as well as technological viewpoints. The International Polar Year must therefore be used to spread scientific and technical knowledge. You are all familiar with the importance of these subjects here in France, and we are all aware of the importance of raising the awareness of our fellow countrymen with regard to these scientific issues: our very future is at stake.

For our country, it is an ancient tradition. A land of seafarers, explorers and audacious scientists, today France can boast of a presence at the poles that was anything but a given: the geography of certain countries naturally encourages them to develop their polar research. This isn't the case for France: its overseas austral territories are mere "confetti" and uninhabited lands. Thanks to our scientific will, adventurous spirit and initiative, we have long demonstrated our interest in the poles. We must assert this scientific tradition, which is greater in the south than in the north. That is why we must lend particular support to the Arctic adventure of Jean-Louis Etienne, who will act somewhat as our standard bearer in this polar region.

We must prove ourselves faithful to this tradition, by relying on the most modern means and methods. The International Polar Year has naturally given rise to a special effort: via the National Research Agency, we have submitted requests for proposals, so as to provide additional means for research. In addition to our annual research funding, we have allocated €13 million in credit. But, above all, this is an opportunity for us to carefully consider these subjects - which the Gaudin report allows us to do, with a general overview that is particularly valuable.

Naturally, our country must fully assume its responsibilities, maintain its means and look after its bases. However, looking ahead, the most effective direction for us to take is that of international – and, in particular, European - cooperation. As I already asserted, this is a cause that goes beyond just us and concerns all of mankind. At the very least, the European dimension should provide a special impetus thanks to the pooling of means, so that Europe – and, through it, France - is present in the polar regions and participates in this fascinating scientific adventure - thanks, ladies and gentlemen, to all of you.

I would like to thank you for your great contribution to contemporary science, to the great questions of vital importance for both our planet and the men and women who inhabit it, and to celebrate this great event that is the International Polar Year. Thank you.

Bruno ROUGIER

Thank you very much, Minister Goulard. We will now welcome a man who has paid particular attention to these speeches, thereby following a long family tradition. Indeed, Prince Albert I participated in four expeditions to Spitzberg. Naturally, I am speaking of His Serene Highness Prince Albert II of Monaco.

Your Serene Highness, on the 16th of April, you planted the Monacan flag at the North Pole at the end of an expedition by dogsled on the polar ice shelf, both to pay homage to your great-great-grandfather, but also as a strong gesture to attract attention to the problem of global warming.

B. HIS SERENE HIGHNESS PRINCE ALBERT II OF MONACO

Honourable Minister,

President of the CNRS,

President of the Parliamentary Office for the Evaluation of Scientific and Technological Choices,

Honourable Senators and Deputies,

Dear members of the scientific community,

Dear friends of the polar regions,

Ladies and gentlemen,

I am infinitely grateful for this opportunity to participate here today, and I would like to thank all of the speakers who succeeded one another and presented their contributions. These testify to the importance assumed by this International Polar Year that we are launching here today.

As for me, ever since I was a young boy, I have been fascinated by the polar regions, undoubtedly influenced by the travel writings and images of my great-great-grandfather, Prince Albert I, a pioneering oceanographer who carried out research and made precise observations during his four expeditions to the polar regions, between 1898 and 1907. At a time when these expanses were still largely unexplored, he committed himself to this project with a qualified, scientific team that was international and, even then, multidisciplinary. Its scientific operations were carried out along first the eastern, then the western coasts of Spitzberg. Soundings, temperature measurements, and water and sediment samplings were made.

During his second expedition, in 1899, he returned to Svalbard, where most of his work was dedicated to carrying out topographic and hydrographic surveys. Thanks to this research, a sea chart for this area was able to be drawn up. The positions of several glacial faces were recorded, to determine their evolution and thereby complete the measurements taken during the 19th century.

During the following voyages, studies were carried out in the fields of hydrography, geography and meteorology. The Arctic programmes undertaken by Prince Albert I allowed for significant progress to be made in all the concerned research domains. He thereby fulfilled a dream of his youth and was happy to have served science – this science which he was convinced would bring humanity greater well-being, justice and peace.

I had long wanted to visit the North Pole and this region that my great-great-grandfather wasn't able to reach. That is why, in July 2005 and April 2006, I undertook two expeditions that allowed me to fuel my thinking by following in his footsteps.

During my first expedition around Spitzberg, I was accompanied by professional divers and renowned scientists from the polar programme of the World Wildlife Fund (WWF) and the International Atomic Energy Agency (IAEA), as well as representatives from the Oceanography Museum of Monaco. By comparing photographs of the same site taken during the trip made by Prince Albert I in May 1906 and during my own expedition, the melting of the glaciers became obvious to me - in particular the Lillihook Glacier, which, based on our observations, has receded by more than 6 km.

