Open ocean sensor deployments

Starting in December 2022, Running Tide executed three open ocean deployments of the company's proprietary verification sensor suite. The purpose of the experiments was to mimic workflows required for the open ocean experiments, to test the sensor systems, sea-truth models with collected data and identify and resolve bugs and errors in computational automation and infrastructure. The verification sensor suites provide critical in-situ data for analytical comparison with model output. The process of gathering data and modeling the results helps us understand and ensure the efficacy of the carbon removal using Running Tide's system.

Instrument overview

For these experiments, we deployed two types of verification instruments: Open Ocean Observation Platforms and Trajectory Sensors.

- **Open Ocean Observation Platforms (3OP)** are equipped with GPS trackers, surface sea temperature gauges, two cages and mounted with cameras that photograph the contents of the cages several times every day and send to our backend infrastructure via satellite.
- **Trajectory Sensors (TS)** are equipped with GPS and a flotation system to trace the drift behavior of deployed substrate.

Sensor deployment overview			
ID	**Date**	**Location**	**Sensors deployed**
IS-SD-1	2022-12-04	Between N62°59.952' / W12°00.074' & N62°59.926' / W11°59.465'	4x 3OP, 34x TS
IS-SD-2	2023-01-13	Between N62°10.833' / W17°06.150' & N61°26.383' / W14°18.316'	2x 3OP, 25x TS
IS-SD-3	2023-03-09	N60°20.9 / W19°23.9'	26x TS

Approach

For each of the deployments, the modeling team selects a deployment location based on the prediction model, optimized for float time, distribution and terminal location. For these tests, we had the constraint of deploying alongside predetermined routes as we were working with shipowners on scheduled tours. At the predetermined location, the crew placed the instrument suites into the ocean.

The data from the experiments was then used to improve our modeling approach and test quantification automation in preparation for our first open ocean carbon removal system deployments. Using the results of these sensor experiments, we were able to develop a methodology for parameter tuning our trajectory model. This unlocked our ability to run

Monte Carlo simulations to quantify uncertainty in the terminal distribution of substrate on the seafloor.

Outcomes

Based on the data collected and the practice of repeatedly performing siting selection, we were able to tune our deployment site selection process, identify the most helpful data sources and resources, and iterate on process strategy to improve accuracy and efficiency.

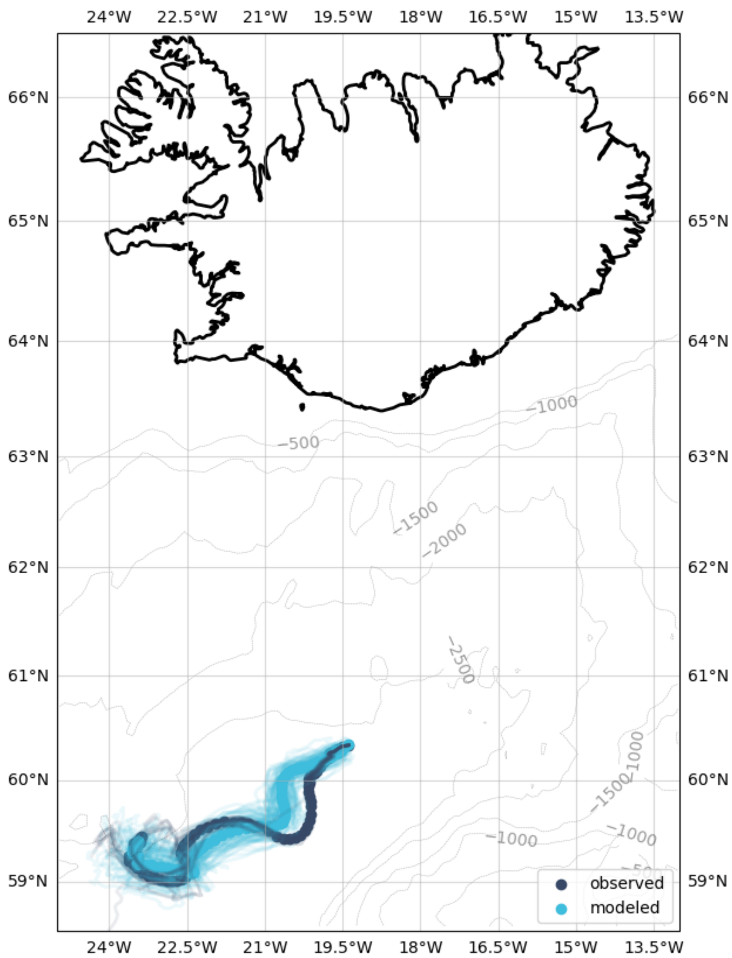

Figure 1: A comparison of modeled to in-situ buoy trajectories from our third deployment. This comparison demonstrates the robustness of our alpha tuning methodology.

We also developed our methodology for alpha tuning, the process of quantitatively determining the vector addition of windage, Stokes drift, and ocean currents that forces modeled trajectories to most closely match observational data. Automating alpha tuning allowed us to take a statistical and quantitative approach to uncertainty. Using the modeling methodology developed during these sensor deployments, we can now report the mass of substrate sunk below 1000m (the threshold for durable sequestration) with 95% certainty. Figure X below demonstrates the strength of our alpha tuning methodology. The average error between our modeled and observed trajectories for our third sensor deployment was under 20 km. We aim to continue improving this methodology and plan to submit a manuscript for peer reviewed publication including such improvements.

Importantly, we were also able to test our hardware in open ocean conditions in the actual candidate region for carbon removal. It is important that >20 trajectory buoys survive and consistently collect and report data to credibly and accurately represent substrate cloud dispersion during surface advection. Thus, it was critical for us to understand failure modes and drive down failure rate through real-world testing. We identified and resolved a mechanical issue that led to a decoupling of the GPS hardware from the flotation on the initial batch of trajectory buoys for Sensor Deployment 1. Sensor Deployments 2 and 3 deployed a hardware iteration that proved to be more resilient with a dramatically lower failure rate. Research during these sensor deployments gave us confidence in deploying 25 sensor buoys instead of 35 per open ocean carbon removal system deployment, materially driving down both cost and impact.

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