



# Working to Advance Marine Carbon Dioxide Removal This Decade

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Ocean Visions is a nonprofit organization at the center of a robust network.

Ocean Visions catalyzes collaboration for the co-design, development, testing, and evaluation of solutions to the interlocking ocean-climate crisis.



UC SANTA BARBARA



**Ocean Visions is  
Advancing a  
Strategic Agenda  
to Address the  
Interlocking Ocean  
and Climate  
Crises:  
4 R's**

**REACH**

Build global capacity to innovate and develop ocean-climate solutions

**REDUCE**

Develop ocean-based pathways to a low carbon society

**REMOVE**

Develop ocean-based pathways to clean up carbon pollution

**REPAIR**

Stabilize critical marine ecosystems to avoid tipping points

## OCEAN-BASED CARBON DIOXIDE REMOVAL

**ELECTROCHEMICAL OCEAN CARBON DIOXIDE REMOVAL**

**DEEP SEA STORAGE**

**OCEAN ALKALINITY ENHANCEMENT**

**RESTORING LIVING BLUE CARBON**

**MICROALGAE CULTIVATION**

**MACROALGAE CULTIVATION AND CARBON SEQUESTRATION**

**ARTIFICIAL UPWELLING AND DOWNWELLING**

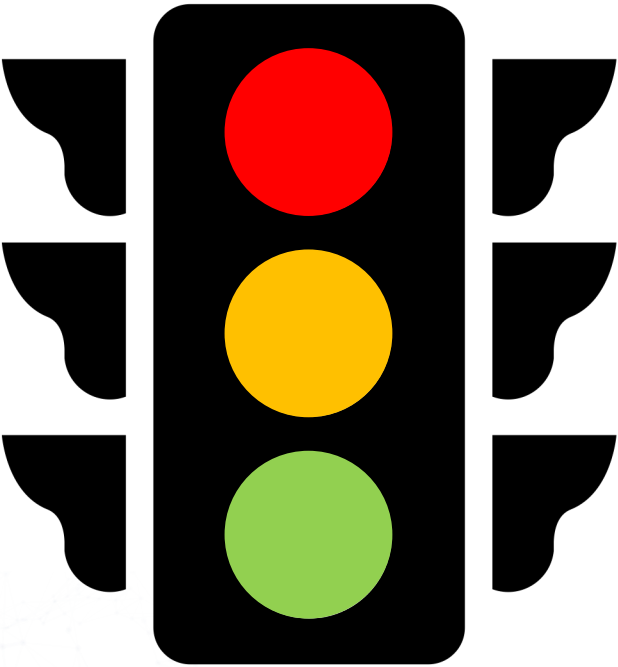
**ACCELERATING OCEAN BIOLOGICAL AND CHEMICAL CARBON UPTAKE**

# Bringing It All Together



**A Comprehensive Program to Prove or Disprove  
Marine Carbon Dioxide Removal Technologies by 2030**

Released in October 2023; <https://oceanvisions.org/high-level-road-map>



- Does the mCDR activity generate a measurable reduction in seawater carbon dioxide concentration?
- Can net additional ocean uptake of atmospheric carbon dioxide be tracked in response to the mCDR activity using a combination of sensors, platforms, and models?
- What are the impacts to marine ecosystems of mCDR activities and are they acceptable when compared with the impacts of the no-action alternative or of other feasible mitigation measures?
- What are the range of impacts to human populations and are they acceptable when compared with the impacts of the no-action alternative or of other feasible mitigation measures?
- What are the necessary materials for scaling an mCDR approach and can they be sourced, transported, and delivered to key regions with acceptable cost and environmental impact (from a lifecycle perspective)?
- What is the required suite of technical, economic, social, and political enabling conditions required to permit growth of a given mCDR technology to the scale of gigatons of annual CDR and what is needed to establish them?

