The oldest ice core: finding a 1.5 million-year record of Earth's climate

EGU press release on research published in Climate of the Past

How far into the past can ice-core records go? Scientists have now identified regions in Antarctica they say could store information about Earth's climate and greenhouse gases extending as far back as 1.5 million years, almost twice as old as the oldest ice core drilled to date. The results are now published in Climate of the Past, an open access journal of the European Geosciences Union (EGU).

By studying the past climate, scientists can understand better how temperature responds to changes in greenhouse-gas concentrations in the atmosphere. This, in turn, allows them to make better predictions about how climate will change in the future.

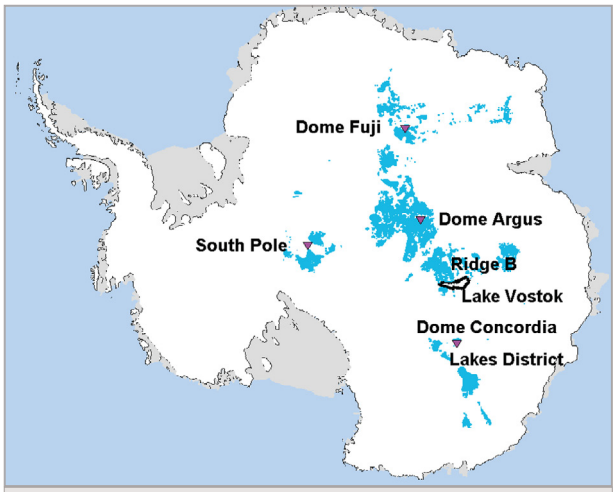
"Ice cores contain little air bubbles and, thus, represent the only direct archive of the composition of the past atmosphere," says Hubertus Fischer, an experimental climate physics professor at the University of Bern in Switzerland and lead author of the study. A 3.2-km-long ice core drilled almost a decade ago at Dome Concordia (Dome C) in Antarctica revealed 800,000 years of climate history, showing that greenhouse gases and temperature have mostly moved in lockstep. Now, an international team of scientists wants to know what happened before that.

At the root of their quest is a climate transition that marine-sediment studies reveal happened some 1.2 million years to 900,000 years ago. "The Mid Pleistocene Transition is a most important and enigmatic time interval in the more recent climate history of our planet," says Fischer. The Earth's climate naturally varies between times of warming and periods of extreme cooling (ice ages) over thousands of years. Before the transition, the period of variation was about 41 thousand years while afterwards it became 100 thousand years. "The reason for this change is not known."

Climate scientists suspect greenhouse gases played a role in forcing this transition, but they need to drill into the ice to confirm their suspicions. "The information on greenhouse-gas concentrations at that time can only be gained from an Antarctic ice core covering the last 1.5 million years. Such an ice core does not exist yet, but ice of that age should be in principle hidden in the Antarctic ice sheet."

As snow falls and settles on the surface of an ice sheet, it is compacted by the weight of new snow falling on top of it and is transformed into solid glacier ice over thousands of years. The weight of the upper layers of the ice sheet causes the deep ice to spread, causing the annual ice layers to become thinner and thinner with depth. This produces very old ice at depths close to the bedrock.

However, drilling deeper to collect a longer ice core does not necessarily mean finding a core that extends further into the past. "If the ice thickness is too high the old ice at the bottom is getting so warm



Antarctic locations (in bright blue) where 1.5-million-year-old ice could exist. The figure is modified from Van Liefferinge and Pattyn (Clim. Past., 2013).

by geothermal heating that it is melted away," Fischer explains. "This is what happens at Dome C and limits its age to 800,000 years."

To complicate matters further, horizontal movements of the ice above the bedrock can disturb the bottommost ice, causing its annual layers to mix up.

"To constrain the possible locations where such 1.5 million-year old – and in terms of its layering undisturbed – ice could be found in Antarctica, we compiled the available data on climate and ice conditions in the Antarctic and used a simple ice and heat flow model to locate larger areas where such old ice may exist," explains co-author Eric Wolff of the British Antarctic Survey, now at the University of Cambridge.

