Catherine Lichten

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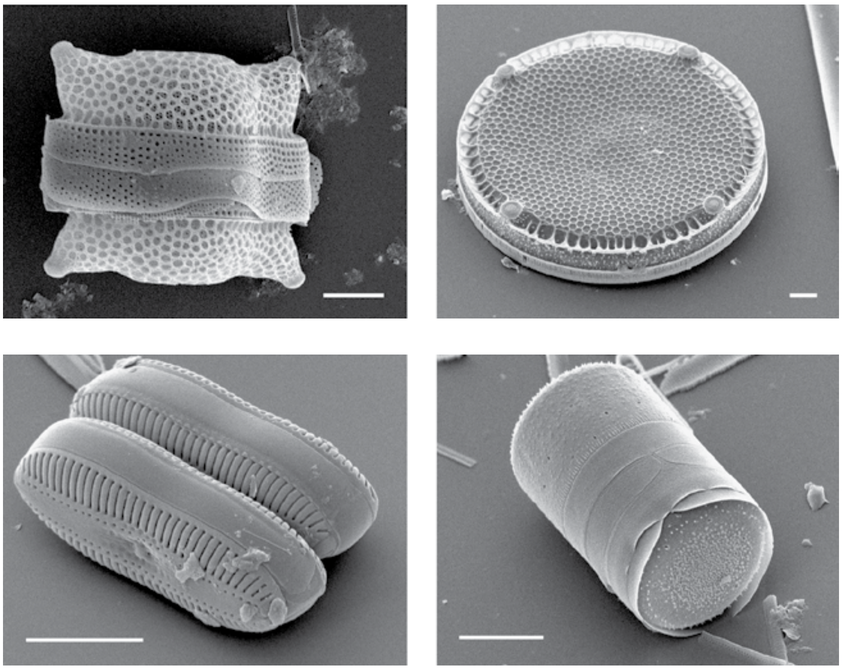
Ocean Iron Fertilization

Capturing carbon to slow climate change

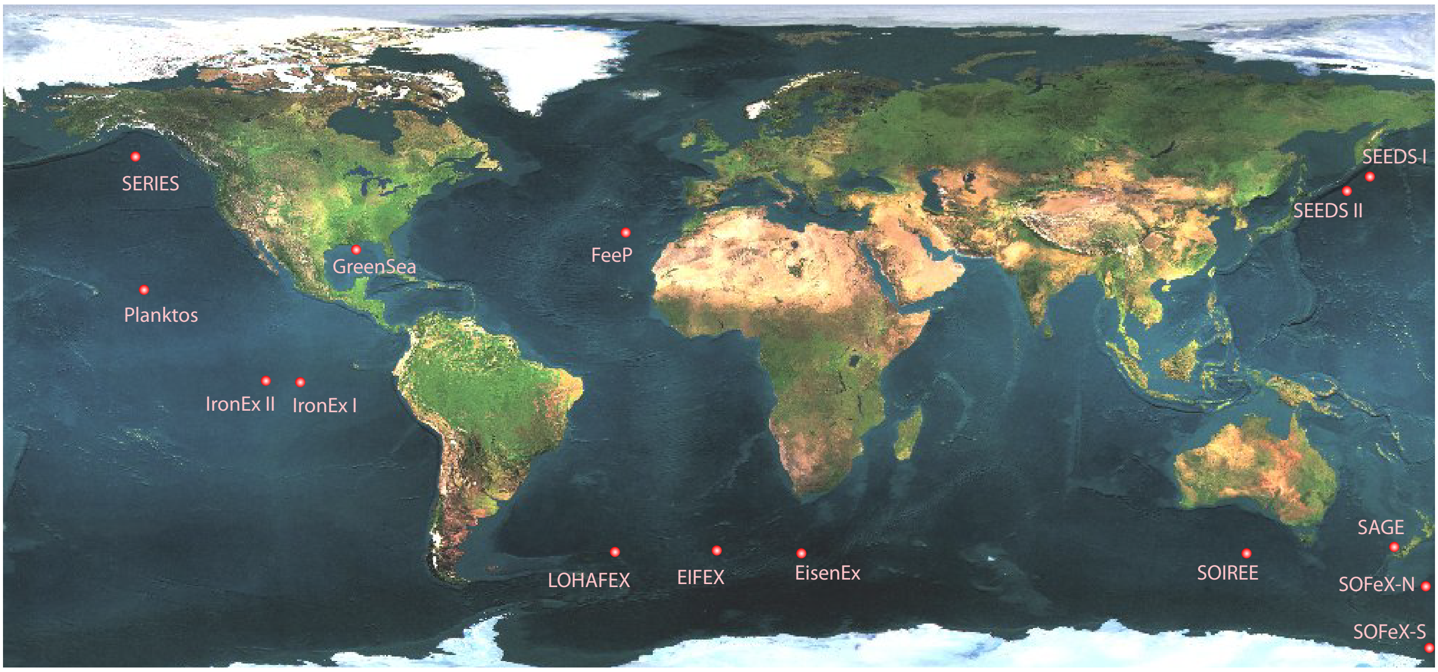
Pouring iron into the oceans. Is this a valuable new way to deal with climate change or reckless tampering with the sea? Catherine Lichten investigates.

