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P4 4 Car Park Cooling

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Abstract

In this paper we discuss the viability of paving over sections of the Earth's vast oceans in an attempt to increase the planetary albedo and reduce acquired thermal energy from the Sun. We determine that it would require us to cover $\approx 14\%$ of the Earth's oceans with paver or concrete or $\approx 3\%$ with white acrylic painted plastic, a minimum of ≈ 10 Million square kilometres, an area larger than Australia.

Introduction

The greenhouse effect poses a serious danger to sensitive balance of global temperature, by trapping Earth emitted infrared radiation the atmosphere acts as a blanket containing the heat that would otherwise have propagated back out into space. The Earth's oceans absorb a large percentage of incident radiation from our Sun when compared to land absorption values, acting as a major source of Earth emitted infrared radiation. This paper will investigate the planetary surface albedo of the Earth and discuss a method of geoengineering by which it may be increased, covering over sections of ocean surface with a more reflective material to reduce absorption.

Theory and Results

Throughout this paper we will be operating under a clear sky assumption, that being that there are no clouds present in the atmosphere, and focusing solely on the albedo impact of planetary surface composition. This is important because the values for Earth's albedo vary depending on the presence of reflective clouds in the atmosphere, with cloud incorporated Earth albedo values cited at $A_{Cloud} = 0.31$ (or 31% reflected incident radiation) [1] and clear sky albedo values cited at $A_{Clear} \approx 0.156$ (or 15.6% reflected incident radiation) [2].

By negating the impact of clouds we can more accurately determine the impact of different planetary surface materials. Earth's surface is 71% covered by oceans [3], leaving a 29% division left to dry land. With the oceans cited as having an albedo of ≈ 0.1 [4], this division of surface area yields the weighted albedo averaged as such;

$$0.156 = (0.71 \times 0.1) + (0.29 \times A_{Land}) \tag{1}$$

This returns an average land albedo value of $A_{land} = 0.293$. Therefore, we can increase the surface albedo of Earth by reducing the percentage of oceans and replacing it with a higher albedo material - potentially by 'paving' over it.

Common construction materials which we considered for this paving of ocean sections include, concrete, paver and white acrylic painted plastic which have albedos of 0.29 [5], 0.28 [5] and 0.7 [6] respectively.

By finding the effective temperature of the

Earth, the temperature of the Earth assuming it is a black body radiator, with our clear sky planetary albedo we can find the required change in planetary albedo to reduce the temperature by the $\approx 1.5°$ Paris agreement target [7];

$$T = \sqrt[4]{\frac{S_0(1-\alpha)}{4\sigma}} \tag{2}$$

Where S_0 is the solar constant for the Sun (1366 Wm^{-2}) [8], α is the albedo of the body and, σ is the Stefan–Boltzmann constant. This equation returns a black body temperature of our clear sky Earth of ≈ 267 K. By rearranging for albedo and setting target temperature 1.5 K lower we find a desired albedo of ≈ 0.175.

Now, we must determine the required reduction in Earth surface ocean coverage percent to produce our desired albedo for each material using this formula, $A_{Clear} = ((\%_{Water} - \%_{Cover}) \times 0.1) + (\%_{Land} \times 0.293) + (\%_{Cover} \times A_{Cover})$. From

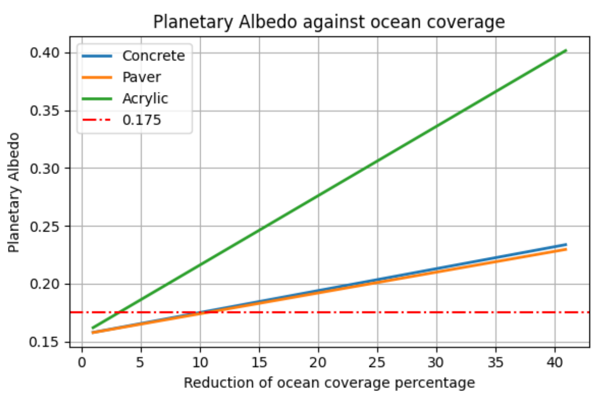

Figure 1: Planetary albedo against reduction of original ocean coverage percentage, target albedo of 0.175 marked accordingly

Figure 1, we can determine the required ocean coverage with our chosen materials to reach our target albedo for global cooling. Paver and concrete perform similarly with a percentage point reduction of ocean coverage of $\approx 10\%$ (71% down to 61% Earth surface coverage), this would require us to cover $\approx 14\%$ of the Earth's oceans with paver or concrete. The acrylic however has a much higher albedo so requires a lower percentage point reduction of ocean coverage of $\approx 2.3\%$ (71% down to 68.7% Earth surface coverage), requiring the coverage of 3% of the Earth's oceans with acrylic.

Discussion

The clear sky assumption removes a major contributor to planetary albedo, clouds but allows us to examine the surface dynamics specifically; in reality, clouds contribute a large fraction to reflectance and would have to be factored in for real world applications of this solution. It is also important to mention that solar radiation bombardment is dynamic and can fluctuate depending on solar activity, weather patterns and obstructing object motion, so a solution that works in the clear sky scenario may dangerously reduce temperatures in the dynamic reality.

Even though the lowest required coverage of 3% with white acrylic painted plastic may seem feasible it would require infrastructure spanning roughly 10 million square kilometres of ocean (an area greater than the country Australia which is ≈ 7.5 Million square kilometres), a massive feat to undertake. This coverage would likely also negatively impact oceanic ecosystems through light exclusion and chemical leaching.

A reduction in emitted infrared radiation would also certainly reduce the additional temperature delivered to the Earth's surface via the greenhouse effect, so small offsets in albedo may drastically reduce average surface temperatures.

Conclusion

The required coverage area to offset the Paris climate agreement target temperature change is likely infeasible in implementation with a minimum value of 10 million square kilometres of ocean (3% of global ocean) having to be obscured to raise the planetary albedo to the required level. Alongside implementation challenges, environmental concerns and potential run away cooling render this solution untenable.

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