# COMINO FOUNDATION

## Climate Change and the Polar Regions

Everyone is aware that the Earth has a North and South Pole and that these are located in the Arctic and Antarctic regions. But most people's knowledge about these parts of the planet is very limited.

One person who has extensive knowledge of both Polar Regions is Dr. John Dudeney OBE, who was formerly Deputy Director of the British Antarctic Survey (j.dudeney@btinternet.com). He has spent many years of his life involved in scientific research of these regions. Global warming is already having an impact on both the Arctic and the Antarctic and his experience, which underpins this article, provides an insight into how higher world temperatures, which will be evident for at least 500 years into the future, are related to the Polar Regions.

FIG 1: ARCTIC REGION

The boundary of the Arctic is somewhat ill-defined but is often taken to be the region northward of the northern most limit of where average summer temperatures above $10^0$C occur (see the red line on Figure 1) The region consists mostly an ocean covered in sea ice, roughly centred on the North Pole. This ocean is surrounded by a margin of (for the most part) frozen ground, which is treeless, in Russia, Alaska, Canada, Northern Europe and Greenland which is a large island covered by a thick icecap. It is a region of 24 hour summer days and 24 hour winter nights. The winter temperature can be $-20^0$C to $-40^0$C dependent on the proximity of the ocean. Unlike the Antarctic, which does not have an indigenous population and, as far as we know never has had, there are approximately 4 million people living in the Arctic region. 80% of these live in Greenland and Canada, 15% in Arctic Norway and 5% in Arctic Russia. Over the centuries they have learned how to survive in some of the harshest conditions on earth and their nomadic cultures remain vital and resilient.

The Arctic is particularly vulnerable to the effect of global warming with climate models predicting greater warming in the Arctic than the world average. This has already become evident through the summer shrinkage of the sea ice in recent years.

FIG 2: Arctic Ocean - Minimum Summer Sea Ice Boundary 2000 - 2007

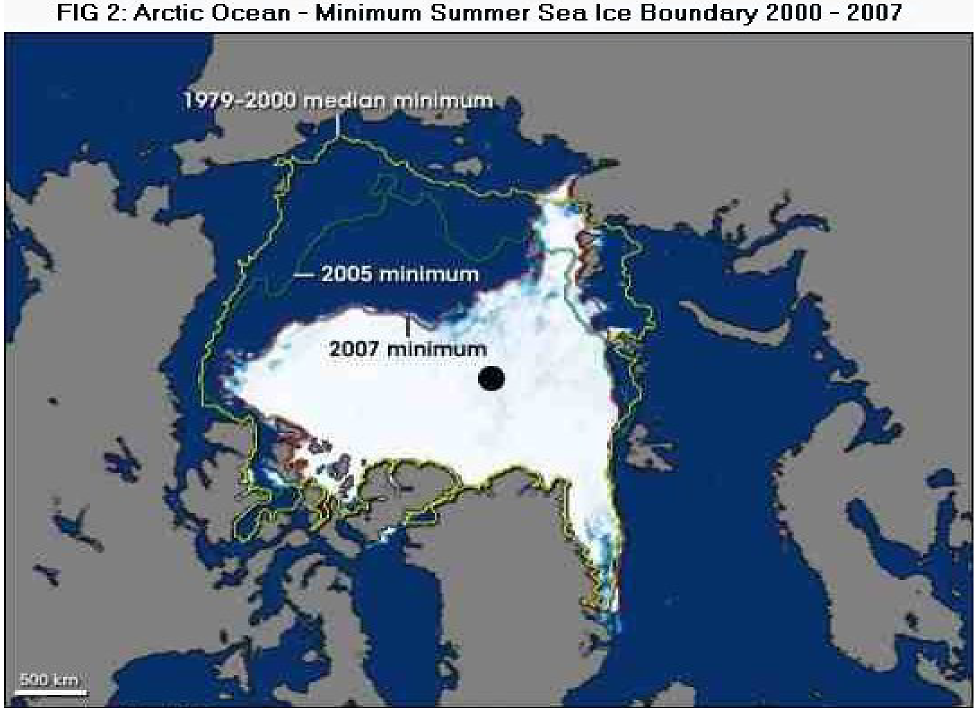



Figure 2 shows that the sea ice in the summer has shrunk by approximately 40% between 2000 and 2007. Scientists are predicting that the Arctic Ocean will be ice-free in the summer before 2015. It will, of course, continue to freeze over in winter.

