The Climate Question Isn't as Simple as It Sounds

By Howard "Cork" Hayden

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In 1980, if you asked a scientist about climate change, the answer would have been almost trivial. Of course, the climate changes. It always has, and it always will. Ice ages came and went, Greenland once supported Viking farms, and ecosystems shifted long before humans had any measurable influence. To say climate change is real would have been like saying water is wet.

Somewhere along the way, that simple idea was transformed into something very different. Today, climate change is no longer just a description of a changing climate. It has come to mean a problem to be controlled, and more specifically, a problem attributed largely to human activity and carbon dioxide. That shift in meaning has had profound consequences, not only for public discussion, but for how the science itself is presented.

To understand what is actually going on, it helps to step back and look at the basic physics. The Earth is governed by a simple energy balance. Energy arrives from the Sun, some of it is reflected back into space, and the rest is absorbed and eventually radiated away as heat. If more energy comes in than leaves, the planet warms. If more leaves than comes in, it cools. There are only three quantities that matter: the incoming solar radiation, the fraction reflected, known as the albedo, and the infrared radiation escaping to space.

If someone wanted to control the climate, those are the only three levers available. You could change the sunlight reaching Earth, alter how reflective the planet is by increasing clouds, ice, or atmospheric particles, or interfere with the infrared radiation leaving the planet. Everything else, storms, ocean currents, droughts, and floods, may be dramatic, but they are internal processes. They matter only to the extent that they affect one of those three quantities.

The modern discussion focuses almost entirely on the third factor, infrared radiation, and the so-called greenhouse effect. The surface of the Earth emits infrared radiation continuously, but the atmosphere does not simply let it pass. Certain gases, especially water vapor and carbon dioxide, absorb and re-emit that radiation. This process reduces the amount of heat that escapes directly to space.

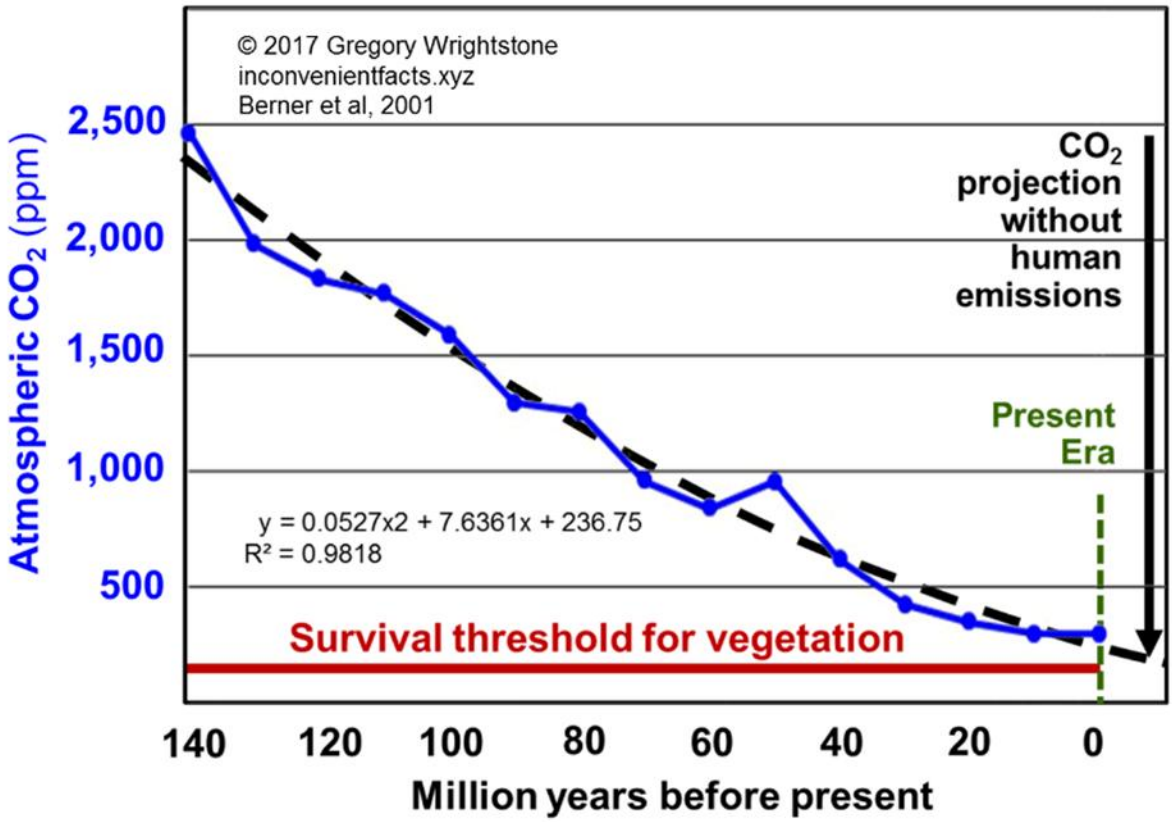
But the greenhouse effect is often described far too simply. It is not a uniform blanket trapping heat. It is a highly selective process, operating wavelength by wavelength. The Earth emits a smooth spectrum of infrared radiation, but what actually escapes to space is uneven, with portions removed or altered by interactions with specific gases.

