Preserving the planet

Geoengineering initiatives have the potential to reverse the effects of climate change, but more research needs to be done to convince the pessimists. Dave Hall discovers that UK universities are leading the charge for change

The Spice project (Stratospheric Particle Injection for Climate Engineering) sounds like something straight out of the movies. A football stadium-sized balloon is sent 20km up into the air. Its mission? To spray a fine blanket of sunlight-reflecting sulphate particles into the atmosphere, thereby reversing global warming and saving planet Earth.

The Hollywood-style happy ending may not be a reality just yet – we're talking about science after all, not science fiction – but the methods are very real. Spice, a collaboration between the universities of Bristol, Cambridge, Edinburgh and Oxford, is just one of the many projects UK universities are currently involved in to mitigate the causes of climate change.

'Geoengineering' – the collective term for methods by which we can consciously alter the environment for the better – comes in many forms, but projects broadly fall into three categories: adaptation; solar radiation management (SRM); and CO_2 removal.

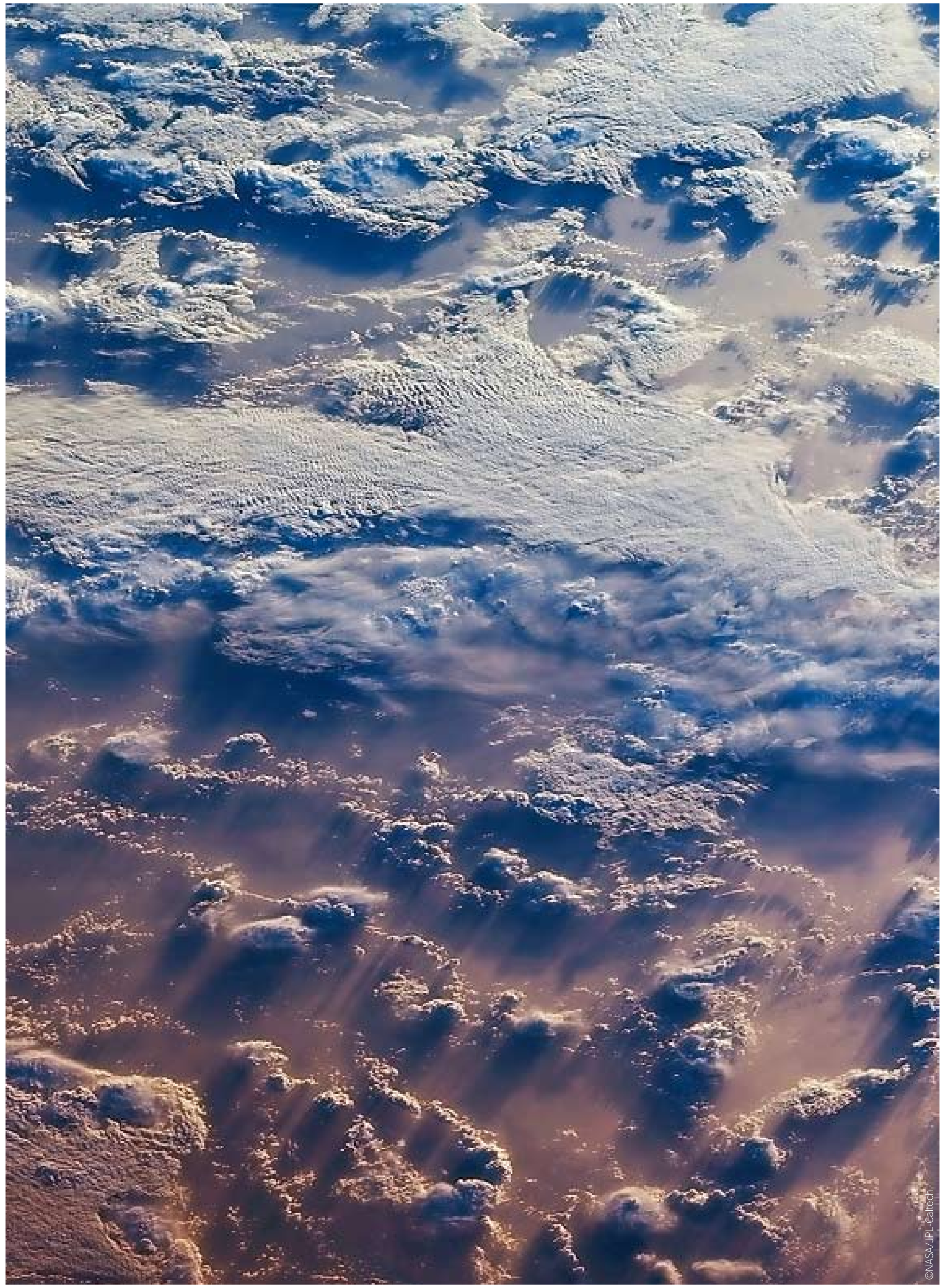
Adaptation solutions attempt to lessen the effects of climate change, rather than attack the causes. One idea is to reduce the risk of hurricanes by sucking cold water from the bottom of the oceans to the surface – cooling the ocean and calming the weather. Another is to flood the deserts with rising seawater (although sceptics point out that any gain would be negligible, should the water simply seep back to the oceans).