This dramatic change in the Arctic sea ice behaviour is likely to render both the North West and North East passages ice free during the Northern summer, providing shipping lanes that will offer significant commercial transportation benefits for traffic between the US and Europe and the Far East. Indeed the Arctic region could become the prime shipping route. In addition the Arctic seabed probably contains substantial mineral resources, including oil and gas. This has led, recently to international debates on sovereignty/ ownership over Arctic waters particularly in the context of continental shelf delimitation under Article 74 of the United Nations Convention on the Law of the Sea.

On the other hand the loss of sea ice in the summer will mean that much of the natural habitat of Polar Bears will disappear with a serious danger to their long term survival. Whether effective alternative arrangements can be put in place to ensure their survival through the summer months is a moot point.

Greenland, which was given home rule by Denmark in 1978 and may achieve full independence in the near future, is the largest island in the world and is ¼ the size of Australia. Uniquely in the Arctic region it is dominated by an ice sheet which covers 81% of its land area. This ice sheet is 2400 kilometres in length, a maximum of 1,200 kilometres wide, 3,000m high at its peak and a thickness of up to 4 kilometres. This gives a total of 2.85million cubic kilometres of ice. The weight of this ice cap has depressed the central land area into the underlying magma to form a basin which lies 300m below sea level.

In line with the Arctic being very vulnerable to climate change scientists have observed that the part of the Greenland ice sheet that has surface melting in summer has increased by 16% in recent years. They have also have calculated that about 240 cubic kilometres of ice melted in 2006 and 592 cubic kilometres in 2007. At these rates it would take between 5 and 10 thousand years for the ice sheet to totally melt unless higher world temperatures increased the rate of melting.

The melting of floating ice has no impact on sea level, but the discharge of land ice through either the calving of glaciers depositing ice directly into the sea or through discharge of melt water can have very significant impacts on sea level. If the entire Greenland ice cap melted it would raise world sea levels by about 7 metres. Whilst there is likely to be continual melting of the Greenland ice cap for the next millennium, the impact on sea levels over the next 100 years is likely to be in the region of 10s of centimetres.

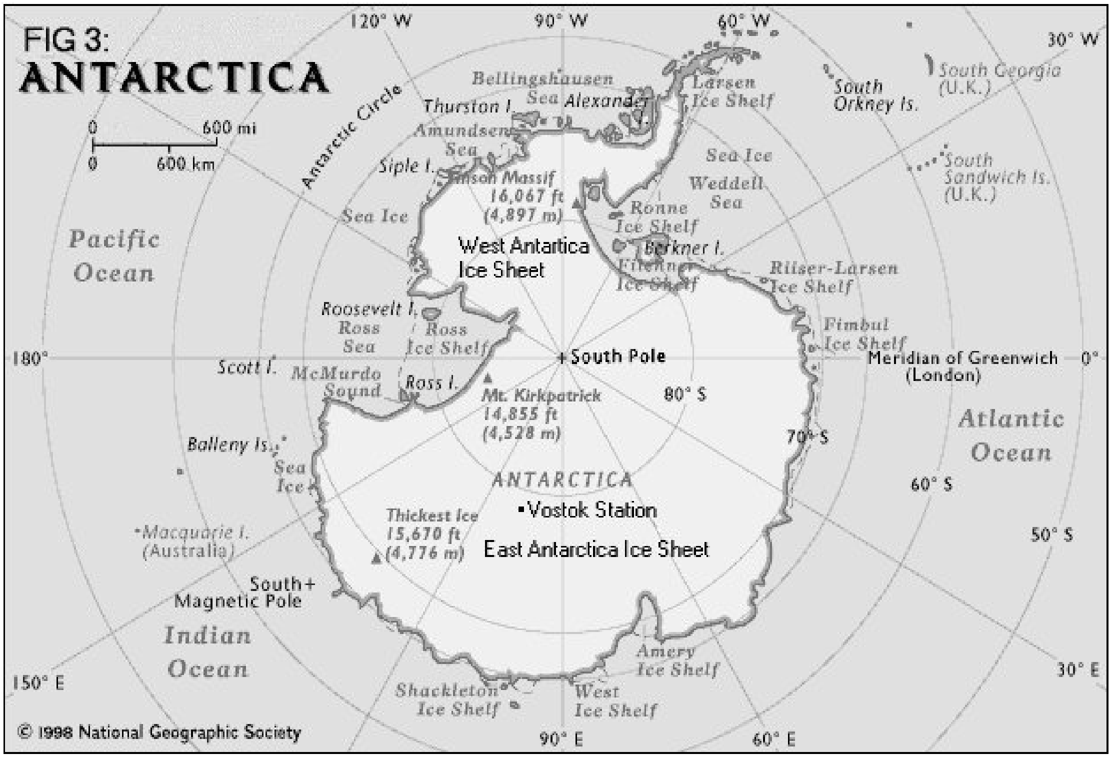
The Antarctic region is entirely different. Antarctica is a pole centred continent surrounded by the Southern Ocean and is the fifth largest continent in the world. It is larger than Europe, double the size of Australia and seven times the size of Greenland. Antarctica has no soverign government and belongs to no country. Seven countries made formal territorial claims to areas of it during the first half of the last century, but since the signing of the Antarctic Treaty1959, these claims have been frozen and signatories to the Treaty have agreed that no new claims will be made whilst the treaty is in force. The continent is therefore politically neutral and is regulated through the treaty and other related agreements, collectively called the Antartic Treaty System, by the countries that are parties to the treaty.

