



## **Geoengineering Earth's Energy Budget: An Overview**

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Here, we focus on proposals to reduce the amount of sunlight absorbed by the Earth with the intent of ameliorating climate consequences of the accumulation of greenhouse gases in the atmosphere.

There would be no warming, on average, if the amount of sunlight absorbed by the Earth were somehow diminished appropriately in tandem with the accumulation of greenhouse gases.

Various methods have been proposed to reduce the amount of sunlight absorbed by the Earth. These include: (1) Make Earth's surface more reflective of sunlight by spreading white particles on the surface of the ocean, building whiter roofs and roads, or planting more reflective crops. (2) Make marine clouds more reflective by providing more condensation nuclei for cloud droplets, making the clouds whiter; this might be accomplished with a seawater droplet spray or by encouraging more biological DMS production in the ocean. (3) Make the stratosphere (or above) more reflective with sulfate aerosols, or micro balloons, or various "engineered particles". (4) Place an extremely large array of satellites in space between the Earth and Sun.

There are *prima facie* reasons to believe that such geoengineering schemes would not leave regional or seasonal climate unaltered. The radiative effect of greenhouse gases is fairly uniform diurnally, seasonally, and latitudinally, whereas changes in solar radiation are felt primarily in the day, in the high latitude summers, and near the equator. Some studies show a perhaps surprising degree of cancellation of temperature changes even on a regional and seasonal basis.

On a global basis, most climate models predict an increase in evaporation and precip-

itation as the planet warms from greenhouse gases. A change in solar radiation more strongly impacts the surface radiation budget than would an equivalent radiative forcing change from greenhouse gases. As pointed out by G. Bala and colleagues, because evaporation is closely tied to the surface radiation budget, changes in evaporation are more sensitive to solar radiation changes than to “radiatively equivalent” changes in greenhouse gases.

Geoengineering schemes that have been proposed heretofore are unlikely to perfectly reverse both hydrological and temperature effects of greenhouse gases. However, initial simulations suggest that a high-CO<sub>2</sub> world with geoengineering is likely to be closer to the pre-industrial world than a high-CO<sub>2</sub> world without geoengineering. Of course, the Earth is much more complicated than our models, so if geoengineering schemes are implemented, we should expect some perhaps ugly surprises.