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Polar Research

Understanding our planet better

The International Polar Foundation (IPF)

Set up in Brussels in 2002 with the aim of informing society on the growing importance of scientific research in the polar regions and its contribution to the understanding of climate change, the IPF conducts numerous information, education and demonstration activities, forming a bridge between science and society.

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The IPF receives wide-ranging support and encouragement from the international polar scientific community, and works closely with polar institutes and bodies in the European Research Area. These include the European Polar Board, the Scientific Committee on Antarctic Research, the Alfred Wegener Institute, the British Antarctic Survey, the Norsk Polarinstitutt, the Laboratoire de Glaciologie et Géophysique de l'Environnement, and the Scott Polar Research Institute.

At the beginning of 2007, the IPF will open the Polaris Climate Change Observatory in Brussels. This exhibition centre is dedicated to explaining how scientific research in the polar regions has contributed to a better understanding of climate change. This centre will be a focus for activities related to the International Polar Year 2007-2008.

This special issue of RTD info was produced in collaboration with the IPF.

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Another *world*

For most of us, the North and South Poles are evocative of another world. But the riches hidden under their thick ice are simply too abundant to cram into the meagre pages of this special issue! Some of these are scientific riches, the fruit of major research projects which have revealed a universe of astounding contrasts. Both distant and near, neglected yet essential, the polar regions include both desert and populated habitats. Although they may appear immutable, these highly dynamic environments play a fundamental role in the health and metabolism of our planet. For example, Antarctica – a continent three times the size of Europe – accounts for 90% of the world's ice, a formidable climatic buffer which protects us from excessively rapid warming.

A voyage to the polar regions of the world is also a trip through time and history. With respect to the past, they constitute an archive of world climatic variations; polar ice makes it possible for scientists to write the history of recent climate changes and to validate the simulation models they are now developing. As for the present, these regions are already seeing major change, due to the effects of global warming. And we should not hesitate to follow the path of time forwards, as these regions hold the key to our future climate and thus the future of humanity. The disappearance of summer pack ice in the Arctic between now and the end of this century (a sadly probable and even realistic scenario) is just one of the symptoms of the major changes which are already profoundly affecting the outline and life of our planet.

In this high-altitude overview, RTD info has tried to consider a broad range of scientific disciplines: glaciology, climatology, astronomy, geomorphology, etc., while not forgetting the life sciences. Although working in the extreme environment of the polar regions raises problems because of the 'inhuman' conditions, we can learn from the survival skills of native populations such as the Inuits and Saami in the Arctic, not forgetting that they too have to learn to accommodate the "innovations" imposed upon them by warming, such as the appearance of swarms of wasps.

Last but not least, European participation in polar research is highly developed and has left its mark on all of the major stages of exploration. This exemplary cooperation is reflected by this special issue which was prepared at the initiative of and in conjunction with the International Polar Foundation.

What's so crucial about polar research?

Although almost opposites in terms of geography and topography, the common characteristics of the Arctic and the Antarctic are of course their coldness, remoteness and the harshness of their environments. This means that polar researchers must often rely on specially adapted methods and technologies to carry out their work, making polar science a complex and extremely expensive activity. But why all this effort, and why would something happening so far away from our daily lives be so crucial?

Although very remote, the polar regions are an integral and highly significant component of the Earth's climate system. Indeed, as a result of the differences in energy input between the equator and the poles, both the Arctic and the Antarctic inject huge masses of cold air and water into the global wind and ocean circulation, affecting climate not just in the high latitudes, but across the entire planet. Furthermore, the massive continental ice caps (together the East and West Antarctic ice sheets account for some 90% of the world's ice, and 80% of its fresh water) possess an inherent inertia that, at least until now, has protected us from rapid global warming, whether as a result of natural or human CO_2 emissions.

Reflecting solar radiation

The climatic buffer provided by the polar regions, however, also depends on the horizontal extent of sea ice. Until quite recently, the combined sea ice cover of the Arctic and Southern Oceans had never dropped below 16 million km^2. These large white surfaces reflect solar radiation back out into space and thus contribute significantly to the natural cooling of our planet. This reflective capacity is known as the *albedo*.

A Carbon sink

Additionally, what is referred to as the thermohaline circulation (heat and salt transit) is driven by the polar oceans. North Atlantic Deep Water (NADW) formation drives the cold current that flows out from the Arctic Ocean through the Fram straight into the Atlantic. Similarly, cold water from the Weddell Sea flows into the Southern Ocean. These bottom currents have a direct impact on the carbon cycle and make the Southern Ocean the Earth's principle oceanic carbon sink by providing the conditions for the growth of CO_2 absorbing phytoplankton.

A privileged and irreplaceable research zone

Apart from the research being carried out on these urgent issues, the polar regions attract scientific investigations into a whole range of disciplines. Glaciology is probably the most talked about in the climate change context, particularly due to the mass of information already produced about past climates.

Indeed the poles themselves have also proven to be key regions for research and observation. For example:

- Studying the interactions between the high atmosphere and ionised particles coming from the sun, which cause both the Aurora Borealis and the Aurora Australis. These interactions also affect radio emissions from satellites;
- Using Antarctica as an observatory for the upper atmospheric layers, including the study of stratospheric ozone and the seasonal polar "ozone holes";
- Taking advantage of the clarity and purity of the air on top of the Greenland and Antarctic icecaps for astrophysical work;

This upside-down piece of Antarctic sea ice shows the mixture of microscopic ice algae responsible for the bulk of the Southern Ocean's ability to absorb CO_2 through photosynthesis.

Sea ice (here in the Arctic) occupies about 7% of the surface area of the world's oceans, and is important climatically because of the large percentage of light it reflects (albedo) compared to the average for the Earth's surface.

Gorgonians, brittle stars, feather stars, sea cucumbers, sea anemones and sponges – amongst others – constitute this rich bottom fauna community in the Eastern Weddell Sea, Antarctica.

- Using the Antarctic ice sheet as a natural substrate in which to study cosmic phenomena and sub-particles such as neutrinos (see p. 40);
- Studying the unspoiled terrestrial ecosystems found in Antarctica and in some regions of the Arctic, and monitoring the invasion of simple communities by alien species;
- Describing and untangling undisturbed and complex sea floor communities, constituting a huge marine biodiversity;
- Using the quasi-lunar environment of the polar regions as experimental grounds for rovers and other space technologies;
- Studying indigenous flora and fauna and their response to environmental change, past and present human exploitation, and tourism;
- Studying bird migration;
- Collecting meteorites from the surface of ice caps and other ice formations where only rocks of extraterrestrial origin can be found.
- Studying the psycho-biology and psycho-sociology of wintering scientists as a model of isolated human communities.

But probably the most challenging issue for scientists is the probable fate of polar ice given the threat of global warming: according to the warning given by the Arctic Climate Impact Assessment Report, warming leading to loss of sea ice and melting of the ice caps will have a huge global effect. No one knows the exact threshold beyond which the melting of sea ice and ice caps will become impossible to reverse. But each of us, whether polar scientists or not, probably understands that it is not just a question of a planet devoid of its polar bears or emperor penguins, as icons of a pristine icy world, but the consequent rise in sea levels which will rob millions of their homes, if not their lives.

An international effort

Due to the high cost of logistics and support activities, polar research often relies on international collaboration, especially for larger projects. International cooperation came to the fore after the last International Geophysical Year in 1957, and has, underpinned by the Antarctic Treaty provisions, played a decisive role in shaping polar research and in maintaining the necessary network of research vessels and stations.

The Antarctic *Treaty*

A closely protected continent

The environment, fauna, flora and mineral resources of the Antarctic continent, sub-Antarctic islands and, more generally, everything south of latitude 60°, benefits from almost complete international protection. This is thanks to the Antarctic Treaty which was signed in Washington on December 1st 1959 by twelve countries: Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, Russia, South Africa, the United Kingdom and the United States.

The Antarctic Treaty laid the foundations for the international and peaceful status of the Antarctic continent. The 45 countries (see list on www.antarctica.ac.uk/About_antarctica/Treaty/) which today adhere to the "Antarctic Treaty System" (which includes the Treaty, its Annexes and supplementary international laws) have pledged not to pursue any territorial claims in the region and to ensure the protection and preservation of its fauna and flora. These nations have also agreed to carry out only peaceful activities and to promote scientific research and cooperation in the region.

However, because the original Treaty needed to be more explicit with respect to protecting the Antarctic environment, in 1991 a supplementary protocol, called the Madrid Protocol, was appended to the Treaty. It reaffirms the imperative need to preserve the Antarctic environment and all its ecosystems, and above all designates the region as a "Natural Reserve devoted to peace and science". Under the protocol, all activities related to the exploitation of mineral resources are prohibited (Article 7). In addition, the multiple components of this natural reserve (aesthetic, climatic, meteorological, biological and even historical) now benefit from total protection.

The 1959 Treaty preserves the pristine landscape of Antarctica for research and peaceful activities.

To find out more:

http://www.scar.org/treaty/
http://sedac.ciesin.org/entri/texts/acrc/at.txt.html
http://www.ifremer.fr/ifrtp/pages/texteslois/traite.html

Arctic and Antarctic research: what makes them different?

Apart from a few obvious similarities, including their remoteness and the coldness of their environment, the Arctic and Antarctic possess striking differences which have impacted on the type and importance of the scientific activities being carried out in these regions.

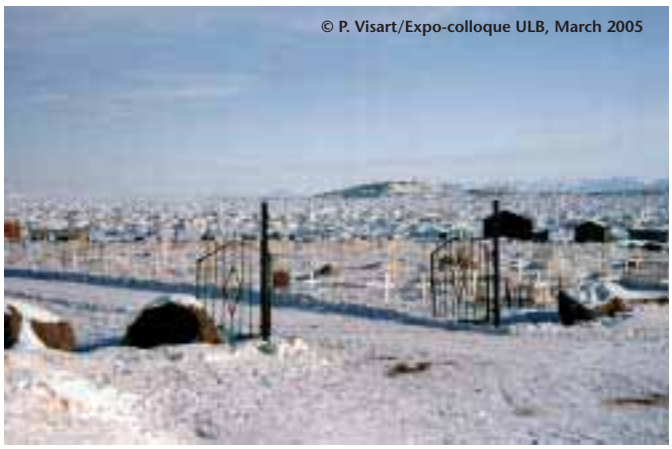
In the South, the Antarctic's massive ice cap and isolation from the rest of the planet by the Southern Ocean prevented any permanent human settlement prior to the establishment of scientific stations in the early 20th century. Man's historical semi-absence, by definition, limits the scope of Antarctic research to the classic range of hard sciences, from geophysics to biology, glaciology, oceanography, meteorology and astronomy, to name a few. However, modern transportation has, in part, overcome access difficulties, especially during the Austral summer, when the sea ice shrinks from 15 to 1 million km².

Human presence in the Arctic

On the other side of the planet, however, the continents surrounding the Arctic Ocean have been temperate enough to harbour indigenous populations for millennia, and more recently the frozen Arctic Ocean was divided between its coastal nations (Iceland, Scandinavia & Greenland, Russia, USA, and Canada). Whilst it does remain remote with permanent sea ice stretching across about 7 million km², the Arctic Ocean has become an intensively monitored region since the Cold War.

As Olav Orheim, Director of the Norwegian Polar Institute in Tromsø, explains, "this continuous human presence has brought a historical, economical and sociological context to the Arctic, which in turn has made Arctic science not only much broader through its human dimension, but has also led to a much bigger volume of purely scientific activities". Indeed, military research, oil and mineral prospecting, environmental impact studies, terrestrial biology and fish stock evaluations are examples of fields of research that are much more developed in the Arctic than in the Antarctic.

Cemetery of Iqaluit the capital city of Nunavut, 6000 inhabitants. This territory is the newest in Canada, created in 1999 after many years of negotiations between the Government of Canada and the Inuit of the Nunavut area.



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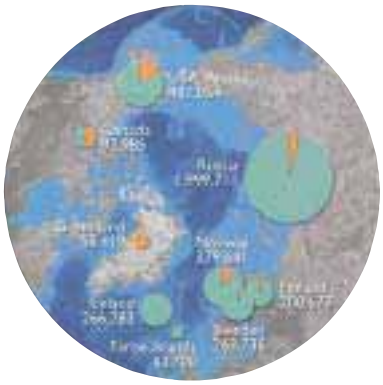


©2004, ACIA/Map Clifford Grabhorn

Numbers are each country's total Arctic population (in the early 1990s) and orange indicates the proportion of indigenous people.

More recent research in the Antarctic

Paradoxically, the relatively more recent and more limited realm of Antarctic science has rapidly evolved to become increasingly international and collaborative. This dimension became fully developed following the International Polar Year of 1957-58 and the ensuing Antarctic Treaty of 1961 and the creation of SCAR (the Scientific Committee for Antarctic Research – see p. 39).

In the Arctic, on the other hand, the end of the Cold War, and the push towards a global understanding of the Earth's climate in the context of global warming can be cited as amongst the decisive factors leading to the birth in the early nineties of the Arctic Council and IASC (the International Arctic Science Committee – see p. 39), as well as the increasingly international integration of scientific programmes.

In the future, the Arctic Council will probably evolve towards exerting more political influence, but will never produce something quite resembling the Antarctic Treaty System. Indeed, because of the undisputed sovereignty of the Arctic rim and ocean, there is no necessity to create a new international body.

The poles, archives of the world's climate

Studying the past climate of our planet is like detective work. The smallest clue is of importance, the slightest irregularity in the composition of ice, submarine sediments or the soil can provide crucial information which highlights ancient jolts to the Earth's climate. But it is still necessary to know where to look, and how to decipher this information. This is what battalions of scientists have been doing for many years in the polar regions.

At the highest latitudes, vast quantities of information can be found imprinted in ice. Continental ice such as can be found in Greenland or the Antarctic is often very thick and results from an accumulation of precipitations going back anything up to a million years. Indeed, throughout their formation, these ice caps have trapped gases, molecules and dust which provide clues to historic and prehistoric environmental conditions.

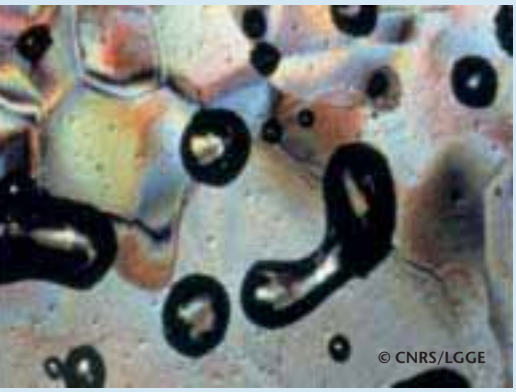
A similar phenomenon also attracts researchers to the floors of our oceans, where our climate and its history can also be studied. There, the stratification of sediments which have slowly accumulated over millions of years reads like a book to those who know how to decipher it.

These data can be further refined by analysing the pollen found in other locations, such as polar tundra, at the bottom of lakes, in the soil or even underground. In temperate regions such as Europe, natural caves which have formed in limestone landmasses also bear the scars of ancient climatic fluctuations and thus supplement the findings from polar regions.

A gigantic history book

Reaching thicknesses of almost 3000 metres in Greenland and 5,000 metres in Antarctica, the gigantic polar ice sheets constitute some of the most precious tools used by paleoclimatologists.

Throughout their formation, these sheets have accumulated countless seasons of snowfall. Each year, during its passage through the atmosphere, this snow has trapped ambient gases, different types of dust or even pollen, and these are compressed every time new layers of snow cover the old ones. Over the centuries, the ice sheet has thus taken the form of a layer cake. It can also be considered as a gigantic book, the pages of which are thin layers in the ice cores extracted during major drilling campaigns. For example, it is possible to detect major volcanic eruptions, or even traces of lead arising from Roman industrial activity 2,000 years ago.



Polarised light projected through a slice from an ice core reveals samples of air from the past as well as aerosol particles deposited by snowfalls – some of which could be from volcanoes which erupted far from the Antarctic

The researchers look for different types of data. For example, analysis of ice core strata also reveals the extent of precipitation through different seasons. The air bubbles trapped by snow and then found in the ice provide clues to the composition of different atmospheric gases in the past.

The isotopic composition of samples makes it possible to determine the temperature at which a layer formed. Study of entrapped particles, their type and their size, provides information on the circulation of the atmosphere. Other physicochemical parameters of the ice, such as its electrical conductivity, provide researchers with further indicators, and by cross-checking these parameters they can reliably reconstitute ancient climatic conditions.

The relationship between the levels of atmospheric CO_2 trapped in the form of bubbles and the temperature at which the ice formed can also demonstrate the extent of the greenhouse effect. Over the past 200 years, this greenhouse effect, exaggerated by the worldwide demographic boom and coupled with growing industrialisation and the development of the combustion engine, has been recorded in polar ice. Also recorded are the different nuclear tests performed during the 1950s and, of course, major natural cataclysms which have affected the atmosphere. ■

Ice cores, and the tiny bubbles of air they contain, have enabled scientists to read the past like a book.

Ice coring: a special selection

In the Arctic

The Greenland ice cap is the principal site in the northern hemisphere for ice-coring campaigns. Since 1989, European researchers have been working at the summit of the ice sheet where it is the thickest and most stable with respect to its flow towards the coast.

The first international extraction site

was set up in 1989, and over several drilling seasons the European project GRIP (GReenland Ice core Project) made it possible to extract cores reaching right down into the bottom layers of the ice cap at 3,027 metres deep.

At the same time, a second drilling site, American this time, was started 28 kilometres to the west of the Summit station used by the GRIP.

The American project, baptised GISP2 (Greenland Ice Sheet Project Two) also collected a long ice core, which reached 3,053 metres down to the bottom of the ice cap and 1.55 metres beneath it into the rocky substrate on which it sits.

However, the quality of the deepest, and thus the most ancient samples, was not as good as had been hoped for by researchers. The GRIP and GISP2 drilling operations were reliable enough to enable climate studies going back as far as 105,000 years, but the ice samples collected from periods before that were of less scientific interest.

Thus, following on from these campaigns, a new European campaign, coordinated by Denmark and bringing together teams from the USA and Japan, was set up and named the NGRIP (North GReenland Ice core Project). The drilling site, 300 kilometres further north than the GRIP and GISP2 stations, started in 1996, and rock was reached in July 2003. The station was closed in the summer of 2004.

