Geo-Engineering, Strong Incentive and Great Danger

By John Benson

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1. Introduction

I have written about the subject of this post, climate change, frequently in the past, and shall also do so this time with a different spin, the hyphenated-word in the title of this post. This post was triggered by an excellent article in October's Scientific American, which is referenced on page 2. Geo-engineering is a potential technique to intentionally modify the climate to temporarily offset the worst effects of human-caused climate change.

Climatologists get a bad case of the cold-sweats when someone suggests this solution, because they believe that the humans that caused climate change, will just make things worse by trying to engineer the climate more than they already (unintentionally or otherwise) have. I am hard-pressed to disagree with them.

However, I also believe we are just starting to see major effects of climate change, and these are likely to get much worse over time. If geo-engineering has the potential to give us more time to stop pumping greenhouse gas (GHG) into the atmosphere and start to draw down the concentration of GHG we have pumped in already, we need to bring it to the table, and start evaluating it.

So let's start with what are the "worse-effects" I mention in the above paragraph? I don't need to look too far to find two related bad effects. The first is damaging weather, and the second is sea-level rise. Why are these related? If you live near sea-level, especially in coastal Florida, you probably already know the answer. If you are only a few feet above the worse-case storm from a typical hurricane, it's easy to imagine what will happen if (1) the hurricanes get stronger, (2) the sea-level rises a few feet, and (3) warmer off-shore ocean-water results in rapid intensification of hurricanes as they approach the coast. The initiating effect for number 3 happened this summer with coastal waters in Florida heating up above 100°F. Per NOAA, number (2) above is coming shortly:

According to the National Oceanic and Atmospheric Administration (NOAA), the global average sea level has risen by 8-9 inches (21-24 centimeters) since 1880. In 2022, the global average sea level set a new record high, 101.2 mm (4 inches) above 1993 levels. The rate of global sea level rise is accelerating: it has more than doubled from 0.06 inches (1.4 millimeters) per year throughout most of the twentieth century to 0.14 inches (3.6 millimeters) per year from 2006–2015.[1]

The projected global sea-level rise by the year 2100 depends on various factors such as greenhouse gas emissions and ice sheet collapse. If we are able to significantly reduce greenhouse gas emissions, U.S. sea level in 2100 is projected to be around 0.6 meters (2 feet) higher on average than it was in 2000. On a pathway with high greenhouse gas emissions and rapid ice sheet collapse, models project that average sea level rise for the contiguous United States could be 2.2 meters (7.2 feet) by 2100 and 3.9 meters (13 feet) by 2150.

[1] From Bing generative AI when asked: "Under current trajectories, how much global seal-level rise will occur by the year 2100?"

Both in the U.S. and world-wide there are thousands of square-miles of low-lying areas, and many of these are densely populated. Also we have not been "…*able to significantly reduce greenhouse gas emissions,"* and other than by my home state (California), I have not seen many signs that we will able to do this anytime soon. Thus I repeat that we need to have our best climatologists evaluate geo-engineering, define ways of testing it (probably via limited deployments), and get ready to deploy it on a wide scale when we are desperate enough.

2. A Risky Gamble

Many people recoil at the notion of solar geoengineering, or solar radiation management (SRM), as it's often called. The idea that humans should try to fix the atmosphere they've messed up by messing with it some more seems fraught with peril—an act of Faustian arrogance certain to backfire. But as it becomes clear that humans are unlikely to reduce emissions quickly enough to keep global warming below 1.5 degrees Celsius, some scientists say SRM might be less scary than allowing warming to continue unabated. Proposals for cooling the planet are becoming more concrete even as the debate over them grows increasingly rancorous.[2]

Author's comment: Regarding the above "1.5 degrees Celsius" goal, we may already have exceeded this depending on how you define "exceed."

In a year already overloaded with so many climate-related superlatives, it's time to add another to the list: September was the most anomalously warm month ever recorded.[3]

And the steady heat building this year could make 2023 not only the hottest year on record but the first to exceed 1.5 degrees Celsius (2.7 degrees Fahrenheit) above preindustrial temperatures, or the stable climate that preceded the massive release of greenhouse gases into the atmosphere from burning fossil fuels. Under the landmark Paris climate accord, nations have pledged to try to keep global warming under that threshold. "It's very worrying," says Kate Marvel, a senior climate scientist at Project Drawdown, a nonprofit organization that develops roadmaps for climate solutions.