# Three (Interconnected) Pillars

- Science and Engineering
- Policy
- Scalability

# Science and Engineering

- Controlled Field Trials
  - Pre-permitted test beds
- Fundamental laboratory and mesocosm science questions
  - NSF Ocean Acidification Program as an example
- Monitoring, Reporting, and Verification-related R&D
  - Sensors
  - Models
  - Model/data integrations
- A coordinated social science research program



# Policy

- Regulatory and Governance Frameworks
  - Must enable **responsible** research
  - Must be deployed at international, national, and subnational scales
- Following a Code of Conduct for **Responsible** Research
- Expanded communications for mCDR R&D
  - Who are the target audiences?
  - Who are the credible spokespeople?
    - Need geographic diversity, and more representation from the Global South

# Scalability

- Scaling Analyses
  - Site suitability
  - Co-products
  - Supply chains
- What can we learn from other areas of innovations to advance mCDR?
- Regional Innovation Hubs



# What We're Doing in 2024 to Advance this Agenda

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# New mCDR Field Trials Database

## mCDR Field Trial Database

(Last updated December 14, 2023)

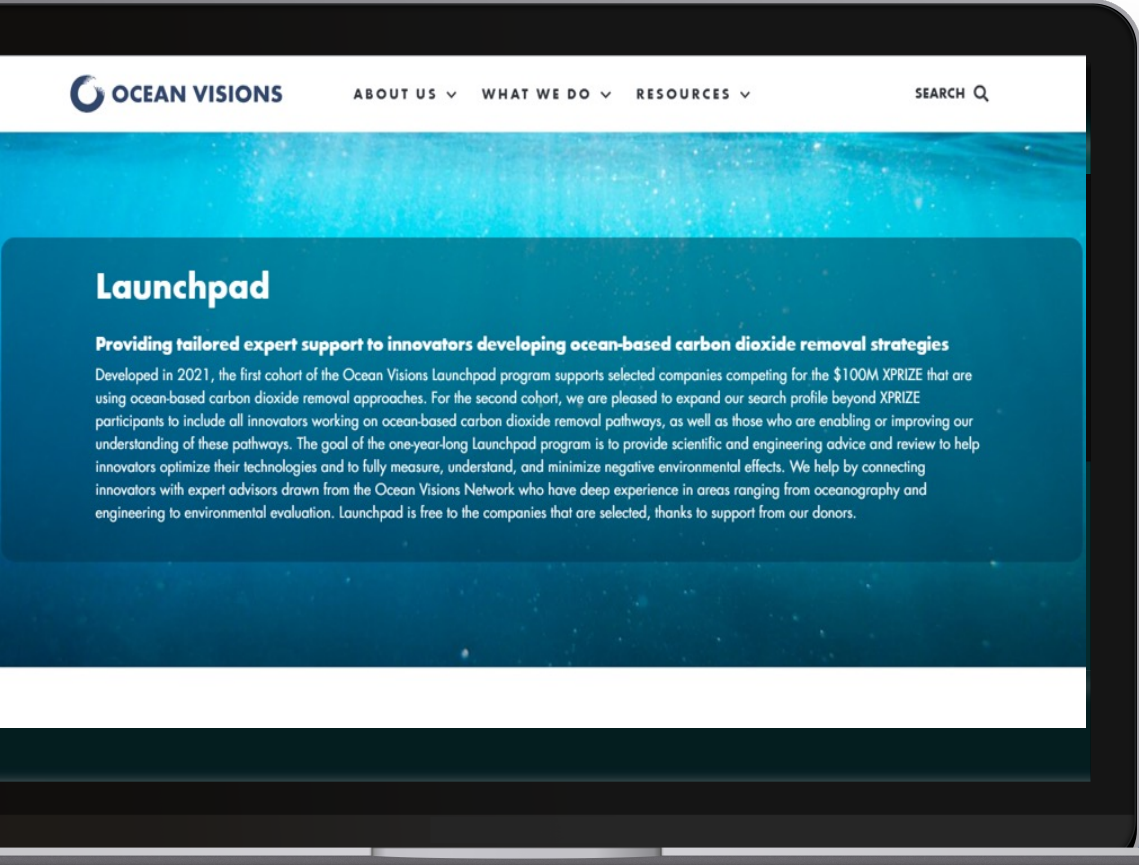
	Trial Name	Leading Organization	Other Leading Organiz...	Or
28	First of a kind Direct Ocean Capture facility on the North Sea Coast	SeaOZ		S
29	Pilot Integrating Direct Ocean Removal Process with a desalination facility in Maagan Michael, Israel	CarbonBlue	[C]Worthy	S
30	Impact of artificial upwelling on macroalgae growth in Aoshan Bay, Shandong Province, China	Xiamen University		A
31	Assessing the impact of OAE on a winter/ spring plankton community in Kiel Fjord, Germany	GEOMAR		R
32	Halifax Harbour OAE Net Carbon Removal Pilot	Planetary Technologies		S
33	Chesapeake Bay Wastewater Alkalinity Injection (NOPP)	Planetary Technologies	University of Maryland ...	A