The bulk of research activity, however, is directed towards SRM and CO_2 removal. The theory behind SRM solutions is to reflect back some of the sun's radiation, either by increasing the reflectivity (the albedo) of the

© Paul Moseley/Fort Worth Star-Telegram/MCT/Getty Images

Right
NASA satellite image indicating how the Earth's cloud tops have been lowering over the past decade, which could be affecting global temperatures

Below
Meteorologists survey tornado damage to a Texan home



Earth's atmosphere or by making the surface of the Earth more reflective.

According to Alan Gadian, a research scientist at Leeds University, some existing theories are better than others. 'The problem with the sulphate particles idea [Spice] is that it doesn't actually cool the poles preferentially – plus it would be extremely expensive,' he says.

His alternative would be to use a boat to inject a fine spray of sea salt from the ocean surface into the clouds. 'This would reduce the size of the water droplets, making them whiter [and, therefore, more reflective of the sun's rays]. The experiment is reversible, easily controlled and relatively cheap,' he says.

A more grounded SRM approach is to increase the reflectivity of roads and even people's roofs. 'This idea has comparatively few negative consequences and cools locally,' says Dan Lunt, a senior research fellow at the University of Bristol and a leading authority on geoengineering. 'So the US eastern seaboard, for example, could be cooled by around two degrees using this method. The problem is that it doesn't have a huge global effect.'

Other SRM ideas include creating sunblocking mirrors in space, covering deserts with plastic sheeting, and growing shinier crops. But even SRM advocates admit its methods, while quick and convenient, are expensive – and only form part of the overall solution. 'If we were to use [stratospheric sulphur] aerosols [which have a dimming effect on the sun's rays], for example, they must be replenished,' says Dr Naomi Vaughan, a senior research associate at the University of East Anglia. 'If they aren't, you could bring on very rapid warming – in, say, 20 years instead of 100.'

And SRM can have unintended consequences too, according to Lunt: 'The mirror proposal would cool the equatorial regions too much and the polar regions not enough, while the more reflective deserts approach would cause the Indian and African monsoons to fail.'

© Jim Reed/Science Photo Library

Above
Meteorologists from the US-based Severe Thunderstorm Electrification and Precipitation Study (STEPS) prepare to launch a weather balloon into a storm

Perception problems

The professional consensus seems to be that more research is needed – and an investigation into the public's perception of geoengineering supports this view. The report, called for by the UK's Engineering and Physical Sciences Research Council (EPSRC) and carried out by the Integrated Assessment of Geoengineering Proposals (IAGP), found that while very few people were 'unconditionally positive' about the idea, most thought that a scaled-down test of the Spice project should be pursued.

Gadian, meanwhile, is worried about the consequences of any success. 'The irony is that if these initiatives work we're in trouble, because that will tempt governments to avoid reducing CO_2.' And most scientists agree that these type of solutions simply don't tackle the root of the problem – human-made greenhouse gas and its effects, such as ocean CO_2 acidification. 'It's no good reflecting sunlight if the volume of greenhouse gas is still increasing,' argues Vaughan.