The early scientific results of this latest campaign have just been published by the researchers[1]. Apart from being the deepest ice core ever collected in Greenland, the data covers approximately 125,000 years and reveals that before the last Ice Age, which started 115,000 years ago, the Greenland climate was hot (interglacial period) and stable, without any abrupt variations, thus confirming that the fluctuations observed for this period in the GRIP core arose from the ice having thawed rather than from the climatic changes themselves.

In the Antarctic

Several countries have set up ice drilling stations in the Antarctic, including the United States, Russia and Japan. However, it is the Europeans who have brought to the surface the most ancient ice cores ever extracted from the ice sheet, in the context of an ambitious project called EPICA (European Project for Ice Coring in Antarctica).

Set up in 1995, the EPICA project comprises two drilling sites in the eastern Antarctic. The Concordia station (or Dome C) is situated at 123° East, 75°06′ South, while the Kohnen station, in the territories of Dronning Maud Land, is sited at 00°04′ East and 75°00′ South. EPICA is a research project common to the European Commission and the European Science Foundation, and involves scientific teams from some ten countries.

The ambitious aim of this programme was to go back as far as possible in the climatic history of our planet. In 2004, after eight years of efforts, this target was achieved. With more than 3 kilometres of ice cores extracted at Dome C, researchers now have samples available to them which are some 900,000 years old. This is the most ancient climatic reconstitution ever achieved from ice cores, being twice as old as the findings of the Vostok drilling station (400,000 years in 1999) and Dome Fuji (350,000 years in 2003).

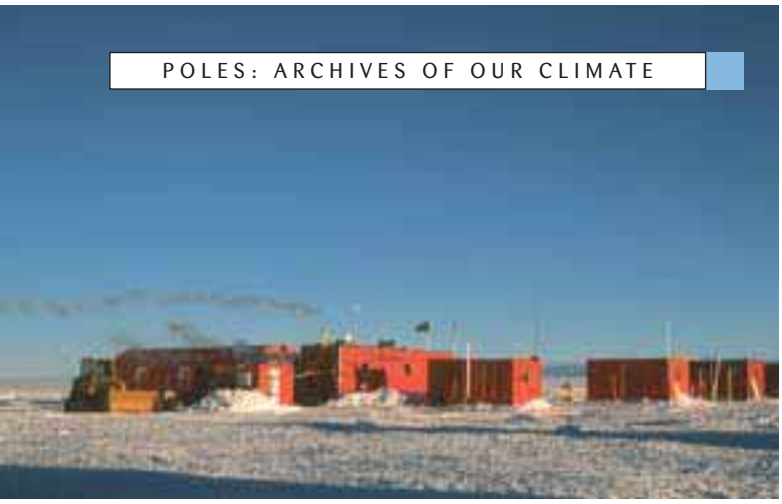
Latest results

The most recent results of EPICA were published in Nature on June 10 2004, and the cover of the journal was devoted to this event. The authors highlighted three major findings[2]: ➔

To find out more:

www.gisp2.sr.unh.edu

www.glaciology.gfy.ku.dk/ngrip/index_eng.htm



The Dome C station is an important part of the EPICA project which brings ancient ice to the surface for study.

- "Over the past 740,000 years, Earth has experienced 8 climate cycles, alternating between glacial periods and warmer, so-called interglacial periods, with an abrupt change in the rhythm of these cycles occurring 420,000 years ago. Thus the warmer periods of the last 420,000 years were characterised by temperatures similar to those we have today, while previous interglacial periods were colder but lasted for longer. This contrasts with what scientists previously thought to be the case.
- The longest warm period during the past 740,000 years took place 420,000 years ago and lasted for about 28,000 years. This period could be considered as "analogous" with that which we are currently experiencing, particularly since the astronomic conditions, the orbit and axis of the Earth which influence exposure to the sun, are identical. These results suggest that the next entry into a glacial period will not happen for several thousand years, but the conclusions of detailed analyses are not yet available.
- An analysis of the air bubbles trapped in the ice confirms that the current levels of greenhouse gases are the highest ever reached during the past 440,000 years." ■

To find out more:

EPICA Project Members, Eight glacial cycles from an Antarctic ice core. Nature, 429, 623-628, 2004.

www.awi-bremerhaven.de/GPH/EPICA/

http://www.esf.org/esf_article.php?activity=1&article=85&domain=3

http://www.antarctica.ac.uk/News_and_Information/Press_Releases/story.php?id=99

North-south comparisons reveal the functioning of the world climate machine

Comparisons of ice sample drilling results from the northern hemisphere with those from the southern hemisphere suggest that, for the same years, the local 'climates' were not always identical, indicating phase shifts of thousands of years.

These intervals between a climatic event in the north and the corresponding reaction recorded in southern ice can be explained by planetary mechanisms for climatic communication, in particular the reaction time of major ocean currents (see the article on the Gulf Stream on page p. 14). This phenomenon is now well understood with respect to the links between the Atlantic and Antarctic Oceans. Future drilling campaigns should help determine more clearly the role played in this vast heat exchange mechanism by the Pacific Ocean, the other great ocean linking the planet's two hemispheres.

[1] North Greenland Ice core Project Members, High-resolution record of Northern Hemisphere climate extending into the last interglacial period. Nature, 431, 147-151, 2004.

[2] Extract from CNRS press release of 9 june 2004 – http://andromeda.insu.cnrs-dir.fr/article.php3?id_article=386

Claude Lorius (left) in the earliest days of glaciology at Camp Charcot.

Ice coring: "In whisky veritas"

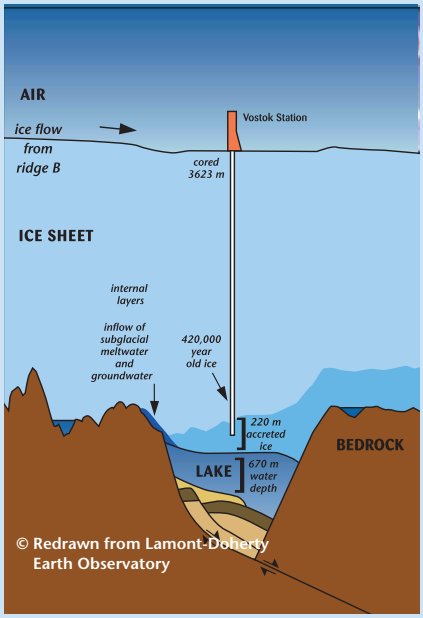
"Looking for young researchers to participate in expeditions organised in honour of the International Geophysics Year". When he answered this job advertisement in 1955, Claude Lorius, a young physicist at the University of Besançon (in eastern France) had no idea that his future career would centre on the polar regions of the world and the study of climate.

Nor did he know that some 22 research expeditions to the Arctic and Antarctic would feature in his life, and that he would become one of the fathers of what is now an essential tool for paleo climatic study: ice coring!

In 1957, after his *initiation* in Greenland into the *new science* of glaciology, he moved to the Charcot research station, a tiny French base perched at an altitude of 2,400 metres on the Antarctic ice sheet.

After several summer campaigns, in 1965 Claude Lorius led the over-wintering team at the Adélie Land coastal base and started to collect ice cores, while at the same time becoming interested in the air bubbles trapped in the ice: *"It was when I saw the bubbles bursting when an ice cube melted in a glass of whisky that I had the feeling they could be reliable and unique indicators of the composition of air, something we subsequently proved was correct"*, he remembers.

Thermophilic bacteria in Lake Vostok



The diagram shows the possible dynamics of Lake Vostok's formation.

Glaciers sometimes hide a lake under their thick layers of ice. And some of these lakes fascinate researchers, particularly because they may contain as yet unknown life forms. In the Antarctic, beneath the Vostok research station, such a lake, of gigantic proportions (surface area 14,000 km²), is whetting the appetite of researchers.

Researchers have already made some surprising discoveries even though they have not yet been able to collect samples of liquid water, as drilling has not yet entered the last few metres of ice, in order to preserve this extraordinary lake from accidental external contamination (for example by bacteria or by chemicals used to prevent closure of the drill holes).

Most recently, in the autumn of 2004, an international research team from Russia, France and the USA studied the composition of the last 85 metres of a deep ice core (made up of refrozen ice containing water from the lake), sampled at a level of 130 m above the liquid interface with the lake. Analysis suggests that the biological content of Lake Vostok is very limited, and that its waters are virtually sterilised by dissolved oxygen (at a pressure equivalent to that of a fizzy drink can) which accumulated after the ice thawed. In addition, traces of DNA discovered in the refrozen ice would appear to be the genetic signature of thermophilic bacteria. Such bacteria are better adapted to very hot environments, like those near hot undersea springs or volcanic chimneys, rather than to cold environments. Yet another mystery to be solved….

To find out more:

www.cosis.net/abstracts/EAE03/04250/EAE03-J-04250.pdf

www.asoc.org/what_other1.htm

gdl.cdlr.strath.ac.uk/scotia/vserm/vserm070904.htm

The greenhouse phenomenon and climatic feedback

The composition of the atmosphere imprisoned in polar ice informs researchers about the glacial and interglacial episodes which our planet has experienced, including how greenhouse gases, such as CO_2 and CH_4, are involved in these processes as part of a feedback loop.

Ice coring at the Vostok research station has shown that over the past 420,000 years, the levels of CO_2 and CH_4 in the atmosphere have constantly been changing. During glaciations, these levels fell in line with the temperature, while during periods of interglacial warming, they rose.

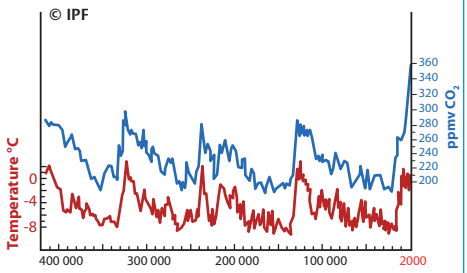
But which phenomenon triggered the other? Was it a rise in temperature which caused an increase in gas levels, or vice versa?

Today, the phenomenon is well understood by scientists. The cyclical climate variations read in ice cores are initiated by astronomic events, such as changes to the distance between the Sun and the Earth, or to the inclination of the Earth's axis. But once they have been triggered, higher concentrations of atmospheric gases have an amplifying "feedback" effect.

For example, methane is produced by the fermentation of bacteria found in periglacial marshland regions (Northern Canada, Siberia, etc.). Imprisoned in the permafrost, these encased bacteria come alive during interglacial periods and start producing large quantities of methane, which amplify the greenhouse effect and raise the temperature even further. Conversely, when a new glacial episode starts, the first periods of cold numb these bacteria, which quickly become blocked, causing a rapid reduction in the atmospheric methane concentration.

The same logic applies to the oceans and CO_2, where such changes are the work of phytoplankton.

Just one other thing. Although the mechanism outlined above can seem simple and almost instantaneous on paper, in fact, these amplifying and accelerating effects of climate trends last for… several thousand years.



In the last two centuries, due to the industrial revolution, CO_2 levels have gone outside the 'envelope' of the regular cyclical CO_2/ temperature variation of the last 400,000 years (ppmv = parts per million by volume).

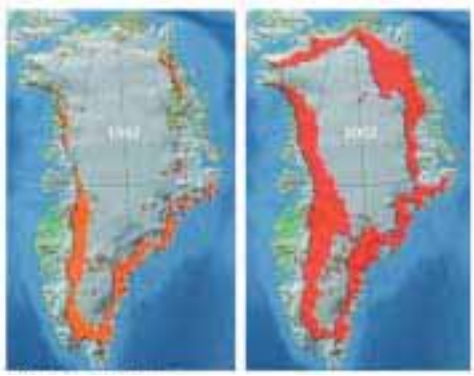
The polar regions: sentinels of *major climate change*

The polar regions are not only the keepers of the Earth's climate archives. They also act as sentinels; a kind of early warning system of what can be expected by the planet as a whole...

Elephant Foot Glacier, at around 81° N along the east coast of Greenland. The grey zone at low elevation is the ablation zone incised by meltwater channels, clearly separated from the white surface accumulation zone higher up.

Philippe Huybrechts is a glaciologist at VUB, the Free University of Brussels in Belgium. In two of his recent articles (published in the journals Nature and Geophysical Research Letters), he clearly demonstrated the current impact of global warming on Greenland. These two studies testifiy to the rapid thaw of the ice cap that covers this vast landmass between the Atlantic and Arctic Oceans.

"The polar regions are the first to suffer from global warming. But they also suffer more acutely than other parts of the world, both in terms of rapidity and intensity," he explains. "It is a question of albedo and temperature. In summer, when the Arctic sea ice melts, the surface of the water is darker and accumulates more solar radiation, thus accelerating the warming phenomenon. The same applies to emerged landmasses such as Greenland, northern Canada and southern Siberia, which have suddenly seen their snow cover disappear. On average, climate warming in these regions is two or three times more marked than elsewhere on the planet," explains the scientist. "The Antarctic, with the exception of its peninsula, currently appears to be protected from this kind of rapid disturbance thanks to its better thermal 'insulation', provided by the Antarctic Ocean."



©2004, ACIA/Map Clifford Grabhorn

Satellite images, available since 1979, have shown an increasing trend in seasonal surface melt extension of the Greenland Ice Sheet at the height of summer.

Greenland is melting

The 'disaster' scenario in the Arctic is no longer science fiction. What was initially only a question of modelling has since been widely confirmed by field observations, one example being changes to the Greenland ice sheet.

"Between 1950 and 1990, we saw a drop in Greenland's temperature of about 1.5°C," explains Philippe Huybrechts. "But since 1990, the temperature has been rising, and this has been exacerbated by a negative balance between precipitations in the region and melting of its ice sheet."

The result is that in a little more than ten years, the ice sheet has shrunk. Indeed, this phenomenon has amplified even further in the past five years. Huybrechts thinks that the situation is nearing a critical point.

"Each year, Greenland is losing about 80 cubic kilometres of ice (total ice sheet volume estimated at three million cubic kilometres). If the ice sheet loses 20% of its volume, the process will become irreversible," he suggests.

Sea levels are rising

The impact of this meltdown on the planet as a whole has resulted in rising sea levels. Each year, shrinkage of the Greenland ice mass causes a global rise of 0.2 millimetres. Over the past fifteen years, the rise has thus totalled 3 millimetres. If the phenomenon continues, i.e. if the temperature of the planet goes on rising, the entire Greenland ice sheet will melt. Huybrechts reckons that the point of no return will be reached when the Earth's temperature has risen by 3 degrees. And if this rise reaches 10 degrees, Greenland will truly merit its name in a thousand years' time – a phenomenon which will also bring about a 7.5 metre rise in the level of the oceans. ■

To find out more:

Geophysical Research Letters, vol. 31, L24402;
Greenland Ice sheet: increased coastal thinning.
Nature, vol. 428, p. 616.

Polar flora *and* fauna facing up to major climate warming


© Thomas Schickan

A global increase in temperature in Antarctica would be expected to affect primarily the largest species within each group, such as this "Red Knight"-crustacean like amphipod.

In agreement with the different climate models developed by researchers and confirmed by the IPCC (the Inter-governmental Panel on Climate Change), the poles are those regions of the world where climate change is and will be the most rapid.
This development is not without impact on the organisms living in these regions, some of which are the subject of increasing concern amongst biologists.

It's getting warm at the poles!

The trend towards Arctic warming is generalised, and in some regions the temperature has risen by more than 3°C over the past 50 years. This is more than ten times faster than the rest of the planet, where the average increase was only 0.6°C over the past century.

At the other end of the world, and although warming at present only affects the Antarctic peninsula, the phenomenon, despite recently slowing, is just as marked: 4-5°C in the past 50 years…


© IPF

Sea-ice, under threat from climate change, is important for walruses during feeding as it provides resting places between dives. This enables them to fish over a wider area.

Early trends in the south...

Because of the effect of temperature on the distribution of living organisms in these extreme environments, such changes are not without consequences.

"On the Antarctic peninsula, only two flowering plants were seen on exceptional occasions in the past," points out Pete Convey, from the BAS (British Antarctic Survey). "But over the past thirty years, antartic grass and pearlwort have been developing in the south, as are several species of moss. All are benefiting from a lengthening in the periods of thaw."

Other effects are seen in the marine environment, following a regional trend towards a halt to the spread of pack ice. This ice is necessary to ensure the winter development of juvenile krill (a small crustacean which looks like a shrimp and upon which an impressive range of predators are dependent) and there has been a reduction in the frequency of successful breeding years. Their predators are also suffering: Wayne Trivelpiece from the NOAA (the US National Oceanic and Atmospheric Administration) has thus seen the disappearance of the chinstrap penguin from the multi-species colony he has been studying for nearly 30 years near to the Polish Arctowski research station: "It is probably the reduction in krill fecundity which is the reason for the decline of Adélie and chinstrap penguins on the Antarctic peninsula." The same effects have been seen in South Georgia, where Keith Reid & John Croxall from the BAS have shown that the growing competition for krill between sea lions and Macaroni penguins has led to a marked decline in the latter.


© IPF

Rising temperatures are having complex effects on penguin populations with growth occurring in some locations while others see declines. Some chinstrap penguin populations have been hard hit as the local supply of krill, their food, has fallen away.

... and much disquiet in the north

As made clear a few months ago by the ACIA (Arctic Climate Impact Assessment) report in Reykjavik, the effects of global warming on fauna and flora are even more pronounced in the Arctic. Terry Callaghan, from the Abisko Scientific Research Centre in Sweden, explains: "On land, amongst other phenomena, warming has caused a gradual melting of the permafrost (permanently frozen ground), with the disappearance of hundreds of pools and lakes (because they have drained into the thawed soil) and the flora and fauna which inhabit them. We have also seen a gradual spread of forest coverage to the north, to the detriment of the tundra, where millions of migrating birds have their breeding grounds."

"Because the forests are darker, the albedo (percentage of reflected solar radiation) of these areas has fallen and thus created a positive retroaction which enhances warming," adds Glenn Patrick Juday, from the University of Alaska. "At the same time we are seeing an increase in the number of fires and massive swarms of insect pests in several regions around the Arctic landmass."

The situation is no better in the Arctic Ocean: the average surface area of pack ice (measured at the end of each summer) has shrunk in 30 years by practically a million square kilometres (around 15 to 20%). This gradual shrinkage is causing increasing problems for species associated with sea ice, whether these are single-cell algae, the copepod crustaceans which graze on them, the fish which hide in them and so on, up the chain to that most emblematic animal of the North Pole, the polar bear. ➔

Polar bears facing major problems

According to Andrew Deroche, from the University of Alberta in Canada, and his colleagues, shrinkage of the pack ice has caused a reduction in the numbers of ringed seals as well as in their accessibility for polar bears, for whom they are the principal prey. This is of crucial importance for the female bears when it comes to building up fat reserves before fasting for several months in winter and giving birth to their young. Indeed, researchers have shown that in Hudson Bay, each week the spring thaw advances represents a 10 kg loss of weight for female bears by the time they enter the snow den where their young will be born. In addition, warming also increases the frequency of winter rains and the collapse of these dens.

