The physics of climate change was described in the 1800s by scientist Eunice Foote

July 23 2021, by Sylvia G. Dee

Eunice Foote described the greenhouse gas effects of carbon dioxide in 1856. Credit: Carlyn Iverson/NOAA Climate.gov

Long before the current political divide over climate change, and even before the U.S. Civil War (1861-1865), an American scientist named Eunice Foote documented the underlying cause of today's climate change crisis.

The year was 1856. Foote's brief scientific paper was the first to describe the extraordinary power of carbon dioxide gas to absorb

heat—the driving force of global warming.

Carbon dioxide is an odorless, tasteless, transparent gas that forms when people burn fuels, including coal, oil, gasoline and wood.

As Earth's surface heats, one might think that the heat would just radiate back into space. But, it's not that simple. The atmosphere stays hotter than expected mainly due to greenhouse gases such as carbon dioxide, methane and atmospheric water vapor, which all absorb outgoing heat. They're called "greenhouse gases" because, not unlike the glass of a greenhouse, they trap heat in Earth's atmosphere and radiate it back to the planet's surface. The idea that the atmosphere trapped heat was known, but not the cause.

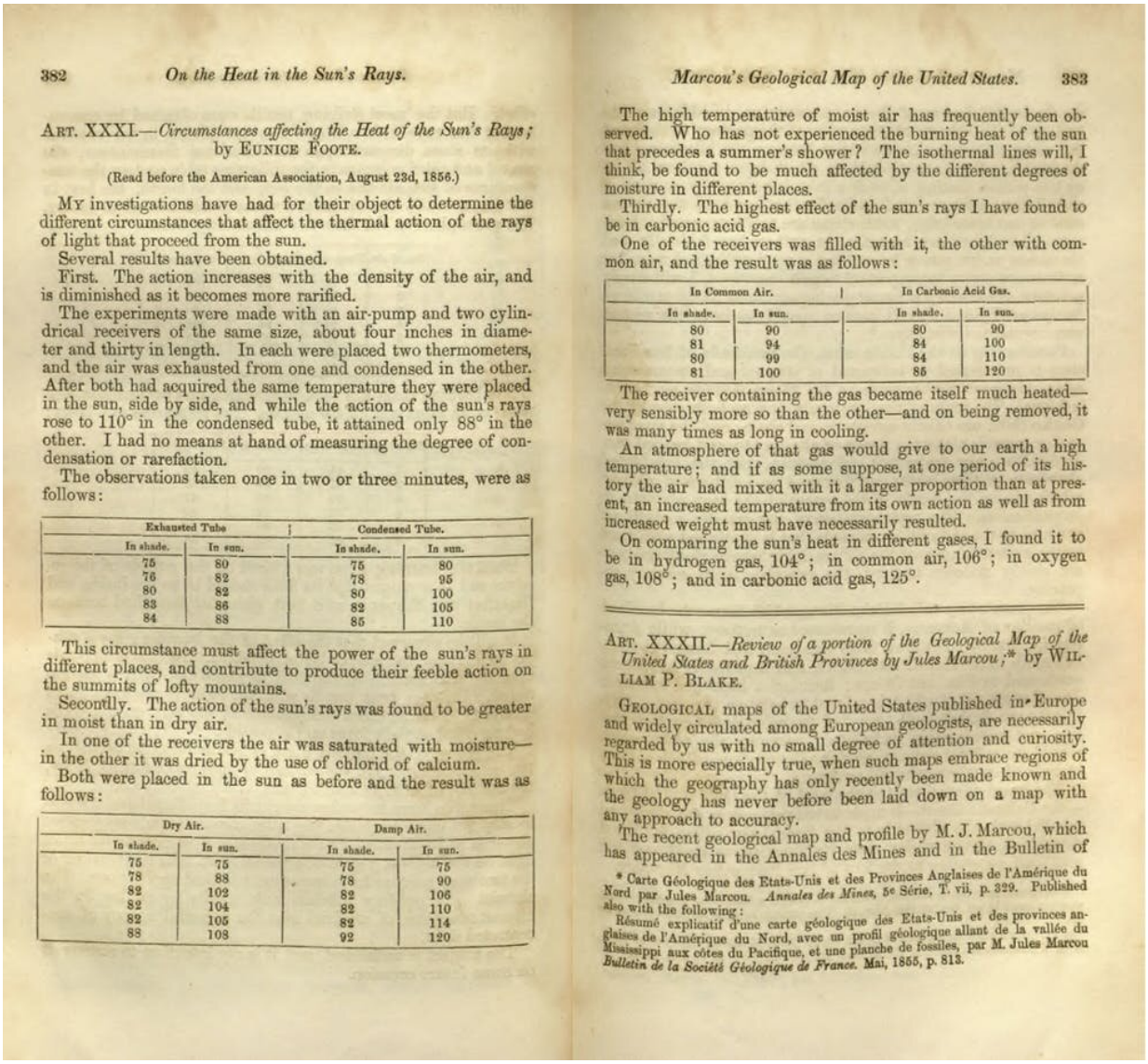
Foote conducted a simple experiment. She put a thermometer in each of two glass cylinders, pumped carbon dioxide gas into one and air into the other and set the cylinders in the Sun. The cylinder containing carbon dioxide got much hotter than the one with air, and Foote realized that carbon dioxide would strongly absorb heat in the atmosphere.