Beyond potentially becoming the hottest year on record, 2023 could also be the first year to top 1.5 degrees C above preindustrial temperatures (some individual months have already passed that threshold). But even if that happens, all hope is not lost for meeting the Paris accord goals. That threshold is measured as an average of several decades, and climate scientists have long expected that a single year would pass that mark a decade or so before the world could be considered permanently above that limit. "There is still time to limit global warming to 1.5 degrees," Marvel says. "It is going to be incredibly difficult. The pathways are narrowing."

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SRM replicates a natural phenomenon created by large volcanic eruptions. When Mount Pinatubo erupted in the Philippines in 1991, it blasted 20 million tons of SO_2 into the stratosphere, creating an "aerosol parasol" that cooled the planet by about 0.5 degree C over the next year or so before the droplets settled back to Earth.

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[2] Douglas Fox, Scientific American, "It's Time to Engineer the Sky," Oct 1, 2023, https://www.scientificamerican.com/article/its-time-to-engineer-the-sky/

[3] Andrea Thompson, Scientific American, "September Was the Most Anomalously Hot Month Ever," Oct 4, 2023, https://www.scientificamerican.com/article/september-was-the-most-anomalously-hot-month-ever/

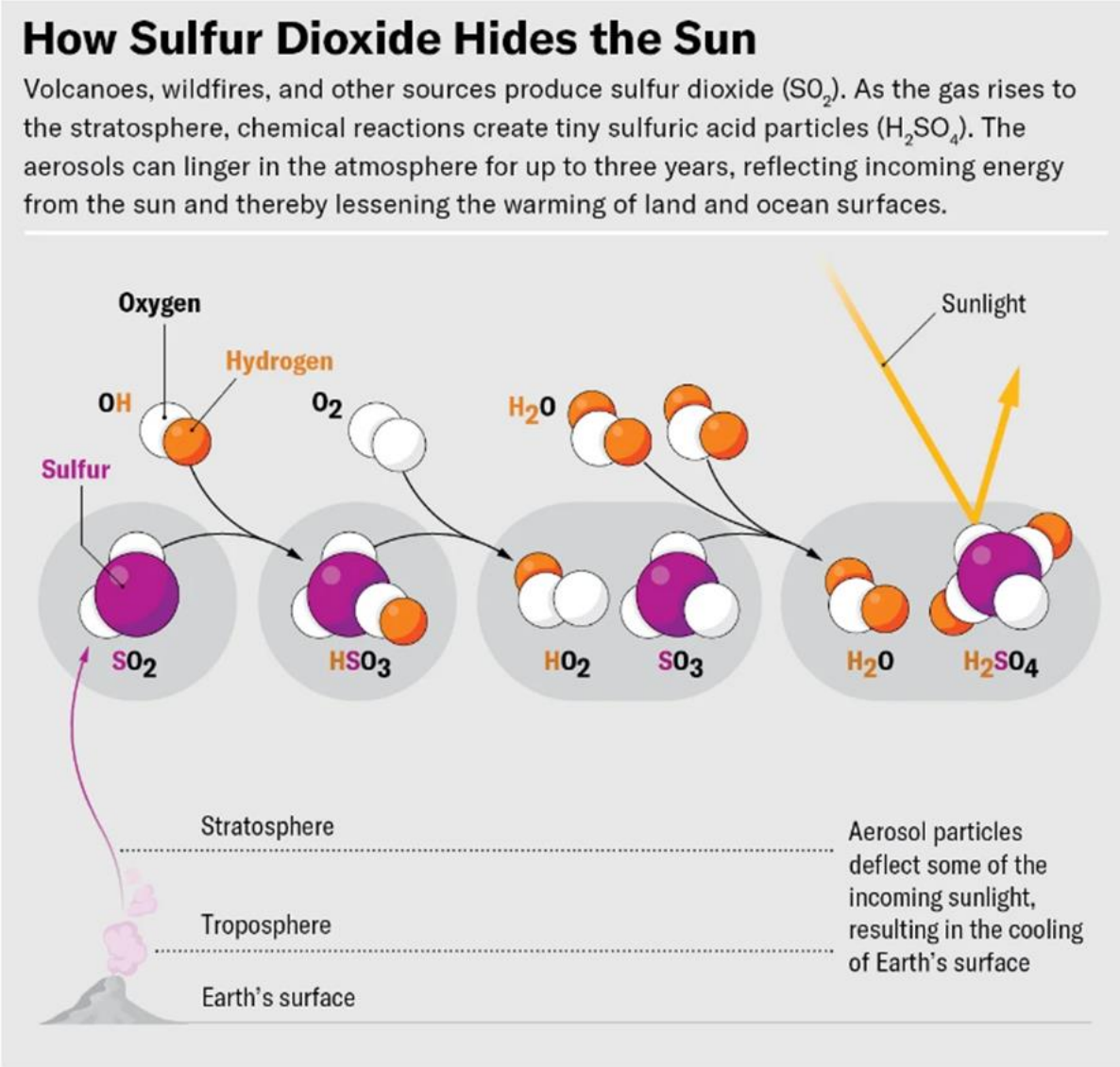
Studies suggest that if SRM were deployed at sufficient scale—maybe one quarter of a Pinatubo eruption every year, enough to block 1 or 2 percent of sunlight—it could slow warming and even cool the planet a bit. Its effects would be felt within months, and it would cost only a few billion dollars annually. In comparison, transitioning away from fossil fuels is expected to take decades, and the CO_2 emitted until then could make warming worse. Using machines to remove billions of tons of CO_2 from the skies, a process called direct-air capture, could slow warming but would be fighting itself—the machines might increase the world's energy consumption by up to 25 percent, potentially creating more greenhouse gas emissions. Because SRM could produce effects quickly, it has political appeal. It's "the only thing political leaders can do that would have a discernible influence on temperature within their term in office," says Ken Caldeira, a climate scientist emeritus at the Carnegie Institution for Science, who is also a senior scientist at Breakthrough Energy, an organization founded by Bill Gates.