Learn more here &  
add your field trial  
to the database



# Science and Engineering Support to Innovators



The logo for Banyu Carbon, featuring the word 'BANYU' in blue above 'CARBON' in blue, with a small red and white icon to the right.

The logo for Brilliant Planet, consisting of a black icon of four dots in a square followed by the text 'Brilliant Planet'.

The logo for Capture6, featuring a stylized blue and orange geometric icon above the text 'CAPTURE6'.

The logo for CarbonBlue, featuring a blue circular icon with a white dot inside, followed by the text 'CarbonBlue'.

The logo for Carboniferous, featuring a stylized blue and green icon of a mountain or wave above the text 'Carboniferous'.

The logo for SeaQ2, featuring the text 'SeaQ2' in a teal color.

The logo for Subtidal, featuring a blue icon of three horizontal lines above the text 'Subtidal'.

The logo for VYCARB, featuring a blue grid icon followed by the text 'VYCARB'.

# Ocean Visions' 2024 mCDR Activities

- Advancing a research framework for OAE (in partnership with Carbon to Sea; more soon)
- Advancing technology development in mCDR through collaboration with adjacent fields not yet involved in mCDR (e.g., artificial intelligence, biotechnology, etc)
- Site suitability analyses to look at pathways for scaling, including for OIF....



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# OIF Site Suitability Planning Tool

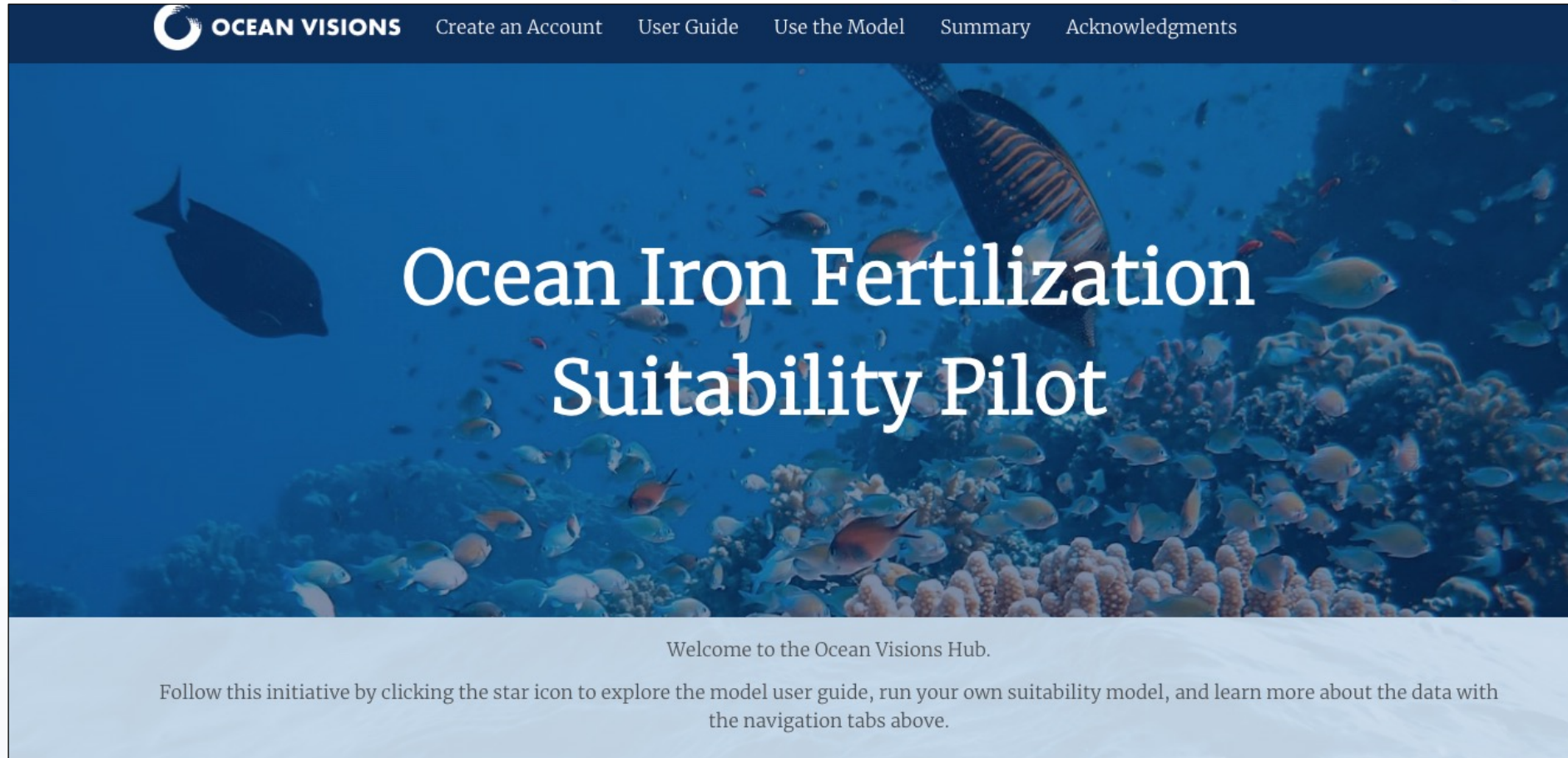
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# Why Ocean Iron Fertilization?