Sadly, there are few prospects for an improvement in the Arctic pack ice, because climate models agree on a continuous rise in the average temperature over the 100 years to come: up to 7°C for the ocean and up to 10°C in winter. The ACIA report even suggests the possible disappearance of summer pack ice between now and 2100…

Dying of heat in the Antarctic

On the other hand, at the other end of the globe, the formidable mass of the Antarctic ice sheet may protect the Antarctic Ocean from global warming. But at a local level, and once again in the context of rising temperatures in the peninsula, a series of joint studies, headed in particular by Lloyd Peck from the BAS and Hans-Otto Pörtner from the Alfred Wegener Institute in Germany, recently put forward new reasons for concern. Their research on several marine invertebrate species has shown that the oxygen supply necessary for several vital functions, such as reproduction, is easily disturbed by a rise in water temperature. In fact, a 4°C rise would be sufficient to condemn several populations, or even some species with a limited distribution, to extinction. ■

The peoples of the Arctic, the first victims of global warming

We forget perhaps too easily that the Dolgans, Inuits, Saami, and all the other native peoples of the Arctic are the first victims of climate change.

The ACIA (Arctic Climate Impact Assessment) report has now spoken on their behalf. Their testimony is slowly being integrated within the context of polar research. At the same time, through the stories told by these direct witnesses, the rest of the planet is becoming aware of the true impact that climate change can have on people's ways of life.

For the peoples of the North, there is a clear impact on their economic and food-producing activities. For example, hunting and fishing are no longer as productive as they once were.

Ice which appears increasingly late and which disappears much earlier considerably shortens the hunting season. In the north of Greenland, this has already forced hunters to kill their sledge dogs because they are unable to feed them when unstable ice prevents them from hunting seals, bears or walrus. It is not difficult to imagine what that could mean in such regions. Reindeer farmers in the north of Europe also face problems. The Saami can only stand and watch as their animals, which normally graze on lichens by digging in the snow, struggle to break through the layers of ice that form after rain has fallen during warmer periods.

What's more, these climate changes are occurring in a context of a loss of identity as a result of the growing influence of western lifestyles.

Unexpectedly, and further aggravating the situation, is the fact that words do not always exist to describe these changes, making it difficult for these people to communicate what they are seeing or experiencing. Previously unknown events now occur, such as lightning and thunder. Species which were previously restricted to temperate regions are now taking up residence in the North. The people of the Arctic have been stunned by the arrival of … wasps! What can they call these insects, when they have never seen them before? These are some of the other, unusual aspects of global warming.

To find out more:
'key-finding 8' for the ACIA overview report, available on http://amap.no/acia/
http://nsidc.org/data/docs/arcss/arcss122/index.html

Native communities in the Arctic total some four million people. They live on the eight million square kilometres of the habitable Arctic landmass, i.e. in Greenland, North America, Europe, Siberia and various archipelagos (see p. 6).

© P. Visart/Expo-colloque ULB, March 2005

Kangiqliniq-Rankin Inlet, Hudson Bay, at the end of spring. Inuit men prepare their sledge for a hunting journey.

And what would happen if the Gulf Stream stopped?

For most people, slowing or even stopping the Gulf Stream could only be a sci-fi story. This vast oceanic current on the surface of the Atlantic, which runs from the intertropical zone towards the shores of Europe (thus ensuring our mild winters and temperate summers) cannot simply 'break down'. However, a reduction in its intensity, or even its coming to a complete halt, is not impossible. The climatic history of our planet shows this. The Gulf Stream has already seen some major disturbances to its 'flow'.

The Gulf Stream is part of the global thermohaline circulation.

Canadian, American and British researchers, whose work was partly funded by the European Union's 5th Framework Research Programme, reckon that over the past ten years, the global warming of our planet has modified the salinity of its oceans, which in turn may disturb the circulation of marine currents (known as thermohaline circulation).

If the Gulf Stream malfunctions, then Europe, deprived of its effects, will in turn lurch towards a new era of lower temperatures. In other words, winters in Lisbon may become as rigorous as those in New York.

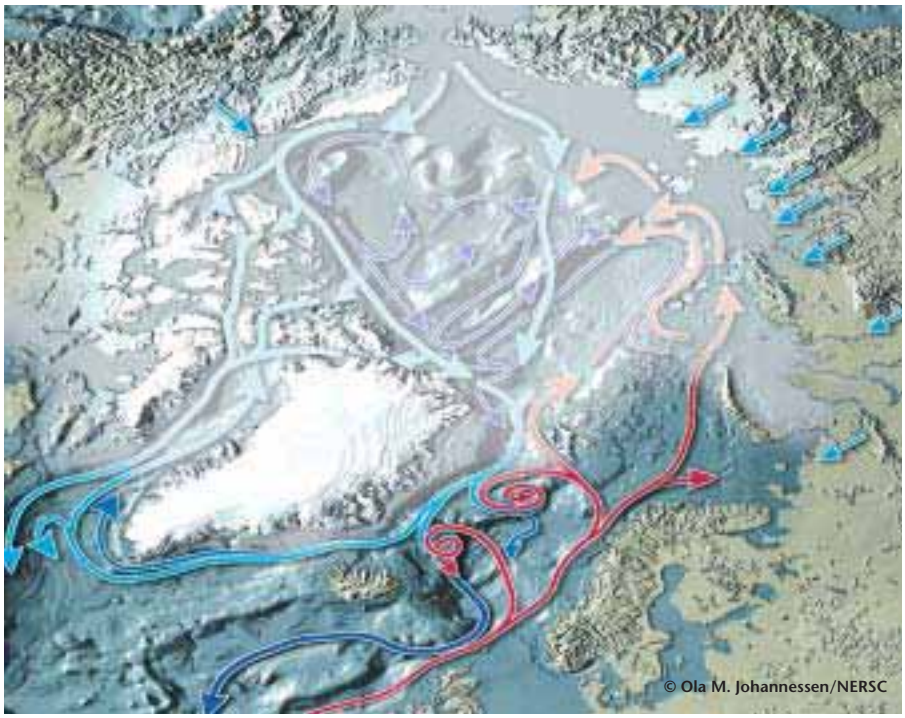
Fact or fiction? The climatic history of our planet shows that such a development in the past – a considerable influx of fresh water in the North Atlantic resulting from a massive offloading of ice from the American ice sheet – has already seen the Gulf Stream mechanism put "out of order". ■

A question of salinity

It is the increased evaporation of surface water in temperate regions, generating a significant surplus of water vapour in the atmosphere and more precipitation of fresh water at higher latitudes, that could be bringing about such a change in the salinity of the North Atlantic.

Water with a lower salt concentration does not drop easily to the ocean depths, which is what usually happens to the Gulf Stream to the north of Iceland. It is here that this famous current plunges to the ocean floor before returning to the tropics and then, further south, towards the Antarctic Ocean. In other words, this deep ocean current is the "return" of the surface Gulf Stream.

After more intense rainfall, however, the additional fresh water in the mix inhibits the Gulf Stream's drop towards the ocean floor, and jams up this vast, worldwide climatic mechanism. This in turn interferes with, or even blocks off, the Gulf Stream on the surface.



The complexity of the Gulf Stream in northern latitudes is evident from this detailed representation.

Ozone story

The discovery of a hole in the ozone layer goes back to the 1980s. It was in the Antarctic that the first ground measurements of ozone levels produced some surprising results. As early as 1985, Joseph Farman, from the British Antarctic Survey (BAS), published the results of his observations in Nature. A "hole", or a drop in concentration, albeit temporary but very marked, appeared each spring in the stratospheric ozone layer above the Antarctic. This phenomenon mainly occurred in the lower stratosphere. What is the situation today?

The Antarctic ozone hole was discovered in 1985 by British Antarctic Survey scientists, from left: Joe Farman, Brian Gardiner and Jon Shanklin.

"What is astonishing about this discovery is that the first measurements indicating a seasonal depletion in the Antarctic resulted from work on the ground," comments Dominique Fonteyn, from the Belgian Institute for Space Aeronomy (BISA), "even though the Americans had a satellite in orbit which was devoted to studying ozone."

Interpreting the data...

Why did the Americans 'miss' this discovery? In fact, the TOMS had indeed measured very low concentrations of ozone above the Antarctic region. But the values were so low that the American researchers decided initially that they should not be taken into account. In their opinion, the data did not reflect the actual situation, but merely indicated a technical problem affecting the orbiting instrument.

In 1987, various hypotheses were put forward as to how this hole had formed in the ozone layer (of the lower stratosphere). Two schools of thought emerged: on the one hand, those who considered that depletion of the ozone levels originated from dynamic effects (winds, etc.) in the upper atmosphere, while others preferred the idea of unsuspected or lesser known effects in the atmospheric chemistry.

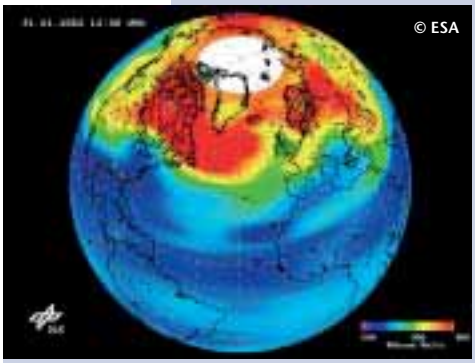
CFC: guilty!

The next year, this phenomenon was investigated by NASA, the American Space Agency. A report drawn up with the help of some hundred or so experts from all over the world suggested that stratospheric ozone concentrations had fallen on average by 1.7 to 3% in the northern hemisphere between 1969 and 1986, despite major annual variations.

However, by the end of the 1980s, the scientific community had reached agreement about the cause of this depletion in both the Antarctic and Arctic regions: halogenated hydrocarbons, and particularly the notorious CFCs (chlorofluorocarbons). Further observational ➔

What is ozone?

Ozone is an unstable molecule made up of three oxygen atoms (O_3). It is found at two levels in the atmosphere. Near the ground (tropospheric ozone), it is toxic, notably for the respiratory tract and mucosa. This ozone is generated by pollution, mainly from motor vehicles. Ozone is also found at high altitude in the stratosphere. Here, there is a "layer" some 20 to 25 km above the Earth, which is formed through equilibrium between its formation and destruction under the effect of solar radiation, from temperature changes and from the presence of other chemical substances. This layer protects us from some of the harmful rays of the sun, such as ultraviolet radiation. When we talk about the hole in the ozone layer it is in this stratospheric ozone.



The Arctic ozone hole is less pronounced due to less severe conditions at the stratospheric level than in Antarctica. This image shows a low-ozone event over the northern hemisphere on 31 January 2002. The central white area was not covered by the satellite observations. Processed by DLR – Data provision by ESA.

and laboratory studies showed that the ozone's seasonal disappearance was indeed linked to chemical reactions in the upper atmosphere which were being triggered by the very low temperatures existing above the Antarctic in winter.

"The 1990s saw the gaps in our knowledge about the mechanisms involved filled in," explains Dominique Fonteyn, "thanks in particular to the eruption of the Pinatubo volcano in the Philippines in 1992, which injected large quantities of particles into the upper atmosphere. Study of these particles helped us to better understand some of the chemical phenomena occurring in the stratosphere, and particularly the catalysing effect they played in the release of different chemical compounds which then attacked the ozone. Parallels could then be drawn with the depletion of the ozone layer outside these major volcanic events, following the emission of different pollutants, including CFCs, into our atmosphere."

To find out more:

http://www.unep.org/ozone
http://www.atm.ch.cam.ac.uk/tour/
http://www.theozonehole.com/

The Arctic is less vulnerable

In the Arctic, depletion of the ozone layer has also been observed, but it is less marked. This can be explained by the fact that the temperatures in the lower stratosphere above the Arctic usually remain higher than those recorded in the Antarctic. The northern hemisphere has greater land mass and more continents, which play a role in its climatic instability. Even when it is very cold in the region around the North Pole, this does not last very long. So a "hole" does exist in the stratospheric ozone layer. Though still a cause for concern, it is neither as extensive nor as severe as in the Antarctic.

Perpetually evolving depletion

The size of the hole in the ozone layer above the Antarctic oscillates wildly. An absolute record was attained in 2000, when the hole covered an area of 29.2 million km^2. In 2001 and 2002, the trend seemed to be downwards, but this respite was of short duration. By the autumn of 2003, the hole had reached more than 28 million km^2, before shrinking again last year. On September 22, 2004, at the peak of the phenomenon, a hole of 24.2 million km^2 was recorded above the Antarctic.

Ultraviolet alert

Because of the enormous proportions the Antarctic hole in the ozone layer has reached in recent years, its first direct effects on human populations in Latin America are now starting to be felt. Higher levels of ultraviolet rays emitted by the sun, which are filtered less by the stratospheric ozone, reach the ground, increasing the risks of skin cancer and cataract.

Thus, in Punta Arenas, in southern Chile, the authorities are now recommending a sort of curfew in the middle of the day. When the sun is at its highest height, between 11.00 and 15.00, the ultraviolet rays are at their most powerful. And in this region, which suffers from depletion of the Antarctic ozone layer, going outdoors without good protection causes sunburn within minutes. ■

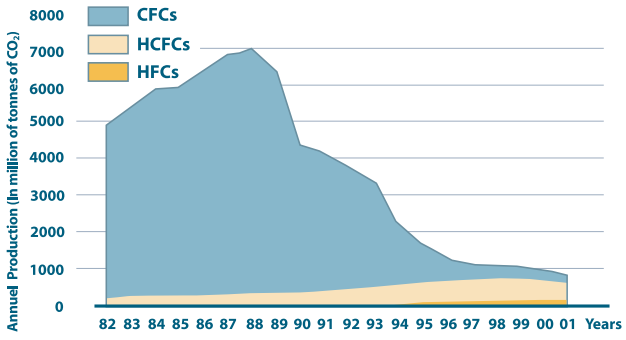
The Montreal Protocol

The Montreal Protocol is an international convention which regulates the production and use of substances which harm the ozone layer, such as CFCs, chlorine and bromine, which mainly result from the halogenated hydrocarbons generated by human activities.

Ozone depletion in the upper stratosphere was recognised as early as the 1970s. It concerned the ozone throughout the world, and not specifically at the poles. Studies carried out after 1970 already incriminated CFCs and halogens as the cause of this depletion. This explains why, in 1987, the Montreal Protocol recommended reducing emissions of these chemical substances which affect both the upper and lower stratospheres.

Since it came into force in 1989, the Protocol has been ratified by more than 180 countries, and amended four times. It has prohibited the use of these substances (particularly in refrigeration) since 1996 in developed countries, and envisages their prohibition in developing countries between now and 2010.

In the long term (because of the momentum of this phenomenon) it should reduce the quantities of chlorinated compounds in the stratosphere and allow the ozone to return to normal levels sometime between now and the end of this century.

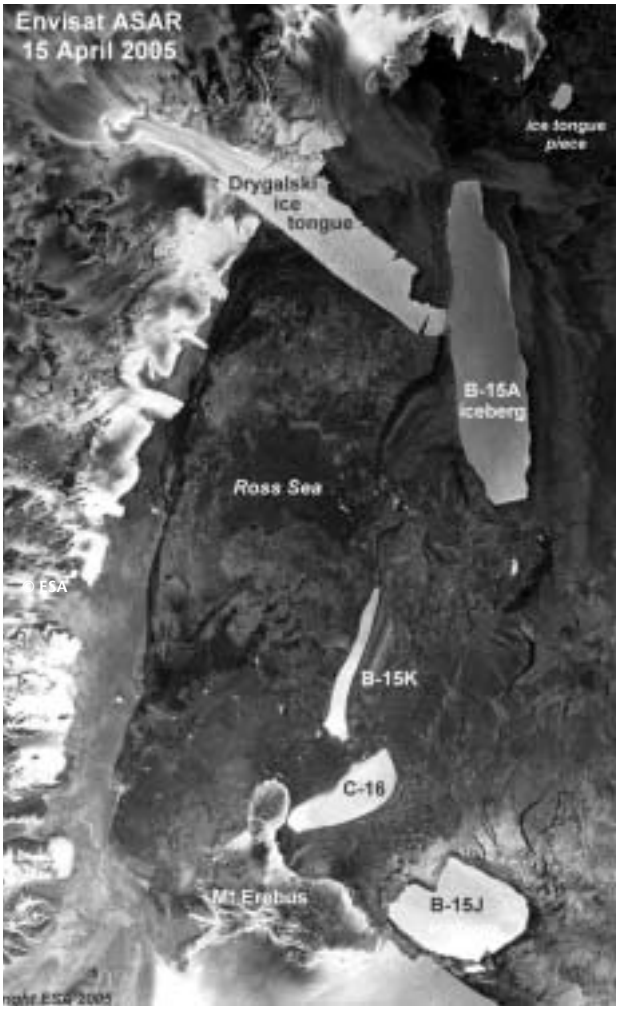


The Montreal Protocol has reduced CFC emissions greatly but it will be some decades before existing CFCs in the stratosphere have decayed and present no further harm to the ozone layer.

Satellites at the service of polar research

The European Space Agency's powerful ENVISAT satellite tracks ice and vegetation trends in the polar regions with extreme accuracy.

Satellites have become essential tools for polar research. For example, they track the movements of many birds and mammals at the poles. But they have proved particularly decisive when observing climate change: spatial teledetection has enabled the study of changes to the extent of pack ice, the volume of ice caps, the productivity of oceanic waters, levels of stratospheric ozone and many other phenomena. Europe is one of the leaders in this field, thanks to the European Space Agency (ESA) which can boast the successful launch of several satellites: ERS 1 and 2, Envisat and, most recently, Cryosat.



Envisat's radar vision pierces Antarctic clouds to give researchers a ringside seat for the journey of the vast, drifting B-15A iceberg.

Miniature ARGOS tracking devices

It was necessary to wait for the miniaturisation of ARGOS tracking devices before the astonishing movements of several species of whale, seal, penguin and albatross, could be tracked. During the 1990s, these systems revealed that the elephant seals in the Antarctic Ocean were champion divers, frequently plunging to depths of 800 metres during the 10 months they spent at sea. The team led by Mette Mauritzen, at the Norwegian Polar Institute in Tromsø, has by this means been studying the adaptation of polar bears to changes in the pack ice around Spitzberg.