On 10 April 2006, I undertook the second part of this project, which consisted of the expedition to the North Pole, with an eight-member team. At the end of four days, we reached the geographic North Pole after having traveled some 150 kilometres, thanks to the exceptional dogs who were of great help to us.

By this tour of symbolic sites, I wanted to investigate for myself these phenomena that are a concern for future generations. I considered it my duty to testify to this peril before my contemporaries, and to make them aware of the urgency to act with regard to our relationship with our planet. There is no longer any doubt that time is of the essence: we must act and act quickly, because we share a common responsibility. The risks and dangers are getting worse with each passing day. The report prepared by the Intergovernmental Panel on Climate Change, which met in Paris at the beginning of last month, forcefully demonstrates, I believe, the gravity of the situation.

We must now show, in every aspect of our behaviour, a shared ethics of ecology, so as to preserve the riches and resources that the Earth has to offer us. This represents the most important issue of this century. A new solidarity must emerge to meet this ecological, economic and social imperative. This planet-wide problem calls for an immediate realization and urgent, concrete actions in response to three major environmental issues: climate change, the loss of biodiversity and the increasing scarcity of water.

That is why, in June 2006, I decided to make a contribution, on behalf of myself and of the principality, by creating the foundation that bears my name. The mission of this foundation is to identify priority, emblematic projects and to speed up their implementation, in order to obtain concrete results, throughout the world, in favour of a sustainable, equitable management of our natural resources. I will also be present, alongside other heads of state, at the future international negotiations on the environment.

The second objective of my foundation is to encourage initiatives, projects and enterprises that reconcile the environment and innovation. We have already identified ten projects to receive funding this year. Via the projects it supports, the foundation also hopes to prove that it is possible to adopt practices and behaviour that are sustainable and respectful of the environment, compatible with an economic, social and human development.

Finally, its third objective is to raise public awareness regarding the various issues and responsibilities related to these themes, via a vigorous communication campaign.

Determination and energy are needed to make these actions succeed, and it is in this state of mind that I will pursue my action. All actions undertaken by the foundation are consistent with the environmental policy of my country. As you are all undoubtedly aware, the principality has been involved for a very long time in numerous international agreements and conventions in support of the environment. The Ramoge agreement to fight marine pollution, ACCOBAMS for the protection of cetaceans, and the headquartering in Monaco of the Mediterranean Science Commission (CIESM) all testify to the principality's continuing international commitment to protecting the marine environment. This ancestral mission is part of our history, as evidenced by the creation a century ago by Prince Albert I of the Oceanography Museum and the Anthropology Museum in Monaco.

At the beginning of this International Polar Year, I would like to emphasize the involvement of the principality, which is happily associated with the project being carried out by the *Tara* boat within the framework of the European DAMOCLES programme. The objective of this partnership with the Monaco Yacht Club is to draw the attention of the principality's population to the evolution of this project. I am delighted at the presence here today of Mr. Charles Terrin, who has been chosen by the Yacht Club to embark on the *Tara* for a six-month voyage.

To conclude, I would like to salute the community of researchers, explorers and scientists who study these regions with passion and rigour and provide us with, among other things, a better understanding of climate change. I hope that the many scientific projects that will be developed during this period will allow us to deepen our knowledge and will encourage a better appreciation of these regions' complexities, in order to increase the effectiveness of the political actions in support of the environment.

Now that we are more aware of the risks facing our planet, man should feel responsible for what Nature has offered him. Prince Albert I liked to say that science must dominate, because it provides for the needs of civilization. Today, is it not civilization's turn to rely on science in order to save humanity?

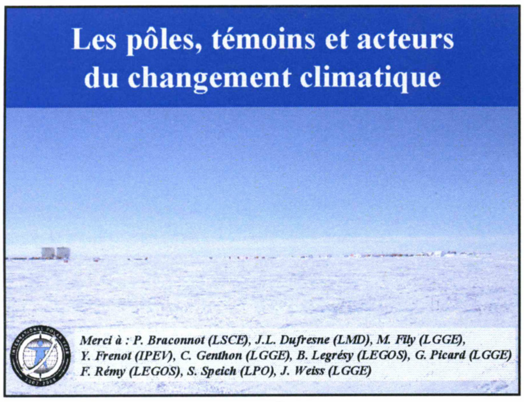
Thank you.

