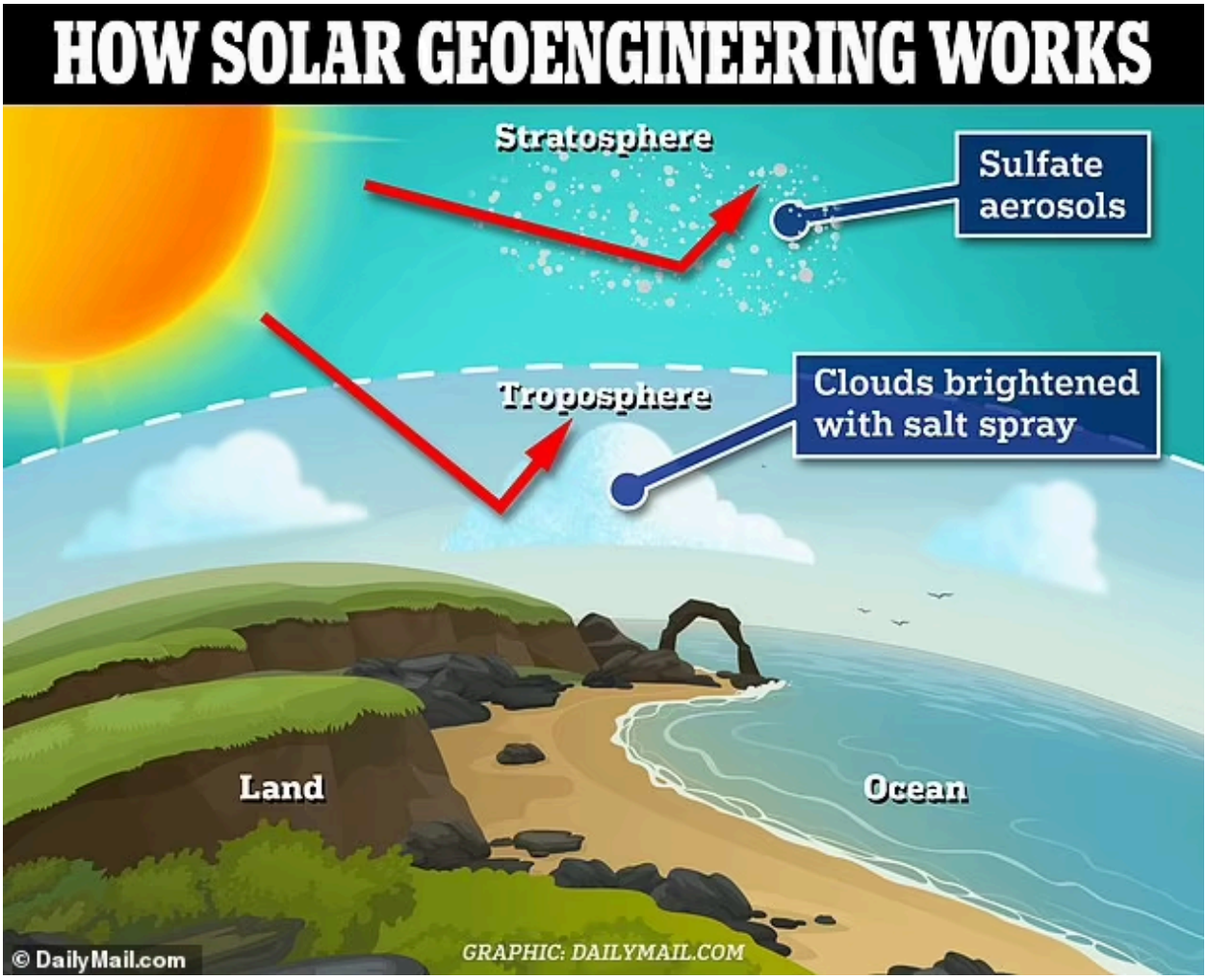
GeoEngineering - Unthinkable?

Let's look at a couple of the most discussed (and controversial) **GeoEngineering** proposals. One is in the Stratosphere, the other in the Troposphere .



Stratospheric Sulfate Aerosol injection.

Approximate "Cheat Sheet":

1 meter → 3 feet **1 degree Celsius (^{0}C)** → 2 degree Fahrenheit (^{0}F)
ppm = parts per million **CO_2** = Carbon Dioxide
1 tonne = 1000 kilograms = 2205 pounds **1 gigatonne (1 Gt)** = 1 billion tonnes
1 trillion tonnes (1Tt) = 1000 gigatons

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The idea for injecting **aerosols into the stratosphere** comes from seeing what happens when the biggest volcanoes erupt, sending huge amounts of material all the way up into the stratosphere.

Pinatubo eruption cloud. This volcano released huge quantities of stratospheric sulfur aerosols and contributed greatly to understanding of the subject.

