

## **The Earth's Deadly Global Warming Feedback Loop**

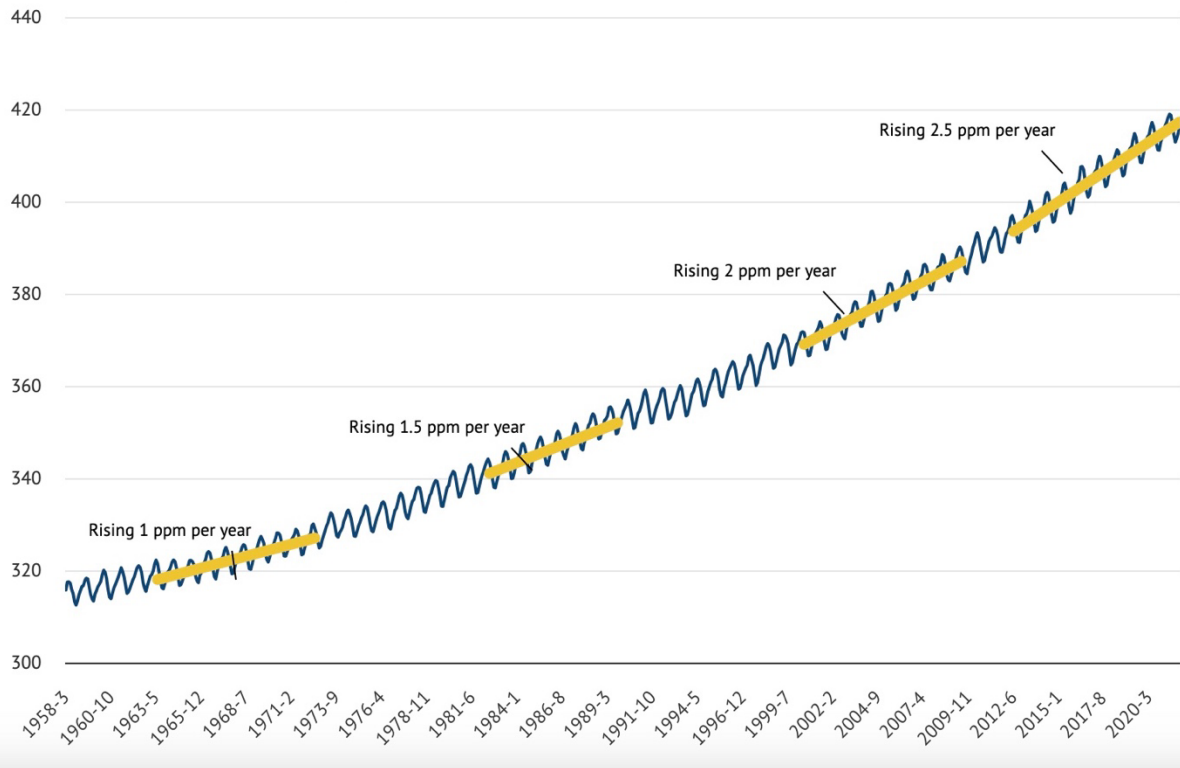
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The purpose of this article is to bring to public's awareness some scientific observations that are rarely highlighted in the current climate change discussions but have multiple profound societal and political implications. First, the observations.

*1. The rate of increase in CO<sub>2</sub> into the atmosphere is increasing.* Based on the Keeling Curve, not only is the level of atmospheric CO<sub>2</sub> continuing to increase, as would be expected until emissions get to net zero, but the rate of this increase is also progressively increasing. The Keeling Curve is produced by the daily monitoring of atmospheric CO<sub>2</sub> levels based on instruments set up on Hawaii's Mauna Loa Mountain in 1958 by David Keeling. Following his death in 2005, his son Dr. Ralph Keeling of Scripps Oceanographic Institute, continued the CO<sub>2</sub> monitoring. Figure 1 shows some remarkable recent results.

## The build-up of CO<sub>2</sub> in the air has been accelerating

Atmospheric CO<sub>2</sub> concentration (parts per million, ppm)



Data from Scripps Institution of Oceanography at UC San Diego. Permission from Creative Commons licenses. Chart by Joe Goodman for Carbon Brief. (Betts R. et al. 2022, How the Keeling curve will need to bend to limit global warming to 1.5°C? *Carbon Brief*).

