Master's Degree Numerical Methods in Engineering

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Communication Skills 1

Assignment 2: Extended abstract

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Abstract

The scope of this document is to evaluate the favorable and unfavorable factors of implementing space mirrors to reduce sunbeams impacting the earth. The proposed implementation tackles directly the amount of heat entering the earth and therefore a drop in temperature is expected. Space mirror is one of the most direct and therefore effective ways of reducing the temperature on the Earth. On the other hand, one of the main problems of Climate Change is the storage of CO_2 because it raises the temperature and acidifies the water. Therefore, the use of space mirror shall be used combining both CO_2 reduction and temperature diminishing.

1 Introduction

The climate system we want to preserve in our Earth is composed by the atmosphere, hydrosphere, cryosphere, lithosphere and the biosphere. Changes in climate are accounted for variations of these systems for long periods (over 30 years) until a new equilibrium is reached [1]. Climate changes have existed since the beginning of the Earth's history, gradual or abrupt changes have been registered and their origin was due to diverse causes, such as changes in orbital parameters, variations in solar radiation, continental drifts, periods of intense volcanism, biotic processes or meteorite impacts. Current climate change is anthropogenic (from 1765 to present) and is mainly related to the intensification of the greenhouse effect due to agricultural and industrial emissions from the burning of fossil fuels [2].
The Earth has undergone several changes in climate along with its history, with major variations of CO_2 shown in Figure 1. A logarithmic scale is used to represent the mixing ratio of atmospheric CO_2 because the radiative forcing of climate is proportional to the logarithm of CO_2. The biggest amounts of CO_2 registered in the figure (Eras 5 and 6) are related to time oxygen was toxic for most of the life in Earth 2.5 billion of years before present (Bybp). What it is important to state from Figure 1 is the strong association of Earth's climate and atmospheric content of CO_2. Throughout history, we can conclude that when CO_2 rises, Earth warms.
Actions needed to be taken to reduce CO_2 and other gas emissions are pretty straight forward, studied, and require less use of fossil fuels and higher efficiency use of all energies. On the other hand, the temperature registered one of the most critical variations in the last two thousand years (>200%) and holds major importance on the conservation of flora and fauna. This variation is related to two mutually reinforcing effects:

1. Increasing amount of greenhouse gasses (gasses held below the ozone layer that distributes sunbeams: thick greenhouse layers deficiently dissipates energy outward the planet);
2. Decreasing extent of polar regions (whiteness of ice acts like a mirror reflecting sunbeams and reducing the storage of energy they provide)

Polar regions are melting because of the temperature rise and the heat they reflect is, therefore, less. For example, northern sea ice (more sensitive to climate changes than Antarctica [3]) registered in September 2019 a surface of about 4.32 million square meters [4], the surface is 50% less than the average between 1981 and 2010 for the same month.

Considering the idea of reflecting heat outwards the Earth and reducing the temperature in its surface, the implementation of *space mirrors* is studied.

