How variable are ocean temperatures?

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Scientists analyzing a sediment core. Credit: Thomas Ronge, Alfred-Wegener-Institut

The earth's climate appears to have been more variable over the past 7,000 years than often thought. This is the conclusion of a new study forthcoming online this week in the U.S. scientific journal *Proceedings of the National Academy of Sciences* (*PNAS*). In the study, scientists from the Potsdam-based Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, and Harvard University show that sea surface temperatures reconstructed from climate archives vary to a much

greater extent on long time scales than simulated by climate models. The consequence: either the analysed climate archives supply inaccurate temperature signals, or the tested models underestimate the regional climate fluctuations in the Earth's recent history.

In order to reconstruct climate history, it is necessary to study natural climate archives since, in terms of the Earth's history, humankind has only very recently begun measuring the planet. There have been instrumental measurements of ocean temperatures for only around 150 years now. For periods prior to that, scientists have to rely on "proxies", i.e. indicators enabling indirect conclusions to be drawn about climate data from earlier times. Such climate archives generally refer to spatially limited areas and differ in their temporal resolution. They may also include significant "background noise".

"In our study we weren't interested in how warm the climate might have been at time X in a specific region. We wanted to retrospectively analyse how much the regional climate temporally varies over decades to millennia," explains Dr. Thomas Laepple from the Alfred Wegener Institute. "One of our biggest challenges was to make it possible to compare various measured data and climate archives from a wide variety of regions and filter out the natural noise that can greatly distort the signal of climate archives."

Laepple and his colleague Peter Huybers from Harvard University compared data from temperature measurements, corals and sediment cores originating from many different marine regions of the world. Climate data from modern corals date back no more than 400 years. They allow conclusions to be made about temperature changes over decades or centuries. Marine sediments may contain much older data, but generally only achieve a centennial or millennial resolution. Using different calibration and filtering processes, the two researchers succeeded in combining a wide variety of available data from

temperature measurements and climate archives in such a way that they were able to compare the reconstructed sea surface temperature variations at different locations around the globe on different time scales over a period of 7,000 years.

"We initially determined that the natural variations of ocean temperatures are surprisingly large - and the longer the periods we analysed, the greater the variations," was the initial conclusion of the two scientists. Then, in a second step, they studied around 20 climate models in over 100 test runs to ascertain how well the models can simulate these temperature variations. The result: measured and climate archive data closely correspond to model runs for periods of years. Toward longer timescales, however, discrepancies grow - most significantly in tropical marine regions. On a millennial time scale, conventional climate models underestimated the variations of sea surface temperatures reconstructed from climate archives by a factor of 50.

"Fundamentally, there are only two explanations," says Thomas Laepple. "Either the climate archives do not provide reliable temperature data, or the climate models underestimate the variability of the climate. Or both may be true to some extent." The results are based on a number of independent climate archives, as well as instrumental records, and hold up whilst applying a wide range of correction methods, which leads Laepple to believe that the problem lies more with the models.

"We seem to have to revise upward predictions of how much climate can regionally vary," suggests Thomas Laepple, based on his findings. "Given the huge amount of greenhouse gases released into the atmosphere, we can be sure that it is getting warmer globally. But the range of changes we are headed for could well be larger than we have generally expected." This has to do with the fact that the natural variations in combination with the warming trend always point in both directions: over a period of decades or a hundred years temperatures in a

particular region may rise to a lesser or greater degree than present-day climate models generally forecast.

Since this is a central issue for the forecasting of future climatic conditions on the Earth, for about a year now the physicist in Potsdam has been heading an interdisciplinary research group that focuses specifically on this topic. It is called "ECUS - Estimating climate variability by quantifying proxy uncertainty and synthesizing information across archives".

According to Laepple: "We are in the middle of an experiment that we cannot reverse, but which we still don't understand well enough to make clear statements at the regional level on longer time scales. Unfortunately, we will just have to continue to live with this uncertainty for some time."

More information: Thomas Laepple und Peter Huybers: Ocean surface temperature variability: Large model-data differences at decadal and longer periods. *PNAS*, DOI: 10.1073/pnas.1412077111

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