This shows that instead of decreasing, both the amount of CO<sub>2</sub> and the rate of accumulation of CO<sub>2</sub> were increasing. For example, the following shows the rates of increase in parts per million from 1967 to 2023. The rate

in 1967 was 1.0 ppm/year,  
in 1987 was 1.5 ppm/year,  
in 2007 was 2.0 ppm/year,  
in 2017 was 2.5 ppm/year, and  
in 2023 was 2.8 ppm/yr.

Until emissions approach zero, no one expected the amount of CO<sub>2</sub> in the atmosphere to decrease. But it is very disturbing to see that the rate of increase in the level of atmospheric CO<sub>2</sub> has also been progressively increasing since 1958.

Keeling's group recently published plots that also showed an increase in the rate of increase in atmospheric CO<sub>2</sub> levels over time. These results (Figure 2) were based on the variable Atmospheric Growth Rate (AGR) measured in gigatons carbon per year.

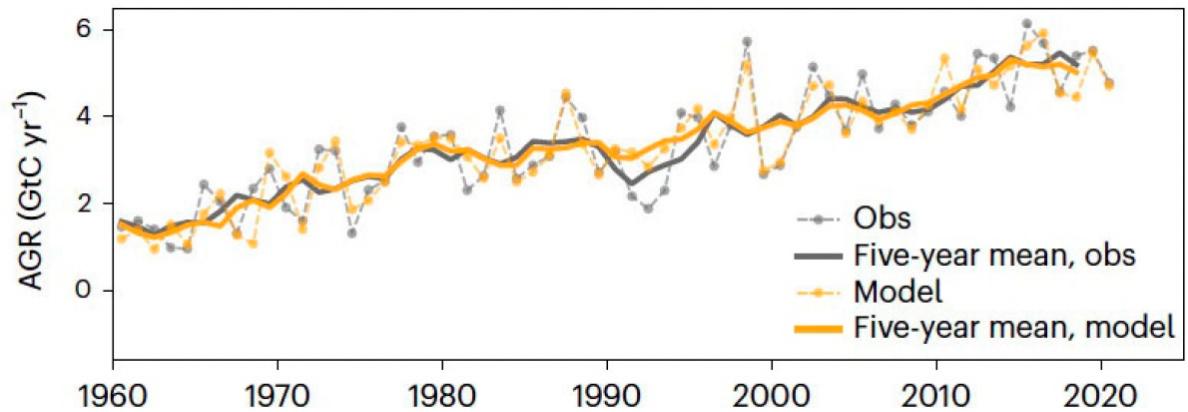


Figure 2. AGR from 1960 to 2020. Permission from creative commons licenses. (Birner B. et al 2023, Surprising stability of recent global carbon cycling enables improved fossil fuel emission verification. *Nat Clim Change* **13**:961-966.).

This showed that the rate of increase in atmospheric CO<sub>2</sub> progressively increased from 1.8 Gigatons Carbon/year (GtC/yr) in 1960 to 5 GtC/year in 2020. These results were consistent with those in Figure 1.

I found these results so disturbing that I wrote a paper suggesting an explanation for the increase in the rates of accumulation of CO<sub>2</sub> (Comings, D.E. 2024, *Is the Earth Now in A Multifactorial CO<sub>2</sub> Tipping Point. The Case for More Aggressive Carbon Dioxide Removal. J. Environmental and Occupational Health.* **12**:1-12). I proposed that the high levels of greenhouse gases in the atmosphere were triggering several additional non-fossil fuel sources of CO<sub>2</sub>. These included the massive forest fires throughout the world in temperate regions, the forest fires in the boreal regions, the burning of peat, deforestation, outgassing CO<sub>2</sub> from the oceans, rivers and soil, the loss of albedo due to melting polar glaciers, the melting of the permafrost, the earth's heat imbalance, die off of phytoplankton,

and others. While I still believe these are contributing to the progressive increase in the rate of accumulation of CO<sub>2</sub> into the atmosphere, as I became more aware of the earth's massive heat imbalance, I realized this was probably the major contributor.