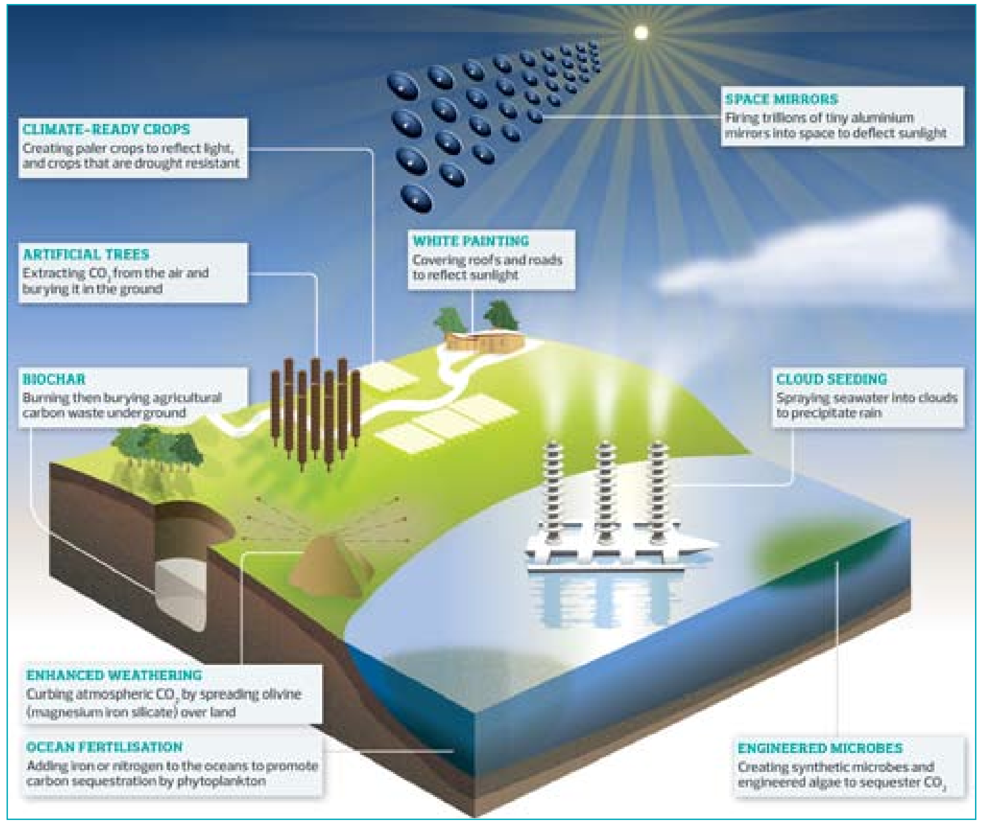
> There is no silver bullet. We need to insulate more, use less energy, and develop more efficient sources, without creating energy poverty in parts of our society

So why aren't we trying to remove the greenhouse gases themselves? Well, attempts are being made – from bizarre concepts such as artificial CO_2-scrubbing 'trees', which would capture CO_2 in the atmosphere and bury it underground, to carbon capture and storage (CCS) ideas that would catch the CO_2 at source.

'CCS involves capturing CO_2 at the power plant or industrial complex, where it is compressed, transported [via a pipeline or vessel] and then safely stored deep beneath the earth in depleted gas and oil fields or saline aquifers [that are unconnected with drinking water],' says Jon Gluyas, a professor in geoenergy at Durham University. 'It is currently estimated that the CCS process requires 30 per cent more fuel than simply letting the CO_2 escape to the atmosphere; however, this method will become far more efficient [in the future]. The fact is we need to curb CO_2 emissions and CCS is very important in this because it helps with the transition to a low-carbon economy.'

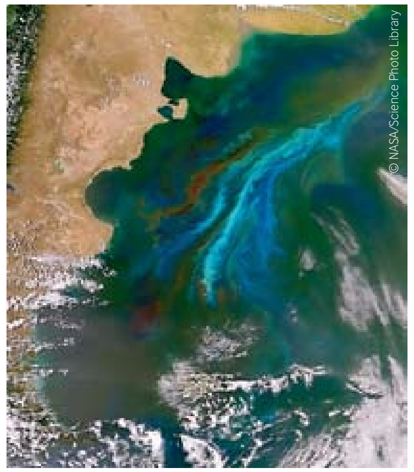
Another approach, says Gluyas, is the bioenergy with carbon capture and storage (BECCS) concept. 'Plants take CO_2 out of the atmosphere,' he explains. 'If you burn the plant and then capture the released CO_2 – storing it in the same way as you would in carbon storage – then you've reduced the CO_2 in the atmosphere. The problem is, of course, that we can't turn the whole planet over to biofuels.'

Ocean-borne phytoplankton remove carbon from the air in a similar way; and, despite representing just one per cent of the Earth's biomass, the photosynthesising microscopic organisms are responsible for drawing down half of the world's CO_2. One experiment recently tried 'fertilising' some 900 sq km of the Atlantic with iron particles to feed blooms of these plants – the theory being that when they die, they sink, locking the carbon to the sea floor. However, the results were less than satisfactory, according to Gadian. 'The fish enjoyed eating the algae, but there wasn't all that much evidence that it achieved its purpose,' he says. Once again, the predictable conclusion (given the relative infancy of the subject) is that more research is required.



© Pete Guest and Giulio Frigieri/The Guardian

Above
Geoengineering initiatives to combat climate change



© NASA/Science Photo Library

Left
A satellite image of an algal bloom in the Atlantic Ocean off the coast of South America

A model example

Encouragingly for potential students interested in this arena, there are numerous and diverse opportunities in the UK to get involved. At the University of Exeter, for instance, research has a distinctly mathematical flavour. 'Our research centre – Exeter Climate Systems – works at the interface between mathematics and climate science,' says Professor David Stephenson, a professor in statistical climatology at the university. 'We have about 20 PhD students specialising in this area because the Met Office, along with other climate scientists, requires accurate mathematical modelling. Without a model, you haven't got a climate prediction.'