To find out more:

http://www.oikos.ekol.lu.se/Oikos.100.1.abstracts/12056Mauritzen.htm

http://www.esa.int/export/esaLP/cryosat.html

Ice monitoring

"Satellites have revolutionized the monitoring of polar ice," explains Frédérique Remy, from the Laboratory of Geophysics and Spatial Oceanography (LEGOS, CNRS) in Toulouse, France, "by allowing us to monitor regularly, and from a distance, areas which are difficult or even impossible to reach because of the winds and very low temperatures. Not to mention total darkness for several months each year!" ERS (European Remote Sensing) satellites have, for example, made it possible to quantify changes in the volume of the Antarctic ice cap: "The Antarctic ice sheet appears to be stable, apart from a sector in the west where the ice is losing its thickness."

Shrinkage of pack ice

The observations are identical with respect to Arctic pack ice, even though an average reduction of 37,000 km² per year (compared with an average summer pack ice area of 7 million km²) has been measured over the past 30 years. However, we still have insufficient hindsight given that the first observations only go back to 1978. Thanks to its ability to measure the thickness of pack ice (to half a metre), the altimeter on board Cryosat, the new satellite which was launched by the ESA in March this year, should confirm whether or not this is in fact a trend.

The impressive diving performances of elephant seals, so named for their massive size and for the trunk-like noses of the males, are followed by satellite tracking.

Head in the clouds but feet firmly on the ground

Despite the rapid development of polar teledetection, work on the ground remains necessary. Firstly because some measurements are still difficult to obtain from space. "That is the case for atmospheric pressure," explains Alan Rodger, from the British Antarctic Survey, "and also the Earth's magnetic field, because 12 hours elapse between each measurement, while on the ground we can follow this parameter continuously." Field work is also essential to calibrate and validate satellite observations. This is true for the stratospheric ozone, which today is being measured by another ESA creation, Envisat, the largest and most elaborate earth observation satellite ever constructed.

Finally, as explained by Bruno Delille, from the University of Liege in Belgium, "the increasing integration of ground and space measurements opens new fields of research: for several years now, we have been studying the role of the Antarctic Ocean and pack ice in exchanges of carbon dioxide between the ocean and the atmosphere. This has been made possible through oceanographic measurements collected in situ supplemented by satellite observations of important parameters such as the chlorophyll biomass, surface temperature, winds and the distribution of ice." ■

Permanent monitoring of the atmosphere from the Svalbard

Greenhouse gases, organic and inorganic pollutants, aerosols... In order to study climate change, account must be taken of a great many parameters, one of the most important being the rapid evolution in the quality of our atmosphere.

It is in the mass of air close to the ground (the troposphere) where major meteorological phenomena occur, and also where different families of gases circulate and mix together with particles and pollutants of all types.

At Ny-Alesund, the science settlement in the archipelago of Svalbard, the Zeppelin Station (78°54 N, 11°53 E) contains one of the major polar laboratories monitoring the atmosphere of the northern hemisphere.

"It is managed by the NILU, the Norwegian Institute for Air Research, in collaboration with the Norwegian Polar Institute," explains Geir Aasbostal, who has for many years overseen daily monitoring of sensors placed on the roof of the building at the top of this 'mountain' (474 metres altitude), and has ensured the quality of the data collected. "We permanently measure levels in the air of different types of gases, such as methane, carbon monoxide, chlorofluorocarbons (CFC) and hydrofluorocarbons (HFC). The same applies to particles suspended in the air, (which we study in terms of their size and distribution) and a range of inorganic pollutants, such as mercury. Finally, when it rains or snows, we collect samples which are also analysed."

To find out more:

Norwegian Institute for Air Research (NILU) www.nilu.no and the site for the Ny-Alesund science settlement: www.kingsbay.no

The Zeppelin Station for Air Monitoring and Research is owned and operated by the Norwegian Polar Institute. The Norwegian Institute for Air Research (NILU) is responsible for the scientific programmes at the station.

A poor record concerning the greenhouse gas HFC

These regular measurements inform researchers about changes to the atmosphere and also the sources, transport, dispersion and possible transformation of pollutants and their impact on the environment. One thing is clear: since 1999, the levels of HFC, a greenhouse gas, measured at Ny-Alesund, have been steadily rising. In 2003, a terrible record was broken, when levels rose by 25%. These data, and others, are essential when contributing and validating the mathematical models used to simulate climate change on a planetary scale. ■

More of Europe at high latitudes

Europe is not lagging behind in terms of polar research. It has a prestigious past, and its current expertise is acknowledged worldwide. As we come to the International Polar Year in 2007-2008, Gérard Jugie, Chairman of the European Polar Board (EPB) and Director of the French Paul Emile Victor Polar Institute (IPEV), updates us on the challenges we face today. An interview.

What role does Europe have to play in research in polar regions?

We have research programmes, logistic resources, and considerable expertise in this field. One of the aims of the EPB is to increase the European countries' awareness of the pivotal role that Europe can play in terms of polar research. All the intellectual, logistic and technical resources of the different Member States devoted to polar research endow Europe with a predominant position in this field. The European network of bases in these regions of the world is testimony to this. That said, I prefer not to refer to 'polar research' but to the many areas of scientific excellence being developed in polar regions.

We also benefit from federal approaches, such as the Europolar programme. This provides coordination for national research programmes in the context of the European Union ERA-NET system (European Research Area) and aims to better organise and optimise research efforts in polar regions.

Finally, we should not forget Europe's know-how in these extraordinary environments. For example, we have now mastered methods for navigation in sea ice, icebreaking technology and the logistics required for polar travel on land. These are undeniably important skills.

What are the major scientific research challenges in these regions?

The EPICA programme for drilling in the Antarctic ice cap, which during the last summer season almost arrived at the rock underlying the Dome C coring site, is one of the best examples (see p. 8 and 32). This major European project, with which we were associated from the start, responds to one of the key global challenges, namely climate change. It is a remarkable reminder that the polar regions constitute excellent witnesses of the changes which have affected our planet.

Gérard Jugie, Chairman of the European Polar Board (EPB) and Director of the French Paul Emile Victor Polar Institute (IPEV)

The polar regions, i.e. lying south or north of 60 degrees latitude, are of extraordinary interest in terms of their specific fauna and flora. We must retain or even enhance our presence in these environments, through the development of new observatories, particularly to study the atmosphere. We need to devote further study to the characteristics of different atmospheric layers at these high latitudes, including interactions between the atmosphere, the local biosphere and the oceans, but also the cryosphere, particularly in the Antarctic.

We also need to better understand the Antarctic Ocean, the circulation of floating ice masses and, more generally, the oceanic and thermohaline circulations. ➔

In Svalbard, several European countries are actively working together on scientific research in the Arctic.

Understanding how icebergs and currents interact in the Southern Ocean is a priority for European research in the Antarctic.

Are there any emerging fields of research?

Absolutely. In astronomy, for example. The Antarctic, and most particularly its plateau, is now of considerable interest to astronomers, with special emphasis being placed on infrared observations. This interest is due to the low levels of humidity and precipitation on the plateau (a maximum of 3.5 cm of water a year), its altitude, the light winds which do not markedly disturb observations, and the lack of light interference. In other words, it is a particularly attractive region and a site here would supplement the major astronomic observatories elsewhere in the world.

Another emerging area, which is of increasing interest to space agencies, is studying isolation of research teams in a very hostile environment. Their psychological and sociological monitoring is the source of much valuable information.

Huge rookeries of rockhopper penguins are found on islands around the edges of the Antarctic region.

Is research in the Arctic less well developed than that in the southern hemisphere?

Certainly not. First of all, the Scandinavian countries are particularly active in this area. Secondly, we must not forget the international campaigns that have been ongoing in Greenland for many years. And finally there is Svalbard, with the Ny-Alesund scientific settlement which groups not only Norwegian research stations but also teams from France, the UK, Italy, Korea and Poland. France has another base in that area, which strives to be a model for future research stations. More globally, we must not lose sight of Russian research efforts in the Arctic. No, you cannot say that the Arctic regions have lost their attractiveness for research.

Will the International Polar Year in 2007-2008 revolutionise European research in these extreme regions of our planet?

Not intrinsically, but it will serve to highlight our activities in polar regions. This will allow us to raise the awareness of decision-makers at all levels, from politicians to the man in the street. The last Polar Year (in fact, more precisely an International Geophysics Year), took place fifty years ago, and made it possible to launch a multitude of new research projects in polar regions. This new Polar Year will regenerate interest in these regions and emphasise the importance to society as a whole of the work carried out there, and should trigger projects for future generations. It is certainly an event which will leave a legacy, particularly in terms of coordination, cooperation and infrastructure.

Will it provide impetus for a shift towards the greater integration of national efforts within the EU?

At present, some countries in Europe are more dynamic than others. I think that the new International Polar Year may act as a catalyst towards greater integration. But in fact, this integration is inevitable, because Europe is now a living entity. I do not know if we shall have a European Polar Agency in 2007, but I am sure that one day, this goal will become a reality. ■

The European Polar Board

Established in 1995, the European Polar Board (EPB) is the European Science Foundation's strategic advisory committee on science policy in the polar regions. It comprises 19 European Union and pre-accession countries, as well as external members such as the Russian Federation.

Concerned with major strategic priorities in the Arctic and Antarctic, the EPB is funded by its members to act as a strategic voice and facilitator of cooperation between national polar institutes, research organisations and funding agencies.

Major initiatives

Since its creation, the EPB has been very dynamic in developing and supporting a whole series of strategic initiatives such as the proposal for a state-of-the-art, pan-European icebreaker, Aurora Borealis (see p. 22), and the proposal for a strategic framework for coordination of European polar research, to be taken forward by a European Polar Consortium.

Endorsements and co-operation

Other initiatives by the EPB include its role in the European endorsement of the 2007-2008 International Polar Year, as well as efforts to coordinate EU projects and proposals in both the natural and the social sciences.

The EPB is also actively in dialogue with the US National Science Foundation (NSF) on a series of joint initiatives, and it is hoped that a position paper on the subject of US/European collaboration in polar regions will be developed during the next year.

Future directions

According to Paul Egerton, EPB Executive Secretary, the Board will, in 2005, give strong support to the European Polar Consortium's activities, including through coordinating the views of EPB members' national polar research bodies.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The long collaboration between France and Russia at Vostok station on invaluable ice-coring work has deepened the scientific links between Russia and Europe.

The European Polar Consortium

The European Polar Consortium (EPC) is the brainchild of the European Polar Board and represents the next step towards the development of a 'European polar entity' that will enable Europe to maximise and direct its critical mass at a global level.

Norway, Germany, Great Britain, Italy and France have all established their own research stations in Ny-Ålesund


© Christian Du Brulle

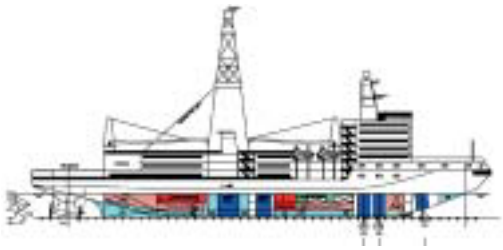
The EPC is composed of 25 ministries, funding agencies and national polar agencies from 19 member countries, including Russia, and was launched in March 2004.

The EPC's brief is to develop a four-year strategic plan and timetable, under the auspices of the EU, which would see European nations, including new EU members, increasingly collaborate in their activities in the polar regions. The resulting common access to infrastructure and transnational programme development would further strengthen European research and Europe's voice in international polar forums. The EPC is supported by ERA-NET (the EU scheme promoting coordinated European research) under the EU Sixth Framework Programme for research and technological development (FP6).

Through mapping Europe's strengths and breaking down legal and administrative barriers to cooperation between research agencies, the Consortium expects to promote valuable synergies in the major areas of European scientific expertise, including climatology, ice coring science and new frontier research areas such as astronomy, astrophysics and life in extreme environments.

The Aurora Borealis: proposal for an advanced European icebreaker

Sediment deposits, lying deep beneath the Arctic Ocean floor, hold the key to understanding the region's climate history, and its effect on the global environment over many millions of years. Drilling for this information while operating in pack ice, however, is a very delicate and costly operation that requires state-of-the-art vessels and technology.



Cross-section of the proposed European research icebreaker, *Aurora Borealis*

Following the recent success of the Arctic Coring Expedition (ACEX – see p. 37) which required an ice-strengthened drilling vessel and two powerful icebreakers to extract a 400 metre core from the Arctic Ocean floor, the European Polar Board (EPB) has been putting together an ambitious proposal for a new, dedicated European research icebreaker. Such a vessel would be capable of operating throughout the year as an autonomous drilling platform in the highest latitudes of the Arctic.

Originally proposed by Jörn Thiede, Director of the Alfred Wegener Institute (AWI) in Bremerhaven, the Aurora Borealis would be equipped with a new twin hull design comprising steeply-sloped side walls capable of breaking ice laterally so as to maintain the ship's exact position during drilling. At 132 metres long for 23,000 tonnes, it would contain berths for 200 crew and scientists.

Participating countries to share the both cost and scientists' time on board

With an estimated price-tag of 300 million euro, the idea is for the Aurora Borealis to be majority funded by a consortium of participating European nations, with other possible non-EU contributors such as the U.S.A., Canada, Japan and China.

Expected to operate up to 300 days a year and to provide some 15,000 scientific working days, the Aurora Borealis would be managed on a share basis, with time being allocated according to individual countries' financial contributions. In addition to drilling activities, the vessel would also provide logistical support for research in the fields of meteorology, oceanography, geophysics, biology and the study of sea ice, and would be equipped with novel technologies such as ROV (Remote Operated Vehicle) and AUV (Autonomous Underwater Vehicle) systems.

With a final decision on its construction expected in the second half of 2005, it is anticipated that the *Aurora Borealis* could be operational as early as 2008-2009.

Unfrozen assets: budgets and staff of European polar research organisations

Although European polar research is very well funded, there exist big discrepancies between individual nations. What is more, whilst some polar research programmes are very centralised, operating under large, integrated organisations and budgets, others only operate as logistical providers or have separate structures for different scientific disciplines and/or regions.

Large and extra-Large

The best-funded polar research programmes in Europe are without doubt those run by Germany and the UK. Centralised around the German Alfred Wegener Institute (AWI) which has an annual operating budget of 60 million euro and over 450 employees, and the British Antarctic Survey (BAS) which has it own annual budget of 43 million euro and just over 400 full-time staff, both national programmes also comprise universities and other separately funded polar organisations such as the Scott Polar Research Institute (SPRI) in Cambridge.

Slightly smaller in size, the French and Italian polar research programmes also have their own central polar research institutions such as the Institut Paul Emile Victor (IPEV), but generally operate in a more open structure with greater financial participation from universities and other organisations. The annual budget of the French IPEV is approximately 20 million euro, whilst about 27 million euro is spent by the Italian polar research programme as a whole.

Medium and small

Medium-sized European polar research programmes include Norway, Denmark, Sweden and Spain, with the Norwegian Polar Institute operating a staff of around 120 people, most of them dedicated to the Arctic.

Among the smaller countries for which figures are available, the Netherlands and Belgium each spend between one and two million euro annually on both national and international projects. They do not currently operate stations (Belgium is planning one), but instead have arrangements with other national programmes whom they pay for logistical support on specific projects.

Poles of excellence: Europe's leading institutes and organisations

With its 25 EU nations and 20 non-members, Europe is as rich in leading polar organisations as it is in polar history. Ranging from dedicated polar research institutes to universities and specialised libraries, today's European polar organisations form an intricate and fertile network active in large areas of the polar regions and in most disciplines of polar research. This network encourages excellence through healthy doses of both cooperation and competition between European nations.

Built on a rich tradition of polar exploration going back to the 18th century and the often heroic expeditions of the early pioneers, leading European organisations draw on an illustrious past to strive to identify and address today's most pressing polar issues and questions: questions relating to the role of the polar regions in the Earth system, to the environmental history of the polar regions, and to the present and future effects of global climate change.

Because of their remoteness and the harshness of their environment, however, the Arctic and Antarctic are some of the most expensive regions of the world in which to carry out scientific research. Indeed, depending on the exact location and nature of the project, some research expeditions and programmes must spend as much as 80% of their budgets on logistics alone. This level of expenditure means that deep pockets are necessary to finance polar research activities and that such research inevitably tends to be the prerogative of larger nations and of Nordic countries with territories and dependencies north of the Arctic Circle.

Since 1994, the German Dallmann lab has been hosted by the Argentinian station Jubany to carry out research in marine and terrestrial biology at King George Island near the Antarctic continent.

Rothera Station is the British Antarctic Survey logistics centre for the Antarctic Peninsula and home to well-equipped biological laboratories and facilities for a wide range of research.

Polar Institutes

Germany

Certainly one of the leading polar institutes in Europe today is Germany's Alfred Wegener Institute for Polar and Marine Research (AWI). Founded in 1980, 90% financed by the German Federal Ministry of Education and Research, and with headquarters in Bremerhaven, the institute was named after the German scientist Alfred Wegener, one of the pioneers of the theory of continental drift, who was a geophysicist, meteorologist and climatologist and carried out the majority of his research work in Greenland, where he died in 1930.

In its short history, the Alfred Wegener Institute has risen to prominence through its integrated programme of research in four main areas: geosystems, climate systems, pelagic ecosystems and benthic ecosystems. It is also a well-equipped polar research institute, with a network of polar research stations, ships and aircraft adapted for polar operations. Its flagship, Polarstern, currently one of the most sophisticated polar research icebreakers in the world, has enabled the institute to carry out many important studies relating to, amongst other things, the ocean-ice-atmosphere system and its importance for the world climate. Furthermore, the AWI is also active in polar logistics cooperation, as can be seen with its Dallmann Laboratory housed at the Argentine Jubany Station on King George Island in the South Shetland Islands and the merging of the Institut Polaire Français and the Alfred Wegener Institute stations at Ny-Alesund in Svalbard.

United Kingdom

Almost as well funded, and operating a greater network of aircraft and stations than the AWI, the British Antarctic Survey (BAS) grew out of a wartime expedition "Operation Tabarin" in 1943. It was then established in 1945 as the Falkland Islands Dependencies Survey (FIDS); an organisation which ran as many as 13 stations during the International Geophysical Year of 1957-58. Renamed British Antarctic Survey in 1962 when the UK became one of the original 12 signatories to the Antarctic Treaty and put aside its Antarctic territory claims, the BAS is perhaps most famous as the organisation which discovered the ozone hole in 1985.