The team concluded that 1.5 million-year-old ice should still exist at the bottom of East Antarctica in regions close to the major Domes, the highest points on the ice sheet, and near the South Pole, as described in the new Climate of the Past study. These results confirm those of another study, also recently published in Climate of the Past.

Crucially, they also found that an ice core extending that far into the past should be between 2.4 and 3-km long, shorter than the 800,000-year-old core drilled in the previous expedition.

The next step is to survey the identified drill sites to measure the ice thickness and temperature at the bottom of the ice sheet before selecting a final drill location.

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"A deep drilling project in Antarctica could commence within the next 3–5 years," Fischer states. "This time would also be needed to plan the drilling logistically and create the funding for such an exciting large-scale international research project, which would cost around 50 million euros."

This press release was originally published on the EGU website

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Terrestrial ecosystems at risk of major shifts as temperatures increase

EGU press release on research published in Earth System Dynamics

Over 80% of the world's ice-free land is at risk of profound ecosystem transformation by 2100, a new study reveals. "Essentially, we would be leaving the world as we know it," says Sebastian Ostberg of the Potsdam Institute for Climate Impact Research, Germany. Ostberg and collaborators studied the critical impacts of climate change on landscapes and have now published their results in Earth System Dynamics, an open access journal of the European Geosciences Union (EGU).

The researchers state in the article that "nearly no area of the world is free" from the risk of climate change transforming landscapes substantially, unless mitigation limits warming to around 2 degrees Celsius above preindustrial levels.

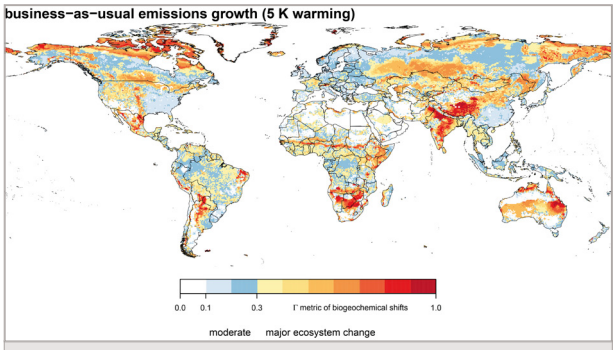
Ecosystem changes could include boreal forests being transformed into temperate savannas, trees growing in the freezing Arctic tundra or even a dieback of some of the world's rainforests. Such profound transformations of land ecosystems have the potential to affect food and water security, and hence impact human well-being just like sea level rise and direct damage from extreme weather events.

The new Earth System Dynamics study indicates that up to 86% of the remaining natural land ecosystems worldwide could be at risk of major change in a business-as-usual scenario (see note). This assumes that the global mean temperature will be 4 to 5 degrees warmer at the end of this century than in pre-industrial times – given many countries' reluctance to commit to binding emissions cuts, such warming is not out of the question by 2100.

"The research shows there is a large difference in the risk of major ecosystem change depending on whether humankind continues with business as usual or if we opt for effective climate change mitigation," Ostberg points out.

But even if the warming is limited to 2 degrees, some 20% of land ecosystems – particularly those at high altitudes and high latitudes – are at risk of moderate or major transformation, the team reveals.

The researchers studied over 150 climate scenarios, looking at ecosystem changes in nearly 20 different climate models for various degrees of global warming. "Our study is the most comprehensive and internally consistent analysis of the risk of major ecosystem change from climate change at the global scale," says Wolfgang Lucht, also an author of the study and co-chair of the research domain Earth System Analysis at the Potsdam Institute for Climate Impact Research.



Simulated ecosystem change by 2100, if the global mean temperature increase is of five degrees Celsius above preindustrial levels. The parameter Γ measures how far apart a future ecosystem under climate change would be from the present state. Blue colours (lower Γ) depict areas of moderate change, yellow to red areas (higher Γ) show major change. The map shows the median value of Γ across all climate models, meaning at least half of the models agree on major change in the yellow to red areas. (Credit: Ostberg et al., 2013)

Few previous studies have looked into the global impact of raising temperatures on ecosystems because of how complex and interlinked these systems are. "Comprehensive theories and computer models of such complex systems and their dynamics up to the global scale do not exist."