Foote's discovery of the high heat absorption of carbon dioxide gas led her to conclude that "… if the air had mixed with it a higher proportion of carbon dioxide than at present, an increased temperature" would result.

A few years later, in 1861, the well-known Irish scientist John Tyndall also measured the heat absorption of carbon dioxide and was so surprised that something "so transparent to light" could so strongly absorb heat that he "made several hundred experiments with this single substance."

Tyndall also recognized the possible effects on the climate, saying "every variation" of water vapor or carbon dioxide "must produce a change of

climate." He also noted the contribution other hydrocarbon gases, such as methane, could make to climate change, writing that "an almost inappreciable addition" of gases like methane would have "great effects on climate."



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ART. XXXI.—*Circumstances affecting the Heat of the Sun's Rays;* by EUNICE FOOTE.

(Read before the American Association, August 23d, 1856.)

MY investigations have had for their object to determine the different circumstances that affect the thermal action of the rays of light that proceed from the sun.

Several results have been obtained.

First. The action increases with the density of the air, and is diminished as it becomes more rarified.

The experiments were made with an air-pump and two cylindrical receivers of the same size, about four inches in diameter and thirty in length. In each were placed two thermometers, and the air was exhausted from one and condensed in the other. After both had acquired the same temperature they were placed in the sun, side by side, and while the action of the sun's rays rose to 110° in the condensed tube, it attained only 88° in the other. I had no means at hand of measuring the degree of condensation or rarefaction.

The observations taken once in two or three minutes, were as follows:

Exhausted Tube		Condensed Tube.	
In shade.	In sun.	In shade.	In sun.
75	80	75	80
76	82	78	95
80	82	80	100
83	86	82	105
84	88	85	110

This circumstance must affect the power of the sun's rays in different places, and contribute to produce their feeble action on the summits of lofty mountains.

Secondly. The action of the sun's rays was found to be greater in moist than in dry air.

In one of the receivers the air was saturated with moisture—in the other it was dried by the use of chlorid of calcium.

Both were placed in the sun as before and the result was as follows:

Dry Air.		Damp Air.	
In shade.	In sun.	In shade.	In sun.
75	75	75	75
78	88	78	90
82	102	82	106
82	104	82	110
82	105	82	114
88	108	92	120

Marcou's Geological Map of the United States. 383

The high temperature of moist air has frequently been observed. Who has not experienced the burning heat of the sun that precedes a summer's shower? The isothermal lines will, I think, be found to be much affected by the different degrees of moisture in different places.

Thirdly. The highest effect of the sun's rays I have found to be in carbonic acid gas.

