The climate of a Sunshade Geoengineered World

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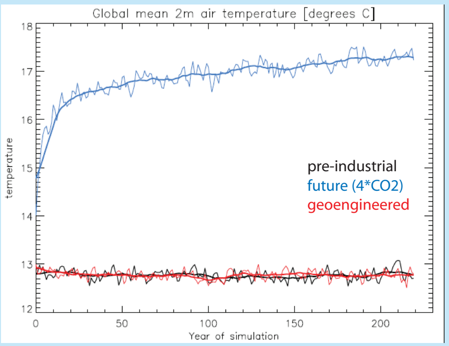
(1) INTRODUCTION

Sunshade geoengineering - the installation of reflective mirrors between the Earth and the Sun to reduce incoming solar radiation, has been proposed as a mitigative measure to counteract anthropogenic global warming. Although the popular conception is that geoengineering can re-establish a 'natural' pre-industrial climate, such a scheme would itself inevitably lead to climate change, due to the different temporal and spatial forcing of increased CO2 compared to reduced solar radiation. We investigate the magnitude and nature of this climate change for the first time within a fully coupled General Circulation Model. We find significant cooling of the tropics, warming of high latitudes and related seaice reduction, a reduction in intensity of the hydrological cycle, reduced ENSO variability, and an increase in Atlantic overturning. However, the changes are small relative to those associated with an unmitigated rise in CO2 emissions. Other problems such as ocean acidification remain unsolved by sunshade geoengineering.

(2) EXPERIMENTAL DESIGN

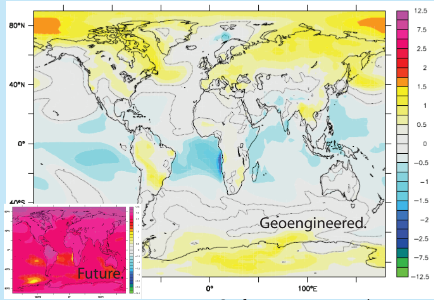
We use the UK Met Office fully coupled GCM, HadCM3L. We carry out 3 simulations; a pre-industrial control, a 4*CO2 simulation, and a 'geoengineered' simulation with 4*CO2 and reduced solar constant. The reduced solar constant is chosen such that the global annual mean surface temperature is equivalent to that of the pre-industrial. The timeseries of surface temperature in the 3 runs is shown below.



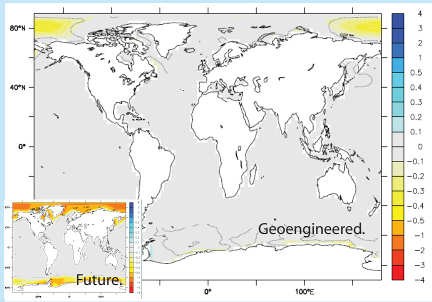
In terms of global annual mean surface temperature,m the geoengineerign has clearly been successful. The required reduction in solar constant is 57 W/m2 (4.2 %).
The figure also illustrates that the high CO2 simulation is yet to reach complete equilibium.

(3) GCM RESULTS

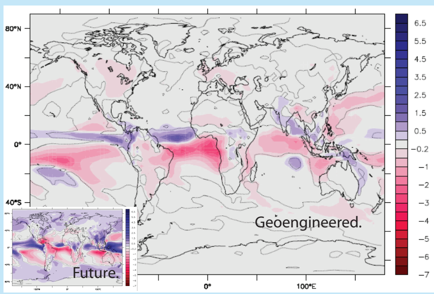
The spatial distribution of climate change relative to pre-industrial (temperature, seaice, and precipitation) are shown below for the geoengineered and future simulations.



Surface temperature change.



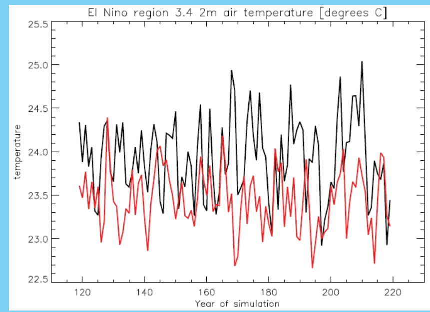
Seaice thickness change.



Precipitation change.

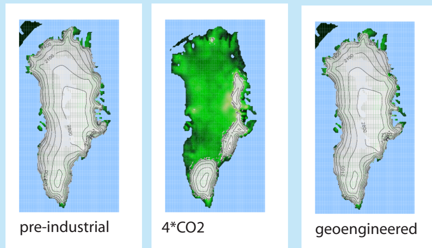
(5) ENSO CHANGES

The dynamic ocean component of HadCM3L allows us to assess possible impacts on ENSO of the geoengineered climate due to the reduction of insolation in the tropics. The Figure on the right shows a timeseries of surface air temperature in El Nino region 3.4, in the preindustrial and Sunshade World. The expected reduction in annual mean temperature is apparent in the geoengineered timeseries, but there is also a decrease in the variability. The decrease in the intensity of the ENSO signal is most likely due to the cooler tropical SSTs and associated reduced tropical convection. This reduces the strength of positive feedbacks which otherwise act to intensify El Nino events by increasing the strength of Walker circulation..



(6) ICE SHEET CHANGES

In order to assess whether the introduction of the sunshade can avert dangerous climate change, we carry out an equilibrium ice sheet model simulation of the Greenland ice sheet. The plots on the right show the simulated present day ice sheet, that of the 4*CO_2 world, and that of the "sunshade geoengineered world".
It is clear that the installation of the sunshade, despite some warming at high latitudes relative to pre-industrial, is able to avert the sea-level rise associated with the demise of the Greenland ice sheet under 4*CO2 forcing.



(6) CONCLUSIONS

To our knowledge, this is the first analysis of sunshade geoengineering using a complex GCM with a fully coupled atmosphere and dynamic ocean. Compared to the pre-industrial, we find that a sunshade geoengineered world with an identical global annual mean surface temperature has a reduced meridional temperature gradient, and cooler tropics. There is a reduction in the intensity of the hydrological cycle, in particular in tropical regions. We simulate a significant decrease in Arctic seaice in the sunshade geoengineered world, and find a reduction in the amplitude of ENSO. Despite significant differences in temperature and seaice relative to the pre-industrial, compared to unmitigated increase in CO2, the predicted changes are relatively small. In this respect, we find that the sunshade geoengineering is highly successful. However, other direct effects of increased CO2 remain unmitigated, in particular ocean acidification and the subsequent impact on ecosystems. Because of this, we can not recommend sunshade geoengineering as an alternative to the reduction of emissions. This is even before the high cost, and possible ethical considerations, of a sunshade geoengineering scheme have been considered.