Author's comment: Our immediate pathway really needs to be (1) make the electricity provided by the grid net-zero (greenhouse gas (GHG) emitted in producing it). (2) Electrify everything we reasonably can in parallel with (1). (3) Then start building direct air- and ocean-capture and sequestration technology powered by the (now net-zero) grid to offset and residual GHG sources.

Caldeira and others say SRM should be pursued with extreme caution—if at all. It could noticeably whiten our blue sky. It could weaken the stratospheric ozone layer that protects us and Earth's biosphere from ultraviolet radiation. It might change weather patterns and move the monsoons that water crops for billions of people. And it wouldn't do anything to remedy other CO_2-related problems such as ocean acidification, which is harming the ability of corals, shellfish and some plankton to form skeletons and shells.

Critics also say that the very idea of an escape hatch such as SRM could undermine support for reducing greenhouse gas emissions. Like a prescription drug, if SRM were used responsibly—temporarily and in small doses—it could be beneficial, easing what is likely to be a dangerously hot century or two and buying humanity some extra time to transition to renewable energy. But it also has potential for abuse. At higher doses it could increasingly distort the climate, altering weather patterns in ways that pit nation against nation, possibly leading to war.

For all these reasons, more than 400 scientists have signed an open letter urging governments to adopt a worldwide ban on SRM experiments. But other scientists are proceeding, if reluctantly. "All the scientists I know who are working on this—none of them want to be working on it," says Alan Robock, a climatologist at Rutgers University. Robock, who previously showed the world how a nuclear winter could shroud Earth, studies SRM out of a sense of obligation. "If somebody's tempted to do this in the future," he says, they "should know what the consequences would be."



Credit: Lucy Reading-Ikkanda

Experts who support trials note that unabated warming is just as consequential. In a recent report, the World Meteorological Organization estimated a 66 percent chance that by 2027 the world's average annual temperature will briefly exceed 1.5 degrees C above preindustrial levels—a dangerous threshold beyond which extreme damage to the environment occurs. On February 27, 2023, 110 climate scientists, including climate change pioneer James Hansen, published a different open letter urging government support for SRM research. The following day the United Nations called for international regulations that could pave the way for experimentation. And in June the Biden administration released a report outlining what an SRM research program could look like.[4]

[4] See "Congressionally-Mandated Report on Solar Radiation Modification," https://www.whitehouse.gov/ostp/news-updates/2023/06/30/congressionally-mandated-report-on-solar-radiation-modification/#:~:text=The%20report%2C%20which%20was%20developed%20in%20coordination%20with,risks%20and%20benefits%20posed%20by%20solar%20radiation%20modification.