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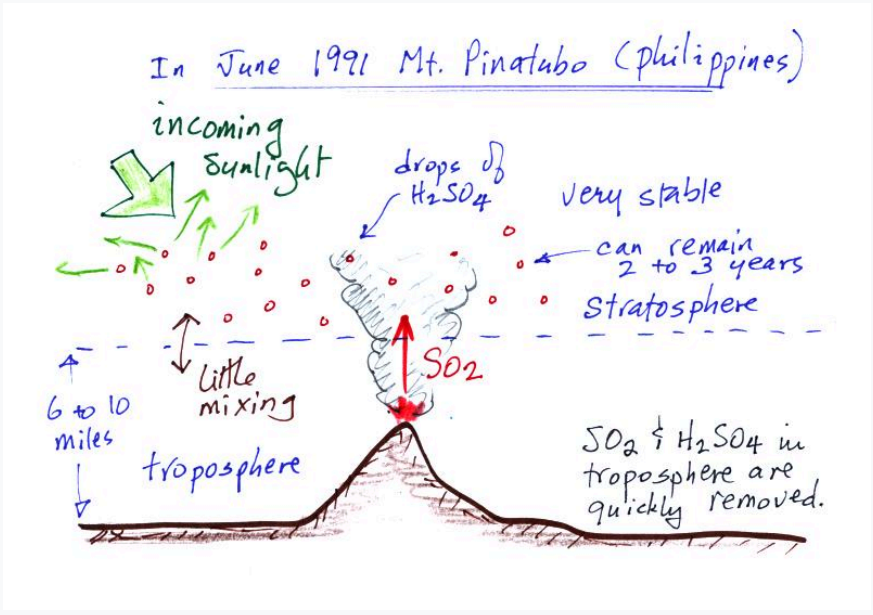
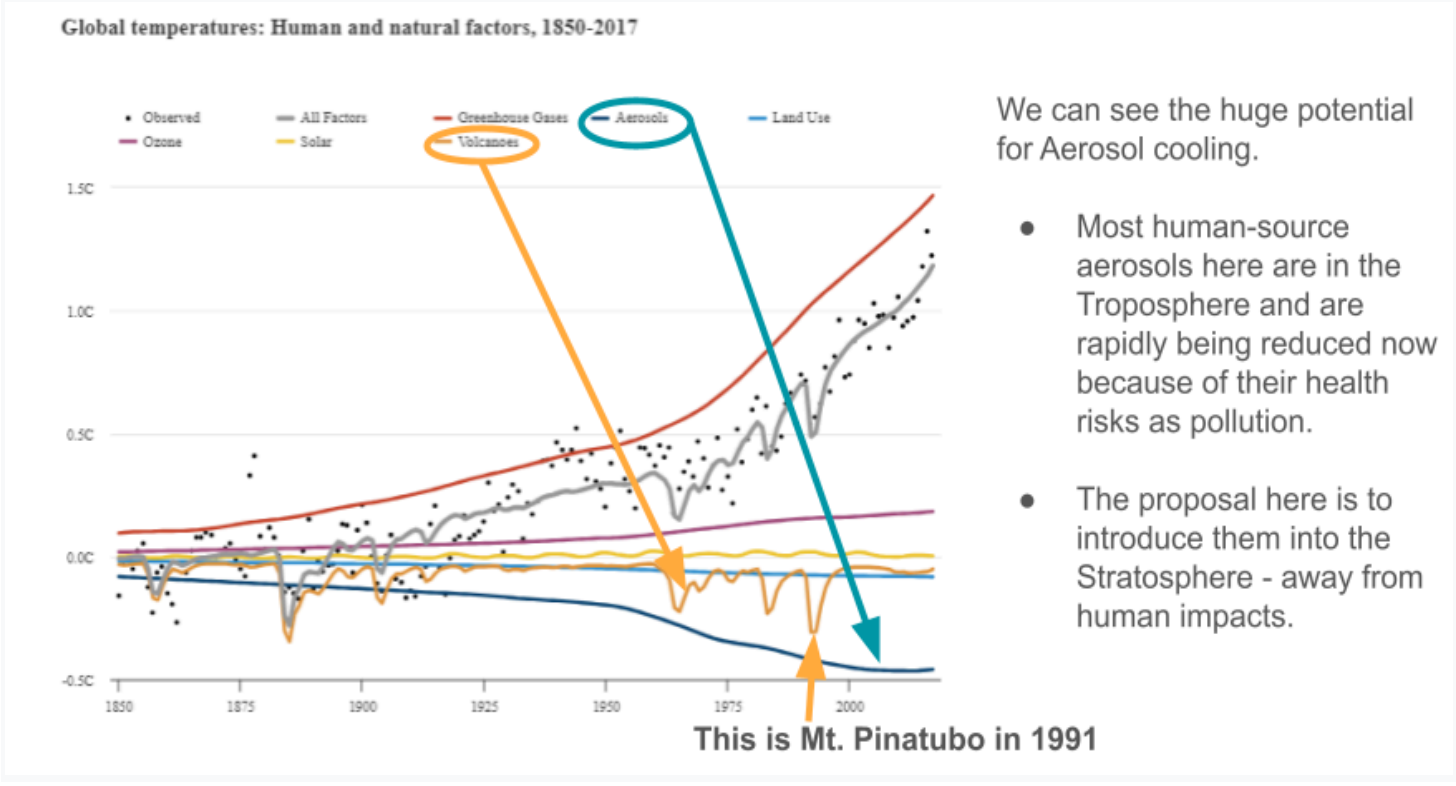