- Ocean iron fertilization (OIF) has been recognized as one of the high potential approaches for marine carbon dioxide removal
- Figuring out where OIF could scale (or not) is not easy. Scaling decisions must be based on science, engineering, economic, social, and political factors to name a few. These factors must be considered **together**.
- Site suitability tools are a good way to consider complex environmental decisions based on many factors. One did not exist for OIF, so...

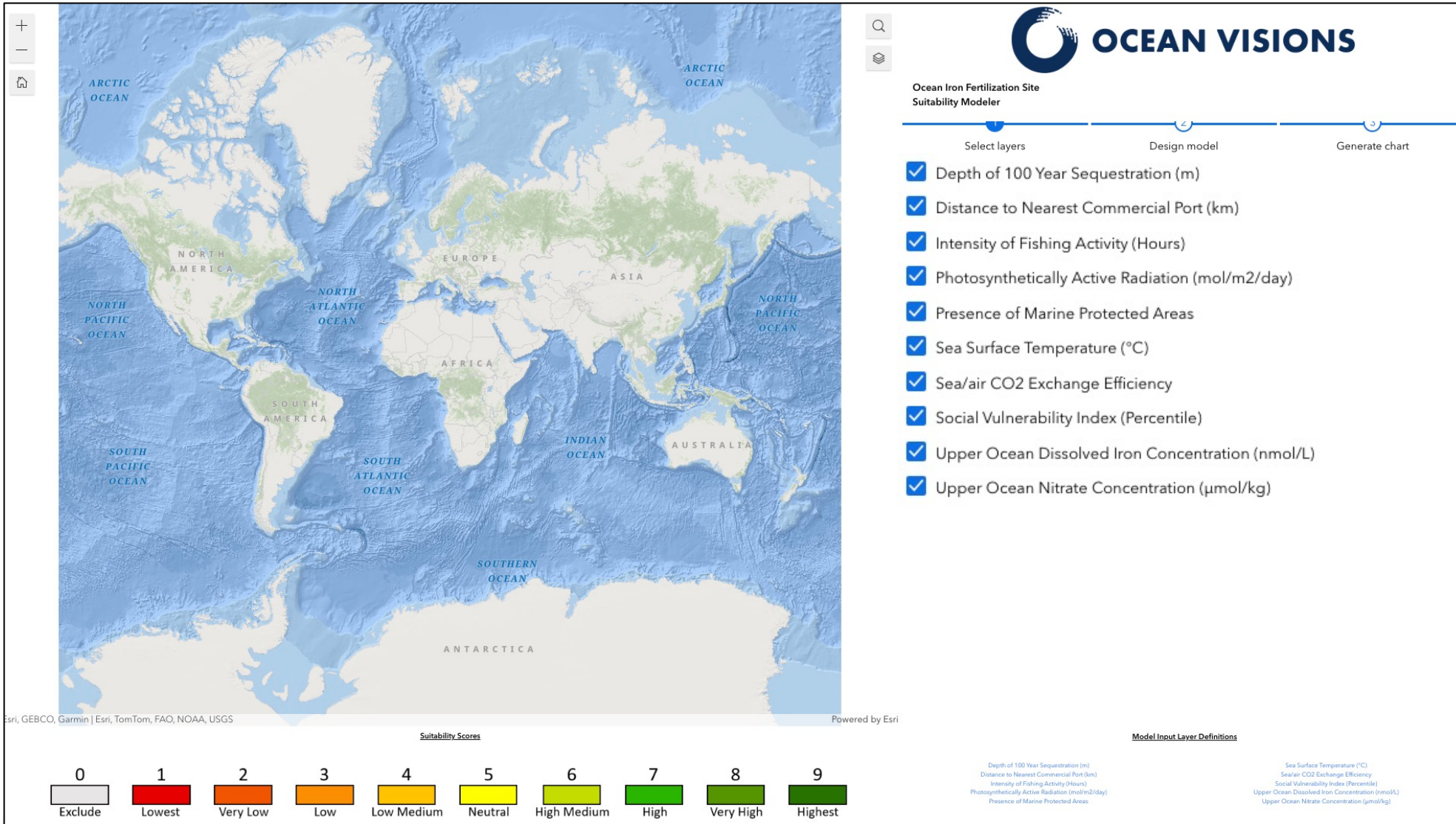


# Ocean Iron Fertilization Site Suitability Planning Tool



Scheduled for March 2024 public release

# Site Suitability Planning Tool: Ocean Iron Fertilization



10 layers:  
oceanographic, social,  
political, and logistical  
factors

Seasonally variable  
results:

- October-March
- April-September

1  
Select layers2  
Design model3  
Generate chart**Design model**Low  High


Depth of 100 Year Sequestration (m)

 10 %

Very Shallow (0 - 377)

 9

Shallow (377 - 560)

 7

Medium (560 - 860)

 5

Deep (860 - 1350)

 3

Very Deep (1350 - 2155)

 1

Distance to Nearest Commercial Port (km)

 10 %

Intensity of Fishing Activity (Hours)

 10 %Photosynthetically Active Radiation (mol/m<sup>2</sup>/day) 10 %

Presence of Marine Protected Areas

 10 %

Sea Surface Temperature (°C)

 10 %Sea/air CO<sub>2</sub> Exchange Efficiency 10 %

Social Vulnerability Index (Percentile)

 10 %

Upper Ocean Dissolved Iron Concentration (nmol/L)

 10 %

Upper Ocean Nitrate Concentration (μmol/kg)

 10 %**Total****100%**

Clear

Export

Run

# Customized Analysis

All dimensional data converted to 1-9 scale; user control over data breaks let's you choose what's most important

Choose which layers to include (or not) and how important each data layer should be in your results