Financed by the UK's Natural Environment Research Council (NERC) and with headquarters in Cambridge, the BAS is currently launching a new suite of science programmes for 2005 to 2010 entitled 'Global Science in the Antarctic Context'. This programme will involve a whole range of research: global and regional signs of climate change; biodiversity and evolution in the Antarctic ecosystem; Southern Ocean science and Earth system integration. One of the most topical aspects of the new programme deals with glacial retreat in Antarctica and the deglaciation of the Earth system. This includes research on the stability of the West Antarctic Ice Sheet (WAIS), a vast reserve of fresh water which would increase global sea levels by up to 6 metres if it were to collapse as a result of climate change.

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France

The French Polar Institut Paul Emile Victor (IPEV) is a public body composed of nine public organisations, amongst which the most important are the French Ministry of Research, which provides most of the funding to the IPEV, and the French Centre National de la Recherche Scientifique (CNRS) which provides two-thirds of the 50 permanent staff at the IPEV headquarters in Brest, Brittany. Previously the Institut Français pour la Recherche et la Technologie Polaires (IFRTP), the IPEV was created in 1992 by the merging of the scientific mission of the Terres Australes et Antarctiques Françaises (TAAF), which managed the French sub-Antarctic islands of Kerguelen, Crozet and Amsterdam, and the Expéditions Polaires Francaises. It is named after Paul Emile Victor, the leading figure of modern French bi-polar research and exploration who died in 1995.

Recently extended to 2014, the IPEV will make use of its three research vessels as well as its stations in the Arctic, sub-Antarctic and Antarctic to continue its programme of research in fields ranging from oceanography to biology, climatology, atmospherics and glaciology. In 2005, in collaboration with the Italian Antarctic Program, the IPEV also operates its first winter campaign at the newly opened, second-generation, Concordia station at Dome C on the Antarctic Plateau. Dome C was originally erected as a summer camp to support the highly successful European Project of Ice Coring in Antarctica (EPICA – see page 32). Amongst many other projects, the institute now hopes to take advantage of the exceptional atmospheric conditions at Dome C to launch an international astronomy programme for which initial site testing is currently taking place.

The French Antarctic station Dumont d'Urville on the Adelie coast was built on an island, part of the Pointe Géologie archipelago. It has good access to the plateau, Cape Prud'homme, less than 5 km away.

Italy

Italy's polar research activities are divided into the National Programme of Antarctic Research (PNRA) and the Arctic Project.

The PNRA was first established in 1985. In 2002 a consortium of four agencies was put in charge of its implementation: the National Research Council (CNR), the Agency for new Technologies, Energy and the Environment (ENEA), the National Institute for Geophysics and Volcanology (INGV), and the National Institute of Oceanography and Experimental Geophysics (OGS). The programme is promoted by the Ministry of Education, Universities and Research (MIUR) and opened its high-tech Mario Zucchelli-Terra Nova Bay summer station in the Ross Sea region in 1986.

The PNRA's research activities include its collaboration with the IPEV on the construction and management of the newly constructed Concordia Station on the Antarctic Plateau, as well as a particularly active programme of cooperation on international projects such as EPICA, the International TransAntarctic Scientific Expedition (ITASE), the Balloon Observation of Millimetric Extragalactic Radiation and Geophysics (BOOMERANG), and the Antarctic Geological Drilling Consortium (ANDRILL).

The Italian Arctic Project started in 1996 when the CNR opened the Dirigibile Italia research station at Ny-Alesund in Svalbard. This was followed by the establishment of the Arctic Strategic Project in June 1997 and its launch of a multidisciplinary programme of research which includes Climatology, the NICE (Nitrogen Cycle and Effects) project, biological adaptation, biomedecine, hydrology, radionuclides, permafrost and human science. The Arctic Strategic Project is managed by the recently created CNR/POLARNET which coordinates polar research activities in both the Arctic and the Antarctic.

Italy's Zucchelli base on the Ross Sea coast, Antarctica, is a summer-only station accommodating up to 90 people.

Nordic Countries

Within Europe, Denmark, Finland, Sweden and Norway all stand out as countries with territories and dependencies north of the Arctic Circle, and as some of the oldest and most prolific contributors to European polar research in both the natural and the social sciences. Together these four Nordic countries study everything from the effect of global warming on the Greenland Ice Cap and Arctic Ocean, to the cultural, historical and social processes that shape the sustainability of circumpolar indigenous peoples – especially the Saami of Northern Scandinavia and the Inuits of Greenland.

The Danish Polar Centre supports and synchronises a vast network of stations and observation posts throughout Greenland and, through its, logistics network, actively supports United States and other international research in the region. The Finnish Institute of Marine Research, the Norwegian Polar Institute and the Swedish Polar Research Secretariat together operate a small fleet of research vessels, as well as a whole panoply of stations and observation posts from Northern Scandinavia to Svalbard, and to Antarctica, where Norway is currently upgrading its Troll station for year-round occupancy.

Norway opened its summer Troll station in 1990. It was upgraded to a full-year facility during the last Austral summer.

Universities and Other Organisations

Although it would be almost impossible to identify all the European universities carrying out research in the polar regions, it is nevertheless possible to mention a few that stand out for their excellence and dedication to these regions.

Notable amongst these is Cambridge University, which maintains a close relationship with the British Antarctic Survey and is home to the Scott Polar Research Institute (SPRI) founded in 1920 as a memorial to Captain Scott and his four

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companions who died on their return journey from the South Pole. The Institute is the oldest international centre for polar research within a university and since the war has been involved in a whole variety of research relating to polar history, the natural sciences and the social sciences.

Housing its own polar museum, as well as the world's most comprehensive polar library and archives, with books, publications, diaries, unpublished material, artefacts and images relating to all aspects of polar research and history, the SPRI serves as an invaluable source of information for international scholars and scientists alike. Furthermore, the SPRI offers a sought-after Masters and PhD programme covering subjects relating to both the natural and the social sciences, and is home to various external organisations such as the Scientific Committee for Antarctic Research (SCAR) and the International Glaciology Society (IGS).

Another important university for polar research is the uniquely located University Centre in Svalbard (UNIS) where every year up to 250 international post-graduate students come to study and carry out research in Arctic sciences, including biology, geology, geophysics and technology. Intended to contribute to the development of Svalbard as an international research platform, UNIS programmes rely heavily on the natural properties of Svalbard as a high-latitude research laboratory and on the extensive research infrastructure in and around Ny-Alesund. In the future, the UNIS will form the core of the Svalbard Science Centre (SSC), an international Arctic centre of expertise in research and education, which will also incorporate other professional and scientific institutions on the islands.

Among other European universities and other organisations which contribute significantly to polar research, one should also mention: the University of Grenoble, whose glaciology laboratory is actively involved in the study of ice cores; the University of Groningen, home to the Dutch Arctic Centre; the University of Lapland, home to the Finnish Arctic Centre; the Norwegian Institute of Technology, home to the SINTEF Polar Technology unit; the University of Copenhagen, home to specialist glaciology and geophysical groups; the Belgian Science Policy and its Antarctic programme; the University of Tromsø; the University of Siena; the University of Dresden; and the University of Stockholm.

Working Together

Whilst all funded and working independently to uphold their own programmes and reputations, together the above-mentioned institutes and universities display the vibrancy of the European polar research community, as well as its common desire to better understand how the polar regions function and evolve both internally and as part of the Earth system as a whole. Indeed, this shared enthusiasm and sense of urgency in the face of global warming is leading to an increasing number of European collaborative programmes and to a more coordinated approach to European polar research as a whole. ■

To find out more:

AWI: www.awi-bremerhaven.de
BAS: www.antarctica.ac.uk
AARI: www.aari.nw.ru/
IPEV: www.ipev.fr
CNR-POLARNET: www.polarnet.cnr.it/polar
NPI: npweb.npolar.no
SPRI: www.spri.cam.ac.uk
UNIS: www.unis.no

High latitude real-estate: European polar stations

The jewels in a polar programme's crown, research stations act as invaluable operational platforms from which to support local and deep-field research expeditions, as well as all types of atmospheric, astronomical, meteorological, biological and medical observations. Rightly or wrongly, stations are also often regarded as the best indication of a nation's commitment and dedication to polar research.

European nations operate a total of twelve year-round and ten summer-only Antarctic and sub-Antarctic stations, as well as about ten dedicated scientific stations in the Arctic. Above and beyond these, Russia still manages the Soviet Union's legacy of eight research stations in Antarctica alone.

The Arctic

While Antarctic stations are easy to add up and classify according to nationality and seasonal usage, the complex geographic, human and political dimension of the Arctic (an ocean surrounded by sovereign, inhabited coastlines), can make it difficult to distinguish dedicated scientific research stations from meteorological and other observation posts. These posts are maintained by local inhabitants, the military or other non-scientific agencies.

Certainly the greatest concentration of dedicated European scientific research stations in the Arctic is in Ny-Alesund, on the Svalbard archipelago. There, France and Germany have just merged their stations into a single polar research platform, whilst Norway, Sweden, Italy, Poland and the UK also maintain stations with the support of a logistical network managed and operated by Norway's Kings Bay AS. ➔

Indeed, with Norway's support, Ny-Alesund has become a thriving polar research community and one of the leading climate and environmental monitoring posts in the entire Arctic region. It is a logistical hub where, amongst many other things, the depreciating thickness of Arctic sea ice and its effect on salinity and ocean currents is being closely monitored. What is more, Ny-Alusund is also home to the University Centre in Svalbard (UNIS) where every year up to 250 international postgraduate students come to carry out research in Arctic biology, geology, geophysics and technology.

Away from Svalbard, other notable European research stations include the Sodankyla Geophysical Observatory and the University of Lapland in northern Finland, as well as the Swedish Abisko Scientific Research Station about 200 kilometres north of the Arctic circle. The Danish Polar Centre and other Danish scientific organisations also operate a whole network of observation posts and stations in continental and coastal Greenland. These outposts are examining closely the history, stability and thinning of the Greenland ice cap, as well as its effect on global sea level rise.

Ny-Alesund in Svalbard, a thriving Arctic research community.

The Antarctic

Of all the European polar research programmes, the British Antarctic Survey (BAS) and the Institut Polaire Français (IPEV) operate the greatest network of Antarctic and sub-Antarctic stations. In the case of the BAS, these range from the relatively accessible King Edward Point on the island of South Georgia, to the remote Halley V on the Brunt Ice Shelf in the Weddell Sea region. Lying within the auroral zone, Halley is ideally situated for geospace research and is where the ozone hole was first discovered in 1985.

By far the most isolated European research station in Antarctica is the new, ultra-modern French-Italian Concordia station at Dome C, high up on the Antarctic Plateau. With a summer population of around 55 and winter population of 15, Concordia is supported and re-supplied by a mixture of land-traverse via France's Dumont D'Urville and air link via Italy's Zucchelli station on the Antarctic coastline. Originally set up as part of the European Project for Ice Coring in Antarctica (EPICA), it was recently rebuilt as a permanent structure to support a whole range of current and future research in glaciology, astronomy, and atmospherics.

Another important European polar research station is Germany's Neumayer in Dronning Maud Land. Buried under eleven metres of ice and snow accumulation, Neumayer is located on a moving ice shelf and, like the British Halley V, is slowly progressing towards the edge of the shelf where it will eventually carve off as part of an iceberg. For this reason, both Neumayer and Halley have been abandoned and rebuilt upstream on several occasions in the past – usually at ten to twenty year intervals. Indeed, plans are currently being drawn up to replace both existing stations within the next three to five years.

Summer stations

Although smaller in size, summer stations, such as Norway's Troll Station (currently being upgraded for year-round occupation), Sweden's Wasa Station, Spain's Gabriel de Castilla Station and Ukraine's Vernadsky (formally the British Faraday) station, also play an important role. They provide logistic and other support for the majority of scientists who carry out Antarctic research during the months when 24-hour daylight is the norm and conditions are at their most favourable. ■

The British Antarctic Survey station Halley V, built on the Brunt Ice Shelf, Coats Land, Antarctica. Lying at the edge of the southern auroral zone, it is ideally situated for geospace research.

Polar armada: Europe's polar research vessels

The *Polarstern* (Germany) has completed 32 expeditions to the Arctic and the Antarctic since 1982.

Polar research vessels owned or operated by European countries range from Germany's icebreaker, *Polarstern*, currently the most sophisticated polar research vessel in the world, to the Polish Academy of Science's three-mast, ice-strengthened *S/Y Oceania*. Together these vessels form a veritable 'polar armada' capable of providing tailored platforms for all kinds of research and logistical operations, from the most ambitious oceanographic research to the most specific and localised coastal operations.

Of the 20 or so European polar research vessels, three are ice-breakers and the remainder are classified as ice-strengthened. Aside from hull strength and a ship's ability to sail through various depths of pack ice, perhaps the single most important quality required from a polar research vessel is the flexibility to support a whole range of scientific disciplines and to operate in capacities ranging from research platform to supply ship, to passenger carrier. Indeed, from this perspective, the unique strength of the European 'armada' rests not only on the flexibility of specific research vessels, but also on the flexibility of the fleet as a whole.

Icebreakers

With her 118 metres in length, a displacement of 17 300 tons, her two helicopters and a double hull that enables her to withstand temperatures of –50˚C and to over-winter in the sea ice of the polar seas, *Polarstern* is the most important tool in Germany's polar research programme. Operated by the Alfred Wegener Institute (AWI) and operational nearly 320 days a year, since its launch in 1982, the *Polarstern* has completed 32 expeditions to the Arctic and the Antarctic, carrying up to 55 scientists at a time and supporting a whole panoply of campaigns in fields ranging from biology to geology, geophysics, glaciology, chemistry, oceanography and meteorology.

Aside from the *Polarstern*, the other two European polar research vessels classified as icebreakers are: the 118 metre, 9 500 tonne, *Oden*, operated by the Swedish Maritime Administration and leased by the Swedish Polar Research Secretariat; and the 141 metre, 16 500 tonne, *Akademic Federov* operated by the Russian Arctic and Antarctic Institute (AARI). Whilst the *Oden* is sometimes leased for commercial icebreaking operations, both vessels serve as polyvalent research and logistical platforms, with *Federov* regularly re-supplying AARI stations in Antarctica.

Ice-strengthened vessels

Among the largest European ice-strengthened vessels operating in the polar regions is the French 120 metre, 10 000 tonne *Marion Dufresne*. It serves as an oceanographic research platform and also provides logistical support and passenger transport for the French sub-Antarctic islands of Kerguelen, Crozet and Amsterdam. Slightly longer, at 130 metres for 5 000 tonnes, the Italian *Italica* also serves for marine science, but mostly as a tanker and logistics vessel for the support of the Italian Antarctic Zucchelli station at Terra Nova Bay. Two European polar research ice →

At 10 000 tons the *Marion Dufresne* (France) is one of the largest European ice-strengthened vessels operating in the polar regions.

strengthened vessels are the British *RRS James Clark Ross*, 90 metres for 5 700 tonnes, serving for marine science, oceanography, logistics and passenger transport and the 80 metre, 5 400 tonne, *RRS Ernest Shackleton*, both operated by the British Antarctic Survey (BAS). Finally, there is the Russian *Akademik Karpinskii* at 105 metres for 5 750 tonnes, which is mostly used for marine science.

To find out more:
COMNAP: www.comnap.aq
FARO: www.faro-arctic.org

Medium-sized, polyvalent ice-strengthened European polar research vessels include: the Spanish, 82 metre, R/V *Hesperides* used for bi-polar research and the re-supply of the Antarctic Gabriel de Castilla and Juan Carlos I stations; the French, 65 metre *Astrolabe* used for marine science and to re-supply the French Dumont d'Urville Antarctic station; the Norwegian, 60 metre, *R/V Lance* used mainly for Arctic research and to re-supply Norwegian stations on Svalbard; the Finnish, 60 metre, *R/V Aranda* used for research in both polar regions; and the Danish 58 metre *Paamiut* operated by the Greenland Institute of Natural Resources and used as a logistics and marine research platform in and around Greenland.

The ice-strengthened *RRS James Clark Ross* (UK) is designed with an extremely low-noise signature to allow sensitive underwater acoustic equipment to operate effectively.

***The Hesperides* (Spain) carries out research in warm, temperate and polar waters and re-supplies Spanish stations in the Antarctic.**

Smaller vessels

Smaller in size, but equally useful in supporting shallow coastal work and other very localised polar research is the beautiful three-mast, 49 metre, Polish *S/Y Oceania*, as well as a whole fleet of 15 to 50 metre vessels operated by the above-mentioned nations and polar programmes. ■

Russia: a promising partner for the EU

A member of the European Polar Board, Russia brings a full range of ships, stations and skills to its EU partners.

Established in 1920, the Russian Arctic and Antarctic Research Institute (AARI) still manages a vast infrastructure inherited from the time of the Soviet Union. Today, the institute is part of the Russian Federal Service on Hydrometeorology and Environmental Monitoring and, at its headquarters in St Petersburg, houses 17 scientific departments, an Arctic and Antarctic museum, a centre for Ice and Hydrometeorological studies, and the Russian Antarctic Expedition (RAE), which manages all the institute's Antarctic stations and activities. What's more, the AARI is the keeper of a vast data collection spanning back to its origin and touching on everything from ice to ocean and atmospheric, geophysical and other processes.

Thanks to its ships and many research stations, the institute continues to perform complex investigations in fields ranging from oceanography to ice dynamics, meteorology, ocean/air interaction, geophysics, hydrochemistry, ecology and polar engineering. More recently, and regrettably often overshadowing its other activities, the AARI has received a lot of publicity for its ice core drilling project at its Vostok Station on the Antarctic Plateau (the world's most remote research station) and its discovery of a lake that has been buried beneath the ice sheet for some 2 million years.

European technologies for and from polar research

The progress of science in polar regions, as in others, relies heavily on continuous improvements in technology. Over recent decades, European polar researchers have developed a number of high-tech methods and equipment. Although some of these are specific to extreme latitudes, such as certain building technologies, others are applicable to other environments, with a few examples given below. Indeed, a particularly noteworthy synergy exists between polar and non-polar marine biologists and oceanographers.