http://www.atmo.arizona.edu/students/courselinks/spring08/atmo336s1/courses/fall11/atmo170a1s1/lecture_notes/climate_change/volcanic_cooling.html



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Why, specifically, would we consider Injecting Sulfate Aerosols into the Stratosphere ?

Here's some helpful text I found:

- **"Stratospheric aerosol injection** is a proposed method of solar geoengineering (or solar radiation modification) to reduce global warming. This would introduce aerosols into the stratosphere to create a cooling effect via global dimming and increased albedo, which occurs naturally from volcanic winter.[1]
- **It appears that stratospheric aerosol injection, at a moderate intensity, could counter most changes to temperature and precipitation, take effect rapidly, have low direct implementation costs, and be reversible in its direct climatic effects.[2]**
- The Intergovernmental Panel on Climate Change concludes that it "is the most-researched [solar geoengineering] method, with *high agreement* that **it could limit warming to below 1.5 °C** (2.7 °F)."[3] However, like other solar geoengineering approaches, stratospheric aerosol injection would do so imperfectly and other effects are possible,[4] particularly if used in a suboptimal manner.[5]**"**

https://en.wikipedia.org/wiki/Stratospheric_aerosol_injection#:~:text=Deposition%20and%20acid%20rain%3A%20The,precipitation%20would%20be%20very%20small.

This looks Great ! (?)

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First, a quick one-page tutorial on: What are "Sulfate Aerosols"? :

1. **First, what is an "Aerosol"? It is simply a suspension of fine solid or liquid particles in gas.** Smoke, fog, and mist are *aerosols*.

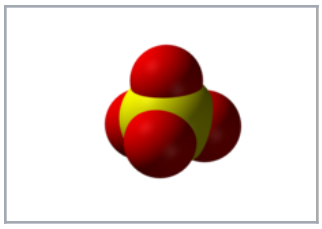
   Now, we can clarify what is a 'Sulfate Aerosol".

2. **We start with Sulfur dioxide**. This is the chemical compound with the formula **SO_2**. The **primary sources of sulfur dioxide are burning of fossil fuels** in power plants, metal smelting, and **volcanic emissions**.

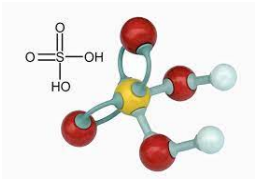
View all

3. **Now this forms a Sulfate -** Sulfur dioxide has a short lifetime in air. It reacts with oxygen **turning into sulfate** in a day near the ground and in a month in the stratosphere.

   $SO_2 + O_2 \rightarrow SO_4$ (this is a sulfate, but it's ready to react with water vapor)



4. **"Sulfate Aerosols" -** The sulfate (above) can react with water to create a haze of **sulfuric acid aerosol.** For these purposes, **Sulfate Aerosols** are the same as **Sulfuric acid aerosols**.



$H_2O + SO_4 \rightarrow H_2SO_4$ (sulfuric acid).

Sulfur dioxide (SO_2) → Sulfate (SO_4) → Sulfate Aerosols

(A Sulfate Aerosol is H_2SO_4 (Sulfuric Acid) suspended in air).

