SUNBLOCKERS

The feasibility and implementation of orbital solar shielding to reduce ambient polar temperature

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BACKGROUND

410,000,000

People expected to be affected by flooding by the year 2100 if the temperature models continue to follow current trends. [4]

1.8%

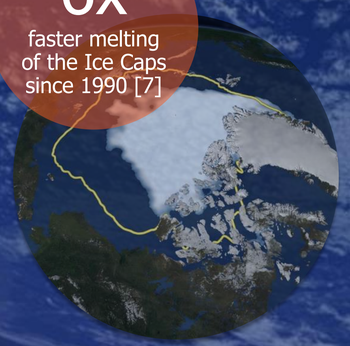
Percentage of solar flux reduction needed to offset the increase in temperature purely through solar radiation management [3]. This may look small, but it's actually 3.1 petawatts!

THE POLAR MELT: WHY SHOULD IT MATTER?

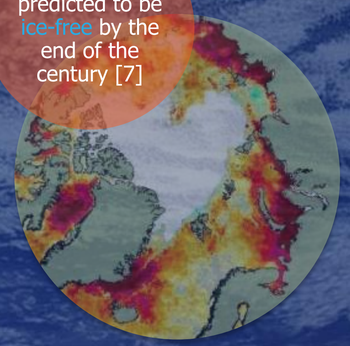
It is difficult to accurately predict the consequences from the Polar ice melting. The rising sea levels contribute to mass flooding globally, the change in salinity in the oceans leading to mass habitat loss, and even longer days from the slower rotation of the Earth as the ice melts and shifts away from the Poles [8]. It is expected that temperatures in Europe would drop to that of Montreal, as the gulf stream drifts downwards and the circulation of the ocean slows, and sea levels could rise up to 58m globally.

13% of polar ice melting per decade [4]

6x faster melting of the Ice Caps since 1990 [7]



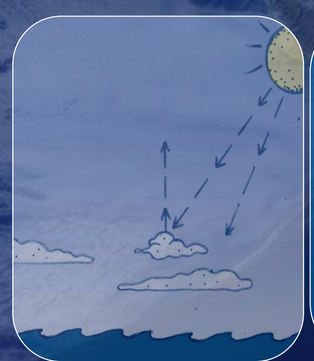
The Arctic is predicted to be ice-free by the end of the century [7]



HISTORIC PROPOSALS FOR SOLAR RADIATION MANAGEMENT

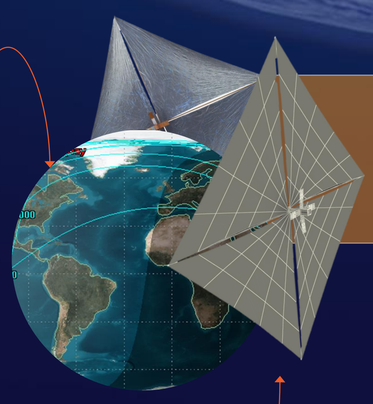
1989: James Early proposed **a large glass shield** manufactured using lunar materials and placed at **L1**, casting the Earth in shadow and reducing incoming solar radiation by 2% - enough to entirely mitigate human impact. This proposal was expected to **span 2,000km and cost $10T** [3]. The key issue with this solution is the price and scale of the project – current manufacturing procedures and launches are not capable of creating such a large-scale shield from Earth or from orbit, let alone launching the shield to L1, 1.5 million kilometres from Earth.

2006: Roger Angel built upon the initial proposal, with the concept of launching "flyers" – **billions of transparent 1m sheets** deflecting the sunlight enough to reduce oncoming sunlight by 1.8%. The flyers would be **assembled prior to launch** and launched in stacks of 800,000 flyers via ion propulsion, vastly reducing launch costs [2]. This proposal is the most feasible thus far, as the costs are **$5T** over 50 years. Angel estimates the proposal could be completed within 25 years and then be active for another 50 years without intervention.

