Climate change variations across the globe
11 May 2023 at the University Women's Club, Audley Sq.

The Discussion was introduced by Professor Dame Jane Francis, Director of the British Antarctic Survey

Jane is a geologist with research interests in past climate change. She has undertaken research projects at the universities of Southampton, London, Leeds and Adelaide, using fossils to determine the change from greenhouse to icehouse climates in the polar regions over the past 100 million years. She has undertaken over 15 scientific expeditions to the Arctic and Antarctica in search of fossil forests and information about climates of the past.

Jane was appointed Dame Commander of the Order of St Michael and St George (DCMG) in recognition of services to UK polar science and diplomacy. She was also awarded the UK Polar Medal by H.M The Queen, the Royal Geographical Society's Patrons Medal and the 2022 Prince Albert II of Monaco Foundation Award for Planetary Health. She is Chancellor of the University of Leeds and a Fellow of the Royal Society.

The broad picture in the lower latitudes is that the primary cause of climate change in in Antarctica is that wind speed has increased and is blowing warmer water underneath the ice shelves. These winds are often referred to as the doomsday winds, with particular reference to the situation under the Thwaites ice shelf which is melting from below. The importance of the vast ice shelves in Antarctica is that they have a restraining effect on the glaciers that are flowing off the continent onto the ocean. Consequently, current research is focussed on these floating shelves, the breakup of which would have a major impact on global sea level rise.

The major part of Antarctica is of course the ice cap sitting over a continent, the vast volume of which had been thought unlikely to be much affected by climate change. However, recent data has shown a significant reduction in surrounding sea ice, from warmer water getting close to the east Antarctic ice cap particularly.

The first geological evidence we have of the existence of an Antarctic ice cap comes from drilling through shallow ice at the margins of the continent, where about Oligocene tillites are found about 34 Ma in age. An ice cap may have already have formed at higher latitudes nearer the centre of the continent of course.

Antarctica moved over the pole in the Cretaceous, about 100 Ma, so the continent has been a polar mass for a very long time, which implies that the changes measured recently, really are very significant. Nonetheless, Cretaceous fossil plants and dinosaur remains occur in Antarctica which shows that a cold temperate environment likely existed at the margins of the continent.

A recent paper published by the Geological Survey of South Australia on 'Early Cretaceous sediments reveal a story of prolonged cold climate, glaciations, oscillating sea level and tectonic changes'. The question arises therefore, whether despite the high global temperature during the Cretaceous, Antarctica could have retained its ice cap. The answer to this question would have profound implications for the present-day as we watch the steady rise in global CO_2.

Discussion

Dropstones have been found on the southern ocean seabed from the Eocene, evidence that at least small ice caps must have reached the coast in very warm oceans about 50 Ma ago. There is similar evidence from the Arctic which clearly points to the existence of ice caps over both poles at that time.

Were a large ice shelf such as Thwaites break up, the addition of such a vast quantity of fresh water to the ocean would have a massive impact on the circulation patterns; the fundamental driver of oceanic circulation is cold, heavy salt water which flows away from Antarctica at depth, and which makes its way to the northern hemisphere. There are already fears that the Antarctic waters are freshening.

The UK is at the same latitude as Labrador, which is considerably colder of course, because it is at the northern end of the Gulf Stream where heat comes from the Indian Ocean flows around southern Africa up across the equator, past Florida and keeps our islands relatively warm. However, if sufficient fresh water from melting of the Greenland ice cap comes into the Atlantic ocean, this warming effect would likely cease.

This is exactly what is interpreted to have happened during the numerous glacial-interglacial periods in the last ice-age, producing an oceanic ice front from Boston to Lisbon over Milankovitch cycles of warming and cooling.

There has been much comment about rising temperatures causing permafrost to melt and releasing huge additional quantities of carbon to the atmosphere, yet the evidence from ice cores is that the methane signal over the past 800,000 years is that CO_2 levels did not rise above about half of present-day levels. A methane time bomb from permafrost melting seems highly unlikely therefore. Permafrost melts each year between 30cm and 3m depth, depending on location, which is insignificant since permafrost is up to 2.5km deep. Consequently, there is a very clear upper figure for the amount of organic material in Siberia that could be converted into methane, albeit variable depending if soil conditions were reducing or oxidising.