*2. The level of the earth's heat imbalance is enormous and increasing.* The earth's heat imbalance refers to the ratio of the amount of sun's heat irradiation retained by the earth versus the amount of the sun's heat irradiation reflected back into space. Ninety percent of this heat retained is adsorbed by the oceans. Nuccitelli (2022, *Bulletin of Atomic Scientists*) calculated that the magnitude of this imbalance was equivalent to 432,000 Hiroshima type atom bombs going off in the ocean every day.

This heat imbalance is caused by two things. The major contributor is the effect of greenhouse gases such as CO<sub>2</sub> and methane in trapping the sun's heat irradiation in the earth. A second contributor is the loss of albedo due to the melting of polar glaciers and sea ice. Albedo refers to the reflection of incoming heat irradiation back into space. Glaciers and sea ice have an albedo of 70 to 90 percent, while ice free water and soil have an albedo of only 6 to 15 percent. The albedo of the whole earth is 30 percent. Clearly as glaciers and sea ice melt, the albedo significantly decreases.

Not surprisingly dumping this much heat into the ocean, heats the ocean. Currently this heat anomaly is at a level of 200 zettajoules. One zettajoule is a 1 followed by 21 zeros, i.e. 1000000000000000000000. Since this forms a positive feedback loop (see below) it would not be surprising that this heat anomaly is progressively increasing. When measured in terms of watts per square meter, it has in fact increased from 0.42 in 1972 to 1993, to 0.87 in 2004 to 2010, and to 0.96 in 2011 to 2024.

According to NOAA the global ocean temperatures have increased by 2.8°F since 1901. This is an average including night and day, the different seasons and different latitudes. Locally it is a different story. For example, in 2023 the temperature off the coast of Florida exceeded 100°F. This is equivalent to the temperature of a hot tub.

3. *Oceans contain 50 times more CO<sub>2</sub> than the atmosphere.* Carbon dioxide in the ocean is present in three forms, dissolved gas (CO<sub>2</sub> g), bicarbonate ions (HCO<sub>3</sub><sup>-</sup>) and carbonate ions (CO<sub>3</sub><sup>2-</sup>). These three combined are termed Dissolved Inorganic Carbon (DIC). At a level of around 38,000 gigatons (Gt) of carbon the ocean contains 16 times as much carbon as the terrestrial biosphere, that is all plant and the underlying soils on our planet. The oceans currently hold 50 times more CO<sub>2</sub> than the atmosphere (Ravin, J.A. and Falkowski, P.G. 1999, Oceanic sinks for atmospheric CO<sub>2</sub>. *Plant, Cell and Environment*. 22:741-755.)

4. *The warmer the ocean temperature the less CO<sub>2</sub> it can contain.* This is well illustrated by the following diagram showing the solubility of CO<sub>2</sub> in water at different temperatures.