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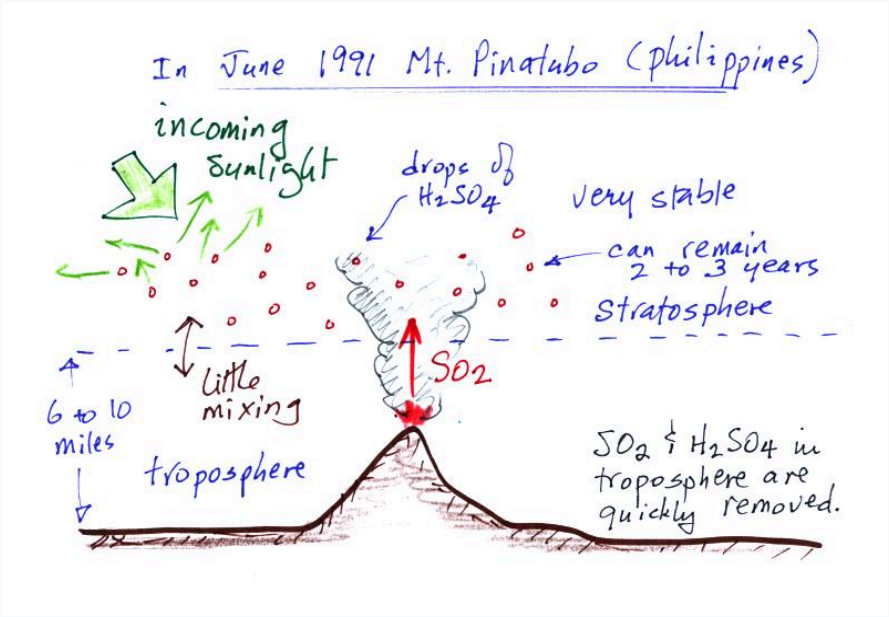
With this, in the Stratosphere we now have "Sulfate Aerosols".
Take another look at this sketch - you see the **Sulfur dioxide (SO_2) i**njected upward from the volcano. The sulfur dioxide reacts quickly with oxygen to form **Sulfate (SO_4)** (not shown below). This reacts with water in the Stratosphere forming **H_2SO_4 (sulfuric acid).** Suspended in the stratospheric air, this is now referred to as **"Sulfate Aerosols". These particles can stay up for a long time and are not getting to our lungs as pollution.**



These particles and/or haze
can be very bright and can reflect incoming sunlight.

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But:

Models suggest injection of sulfate aerosols into the stratosphere could have unintended consequences

The researchers report that overall, the models showed the desired cooling impact. But they also showed something less helpful—reduced global rainfall.

- The models showed that the **changes in rainfall would not be uniform**, either; some areas would get less than others.
- And as some of those areas, such as the North Atlantic, received less rainfall, the ocean would experience an increase in salinity, which would make the water denser. That denser water would then have an impact on the **Atlantic Meridional Overturning Circulation**, burying more heat in the deep ocean.
- The net result would be a warmer ocean, more polar melting and **faster rising sea levels**.

https://phys.org/news/2018-10-sulfate-aerosols-stratosphere-unintended-consequences.html

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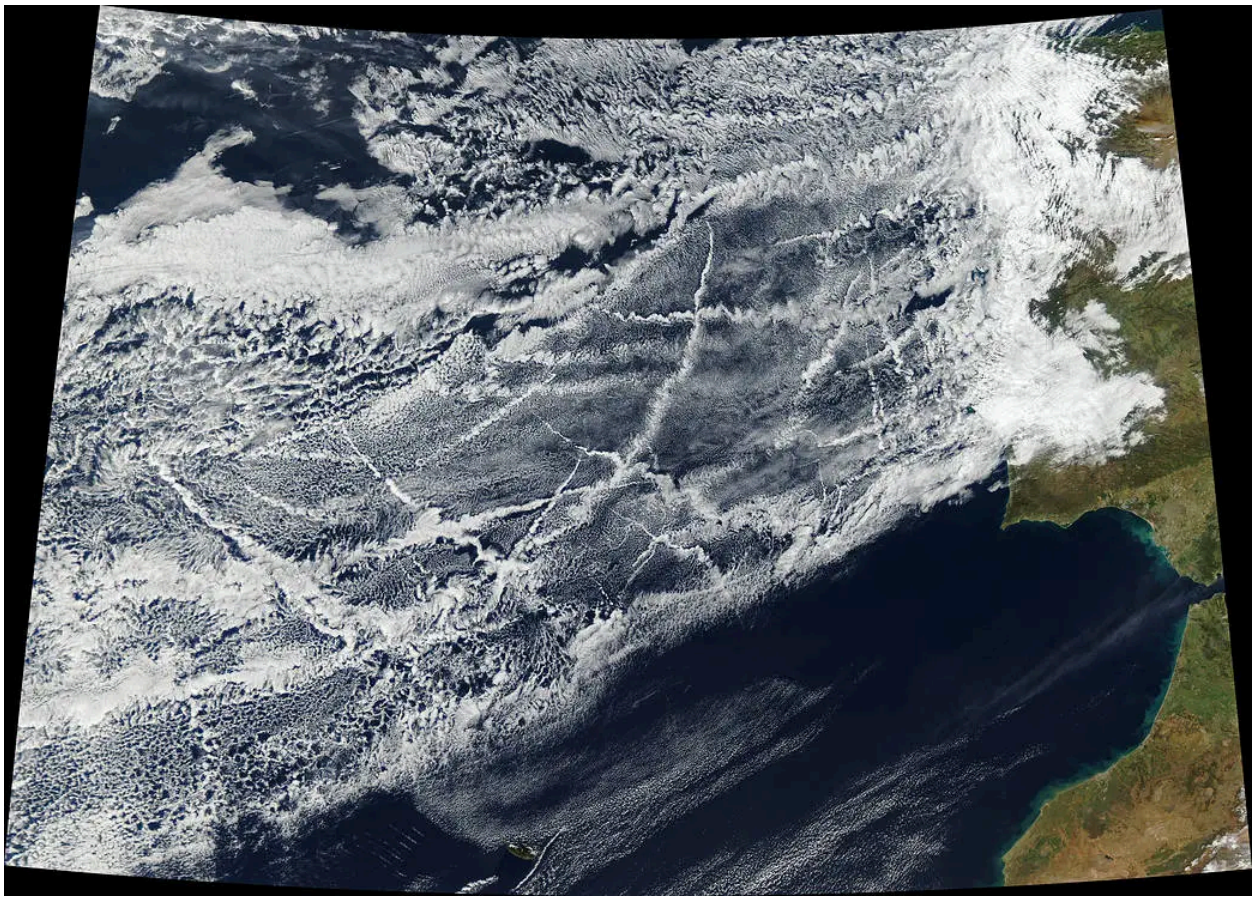
A similar but very different idea is being discussed for the Troposphere:

(copied in part from the Daily Mail article above)

Clouds Brightened with Salt Spray in the Troposphere

Another technique which solar geoengineering advocates believe could work is 'Marine Cloud Brightening' where **clouds over the ocean are injected with tiny droplets to make them brighter and more reflective**.



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Marine cloud brightening hopes to reflect sunlight by delivering materials (including sea salt) to clouds such as stratocumulus to **rapidly reduce warming**.

It mirrors an effect caused by pollutants released from ships.

Some scientists suggest that solar geoengineering could spark 'termination shock' when it ends, where **temperatures rebound rapidly** if the geoengineering flights are stopped.

Others have warned that it **might spark conflict, for instance if one nation used geoengineering to cool a particular area and it caused problems in another.**

Dr. Jens Holtvoeth, Senior Lecturer in Geology, School of Health & Life Sciences at Teesside University told DailyMail.com, 'Solar engineering seeks to provide a quick measure to temporarily cool the Earth's atmosphere during the time it takes to bring down the concentrations of the main atmospheric greenhouse gasses, carbon dioxide and methane, which is a slow process.'

'While some cooling may be achieved, the artificial changes in temperature may also lead to a **redistribution of precipitation** that does not merely revert the patterns brought by climate change.

'The **changes in rainfall distribution** would also affect terrestrial ecosystems and agricultural production in ways that are currently unforeseeable.'

So, both of these GeoEngineering techniques hold great potential benefits, but could have profound and scary unintended consequences.

Why are we even giving serious consideration to these technologies???

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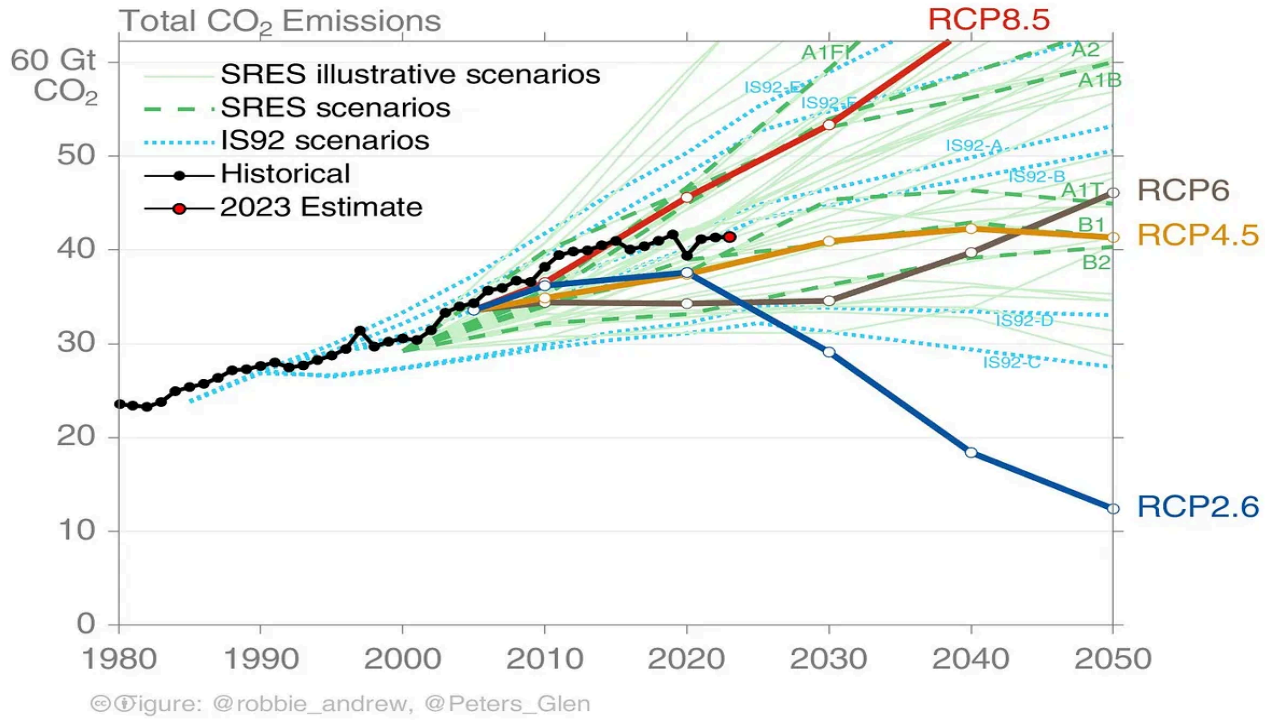
Why might we have to go to Unthinkable Solutions to Cool the Planet ?