To get around this problem, the team measured simultaneous changes in the biogeochemistry of terrestrial vegetation and the relative abundance of different vegetation species. "Any significant change in the underlying biogeochemistry presents an ecological adaptation challenge, fundamentally destabilising our natural systems," explains Ostberg.

The researchers defined a parameter to measure how far apart a future ecosystem under climate change would be from the present state. The parameter encompasses changes in variables such as the vegetation structure (from trees to grass, for example), the

carbon stored in the soils and vegetation, and freshwater availability. “Our indicator of ecosystem change is able to measure the combined effect of changes in many ecosystem processes, instead of looking only at a single process,” says Ostberg.

He hopes the new results can help inform the ongoing negotiations on climate mitigation targets, “as well as planning adaptation to unavoidable change.”

This press release was originally published on the EGU website

Note

Even though 86% of land ecosystems are at risk if global temperature increases by 5 degrees Celsius by 2100, it is unlikely all these areas will be affected. This would mean that the worst case scenario from each climate model comes true.

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Tiny plankton could have big impact on climate

EGU press release on research published in Biogeosciences

As the climate changes and oceans’ acidity increases, tiny plankton seem set to succeed. An international team of marine scientists has found that the smallest plankton groups thrive under elevated carbon dioxide (CO_2) levels. This could cause an imbalance in the food web as well as decrease ocean CO_2 uptake, an important regulator of global climate. The results of the study, conducted off the coast of Svalbard, Norway, in 2010, are now compiled in a special issue published in Biogeosciences, a journal of the European Geosciences Union (EGU).

“If the tiny plankton blooms, it consumes the nutrients that are normally also available to larger plankton species,” explains Ulf Riebesell, a professor of biological oceanography at the GEOMAR Helmholtz Centre for Ocean Research Kiel in Germany and head of the experimental team. This could mean the larger plankton run short of food.

Researchers check the ‘mesocosms’, eight-metre long floatation frames carrying plastic bags with a capacity of 50 cubic metres, deployed for a five-week long field study on ocean acidification conducted in the Kongsfjord off the Arctic archipelago of Svalbard. (Credit: Ulf Riebesell/GEOMAR)

Large plankton play an important role in carbon export to the deep ocean, but in a system dominated by the so-called pico- and nanoplankton, less carbon is transported out of surface waters. “This may cause the oceans to absorb less CO_2 in the future,” says Riebesell.

The potential imbalance in the plankton food web may have an even bigger climate impact. Large plankton are also important producers of a climate-cooling gas called dimethyl sulphide, which stimulates cloud-formation over the oceans. Less dimethyl sulphide means more sunlight reaches the Earth’s surface, adding to the greenhouse effect. “These important services of the ocean may thus be significantly affected by acidification.”

Ecosystems in the Arctic are some of the most vulnerable to acidification because the cold temperatures there mean that the ocean absorbs more carbon dioxide. “Acidification is faster there than in temperate or tropical regions,” explains the coordinator of the European Project on Ocean Acidification (EPOCA), Jean-Pierre Gattuso of the Laboratory of Oceanography of Villefranche-sur-Mer of the French National Centre for Scientific Research (CNRS).

The increasing acidity is known to affect some calcifying organisms in the Arctic, including certain sea snails, mussels and other molluscs. But scientists did not know until now how ocean acidification alters both the base of the marine food web and carbon transport in the ocean.

The five-week long field study conducted in the Kongsfjord off the Arctic archipelago of Svalbard, under the EPOCA framework, intended to close this knowledge gap. For the experiment, the scientists deployed nine large ‘mesocosms’, eight-metre long floatation frames carrying plastic bags with a capacity of 50 cubic metres. These water enclosures, developed at GEOMAR, allow researchers to study plankton communities in their natural environment under controlled conditions, rather than in a beaker in the lab. Few studies have looked at whole communities before.

The scientists gradually added CO_2 to the mesocom water so that it reached acidity levels expected in 20, 40, 60, 80 and 100 years, with two bags left as controls. They also added nutrients to simulate a natural plankton bloom, as reported in the Biogeosciences special issue.

The team found that, where CO_2 was elevated, pico- and, to a lesser extent, nanoplankton grew, drawing down nutrients so there were less available to larger plankton. “The different responses we observed made it clear that the communities’ sensitivity to

acidification depends strongly on whether or not nutrients are available," Riebesell summarises.