Even familiar experiences hint at how these processes work. When you pump air into a bicycle tire, the pump becomes warm, not because of pressure alone, but because of compression. Similarly, air descending from mountains warms as it is compressed. These are basic physical processes, yet they are rarely part of the public conversation about climate.

Carbon dioxide, the centerpiece of modern climate concern, is present in surprisingly small amounts, about 400 molecules per million in the atmosphere. That number can sound insignificant, **yet all** [complex] **life on earth depends on that tiny amount of CO_2; without it, photosynthesis cannot happen.** Some climate scientists often treated it as the primary driver of global temperature. To understand its role, it helps to place it in a longer historical context.

Over the vast history of the Earth, carbon dioxide levels have varied enormously. Roughly 170 million years ago, atmospheric CO_2 concentrations were on the order of 2,500 parts per million, far higher than today. During the most recent ice age, about 18,000 years ago, levels dropped to around 180 parts per million. Below about 150 parts per million, plant life begins to struggle to survive.

Fig I-12: The dangerous 140-million-year decline in CO2

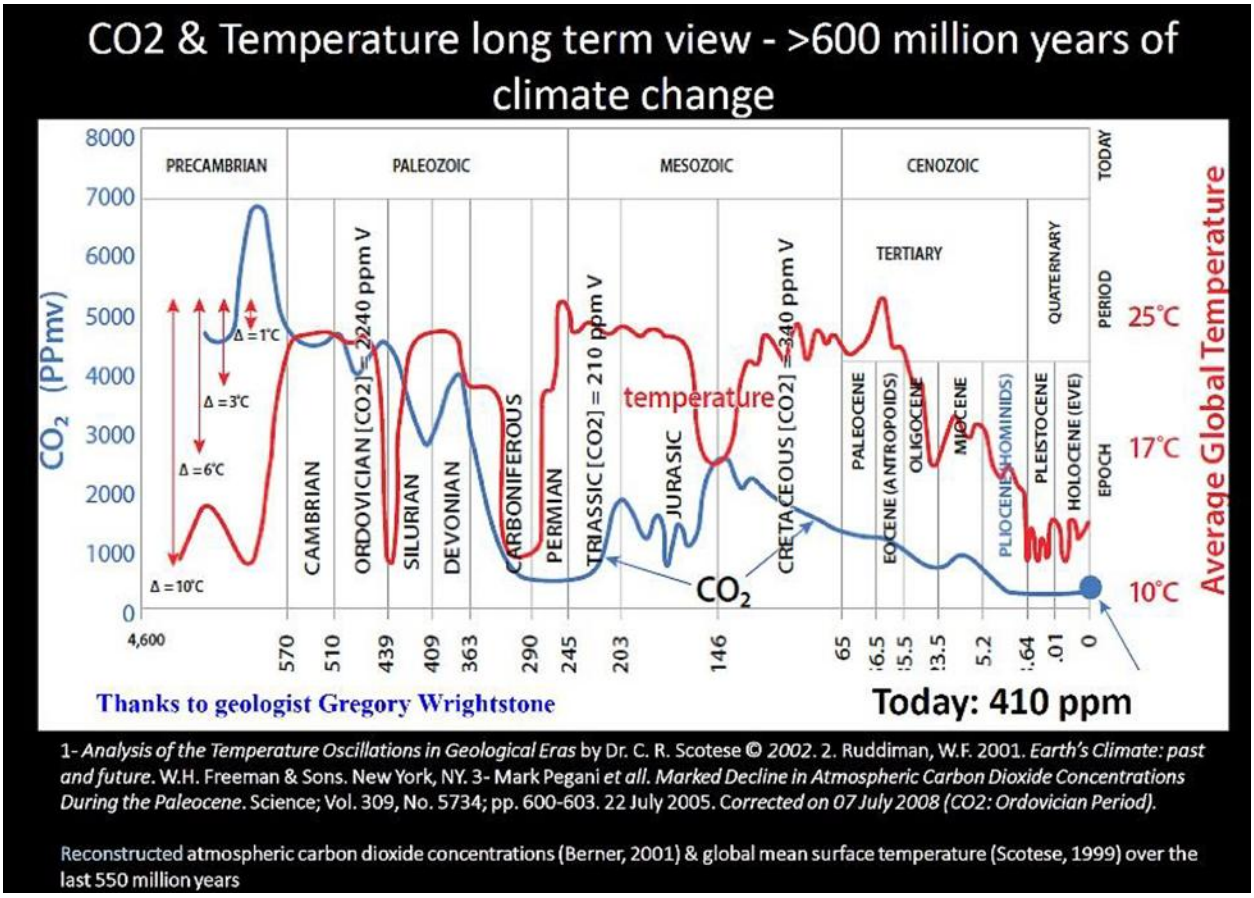


Berner RA, Kothavala Z (2001) GEOCARB III: A revised model of atmospheric CO2 over Phanerozoic time, IGBP PAGES and World Data Center for Paleoclimatology, Data Contribution Series # 2002-051. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

Long term decline in atmospheric CO_2 over the past 140 million years

These long-term trends show that present day levels are not unusually high in geological terms. In fact, they are relatively modest compared to much of Earth's past, and closer to the lower boundary required for plant life than to historical highs.

This raises an important question. If carbon dioxide alone were the dominant control on temperature, one might expect a clear and consistent relationship between its concentration and climate. Yet the evidence is more complicated.



Reconstructed atmospheric CO_2 and global temperature over hundreds of millions of years.

Over long periods of Earth's history, the relationship between carbon dioxide and temperature is not consistent. There are intervals where the two rise and fall together, but there are also long stretches where they diverge. This suggests that carbon dioxide is part of the system, but not necessarily its controlling factor.

One such factor is albedo, the reflectivity of the planet, and it is here that the discussion becomes particularly important. Albedo determines how much of the Sun's energy is reflected back into space before it ever reaches the surface. Bright surfaces such as clouds, snow, and ice reflect large amounts of sunlight, while darker surfaces absorb it. A change in albedo is therefore not subtle. It directly alters how much energy the Earth retains.

