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Greenland ice cores tell story of warm spell

The analysis of ice cores extracted at the NEEM [1] ice-drilling site has enabled an international team of scientists to reconstruct Greenland's climate history over the past 130,000 years, with the participation in France of CNRS, CEA, UVSQ, Université Joseph Fourier[2] and IPEV. For the first time in the Arctic, the researchers have succeeded in retrieving ice formed during the last interglacial period, 130,000 to 125,000 years ago, which was marked by significant warming in that region. Their findings show that the Greenland ice sheet only contributed 2 meters to the 4—8 meters of sea level rise observed during that period. Published on 24 January in *Nature*, this study provides valuable information about the relationship between climate and sea level rise.

NEEM is an international ice-drilling project aimed at extracting ice cores in northwest Greenland. Its goal was to obtain, for the first time in the Arctic, samples reaching back 130,000 years to the last interglacial period, the Eemian, a warm episode in Earth's history. Led by the University of Copenhagen and involving 14 countries including France, the NEEM team drilled more than 2.5 km down to the bedrock in two years, between 2010 and 2012. They extracted the first complete record of the Eemian, providing estimates of changes in temperature, amount of precipitation and atmospheric composition.

The Greenland ice cores, formed by the accumulation and compaction of snow layers, were studied using a range of tests carried out not only on the ice but also on the air trapped inside it. Measuring the stable water isotopes provided information about changes in temperature at the surface of the ice sheet and in moisture transport over time. The isotopic composition of the water and the atmospheric composition of the trapped air enabled the scientists to identify past variations in the climate of Greenland, recorded annually like the growth rings in trees. Finally, the amount of gas present in the ice provided information about variations in the thickness of the ice sheet, since the quantity of trapped air varies according to the elevation of the site.

On the basis of these tests, the scientists were able to describe how the climate has changed in Greenland over the past 130,000 years. Their results show that during the Eemian, 130,000 to 125,000 years ago, the climate of northern Greenland was 4—8 °C warmer than today. Such temperatures are higher than those

[1] North Greenland Eemian Ice Drilling.

[2] The main French laboratories involved are the Laboratoire de Glaciologie et de Géophysique de l'Environnement (LGGE, CNRS/UJF) and the Laboratoire des Sciences du Climat et de l'Environnement (IPSL/LSCE, CNRS/CEA/UVSQ). The Grenoble Images Parole Signal Automatique Laboratory (CNRS/Grenoble-INP/UJF/Université Stendhal) contributed to modeling air capture. Coordinated by Valérie Masson-Delmotte, the French teams took part in field operations (drilling, ice core processing), analysis of dust, water isotopes, air composition and physical properties, and modeling air capture and ice sheet flow. They played a key role in dating the deep ice retrieved in the drilling program.

simulated by climate models for that period[3]. However, surprisingly, the elevation of the ice sheet in the neighborhood of the NEEM site is only a hundred meters lower. At the beginning of the interglacial period, around 128,000 years ago, it exceeded its current level by 200 meters. The thickness of the ice sheet then decreased at an average rate of 6 cm per year. Then, around 122,000 years ago, the surface elevation fell to approximately 130 meters below present levels. The thickness of the ice sheet subsequently remained stable (around 2,400 meters) until the beginning of the last glaciation, some 115,000 years ago. Therefore, the Greenland ice sheet can only have contributed 2 meters to the 4—8 meters of sea level rise that occurred during the Eemian.

Moreover, the researchers estimate that the volume of the Greenland ice sheet decreased by around 25% in 6,000 years during the Eemian. Over that period, extensive surface melt occurred, as recorded in the ice cores by layers of re-frozen melt. These are the result of melt water from surface snow, which trickled down into the underlying snow and re-froze. Such melting events have been extremely rare over the past 5,000 years, confirming that the surface temperature at the NEEM site was considerably warmer during the Eemian than now. Nonetheless, this phenomenon was observed in the summer of 2012 by the team present at the NEEM drilling site.

These findings confirm the vulnerability of the Greenland ice sheet to temperature increases. However, the fact that it did not entirely disappear during the Eemian implies that the Antarctic icecap must have contributed a significant proportion of the 4—8 meter sea level rise that occurred during the Eemian. The Antarctic ice sheet, whose past behavior remains poorly understood, would therefore appear to react significantly to climate warming. This reconstruction of the Eemian climate provides reference data that will be compared with simulations of the climate and of ice sheet evolution. This data is the only available tool for assessing the risk of future climate and sea level change.

In France, support for the NEEM project was principally provided by CNRS, CEA, IEV and ANR's 'Vulnérabilités, Milieux et Climat' program.

[3] The reason why Greenland became warmer during the last interglacial period is well understood: summer sunshine increased due to a difference in Earth's orbit.

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Professor Dorthe Dahl-Jensen, coordinator of the NEEM project, holding an ice core section extracted during the project. A large number of tests are required to reveal the secrets of the climate preserved in the ice.
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The ice cores are cut and measured by an international team of scientists at the NEEM site. The picture shows Christopher Stowasser of the University of Copenhagen in Denmark.
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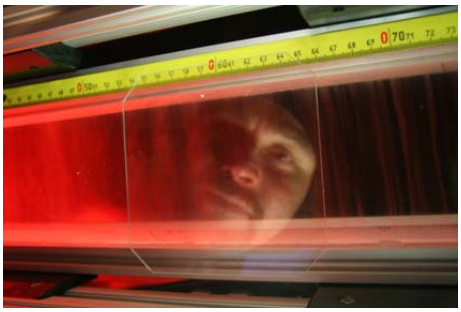

Reflection in an ice core extracted during the NEEM drilling project.
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Once the corer is at the surface it is placed horizontally to allow the ice core to be removed. The ice core has a diameter of 10.2 cm and a length of 3.5 meters.
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