The year is 2200. Amidst gusting winds, churning waves, and across vast expanses of the stormy Southern Ocean, ships carrying teams of scientists and engineers stake out their territory, preparing to release hundreds of tons of iron dust into the sea in an effort to save the planet. Could this be the start of the next Armageddon sci-fi flick, or a clever, realistic (and economically lucrative) solution to managing global warming?

This activity is called ocean iron fertilization (OIF). The idea behind it is to slow climate change by using a process that already occurs naturally. Nature has a way to draw carbon dioxide (CO_2) from the air down into the ocean. If we could speed that process up, we might be able to prevent the climate change that results from CO_2 building up in the atmosphere, or so the thinking goes. But many worry that fiddling with the Earth's natural processes got us into the climate change mess and won't get us out of it.



Electron microscope images of the shells of diatoms, one of the most common types of phytoplankton. Size bars are 10 μm. Image courtesy of Mary Ann Tiffany, San Diego State University, published in Bradbury J: Nature's Nanotechnologists: Unveiling the Secrets of Diatoms: PLoS Biol 2004.

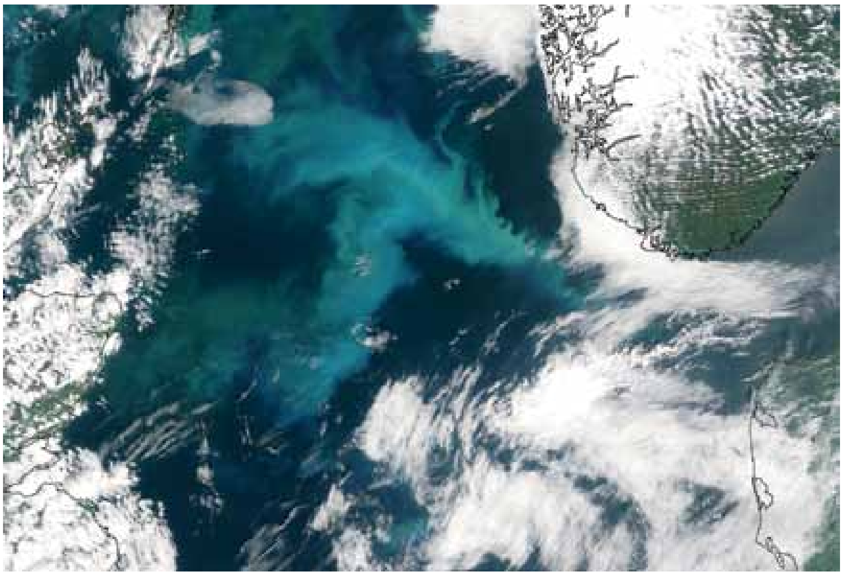


Locations of OIF experiments also showing commercial demonstrations by the companies Planktos and GreenSea Ventures

Due to the scarcity of scientific data about the effectiveness and long-term consequences of the method, a debate rages among environmentalists, scientists, and private companies whether dumping iron into international waters would reverse global warming or cause irreparable damage to the Earth's ecosystem.

How would it work?

The existing natural process for transferring carbon from the air to the ocean centres on phytoplankton, the organisms which form the foundation of the marine food web. These organisms carry out photosynthesis, taking up CO_2 from the atmosphere. When they die and sink to deeper water, the carbon within them enters long-term storage that could last for decades or centuries. Having more phytoplankton around should mean more photosynthesis would happen, which would mean more carbon getting taken from the atmosphere and brought down for deep-ocean storage.



Phytoplankton bloom in the North Sea. The UK is on the left.

How can we increase the activity of phytoplankton? To answer this question, we have to look back twenty years at work done by oceanographer John Martin. At the time, scientists were puzzled about so-called 'desolate zones' in the ocean. These were areas that were high in many nutrients but were home to surprisingly little marine life.

It turned out that the zones were rich in many nutrients except iron. Martin hypothesized that iron was the limiting factor keeping phytoplankton from growing in the desolate zones. He thought that if you could add iron to desolate zones, phytoplankton would start growing like crazy.

