The Economist

Geoengineering

Lift-off

Research into the possibility of engineering a better climate is progressing at an impressive rate—and meeting strong opposition

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AS A way of saying you've arrived, being the subject of some carefully contrived paragraphs in the proceedings of a United Nations conference is not as dramatic as playing Wembley or holding a million-man march. But for geoengineering, those paragraphs from the recent conference of the parties to the Convention on Biological Diversity (CBD) in Nagoya, Japan, marked a definite coming of age.

Geoengineering is shorthand for the idea of fixing the problem of man-made climate change once the greenhouse gases that cause it have already been emitted into the atmosphere, rather than trying to stop those emissions happening in the first place. Ideas for such fixes include smogging up the air to reflect more sunlight back into space, sucking in excess carbon dioxide using plants or chemistry, and locking up the glaciers of the world's ice caps so that they cannot fall into the ocean and cause sea levels to rise.

Many people think such ideas immoral, or a distraction from the business of haranguing people to produce less carbon dioxide, or both—and certain to provoke unintended consequences, to boot. It was the strength of that opposition which drove the subject onto the agenda at Nagoya. But that strength is also a reflection of the fact that many scientists now take the idea of geoengineering seriously. Over the past few years research in the field has boomed. What is sometimes called Plan B seems to be taking shape on the laboratory bench—and seeking to escape outside.

Stratospheric thinking

The most widely discussed way of cooling the Earth is to imitate a volcano. Volcanoes inject sulphur dioxide into the stratosphere, where it eventually forms small particles of sulphate that reflect sunlight back into space. Volcanoes, though, do this on a one-off basis. Geoengineers would need to leave the cloud up for a long time, which could get tricky. If you put sulphur dioxide into air that already has a haze of particles in it, the gas will glom onto those particles, making them bigger, rather than forming new small particles of its own. Since what is needed for cooling is a lot of small particles rather than a few big ones, this approach would face problems.

David Keith, of the University of Calgary, and his colleagues recently came up with a way of keeping the particles small: use sulphuric acid rather than sulphur dioxide. Released as a vapour at high altitude it should produce a screen of properly sized particles, even in a sky that is already hazed. And the fleet of aircraft needed to keep that screen in being turns out to be surprisingly small. A study that Dr Keith commissioned from Aurora Flight Sciences, a Virginia-based company that makes high-altitude drones, concludes that it could be done by an operation smaller than an airline like Jet Blue, operating from a few bases around the world.

That airline would, however, do best with a fleet of newly designed aircraft. The most straightforward option, according to the report, would be to develop a vehicle capable of flying at altitudes of 20-25km (about 65,000-80,000 feet), distributing ten tonnes of acid a flight. Such craft might look like slightly portly U-2 spy planes, or possibly like the *White Knight* mother ship developed to launch Virgin Galactic's tourist spaceships. About 80 such planes would allow the delivery to the stratosphere of a million tonnes of acid every year at a cost of one or two billion dollars over an operational life of 20 years.

A more intriguing idea suggested in the study would be to use a sort of hybrid plane-blimp along the lines of Lockheed's experimental P-791 (pictured above), which generates lift through both buoyancy and aerodynamics. Lift is a problem in the rarefied air of the stratosphere, and it seems such a design can help. The study dismisses another blimpish idea, though: that of pumping sulphurous chemicals up a long pipe held aloft by a large tethered balloon. It also rejects the use of rockets and guns, both of which have also been proposed as ways of getting sulphur into the stratosphere (see chart).

On the face of it Aurora's study is extraordinary. Given that a few million tonnes of sulphur a year might be enough to cool the Earth by a degree or two, the report seems to confirm what Scott Barrett, a political scientist at Columbia University, has called the "incredible economics" of geoengineering. The thought that a couple of billion dollars a year spent on sulphur could offset warming as effectively as hundreds of billions of dollars of investment in low-carbon energy suggests there is a real bargain to be had here. Maybe. But opponents of the idea are inclined to insert the word “Faustian” first.

The smog of war

One reason for rejecting sulphate hazing out of hand might be the damage it could do to the ozone layer. Ozone-destroying reactions happen faster on surfaces, such as those provided by sulphate particles, than they do in the open air. It is therefore likely that the addition of sulphate to the stratosphere would result in a loss of ozone, and thus in more ultraviolet radiation getting through. Indeed, the eruption of Mount Pinatubo in 1991 led to just such a loss, even as it cooled the climate.

Current research suggests, though, that any risk to the ozone layer is probably not sufficient reason to abandon the idea. The Montreal protocol, which banned various ozone-depleting chemicals, has left the ozone layer’s long-term prospects looking quite bonny. Sulphate-based geoengineering would certainly slow down its recovery, but would not send it into reverse. The climatic gains might thus be worth the ultraviolet losses.

