PAUL GOODMAN

# Ocean sensors can track progress on climate goals

*Uncertainties around carbon emissions will make climate agreements tough to enforce. The answer floats in the seas, says* **Joellen Russell.**

Almost 200 nations have pledged to reduce their greenhouse-gas emissions under the Paris Agreement on climate change. We need a way to know whether they are succeeding.

For the accord to work, each country must track its net carbon output: the total carbon dioxide entering the atmosphere from fossil-fuel emissions and deforestation, minus that absorbed by growing plants. Both human emissions and land use are difficult to track precisely. Most nations extrapolate from government energy data, which are often incomplete, inaccurate or inconsistently reported.

As a result, the picture of who emits how much is murky. In 2015, for instance, China admitted that it had underestimated its annual coal consumption by up to 17%.

A solution lies in the seas. The ocean acts as a carbon sink, taking up about one-quarter of the world's global carbon emissions. If oceanographers can better monitor carbon uptake and then feed these data, along with other atmospheric and marine observations, into Earth-system models, we could track carbon output — including from land-use changes — regionally.

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But we have too few measurements from the ocean. Fierce winds, high waves and long distances from port make working on ships expensive, inconvenient and dangerous. Vast swathes of sea need to be studied, especially in winter.

Enter the floating robots. Or rather, 1.3-metre tubes kitted out with batteries, sensors and a data-transmission system. A bladder lets the float sink to depths as great as 2,000 metres before surfacing to communicate its position and data to satellites. Many of these drifting floats are already active. Launched nearly two decades ago, the international Argo programme maintains an array of more than 3,800 floats to track the temperatures and salinities of oceans around the globe. All data are publicly accessible online.

But those measurements do not allow for assessments of marine carbon: researchers estimate this mainly from the few academic-research ships that sample at depth, and from the surface-only measurements they can get from commercial ships carrying sensors, as well as some sensors on deep-sea moorings, monthly campaigns off Hawaii and Bermuda, and ocean colour from satellite images. These sparse data, collated in the Surface Ocean $CO_2$ Atlas database, enable only rough, yearly estimates of carbon uptake.

To rectify this, my colleagues and I have been deploying Argo floats in the Southern Ocean that have been modified with biogeochemical sensors to measure oxygen and nitrate levels, pH and more. This project, called SOCCOM, has expanded our ability to measure carbon and carbon flux across seasons, at the ice edge, under the ice and in waters surrounded by ice. They work in storms, winds and heavy waves.

Other biogeochemical-sensor arrays also float in the North Atlantic, Mediterranean, North Pacific and Indian oceans. These are locally useful, but their data cannot be integrated across arrays. To help track regional carbon emissions, we need a global network of 'climate-quality' instruments: observations from each float must be sufficiently calibrated to permit comparisons to every other float, today and in the future.

Scientists from the main nations participating in Argo have agreed to the goal of adding biogeochemical sensors to some floats in the array, and the international plan for implementing a global network has been established.

What's stopping us? Mainly funding.

Building and maintaining the modified Argo network will require about US$27 million annually. The US National Science Foundation has funded 200 modified floats, of which we have so far deployed 107. Ultimately, we need about 1,000 floats, each roughly 500 kilometres apart. A single modified float costs an estimated $107,000, and will, over a 5- to 7-year deployment, collect thousands of measurements over a range of depths, down to 2,000 metres, and at the surface. For comparison, a day on a ship would cost at least $50,000 and yield three depth profiles.

Globally flat funding for research — and the current political climate in the United States — makes it difficult to find extra funding to scale up even a highly successful, cost-effective project.

It is also technically challenging to build these floats, which are currently kitted out by hand to meet the standards necessary for calibrated measurements. Their manufacture must move from the laboratory to an industrial scale to produce the number needed to build and maintain the array. Finally, to crunch so many data, we need to train more oceanographers.

Other ways of reducing uncertainty in the global carbon budget include NASA's Geostationary Carbon Observatory satellite, planned for the early 2020s, which will continuously measure greenhouse-gas emissions. Scientists have also proposed adding 'smart' nose cones to commercial airliners that could measure carbon dioxide and methane as the aeroplanes take off and land. These observations would nicely complement those from floating sensors.

Climate change and the grand experiment we are carrying out on our atmosphere make our future more uncertain than it has ever been. For the past 30 years, oceanographic research has been a priority of the US Navy, which believes that knowledge from the seas is essential to our collective interests and way of life. That is only more true today. ■

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