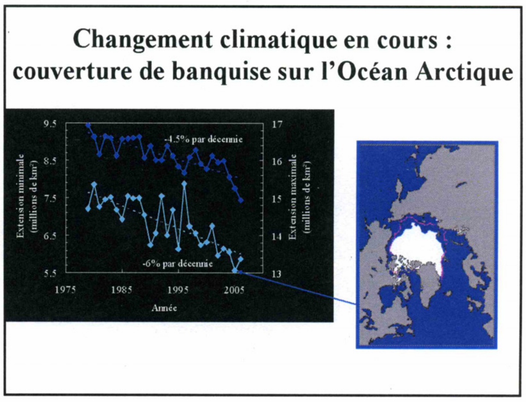
Bruno ROUGIER

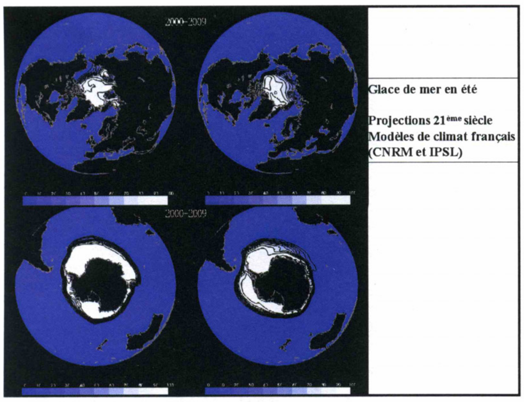
Your Serene Highness, I thank you. And so finishes this opening day. We will meet again in the coming months, in the coming years, to consider the results of the 209 projects selected for this International Polar Year.

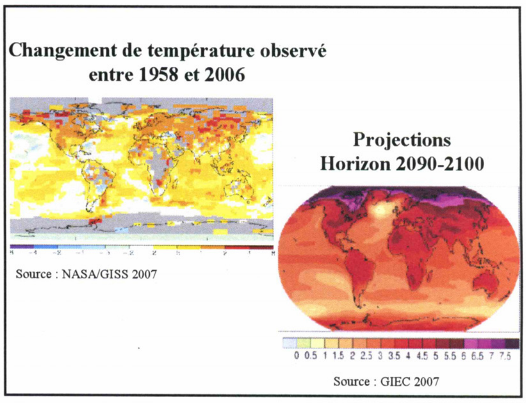
APPENDICES

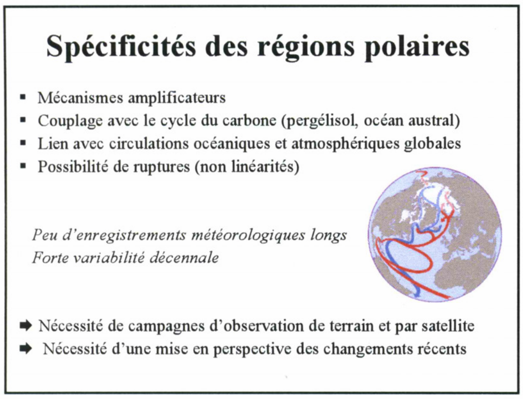
APPENDIX 1: DOCUMENTS PRESENTED BY MS. VALÉRIE MASSON-DELMOTTE, CLIMATOLOGIST – CEA