Might. But that, too, is an area that would bear investigation. For another risk lies in the subtle distinction between “global warming” and “climate change”. Double the amount of carbon dioxide in the atmosphere and the average global temperature will go up. Add the right amount of stratospheric sulphur and the temperature will come back down to where it began. There will, in other words, be no net global warming. But though the average temperature is unchanged, the climate is not. Modelling suggests that a world where additional greenhouse warming has been cancelled out this way will still be warmer at the poles and cooler at the tropics. Moreover—and more worryingly—it will have less rainfall.

Every computer model of a stratospheric haze shows some decrease in rainfall, though the details vary. The more carbon dioxide that gets put into the atmosphere and the more sunshine that is removed from the sky, the greater the drying becomes. And that drying is worse in some places than in others. One recent study, for example, suggested that engineered cooling of this sort would lead to a much bigger loss of rainfall in China than in India. That might have political ramifications—even though both countries come closer to their original climates with the other’s optimal level of geoengineering than with no geoengineering at all.

Understanding the mechanism and implication of these effects is another crucial research step, and a difficult one to take at the moment because it is hard to assess the results from one paper on geoengineering in the light of another. That is because they all start from different assumptions, something that Alan Robock of Rutgers University hopes to overcome. Dr Robock, who carries out geoengineering research while taking an avowedly hostile approach to any suggestion of deploying the technology, has teamed up with climate modellers at other institutions to produce a set of options that could be run on a range of computer models.

This grand intercomparison, which may involve ten or more modelling teams, should allow researchers to get a better grip on what is really happening, and to see which of their results might be dependent on the vagaries of a particular piece of software. Considering that, a few years ago, it was rare to get the computer time needed to do even a single geoengineering simulation with a state-of-the-art climate model, this investment of time and effort marks a big step forward.

Whatever the models reveal about the pattern, impacts and nature of the loss of rainfall, it is hard to imagine that it will not be bad news of some sort. This is one of the reasons why most in the geoengineering field reject the notion that the “incredible economics” offer a real bargain. Hazy cooling and greenhouse warming cannot be traded one for the other; simply adding more and more sulphate to counterbalance more and more carbon dioxide would be dessicatory and dangerous. Cooling might take the edge off the peak of a planetary fever, or perhaps buy time as emissions cuts begin to have the desired effects. But hazing is a complementary medicine, not an alternative one.

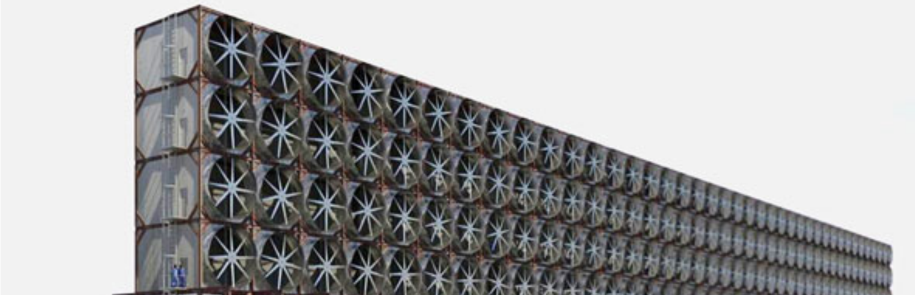
Screening sunlight from the sky with sulphates is not, though, the only suggestion around. Various entrepreneurial researchers are looking at ways of extracting carbon dioxide from the atmosphere and stashing it out of harm’s way.

Suck it and see

Nature already provides one method: photosynthesis. Using political and financial tools to encourage the growth of forests, and chemical ones to encourage the growth of photosynthetic plankton, are both possibilities—though both, especially the chemical approach, have their sceptics. Planet hackers of an industrial bent, however, propose proper bent-metal engineering: so-called “direct air capture” technology that would chemically scrub carbon dioxide out of the air, then release it from those scrubbers in a concentrated form that could be sequestered underground. Various companies, including one started by Dr Keith, are trying to produce demonstrators for such technologies. One way is to use arrays of fans to pass air in large volumes through cleverly contrived surfaces along which an absorbing fluid flows.

An alternative approach is to use the ocean as your absorber. Among those investigating this possibility is Tim Kruger, fellow and currently sole employee of the newly founded Oxford Geoengineering Programme at the eponymous university. Mr Kruger proposes dumping quicklime—calcium oxide—into the sea. That change in ocean chemistry would encourage carbon dioxide dissolved in the water to turn into ions of carbonate and bicarbonate, freeing chemical “space” into which carbon dioxide from the atmosphere could flow.

The chemically literate will spot a potential snag. Calcium oxide is made by heating up limestone (calcium carbonate). This drives off carbon dioxide. Generating the heat is also likely to involve the release of that gas. All this carbon dioxide will have to be squirrelled away in the same way carbon dioxide scrubbed from the air (or a power station’s chimney) would. But that might not be too hard. The gas will already be concentrated and pure if the kilns work the right way.