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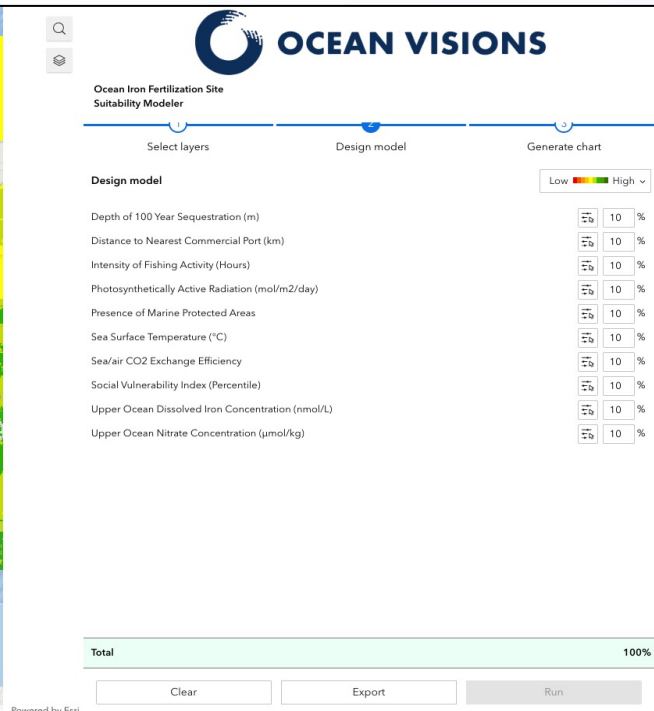
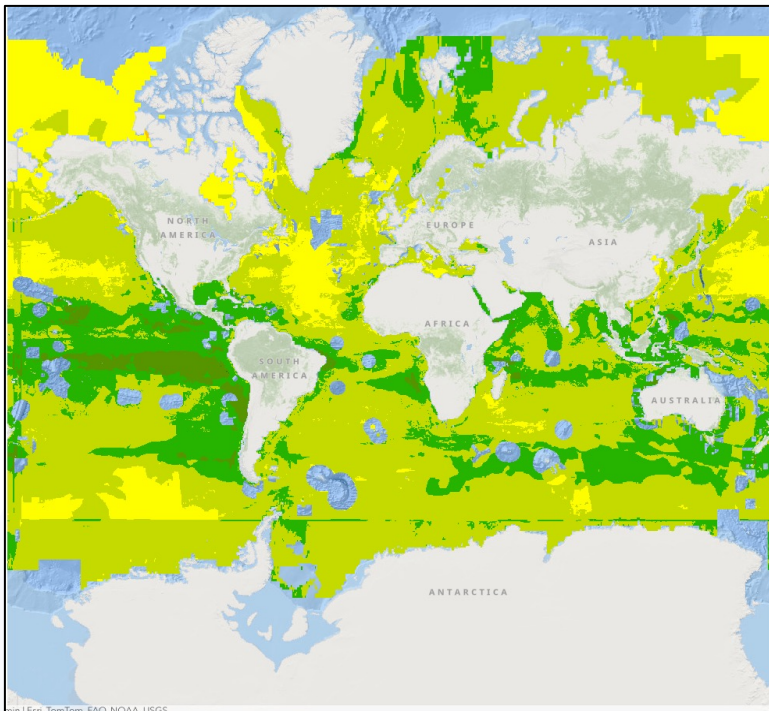
