Why regional differences in global warming are critical

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Planktonic foraminifera are microorganisms that live in the uppermost water layers of all oceans. When they die their small calcareous shells sink to the seafloor and remain preserved in the sediments there. The fossil foraminifera documents the conditions in the oceans, and their study enables a view into the past. Credit: MARUM—Center for Marine Environmental Sciences, University of Bremen; M. Kucera

Tiny fossils in marine sediments verify that climate models provide accurate calculations of average ocean temperatures during the last glacial maximum around 20,000 years ago, but that the spatial distribution of simulated temperatures is too uniform and thus only partially valid for predicting future climate.

A new method now shows how past climate model simulations can be better assessed. Dr. Lukas Jonkers of MARUM—Center for Marine Environmental Sciences at the University of Bremen, and his team of colleagues, have now published their results in the journal *Nature Geoscience*.

Scientists use climate models to simulate past climate, in order to determine how and why it has changed. As a result of man-made climate change, it is not possible to apply models directly to the future, because the boundary conditions have changed.

"We thus have to simulate the past in order to test the models. Simulations of climate from the Last Glacial Maximum, the LGM, are therefore important in the evaluation of climate models," says first author Lukas Jonkers, adding that the glacial maximum provides a good test scenario. "Because how much the Earth has warmed since then could generally reflect what we can expect in the future."

Although previous studies have shown that the overall change in global climate from the LGM until the present is reasonably consistent between the models and paleoclimate reconstructions, the spatial temperature patterns that impact ecosystems and habitats and directly affect human society have not been sufficiently considered.

New approach is based on a fundamental macroecological principle

To check whether the simulations provide an accurate picture of past climate, researchers compare them with reconstructions based on fossils. Both approaches possess a certain degree of uncertainty. Thus, when the two disagree, is it because of a problem with the simulation or the reconstruction? To be able to better test and evaluate climate models, Dr. Lukas Jonkers of MARUM and his co-authors have designed a new approach, which they have now presented in the journal *Nature Geoscience*.

By applying a fundamental macroecological principle, the approach reduces the uncertainty of traditional reconstruction methods. This principle is that the further apart species communities are, the more they differ. A well-known example of this is the change in the vegetation with increasing altitude.

"In the marine realm, we see the same pattern of a reduction of the similarity between species communities. The further we move from the equator toward the poles, the more the species change," says Jonkers.

"In the ocean, this decreasing similarity is closely correlated to temperature. So, if the climate models predict past temperatures correctly, then we should, when we compare the simulated past temperatures with fossil species communities, observe this decline in similarity with increasing temperature difference."

Researchers can, therefore, use plankton distribution data from the glacial maximum to assess whether the simulated temperatures for the LGM can reproduce the same pattern of decreasing similarity of the assemblages as we observe it today.

For their study, the international team investigated more than 2,000 species assemblages of planktonic foraminifera from 647 sites. Planktonic foraminifera are widely distributed marine plankton that live in the upper water layers of all the oceans. When they die, their small shells sink to the seafloor and are preserved in the sediments.

The team discovered a different pattern of species similarity decline in the ice age data than observed in modern plankton. They interpreted this as evidence that the simulated temperatures do not represent the true ice-age temperatures.

"Our analysis indicates that the simulated temperatures were too warm in the North Atlantic and too uniform globally. New simulations using weaker ocean circulation that transports less heat to the north, resulting in a cooler North Atlantic, fit the pattern better," explains Lukas Jonkers.

The underlying reason for this is related to the strength of the Atlantic Meridional Overturning Circulation and ice-ocean interactions. The researchers conclude that the new method makes model comparisons more reliable. The new simulations show too that the models can in principle correctly calculate the temperature pattern during the last high ice age. According to the team of authors, this indicates that a correct prediction of the spatial temperature pattern—if the right processes are taken into account—is also possible for the future.

More emphasis on the spatial impact of climate change

"Global climate change will have different impacts in different regions. This is important, as our society and the ecosystems depend on what happens directly around us," concludes Jonkers. "Our study highlights the need to investigate the spatial effects of climate change. This is important when we talk about limiting global warming to 1.5 degrees, because this value only refers to a global average."

The publication appears as part of the PalMod climate modeling initiative. Under this initiative, researchers are working to decipher the climate of the past 130,000 years in order to predict the climate of the future. Their goal is to understand the scope of the models and the parameters on which they are based, and to make better predictions for the future.

The study is the result of a cooperative effort between researchers at the University of Bremen (MARUM and Faculty of Geosciences) and the University of Oldenburg under the framework of the Cluster of Excellence "The Ocean Floor—Earth's Uncharted Interface." Scientists from the Alfred Wegener Institute Helmholtz Center for Polar and Marine Research Potsdam and Bremerhaven, as well as the Southern Marine Science and Engineering Guangdong Laboratory Zuhai (China) and Oregon State University (U.S.) are also involved in the study.

More information: Lukas Jonkers et al, Strong temperature gradients in the ice age North Atlantic Ocean revealed by plankton biogeography, *Nature Geoscience* (2023). DOI: 10.1038/s41561-023-01328-7

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