Consider a simple example. If cloud cover decreases slightly, more sunlight reaches the surface. That additional energy must go somewhere. It warms the land, the oceans, and eventually the atmosphere. Unlike the greenhouse effect, which works indirectly by slowing the escape of heat, a change in albedo affects how much energy enters the system in the first place.

Observations in recent decades suggest that changes in absorbed solar radiation, particularly those associated with cloud cover, may play a significant role in warming. In this view, the planet is warming not primarily because it is failing to shed heat, but because it is absorbing more energy to begin with.

Over longer timescales, albedo has played an even more dramatic role. Ice ages are closely tied to changes in reflectivity. Expanding ice sheets reflect more sunlight and reinforce cooling, while melting ice reduces reflectivity and promotes warming. These feedbacks can amplify relatively small changes into large shifts in climate. **Over the last million years or so, orbital changes have increased and decreased the amount of sunlight reaching the earth, in particular the far-northern latitudes. The temperatures correspondingly changed, and then the amount of carbon dioxide changed.**

For every increase in the amount of carbon dioxide in the atmosphere, there is an increase in the amount of infrared that the gas can inhibit from going to space. For every increment in the surface temperature, there is an increase in the amount of infrared that the surface emits. The "most probable" climate models predict temperature increases that would emit almost five times as much infrared as the increase in carbon dioxide could retain on the planet. However, no climate model ever published has accounted for that increase in infrared emitted by the surface.

The climate system is not governed by a single control. It is a complex interplay of factors. How much energy arrives, how much is reflected, and how efficiently heat escapes all play a role. Carbon dioxide is part of that system, but it is clearly not the whole story.

Think of the colors of a rainbow. Although we cannot see infrared radiation, it has its own "colors," for which we can measure the wavelengths. The greenhouse effect is all about the interaction between greenhouse gas molecules and infrared radiation on a wavelength-by-wavelength basis. Read every word in every IPCC Assessment Report, and you will find no reference whatsoever to that spectrum. You will find no calculations about how that wavelength is absorbed — or emitted — by that greenhouse gas.

Climate does change. It always has. The real question is not whether it changes, but why, and whether we truly understand all the factors involved. Answering that question requires careful attention to the underlying physics and a willingness to consider the full complexity of the system.