"Time and [time] again the tiniest plankton benefits from the surplus CO_2, they produce more biomass and more organic carbon, and dimethyl sulphide production and carbon export are decreasing," he concludes.

This press release was originally published on the EGU website

Note

With 35 participants from 13 European institutions, the GEOMAR-coordinated mesocosm experiment was the largest project of EPOCA, a large EU-funded research initiative on ocean acidification that ran from 2008 to 2012. It was supported by the French–German Arctic Research Base.

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How pigeons may smell their way home

EGU press release on research published in Biogeosciences

Homing pigeons, like other birds, are extraordinary navigators, but how they manage to find their way back to their lofts is still debated. To navigate, birds require a 'map' (to tell them home is south, for example) and a 'compass' (to tell them where south is), with the sun and the Earth's magnetic field being the preferred compass systems. A new paper provides evidence that the information pigeons use as a map is in fact available in the atmosphere: odours and winds allow them to find their way home. The results are now published in Biogeosciences, an open access journal of the European Geosciences Union (EGU).

Experiments over the past 40 years have shown that homing pigeons get disoriented when their sense of smell is impaired or when they don't have access to natural winds at their home site. But many researchers were not convinced that wind-borne odours could provide the map pigeons need to navigate. Now, Hans Wallraff of the Max Planck Institute for Ornithology in Seewiesen, Germany, has shown that the atmosphere does contain the necessary information to help pigeons find their way home.

In previous research, Wallraff collected air samples at over 90 sites within a 200 km radius around a former pigeon loft near Würzburg in southern Germany. The samples revealed that the ratios among certain 'volatile organic compounds' (chemicals that can be a source of scents and odours) in the atmosphere increase or decrease along specific directions. "For instance, the percentage of compound A in the sum A+B or A+B+C+D increases the farther one moves from north to south," Wallraff explains.

These changes in compound ratios translate into changes in perceived smell. But a pigeon that has never left its loft does not know in what directions what changes occur – unless it has been exposed to winds at its home site.

At home, a bird is thought to associate certain smells with particular wind directions. "If the percentage of compound A increases with southerly winds, a pigeon living in a loft in Würzburg learns this wind-correlated increase. If released at a site some 100 km south of home, the bird smells that the ratio of compound A is above what it is on average at its loft and flies north," Wallraff explains. To use an analogy, a person in Munich could smell an Alpine breeze when there is wind blowing from the south. When displaced closer to the mountains, they would detect a strong Alpine scent and remember that, at home, that smell is associated with southerly winds: the person would know that, roughly, they needed to travel north to find home.

But this explanation of how pigeons might use wind-borne odours to find their loft was just a hypothesis: Wallraff still needed to prove that the atmosphere does indeed contain the basis of the map system pigeons need to navigate. In the new Biogeosciences paper, he develops a model showing that 'virtual pigeons' with only knowledge of winds and odours at home, can find their way back to their lofts by using real atmospheric data.

"My virtual pigeons served as tools to select those volatile compounds whose spatial distributions, combined with variations dependent on wind direction, were most suitable for homeward navigation," explains Wallraff.

The model uses an iterative approach to imitate animal evolution by introducing random mutations in the virtual pigeons, making them most sensitive to those volatile compounds that are most effective for navigation. By selecting the best mutations in the course of thousands of generations, the model creates virtual pigeons capable of finding their bearings as well as real pigeons, showing that even inexperienced birds could use atmospheric information for navigation. The findings present a missing piece in the puzzle of homing pigeon navigation, confirming that winds and odours can indeed work as a map system.

"Work with real pigeons was the beginning of the story. In this research, I wanted to find out whether and in what way the chemical atmosphere fulfils the demands for avian navigation. Eventually, to identify the chemical compounds birds actually use for home-finding, we will need real birds again. But this is far in the future."

This press release was originally published on the EGU website

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Using digital SLRs to measure the height of Northern Lights

EGU press release on research published in Annales Geophysicae

Scientific research doesn't often start from outreach projects. Yet, Ryuho Kataoka from the National Institute of Polar Research in Tokyo, Japan, came up with an idea for a new method to measure the height of aurora borealis after working on a 3D movie for a planetarium. Kataoka and collaborators used two digital single-lens reflex (SLR) cameras set 8 km apart to capture 3D images of Northern Lights and determine the altitude where electrons in the atmosphere emit the light that produces aurora. The results are now published in Annales Geophysicae, a journal of the European Geosciences Union (EGU).

