Ocean Vital Signs

The immediate focus of Ocean Vital Signs is answering a multitrillion-dollar question: Can new drone technologies and artificial intelligence help us learn how the upper ocean carbon cycle works, improve air-sea CO_2 flux estimates, and create a super-accurate monitoring network?

We don't yet know the complete answer to this question. Here, we propose harnessing the *mens et manus* (and *machina*) ingenuity of the MIT community to figure it out.

PRIMARY OBJECTIVE

The project's main objective is to accelerate the design and development of a smart and scalable in-situ monitoring network to accurately measure atmosphere-ocean CO_2 fluxes.

This objective would directly benefit all carbon capture and emission reduction projects. The project aims to address a major uncertainty in the global CO_2 budget for which there is currently no clear solution. The present level of air-sea CO_2 flux uncertainty is sufficiently large that all manner of envisioned emissions reduction and sequestration initiatives in practice cannot currently garner timely efficacy information to quickly show whether they are having their expected impacts on global atmospheric CO_2 levels.

On average, every person on Earth generates fossil fuel emissions equivalent to ~8lb carbon, every single day.

ADDITIONAL IMPACTS

The ocean is arguably the largest economic externality in the climate system. Net global absorption of CO_2 and global warming heat by the ocean are among the largest natural counterbalances to anthropogenic emissions. In principle, new generation autonomous technologies offer the potential to disruptively transform our knowledge and capacity to monitor, and ultimately sustainably manage, the global ocean. However, the adoption, deployment, and leveraging of autonomous ocean technologies remains—technically and economically—an underappreciated societal proposition that is proceeding at a relatively slow pace. Consequently, knowing the day-to-day ocean surface environment that profoundly impacts everyone on Earth remains a significant grand challenge to humanity.

Our grand challenge project aims to accelerate real-time surface ocean observation from an experimental research endeavor to a sustained, impactful, societal capability that impacts:

- Fundamental understanding of the ocean carbon cycle and of other ocean chemical cycles central to supporting life on Earth
- Monthly to seasonal timescale weather forecasting
- Better understanding of ocean heat uptake and upper ocean dynamics
- Severe storm track and coastal inundation forecasting
- Monitoring ocean acidification and ocean biology mediated CO_2 sequestration
- Improving the representation of carbon cycles in climate modeling systems
- Enhancing remote sensing platform calibration capabilities
- Public interest legal-societal initiatives toward a sustainable global ocean environment

PROPOSED SOLUTION

We want to evaluate and demonstrate a potentially cost-effective approach to air-sea CO_2 flux uncertainty reduction that combines:

- New targeted observations
- Application of the observations to improve localized process models
- The use of process model results to train machine learning tools that can learn the relationships between global observations, model estimates, and air-sea CO_2 fluxes

In all three areas, our team has prior experience. The overall approach to our design study centers on extending and integrating these previous activities to design and field-evaluate an integrated and potentially enduring system for monitoring air-sea CO_2 fluxes at high spatial and temporal resolution.

OUTCOMES

Ideally our projected five-year outcome would be a much improved, frequently updated air-sea flux budget of CO_2 for the global ocean with uncertainties that are an order of magnitude smaller than at present. At that level, the impacts of large-scale emission reduction initiatives will not be masked by unknown ocean variability. At a minimum, the outcome of our project will be a detailed, field-validated design and cost assessment for a network that can be scaled to achieve that goal.

Specific outcomes within the validated design will include:

- Demonstrating that sustained drone measurements can help reduce uncertainty
- Establishing a relationship between the number and type of measurements and uncertainty
- Quantifying the density, frequency, and type of drone measurements needed to reduce air-sea CO_2 flux uncertainty to 10% of current level
- System tests that validate the conclusions and demonstrate the end-to-end operational design of a permanent long-term network
- Proactive dialogue toward an economic model for sustaining a global network

TEAM EXPERTISE AND LEADERSHIP

Our project involves a team from across MIT and collaborators elsewhere. We hope to support more than 5,000 drone days of observations in five missions over five years sampling five ocean basins. We aim to resolve an arguably multitrillion-dollar uncertainty in the climate system and improve climate science knowledge of the ocean carbon cycle.