There is a growing awareness that the **"Remaining Carbon Budget"** for avoiding further heating is even less than projected only three years ago. The 2021 International Panel on Climate Change (IPCC) estimates were updated in 2023 and show we are closer to passing 1.5 and 2.0 ^{0}C than estimated earlier.

A couple of studies by Zeke Hausfather are helpful in getting our minds around the situation:

- First, some good news: he noted that **Emissions are no longer following the worst case scenario** in https://www.theclimatebrink.com/p/emissions-are-no-longer-following. This is indeed good news. Look at his chart in the context of numerous modeling exercises. The **dotted black line** of yearly actuals shows global emissions have been leveling off and the IPCC worst case "business as usual" scenario (**RCP8.5 in RED**) is currently being avoided. That's great, but notice there is **no drop toward Zero Net Emissions,** which is essential.

[Note the pandemic dip in 2020.]



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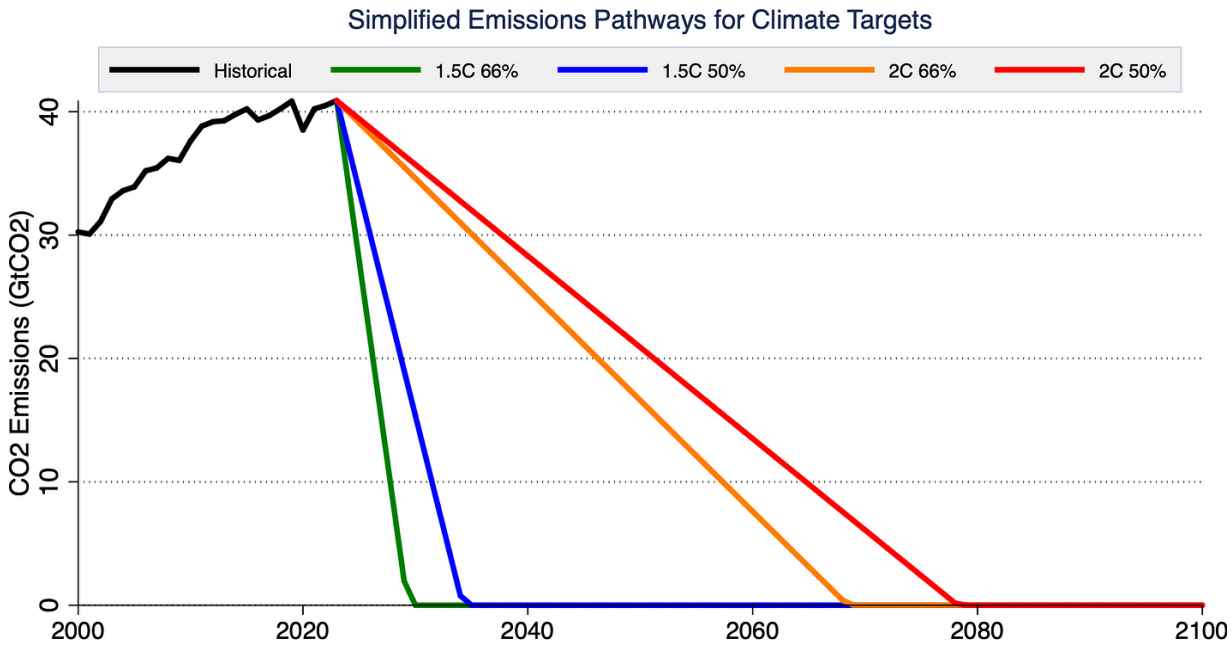
- On the other hand, he took the **updated "Carbon Budget" values** necessary to limit heating and simply plotted the direct pathways it would take for us to keep within 1.5 ^{0}C and 2.0 ^{0}C. These reflect **some confidence** (66% chance of the planet responding as we project) and **possible** (50-50 chance). These charts can be found at https://www.theclimatebrink.com/p/the-rapidly-shrinking-carbon-budget.