For the purposes of the Treaty System, Antarctica is defined as all the land and ice shelves south of 60° S. The treaty was originally signed by twelve countries including the seven claimant states ( UK, France, New Zealand, Australia, Norway, Chile and Argentina) together with South Africa, the Soviet Union ( now Russia), Japan, Belgium and the United States. It set aside Antarctica as a scientific preserve, established freedom of scientific investigation, and banned military activity on that continent, the dumping of nuclear waste, and established a rigourous inspection regime. Subsequent subordinate conventions have provided a comprehensive international framework of environmental protection, culminating in the Protocol for Environmental Protection (also known as the Madrid Protocol) agreed in 1991 and ratified by 1998. There are now 28 full (or consultative) signatories to the Antarctic Treaty and a further 17 “contracting” countries where the latter are entitled to attend meetings but do not have decision making rights.

Whilst Antarctica has no indigenous population due to its geographical isolation from other continental landmasses throughout the evolution of humanity and the harsh climate conditions the 28 countries that have an interest in Antarctica maintain about 45 permanent research stations and 15 summer only stations. The population undertaking and supporting scientific research on the continent and its nearby islands varies from approximately 4,000 persons during the summer season to a total of 1,000 persons during winter. There are, however, about 400,000 Emperor Penguins who populate 80 breeding colonies on floating fast-ice up to 140 kilometres from the sea-ice edge in the antarctic winter. Over millions of years they have developed a physique that allows them to be the only natural living creatures in this harsh environment in winter.

The continent is divided in two by a vast mountain chain - the Trans-Antarctic Mountains - with the highest mountains approaching 5,000 metres (higher than the Matterhorn in the Alps). To the West of the mountain range is the West Antarctic Ice Sheet, to the East is the East Antarctic Ice Sheet and Plateau. This plateau which includes the South

Pole and the Vostok Station has an average altitude of 3,000 metres but rises in places to over 4000 m.




It is the coldest, driest and windiest of the seven continents and has the highest average elevation of all continents. About 98% of Antarctica is covered in ice which is, on average, 2 kilometres thick but at its thickest is 4.7 kilometres. The continent has about 90% of the world's ice and 70% of its fresh water. Antarctica is the coldest place on earth and scientists have recorded $-89^0$C at the Vostok Station which is the coldest temperature ever recorded. Temperatures reach a minimum of $-80^0$C to $-90^0$C in the interior in the winter and a maximum of $5^0$C to $15^0$C at the coast in summer. Snowfall in the very dry air at the interior is less than 4in a year, making most of inland Antarctica into an ice desert, but there can be snowfalls of several feet at the coast. Most of the ice mass is in the East Antarctic Ice-sheet with less than 10% being located in the West Antarctic Ice-sheet.