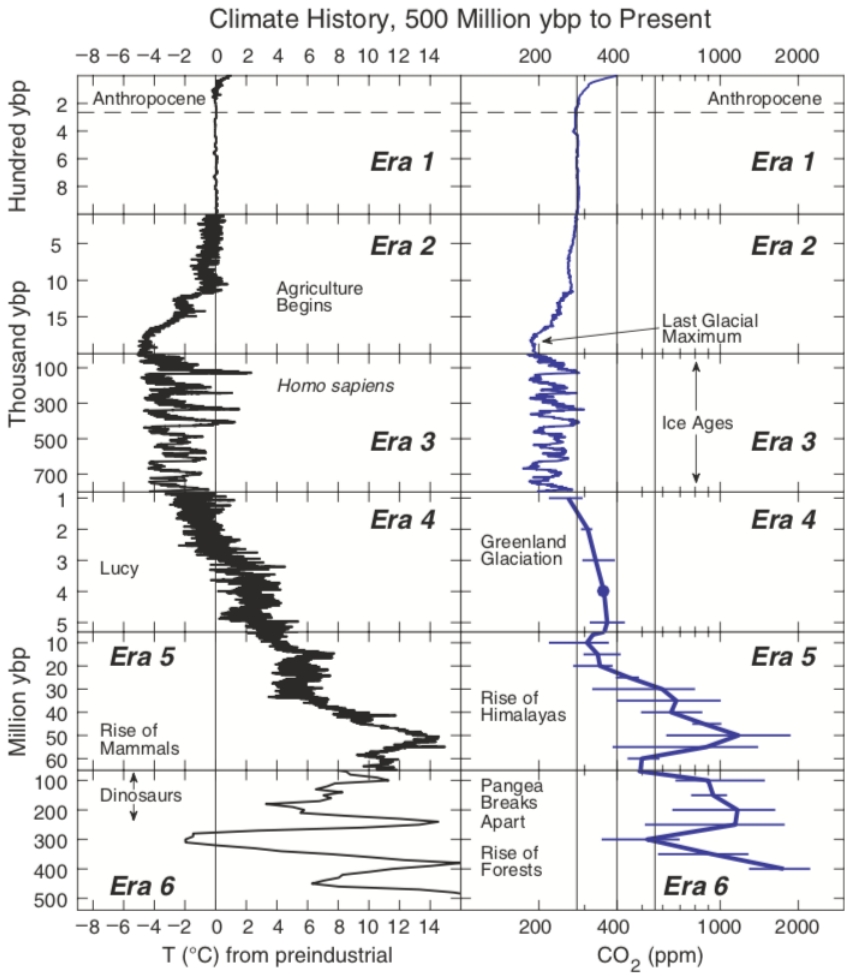

Figure 1: Variation of temperature and CO_2 in the Earth. Salawitch et al. 2017 [2].

2 Geoengineering

Geoengineering or climate engineering is what we know as the intervention in the Earth's climate system, with the purpose of mitigating the adverse effects of global warming. One of the most important subcategories of geoengineering is solar radiation management, which focuses on offsetting the detrimental effects of greenhouse gases by reducing the solar radiation absorbed by the Earth [5].

Another implementation of geoengineering is carbon sequestration or carbon dioxide removal, which comes after the great amount of CO_2 concentrated on Earth, increasing atmospheric temperature and acidifying oceans. If CO_2 were to be removed, the impact on the reverse of climate change would be positive.

3 Space mirror

Space mirror is an application of climate engineering consisting of man-made satellites aiming to change the quantity of solar radiation impacting on the Earth. This idea was considered in the 2000s as a way to deflect sunlight to counter global warming [6]. There have been several

studies to implement the space mirrors, however, the only implemented project is the "Znamya project" designed in Russia, see Figure 2 [7].

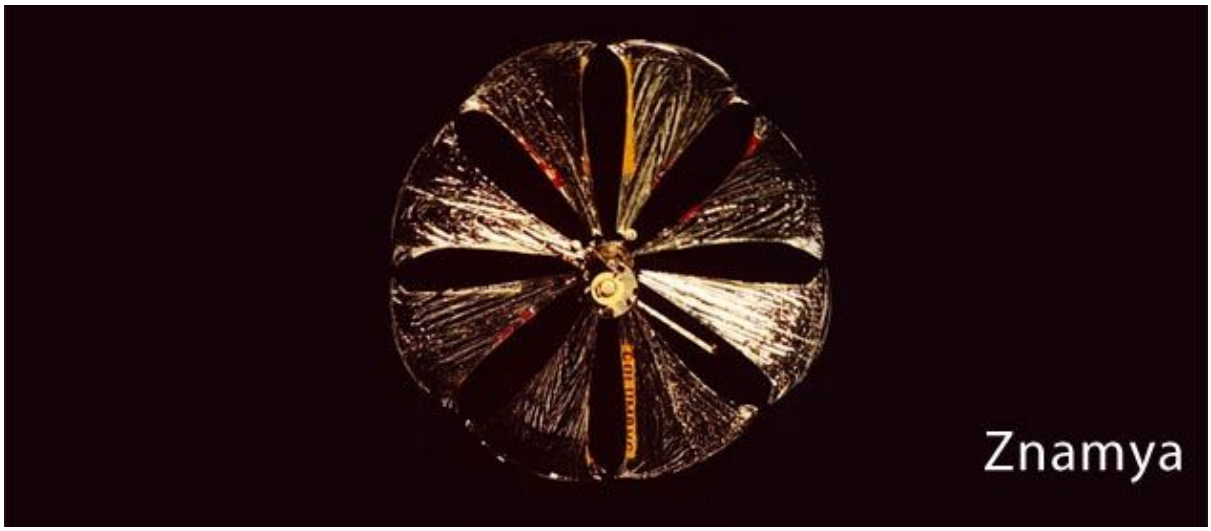

Figure 2: Znamya satellite

3.1 Purpose

The aim of space mirrors is to decrease the amount of energy reaching the planet from the sun in order to change the increasing temperature of the planet. Also, it is interesting to point out that the space mirrors can also be used for increasing the amount of heat impacting the Earth if the objective in future changes [8].

