Geoengineering - Cloud Whitening

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In the Revenge of Gaia (2009), James Lovelock argued that catastrophe will happen within the next 30 years, severe storms and droughts will become the norm, carbon offsetting a joke, and current ethical efforts a scam. Is he right? An alternative proactive approach is discussed.

Background to Geoengineering;

Geo-engineering, we define as man-made Environmental Change. Since the industrial revolution, mankind has been geoengineering the planet, cutting down rainforests, burning fossil fuels, pumping CO_2 and other radiative gases into the atmosphere. The current acceleration of environmental temperature change, is not only due to CO_2 but also due to the release of other gases such as methane, not just from agriculture, but also because of the significant thawing of the Canadian and Siberian permafrost which enables the underground captured methane gas fields, to escape. Although methane is a relatively short-lived in the atmosphere, it is between 20-70 times more radiative than CO_2 and could cause a runaway heating effect, only mitigated by the large scale latent heat sink needed to melt the ice caps.

The Philosophy of Geoengineering - Cloud Whitening:

The so-called "*Geoengineering schemes*" are designed to be restorative, with a view that they could provide a breathing space. However, there is a need to understand their science, thus avoiding the effect of " *unintended consequences*" . Several possible schemes were analysed and discussed and analysed in the Royal Society Report "Geoengineering the climate, published 1st September 2009. The report recommended research into two of the solar radiation management, one of which was this Cloud Whitening scheme. This technique could provide a breathing space, whilst CO_2 reduction methods could be implemented. Further, it would be very wise to research into the viability of these schemes, "in case we need them in an emergency". The scheme requires continuous operation and produces a "one off effect" but, the advantages of the scheme, are the low ecological impacts:-

- the only ingredients are seawater and air.
- energy is derived from wind and relatively inexpensive.
- it is an easy termination system which can be shut down immediately, conditions returning to normal within a few days.
- it would have precise and rapid control via satellite measurements of albedo and cloudiness fed back through **a** global model.
- it is cheap to implement, and if the small scale scientific experiments verify the theory, could be deployed relatively quickly

Stratocumulus Clouds.

Oceans cover 70% of the globe and low level strato-*cumulus* (layer) clouds, cover 30% of the Oceans. These clouds are very important in atmospheric and ocean global heat engine system. In November 2008 a large international field project, based in Arica, Chile, with over 200 scientists, 5 aircraft and two ships, measured these clouds in situ and with remote sensing. NERC funded a consortia project, VOCALS, with BAE146 and Dornier 128, and scientists from 4 UK participating universities. A GOES satellite image (Figure 1) taken during the project, indicates the extent of these clouds.

The water droplets in clouds reflect solar radiation back to space. The numbers of droplets in clouds are largely controlled by the number of Cloud Condensation Nuclei (CCN). Many CCN are produced over the land. Land-locked clouds therefore contain many hundreds of cloud droplets per cubic centimetre, whilst clouds that form over the sea contain substantially less: typically only a few hundred per cubic centimetre. Generally, the more droplets that are present in a cloud, the smaller they are for a given liquid water path. These clouds are maintained by a complex balance of dynamics, radiation and precipitation. The rate of collisions and coalescence, determine whether the water droplets precipitate out, or maintain a stable system. Much is still unknown about the interaction of these processes. However, Figure 3, shows the effect of ship tracks, over the Bay of Biscay; the lower images showing the concurrence of the small droplets, and the brighter more reflective clouds.

Latham (1990) suggested that by increasing the number of droplets in maritime layer clouds (stratocumulus), the reflectance of these clouds could be significantly increased. These clouds cover a third of the ocean. For a given mass of water in a cloud, clouds with smaller droplets tend to be whiter.
The proposal is to inject a fine spray of sea salt from the ocean surface into the clouds, to artificially increase the number of drops, hence reduce their size and increase the reflectance of the cloud; i.e. to make the clouds whiter. This increase in reflectance can buy time; maybe as much as 50 years.

Numerical modelling and field experiments are needed to determine the ideal size of the sea-salt CCN. Results from climate models show that a modest increase of CCN in marine stratocumulus clouds can produce the desired cooling (Figure 3). Further research is required, but preliminary results suggest that up to a doubling of atmospheric CO2 from pre-industrial levels could be compensated for.

Initial results, from models, suggest that the biggest cooling with this scheme (as opposed to stratospheric injection of sulphate) occurs in the Polar Regions (Gadian, also Rasch, unpublished), which is consistent with theory and is precisely where cooling is most needed, i.e. to prevent the permafrost melting. It uses natural sea water spray and can be turned off immediately, if undesirable consequences are produced.