Even if SRM reduced average temperatures, it wouldn't reset the climate to its preindustrial state, says David Keith, head of climate systems engineering at the University of Chicago, who has studied the idea for over two decades. But it could lessen the hurt coming for us…

The idea of planet-scale engineering didn't gain much traction over the next two decades. When Lowell Wood, an engineer at Lawrence Livermore National Laboratory in California… stood up at the 1998 Aspen Global Change Institute conference to tout the cooling effects of stratospheric aerosols, the reception was chilly. "Ken [Caldeira] and I stood in the back room and almost shouted at him," Keith recalls. He "was completely overstating how well it would work." Their skepticism was based on simple logic: CO_2, by absorbing long-wave radiation rising from Earth, warms the planet uniformly from the equator to the poles year-round, day and night—whereas sunlight warms the planet mainly at lower latitudes, with stronger effects during the summer and the daytime. They thought dimming the sun would cool the planet unevenly, Caldeira says. "You get much more cooling at the equator," more cooling during summer, and less at the poles.

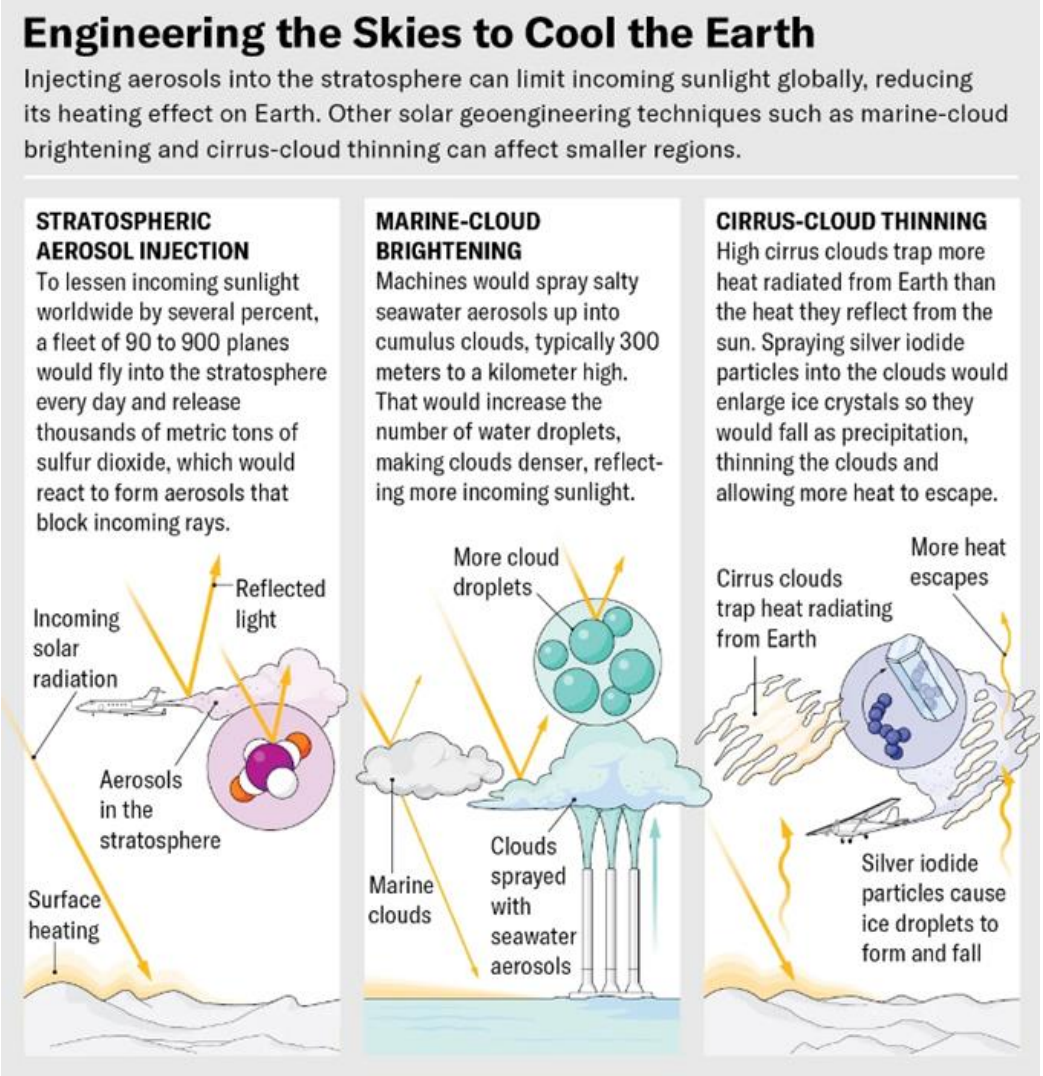
Caldeira returned to Livermore[5], where he also worked, and persuaded Govindasamy Bala, a climate scientist there, to test the idea with a sophisticated computer model. The model diminished incoming sunlight by 1.7 percent—enough to counteract the warming effects of CO_2 levels that were double what they had been in preindustrial years. "It worked a hell of a lot better than we expected," Caldeira says. The results, published in 2000, indicated that SRM would still cool the tropics a little more than the poles and make a bigger difference in summer than in winter, but overall the cooling would be far more uniform globally than Bala, Caldeira and Keith had thought.

