Geoengineering the climate

Joanna Haigh outlines the range of options currently being investigated by researchers and technologists to modify the climate system to try to prevent dangerous climate change – but finds that there are no 'magic bullets' here.

By trapping infrared radiation, naturally occurring greenhouse gases maintain the Earth's average surface temperature at about 33°C warmer than it would be without an atmosphere. About two-thirds of this is due to the presence of water vapour and about one-third carbon dioxide, with other gases playing much smaller roles. As the concentrations of man-made greenhouse gases (particularly carbon dioxide and methane) increase so does the trapping of heat radiation so that, in the current state of the climate, the global average surface temperature increases approximately in proportion to the logarithm of the CO_2 concentration.

The most obvious means of slowing down or preventing further warming would be to reduce emissions of greenhouse gases. Concerted international action in this direction, however, has been slow and, currently, there appears to be no credible emissions scenario that could produce a reversal in the upward temperature trend within the next century. Indeed, unless global greenhouse gas emissions are reduced by 2050 to below 50% of their 1990 levels, then it seems likely that global surface temperature will rise by more than 2°C this century. This level of warming has the potential to cause climate change with severe impacts on human activity and the natural environment.

Options for geoengineering

In the absence of sufficient reductions in greenhouse gas emissions, or in order to buy time to reduce emissions, various schemes have been proposed for large-scale intervention in the climate system. These schemes for 'geoengineering the climate' can be divided into two fundamentally different approaches, as follows.

1. Carbon Dioxide Removal (CDR) techniques remove CO_2 from the atmosphere.
These include:

- *Land use management, afforestation*. Careful planting can help limit the growth of CO_2 concentrations, has relatively few side effects (except possible land use conflicts, demands for water or implications for biodiversity) and could be implemented immediately and cheaply. The scope for significant impact is, however, small.
- *Sequestration of biomass*. Crop waste or charcoal can be buried on land or in the deep ocean. Crops grown for bioenergy and biofuels (although with potential adverse impact on food production) might be utilised with CO_2 capture and sequestration (CCS). The potential impacts on ecosystems of all sequestration methods need to be assessed. Methods for sequestration of CO_2 from ocean gas platforms in utsira-formations (layers of sand and brine under the sea floor) have already been designed, and might be implemented for other sources, but the costs are high and the longevity and leakiness need to be better understood.
- *Enhanced weathering*. For this, the absorption of CO_2 by silicate minerals (e.g. olivine) would be accelerated and the resulting solid carbon stored on land or in the ocean. This would involve mining, treatment and transportation of the minerals, with significant energy implications. It would also be slow to take effect.
- *Chemical capture of CO_2 from the air*. 'Artificial trees' have been designed to extract atmospheric CO_2. The technology appears to be feasible, but again must cope with the problems associated with CCS.
- *Enhancement of the take-up of CO_2 by ocean plankton*. This would be achieved by enhancing photosynthesis by increasing the availability of the necessary nutrients – either by 'fertilisation' of the ocean with iron, phosphorus or nitrogen or by (wind or tidal-driven) pumping of deep ocean water to the surface. There is currently insufficient evidence to determine if this would be effective. An important consideration is the potential for undesirable ecological side effects.

2. Solar Radiation Management (SRM) techniques reduce the amount of solar energy absorbed at the Earth's surface by enhancing global albedo (reflectivity) and thus returning some solar radiation back to space. These include:

- *Space-based reflectors*. Proposed schemes include the launch of trillions of small refracting disks up to the L1 (equal gravity) point between the Earth and the Sun or the manufacture on the Moon of refractors made from lunar glass.
- *Stratospheric aerosols*. Sulphate particles released into the stratosphere would simulate the effects of massive volcanic eruptions, which have been shown to introduce temporary reductions in global mean temperature. Of concern here would be the indirect effect on stratospheric ozone concentrations and atmospheric acidity.
- *Enhancement of cloud reflectivity*. It is proposed that this might be achieved by the injection of sea salt particles into clouds (or potentially cloudy regions) from specially designed ships. The salt particles would act as condensation nuclei for cloud droplets and the resulting cloud, composed of more numerous but smaller droplets than might otherwise exist, would have higher reflectivity and, probably, longevity.
- *Enhanced land surface albedo*. This might be achieved through the use of more reflective crops, or by covering deserts with highly reflective material, or by painting urban settlements white. These schemes tend to be very expensive and may produce undesirable local ecological impacts.