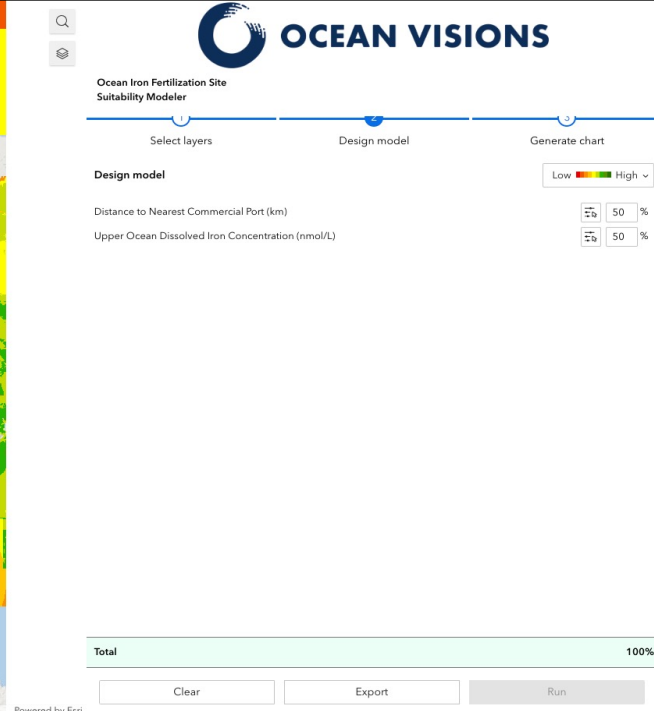
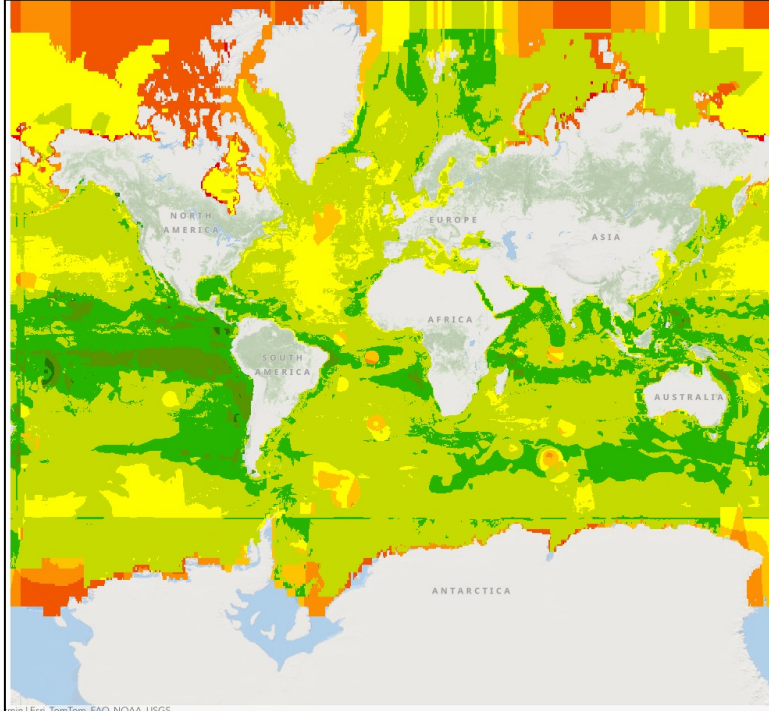
# Explore Results