The technology

Salter et al. (2008) have suggested a design for a fleet of about 2000 wind-powered, unmanned yachts which incorporate a sophisticated spray mechanism. Figure 4. shows the ship design, with details of the spray mechanism omit detailed in the paper. Sea-spray of diameter ~ 0.8micron would be released and provide the CCN for the clouds.

What is needed?

We are proposing to perform detailed research into the scheme and provide an answer as to its viability within five years. There are four elements:

- Cloud physics modelling. There are questions about the optimal size of sea-salt CCN and how the clouds will respond to the increased numbers of CCN. We are already collaborating with top US cloud physicists.
- Further Climate modelling.
- Development and building of Stephen Salter's test yachts.
- Field experiment. A limited-area field experiment is needed in a region of stratocumulus

What is the cost?

About ~ £6 million is required to fund development of a test spray system and conduct a field experiment to assess the scheme's viability. This is an insignificant sum compared with the cost of doing nothing. Will we know in 5-10 years whether we can provide an answer to Lovelock's question:
"Could we have done anything to slow down the warming and the irreversible change in the Earth system?"

References:

Latham, J. 1990 Control of global warming? Nature 347, 339–340. doi:10.1038/347339b0

Latham J. et al. 2008, Global temperature stabilization via controlled albedo enhancement of low-level maritime clouds Phil. Trans. R. Soc. A doi:10.1098/rsta.2008.0137

Lovelock, J. 2009, Revenge of Gaia, Penguin

Salter, S. et al. 2008, Sea-going hardware for the cloud albedo method of reversing global warming Phil. Trans. R. Soc. A (2008) 366, 3989–4006 doi:10.1098/rsta.2008.0136

