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MANAGING SOLAR RADIATION



Geoengineering includes **two broad categories of technologies** to counteract global warming caused by man-made greenhouse gas (GHG) emissions:

- Carbon dioxide capturing and sequestration technologies (see the "Oceans as laboratories" PDF)
- The so-called "solar radiation management" (SRM) technologies that are the subject of this PDF

SRM aims at **cooling the planet by increasing the amount of incoming solar radiation that is reflected back into space.**

EARTH'S GLOBAL ALBEDO OR HOW TO MAKE EARTH REFLECTIVE

Every object reflects some of the solar energy it receives. The **albedo** measures the proportion of solar energy reflected in relation to that received. **The brighter a body is, the more reflective it is: its albedo is high.** A dark body absorbs more of the sun's rays: its albedo is low.

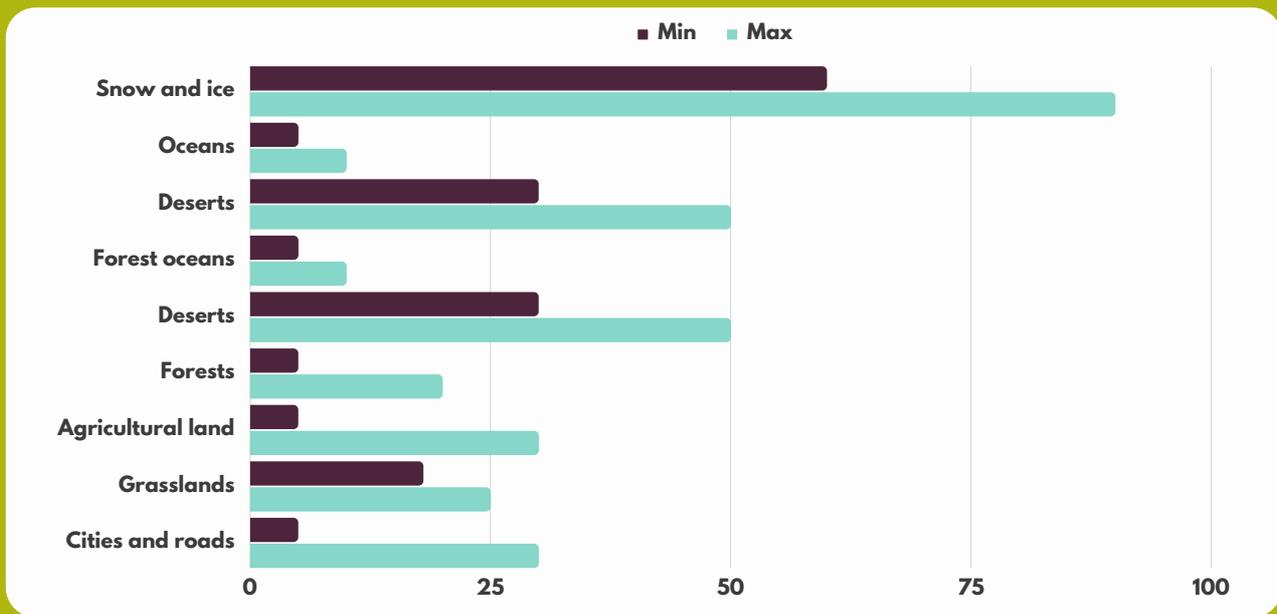
The solar radiation incident on the planet (about 342 Wm^{-2} on average per year at the top of the atmosphere) is not completely absorbed by Earth's surface. **Part of the solar flux (about 30%) is reflected back to space** by the atmosphere (6% by air, 20% by clouds) and by the Earth's lands. (4%). The global terrestrial albedo expresses this fraction (which is worth 0.3) of solar radiation that is not used to heat the planet.

Clouds, atmospheric particles (e.g., volcanic plumes) **act as a sunshade, preventing some of the sun's rays from reaching the earth's surface.**

They play the role of a parasol by preventing a part of the sun's rays from reaching the earth's surface: **their albedo is high.**



VARYING DEGREES OF ALBEDO (IN %)



The albedo effect thus plays a role in the climate and thermal balance of the planet. It is affected by human activities and global warming. For instance, the observed melting of glaciers in the mountains and the ice pack in the Arctic leads to a **reduction of the reflective surface and the local albedo decreases**, leading to **further warming of the region**, which in turn amplifies the melting. It causes a snowball effect called “**climate change feedback**” by climatologists.



SOLAR RADIATION MANAGEMENT (SRM)

SRM techniques aim to regulate the light and heat from the sun by increasing the proportion that is reflected back to space. The average albedo of the earth is about 30%. Can we compensate for some of the warming by increasing this value?

All the options considered have **two essential characteristics in common**:

- They claim to address the **symptoms of the disease (global warming) rather than its causes** (increasing human GHG emissions), while leaving the others untouched: In particular the acidification of the oceans.
- They are based on **hyper-technological scenarios with underdeveloped devices and major uncertainties** about their effectiveness, stability, cost and climatic, environmental, social and political impacts.

Among the multiple options considered, more or less credible, sometimes delirious, very often exaggeratedly optimistic, we find the following techniques:

- Cloud brightening
- Land surface discoloration
- Volcanic mimicry
- Spraying sulphur into the upper atmosphere

We will stress the latter, as the first two are of much less interest and, for the time being, are much less likely to be implemented.