CDR techniques may be viewed as preferable to SRM techniques in that they attempt to return the climate to a more natural state and they would, in general, be safer. However, they tend to be very slow to take effect and very costly if they are to make significant impact. Furthermore, the methods for the carbon sequestration required as part of most of these schemes are not well proven to be without undesirable environmental side effects. SRM techniques are inherently less safe than CDR methods in that, while they provide a correction to the global radiation imbalance introduced by the greenhouse gases, they do not return the atmosphere to its natural state. They do nothing to reduce other effects of high CO_2 concentrations, such as ocean acidification, and they place the climate in an unnatural 'High CO_2 Low Sun' state under which regional weather patterns may be quite different, impacting on water or food resources. SRM schemes would, however, be easier than CDR methods to implement (or reverse) swiftly. But if they were introduced with a view to long term mitigation of global warming then humankind would be committed to maintaining them into the indefinite future: any sudden cessation of the SRM would plunge the world very fast into the much warmer state associated with higher CO_2 concentrations.

Ethical issues

While the scientific and technical issues posed in the development of geoengineering methods are challenging, possibly an even greater problem would come in addressing ethical and political issues. Some of the schemes, such as capture of CO_2 from the air, might be regulated with existing national legislation such as pertains, for example, to air pollution. Other geoengineering methods, such as space-based reflectors, would throw up much greater challenges. There are no clear mechanisms to govern the implementation, operation or control of geoengineering activities as yet.

Another ethical aspect that is frequently cited is 'moral hazard', whereby the potential existence of geoengineering schemes discourages concerted action to reduce CO_2 emissions. I fear, however, that that cat is already out of the bag, and hence we find a surge of international interest in this issue. No geoengineering method has been identified which can address the issue of climate change in a timely, safe and affordable way and the problems of international governance may be insurmountable. It must be reiterated that the safest and most reliable way to combat climate change is to attack the problem at source, to identify alternative sources of low-carbon energy and to use existing energy sources as efficiently as possible.

Joanna Haigh is Professor of Physics at Imperial College, London, and sat on the Royal Society's Working Group on Geoengineering.

Further reading

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New Anglo-French nuclear weapons treaties threaten disarmament

Peter Nicholls highlights how two new 50-year treaties could undermine nuclear disarmament.

Two treaties – known as 'Teutates' (after a Celtic war god)[1] – have been agreed between France and the UK for sharing nuclear weapons research facilities. They were signed in autumn 2010. One is for Defence and Security Co-operation,[2] with the other "relating to Joint Radiographic/Hydrodynamics Facilities".[3] The texts were 'laid upon the table' in the House of Commons but there was no demand for a debate. So under the Ponsonby rule they were cleared for ratification, which has recently taken place. So much for democracy and the alertness of our elected representatives – because these treaties raise serious questions about the willingness of both countries to adhere strictly to the terms of the NPT (Nuclear Non-Proliferation Treaty) and to consider steps towards disarmament.

Their official purpose includes exchange of classified information on nuclear weapons and the creation and operation of joint radiographic/hydrodynamics facilities. The radiological facility in France (Teutates EPURE) will be built at Valduc. The UK Teutates Technological Development Centre (TDC Facility) will be built at the Atomic Weapons Establishment, Aldermaston. The radiographic/hydrodynamics facilities will permit design of new generations of nuclear weapons. This is at odds with the spirit of the Comprehensive Nuclear Test Ban Treaty as well as the NPT. Cooperation between the UK and France is agreed to continue for the next 50 years – beyond the life expectancies of all the signatories including even our youthful Prime Minister. In 1996, the International Court of Justice said: "There exists an obligation to pursue in good faith and bring to a conclusion negotiations leading to nuclear disarmament in all its aspects." This obligation has already been in existence for 43 years. Another 50 years brings us beyond the lifetimes of the initial NPT signatories' children.

There is also a possible loss of UK independence in making any moves towards nuclear disarmament and consequently to alter the focus of research at Aldermaston to purely maintenance, verification and transparency measures instead of warhead development. Information and technical transfers between the UK and France may well conflict with the letter as well as spirit of the NPT.

Absent a Parliamentary debate, the UK and French Abolition 2000 groups held a joint London meeting in February to discuss the consequences of the treaty and our responses to it. We looked at the treaties' technical, legal and political aspects. Outputs of this meeting are available to download.[4,5] The discussions continued at a Paris meeting in June, with outputs being transmitted to our representatives at the meeting of the 'P5' nuclear weapons states, also held in Paris at the end of that month. We are cautiously optimistic that, although ratified, the Teutates treaties' scope will be limited if 'civil society' concern can be demonstrated.

Peter Nicholls is Chair of Abolition 2000 UK, and a Visiting Professor at the University of Essex.

References and further reading

(web links correct as of 15 September 2011)

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