Automated magnetometry

Mervyn Freeman, Mike Rose and colleagues from the British Antarctic Survey (BAS) have developed a new technology that allows magnetometers to use very little power and to survive the winter on solar power stored during the summer months. This allows the magnetometers to operate unmanned throughout the year and works by having them switch on for only the minimum amount of time needed to take a measurement (around 150 milliseconds anywhere from once a second to once a minute). A network of 11 such Low Power Magnetometers has been deployed across the Antarctic continent in order to measure and understand 'magnetic weather' (useful, for example, for telecommunications and the aerospace industries to better protect spacecraft).

Ice buildings

Heinz Ahammer from the Alfred Wegener Institute (AWI), Germany, has produced a system for the production of vaulted rooves constructed solely from snow. Snow is compacted over an inflatable and reusable device which is then deflated and removed to give way to a hollow, vaulted space. Similarly, removable air cushions have been developed to protect buildings from the accumulation of drifting snow: the cushions create hollow spaces which decrease the weight of the snow layer covering buildings.

Low Power Magnetometers run all year on solar energy stored during the summer.

Weather above and under the sea ice

For more then 20 years, drifting buoys (or 'drifters') have been used for the study of the sea ice interface in both polar regions. These Buoys are equipped with an automatic weather station, a GPS positioning system, an Argos transmitter, and sometimes, an ice-thickness gauge. More recently, increasingly efficient autonomous underwater vehicles, or AUVs (already used worldwide to record water currents and temperatures), have been fitted to work under the ice. Some are used by the team of Michael Klages (AWI) deep under the Arctic sea ice and others by Keith Nicholls (BAS) and his colleagues from the Southampton Oceanography Centre, UK, under the Ronne-Filchner ice shelf in Antarctica.

Autonomous underwater vehicles, such as this one operated by the Alfred Wegener Institut, are now able to work under ice.

However, a joint team of scientists from the Norwegian Polar Institute and the University of St Andrews, Scotland, has probably found the cheapest deployment platform for oceanographic measurements, with their CTD (conductivity, temperature & depth) loggers, fitted on seals and white whales living in the wild. This innovative application allows measures to be taken under the Arctic ice at depths of up to 250 m. Similar programmes are also in the process of being launched in Antarctica, this time using crab-eater and elephant seals which can dive down to depths of up to 1 km! ■

To find out more:

http://www.antarctica.ac.uk/BAS_Science/programmes2000-2005/MRS/LPM/index.html

http://www.antcrc.utas.edu.au/antcrc/buoys/buoys.html

http://www.smru.st-and.ac.uk/research/individuals/Martin/SEaOS.htm

Cold comfort: living and working in Antarctica

Life on an Antarctic station varies immensely depending on season, location, infrastructure, a country's resources and the availability of supplies.

Don't forget a warm hat and scarf …

Location

Antarctic stations also vary greatly depending on whether they are coastal or continental. Coastal stations are usually located in protected bays accessible to ships, making them much easier to re-supply with food, fuel, equipment and other essentials. Their proximity to the sea also means that they can benefit from unlimited water supplies through reverse osmosis.

Inland stations on the other hand, are dependent on air links or tracked vehicle traverses for re-supplies, making them more dependent on weather conditions and far more expensive to run. They also depend on the labour-intensive melting of snow for water and are often built directly on the ice, meaning that they must be specially designed (often on stilts or under the surface) to compensate for sinking and snow accumulation.

Seasons

According to Frank Swinton, base doctor at the British Antarctic Survey Halley station, however, nothing influences life in Antarctica as much as the seasons. Whilst the vast majority of scientists only travel to Antarctica during the summer months so as to benefit from optimal light and weather conditions, 10 to 20% of Antarctica's summer population stays behind during the winter months to man all-year stations and experiments. For these people, coping with the 24-hour darkness, the psychological effects of living in small, isolated communities and the possibility of developing serious medical problems that might not be treatable in situ requires an altogether greater level of adaptability and resilience. ■

Infrastructure

Some Antarctic stations are little more than interconnected shipping containers or pre-assembled huts providing the most basic protection and comfort for short summer visits. Others are the height of modern convenience with everything from gyms to ice cream machines – not to mention private bedrooms, hot running water, sewage plants and 24-hour communication links.

Belgian science team in charge of locating the best site in the Sør Rondane mountains for the Belgo-Japanese summer station.

To find out more:

British Antarctic Survey:
www.antarctica.ac.uk/Living_and_Working/index.html

European research priorities in polar regions

At the European Commission, Ib Troen supervises various joint research programmes being carried out in polar regions. An interview.

Ib Troen visiting the North Greenland ice core project in 1997.

© Ib Troen

Is there a clear European strategy for polar research?

We cannot really talk about a "polar strategy". Within the European scientific community, many researchers are carrying out work in this kind of field. But this community is highly diverse and does not constitute a single entity. Some researchers are interested in how ice evolves, while others are looking at sediments, greenhouse gases or biodiversity. Joint and cross-disciplinary meetings are organised. And research programmes are involving increasing numbers of partners from outside the EU, for example from Russia. These efforts naturally receive political backing. But at the level of the European Commission, there is no research theme that could be qualified as 'polar'.

Should we then be talking about priority themes which are relevant to the polar regions?

That is closer to the reality. For example, one of our priorities is the study of climate development. This type of research is indeed carried out in polar regions and requires the involvement of different disciplines. Research programmes targeting geographical regions tend to be rarer, although there have been some exceptions, notably concerning the Mediterranean basin.

What are the main European programmes being carried out in this type of environment?

In the first instance, the Commission provided support for ice coring projects, such as the GRIP project in Greenland, which was carried out in partnership with the European Science Foundation (ESF). The success of this project certainly contributed to the subsequent decision to launch the EPICA programme, this time in the Antarctic. EPICA has now shown that it can compete on equal terms with identical projects commissioned by other countries, such as the United States or Russia. We should remember that in this last winter, drilling by EPICA broke all records with respect to the age of the ice extracted from a polar ice cap, at 900,000 years.

In other areas, still linked to recent programmes on world climate change, we should also mention the Arctic Ice Cover Simulation Experiment (AICSEX) project, which has focused on the Arctic ice cap, its evolution and modelling. Other programmes concern thermohaline circulation. In this area, new data are now available to help us refine the models and will open up new perspectives for the measurement of marine currents, temperatures, carbon uptake, atmospheric circulation and pollution, etc.

Do you think there is a certain preference for projects in one hemisphere rather than the other?

It is clear that programmes in the Arctic polar regions are more attractive than research carried out in the southern hemisphere. Particularly because the former have a direct impact on the European Union and its citizens, and also because the region is more accessible. In the context of polar research, where a high proportion of the budget is allocated to logistics, this factor is of considerable importance.

What role will polar research have to play in the next Framework Programme?

Climate change remains a crucial theme within the European Union. But it is too soon to say how much priority will be given to it in the next Framework Programme, and which disciplines will be involved. There may be a resurgence of interest in the problem of aerosols, for example, which have an effect on radiation, its absorption and the physics of clouds. The content of the 7th Framework Programme has not yet been decided.

Might the European Union consider a new major infrastructure for polar research?

Not as such. We will not be building a Joint Research Centre, such as ISPRA, in polar or subpolar regions. This type of very costly initiative could be organised in the context of a partnership with Member States. If relevant, we could then provide support for national initiatives. This is clearly a topic for discussion in relation to development of the European Research Area, which we are pursuing while facilitating the coordination of national efforts. ■

New European initiatives

The European Union, via the Commission and its Research Directorate-General, has just approved funding for two new scientific research projects in the polar regions, one in the Antarctic and the other in the Arctic. This is the most recent phase in the EPICA programme, "Epica-MIS" in the Antarctic, and a new coordination programme in the Arctic, being carried out in close collaboration with the next International Polar Year, the "IPY-Care" project.

Researchers at the Dome Concordia drilling site carefully remove an ice core.

Epica-MIS

The European Project for Ice Coring in the Antarctic (EPICA) has been a huge success. At the Dome Concordia (Dome C) drilling site, researchers have extracted ice cores whose deepest samples go back 900,000 years. The recently launched new phase of the Epica programme is being coordinated by Dominique Raynaud (LGGE-Grenoble) and will consist of drilling at another site (the Kohnen station in Dronning Maud Land, or DML) and also studying the ice cores already extracted from the two drilling sites (Dome C and DML).

"We need to complete the two drilling programmes," explains Dominique Raynaud, "because they are complementary. At Dome Concordia, the ice is older than at Kohnen, but comparison of the data from samples collected at both sites will ultimately provide us with a clearer picture. The new phase will therefore allow us to interpret our results in greater detail."

Oceans also under scrutiny

But this new phase also includes a section on oceanography, as indicated by the suffix 'MIS' (Marine Isotopic Stages). "With the help of oceanographers, we will be comparing data from our ice cores with those obtained from cores drilled in the sedimentary layers of the ocean floor. This comparison of data from oceanographic climate archives with our atmospheric ice archives will be extremely informative. Our aim is to determine whether the link between greenhouse gases and temperature was equally as strong more than 400,000 years ago, as has been established by ice cores from the Vostok research station. We want to find out how stable the Antarctic has been over the past half a million years, and to better assess the impact of orbital forcing (the evolution of insolation following changes to astronomic conditions) on climate change."

This desire for cross-disciplinary work is in line with European Commission plans for the new phase of the Epica programme. "We feel it is indeed essential to combine the information obtained using these two research techniques so as to achieve major advances in our paleoclimatic knowledge" confirms Hans Brelen, the Scientific Manager at the European Commission. "It was with this in mind that the new phase of EPICA was approved."

IPY-Care

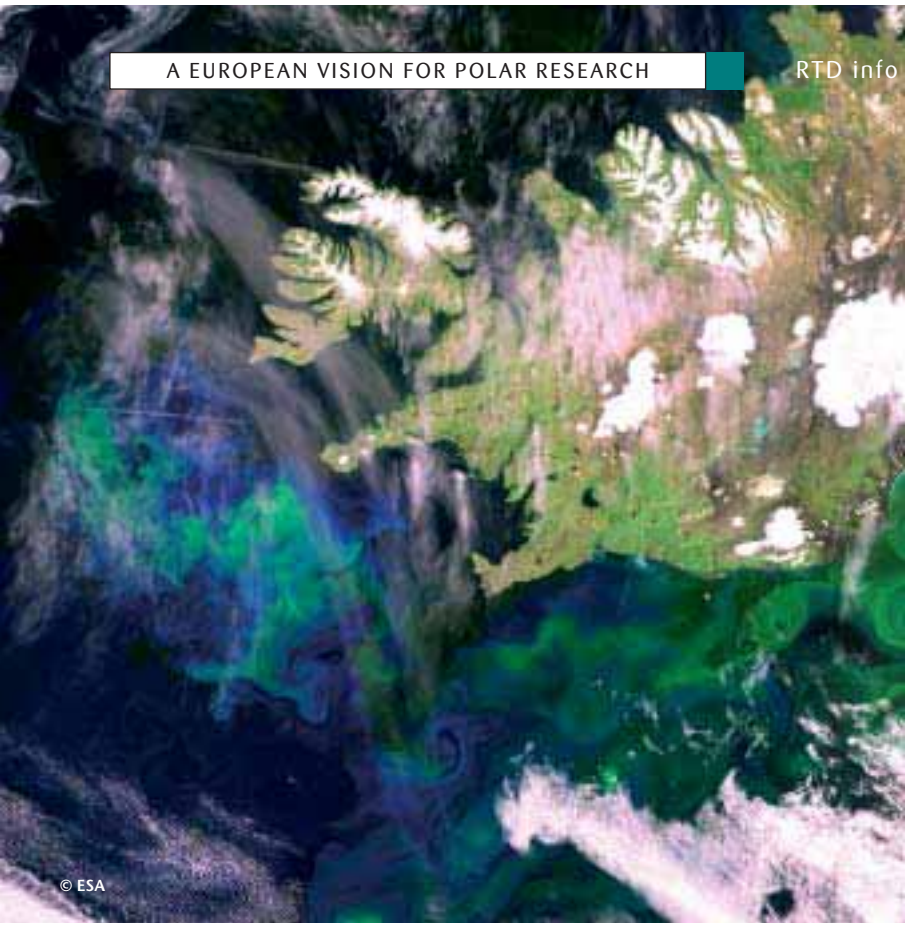
The next International Polar Year in 2007-2008 (IPY) is already the focus of much attention. This is also the case for the Arctic and the rapid changes that are taking place there as a result of global warming, as recently demonstrated by the 'Arctic Climate Impact Assessment' (ACIA). It was for this purpose that the IPY-Care (International Polar Year – Climate of the Arctic and its Role for Europe) project was launched with the support of the European Union.

"The aim is to coordinate, integrate and strengthen European research programmes on the Arctic climate and its evolution," explains Ola M. Johannessen, from the Norwegian Nansen Environmental and Remote Sensing Centre (NERSC), which is coordinating the project.

Over the past thirty years, warming of our planet has affected the Arctic more than other regions. Its ice cover has markedly shrunk, and it is estimated that between now and the end of this century, this vast polar ocean will become wholly navigable during the summer. Of course, this has certain economic advantages. But it will also trigger a series of deleterious effects on the environment and on populations in both northern regions and in Europe, which will reverberate southwards to the Mediterranean basin.

To find out more:

www.nersc.no



One IPY-Care priority is to study further how climate change affects marine vegetation such as this massive phytoplankton concentration off the north-west coast of Iceland. Picture from Envisat's Medium Resolution Imaging Spectrometer (MERIS).

Six main research themes

So as to better assess the importance of these changes, the IPY-Care programme is drawing up a coordinated plan for polar research, which will be based on six clearly defined themes: study of the processes which determine climate variability in the Arctic; the evolution of marine biological processes as a reaction to these changes; links between sea water, ice and the atmosphere; study of the variability of paleoclimates; teledetection and the use of new technologies for climate data collection; and finally, evaluation of the impact of these changes on the European climate and the socio-economic consequences.

The consortium of 19 scientific institutions from 13 countries (including Russia), which are partners in this programme, will be organising conferences and meetings to prepare and coordinate the research projects (subsequent meetings and symposia will, in the long term, aim to disseminate the new knowledge thus acquired), and supervise the 'operational' phases which will take place during the International Polar Year (mobilisation of European polar research ships, associated Russian stations, planes, etc., with a view to joint actions with other partners such as Canada, Japan and the United States). ■

A new start for Dome C?

In Europe, 2005 will also be marked by a series of new proposals for polar research.

"A lot of projects are in gestation, or rather I should say are the subject of intense cogitation and discussion on all sides," says Dominique Raynaud, (LGGE-Grenoble). "For example, it has been suggested that the Concordia station, which is one of the two drilling sites for the Epica project, could be developed into a multidisciplinary research station, with a more European or even international remit (until now, Dome C has been run jointly by France and Italy). It would then be possible to carry out research on surface ice, perform radiosonde observations, or even conduct new drilling to study the composition of sub-glacial lakes, of which there are several in the region around Concordia. They are less extensive than the famous Vostok Lake, but are nonetheless of considerable interest.

Finally, it may also be possible to initiate a new deep drilling project to discover even more ancient ice, which would provide information on the history of our planet more than a million years ago. This would require preliminary international prospecting campaigns at several sites on the Antarctic continent.

Apart from Dome C, another research theme may focus on a series of ice samples at higher levels, around the edges of the Antarctic continent. These cores, going back in time between 1000 and 10,000 years, would help us understand natural climatic changes, and to clarify the atmospheric circulation around the Antarctic since the end of the last Ice Age.

Finally, studies on the past and present stability of the ice cap would provide valuable data with which to model its future. This is of course of major interest to mankind as a whole."

France and Italy are working together to construct a new research station: the Concordia.

A compendium of European research on land and under the sea

Although in recent years the different phases of the Epica ice coring programme seem to have focused efforts mostly in Antarctica, European research in polar regions involves both the northern and southern hemispheres.

AICSEX: Arctic Ice Cover Simulation Experiment

This project, coordinated by Ola M. Johannessen, from the Nansen Centre for the Environment and Teledetection in Bergen (Norway), focuses on pack ice and its development through the study of parameters such as surface temperature, the thickness and surface area of sea ice, snow cover and the flow rate of rivers at their mouths. For this research, field observations have been combined with modelling, and in both cases researchers have reached similar conclusions, namely that the surface area of pack ice is regularly shrinking as each summer passes, and that between now and the end of the century, the Arctic Ocean may be totally free of ice, with major consequences for economic and other activities.
http://www.nersc.no/AICSEX/

ASOF-N: Arctic-Subarctic Ocean Flux Array for European Climate – North

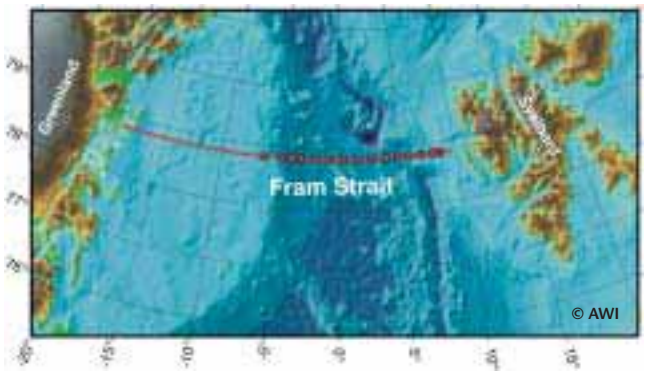
Calorie exchanges and water mass transfers between the Arctic Ocean and northern seas are the areas targeted by the scientists coordinated by Ebelhard Farbach from the Alfred Wegener Institute (AWI) in Bremerhaven (Germany). Models and field observations have been used to improve knowledge in this area. It should be noted that an ASOF-W programme (for 'West') has also been set up. Field measurements are taken off the south-eastern shores of Greenland, using immersed sounding instruments which pick up data on the currents and salinity of water masses flowing from the northern seas into the North Atlantic.
http://www.awi-bremerhaven.de/Research/IntCoop/Oce/ASOF/

GreenICE: Greenland arctic shelf Ice and Climate Experiment

Here again, sea ice is the focus of scientific studies being led by Peter Wadhams from the Scottish Association for Marine Science in Oban (United Kingdom). The aim of this programme is to measure changes to the structure and dynamics of shelf and drifting ice following Arctic oscillations. Additional work is also being carried out using data collected from marine sediments to compare current findings with the past with a view to learning lessons about long-term developments in these areas.
http://www.greenice.org/index.htm

CANDIDOZ: Chemical and dynamical influences on decadal ozone changes

This project aims to establish the scientific bases for an advanced system for detecting improvements in stratospheric ozone levels following implementation of the Montreal Protocol and its amendments. This involves long-term studies of data from both polar regions and those at medium latitudes.
http://fmiarc.fmi.fi/candidoz/



Temperatures measured within the ASOF-N programme by moored instruments in the eastern and central part of the Fram Strait were 2°C warmer in 2004 than in 2003, as well as up to 1.8 °C warmer than the climatological mean for August.