Ideally, we need to cease producing CO_2 and also bury vast quantities that has already been added to the atmosphere. Even if both these ideals were realised however, there would still be a 200+ year-long delay for the Earth's system to actually reverse the climate change process. The key to understanding this lies in the fact that mankind has been adding vast amounts of CO_2 to the atmosphere since the industrial revolution, but the temperature rise has been very slow to 'catch up'.

When most of our electricity was generated from coal, it would have been technically possible to extract the high concentration of CO_2 from the chimneys and pump it into depleted N Sea gas reservoirs (carbon capture and storage, CCS). However, liquified or highly compressed CO_2 will be highly acidic and carry unknown risks for long term geological storage.

Such concentrated sources are declining of course and CO_2 now comes from billions of tiny sources: vehicle tailpipes and boiler flues in buildings. It follows that if CCS were to happen, it would have to come from direct air capture, where the concentration is only 0.04%, requiring gigantic amounts of energy to undertake.

The question arose of how much detail is known about geological evidence for climate change timescales in the southern hemisphere, notably the Dwyka tillite in S Africa when the Gondwana landmass was over the S pole. This was in fact a Carboniferous glaciation, so considerably older than the Eocene or Cretaceous tillites referred to earlier. and very little is known about the speed of climate change at that time. Given the size of the Gondwana continent pre-breakup, the ice sheet at the time would inevitably have caused dramatic sea level change, causing the changes we see in the in the N hemisphere (coal to grit cycles in the Coal Measures) at the time when there was no continent over the N pole.

As there is no land over the N pole where the ice is comparatively thin and is known to have reduced in size dramatically in modern times. Consequently, the dominant ice volume in the N hemisphere is on Greenland, which is in irreversible change. The glaciers are melting on both sides of Greenland, and surface water is penetrating down crevasses and lubricating the base of the ice, warmer water is coming into the fjords, the valley glaciers are retreating back onto the land. In total, a nightmare scenario.

Sea level rise globally is about 4mm a year, the net increase since 1900 is estimated to have been 60cm with the rate of SL rise having increased since 1950. However, there are marked climate variations: the temperature rise now is 3 to 4 times as fast in the arctic as it is in the Antarctic. As darker ice reduces the albedo is diminishing and hence the arctic absorbs much more heat from the sun.

The other source of methane in the arctic could also be the deep, cold continental shelf on which vast quantities of methane is locked up in methane hydrates which are known to be disturbed by deep water drilling. The key question is to what extent oceanic surface warming will penetrate down the arctic seabed and melt the hydrates. The stability field for these hydrates in not known with any certainty, but it does seem highly unlikely that they would melt down to a depth of a thousand metres. The good news, if there is any, is that at such depths any methane released will be expected to be absorbed by methanophilic bacteria in the water column. Biogenic methane seeps visible are present on the Antarctic seabed now, and occur as ‘chimneys’ in Antarctic Cretaceous rocks.

The southern ocean current is powerful but it is at least proving to be an important absorber of heat. Will this result more algal growth in the surface waters as a result? Unlikely, such as algal growths are focussed on the river output with its associated agricultural runoff, so it is a coastal rather than an oceanic effect. In the Cretaceous period there were large anoxic events, and in the Jurassic the Kimmeridge oil source rocks were deposited, both of which imply a very warm ocean that is highly stratified, with an extreme deoxygenation zone below about 1,000m depth. The Pacific is already significantly close to being anoxic as it is at the end of the oceanic flow system, and the Arabian Sea and Black Sea are both deeply anoxic at the present day.

On the question of how fish adapt to global changes, so called Atlanticisation of Arctic waters occurs in Svalbard waters where Arctic cod are being replaced by Atlantic cod. The central Arctic ocean has not been available for research although there is still an international fishing moratorium there.

The other area for research in future is to what extent the bedrock which was once covered by ice around Greenland is contributing heat to the ocean.

John Bennett