See how different data layer inputs and weightings change suitability scores

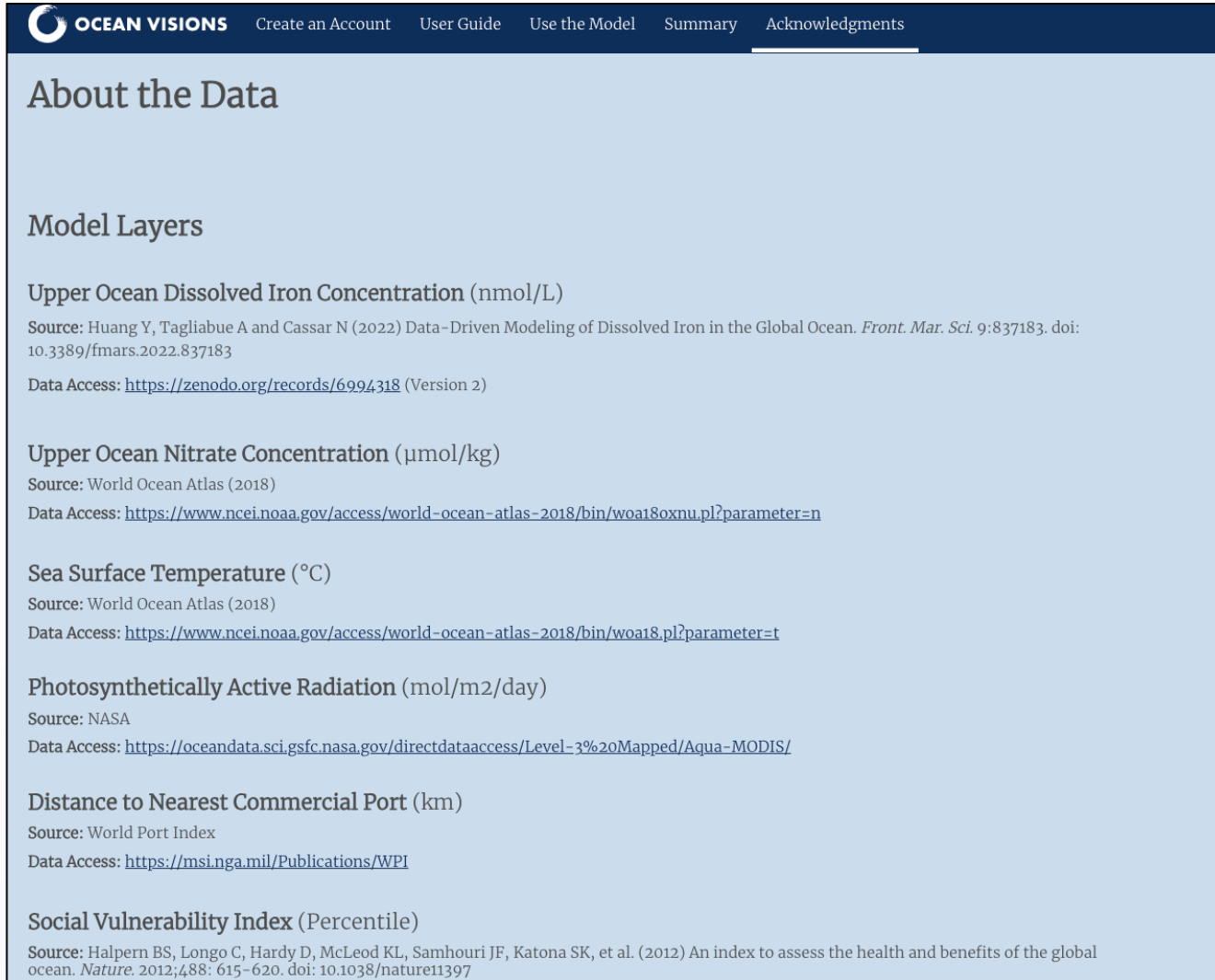
Export map displays of your results. Choose global or zoomed in local displays for regions of interest

