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Regional consequences of last glacial climate fluctuations in ultra-high resolution with the help of climate indicators

Using a sediment core from the Black Sea, Warnemünde geologists reconstructed together with an international team how the transition into the Greenland Interstadial 10 (GI10), a climate warming 41,000 years ago, affected the Black Sea region over the course of decades. The in-depth study was made possible by a precise synchronization with the ice cores and high resolution multi-proxy analyses. Results show that the regional Black Sea climate did not react synchronously and warmer and wetter conditions delayed by about 190 years. Since this detailed paleo study covers time scales comparable to those of the recent global warming, it contributes to the understanding of relevant processes.

The last glacial is characterized by rapid climate fluctuations with particularly strong amplitudes in the high latitudes of the northern hemisphere: transitions to so-called interstadials document warmings within decades that lasted several hundred to a few thousand years. Most paleoclimate researchers see the cause for these abrupt warmings in a reestablishment of the North Atlantic Overturning Circulation, which, as today, ensures that the North Atlantic Current, as a northern extension of the Gulf Stream, brings warm water far to the north. This circulation weakened or even collapsed during the cold phases of the last glacial with short-term revival periods causing the interstadials.

In Greenland ice cores, a number of such sudden warmings have been recorded. To understand the hemispheric impact of such changes originating in the North Atlantic, detailed regional climate reconstructions are needed that can be compared with high temporal accuracy to the ice core signals. Most methods of independent age dating, however, are too imprecise – especially for relatively short events such as the transitions to the interstadials – to guarantee the synchronicity of the archives.

Here, the cosmogenic radionuclide ^{10}Be (pronounced: beryllium 10), produced by cosmic radiation worldwide at the contact of the Earth's atmosphere with space, comes into play as a suitable synchronisation tool. Patterns of the globally uniform fluctuations of its atmospheric production rate are preserved in both sediments and ice archives. Thus, the change in ^{10}Be content over a certain period of time will be identical in a Greenland ice core and in a sediment core from the Black Sea, even though both locations are thousands of kilometres apart.

Geologists from the Leibniz Institute for Baltic Sea Research, the Helmholtz Centre Potsdam - GFZ, the University of Lund and the ETH Zurich took advantage of this fact to identify the effects of the Greenland Interstadial 10 in a sediment core from the southern Black Sea in high resolution. They published their results most recently in the journal *Proceedings of the National Academy of Sciences of the USA (PNAS)*.

Using the ^{10}Be method, they were able to identify those sections of the sediment core that were deposited at exactly the same time as the Greenland Interstadial 10, about 41,000 years ago. In these marine sediments, they investigated in time steps of less than 10 years with various environmental proxy methods how the environment changed.



They used three different proxies: 1) so called ice-rafted-detritus (IRD), ice-transported tiny pieces of sand and gravel that indicate the presence of coastal ice floes during particularly cold winters, (2) the potassium/titanium ratio of sediment transported by rivers from land that reflects the precipitation in the hinterland, and (3) the calcium content that indicates calcium carbonate precipitation in the Black Sea waters during warmer periods, thus serving as an temperature proxy.

The results show the succession of the climatic events in the southern Black Sea region during the transition to and in the Greenland Interstadial 10 as if in a flip-book: At the beginning, the decrease of coastal ice signals that the warming in the North Atlantic simultaneously led to milder winters in the Black Sea region. Later on, with a delay of about 190 years, regional precipitation and the temperature of the surface water of the Black Sea - which was a freshwater lake at that time – started to increase. The authors were able to confirm this response pattern of an immediate reaction of the winter coastal ice on the one hand and a delayed occurrence of higher precipitation and warmer temperatures of the surface water on the other hand also for Greenland interstadials 9 and 11 and explain it with the help of a plausible climate mechanism.

“Due to the lack of stratigraphic accuracy, earlier studies assumed that interstadial climate changes had approximately synchronous effects on the respective hemisphere. We can now see that this is not true,” explains marine geologist Markus Czymzik. “According to our assumptions, the North Atlantic and Mediterranean surface waters first had to warm up to such an extent that the dominant atmospheric circulation pattern also changed. This then affected the regional precipitation and the temperature of the surface water in the Black Sea.”

Helge Arz, head of the Marine Geology department at the IOW, adds: “This highlights the importance of a close look at the different components of the climate system also on a regional scale in order to better anticipate the temporal and spatial distribution of the consequences of man-made global warming.”

The results can be read in detail at: Czymzik, M., Nowaczyk, N. R., Dellwig, O., Wegwerth, A., Muscheler, R., Christl, M., Arz, H. W.: *Lagged atmospheric circulation response in the Black Sea region to Greenland Interstadial 10. Proceedings of the National Academy of Sciences, Nov 2020, doi.org/10.1073/pnas.2005520117*

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