Martin also hypothesized that this increase in the phytoplankton concentration would reduce the levels of atmospheric carbon. He famously proclaimed, "Give me half of a tanker of iron, and I'll give you the next ice age."

In short, to get more phytoplankton, you'd dump iron into the ocean. The idea is irresistibly simple: add iron, get plankton, stop climate change. But does it work?

The proof is in the (iron-fertilized) pudding

Since Martin described his 'iron hypothesis', research groups around the world have completed 13 fertilization experiments. They have monitored the effects of adding hundreds to thousands of kilograms of iron sulfate to the oceans to patches ranging in size from 40 to 300 square kilometres (see figure). Iron sulfate is the compound of choice because it dissolves in seawater and it's an industrial by-product, so it's not too difficult to obtain.

Their results validated the first part of Martin's hypothesis. Increasing the iron concentration in the fertilized areas created phytoplankton blooms visible by satellite. This phytoplankton growth explosion confirmed that it was a lack of iron that had previously kept plankton numbers low.

The second part of the hypothesis, that increasing the phytoplankton population would help transfer CO_2 out of the atmosphere and into long-term storage, has yet to be proven true. So far, most experiments have been focused on simply testing the first part, and it is difficult to determine whether the carbon taken up by iron-induced blooms goes into long-term storage.

A recipe for disaster?

Pressure to address climate change is building all the time, but scientists have yet to discover whether or not OIF is an effective, practical solution. In a 2008 article in the journal *Science*, written by 16 iron fertilization researchers, oceanographer Ken Buesseler explains, "Although [our] experiments greatly improved our understanding of the role of iron in regulating ocean ecosystems and carbon dynamics, they were not designed to characterize OIF as a carbon mitigation strategy." Still, entrepreneurs and economics experts have taken an interest in OIF. And scientists and environmentalists have begun to worry that politicians and businesses will push to start using it before all the facts are in.

Of major concern is the fact that no one knows what the long-term effects of OIF would be. The marine ecosystem is a complex network of chemical, physical, and biological processes. Disturbing it would undoubtedly have effects beyond the what is intended, but those are hard to predict. Potential side-effects include disrupting the ecosystem, affecting organisms all the way from bacteria up to whales, making the ocean more acidic, reducing the levels of dissolved oxygen that fish breathe, and even increasing levels of other greenhouse gases in the atmosphere.

A natural laboratory: Volcanoes can act as natural sources for iron fertilization as volcanic ash is rich in iron, and researchers have noticed that atmospheric CO_2 levels dip following major eruptions. The photo shows Iceland's Eyafjallajökull erupting in March, 2010. Scientists from the National Oceanography Centre in Southampton made two visits to the North Atlantic in the summer of 2010 to explore the effects of the ash from Eyafjallajökull.

Is it legal?

Although existing regulations could apply to OIF, the laws are ambiguous because OIF is regulated by more than one UN convention. As of a few years ago, none of those addressed OIF directly, but additional legislation is in the works.

Two relevant conventions restrict pollution and ban the dumping of waste. They allow OIF for 'legitimate scientific research' but could restrict the large-scale OIF that businesses might carry out. The UN Convention on the Law of the Seas governs general conduct on the high seas. Its general assembly has not passed any specific resolutions on OIF, but did support calls for further OIF research and bans on large-scale OIF. Yet another convention bans large-scale fertilization and applies to OIF insofar as large-scale fertilization could impact the marine food web.

A 'United Nations convention' is an agreement between nations; nations agree to abide by it, but it may not have the force of law.

On the whole, regulation remains incomplete, but the wheels of policy-making have been set in motion. Through OIF's rapid evolution from a purely scientific pursuit to an attractive, prospective quick-fix for climate change, it has become clear that specific legislation is required.

The Polarstern is a German research vessel which has taken part in iron-seeding experiments.

The bottom line

As the reality of climate change sets in, we face the dilemma that, as much as we want to prevent climate change, we are reluctant to reduce our energy consumption and greenhouse gas emissions. In light of this, possible solutions that don't require us changing our behaviour have an irresistible appeal.

OIF remains controversial because no one knows what its impacts will be, but we cannot truly resolve the controversy without actually carrying it out. Instead of that, we must use the evidence available to predict whether it would be a safe and effective activity. There is little doubt that climate change is upon us, but no amount of panic over global warming or economic potential will change the risks and benefits. Legislation must reflect the available evidence so that the lure of profits and the urge to find a quick fix for climate change cannot overshadow the facts about its side-effects and effectiveness.

***Science* is a prestigious scientific journal, published in the USA.**

Catherine Lichten is studying for a PhD in Biology at Edinburgh University. A version of this article appeared in EUSci, the Edinburgh University Science Magazine, April 2010.