A consortium of researchers that included Robock later replicated Bala's results across a dozen different climate models. But their 2013 findings revealed a red flag. As concentrations of stratospheric aerosols increased, the cooling grew less uniform, and the climate became more distorted. If stratospheric aerosols were used to offset the average warming caused by a quadrupling of CO_2 levels, the tropics would be 0.3 degree C cooler than in preindustrial times, but the polar-regions would still be 0.8 degree C warmer. Permafrost and sea ice might not fully recover, meaning we would fail to reverse some of climate change's most damaging effects.

Bala discovered another worrisome detail: stratospheric aerosols might reduce rain and snowfall. Researchers knew that more warming increases the evaporation of water, leading to more precipitation, so it stood to reason that the reverse would also be true. But Bala found that dimming the sun could reduce rainfall more than it reduces temperature. That's because blocking sunlight, while leaving CO_2 high, slightly reduces the tendency of water vapor to form clouds. Simulations across the 12 models predicted that if SRM was used to fully counteract the warming of quadrupled CO_2, some parts of the tropics would receive 5 to 7 percent less annual rainfall compared with preindustrial times, potentially harming crops or tropical forests.

[5] Livermore has been the author's home town for several decades.

This and other observations led Keith and his colleagues to suggest a lower-dose approach to SRM in which stratospheric aerosol injections would be used temporarily to reduce the effects of climate change, buying nations time to cut greenhouse gas emissions and draw down (or "capture") CO_2 from the atmosphere.



Credit: Lucy Reading-Ikkanda

Keith sketched out this scenario in a 2018 paper co-authored with climate scientists Douglas MacMartin of Cornell University and Katharine Ricke of the Scripps Institution of Oceanography. They envisioned a world in which greenhouse gas emissions are cut and carbon capture is deployed so that CO_2 peaks in 2070 at just over twice its preindustrial concentration before starting to slowly decline. This would cause roughly three degrees C of warming—a lot. To limit warming to 1.5 degrees C, stratospheric aerosol injections would be initiated around 2030 and slowly ramped up. Injections would peak in 2070 and be slowly reduced before being halted about two centuries later, when CO_2 levels had fallen sufficiently. Peter Irvine, a climate scientist at University College London, ran this scenario through 13 models. The results, published in 2019 in Nature Climate Change, showed that during the period of peak CO_2 concentrations, stratospheric aerosols would reduce warming and lessen precipitation extremes (including droughts and deluges) for 99.6 percent of the planet's ice-free land surface…

Planes capable of carrying tons and tons of SO_2 could be developed with largely existing technologies, says Wake Smith, a former aviation-industry executive and a climate researcher at the Yale School of the Environment. Since 2017 Smith has refined the concept of a six-engine plane based loosely on the B-47 Stratojet, a high-altitude U.S. Air Force craft designed in the 1940s to deliver nuclear bombs deep inside Soviet territory. Smith's Stratospheric Aerosol Injection Lofter would heft 15.7 tons of aerosol to a height of 20 kilometers every flight. Depending on how much SRM is desired, Smith envisions 90 to 900 planes flying missions every day by 2100. Building the first plane might take seven to 10 years; building a fleet could take 20 years.

Smith estimates that once the planes are built, the program might cost $18 billion annually per degree C of cooling. That's a small amount compared with the hundreds of billions of dollars a year it would take to remove billions of tons of CO_2 from the atmosphere. But SRM has a much higher chance than carbon removal of causing nightmarish unintended consequences. Stratospheric injections by any country would affect the entire globe. Done wrong, they could disrupt weather patterns and the lives of billions of people…