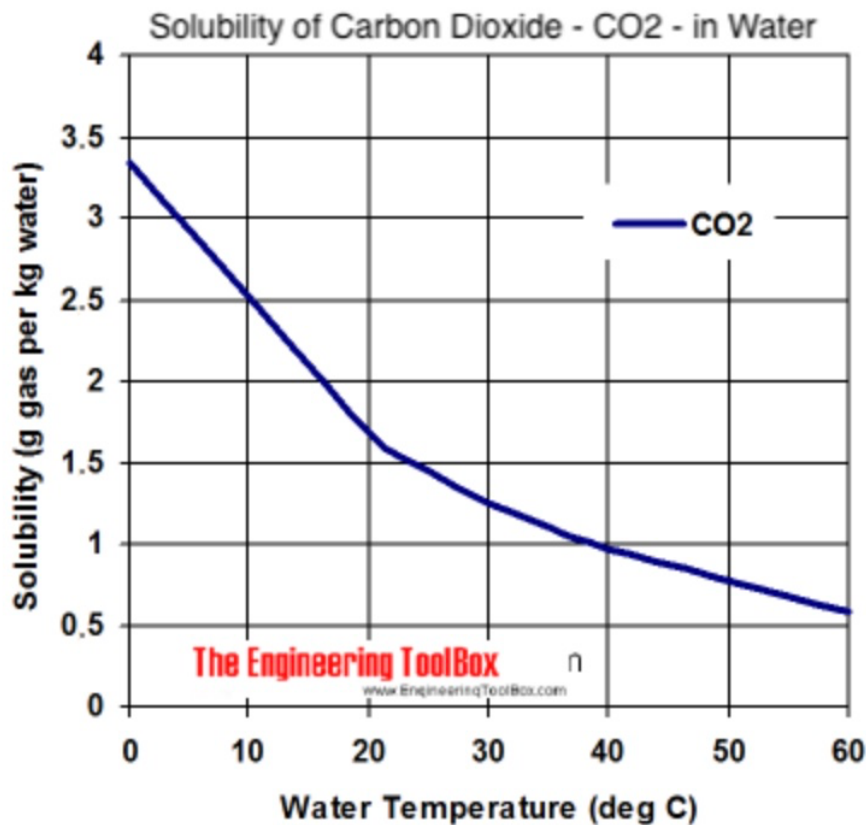


Figure 3. [www.TheEngineeringToolBox.com](http://www.TheEngineeringToolBox.com).

As the temperature of the water increases the solubility of CO<sub>2</sub> decreases. Thus, as the ocean temperature increases it will release larger and larger amounts of its stored CO<sub>2</sub> back into the atmosphere. (See Figure 4.)