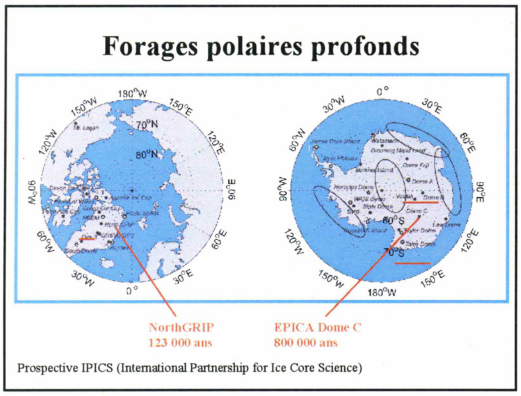


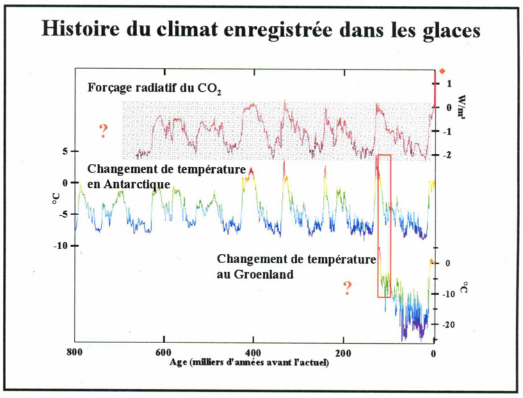


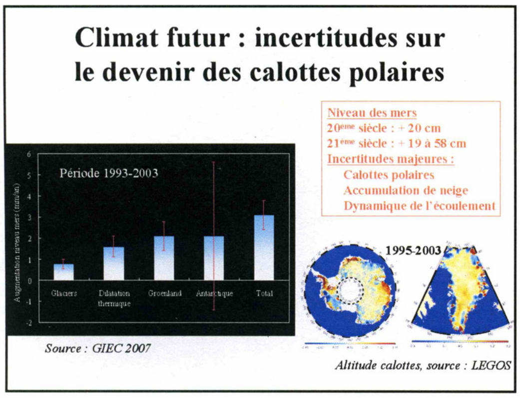


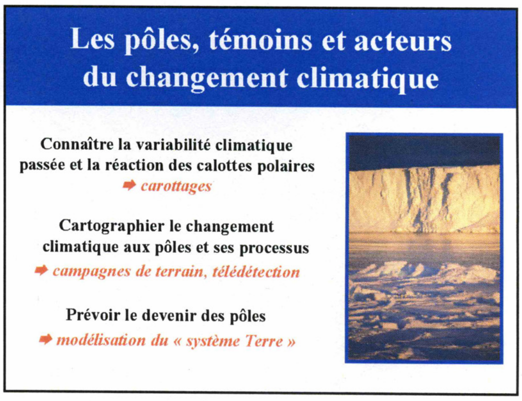




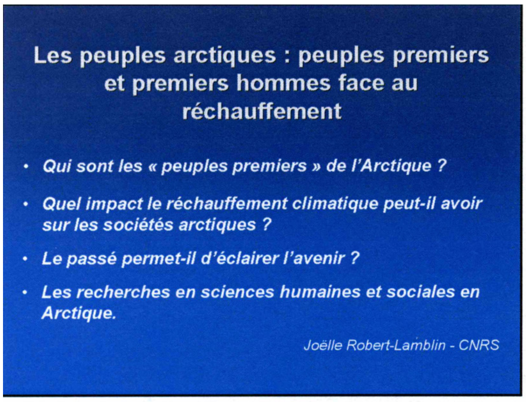

Forages polaires profonds
NorthGRIP
123 000 ans
EPICA Dome C
800 000 ans
Prospective IPICS (International Partnership for Ice Core Science)

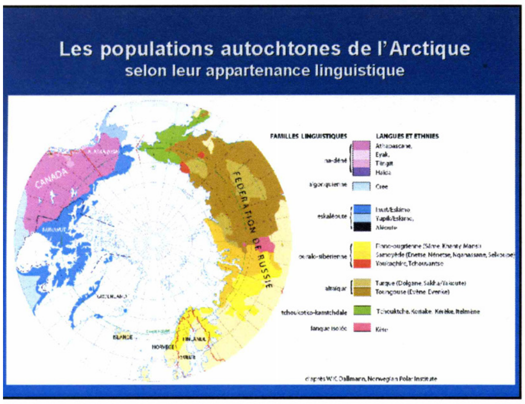

Histoire du climat enregistrée dans les glaces
Forçage radiatif du CO2
Changement de température
en Antarctique
Changement de température
au Groenland
Age (milliers d'années avant l'actuel)
W/m²
°C

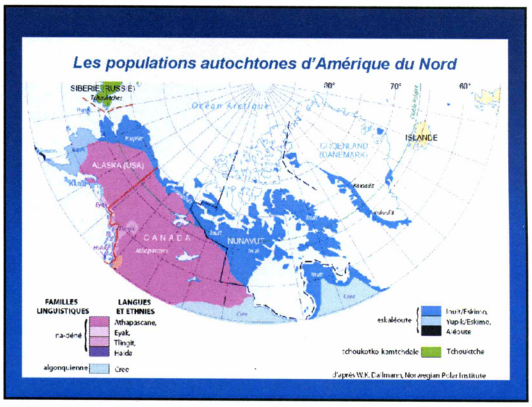

Climat futur : incertitudes sur
le devenir des calottes polaires
Niveau des mers
20ème siècle : + 20 cm
21ème siècle : + 19 à 58 cm
Incertitudes majeures :
Calottes polaires
Accumulation de neige
Dynamique de l'écoulement
Période 1993-2003
Glaciers
Dilatation thermique
Groenland
Antarctique
Total
Source : GIEC 2007
1995-2003
Altitude calottes, source : LEGOS