One of the receivers was filled with it, the other with common air, and the result was as follows:

In Common Air.		In Carbonic Acid Gas.	
In shade.	In sun.	In shade.	In sun.
80	90	80	90
81	94	84	100
80	99	84	110
81	100	85	120

The receiver containing the gas became itself much heated—very sensibly more so than the other—and on being removed, it was many times as long in cooling.

An atmosphere of that gas would give to our earth a high temperature; and if as some suppose, at one period of its history the air had mixed with it a larger proportion than at present, an increased temperature from its own action as well as from increased weight must have necessarily resulted.

On comparing the sun's heat in different gases, I found it to be in hydrogen gas, 104°; in common air, 106°; in oxygen gas, 108°; and in carbonic acid gas, 125°.

ART. XXXII.—*Review of a portion of the Geological Map of the United States and British Provinces by Jules Marcou;** by WILLIAM P. BLAKE.

GEOLOGICAL maps of the United States published in Europe and widely circulated among European geologists, are necessarily regarded by us with no small degree of attention and curiosity. This is more especially true, when such maps embrace regions of which the geography has only recently been made known and the geology has never before been laid down on a map with any approach to accuracy.

The recent geological map and profile by M. J. Marcou, which has appeared in the Annales des Mines and in the Bulletin of

* Carte Géologique des Etats-Unis et des Provinces Anglaises de l'Amérique du Nord par Jules Marcou. *Annales des Mines*, 5e Série, T. vii, p. 329. Published also with the following:

Résumé explicatif d'une carte géologique des Etats-Unis et des provinces anglaises de l'Amérique du Nord, avec un profil géologique allant de la vallée du Mississippi aux côtes du Pacifique, et une planche de fossiles, par M. Jules Marcou *Bulletin de la Société Géologique de France*. Mai, 1855, p. 813.

Eunice Foote's paper in the American Journal of Science and Arts. Credit: Royal Society

Humans were already increasing carbon dioxide in the 1800s

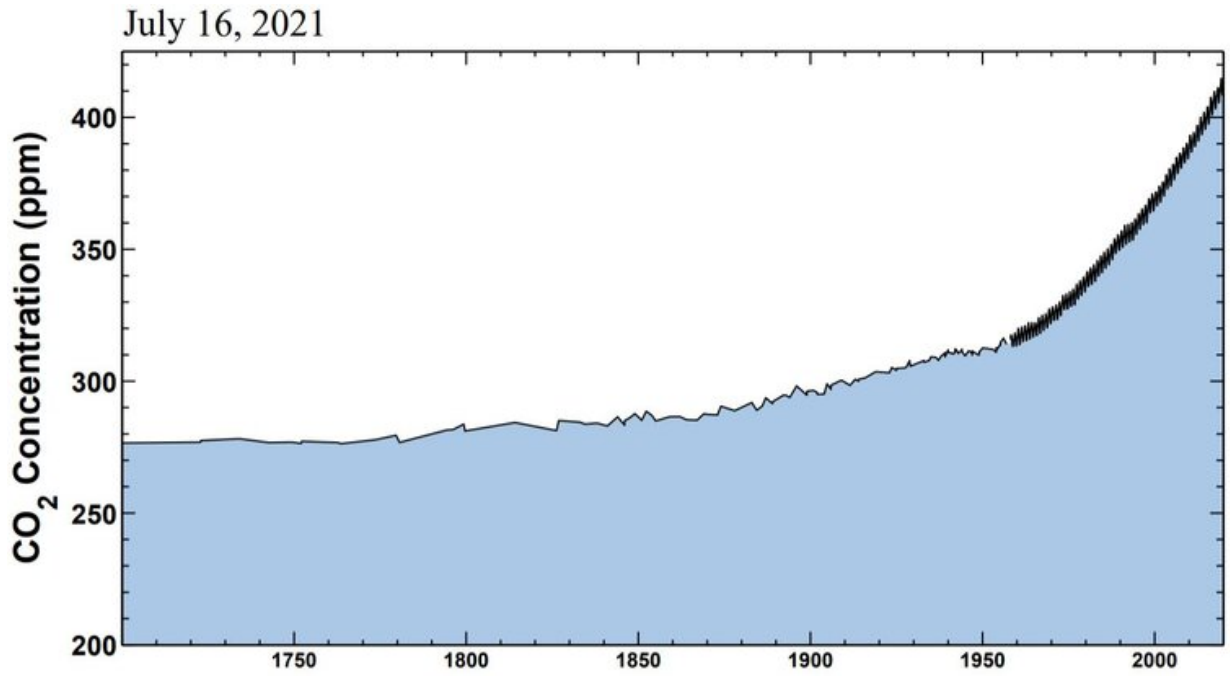
By the 1800s, human activities were already dramatically increasing the carbon dioxide in the atmosphere. Burning more and more fossil fuels—coal and eventually oil and gas—added an ever-increasing amount of carbon dioxide into the air.