FIGURES:-

Figure 1. GOES IR East Geostationary Satellite image, 2008-11-07 1200 UTC. Grey stratocumulus clouds are visible off the coast of Chile, and were measured using the NERC BAE 146 and Dornier 128 aircraft on the NERC funded VOCALS consortia project.
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Figure 2. Ship tracks in the Bay of Biscay. The upper image shows the visible ship tracks; the lower images the optical thickness and the effective droplet radius. The smaller the droplet radius, the higher the reflectance and the greater the optical thickness. (Courtesy of Phil Rasch)
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Figure 3. Radiative forcing (W m^{-2}) at TOA between control and modified runs in the UK MO HADGaM model, using N = 375 cm^{-3} in all regions of low-level maritime cloud. This creates a total global cooling of ~ - 8 Wm^{-2}. Doubling of CO_2 is ~ 3.7 Wm^{-2} (Latham *et al., Proc Roy Soc*, rsta.2008.0137, Nov. 2008)
Courtesy of the Royal Society.
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Figure 4. Ship Spray design, courtesy of Stephen Salter's design, picture courtesy John McNeill
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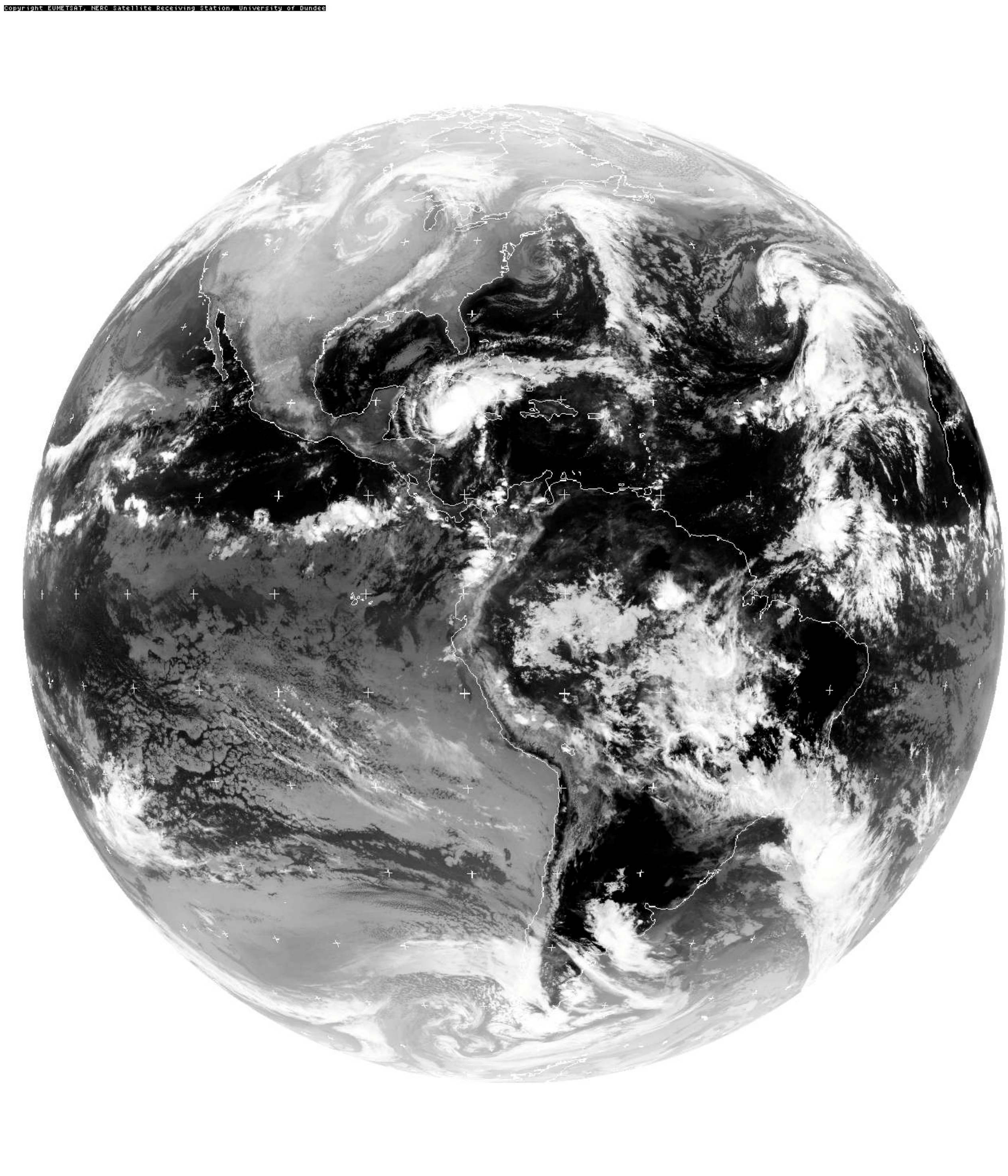
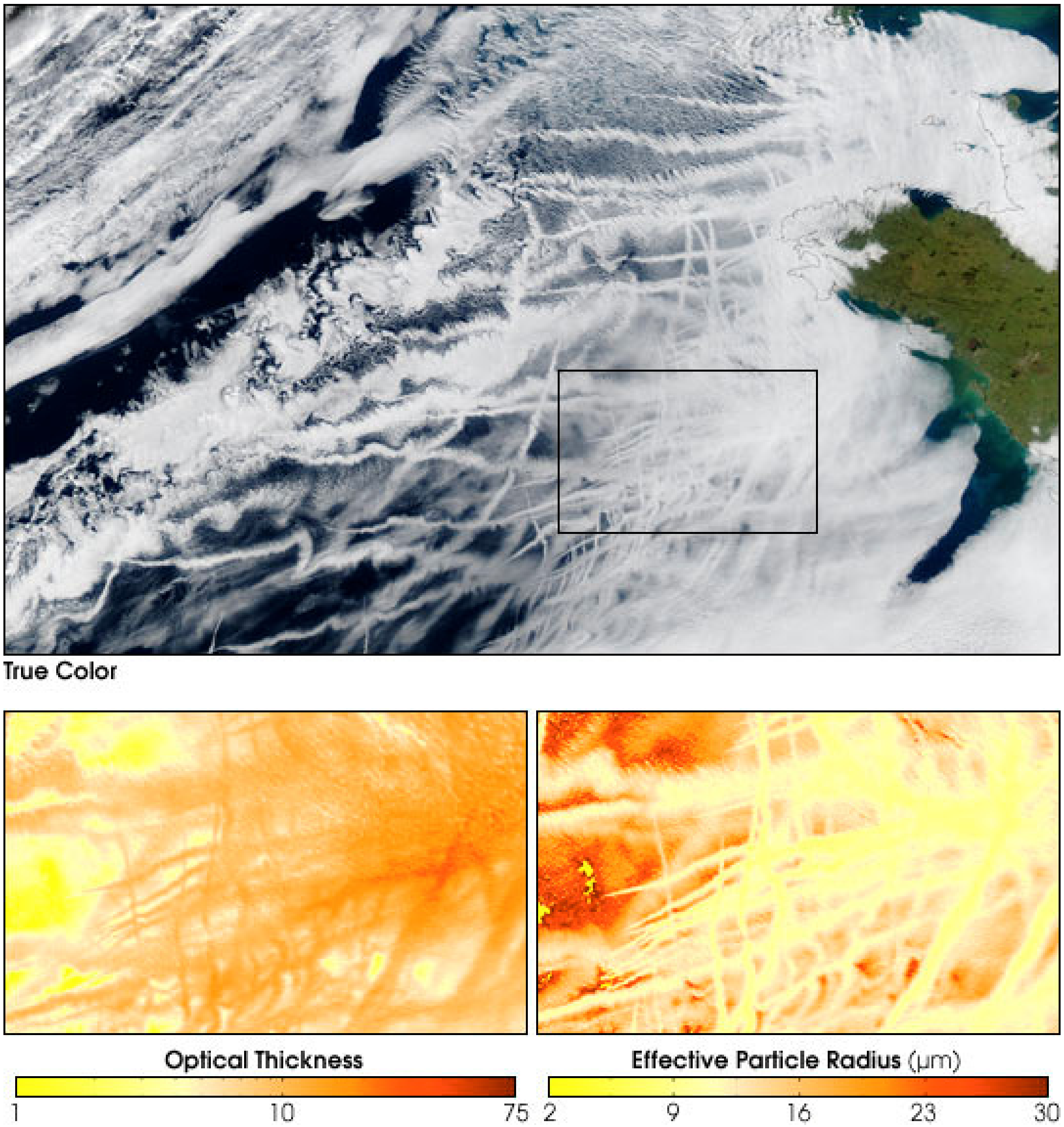