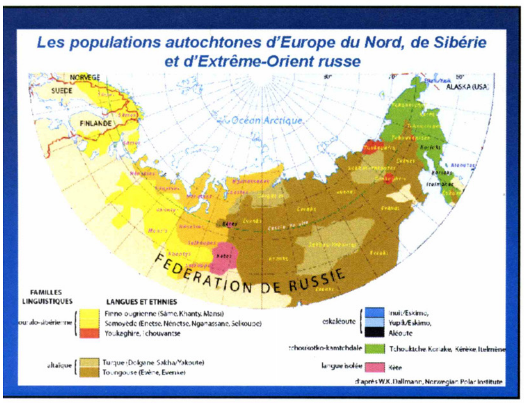

Les pôles, témoins et acteurs
du changement climatique
Connaître la variabilité climatique
passée et la réaction des calottes polaires
➡ carottages
Cartographier le changement
climatique aux pôles et ses processus
➡ campagnes de terrain, télédétection
Prévoir le devenir des pôles
➡ modélisation du « système Terre »

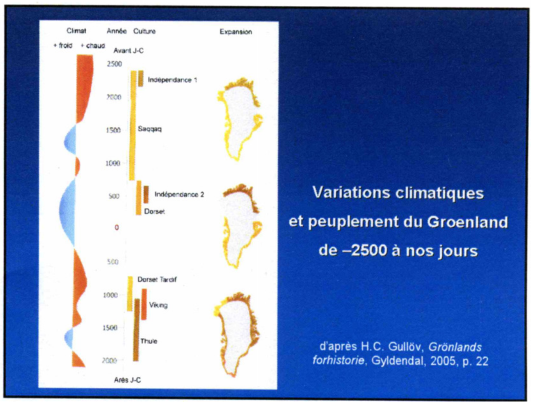
APPENDIX 2: DOCUMENTS PRESENTED BY MS. JOËLLE ROBERT-LAMBLIN, ANTHROPOLOGIST – CNRS