Here we can see that to meet our climate targets, **global emissions would have to reach <u>zero</u>** in these timeframes:

1.5C with a 66% chance – 2030

1.5C with a 50% chance – 2035

2C with a 66% chance – 2069

2C with a 50% chance – 2079

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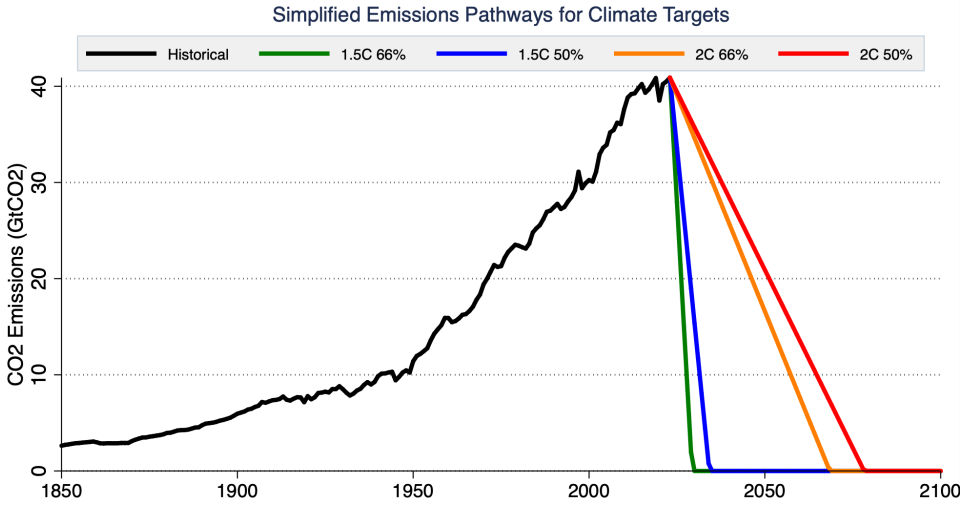
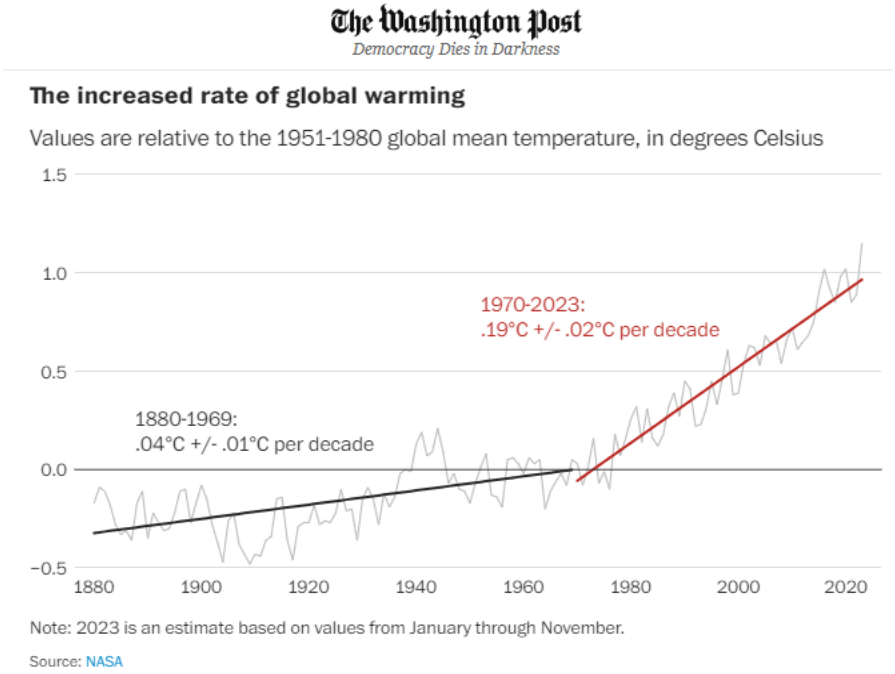
And to put this into even more context, he drew a broader picture of annual emissions, starting all the way back in 1850:



Add to that the documented **acceleration of warming** noted by the Washington Post in https://www.washingtonpost.com/climate-environment/2023/12/26/global-warming-accelerating-climate-change/.



Yikes! It doesn't take much to realize **that getting to ZERO quickly enough to avoid 1.5 or 2.0 ^{0}C (or higher) just isn't likely given the inertias in our societies and the desires of less developed regions for better quality of life**.

