More tropical cyclones in past could play role in warmer future

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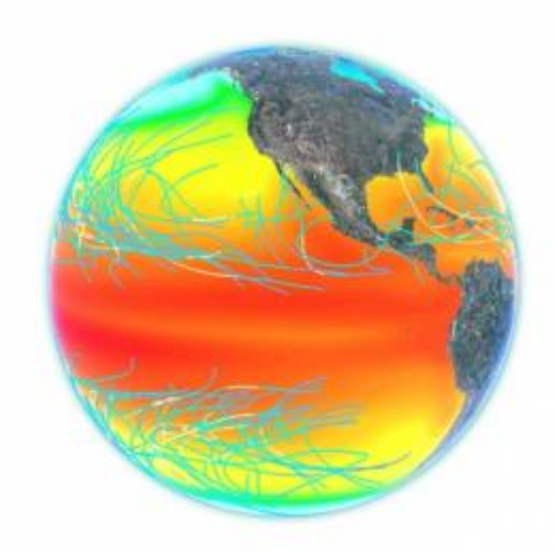

When ocean mixing from hurricanes is included in an early Pliocene global climate model simulation, the number and intensity of hurricanes increases, as well as the warm pool in the Pacific Ocean. Image: Chris Brierley and Google Earth

(PhysOrg.com) -- A question central to research on global warming is how warmer temperatures caused by increased greenhouse gases could influence climate. Probing the past for clues about this potential effect, MIT and Yale climate scientists examined the Pliocene period, which began five million years ago and which some consider to be a potential analog to modern greenhouse conditions.

They found that hurricanes influenced by weakened atmospheric circulation — possibly related to high levels of carbon dioxide — contributed to very warm temperatures in the Pacific Ocean, which in turn led to more frequent and intense hurricanes. The research indicates that Earth's climate may have multiple states based on this feedback cycle, meaning that the climate could change qualitatively in response to the effects of global warming.

Although scientists know that the early Pliocene had carbon dioxide concentrations similar to those of today, it has remained a mystery what caused the high levels of greenhouse gas and how the Pliocene's warm conditions, including an extensive warm pool in the Pacific Ocean and temperatures that were roughly 4 degrees C higher than today's, were maintained.

In a paper published Feb. 25 in *Nature*, Kerry Emanuel, the Breene M. Kerr Professor of Atmospheric Science in the Department of Earth, Atmospheric and Planetary Science, and two colleagues from Yale University's Department of Geology and Geophysics suggest that a positive feedback between tropical cyclones — commonly called hurricanes and typhoons — and the circulation in the Pacific could have been the mechanism that enabled the Pliocene's warm climate.

The Pliocene ended around three million years ago with the onset of large ice sheets in the Northern Hemisphere. There has been a slow reduction in carbon dioxide levels in the atmosphere for about 15 million years, and it is thought that the start of the glacial cycles was the climate's response once those levels reached a certain threshold, according to co-author Chris Brierley. While that level remains unknown, this research indicates that by increasing carbon dioxide levels, humans could reach the threshold that would induce a Pliocene-like climate.

By combining a hurricane model and coupled ocean-atmosphere general circulation model to investigate the early Pliocene, Emanuel, Brierley and co-author Alexey Fedorov observed how vertical ocean mixing by hurricanes near the equator caused shallow parcels of water to heat up and later resurface in the eastern equatorial Pacific as part of the ocean wind-driven circulation. The researchers conclude from this pattern that frequent hurricanes in the central Pacific likely strengthened the warm pool in the eastern equatorial Pacific, which in turn increased hurricane frequency — an interaction described by Emanuel as a "two-way feedback process."

The researchers believe that in addition to creating more hurricanes, the intense hurricane activity likely created a permanent El Niño-like state in which very warm water in the eastern Pacific near the equator extended to higher latitudes. The El Niño weather pattern, which is caused when warm water replaces cold water in the Pacific, can impact the global climate by intermittently altering atmospheric circulation, temperature and precipitation patterns.

The research suggests that Earth's climate system may have at least two states — the one we currently live in that has relatively few tropical cyclones and relatively cold water, including in the eastern part of the Pacific, and the one during the Pliocene that featured warm sea surface temperatures, permanent El Niño conditions and high tropical cyclone activity.

Although the paper does not suggest a direct link with current climate models, Fedorov said it is possible that future global warming could cause Earth to transition into a different equilibrium state that has more hurricanes and permanent El Niño conditions. "So far, there is no evidence in our simulations that this transition is going to occur at least in the next century. However, it's still possible that the condition can occur in the future."

Whether our future world is characterized by a mean state that is more El Niño-like remains one of the most important unanswered questions in climate dynamics, according to Matt Huber, a professor in Purdue University's Department of Earth and Atmospheric Sciences. He praised the research, saying it is the "very specific predictions it makes about how cyclones can warm the eastern equatorial Pacific that is the most unique and exciting."

Reconstructing the Pliocene

To investigate the hurricane activity of the Pliocene, the researchers relied on proxy ocean temperatures based on variations in several chemical tracers in drill cores of the ocean floor. The exact value of these chemical properties is known to correlate well with sea surface temperatures in the modern ocean and are used as proxies for past temperatures. Using these proxy temperatures, the researchers reconstructed the global distribution of sea surface temperatures. They then plugged these sea surface temperatures into an ocean-atmosphere general circulation model, which is a computer-based mathematical model used for climate forecasting, to determine the Pliocene's

atmospheric conditions. This showed that the early Pliocene had a weakened atmospheric circulation, and therefore, reduced vertical wind shear, which is favorable for tropical cyclone growth.

Next, Emanuel entered data from the large-scale climate model of the Pliocene into a Statistical DownScaling Model (SDSM), which is software used to derive regional climate information, such as hurricane activity, based on global climate data. By producing synthetic hurricane tracks with the SDSM, researchers can study the effects of hurricanes on ocean temperatures in different regions.

Their observations included nearly twice the number of tropical cyclones than occur in our current climate system, including storms with lifespans that averaged two to three days longer than our current system. The hurricanes appeared in places, such as Hawaii, that differ from where they typically occur today, and also occurred throughout the seasons.

The researchers traced this storm activity to the expansion of the warm pool in the eastern equatorial Pacific that resulted from resurfaced parcels of warm water created by the hurricanes — essentially, both the cause and effect of the observed increased tropical cyclones.

Fine-tuning the theory

Additional research will focus on why the Pliocene was so warm at higher latitudes, including an iceless North Pole, and whether this resulted from moisture produced by the tropical cyclones, Fedorov said.

Brierley hopes to develop an interactive model to strengthen the group's theory. Rather than examining individual components, such as sea surface temperatures, and then imposing that data onto a model to figure out potential ocean mixing and hurricane activity, the researchers would like to include everything in the same interactive model.

Resolving other issues, such as how to more precisely estimate the contribution of tropical cyclones to ocean mixing, will not only help improve the early Pliocene climate model, but also help predict future climate change for which the feedback between hurricanes and the ocean circulation could be crucial.

Provided by MIT