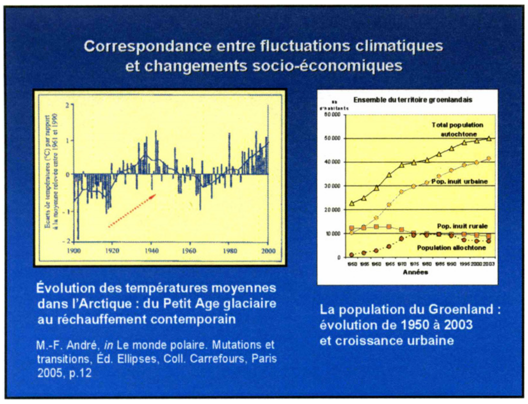




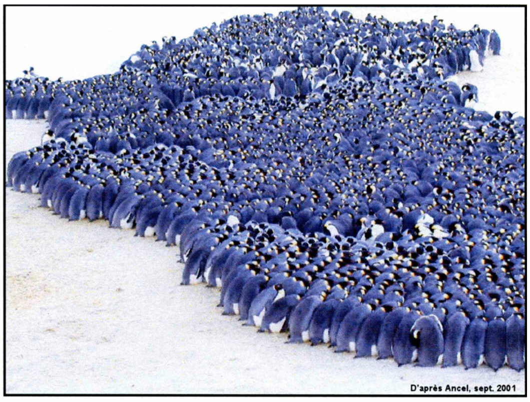


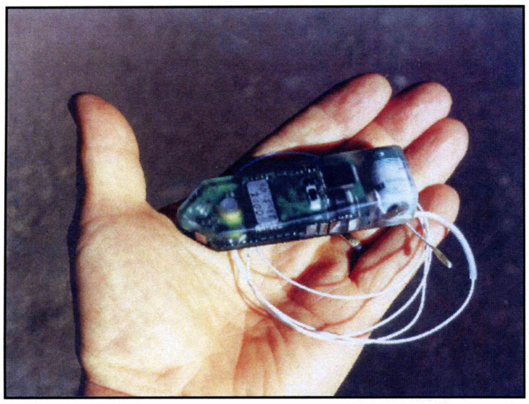


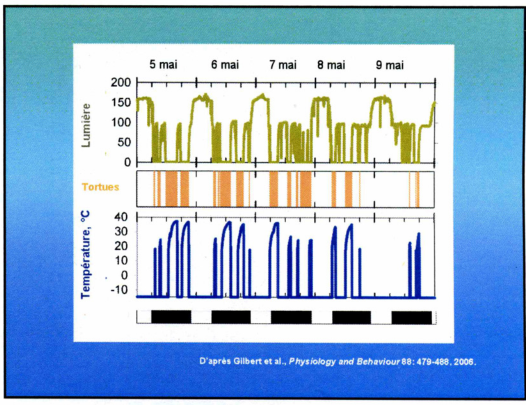


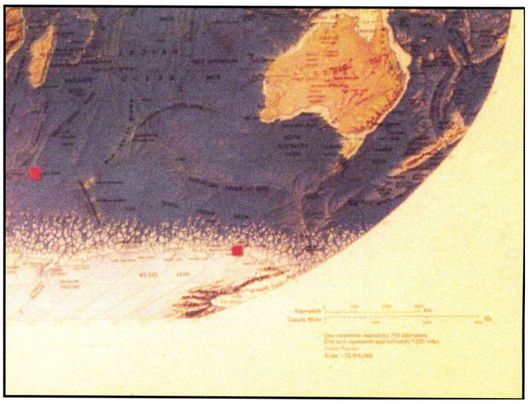

Correspondance entre fluctuations climatiques
et changements socio-économiques
Ecarts de températures (°C) par rapport à la moyenne relevée entre 1961 et 1990
2
1
0
-1
-2
1900
1920
1940
1960
1980
2000
Ensemble du territoire groenlandais
60 000
50 000
40 000
30 000
20 000
10 000
0
Total population autochtone
Pop. inuit urbaine
Pop. inuit rurale
Population allochtone
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2003
Années
Évolution des températures moyennes dans l'Arctique : du Petit Age glaciaire au réchauffement contemporain
M.-F. André, in Le monde polaire. Mutations et transitions, Éd. Ellipses, Coll. Carrefours, Paris 2005, p.12
La population du Groenland : évolution de 1950 à 2003 et croissance urbaine