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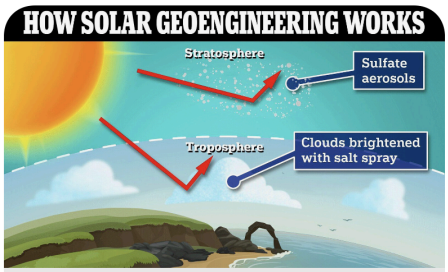
It is in this context that there is a lot of talk and **hot debate** about doing something as RADICAL AS PUTTING CO_2 UP IN THE ATMOSPHERE IN THE FIRST PLACE → **Putting <u>other</u> stuff up there!**

Scientists resort to once-unthinkable solutions to cool the planet

The Wall Street Journal

News

https://apple.news/A1nYZ72g4Ob6ZfrOOADG63w

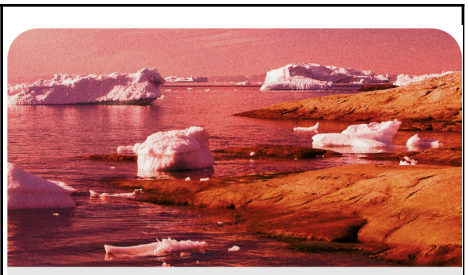


Six technologies which could help control global warming

Daily Mail

News

https://apple.news/AcihRWvwVSHq7dWv4hvpqSg



Scientists Desperately Studying How to Hack Climate

Futurism

News

https://apple.news/AMdajsZSbR6aN-73meqYsZA

Here are some **<u>other conceptual technologies</u>** presented in the *Daily Mail* article above:

Saving the planet with whale poop

An experiment using artificial whale excrement (poop) aims to suck up carbon dioxide from the atmosphere thanks to phytoplankton.

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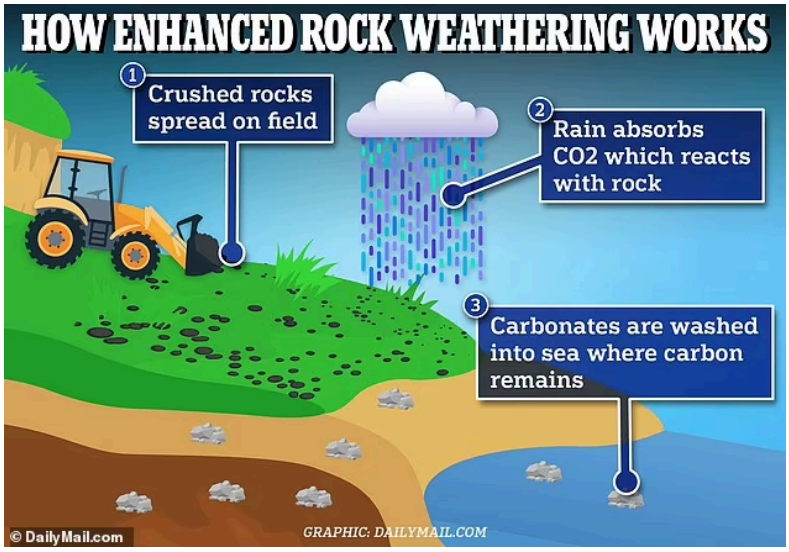
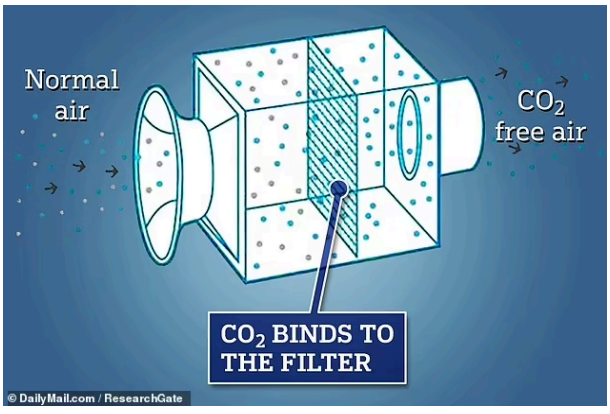
Soaking up CO2 using crushed rocks

The natural carbon-absorbing abilities of rocks could be used to 'suck' CO2 from the atmosphere in huge quantities. **[How the Himalayas cooled the Earth!]**



Sucking CO2 out of the air

Direct Air Capture (DAC) is one of the most ambitious - and expensive - ways to deal with climate change, using chemical reactions to pull CO2 out of the air.



Heirloom unveiled a direct-air-capture facility in California in November 2023

BONUS !

Can anyone take a look at these clouds and see if they can find what is happening here (I would try googling “Clouds” and scanning through Images)? It looks like these could be moisture rising to the stratosphere and then spreading out in **both directions** as they hit the wall (like the “anvil clouds’) (?).

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