The first quantitative estimate of carbon dioxide-induced climate change was made by Svante Arrhenius, a Swedish scientist and Nobel laureate. In 1896, he calculated that "the temperature in the Arctic regions would rise 8 or 9 degrees Celsius if carbon dioxide increased to 2.5 or 3 times" its level at that time. Arrhenius' estimate was likely conservative: Since 1900 atmospheric carbon dioxide has risen from about 300 parts per million to around 417 ppm as a result of human activities, and the Arctic has already warmed by about 3.8 C (6.8 F).

Nils Ekholm, a Swedish meteorologist, agreed, writing in 1901 that "The present burning of pit-coal is so great that if it continues … it must undoubtedly cause a very obvious rise in the mean temperature of the earth." Ekholm also noted that carbon dioxide acted in a layer high in the atmosphere, above water vapor layers, where small amounts of carbon dioxide mattered.

All of this was understood well over a century ago.

Initially, scientists thought a possible small rise in the Earth's temperature could be a benefit, but these scientists could not envision the coming huge increases in fossil fuel use. In 1937, English engineer Guy Callendar documented how rising temperatures correlated with rising carbon dioxide levels. "By fuel combustion, man has added about 150,000 million tons of carbon dioxide to the air during the past half century," he wrote, and "world temperatures have actually increased …."



The Keeling curve tracks the changing carbon dioxide concentration in the atmosphere. Observations from Hawaii starting in 1958 show the rise and fall of the seasons as concentrations climb. Credit: Scripps Institution of Oceanography

A warning to the president in 1965, and then …

In 1965, scientists warned U.S. President Lyndon Johnson about the growing climate risk, concluding: "Man is unwittingly conducting a vast geophysical experiment. Within a few generations he is burning the fossil fuels that slowly accumulated in the earth over the past 500 million years." The scientists issued clear warnings of high temperatures, melting ice caps, rising sea levels and acidification of ocean waters.

In the half-century that has followed that warning, more of the ice has melted, sea level has risen further and acidification due to ever

increasing absorption of carbon dioxide forming carbonic acid has become a critical problem for ocean-dwelling organisms.

Scientific research has vastly strengthened the conclusion that human-generated emissions from the burning of fossil fuels are causing dangerous warming of the climate and a host of harmful effects. Politicians, however, have been slow to respond. Some follow an approach that has been used by some fossil fuel companies of denying and casting doubt on the truth, while others want to "wait and see," despite the overwhelming evidence that harm and costs will continue to rise.

In fact, reality is now fast overtaking scientific models. The megadrought and heat waves in the western U.S., record high temperatures and zombie fires in Siberia, massive wildfires in Australia and the U.S. West, relentless, intense Gulf Coast and European rains and more powerful hurricanes are all harbingers of increasing climate disruption.

The world has known about the warming risk posed by excessive levels of carbon dioxide for decades, even before the invention of cars or coal-fired power stations. A rare female scientist in her time, Eunice Foote, explicitly warned about the basic science 165 years ago. Why haven't we listened more closely?

Provided by The Conversation

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