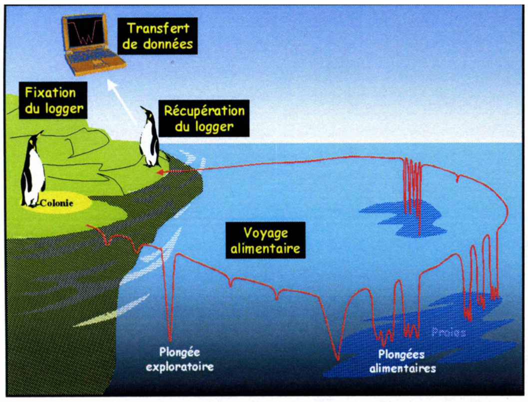
APPENDIX 3: DOCUMENTS PRESENTED BY MR. YVON LE MAHO, BIOLOGIST – CNRS

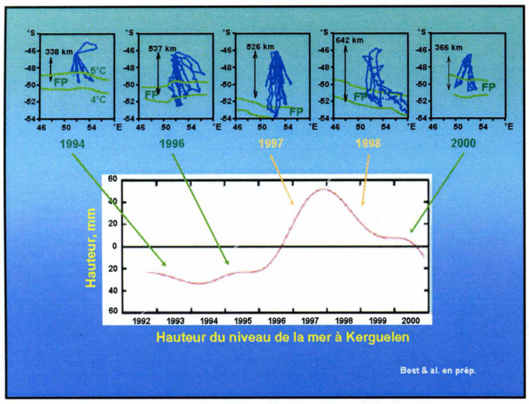


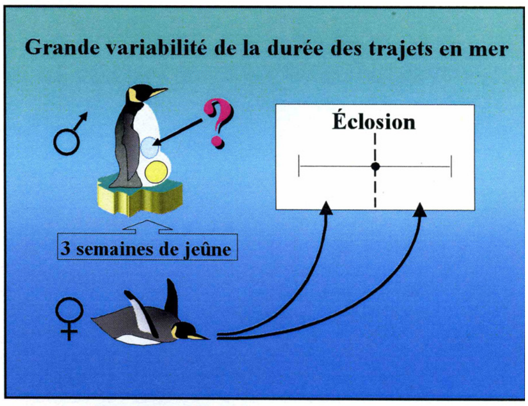


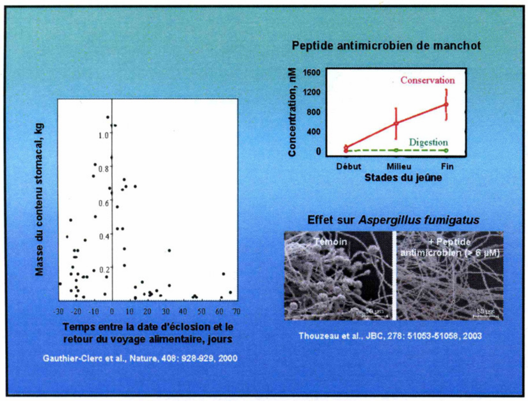


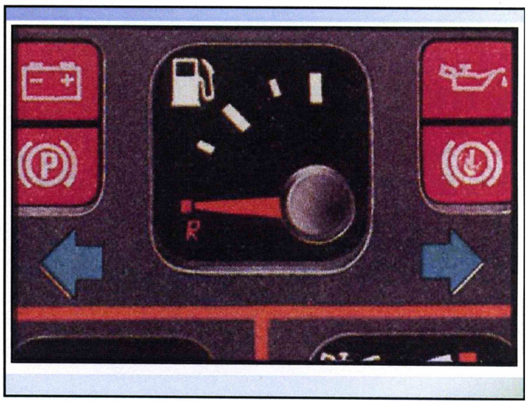


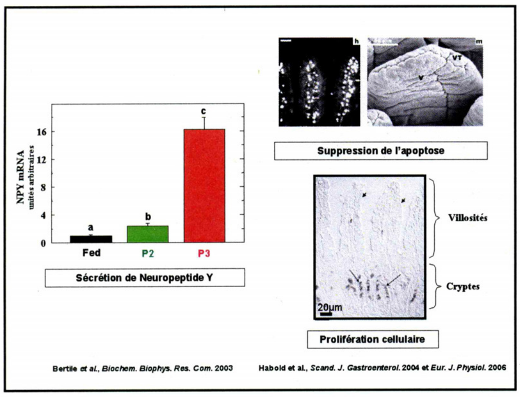

Transfert
de données
Fixation
du logger
Récupération
du logger
Colonie
Voyage
alimentaire
Plongée
exploratoire
Plongées
alimentaires
Proies

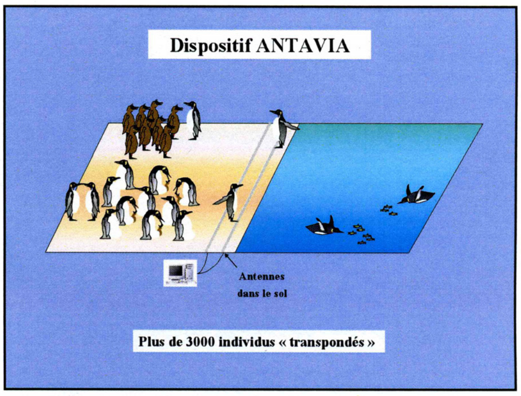

338 km
537 km
626 km
642 km
366 km
FP
6°C
4°C
1994
1996
1997
1998
2000
Hauteur, mm
Hauteur du niveau de la mer à Kerguelen
Bost & al. en prép.

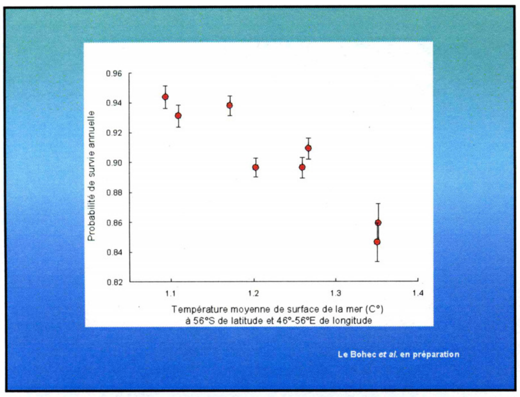

Grande variabilité de la durée des trajets en mer
♂
?
Éclosion
3 semaines de jeûne
♀

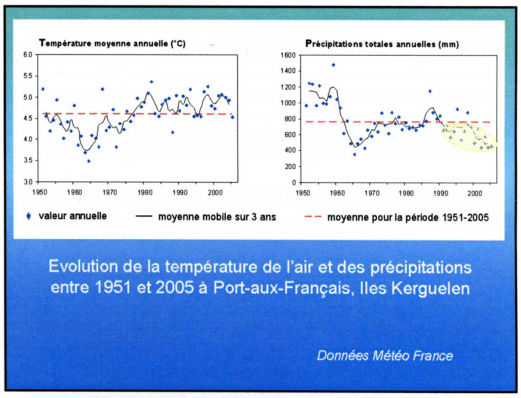

Masse du contenu stomacal, kg
Temps entre la date d'éclosion et le retour du voyage alimentaire, jours
Gauthier-Clerc et al., Nature, 408: 928-929, 2000
Peptide antimicrobien de manchot
Concentration, nM
Conservation
Digestion
Début
Milieu
Fin
Stades du jeûne
Effet sur Aspergillus fumigatus
Témoin
+ Peptide antimicrobien (> 6 µM)
Thouzeau et al., JBC, 278: 51053-51058, 2003