GLIMPSE: Global implications of arctic climate processes and feedbacks

Klaus Dethloff, from the Alfred Wegener Institute in Potsdam (Germany) is coordinating this programme to identify, compare and model changes to the climate of the Arctic and other regions.
http://www.awi-potsdam.de/www-pot/atmo/glimpse/

EUPLEX: European Polar Stratospheric Cloud and Lee Wave Experiment

This programme aims to test the different hypotheses relating to the depletion of stratospheric ozone concentrations at the North Pole, and in particular the mechanisms underlying the formation of stratospheric polar clouds, their activation and ozone loss.
http://www.nilu.no/euplex/

QUOBI: Quantitative Understanding of Ozone losses by Bipolar Investigations

Balloon-derived precise measurement of reductions in ozone concentrations in the Arctic and Antarctic. The results will then be compared with three-dimensional atmospheric models.
http://www.nilu.no/quobi/

QUILT: Quantification and Interpretation of Long Term UV-Visible Observations of the Stratosphere

Analysis of ozone losses over the past ten years and during the period 2000-2003. This will be achieved by improved analytical methods, consolidating the available data series and integrating them with real-time atmospheric models.
http://nadir.nilu.no/quilt/

Polar-Ocean-Polar

Marine sediment cores provide an enormous quantity of data on the history of the Earth's climate, as do ice cores essentially with respect to the composition of the atmosphere. The POP project, backed by the 5th European Community Framework Research Programme and led by Nicolas Shackleton (from Cambridge University in the UK) concerns the development of methods which will enable a common timescale for the two types of cores, so as to improve the accuracy of climate models.
http://www-pop.esc.cam.ac.uk/

In from the cold: new Member States and polar research

In May 2004, an additional ten nations joined the European Union, bringing the total to 25. Although only a handful of these new Member States are currently maintaining or developing polar research programmes, together they contribute to raising awareness of the polar regions within Europe, whilst demonstrating the value and relevance of more targeted and localised data collection and research.

Of the ten new European Union Member States, Poland has the longest-standing polar research tradition. With year-round research stations in Antarctica and Svalbard in the Arctic, as well as an Arctic research vessel, the Polish Academy of Science has a long history of scientific investigation in fields ranging from Polar oceanography to climatology. Its Henryk Arctowsky Station on King George Island, Antarctic Peninsula, was inaugurated in 1977, enabling Poland to join the 12 original consultative members of the Antarctic Treaty. With a maximum summer population of 70 and a winter crew of around 20, research is carried out in association with a wide range of international scientific programmes and organisations such as the Scientific Committee for Antarctic Research (SCAR) and the European Polar Board (EPB).

The Polish station of Hornsund, in the Arctic archipelago of Svalbard, has operated since 1957 and can accommodate up to 30 people during summer and 12 during winter.

New stations

As a consultative member to the Antarctic treaty, the Czech Republic is another new European Union Member State with a long and distinguished history of polar research, especially in the Antarctic.

Thanks to active cooperation with scientists from across the international polar research community and regular visits by Czech scientists to Russian and U.S. stations, the Czech Republic has been able to acquire the necessary expertise to operate its first Antarctic station on James Clark Ross Island on the north-eastern side of the Antarctic Peninsula. With construction due to have been completed over the Austral summer of 2004-05, the new high-tech station will accommodate up to fifteen logistical staff and scientists who will implement a multidisciplinary programme of research including geology, hydrology, geomorphology, ecology and physiology.

Among the Baltic States, Estonia stands out for its long history of bi-polar research during the Soviet era and as one of the smaller non-consultative members to the Antarctic treaty. It is also the first Baltic nation to be developing its own polar research programme with the planned construction of a small Antarctic station at Edmonson Point South in the Ross Sea region of Antarctica. Although this project has been met with some reservations by certain Antarctic Treaty nations who would prefer to limit the number of new stations on the continent, for Estonian scientists it represents an opportunity to study the rich biology of this rare ice-free Antarctic oasis.

Pre-accession countries and external members

Among the present candidates to the European Union and other external members, Bulgaria and Ukraine should be mentioned for their active polar research programmes and stations in the Antarctic and their membership of the EPB. Following an arrangement with the United Kingdom in 1995, Ukraine has taken over the jurisdiction of Faraday, the British Antarctic Survey's oldest operational station in Antarctica, and renamed it Vernadsky. Situated on Galindes Island on the Antarctic Peninsula, Vernadsky has continued the climate record started by the British in 1947.

With its summer station, St Kliment Ohridski, on Livingstone Island, the Bulgarian Antarctic Institute has also been carrying out a sustained programme of polar research for over twenty years, gathering and interpreting meteorological, geological and biological data in the South Shetlands.

Small is beautiful

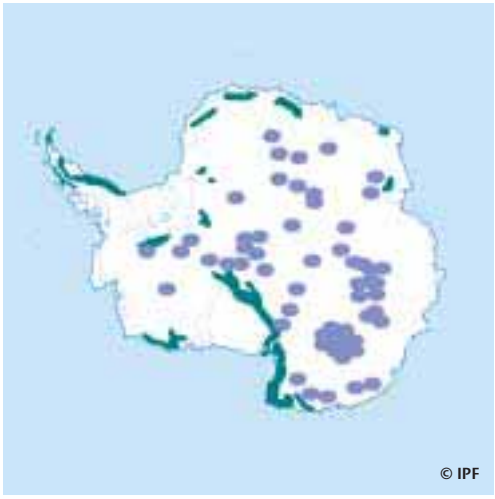
Whether large or small, the polar programmes of new Member States display both the vibrancy and dedication already demonstrated by polar research across the European Union. They also bring to light the importance of smaller polar programmes in acquiring, interpreting and publishing data from parts of the polar regions that might otherwise be overlooked – thus providing scientists across the globe with a much broader picture of the Arctic and Antarctic environments. ■

To find out more:
COMNAP: www.comnap.aq
FARO: www.faro-arctic.org/

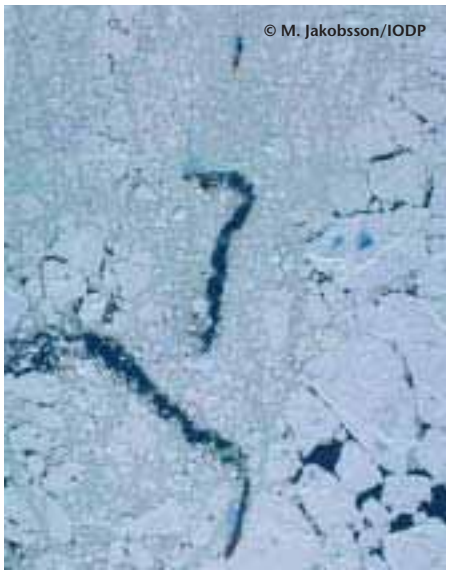
Ukraine's Vernadsky station, formerly the British station Faraday, is continuing an Antarctic climate record begun in 1947.

European nations *at the forefront of* international collaboration

With the growth of scientific networks and the considerable benefits reaped from past International Polar Years, contemporary polar research represents a vast collaborative effort with the shared goal of better understanding the dynamics of the polar regions and the role which they play in the Earth System as a whole.



At least 145 lakes have been discovered lying beneath the Antarctic ice sheet.



As part of the Arctic Coring Expedition Russia's Sovetskiy Soyuz breaks large ice floes, Sweden's Oden crushes mid-sized ice floes and Norway's Vidar Viking holds station over the drill site.

In this context, European nations have not only been amongst the most active members of coordinating organisations such as the Scientific Committee for Antarctic Research (SCAR) and the International Arctic Science Committee (IASC), but have also been avid supporters and initiators of international polar research initiatives across all fields, whether individually or through the European Polar Board (EPB).

Europe and the International Polar Year

European national polar programmes and pan-European organisations such as the EPB have been at the forefront of the 2007-08 International Polar Year (IPY), in its development, through membership, and in submitting research proposals. Europe's involvement continues to be strong. For example, the IPY's International Programme Office (IPO) is housed at the British Antarctic Survey (BAS) headquarters in Cambridge, and the Director of the BAS, Professor Chris Rapley, plus several leading European scientists, are members of the joint IPY ICSU-WMO[1] committee.

To find out more:

IPY: www.ipy.org
EPB: www.esf.org/epb
SCAR: www.scar.org
IASC: www.iasc.no
ACIA: www.acia.uaf.edu/
IPICS: nicl-smo.unh.edu/IPICS/IPICS.html
AICI: http://www.igac.noaa.gov/AICI.php

Increasing US cooperation

Recent years have also seen the European Polar Board forging a close liaison with the United States National Science Foundation Office of Polar Programs (NSF/OPP) in an effort to instigate joint initiatives and encourage close dialogue between the directors of polar agencies in Europe and the US.

Participating in a new research plan in the Antarctic

Through their full membership of SCAR, 13 European nations are actively involved in its new, recently approved science plan, entitled: 'Antarctic Science Changes Direction'. According to Colin Summerhayes, SCAR's Executive Director, this plan aims to refocus member nations' work on a few select themes that will be relevant for the next decade or more.

Three of these themes, Antarctica and the Global Climate System (AGCS), Antarctic Climate Evolution (ACE), and Evolution and Biodiversity in the Antarctic (EBA), relate directly to climate change, whilst ICESTAR relates to the interactions of the solar wind with the Earth's outer atmosphere, and Subglacial Antarctic Lake Environments (SALE) relates to the 145 or so lakes buried deep beneath the Antarctic ice sheet.

Involvement in Arctic projects

With a couple of exceptions, those European countries that are full members of SCAR are also members of IASC and have been involved in a whole series of IASC projects ranging from the study of Arctic coastal dynamics to nutrition and health among northern indigenous peoples. Many have also contributed to the far-reaching and alarming Arctic Climate Impact Assessment (ACIA) report presented by Robert Corell, Chair of the ACIA, to the US Senate Committee on Commerce, Science and Transportation in November 2004.

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More international projects...

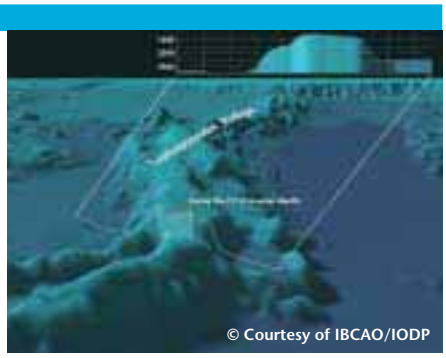
Other international polar research projects in which European nations are involved include:

- The International Partnership in Ice Coring Science (IPICS) which is endorsing a programme of coring coastal sites around both Greenland and Antarctica to complement the information being gathered from continental ice caps by projects such as EPICA.
- The European Partnership in Ice Coring Science (EPICS) which will enable enhanced structuring, coordination and strategic issues between ministries and funding agencies in ice coring at the European level, thus connecting with IPICS activities.
- The Arctic Coring Expedition (ACEX). See article below.
- The Aurora Borealis Arctic research icebreaker, providing a platform for deep drilling and investigations of climate change of the most inaccessible parts of the planet.
- Histories from the North – environments, movements and narratives (BOREAS). See article on the Social Sciences on p. 22.
- Southern Ocean – Climate Interactions, Resources and Carbon Links within the Earth System (SO-CIRCLE). An EPB-sponsored initiative which aims to address climate variability, biogeochemical cycling and ecosystem dynamics in the Southern Ocean.
- Air-Ice Chemical Interactions (AICI) documenting the full range of processes that arise at the air-ice interface, and how they depend on environmental conditions. ■

[1] International Council for Science – World Meteorological Organization

ACEX: The Arctic coring expedition

In August 2004, an international group of scientists retrieved a 370-metre core from the seafloor beneath the Arctic ocean, providing them with 55 million years of Arctic climate data.



The ACEX coring site on the Lomonosov Ridge crest, at 1124 metres down, is an optimum drilling site as erosion has exposed very old sediments.

Funded by 16 European countries and supported by the European Union (through a ERA-NET), the United States and Japan, the international Integrated Ocean Drilling Program (IODP) instigated the 9.5 million Arctic Coring Expedition (ACEX) with the aim of better understanding both the climate history of the Arctic region and the role which the Arctic has played and continues to play in the Earth's ongoing climatic variations.

Located 1 200 metres below the surface and roughly 230 kilometres from the North Pole along the deep Lomonosov Ridge, the Arctic's first scientific borehole was cored by a fleet of three powerful icebreakers: the Norwegian *Vidar Viking* for drilling, the Swedish *Oden* and the Russian *Sovetskyi Soyuz* for protecting the coring platform from the harsh Arctic environment and drifting sea ice. The Lomonosov Ridge was selected as the best possible drilling site due to its eroded aspect and the absence of more recent, less interesting sediment deposit such as would be found on oceanic valley floors.

Sediment samples from beneath the Arctic seabed reveal 55 million years of climate history, including evidence of massive fluctuations in water temperature and general Arctic environmental conditions.

According to the expedition's co-chief investigator, Jan Backman of the University of Stockholm, initial analysis of the microfossils found in the core show evidence of massive fluctuations in the water temperature and general environmental conditions of the Arctic over the past 55 million years. Indeed, the Lomonosov core is the first to show evidence of ice-free, subtropical, shallow seas with water temperatures of 20˚C compared to today's average temperatures of –1.5˚C. Such a truly massive cooling of the Arctic Ocean, which is thought to be responsible for the mass extinction of sea-bottom-living organisms, suggests that worldwide environmental conditions are much more variable than previously anticipated. ■

Polar research outside Europe

Even more so than within Europe, polar research outside of the European context can be characterised by the great range in size of the different polar programmes, as well as by the large diversity of science that is conducted through these programmes. Indeed, a rapid glance through the various North American, Asian, Australasian and African polar programmes reveals a veritable kaleidoscope of where and how research is carried out on the world stage.

The Chinese Great Wall station in the South Shetland Islands can accommodate up to 15 during winter.

The Chilean Frei Base and its air strip on King George Island, Antarctica, sits cheek-by-jowl with Russia's Bellingshausen.

North America

By far the largest polar research programme in the world, the United States National Science Foundation Office of Polar Programs (NSF-OPP), maintains three research stations in the Antarctic: McMurdo in the Ross Sea region, Amundsen-Scott South Pole station, and Palmer station on the Antarctic Peninsula. The NSF-OPP also leases and operates a fleet of two state-of-the-art research vessels, two logistical icebreakers, and a task force of helicopters, Hercules and Twin Otter aircraft for all types of Arctic and Antarctic logistical support.

With an annual budget of 300 million dollars for Antarctic research and 62 million dollars for Arctic research, the NSF-OPP takes over 800 scientists and their support teams to the polar regions every year, facilitating science projects in everything from the demography of penguins, to sub-particles and astrophysics.

Although much smaller in scale and mostly focused on the Arctic, Canada's polar research programme is divided between several organisations: the Aurora Research Institute conducts research and promotes technological development in the western Canadian Arctic and northern Yukon; the Canadian Polar Commission serves as the national advisory body on Antarctic matters; and the Polar Continental Shelf Project provides Arctic logistical support to scientific groups from more than 40 Canadian and international scientific organisations every year.

South America

Because of the distance that separates them from the Arctic, South American polar research programmes tend to be almost entirely focused on Antarctica. With over twenty bases between them, Chile and Argentina's logistical infrastructure is amongst the most prominent on the entire continent. Ranging from small summer huts to year-round bases with resident families, schools and chapels, these stations facilitate oceanographic, biological, glaciological, meteorological and geological research whilst also enabling these two, often rival, nations to maintain a strategic territorial presence on the continent.

Much smaller in scale, but nevertheless conducting an important programme of Earth and atmospheric sciences, the Brazilian polar research programme maintains an all-year research station, Ferraz, situated on King George Island, at the most accessible northern end of the Antarctic Peninsula, not far from the Uruguayan station, Artigas, and the Peruvian summer station, Machu Picchu.

Asia

With China, Japan, and Korea operating research stations both in the Antarctic and at Ny-Alesund on the islands of Svalbard in the Arctic, Asian nations are among the most active in international polar research.

Indeed, whilst China is in the process of rebuilding its two Antarctic stations – Zongshan station in Eastern Antarctica, and Great Wall station on King George Island, close to Korea's King Sejong station – Japan's National Institute of Polar Research (NIPR) spends over 39 million dollars annually supporting a network of stations that includes Dome Fuji – one of only a handful of research facilities on the Antarctic Plateau.

Much smaller in scale, India's National Centre for Antarctic and Ocean Research (NCAOR) operates a single Antarctic station,

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Maitri, from where it conducts an inter-disciplinary programme of research into subjects ranging from meteorology to human physiology, geology and biology.


© J. Davis/AAD

Australia's Mawson station can meet more than half its energy needs through wind turbines.

Australasia

With their close proximity to Antarctica, Australia and New Zealand focus almost all of their polar research efforts on the southern polar regions. Serving as gateways from which many other national polar programmes operate their logistical operations to the Antarctic, Australia and New Zealand are also very pro-active in their own right and play a significant role in pure research, whether through national or international projects. With its station, Scott Base, only a few miles from the US McMurdo station, Antarctic New Zealand (ANZ) enjoys a particularly close relationship with the NSF-OPP with which it shares logistics and has, among other things, collaborated on the highly successful ANDRILL deep-sea drilling project in the neighbouring McMurdo sound. Although more isolated geographically, the three Australian stations (Casey, Davis and Mawson) are used by the Australian Antarctic Division to support a whole range of research, with a strong emphasis on climate, marine and environmental issues.

Africa

As another southern hemisphere nation and the only African country with a polar research programme, South Africa also concentrates almost entirely on Antarctica and is involved in a number of important international Antarctic projects such as the Southern Hemisphere Auroral Radar Experiment (SHARE). What is more, its South African National Antarctic Programme (SANAP) operates one summer and one all-year station in Queen Maud Land, as well as two stations on the Marion and Gough sub-Antarctic islands, facilitating research in the physical, oceanographic, earth and biological sciences. ■

To find out more:
COMNAP: www.comnap.aq
FARO: www.faro-arctic.org/

SCAR and IASC: getting nations together

The Scientific Committee for Antarctic Research (SCAR) and the International Arctic Science Committee (IASC) operate as separate but parallel organisations working under or in association with the International Council for Science (ICSU) to facilitate international polar research initiatives across all disciplines. Both have the most active European polar research nations as full members.

