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Ice sheet retreat and forest expansion turned ancient subtropical drylands into oases

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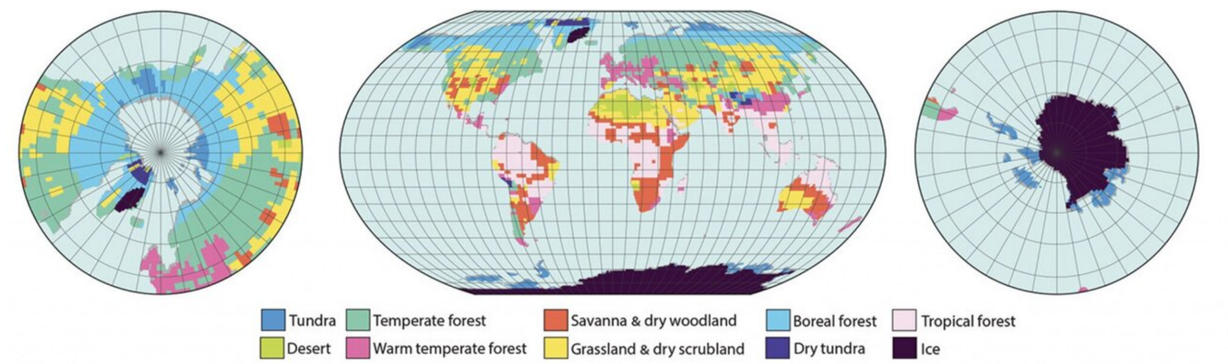

A map showing the biome and ice sheet distribution of the mid-Pliocene. Credit: Ran Feng

As human-caused greenhouse gas emissions continue to rise beyond limits for what our species has experienced, researchers are looking to a mystery in the past to answer questions about what may lay ahead.

This work, published today in *Nature Communications* by an international team of scientists, is part of a project called the 2^{nd} Pliocene Model Intercomparison Project, or PlioMIP2.

The team focused on the climate of the Pliocene, over 3 million years ago, the last time Earth has seen concentrations of over 400 PPM CO_2 in the atmosphere, similar to today's concentrations. The Pliocene prompts a long-standing question, says UConn Department of Geosciences researcher and lead author Ran Feng: despite the similarity to the present-day, why were dry areas like the Sahel in Africa and Northern China much wetter and greener in the Pliocene than they are today?

The Pliocene was warmer than present-day conditions by 2 to 3°C, and everything we know about the physics of the climate system suggests the Pliocene should have been drier in the subtropics, says co-author Tripti Bhattacharya, Thonis Family Professor of Earth and Environmental Sciences at Syracuse University.

"Our paper was motivated by a desire to understand this apparent discrepancy and see whether there are processes that can account for wetter Pliocene subtropics," Bhattacharya says.

The answer, the researchers found, is more complex than simply looking at CO_2.

Evidence from the geologic record—which includes a wide variety of sedimentary and paleobotanical indicators of past climate—show that the Sahel and subtropical Eurasian regions were once home to lusher landscapes with drastically different hydroclimates. Along with proxy data, the team utilized a suite of the latest state-of-the-art model simulations to identify the factors responsible for subtropical rainfall changes in the Pliocene.

Previous studies suggest the only explanation for the Pliocene discrepancy was that there must be some mechanism unaccounted for in models to explain the Pliocene. However, to their surprise, the researchers found that current generation models perform well at simulating wet conditions on Pliocene subtropical continents.

"We discovered the hydroclimate in the dry areas like the Sahel and subtropical East Asia get much wetter when we prescribed vegetation and ice sheet changes in the Pliocene simulations," says Feng.

Feng explains this work is providing a new perspective when studying hydrological cycle responses to CO_2 changes: long-term changes in terrestrial conditions like the shifting range of the biomes and the ice sheets are important.

"Continental greening and ice sheet retreat have profound impacts on the surface temperature through lowering the surface albedo—the ability of the Earth's surface to reflect sunlight back to space—and a profound effect on the hydrological cycle through allowing for greater evaporation and altering paths of moisture transport. In the long run, there's much bigger change in hydrological cycle, compared to what we are anticipating today," says Feng. "Currently, few of these changes is considered when predicting climate conditions for the next 10 years, or next 50 years."

This is cause for concern, says Feng, because changes in the Earth system's hydrological cycle will mean places already receiving excessive amounts of summer rainfall such as Southeastern Asia, Northern India, and West Africa, are going to see even more summer rainfall as continental greening increases and the ice sheets continue to recede.

Additionally, this work redefines the way we see the Pliocene climate, says Bhattacharya. "The other nice takeaway is that the Pliocene does not really challenge our fundamental understanding of the physics of climate. Our study suggests that we do not need exotic physical mechanisms to explain the Pliocene. Rather, we can explain regional patterns of change in aridity by including earth system feedbacks in models and considering the relationship between earth system sensitivity and rainfall changes. This ultimately increases our confidence that models do a good job at simulating the past and can be trusted to provide reliable projections of future climate."

Feng says that when thinking about the long-term health of our planet, we must regard the whole planet as a system, and look at these long-term responses and their wide-ranging impacts.

"For us as a species, we need to have long-term plans, beyond the next several decades. By looking back to past climates and learning what the world was like, we can better prepare for the future of our society."

More information: Ran Feng et al, Past terrestrial hydroclimate sensitivity controlled by Earth system feedbacks, *Nature Communications* (2022). DOI: 10.1038/s41467-022-28814-7

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