Cloud Brightening for Climate Restoration on One Page

The best way to get rid of unwanted energy is to reflect it out to space. Sean Twomey studied cloud reflectivity. He flew over clouds measuring the solar input from above and the reflection coming back up. He then flew into the clouds to scoop drops to measure their size and concentration. He found that reflectivity depends on drop size distribution. Lots of small drops reflect more than the same amount of liquid water in fewer but larger drops. Cloud reflectivity is often between 25% and 75%. In many conditions doubling the drop concentration increases reflectivity by a bit over 5%.

Making a cloud drop needs a relative humidity slightly more than 100% and also some form of seed called a cloud condensation nucleus to get it started. Köhler studied the excess humidity needed for nucleation as a function of the mass and chemical nature of the nucleus material. Efficient nuclei are plentiful over land, 1000 to 5000 in every cubic centimetre of air. But they are usually scarce, 10 to 100, in clean mid ocean air. John Latham suggested that salt fragments from the evaporation of very small drops of sea water would be ideal condensation nuclei. He calculated the amount of water that would be needed to whiten clouds enough to offset the thermal effects since preindustrial times. He was surprised at how little, about 10 cubic metres a second, would do. It is the number of successful nucleations, not the mass of water that matters.

When wind blows over the sea it produces turbulence which mixes small particles through the bottom of the atmosphere up to the top of the marine boundary layer. The falling velocity of the salt particles in still air would be far below the velocities of turbulence so the nuclei remain aloft until washed out by rain. The change in reflected solar energy when an extra nucleus changes one 25-micron diameter cloud drop into two 19-micron ones is many millions of times more than the surface tension energy to make the nucleus on which the second drop grew.

Spray could be produced by wind-driven spray vessels cruising the oceans under the direction of climate controllers to the best places. At full power each vessel would release 10^{17} nuclei per second from 300 kW of power from the wind. The short life of spray, half the mean time between rain showers, gives seasonal and regional control depending on how well we can forecast wind speed and direction for a few days ahead and how quickly we can get vessels to the right places.

Regional suitability varies over a 30 to 1 range depending on solar input, initial nuclei concentration and subsequent life. For a month either side of midsummer the solar energy going into the Arctic has a ***higher*** power-density than into the equator. For other months we can obtain polar cooling anywhere over water moving towards the poles if we can wait a little longer for the result.

If we know the rate of ice loss and the latent heat of ice we can calculate the reduction in solar input that would be necessary for ice restoration. Marine cloud brightening can moderate hurricanes and El Niño events, alter the gradient of the Indian Ocean dipole, save coral and cool sea water to increase the flow of oxygen to the deep ocean. Given enough time it can reverse rising sea levels. Precipitation can be varied in both directions. Work by Stjern at the Norwegian Cicero labs showed a trend of increased rain over drought-stricken regions with the reductions being over mid-ocean.

Engineering design for spray vessels is well advanced but UK funding for vessel construction has remained at zero.

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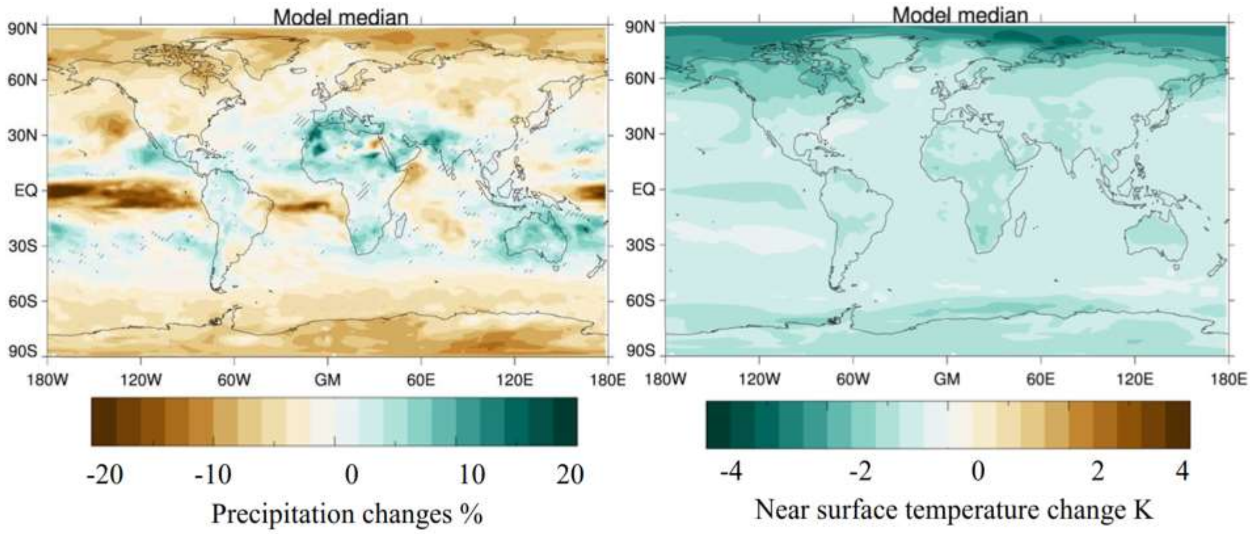
Glass balls with diameters of 4 mm and 40 microns demonstate the optics of the Twomey effect.

An artist's impression of the 2021 spray vessel. At full power of 300 kW from the wind they would release 10^{17} drops a second.



The Norwegian Cicero lab result for a 50% increase in the concentration of condensation nuclei in ocean regions of low clouds. This is the mean of nine leading climate models. See Stjern et al. doi.org/10.5194/acp-2017-629 figure 4b.

A NASA image of surface melt in Greenland.

No comment