Special Report **50 Ideas to Change the World**

Special Report **Climate change**

Satellites, lasers and undersea bots track world carbon stocks

Technology improves understanding of forests' and oceans' role in climate change

Eyes everywhere: Satellites help monitor the planet's carbon cycle but need ground-level data too

Adam Green MARCH 29 2018

Satellite and aerial observation are improving our understanding of the environment and climate change. In places harder to see, however, ground-based lasers and ocean-going robots can reveal much more about the planet's carbon cycle.

Fleets of tiny satellites are buzzing around the planet monitoring pollution and emissions. They track wildfires, help farmers estimate crop yields, and assist ships navigating iceberg-infested seas. Mason Peck, associate professor at Cornell University and former chief technologist at Nasa, believes satellite innovation will tackle a widening range of social and economic problems.

"We'll discover more about Earth than we thought possible — from ancient cities in the jungle to patterns of flooding, erosion, and plate tectonics that can inform how we build the cities of the future," he predicts. "Widespread deforestation, human rights abuses, pollution, and other offences against humanity and the planet, cannot hide any longer".

Environmental observation is one of the most pressing projects. Programmes like the European Space Agency's Sentinel can now pinpoint emission sources with increasing accuracy, and identify the 'fingerprint' of individual gases.

However, two areas that play a crucial part in the planet's carbon cycle — beneath the forest canopy, and in the darker recesses of the sea — cannot be observed by satellites alone, even though they will profoundly affect how climate change plays out. Complementary technologies are being developed to complete our understanding.

Forests

Start with forestry. Trees are the earth's lungs, absorbing carbon dioxide through photosynthesis and storing it as carbon in new wood; approximately half their total dry weight is carbon, says Andrew Burt, a research associate at University College London. The UN-led framework for protecting forests, known as REDD+, tries to deter deforestation by ascribing a monetary value to trees based on the environmental benefits they provide, such as capturing carbon.

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"If you are going to put a dollar value on carbon in tropical forests to stop deforestation, then getting that number right is key," says Mat Disney, reader in remote sensing in the department of geography at University College London. "At least as important, if not more so, is the transparency of how forest carbon is measured, such that individual countries will sign up".

In the past, carbon stock estimation has been very imprecise. Simply measuring the size of a forest from the air or from space is not sufficient because it is biomass — the density and complexity of trees' bodies — that determines carbon absorption. A humble sycamore in an English garden can have over 10 kilometres of branching if it were laid out end-to-end, says Mr Disney, even if it weighs only a few tonnes. Conversely, a giant African moabi tree might look majestic, at twice the height and 10 times the mass of the sycamore, but only has half the length of branches, with almost all its mass in its near-branchless trunk.

In the past, carbon stocks were measured by manually recording tree diameter and extrapolating through a set of empirical relationships. This method could be very inaccurate, however, Mr Burt says.

Instead, the UCL researchers get up close with terrestrial lasers. Historically used in forest surveying, over the past five years terrestrial laser scanners have enjoyed a rebirth through their deployment for measuring and understanding forest structures and ecology.

Emitting laser pulses throughout the forest, they collect millions of individual measurements of each tree. "From that we generate complex point clouds which give a complete 3D map of individual trees, to an accuracy of several millimetres," says Mr Burt adding that this enables scientists to estimate the trees' volume and weight.

Their work is feeding into two radar-based biomass satellite programs, Nasa's Gedi radar, and the ESA's Biomass radar, due to begin operating by 2021. Both Gedi and Biomass work by estimating the height and density of forests, and then relating that to biomass. "They need to calibrate their algorithms pre-launch, and then validate the resulting estimates they get post-launch", says Mr Disney, adding that terrestrial laser is the best way to do that. This collaboration between laser scanning and satellite data could ensure a more transparent and rigorous process for measuring carbon absorption.

Oceans

A second part of the carbon cycle that satellites cannot alone illuminate is the deep sea. Oceans, like forests, counterbalance emissions by absorbing some CO2 but the interplay between oceans and atmosphere is not fully understood.

Oceans contain 50 times more carbon than the atmosphere, and have absorbed 150 billion tonnes of carbon since 1870, equivalent to around 30 per cent of emissions resulting from human activity. This is thanks to multiple interlinked processes, which include photosynthesis by surface-floating phytoplankton which then enter the marine food chain. Carbon biomass also converts into fecal pellets, detrital matter and dead cells, falling into deeper ocean currents and even the sea floor.

A crucial layer is the "mesopelagic", between 200 and 1000 metres from the surface, where very little light penetrates, and whose life forms are poorly documented. Satellites can see only a few centimetres below the surface and once carbon enters the ocean, it is hard to track, limiting our understanding of oceanic carbon absorption and its influence on climate.

To learn more, the Woods Hole Oceanographic Institution (WHOI) is developing the "mesobot" to study the animals that live at that depth and the fate of descending particles.

"Mesobot will use stereo cameras and on-board intelligence to track animals automatically as they migrate daily up and down in the water column," says Dana Yoerger, senior scientist in the Applied Ocean Physics and Engineering Department at WHOI.

The WHOI says the mesobot "provides a new and unique capability that can fill critical gaps in our understanding of midwater ecosystems, the biological pump, and their collective influence on the global carbon cycle".

The work will complement other research efforts such as a UK-based programme, led by the National Oceanography Centre, to collect organic, carbon-rich particles sinking through the ocean, using nets and traps in the tropical Atlantic and Southern Ocean. That group believes such particle collection will help our understanding of carbon dynamics in the ocean's interior, and further improve climate change predictions.

Together with satellite imagery, these new ways to measure land and sea will make tracking the carbon cycle a much more precise science.

50 ideas to change the world

We asked readers, researchers and FT journalists to submit ideas with the potential to change the world. A panel of judges selected the 50 ideas worth looking at in more detail. This fifth and final tranche of 10 ideas (listed) is about meeting challenges on a planetary scale and beyond.

- Oceans harnessed for carbon storage
- How to create a carbon trading system that works
- Lasers and bots track carbon in the forests and seas
- Cleaning up the plastic in the oceans
- Metal-organic frameworks create molecular ‘supersponges’
- Mobile phone networks help forecast disasters
- Invisibility cloak’ metamaterials reach the market
- Strategies to dodge space junk
- Asteroid ‘fuelling stations’ for space exploration
- Video: new techniques to find extraterrestrial life