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Fighting global warming by climate engineering: Is the Earth radiation management and the solar radiation management any option for fighting climate change? ☆

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ABSTRACT

The best way to reduce global warming is, without any doubt, cutting down our anthropogenic emissions of greenhouse gases. But the world economy is addict to energy, which is mainly produced by fossil carbon fuels. As economic growth and increasing world population require more and more energy, we cannot stop using fossil fuels quickly, nor in a short term.

On the one hand, replacing this addiction with carbon dioxide-free renewable energies, and energy efficiency will be long, expensive and difficult. On the other hand, meanwhile effective solutions are developed (i.e. fusion energy), global warming can be alleviated by other methods.

Some geoengineering schemes propose solar radiation management technologies that modify terrestrial albedo or reflect incoming shortwave solar radiation back to space.

In this paper we analyze the physical and technical potential of several disrupting technologies that could combat climate change by enhancing outgoing longwave radiation and cooling down the Earth. The technologies proposed are power-generating systems that are able to transfer heat from the Earth surface to the upper layers of the troposphere and then to the space. The economical potential of some of these technologies is analyzed as they can at the same time produce renewable energy, thus reduce and prevent future greenhouse gases emissions, and also present a better societal acceptance comparatively to geoengineering.

Contents

Abbreviations: AVE, atmospheric vortex engine; BC, black carbon; CCS, carbon capture and sequestration; CDR, carbon dioxide removal; CE, climate engineering; CSP, concentrated solar power; DET, downdraft energy towers; ERM, earth radiation management; GE, geoengineering; GH, greenhouse; GHG, greenhouse gases; GW, global warming; HMPT, Hoos mega power tower; IPCC, Intergovernmental Panel on Climate Change; MR, meteorological reactors; *OTEC*, ocean thermal energy conversion; PCM, phase change materials; SCPP, solar chimney power plant; SRM, solar radiation management; SRM, sunlight reflection methods; URE, unusual renewable energies; UV, ultraviolet

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1. Introduction

The most serious and important problem humankind has ever had to face might be global warming with disastrous consequences and costly adverse effects [1]. Adaptation and mitigation strategies might not be sufficient. In May 2013 the CO_2 concentration in the Earth's atmosphere officially exceeded 400 ppm, according to the Mauna Loa Observatory in Hawaii, which has been monitoring atmospheric CO_2 since 1958 when that figure was around 320 ppm. At the time the Intergovernmental Panel on Climate Change (IPCC) issued its 2007 assessment [2], it recommended to keep atmospheric greenhouse gases below 450 ppm in order to keep the temperature rise under a 2 °C target [3].

Many scenarios have been considered in order to slowly decrease our greenhouse gases (GHG) emissions to try to keep the average temperature heat rise under +2 °C. But without an international agreement signed by the biggest polluters, this $\leq$2 °C figure will remain only empty words and will not be followed by actions and effects.

Human GHG emissions have already been so important and some of these GHG have such extraordinarily long lifetimes that even if by a magic wand we could stop all emissions overnight, the average temperature of Earth would continue to rise or stay at current levels for several hundred years [4].

Global warming results from the imbalance between the heat received by the Earth and, the heat reradiated back to space. This paper proposes methods to increase the IR radiation to space. The surface outgoing longwave radiation is defined as the terrestrial longwave radiative flux emitted by the Earth's surface beyond the 3–100 μm wavelength range. The shortwave incoming solar radiation also called global irradiance or solar surface irradiance [5] is the radiation flux density reaching a horizontal unit of Earth surface in the 0.2–3 μm wavelength range. Both are expressed in $W\,m^{-2}$.

The GHGs trap some heat and, by greenhouse effect, warm the Earth surface. Incoming and reflected shortwave sunlight patterns are represented on the right side of Fig. 1 from NOAA [6] (inspired by Kiehl [7] and Trenberth [8]); outgoing infrared or longwave radiation modes are symbolized on the left side. The Earth's energy budget expressed in $W\,m^{-2}$ is summarized in this figure. The principal atmospheric gases ranked by their direct contribution to the greenhouse effect are [7] water vapor and clouds (36–72%), carbon dioxide (9–26%), methane (4–9%) and ozone (3–7%).

Tackling climate change will require significant reductions in the carbon intensity of the world economy. Developing new low-carbon technologies and adopting them globally is therefore a priority. But even moving relatively quickly toward a carbon-neutral economy will still result in a net increase in CO_2 in the atmosphere for the foreseeable future. It seems that we are nowhere close to moving quickly in this direction: gas and fossil fuel reserves have effectively increased, due to improved technologies for extraction. Huge underwater oceanic reserves of methane hydrates or clathrates [9,10] will possibly become extractible in the near future. The recent shale gas boom in USA and the methane reserves do not militate in favor of a reduction of the energy consumption, nor in a reduction of CO_2 and CH_4 emissions. With gas prices hitting rock bottom, the cost competitiveness of renewable energies in the short- to mid-term will be harder to meet than ever before. This has brought further uncertainty about the future of solar projects and offshore wind technologies,