An airscrubber, from an artist’s imagination

The idea of liming is a comparatively old one, first mooted by Haroon Kheshgi, a researcher at ExxonMobil, in the mid-1990s. Dr Kruger’s work, meanwhile, was recently supported by a grant from another oil company, Shell, through what it calls its GameChanger programme. Cynics may smile at the oil companies’ involvement, and at the intellectual property and plans for profit that companies trying to pull carbon out of the atmosphere all rely on. But money is needed. Shell’s money, for instance, paid for a panel of researchers to look into Mr Kruger’s plans. They concluded that if put to use they might lock up carbon dioxide for $40 a tonne—which seems almost embarrassingly cheap, and which, as a preliminary figure, Mr Kruger is keen not to hype. Dr Keith thinks his air capture might, with luck, manage $100 a tonne. People further from the technology, but with less of a direct interest in its success, think prices will be higher.

Nor is Mr Kruger’s esprit untypical. Other fields of research are being drawn, blinking, into the light by geoengineering’s new-found popularity. “Cloud whitening” provides a nice example. Until 2006 work on the idea of cooling the planet with the help of a fine mist of sea salt sprayed into low layers of maritime cloud, to make them whiter, was the province of two semi-retired British academics. A mere four years later John Latham, the cloud physicist who thought up the idea, and Stephen Salter, a marine engineer who designed systems that might embody it, have been joined by 23 other authors from seven different institutions on a paper outlining current work on the matter. This paper looks not only at the cooling effects such a scheme might have on the climate and the practicalities of creating such a spray from boats at sea, but also at the possibilities of a field trial and what might be learned from such a trial about the way clouds work—a problem that climate scientists, limited to observations and models without the help of direct intervention, have yet to answer.

Whitening some clouds has a certain aesthetic appeal; it is certainly hard to see as an environmental threat in itself. Perhaps the most benign-sounding idea of all, though—and one that brings a Herculean sense of effort that messing around with the air and oceans cannot match—is Slawek Tulaczyk’s nascent proposal to lock the world’s ice caps in place.

Dr Tulaczyk, a specialist in glacial flow who works at the University of California, Santa Cruz, observes that one of the most catastrophic consequences of climate change could be a rise in sea level. The risk is not so much that the ice caps of Greenland and Antarctica will melt, but that enough meltwater will get under them to lubricate their journey from the land into the sea. At a meeting held at his university last month he outlined ideas he has been developing which might slow that process down, either by pumping the meltwater out, or by refreezing it *in situ* using liquid nitrogen. What makes this scheme merely ambitious, rather than totally crazy, is that you might need do it in only a few places. A large fraction of the ice coming off Greenland, for example, flows down just three glaciers. Work out how to slow or stop those glaciers and you may have dealt with a big problem.

The Devil and the details

Polluting the stratosphere. Liming the oceans. Locking Greenland's glaciers to its icy mountains. It is easy to see why sceptics balk at geoengineering. And if viewed as a substitute for curbing greenhouse-gas emissions, a cover for business-as-usual into the indefinite future, then it might indeed prove a Faustian bargain. But that is probably the wrong way of looking at it. Better to use it as a means of smoothing the path to a low-carbon world. Most of the researchers working in the area of stratospheric hazing, for example, think that its best use might be reducing the peak temperatures the Earth would otherwise face at a time in the future when greenhouse-gas emissions have started falling but atmospheric levels are still going up.

To see whether any form of geoengineering could work, though, small-scale experiments need to be carried out. Fertilising the ocean with iron has already been tried—admittedly without much success, but also without perceptible harm being done. Such experiments are, however, regulated by an international body, the London Convention on maritime dumping, which the CBD approves of. But what of other experiments? The CBD's decision at Nagoya allows small-scale experimentation. But small by what standard? That of a laboratory or that of a planet? And small by whose? That of an enthusiast or that of an opponent?

Take hazing experiments. Such experiments could start fairly soon, were money available. One could easily imagine releasing sulphuric acid from a high-altitude aircraft and studying the chemistry going on in its wake using another aircraft. NASA, America's aerospace agency, is already equipped with a modified U-2 that would do the job well.

Experiments of this sort would not be harmless. But they would do a lot less harm to the stratosphere than Concorde or the space shuttle, devices that were accepted by most people. The harm done by stopping geoengineering experiments is that the good which might come from them will never be known.

Yet even some enthusiastic researchers worry about undue haste. Dr Keith, long an advocate of more research, says he unexpectedly finds himself thinking that things are moving, if anything, faster than he would want. "Taking a few years to have some of the debate happen is healthier than rushing ahead with an experiment. There are lots of experiments you might do which would tell you lots and would themselves have trivial environmental impact: but they have non-trivial implications." Geoengineering's growth spurt will need to be matched by some grown-up questioning. Who benefits? Who decides? Who faces the risk?

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