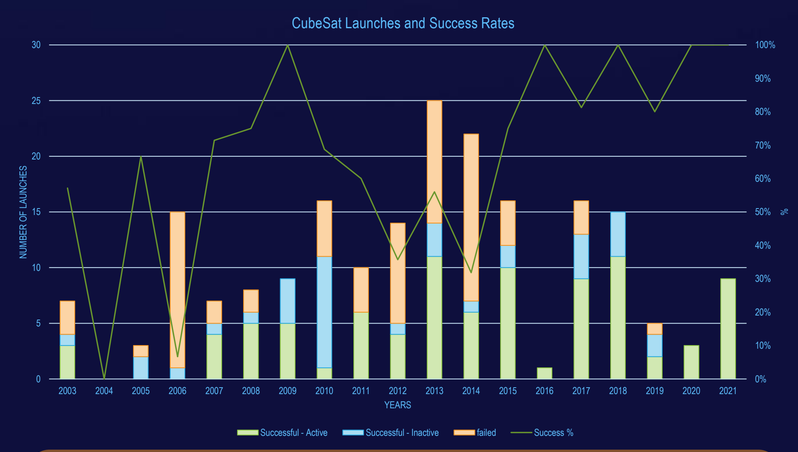


The planetary Albedo of Earth is approximately 0.3, with cloud cover and snow being the primary sources of reflectance. A variety of proposals therefore argue for manipulating these properties – **making clouds brighter** through sea salt injection, adding a layer of **reflective sulphates into the atmosphere** to emulate a volcanic eruption, and countless others. The key issue with these proposals is the **longevity of the effects** – unlike with orbital proposals, there is no quick way to deactivate these solutions in the events of unforeseen consequences. [9]

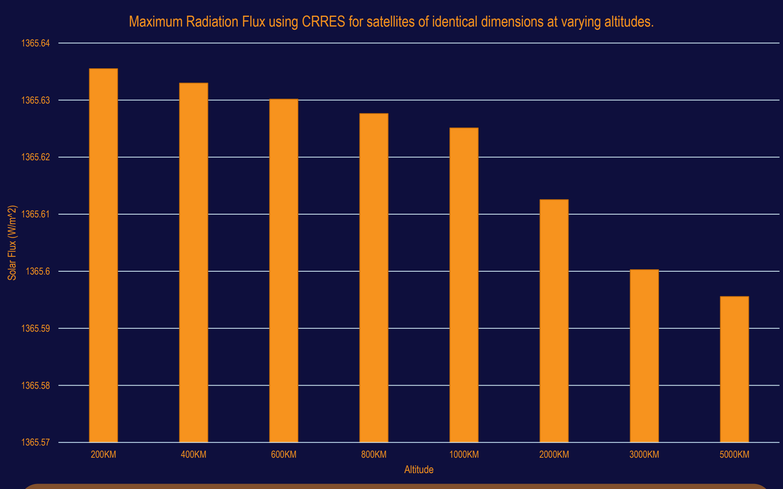
AN ALTERNATE PROPOSAL



- Placing the swarm of nanosatellites in a near-Polar orbit, such as a Sun-Synchronous Orbit (SSO) would allow for coverage over key regions such as the Arctic. Likewise, a benefit of SSO orbits is the orbit itself – the orbit passes each point at the same local solar time each time, allowing for more controlled solar reduction.
  - The satellites are subject to a much greater moment of inertia than typical CubeSats due to the large sail area. This can be beneficial, as it acts as an attitude determination and control system (ADCS) without the use of additional propellants. The satellite can utilise the solar radiation to orientate itself, burn to different altitudes and increase the time spent over specific areas.
    - The sail can be unfurled in orbit, with successful deployments such as NanoSail D2, LightSail 2 and, on a much larger scale, the James Webb Telescope.



Sunblockers is a proposal for a swarm-like constellation of CubeSat solar sails in Low Earth Orbit (<1000km). CubeSats have been successful in a wide variety of missions in recent years, and the **standardisation of the designs** and use of **COTS** parts allows for complex missions at a **much reduced cost**. CubeSats can be co-launched easily with other planned missions, reducing the number of launches and costing a fraction of the amount. Likewise, the small nature of CubeSats makes them **ideal for constellation-style missions**, such as with other small satellite missions - *Starlink* being one such example!