The East Antarctic Ice-sheet has been largely untouched by climate change, so far, it may even be acting as a slight brake on global sea level rise through somewhat inceased snowfall. However, the Antarctic Peninsula is one of three "hotspots" on the globe (the other two being in Alaska and Siberia) where warming is occuring faster than anywhere else. Here marginal iceshelves have been collapsing, with these collapses working steadily southward.

In 2003 the 3,250 square kilometre Larsen-B ice shelf collapsed owing to global warming. According to some observers, the most significant Antarctic melting in the past 30 years occurred in 2005, when a mass of ice comparable in size to California briefly melted and refroze; this may have resulted from temperatures rising to as high as 5 °C (41 °F). In February/ March 2008 about 570 square kilometres of ice from the Wilkins Ice Shelf in Western Antarctica suddenly collapsed, putting the remaining 15,000 square kilometres of the ice shelf at risk. This ice is only being held back by a "thread" of ice about 6 km wide.

Such collapses do not in themselves contribute to sea level rise as the ice was already floating, however the loss of the iceshelf allows the feeder glaciers to speed up and hence both discharge more ice into the sea and retreat. Almost all the glaciers on the Peninsula are now doing just this with a measurable impact on sea level.

These recent losses of ice from the Antarctic Peninsula illustrate that there is likely to be progressive further loss of ice from this vulnerable area of Antarctica due to global warming. The region which is of most concern is the West Antarctic Icesheet (WAIS). Unlike the East Antarctic Icesheet which sits on a continental land mass, the WAIS is pinned in place by an archipeligo of islands and is drained to the sea by several vast glaciers known as icestreams, the most notable being the Thwaites and Pine Island glaciers. Satellite altimetry has revealed that the ice basins which these glaciers drain has fallen in elevation by several metres in recent years indicating increased discharge into the ocean. The WIAS contains sufficient ice to raise sealevels by 7 metres if it were all to melt.

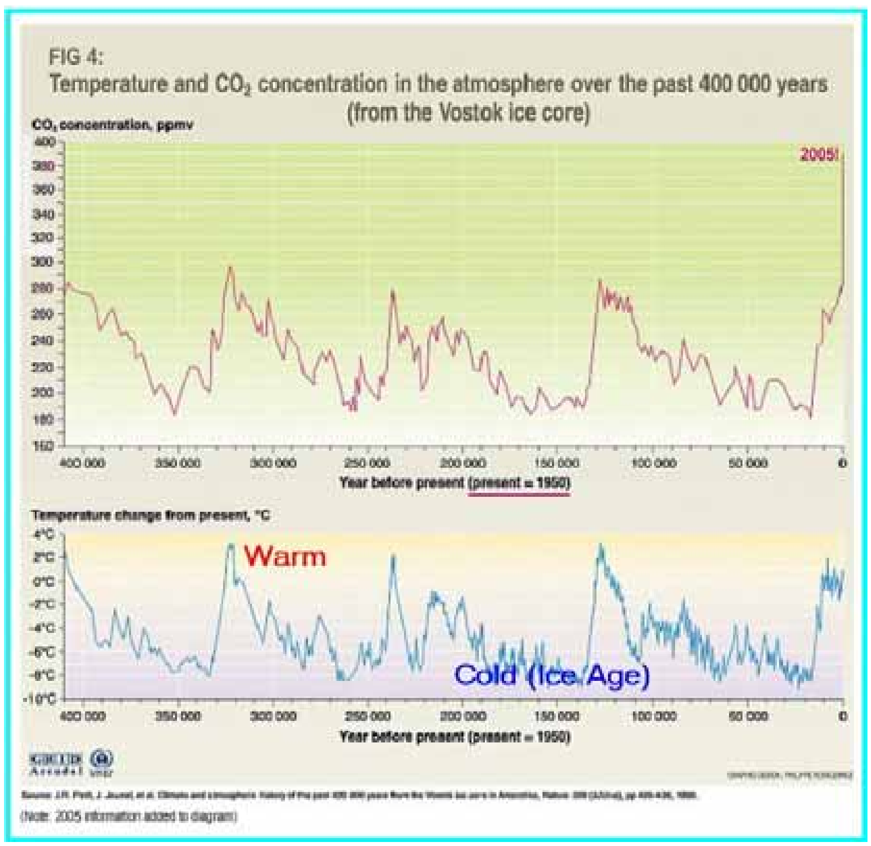
This loss of ice is causing world sea levels to rise several millimetres a year. Until recently, scientists believed that the combined impact of melting ice from both Polar regions would not be a significant contributor to increased sea levels up to the year 2100. However, recent evidence both from the increase of summer melting on the Greenland Icecap and the behaviour of the Antarctic Peninsula and WAIS is now raising the risk of contributions of up to a metre, but still with much uncertainty.