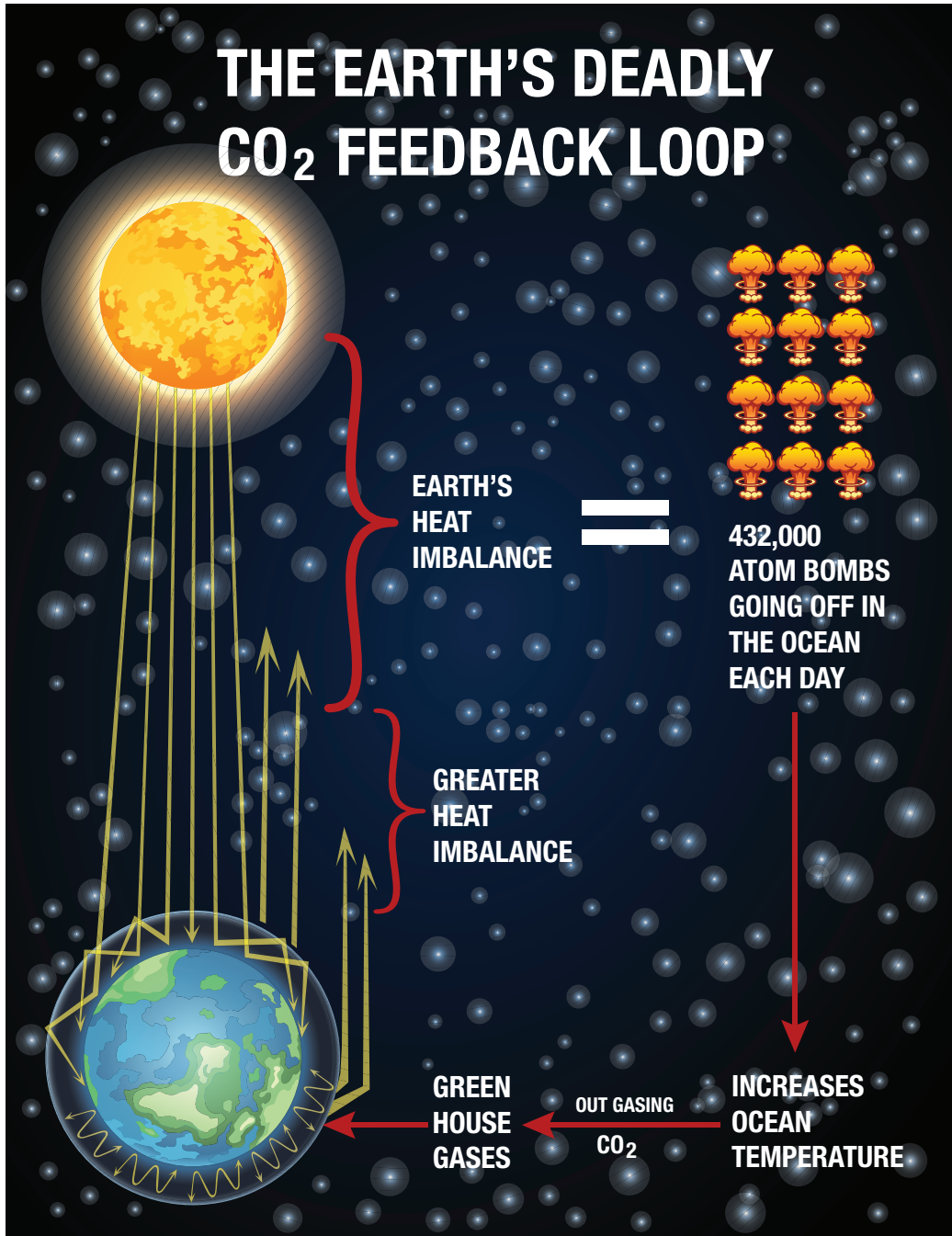


Figure 4. A positive CO<sub>2</sub> feedback loop by which the massive level of the earth's heat imbalance heats the ocean causing it to release its stored CO<sub>2</sub> which in turn increases the level of greenhouse gases resulting in a further increase in the earth's heat imbalance.

*What are the implications of this?* There are many.

*First*, attaining Net Zero in fossil fuel emissions would slow the accumulation of CO<sub>2</sub> in the atmosphere and help to prevent further increases in the earth's heat imbalance, but it will not significantly decrease the current level of that heat imbalance because the carbon dioxide causing the greenhouse effect stays in the atmosphere for hundreds to thousands of years.

*Second*, the only effective method of decreasing this greenhouse effect is to remove the CO<sub>2</sub> and safely sequester it. This is called CDR or Carbon Dioxide Removal. The level of CO<sub>2</sub> in the atmosphere in 2023 was 420 ppm. This is equivalent to 3,323 GtCO<sub>2</sub>. In 1967 the level was approximately 320 ppm equivalent to 2,531 GtCO<sub>2</sub>. Thus, during this 56-year period the levels increased by 79.2 gigatons or 1.41 gigatons/year.

Using the GtC/year AGR variable, in 1960 this was 1.8 and in 2020 approximately 5, indicating an increase of 3.2 over a period of 60 years or 0.53 GtC/year/year. Since one gigaton of C equals 3.67 gigatons of CO<sub>2</sub>, using AGR the rate of CO<sub>2</sub> uptake into the atmosphere is increasing by 1.95 gigatons/year. This is similar to the rate of 1.41 gigatons/year based on the ppm data.

It has been recommended that to adequately combat global warming 10 Gt of CO<sub>2</sub> per year needs to be removed from the atmosphere until 2050 and then 20 GtCO<sub>2</sub>/year to the end of the century. (National Academy of Sciences, Engineering, and Medicine and Intergovernmental Panel on Climate Change, 2019).

The current emphasis for CDR is DACS (Direct Air Capture and Sequestration) with burying of the captured CO<sub>2</sub>. I have listed 10 potential problems with DACS and suggested the addition of three safer and effective alternatives for removing gigatons of CO<sub>2</sub> from the atmosphere, plus a fourth consisting of repairing the earth's albedo (Comings, 2025).

*Third* The current Trump administration has called climate change a hoax and is adamantly opposed to undertaking any ventures to help combat global warming. However, much of what conservatives complain about relates to the processes involved in attaining Net Zero emissions from fossil fuels. Combating the above feedback loop involves a marked acceleration of CDR. This switch in

emphasis from Net Zero to CDR might be far more palatable to conservatives than what is involved in only pushing for Net Zero. If left alone those outside the government can handle Net Zero part.

We should not lose sight of the fact that global warming is real and if not contained and reversed by greatly accelerating CDR and reducing emissions, continued emissions and the feedback loop described here will result in highly destructive consequences to humanity.

The climate change deniers in the current administration are mostly in their 50's to 70's, ages at which they will not be around to see the worst of progressive global warming. By contrast, their grandchildren will be severely affected. For many years we were told the world's temperature absolutely must not exceed 1.5°C over preindustrial levels. In 2024 we blew past that with ease. Our grandchildren are likely to see global temperatures of 3.7°C and greater, with truly dystopian effects. If for no other reason, the deniers need to change course to protect them.

### **Further Reading**

Comings, David. E. (2025). *If I Were a Billionaire, these are Four Things I Would Do to Combat Global Warming and Help Save the Planet. The Science of Global Warming.*

Gunther, Genevieve (2024) *The Language of Climate Politics.*

Wallace-Wells, David (2019) *The Uninhabitable Earth.*