Many UK universities also take part in global projects that form the basis of our most advanced knowledge of geoengineering. In addition to the Spice project, for example, Lancaster, the University of East Anglia (UEA), Cambridge and Cardiff are all involved in the work of the IAGP. UEA, which has the largest school of environmental sciences in Europe, has also set up the GeoEngineering Assessment and Research group (GEAR) to provide impartial advice to scientists and policymakers on the environmental risks of geoengineering. Another large academic project is the Tyndall Centre for Climate Change Research, which brings together researchers from eight UK universities (Sussex, Cambridge, Manchester, Newcastle, Southampton, Oxford, Cardiff and the UEA) and one from China (Fudan University).

> The irony is that if these initiatives work we're in trouble as it will tempt governments to avoid reducing CO_2

Fortunately, funding for such initiatives is available via many different channels. Durham's groundbreaking work, for example, is well supported by industry, while other institutions rely on grants from research councils such as the Natural Environment Research Council (NERC) and the National Centre for Atmospheric Science (NCAS). Some international students support themselves, although the UK-based Collaborative Awards in Science and Engineering funds students alongside industrial partners such as the Met Office. Indeed, many research scientists from UK universities go on to work at the Met Office's Hadley Centre in Exeter, one of the UK's foremost climate change research centres, which advises the public and government on climate science issues. International students are always encouraged, says Lunt, who points out that in his small department at Bristol about half the applicants are from outside the UK. 'More and more people are entering this field,' he says.

No easy answers

Prospective students should not be in any doubt as to the scale of the challenge facing them. The Intergovernmental Panel on Climate Change (IPCC), for example, predicts global warming of between one and four degrees by 2100 – if we stop using fossil fuels now. This would equate to a 59cm rise in sea levels – enough to submerge most of Venice.

'There is no silver bullet,' says Gluyas. 'We need to insulate more, use less energy, capture and store our used carbon dioxide safely, and develop more efficient wind, photovoltaic and other sources without creating energy poverty in parts of our society. The task is enormous.' Certain pessimistic scientists feel we've already passed the tipping point and have created a 'feedback loop'. In other words, the warmer it gets, the less ice there will be to reflect sunlight. This will cause permafrosts to melt which, in turn, will release locked-up methane, causing even more warming – in short, we could see a runaway greenhouse effect emerge. As geoengineering blogger Sam Carana puts it: '[Action has] to be taken immediately by world governments if there is any faint hope of preventing the human race being boiled like lobsters.'

Even if it were possible to rebalance the Earth's ecosystem, there are plenty of opponents to geoengineering projects. Many believe such schemes give governments an excuse to ease off on emission-reduction targets, while others are simply opposed to meddling with the natural order. The IAGP survey reveals the extent to which the industry has to work towards winning over the public, with responses such as: 'The Earth's temperature is too complicated to fix with one technology'; 'Humans should not be manipulating nature in this way'; and 'Research into solar radiation management will lead to a technology that will be used no matter what the public thinks'.

Some scientists say that, sooner or later, doing something will be less risky than doing nothing – the so-called precautionary principle. Gadian's approach is a refreshing one. 'I define geoengineering simply as 'man-made climate change' – deliberate or otherwise,' he says. 'We are already doing it, and have been since the industrial revolution.' Now, perhaps, is the time to fix those mistakes. ■

Find science and engineering courses at www.educationuk.org

Right
Melting icebergs threaten polar bears' existence

© Juniors Bildarchiv/Alamy

The researcher's view

Robert Bellamy is studying a PhD on ways of appraising geoengineering at the University of East Anglia

I am affiliated to the Tyndall Centre for Climate Change Research, the IAGP project, and the Science, Society and Sustainability (3S) research group. Geoengineering is a fast-growing area of research, and attracts expertise from many different disciplines, spanning both the natural and social sciences. My work assesses geoengineering proposals and I am currently evaluating ways of assessing geoengineering – in particular, how subjectivity can influence opinion. For example, in the Experiment Earth? public dialogue in 2010, experts described the conditions under which we might be forced to consider geoengineering. Presented with a climate 'emergency', people may be likely to view geoengineering more favourably than if they had been presented with a less extreme scenario.

I will also be the lead researcher in a ground-breaking public discussion on geoengineering. Both experts and members of the public will evaluate geoengineering as a response to climate change alongside mitigation (limiting the causes of climate change) and adaptation (limiting the effects). The aim is to give a 360-degree view of the different perspectives that affect contemporary climate change decision making.

In my opinion, it's not too late to avoid exceeding the IPCC's two-degree target if we undertake strong mitigation measures. But this window of opportunity is closing rapidly, so it would seem prudent to seriously consider whether geoengineering can contribute to the climate strategy.