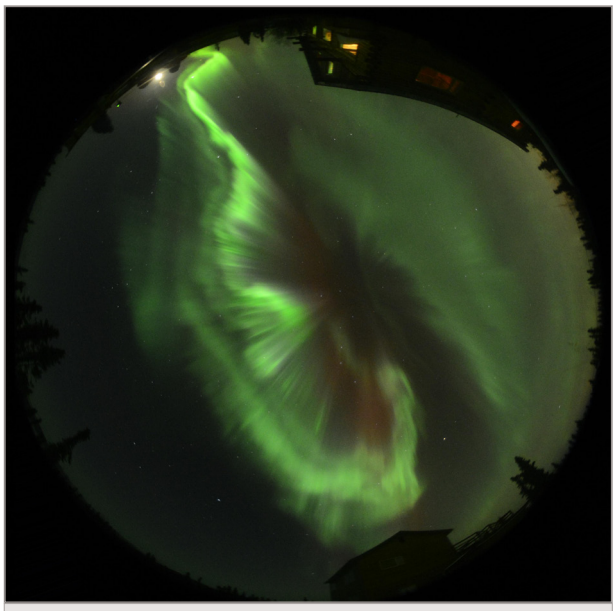
"We had initial success when we projected the digital SLR images at a planetarium and showed that the aurora could be seen in 3D. It was very beautiful, and I became confident that it should be possible to calculate the emission altitude using these images," recalls Kataoka, who also works at the Graduate University for Advanced Studies (Sokendai) in Hayama, Japan. He teamed up with other Japanese researchers and an American scientist to do just that.

The separation distance between the human eyes is what allows us to see in 3D. When we look at an object, the images captured by the left and right eyes are slightly different from each other and when combined they give the brain the perception of depth. But because the distance between our eyes – about 5 cm – is small, this only works for objects that are not very far away.

Since aurora extend between about 90 and 400 km in altitude, a much larger separation distance is needed to see them in 3D. The researchers used two cameras, mimicking the left and right eyes, separated by 8 km across the Chatanika area in Alaska. Their two digital SLRs, equipped with fisheye lenses and GPS units, captured two simultaneous all-sky images that the researchers combined to create a 3D photograph of the aurora and measure the emission altitude.

"Using the parallax of the left-eye and the right-eye images, we can calculate the distance to the aurora using a [triangulation] method that is similar to the way the human brain comprehends the distance to an object," explains Kataoka. Parallax is the difference in the apparent position of an object when observed at different angles.

Scientists have obtained altitude maps of aurora before. They are useful because they provide information about the energy of the electrons that produce the lights. But this is the first time the emission height of Northern Lights has been measured using images captured with digital SLR cameras. As the authors explain in the new Annales Geophysicae paper, the altitude maps obtained in this way are consistent with previous observations.



The authors used two digital SLRs (single-lens reflex cameras), equipped with fisheye lenses and GPS units, to capture two simultaneous all-sky images of aurora in Alaska, USA, one of which is shown here. The subtle differences between the two pictures allow researchers to measure the altitude where electrons in the atmosphere emit the light that produces aurora. You can see the two images, and a 3D side-by-side video of aurora, on the EGU website. (Credit: Kataoka et al., 2013)

The technique is low cost and allows researchers to measure the altitude of small-scale features in the aurora. Further, it opens up the door for citizen scientists to get involved with auroral research.

"Commercially available GPS units for digital SLR cameras have become popular and relatively inexpensive, and it is easy and very useful for photographers to record the accurate time and position in photographic files. I am thinking of developing a website with a submission system to collect many interesting photographs from night-sky photographers over the world via the internet," says Kataoka.

The researchers believe this may lead to new scientific findings, while working to engage the public in auroral research. After all, it was the beauty of 3D imaging of auroras that inspired Kataoka to develop a new tool for scientific research in the first place.

This press release was originally published on the EGU website

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