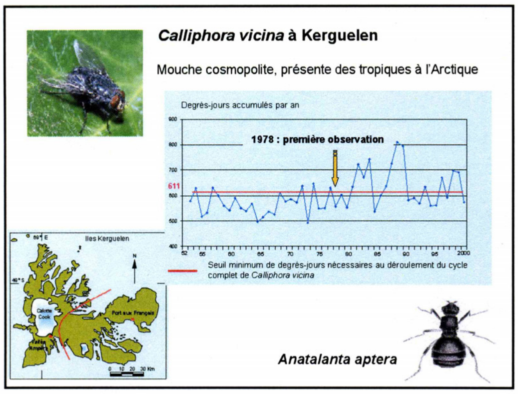


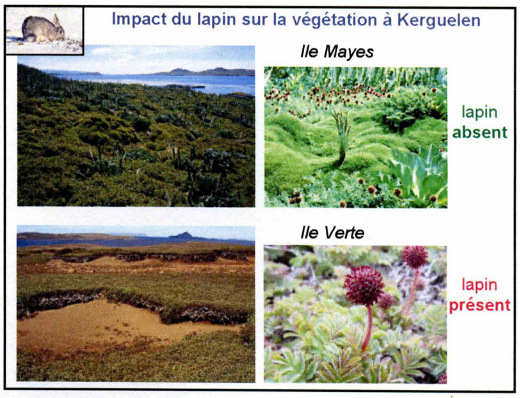

NPY mRNA
unités arbitraires
Fed
P2
P3
Sécrétion de Neuropeptide Y
Suppression de l'apoptose
Villosités
Cryptes
20µm
Prolifération cellulaire
Bertile et al., Biochem. Biophys. Res. Com. 2003
Habold et al., Scand. J. Gastroenterol. 2004 et Eur. J. Physiol. 2006

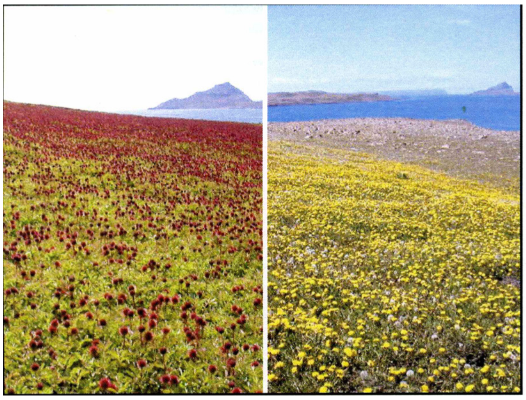

Dispositif ANTAVIA
Antennes
dans le sol
Plus de 3000 individus « transpondés »


Probabilité de survie annuelle
Température moyenne de surface de la mer (C°)
à 56°S de latitude et 46°-56°E de longitude
Le Bohec et al. en préparation


Température moyenne annuelle (°C)
Précipitations totales annuelles (mm)
valeur annuelle
moyenne mobile sur 3 ans
moyenne pour la période 1951-2005
Evolution de la température de l'air et des précipitations
entre 1951 et 2005 à Port-aux-Français, Iles Kerguelen
Données Météo France


Calliphora vicina à Kerguelen
Mouche cosmopolite, présente des tropiques à l'Arctique
Degrés-jours accumulés par an
1978 : première observation
611
Seuil minimum de degrés-jours nécessaires au déroulement du cycle complet de Calliphora vicina
Iles Kerguelen
Port-aux-Français
Anatalanta aptera


Impact du lapin sur la végétation à Kerguelen
Ile Mayes
lapin
absent
Ile Verte
lapin
présent

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Yves Frenot
Michel Gauthier-Clerc
Jean-Paul Gendner
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Caroline Habold
Céline Le Bohec
Marc Lebouvier
Jean-Hervé Lignot
Thierry Raclot
Laurence Sabatier
Cécile Thouzeau
Philippe Vernon

On the eve of the International Polar Year, it was necessary to evaluate French research and our country's position in these regions. Subjected to accelerated climate change which threatens their biodiversity, these regions are at the heart of current concerns. As they become more accessible, they become strategic.

Senator Christian Gaudin, the first member of the French parliament to have visited Antarctica, takes stock of the situation, analyzing the most important scientific issues, as well as the organization of our means and on-site presence.

At the end of this study, he presents recommendations for our country to adopt a strategy, organization and resources to provide itself with the means for excellence.

The website of the National Assembly :
http ://www.assemblee-nationale.fr

The National Assembly kiosk :
4, rue Aristide Briand
F-75007 Paris
Tel : 33 (0)1.40.63.61.21

The website of the Senate :
http ://www.senat.fr

The Senate bookshop :
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