Absence of clouds caused pre-human supergreenhouse periods

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In a world without human-produced pollution, biological productivity controls cloud formation and may be the lever that caused supergreenhouse episodes during the Cetaceous and Eocene, according to Penn State paleoclimatologists.

"Our motivation was the inability of climate models to reproduce the climate of the supergreenhouse episodes of the Cetaceous and Eocene adequately," said Lee R. Kump, professor of geosciences. "People have tried increasing carbon dioxide in the models to explain the warming, but there are limits to the amounts that can be added because the existing proxies for carbon dioxide do not show such large amounts."

In general, the proxies indicate that the Cretaceious and Eocene atmosphere never exceeded four times the current carbon dioxide level, which is not enough for the models to create supergreenhouse conditions. Some researchers have tried increasing the amount of methane, another greenhouse gas, but there are no proxies for methane. Another approach is to assume that ocean currents changed, but while researchers can insert new current information into the models, they cannot get the models to create these ocean current scenarios.

Kump and David Pollard, senior research associate, Earth and Environmental Systems Institute, looked for another way to create a world where mean annual temperatures in the tropics were above 100 degrees Fahrenheit and polar temperatures were in the 50-degree Fahrenheit range. Changing the Earth's albedo -- the amount of sunlight reflected into space – by changing cloud cover will produce supergreenhouse events, the researchers report in today's issue of *Science*.

According to the researchers, changes in the production of cloud condensation nuclei, the tiny particles around which water condenses to form rain drops and cloud droplets, decreased Earth's cloud cover and increase the sun's warming effect during supergreenhouse events.

Normal cloud cover reflects about 30 percent of the sun's energy back into space. Kump and Pollard were looking for a scenario that allowed in 6 to 10 percent more sunlight.

"In today's world, human generated aerosols, pollutants, serve as cloud condensation nuclei," says Kump. "Biologically generated gases are dominant in the prehuman world. The abundance of these gases is correlated with the productivity of the oceans."

Today, the air contains about 1,000 particles that can serve as cloud condensation nuclei (CCN) in a cubic centimeter (less than a tenth of a cubic inch). Pristine ocean areas lacking human produced aerosols are difficult to find, but in those areas algae produce dimethylsulfide that eventually becomes the CCNs of sulfuric acid or methane sulfonic acid.

Algae's productivity depends on the amounts of nutrients in the water and these nutrients come to the surface by upwelling driven by the winds. Warming would lead to ocean stratification and less upwelling.

"The Cetaceous was biologically unproductive due to less upwelling in the ocean and thermal stress on land and in the sea," says Kump. "That means fewer cloud condensation nuclei."

When there are large numbers of CCN, there are more cloud droplets and smaller droplets, consequently more cloud cover and brighter clouds. With fewer CCN, there are fewer droplets and they are larger. The limit to droplet size is 16 to 20 microns because the droplets then are heavy enough to fall out as rain.

"We began with the assumption that what would change was not the extent of clouds, but their brightness," says Kump. "The mechanism would lead to reduced reflection but not cloudiness."

What they found was that the clouds were less bright and that there were also fewer clouds. If they lowered the production of biogenic CCNs too much, their model created a world with remarkable warming inconsistent with life. However, they could alter the productivity in the model to recreate the temperature regime during supergreenhouse events.

"The model reduces cloud cover from about 64 percent to 55 percent which lets in a large amount of direct sunlight," Kump says. "The increased breaks in the clouds, fewer clouds and less reflective clouds produced the amount of warming we were looking for."

Source: Penn State

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