Copyright EUMETSAT, NERC Satellite Receiving Station, University of Dundee
Channel 4 received on 7/11/2008 at 1200 from satellite GOES12

Figure 1.

Figure 2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Optical Thickness
1
10
75
Effective Particle Radius (µm)
2
9
16
23
30

Figure 3

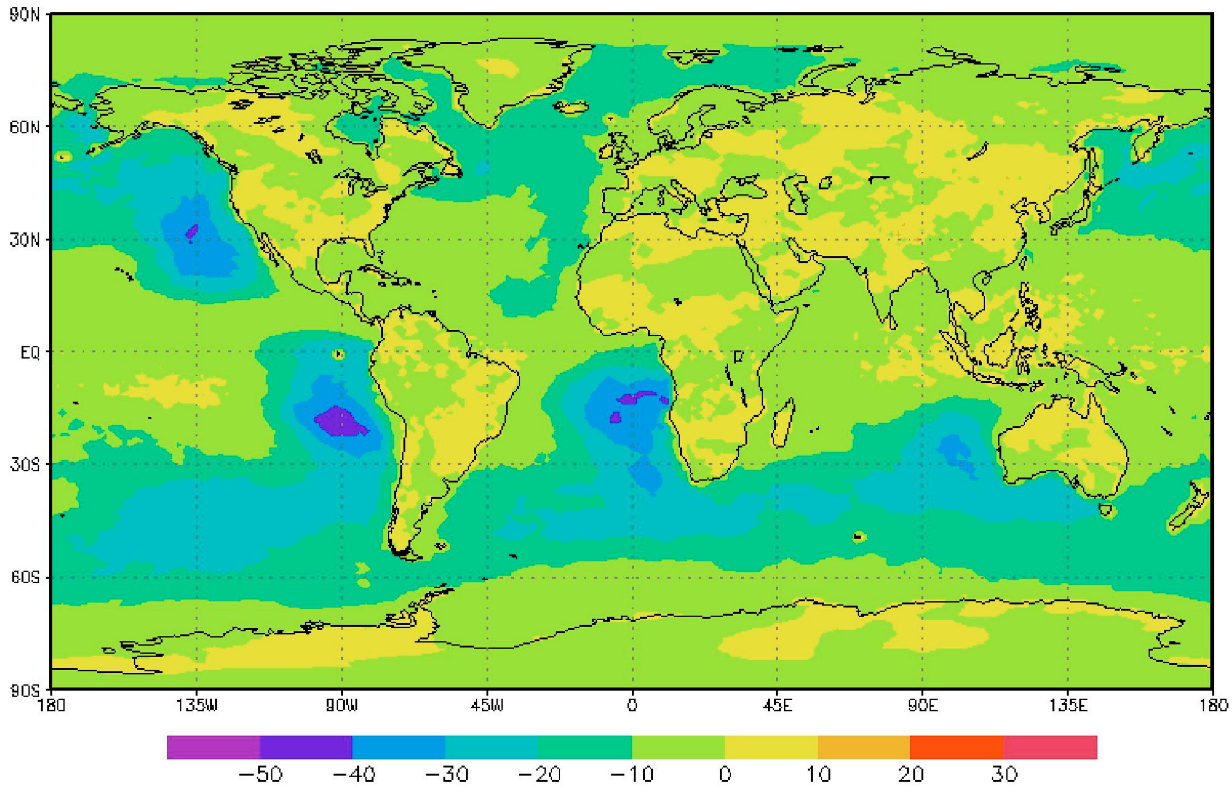
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Figure 4