A single CubeSat with a standard Solar Sail configuration can block up to 1365W per metre square. A 10x10m thus would provide up to 13650W of coverage per satellite, or 0.05% of the overall radiation reduction required to completely mitigate the human impact. However, as the sheer quantity of CubeSats required to accomplish this goal would be financially prohibitive and clutter the LEO region, having a smaller quantity to help reduce the acceleration is sufficient.

ETHICS

- A key ethical consideration is the long-term effects of geo-engineering. These proposals reduce this risk as they do not directly affect the key cause of climate change – CO_2 emissions – but rather seeks to break the links between the cause and effect. The satellites would provide an **immediate effect** on temperature when active, and can likewise be **"switched off"** should any unexpected consequences arise. The impact of he solution is thus entirely dependant on how many satellites are active.
- There is the concern that, by introducing a method to reduce the impact of climate change, the **root causes** would be ignored and humanity would continue to act as they are **without taking steps to combat the damaging habits** currently contributing to Global Warming. As such, it should be stressed that this proposal is intended as a support, not a fix.

SUSTAINABILITY

- Another benefit of the solar shielding is the generation of **space power**. It is estimated[1] that **50% of the power needed by people on Earth can be beamed to Earth as microwaves**. The solar shields direct their energy to an orbiting transmitter which beams the energy to a terrestrial receiver. **Money from the space power could be used to finance the solar shields**.
- CubeSats have a standardised design heavily utilising **COTS** (Commercial Off The Shelf) components. As a result, CubeSats are **inexpensive to manufacture** and **easy to maintain** compared to traditional bespoke satellites. This allows for the swarm to be maintained in orbit and ensures **easy replacement for individual satellites.**

RECOVERY

- While it is infeasible to achieve the 2% reduction of solar radiation required, the implementation of a swarm of satellites would still **effectively reduce the acceleration of the polar thaw**. The exact impact is dependent on the number of satellites manufactured and launched.

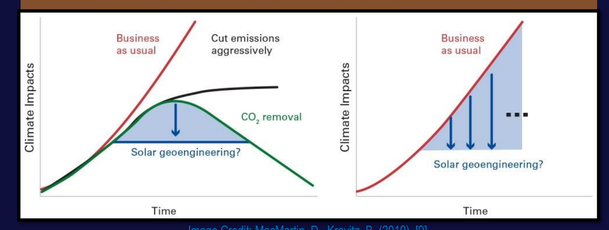


Image Credit: MacMartin, D., Kravitz, B. (2019). [9]

REFERENCES

[1] Creutzig, F., Agoston, P., Goldschmidt, J. et al. (2017). The underestimated potential of solar energy to mitigate climate change. Nat Energy 2, 17140. https://doi.org/10.1038/nenergy.2017.140

[2] Angel, R. (2006). Feasibility of cooling the Earth with a cloud of small spacecraft near the inner Lagrange point (L1). Proceedings of the National Academy of Sciences, 17184-17189. doi:10.1073/pnas.0608163103

[3] Early, James T. (1989). Space-based solar shield to offset greenhouse effect. Journal of the British Interplanetary Society 42, pp. 567–569.

[4] Hooijer, A., Vernimmen, R., (2021), Global LiDAR land elevation data reveal greatest sea-level rise vulnerability in the tropics. Nat Commun 12, 3592. https://doi.org/10.1038/s41467-021-23810-9

[5] NASA (2022). Global Climate Change; Vital Signs of the Planet. url: https://climate.nasa. gov/vital-signs/sea-level/

[6] Worldwildlife, (2022), https://www.worldwildlife.org/pages/six-ways-loss-of-arctic-ice-impacts-everyone#:~:text=Polar%20ice%20caps%20are%20melting,declined%20by%20a%20stunning%2095%25

[7] Carrinngton, D. (2020). https://www.theguardian.com/environment/2020/mar/11/polar-ice-caps-melting-six-times-faster-than-in-1990s

[8]Morales, M. (2021). https://www.sciencetimes.com/articles/30821/20210422/melting-polar-ice-caps-what-are-its-effects-earth-rotation-here-s-what-expert-says.htm

[9] : MacMartin, D., Kravitz, B. (2019). Mission-driven research for stratospheric aerosol geoengineering.