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Polar ice sheet formation: paradox solved

The beginning of the last glacial period was characterized in the Northern hemisphere by significant accumulation of snow at high latitudes and the formation of a huge polar ice sheet. For climatologists this was paradoxical, since snowfall is always associated with high humidity and relatively moderate temperatures. Now, a French team coordinated by María-Fernanda Sánchez-Goñi, a researcher at EPHE[1] working in the 'Oceanic and Continental Environments and Paleoenvironments' Laboratory (CNRS/Universités Bordeaux 1 & 4)[2] has solved this paradox. By analyzing sediment cores dating back 80,000 to 70,000 years, the researchers have shown that during that period, water temperatures in the Bay of Biscay remained relatively high, whereas those in mainland Europe gradually fell. Carried northwards by wind, the humidity released by this thermal contrast appears to have caused the snowfall that formed the polar ice sheet. This work was published on the *Nature Geoscience* website on 1 September 2013.

Over the past two million years, the Earth has experienced long glacial periods separated by short, warmer intervals known as interglacials. This succession of glacials and interglacials is caused by changes in insolation brought about by cyclical variations in the distance between the Earth and the Sun and in the tilt and direction of our planet's rotation axis relative to the Sun. The last glacial period, which ended 12,000 years ago, began between 80,000 and 70,000 years ago. This period was marked by climate variability at the millennial time scale, with short cooling periods alternating with increasingly small improvements in the climate as glaciation set in.

Sea levels dropped by 80 meters following a reduction in insolation 70,000 years ago. This shows that there was a large accumulation of snow at high latitudes, which was the cause of the ice sheet around the North Pole. However, cold temperatures are generally associated with dry weather and scarce precipitation. For snow to fall, the weather needs to be humid and the temperature only moderately low. In these conditions, how can the accumulation of snow at the pole be explained?

To answer this question, the researchers analyzed marine sediment cores collected off Galicia (Spain) and from the Bay of Biscay, containing pollen and foraminifera, microscopic marine organisms with calcareous

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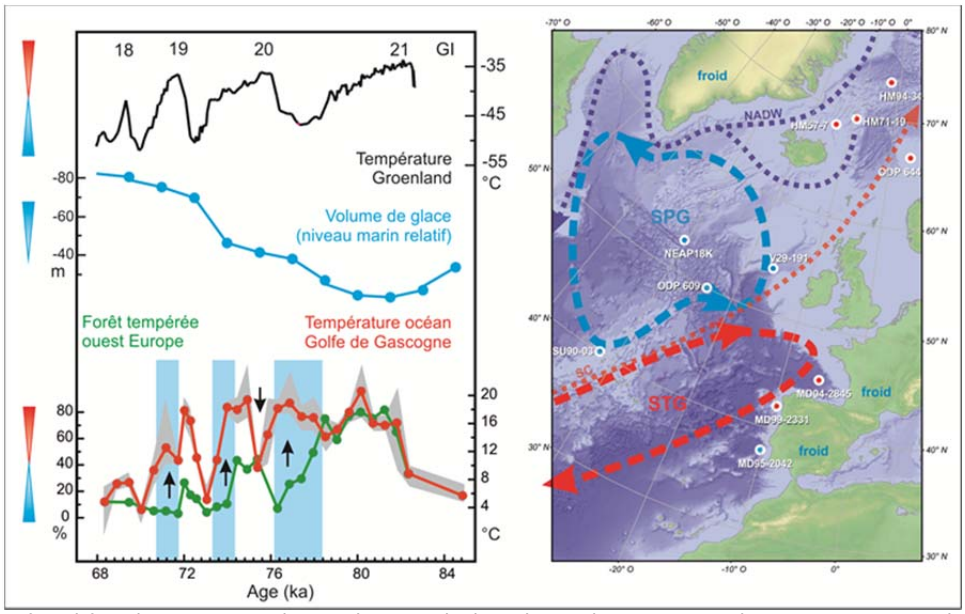
[2] In collaboration with the European Center for Research and Teaching in Environmental Geosciences (Aix-Marseille Université/CNRS/IRD/Collège de France), Laboratoire des Sciences du Climat et de l'Environnement (CEA/CNRS/UVSQ) and the 'De la préhistoire à l'actuel : culture, environnement et anthropologie' Laboratory (CNRS/Université Bordeaux 1/Ministère de la culture et de la communication/INRAP).

skeletons. Pollen grains are excellent indicators of the vegetation and temperature of the continent, while foraminifera provide information about the temperature of the ocean.

The scientists were thus able to reconstruct changes in the vegetation cover of the Atlantic seaboard and in the temperatures of the Atlantic Ocean. They observed an astonishing decoupling between the temperature of the Bay of Biscay and that of the European mainland. When temperatures were very cold on the mainland, the oceans remained warm, especially during the periods of intense cooling that took place at the onset of glaciation. The decoupling corresponds to periods when the Gulf Stream, a powerful marine current that carries the warm waters of the Gulf of Mexico northwards, was pushed towards the Bay of Biscay by the moderate iceberg break-up from the North of the American continent. It is the temperature contrast between the Bay of Biscay and the adjacent mainland that released high humidity, which was carried towards the North Pole by the winds, thus causing the heavy snowfall that formed the polar ice sheet, researchers believe.



Left and from bottom to top: changes in atmospheric and oceanic temperatures in Western Europe and the Bay of Biscay; changes in the overall ice volume; changes in atmospheric temperature in Greenland (GI indicates periods of warming in Greenland). The blue strips represent cooling phases in the west of Europe and warming of water in the Bay of Biscay.
Right: Proposed oceanic circulation model to explain the presence of warm waters in the Bay of Biscay during phases of atmospheric cooling at the onset of glaciation. The red arrows and dots show warm surface waters; blue arrows and dots show cold surface waters. NADW: North Atlantic Deep Water, SC: surface current, STG: subtropical gyre, SPG: subpolar gyre.

Reference

Air-sea temperature decoupling in Western Europe during the last interglacial/glacial transition
María-Fernanda Sánchez-Goñi, Edouard Bard, Amaelle Landais, Linda Rossignol, Francesco d'Errico. *Nature Geoscience*, 1 September 2013. DOI : 10.1038/ngeo1924

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