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The Big Question: Is there a technological solution to the problem of global warming?

By Steve Connor

Why are we asking this now?

For two reasons. A German research ship, the Polarstern, is steaming towards a region off the coast of Argentina in the South Atlantic, where it intends to release six tonnes of iron sulphate over an area of 115 square miles. The aim is to study the impact of this "iron fertilisation" on the blooms of plankton that absorb carbon dioxide from the sea and, ultimately, the atmosphere. Some scientists believe this could offer a way of boosting a natural carbon "sink", where carbon is stored or sequestered for a long time. The second reason is a study published yesterday in the journal Nature which backs up this idea of a geo-engineered solution to global warming with hard, scientific observations.

What are these latest observations?

A team at the National Oceanography Centre in Southampton studied two areas of the Southern Ocean around the Crozet Islands and Plateau, about 1,400 miles south-east of South Africa. One region is rich in iron, because of the run-off from the volcanic islands, whereas the other is deficient in iron. The researchers found that the iron-rich region also has between two and three times as much carbon sequestered in seafloor sediments and the deep ocean beneath the plankton blooms that form at the sea surface each summer. These sediments have built up over thousands of years since the last ice age. The scientists point out that this supports the idea that iron-rich seas result in greater amounts of carbon being sequestered in deep layers, because atmospheric carbon dioxide is drawn into the sea by the vast blooms of plankton at the surface.

How will fertilisation help fight global warming?

The increase in average global temperatures over the past century or two is now widely accepted as being linked with the increase in carbon dioxide levels in the atmosphere caused by the burning of fossil fuels such as coal and oil. About half of the man-made carbon dioxide released since the Industrial Revolution has been absorbed by the natural carbon "sink" of the ocean. Scientists believe one way of augmenting this natural sink is to boost concentrations of iron, which is known to be the limiting factor that inhibits the absorption of carbon dioxide by plankton. Fertilising the sea with iron, the limiting mineral in seawater, is known to stimulate phytoplankton blooms. Phytoplankton, the microscopic plants at the base of the marine food chain, convert sunlight into chemical energy using the raw material of carbon dioxide dissolved in seawater. The more they grow, the more carbon they use and the more carbon dioxide from the atmosphere ends up being dissolved at the sea surface.

How will we know if it works?

The key to the success of iron fertilisation is showing that much of the carbon trapped in the cells of dead plankton ends up falling to deeper layers of the ocean and on to the seafloor, where it will be trapped for a least 100 years – and so be taken out of the more immediate carbon cycle. Some studies have suggested that, although iron fertilisation can cause blooms to form, they are quickly eaten up by other marine organisms and digested in a way that releases carbon dioxide back into the atmosphere. The latest study, however, implies that, in the natural situation, iron-rich water does indeed lead to long-term sequestration of carbon. This is why iron fertilisation is being seen as a possible technical fix to the problem of global warming.

Are there any other fixes?

Several, but only a few are being taken seriously. For instance, the Nobel prize-winner Paul Crutzen, of the Max Planck Institute in Germany, has suggested it would be possible to inject sulphate particles into the atmosphere to mimic the effects of a volcanic eruption. These particles could act as a reflective surface for incoming sunlight, producing a discernible cooling effect on Earth. For example, the eruption of Mount Pinatubo, on the Philippine island of Luzon, in 1991 released vast amounts of sulphate particles into the global atmosphere, with the result that the Earth cooled by about 0.5C for the year or two following the eruption. Mr Crutzen suggested that, in extremis, it could be possible to mimic this effect by releasing artificial sulphate particles, a process that which could easily be reversed if necessary. But some have questioned possible side-effects, such as acid rain.

Are there any other viable ideas?

Other scientists have suggested doing something similar by creating low clouds over the ocean by spraying water droplets into the air from ships. The formation of these clouds would have a cooling effect and the process could be quickly turned off if necessary. Another theory is to stimulate the mixing of the ocean with long, floating, vertical pipes that take surface water down to deeper levels using wave energy. This would result in carbon dioxide dissolved in surface layers being taken down to deeper layers and deposited there for long periods. James Lovelock, the author of the Gaia hypothesis, is known to favour this idea. One of the more extreme suggestions for the geo-engineering of the climate is to put mirrors in space to deflect incoming sunlight – a technical fix too far for most scientists who are investigating this area of research. Apart from the expense and the practical implications of parking such a complicated set of mirrors is space, people will want to know who would have control such an important technical structure?

Is anyone taking these ideas seriously?

It is fair to say that most experts would, until recently, have discounted such suggestions to counter global warming. However, there is growing concern that international attempts to curb rising levels of carbon dioxide could fail. Since the signing of the Kyoto agreement a decade ago, carbon dioxide concentrations have risen faster than even the worst-case scenarios that the Intergovernmental Panel on Climate Change suggested. Some scientists are now saying we should have a back-up, or "plan B".

Is there a consensus about a 'plan B'?

A survey of climate experts carried out by The Independent at the end of last year found that many now believe that a "plan B" is necessary if global temperatures continue to rise. Just over half – 54 per cent – of the 80 international specialists who responded to our survey said the situation was now so dire that we must consider the artificial manipulation of the global climate to counter the effects of man-made emissions of greenhouse gases.

So where can we go from here?

The Royal Society has set up a working committee to study the feasibility of geo-engineering and its report is due to be published this summer. A number of research projects, such as the one being conducted aboard the Polarstern, are under way and their results will be published in the scientific literature. The opponents argue that the Earth's climate system is far too complex to be interfered with in this way, but others argue that we may end up having no alternative if carbon dioxide concentrations continue to rise, along with global temperatures. There may come a point when we have no alternative but to try geo-engineering.

Should we fight climate change with iron dust and solar screens?

Yes...

* Carbon dioxide levels are rising so fast we may have no alternative if we are to maintain a habitable world

* Natural carbon sinks that absorb carbon dioxide are weakening, so we need to may need to boost them

* We are already engaged in a massive climate experiment by pumping greenhouse gases into the atmosphere

No...

* The risks of uncontrolled side-effects are too great

* Geo-engineering is a dangerous distraction from the goal of curbing man-made greenhouse gas emissions

* We caused one environmental disaster with global warming and we have no right to risk causing another with geo-

engineering