SCAR

First established in 1957 as the then ICSU Special Committee on Antarctic Research in charge of coordinating the work of twelve nations involved in the International Geophysical Year of 1957-8, SCAR remains the only international, non-governmental organisation that can draw on the experience and expertise of scientists from all nations and across all disciplines to initiate and co-ordinate scientific research in Antarctica. In this capacity, SCAR is also an obvious source of advice on a wide range of scientific questions relating to Antarctica, and has provided such advice to the Antarctic Treaty System for the past 30 years.

The SCAR international scientific community meets every two years at the SCAR Delegates Meeting (most recently held in October 2004 at the Alfred Wegener Institute (AWI) in Bremerhaven, Germany) and the SCAR Secretariat is housed at the Scott Polar Research Institute (SPRI) in Cambridge.

IASC

First established in 1990, the IASC, like the SCAR, is a non-governmental organisation whose aim is to encourage and facilitate cooperation in all aspects of Arctic research, in all countries engaged in Arctic research and in all areas of the Arctic region.

The 18 IASC member organisations are national science organisations covering all fields of Arctic research and the IASC acts as a consultative and testing forum for research proposals, especially encouraging those with a circum-Arctic or cooperative reach. According to Dr. Professor Patrick J. Webber, IASC President , the next high priority is to establish an international science programme planned and recommended by the IASC.

To find out more:
SCAR – www.scar.org
IASC – www.iasc.no

With a secretariat in Oslo, Norway, the IASC science community meets annually at the IASC council meeting, the last of which was held in Reykjavik, Iceland, on 22 April 2004.

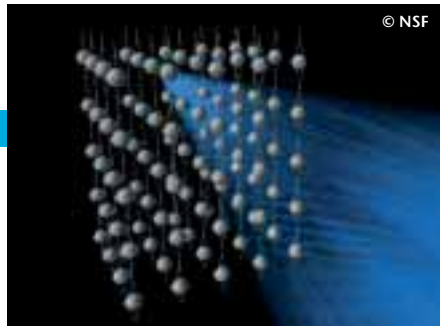
When polar science goes beyond the poles...

Aside from pure information, such as the insight into the evolution of climate change provided to us by ice cores, polar research often also produces direct and sometimes unexpected applications for humans. These applications touch on everything from space and material sciences, to medicine and cold enzymes. See below for a quick – and non exhaustive! – tour.

- NASA is using Lake Vostok (see p. 10), buried under four kilometres of Antarctic ice, as a testing ground for developing a 'cryobot/hydrobot' tandem vehicle able to penetrate the liquid realm hidden under the thick icy crust of Europa, one of Jupiter's satellites.
- The ESA has been supporting Frenchman Gilles Elkaim in his 12,000 km solo Arctic trek to benefit from his experience of isolation for future manned missions to Mars.
- Stuart Egginton, from the University of Birmingham's Medical School, studies the physiology of Antarctic cod to better understand the problems faced by the human heart when confronted with hypothermia.
- Cécile Thouzeau from the French Centre National de la Recherche Scientifique investigates the bactericides produced in King penguins' stomachs for biomedical applications, including long-term food storage.
- The European funded BIOTECH 2 programme is devoted to studying cold enzymes found in Antarctic bacteria and used extensively by industry in applications as diverse as preparing food, formulating detergents and detecting pollutants using biosensors.
- Christian Hamm from the Alfred Wegener Institute finds inspiration in polar plankton bioceramic shell geometry to improve the performance of stable lightweight constructions.

IceCube: *Antarctica's* crystal ball

Buried deep within the East Antarctic ice sheet at the South Pole, a giant high-energy neutrino observatory due for completion in 2009 could provide scientists, including from Europe, with an unprecedented window to the Universe, as well as a means to answer some of the most fundamental questions of astrophysics and cosmology.



Artist's rendering of a Cerenkov blue light cone in the IceCube telescope. The optical sensor array allows IceCube to detect and reconstruct a muon's path, and hence the path of the original neutrino.

Instigated by the University of Wisconsin in Madison, and financed to the tune of 295 million dollars by the US National Science Foundation (NSF) in association with several European universities in Sweden, Belgium, Germany, the UK and the Netherlands, IceCube is by far the single most ambitious and expensive research project currently taking place in Antarctica.

Neutrinos

Neutrinos are extremely small, virtually massless subatomic particles born of nuclear reactions. Whilst the Sun and other nearby phenomena produce low-energy neutrinos, high-energy neutrinos originate from such distant and supremely violent cosmic events as black holes, supernovas and the Big Bang.

Once born from such cosmic events, neutrinos travel at the speed of light and do not stop. Because they have virtually no mass, they only very rarely interact with other particles, allowing them to move in a straight line to the edge of the Universe, passing straight through stars, planets, vast magnetic fields and entire galaxies as if they did not exist. Trillions of neutrinos reach the Earth every nanosecond and, for astrophysicists, every one of these tiny particles is a potential messenger carrying information from its source of origin.

The problem for scientists, however, is that the very properties that allow neutrinos to carry this information also make them notoriously difficult to detect. Fortunately, on rare occasions, a high energy neutrino does collide with a molecule. The collision breaks the nucleus apart and the neutrino converts into another particle called a muon. Once created, a muon continues along the same path as the neutrino and can be recognised from the cone of blue light that follows it. Known as Cerenkov radiation, the cone is similar to the air waves behind a bullet as it travels.

IceCube

However, in order to be able to detect such a collision by seeing the Cerenkov radiation behind the traveling muon scientists must be able to monitor a huge volume of a substance that is both perfectly transparent and plunged into darkness. The creation of such a detector was first attempted in the early 1980s off the coast of Hawaii by lowering detectors

into the deep ocean. Unfortunately, however, the experiment was plagued by the unpredictability of the weather and the instability of the sea.

It was not until a few years later that ice was thought of as the ideal solution. An expansion of the first-generation Antarctic Muon and Neutrino Detector (AMANDA), when completed IceCube will consist of 5 000 photomultiplier detectors buried across 1 km^3 of the Antarctic ice sheet, at a depth of 1 400 to 2 400 meters beneath the South Pole: an environment which is not only plunged in darkness, but where the pressure is so great that all air bubbles and other disruptive elements have been squeezed out of the ice, giving it the clarity of crystal.

Once in place, the photomultiplier detectors act as powerful sensors which capture the streaks produced by a muon's Cerenkov radiation, then amplify the faint signal by over a hundred million times and send it up to the surface where it gets picked up by computers. From this information, the scientists calculate which direction the initial neutrino came from and where in the sky they can find the cosmic event that created it. Once they have pinpointed the event, they can study it directly.

Window to the Universe

According to Francis Halzen, Professor at the University of Wisconsin and Chief Investigator on both the AMANDA and IceCube projects, the extraordinary thing about IceCube, however, is not so much the answers that it might provide to our existing questions about black holes, supernovas, the Big Bang, dark matter and the future of the Universe, but that in the past, every time astronomers have opened a new window to the cosmos, they have discovered things that they were not even looking for. ■

To find out more:
icecube.wisc.edu/

The human dimension: coming out of the shadows

Although Arctic social science research has flourished for many decades, it has also often struggled to make its voice heard in the wider, natural science-inclined, polar research community. However, with the advent of the 2007-2008 International Polar Year (IPY) and the dramatic effect which global climate change is starting to have on the Arctic and its people, this field of research is coming out of the shadows with important contributions to our understanding of the far north and its rapidly changing face.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Fishing, the main food source for the Inuit, is being affected by climate change with species observed that have not previously been seen at high latitudes.

Spearheaded by the International Arctic Social Sciences Association (IASSA) and supported by a host of European organisations such as the Scott Polar Research Institute (SPRI) in Cambridge and the University of Tromsø in Norway, the Arctic social sciences encompass disciplines ranging from psychology to anthropology, archaeology, linguistics, history, health and education.

Early Warning System

Through this panoply of interconnected subjects, the Arctic social sciences have much to tell us about a region which encompasses a large proportion of Europe, Asia and North America and which contains many indigenous peoples such as the Saami and the Inuit, as well as settlers of European origin. According to Piers Vitebsky, Head of Anthropology and Russian Northern Studies at the SPRI, the Arctic is indeed a region "in which some widespread phenomena and universal challenges can be studied more clearly than anywhere else; a social, cultural and environmental early warning system for changing relations between society and the environment on a global scale".

International Polar Year

As a strong indicator of the rising profile of Arctic social sciences, the 2007-2008 International Polar Year Planning Group recently endorsed 'The Human Dimension' as one of six themes to be prioritised as part of the IPY, with the specific aim to "investigate the cultural, historical and social processes that shape the sustainability of circumpolar human societies, and to identify their unique contributions to global cultural diversity and citizenship". As well as introducing a new dimension to the IPY, the incorporation of this sixth theme is intended to encourage a greater level of cooperation between social and natural scientists.

BOREAS

Another initiative currently being launched, this time by the European Science Foundation EUROCORES programme for international collaborative research, is entitled 'Histories from the North – environments, movements and narratives', or BOREAS for short. Spearheaded by Piers Vitebsky and supported by 170 scholars and institutions, this initiative is intended to coincide with the 2007-2008 IPY and to be both complementary and distinct from the natural sciences. Led by anthropology, it aims to promote the value of indigenous knowledge in the context of environmental change, to explore the philosophical and spiritual foundations of this knowledge, and to study the mechanics of ecological adaptation to a changing climate as already initiated by the ACIA (Arctic Climate Impact Assessment) group. ■

To find out more:
IASSA: www.uaf.edu/anthro/iassa/
SPRI: www.spri.cam.ac.uk

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Alain Hubert, Belgian polar explorer and Head of the International Polar Foundation.

"Communication is an investment"

Alain Hubert is a civil engineer and polar explorer. A ceaseless wanderer in the snow-covered regions of the world, and co-founder of the International Polar Foundation (IPF), he is an excellent communicator. His principle aim is to increase awareness of polar research. An interview.

Why is there a need to communicate to a wide audience about research in polar regions?

Because the challenges of polar research are crucial to the future of humanity. The polar regions are the only ones in the world which can provide an accurate picture of the climatic history of our planet. No ancestors have left us sealed bottles containing historic samples of the atmosphere, but polar ice contains tiny air bubbles which can tell us when, how and why the Earth's environment has fluctuated over the centuries and millennia. We thus have access to an exceptional scientific heritage which we need to study and also to explain.

What are the highlights of communicating about research in a polar environment?

They are many. It is certainly the ideal subject, combining dreams, adventure, beauty and polar animals: everything about that world is fascinating, so people are immediately interested.

It is also a very topical subject: climate change is increasingly being mentioned by the media and the latest findings are somewhat alarming.

The impressive research results obtained so far, such as being able to go back nearly 850,000 years thanks to the information sealed in ice cores, or even more than 55 million years in sediments, are quite extraordinary!

Above all, it is a subject which affects us all. A clearer understanding of these phenomena and their causes may enable true awareness of the importance of research and, above all, the changes we need to make to our behaviour in order to take up the challenge we face today with respect to climate change.

Science is not always easy to explain clearly...

It is true that the subjects are sometimes complex and difficult to explain. But they are usually fascinating, so that the potential for communication is considerable. And if scientists are not always inclined to communicate their findings it is mainly because they are concentrating on their research.

Communication is another job altogether, even though some scientists have an excellent gift for it. A few of the major research institutes have understood this, but they remain the exception.

Who are the most important targets when it comes to communicating about polar research?

I see three: young people, decision-makers and the general public.

Young people, because they are aware of the threats to our planet, and polar research has a special role to play in this respect. And it is they who must be encouraged to become involved in scientific research. In that respect, polar research is an excellent catalyst because of its magical, extreme and adventurous aspects.

Political decision-makers, because it is they who must today make the environmental, and particularly climate change, pledges which are now necessary, as polar research results have made clear. More prosaically, it is also they who provide the largest share of funding for this research, a point we must not forget.

And finally, the general public, as people can put pressure on political decision-markers and also act directly by changing their own behaviour. They therefore need to be sufficiently well-informed to understand the challenges we face and to take a stand. For example, is it widely known that there is now a general consensus on the link between global warming and human activities? Is it known that current levels of CO_2 are the highest they have been for at least 850,000 years? Here again, polar research can deliver its message and encourage citizens to take action.

Is it really possible to reach such a broad target group?

Although it is quite easy to imagine raising awareness amongst a few thousand political decision-makers, the problem is quite different when it comes to reaching hundreds of millions of people throughout the world, with their different languages and cultures.

We therefore require relay points, the most classic being the media: press, television, Internet, etc. But to work with them, we need a

➔

degree of know-how, to be able to showcase interesting examples and put forward attractive approaches. Journalists do not always have the time for in-depth coverage, so they look for stories to tell, people to meet or sites to visit. In my opinion, one of the keys to success is direct contact. The EU Research Directorate has recently taken several initiatives in this respect that have brought scientists and journalists together. In 2004, a symposium enabled them to meet and exchange their different views. The meeting was a great success and will be repeated in November 2005. And inviting the press to visit the Polarstern research ship was an initiative which was both original and very useful.

And beyond the media?

I see two other channels of communication we must target: teachers, because they have a crucial role to play as an interface with young people, and the NGOs – international, national and also local – because they are in direct contact with citizens and are thus able to carry out essential local work.

These organisations set up awareness programmes, create teaching tools, open museums and exhibitions and set up internet sites, etc., which aim to reach people in their homes and everyday lives, in their villages or local areas.

Representatives from innumerable small, local associations throughout Europe visit schools to talk about subjects such as energy problems, climate change and sustainable development. This type of initiative must be encouraged and increased. And research in polar regions offers a broad range of topics which can be fully integrated in these efforts.

Reference is often made to information technologies as the best means of making contact with young people. What is your opinion?

Web animations are amongst the main ICT (information and communication technologies) tools for getting the message across to the young – tomorrow's decision-makers. See www.educapoles.org.

The principal advantage of information technologies is their access on-line. Being able to collaborate with other pupils or students, ask questions of specialists, consult scientific opinions, interact with teachers and compare working hypotheses are essential tools when it comes to learning in our modern society.

The broad range of media available is another advantage of information technology. Not only texts and images, but also interactive programmes to supplement a film or radio report, simulation tools which can, for example, explain the principles of modelling, or interactive questionnaires – there are endless opportunities.

But communicating is an expensive activity

It is for this reason – and increasingly – that a specific budget must be allocated as soon as a project is proposed. Communication must form an integral part of the project and not be considered a luxury or a waste of time and money to the detriment of research work. On the contrary, communication is now key in ensuring and increasing the funding of research. Science is a passion for those involved, but we also need to make this known and demonstrate the relevance of our research efforts, which are too often considered as being of little practical use to solving society's problems. If research is to attract more money, we need to talk about it, explain our results, demonstrate its usefulness, render it more appealing and interesting, and make sure that everyone wants to find out more. Spending funds on communication is not a waste: it is an investment for the future. ■

In terms of communication, the polar world can count on some fantastic allies. Polar bears in the Arctic and Emperor penguins in the Antarctic fascinate young people and children.

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An Internet journey through polar science

The websites listed hereunder have been chosen because they constitute good entry points and can quickly help you build a wide array of web resources covering whatever portion of the polar sciences you are interested in.

Begin your journey

Polar pointers
http://polarmet.mps.ohio-state.edu/cgi-bin/genpp.cgi
As the name suggests, this website is an enormous list of polar pointers sorted by topic or country. This is indeed a handy start page for your Internet journey to the polar regions!

Antarctic websites

Australian Antarctic Division
http://www.aad.gov.au/
Nicely designed, well organised and chock full with high-quality content, this website will give you a good insight into the Australian presence in the Antarctic. General information, news and resources are also available. The 'cool science' section is particularly interesting for its cutting-edge scientific articles.

Alfred Wegener Institute for Polar and Marine Research (AWI)
http://www.awi-bremerhaven.de/index-e.html
Although this website is a bit hard to use due to a complex content architecture and navigation structures, it is certainly worth exploring. This is a website by scientists for scientists, giving detailed information regarding research programmes and their results. The 'click and learn' section is dedicated to the non-scientific visitor.

Scientific Committee on Antarctic Research (SCAR)
http://www.scar.org/
The SCAR is the only international, interdisciplinary, non-governmental organisation co-ordinating scientific research in the Antarctic and acting as a consultancy body for the Antarctic Treaty system. Dependent on the International Council for Sciences, this website is a must-see for everyone interested in scientific research regarding the Antarctic. Information papers and reports are made available to the public.

British Antarctic Survey (BAS)
http://www.antarctica.ac.uk/index.php
A pleasing design and well-organised navigation make this website very usable. Good information available in a wide variety of topics. All articles available on-line are quite short which can disappoint some visitors looking for in-depth information.

Antarctic and Southern Ocean Coalition (ASOC)
http://www.asoc.org/index.htm
The ASOC is a coalition of environmental NGOs working together to preserve the Antarctic continent. The information section features papers, articles, resources and regularly updated news.

Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)
http://www.ccamlr.org/default.htm
As the name suggests, this website is dedicated to marine life in the Antarctic. A good part of the website deals with the Commission itself, how it works, who participates, etc. Apart from that, publications and scientific articles are available for the public (largely through PDF documents).

Council of Managers of National Antarctic Programmes (COMNAP)
http://www.comnap.aq/comnap/comnap.nsf
The mission of this international body is to deal with the logistical side of Antarctic science in the framework of the Antarctic Treaty. If you are looking for centralised information regarding scientific infrastructures in the Antarctic (bases, ships, weather stations,etc.) , this is where to look.

Arctic websites

National Oceanic and Atmospheric Administration (NOAA) – Arctic theme page
http://www.arctic.noaa.gov/
Very interesting website on the Arctic regions featuring papers, articles and essays aimed at scientists and at the general public. Every one of them features links to resources concerning the topic they focus on, enabling visitors to broaden their knowledge.

Arctic research consortium
http://www.arctic.at/castaway/
This website features a huge collection of links and resources concerning the Arctic and Antarctic (bases, sites and live webcams, list of scientific research websites, explorers, tourism offices, books, etc.). It gives a very good overview of available on-line resources concerning the polar regions.

Arctic Monitoring and Assessment Programme (AMAP)
http://www.amap.no/
The role of the AMAP is to advise the governments of Arctic countries on threats to the Arctic region from pollution and associated issues. Reports aimed at the general public are available to download, as are scientific ones. Videos, maps and graphics are also made accessible.