However, the minimum anticipated rise in global temperature due to very high levels of carbon dioxide in the atmosphere will remain for at least 500 years as this is the length of time that the increased level of carbon dioxide will remain in the atmosphere. This will cause further, progressive loss of ice from both Greenland and Antarctica. Sea levels could rise by 10 metres, or even more, throughout the current millenium, which equates to about 15% of the total ice in the world. 25% of the world's cities are located close to the sea and this rise in sea level will almost certainly make some cities uninhabitable as well as submerging a significant number of low lying islands that are currently inhabited.

The drilling of ice cores through the ice mass in Antarctica (most notably at Vostok Station on the East Antarctic Plateau) has made a crucial contribution to understanding the parameters that change the temperature of the earth on a timescale of 100's of thousands of years.

In the 1970s The Soviet Union drilled a set of cores 500–952 m deep. In the next couple of decades more holes were drilled until drilling was stopped at a depth of 3623 m when the drill began to pentrate re-frozen ice from  a sub-glacial lake known as Lake Vostok which is the size of Lake Ontario and is 4 kilometres below the central Antarctica ice sheet. These ice cores, drilled collaboratively with the French and the USA, produced a record of past environmental conditions stretching back 420,000 years and covered the most recent four glacial periods. This was the only core to cover several glacial cycles until a new core was recovered  by European scientists from Dome "C" in 2004 which covered over 800,000 years and confirmed the Vostok findings.

From the ice cores scientists were able to measure the temperature of the atmosphere and, from air bubbles in the ice, the concentration of carbon dioxide going back over 400,000 years. When these measurements are shown graphically they illustrate the temperature cycles that are caused by the eccentricity, axial tilt and precession of the earth's orbit. This has resulted in ice age cycles every 100,000 years over the last million years. These cycles, which have been now been researched in detail, are called the Milankovitch cycles after the Serbian civil engineer and mathematician who first introduced the concept.



In figure 4 the bottom graph shows the earth's average temperature variance over 400,000 years. It shows that the temperature has been at most $3^0$C warmer than current temperatures but up to $8^0$C colder. The cold periods correspond to past ice ages.

The top graph shows the concentration of carbon dioxide in the atmosphere in parts per million. These two graphs demonstrate that there is a very close relationship between the temperature of the earth and the concentration of carbon dioxide in the atmosphere.

The top graph shows that the concentration of carbon dioxide in the atmosphere has already reached 390 parts per million, a level which best estimates suggest will cause the temperature to rise by at least $2^0$C over the next 100 years.

Humankind's economic activity over the last 200 years has released such large quantities of carbon dioxide into the atmosphere that its level is significantly higher than levels seen by the earth in the last million years. How these levels of carbon dioxide will impact on average world temperatures, sea levels and the living conditions for future generations, over the next millennium has yet to be fully understood.

What is clear is that the research from, and understanding of, the Polar Regions provides a very clear indication of how the activities of mankind are impacting on the temperature of the earth over time and taking mankind into unknown, and possibly very dangerous, territory. There have been periods of mass extinction in the earth's history.

To ensure that mankind can retain the advanced living conditions that the current period in the Milankovitch cycle permits mankind must take urgent action to stabilise, and then reduce, the level of carbon dioxide in the atmosphere. Achieving stabilisation and beginning to return to the historical Milankovitch cycle levels may take a millennium.

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