As a measure of climate engineering, the majority past proposals to develop space mirrors were used to reduce the progression of climate change on Earth. Also, there are proposals to develop space mirrors focused on the ability to substitute localized lighting conditions on the surface of the planet by reflecting sunlight onto little sections or shading certain sections. This could enhance crop growth adding potentially sunlight or even allow differentiated climates in local areas.

3.2 History and feasibility

Space mirroring first approaches comes from the '80s when researchers were looking to reflect sunlight to reduce global warning's rate on Earth by deploying mirrors into space.James Early was the pioneer on this subject, starting the first research back in 1989, and proposing a two thousand kilometres glass shield, planned to be constructed on the Moon using materials from there. Then Lowell Wood proposed to send a massive mirror into the orbit of Lagrange point 1 (one million miles away from Earth), but the size of the mirror was still huge and very challenging to be sent so the projects were never done. In 2006, a researcher from the University of Arizona, Roger Angel, after realizing that one of the main challenges was the size of the mirror, proposed to send millions of mirrors instead of sending one massive being more feasible[9].

The feasibility of the project does not only depend on the environmental and engineering point of view but economics as well. The space mirroring has to be capable of providing clean energy to the Earth as well. Therefore, *Star Technology and Research* proposed launching several hundred space mirror spacecraft into orbit close to Earth, orbiting around the equator and remotely

controlled to steer around Earth. In addition, these mirrors would be equipped with solar panels in order to capture and store energy. Even if the energy problems were to be fixed, the estimated cost for the deployment, transportation, construction and ground support operation of sending a fleet, will be approximated of 750 billion dollars. With an estimated maintenance cost of 100 billion dollars for every year, making the project unattainable[9].

Moreover, space debris around Earth's orbit has to be considered. Even though the average weight is around 1 g, the speed of the space debris can be threatening when it comes to terms of collision. Space mirrors should avoid being hit by these dangerous tracked space debris. In either case (multiple space mirrors or a massive mirror), carrying out this action properly will be of great difficulty.

In 2007, The Guardian declared that the US government advised that investigation on sunlight deflection (including space mirroring) should be included in the next United Nations Report on Climate Change. Furthermore, it was proposed sunlight-reducing techniques such as launching thousands of highly reflective balloons [10]. In November 2007, in a climate engineering conference organized by Daniel Schrag of Harvard University and David Keith of the University of Calgary, it was agreed that it was worth to study further the space mirroring ideas, regardless the doubtful feasibility of the space mirrors and their high-cost [11].

3.2.1 Russian implementation

Between 1992 and 1999, the Znamya project was executed. The project included a series of orbital mirror used to beam solar energy to Earth by reflecting sunlight. It involved two experiments: the Znamya 2 experiment and the Znamya 2.5 experiment, which failed, and finally, the Znamya 3 was proposed. Russian Federal Space Agency abandoned the project after failing the deployment of the Znamya 2.5 [12]. In 1992, Znmaya 2 mission was executed, it was composed of space solar mirror of 20-metre wide. It was launched successfully in the desired orbit, its functioning was proved (reflecting a light similar to a full moon) and then was de-orbited after several hours of normal functioning and it ended up burned in atmospheric reentry near Canada. In 1999, the Znmaya 2.5 mission was executed, it was the successor of the Znamya 2 with a diameter of 25 metres. However, after deployment, the mirror got caught in an antenna and ripped. Then it was de-orbited and it burned upon reentry. Finally, the Znamya 3 was an attempt to be a version of the two previous Znamyas, with 60-70 metres of diameter. It was never executed and the project was abandoned after the Znamya 2.5 failed.

4 Conclusions

Advantages and disadvantages of space mirror as a geoengineering proposal were studied. Space mirror tackles directly the temperature rise issues and it is expected to act in a short period of time. Conversely, some potential problems that may arise from the implementation of the space mirrors: high costs of construction, transportation and ground support operation; not enough evidence of what consequences will have on plants, animals and human beings; the fact that decreasing temperature will not erase the amount of CO_2 in the Earth, that not only rise temperature but also acidifies water.
The implementation of space mirror would be a good idea as a backup plan in an emergency case and a short-term solution. It is necessary that the implementation of space mirrors is taken along with the CO_2 reduction policy.

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