MIMICING THE PINATUBO ERUPTION



The most spectacular of the current SRM options is '**artificial volcanism**' created by **spraying sulphur particles into the upper atmosphere** to reflect the sun's rays back into space and redirect their heat back into space. The scenario is based on the observation of eruptions that have led to a significant drop in temperatures over the last two centuries.

The cooling observed would be due to volcanic dust and sulphuric acid droplets. In the 1970s, Soviet climatologist Mikhail Budyko announced that it was possible to **cause global cooling by introducing aerosols into the stratosphere**. Paul Crutzen, who won a Nobel Prize in 1995 for his work on the ozone layer, followed suit in 2006 in an article in the journal Climatic Change magazine and advocated injecting large quantities of sulphur dioxide to reflect sunlight. Since then, the initial concept born from the observation of the Pinatubo effect has **been further developed in the laboratories of Bala Govindasamy and Ken Caldeira at Lawrence Livermore National Laboratory**.

They have suggested artificially inducing a change in the Earth's insolation by **deploying aerosols into the stratosphere** using balloons, fighter jets or heavy artillery.

THE WIZARD APPRENTICES OF CLIMATE: PLAYING WITH FIRE

This hyper-technological 'sun filter' scenario is often presented as an **alternative to the successive failures of international political negotiations**. The complexity and uncertainties of the climate system make it **impossible to draw conclusions about what would happen**.

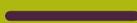
Temperature regulation using a solar filter would require **quantities of sulphur equivalent to an eruption of Mount Pinatubo every 4 years**. The process does not address the root causes of warming (greenhouse gas emissions or GHGs) or its effects such as acidification. **There is no substantive equivalence between a world with more greenhouse gases and stratospheric aerosols and one without either**.

The principle of urgency would then replace the principle of precaution and push promoters to be **exaggeratedly optimistic about the global benefits of their options**. However, there are many voices raised about the risks and consequences (including regional climate risks) that could result from such voluntary alterations.

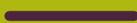
Distinguishing the effects of the solar filter from other causes of climate variability seems impossible other than over a very long period (10 years minimum) and **many risks exist**:



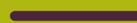
Disruption of rainfall



Food security issues



Damaged ozone layer



Rebound effect

IN MORE DETAIL...

- **Probable disruption of rainfall:** for instance, there was a very serious worldwide deficit of rainfall compared to normal in 1992 following the eruption of Pinatubo.
- **Significant reduction in the monsoon regime:** in Africa and Asia with dramatic impacts on the food security of local communities.
- **Impact on the ozone layer:** how would sulphur compounds react with ozone? The lifetime of GHGs in the atmosphere is much longer than that of sulphates in the stratosphere. Therefore, the increasing and continuous injection of aerosols should be anticipated.
- **Rebound effect:** modelling results suggest that, assuming the implementation of a solar radiation management (SRM) program without a concomitant reduction in greenhouse emissions, a sudden stop of this program (which could be due to technical or diplomatic issues) would be followed by an extremely abrupt and large increase in global temperature. GRS is therefore similar to a technique that would be impossible, once deployed, to stop under penalty of dramatic consequences.



Pragmatically speaking, the large-scale deployment of GRS techniques raises **important implementation issues**: which authority would be responsible for coordinating the spraying of massive amounts of sulfur aerosols? Sustainable and stable international cooperation would be essential to prevent individual powers from getting their hands on the "global thermostat" and turning it into a **diplomatic weapon**. Yet, the repeated examples of climate negotiations have clearly underlined the **difficulties of countries to agree on this type of issue**.

SRM : SEARCHING FOR ALTERNATIVES AT THE RISK OF BEING GROTESQUE...

- **Lightening the clouds:** the whiter the clouds, the greater the amount of reflected light. The idea of the meteorologist J. Latham is to whiten the stratocumulus clouds which cover between 1/4 and 1/3 of the oceans by vaporizing droplets of sea water in the air (smaller than a micron) whose salty residues after evaporation would stimulate cloud condensation. It would be required to have recourse to an immense armada of boats able to diffuse a perpetual flow of these microscopic droplets. The technology behind this 'miracle spray' remains to be invented. The supporters of this option are unable to predict the real efficiency of this option, nor its actual meteorological consequences.
- **Bleaching the Earth's lands:** the idea is based on the same principle as for the lightening of clouds; if a large surface of the Earth could be bleached, it would allow to reflect more solar energy. Several ideas have been put forward in this sense:
- **Colouring the cities:** - H. Akbari and S. Menon (Nobel Peace Prize winners as co-authors of the latest IPCC report) have estimated that in dense cities (about 1.5 million km²) 25% of the surface is occupied by roofs and 35% by asphalt streets with low albedo. Their solution is to cover these dark surfaces with a layer of white paint. One can doubt the effectiveness of this "Greek village" option: what would happen in the United Kingdom where the sun shines on average only 61 days a year. How to produce enough paint and solvents? What is the carbon footprint of the operation? How much would it cost? How long will it take to implement and when will we have to start again?
- **Bleaching the mountains** - The disappearance of the glaciers in Peru deprives meadows and livestock of water reserves. The idea of repainting the darkened mountains in white with a slurry of water, sand and lime would allow to maintain the glaciers at a lower temperature, the ice to form and at the same time increase the reflection of solar energy. Here again, one can doubt the effectiveness and the implementation of such an option (whose research is financed by the World Bank.).

"Fiddling" of climate brings many more questions than answers to the problem of climate change. For scientists, investors and politicians who promote it, it seems more like a Promethean delirium of domination of nature or a headlong rush to use technoscience to repair the mistakes of technoscience.

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