Overlay additional important geospatial layers such as EEZ boundaries for extra insight

Scheduled for March 2024 public release



# Built on Open Data



**OCEAN VISIONS** Create an Account User Guide Use the Model Summary Acknowledgments

## About the Data

### Model Layers

**Upper Ocean Dissolved Iron Concentration (nmol/L)**  
Source: Huang Y, Tagliabue A and Cassar N (2022) Data-Driven Modeling of Dissolved Iron in the Global Ocean. *Front. Mar. Sci.* 9:837183. doi: 10.3389/fmars.2022.837183  
Data Access: <https://zenodo.org/records/6994318> (Version 2)

**Upper Ocean Nitrate Concentration ( $\mu\text{mol/kg}$ )**  
Source: World Ocean Atlas (2018)  
Data Access: <https://www.ncei.noaa.gov/access/world-ocean-atlas-2018/bin/woa18oxnu.pl?parameter=n>

**Sea Surface Temperature ( $^{\circ}\text{C}$ )**  
Source: World Ocean Atlas (2018)  
Data Access: <https://www.ncei.noaa.gov/access/world-ocean-atlas-2018/bin/woa18.pl?parameter=t>

**Photosynthetically Active Radiation ( $\text{mol/m}^2/\text{day}$ )**  
Source: NASA  
Data Access: <https://oceandata.sci.gsfc.nasa.gov/directdataaccess/Level-3%20Mapped/Aqua-MODIS/>

**Distance to Nearest Commercial Port (km)**  
Source: World Port Index  
Data Access: <https://msi.nga.mil/Publications/WPI>

**Social Vulnerability Index (Percentile)**  
Source: Halpern BS, Longo C, Hardy D, McLeod KL, Samhuri JF, Katona SK, et al. (2012) An index to assess the health and benefits of the global ocean. *Nature.* 2012;488: 615-620. doi: 10.1038/nature11397

All data sets used to feed the planning tool are publicly available, including data from NASA, NOAA, and others

Scheduled for March 2024 public release

# User Guide Helps Anyone Get Started Quickly



The screenshot shows a web page with a dark blue header. On the left is the 'OCEAN VISIONS' logo. To its right are navigation links: 'Create an Account', 'User Guide' (which is underlined), 'Use the Model', 'Summary', and 'Acknowledgments'. The main content area has a light blue background with a wavy pattern. It features a large title 'How to Use the OIF Suitability Model' and a list of links for further exploration: 'General Overview: Introduction / Purpose / Using the Model', 'About the Model: Layers / Layer Weighting / Suitability', 'Map Experience', and 'Export Results / Best Practices / Resources'.

**OCEAN VISIONS** [Create an Account](#) [User Guide](#) [Use the Model](#) [Summary](#) [Acknowledgments](#)

## How to Use the OIF Suitability Model

General Overview: [Introduction](#) / [Purpose](#) / [Using the Model](#)

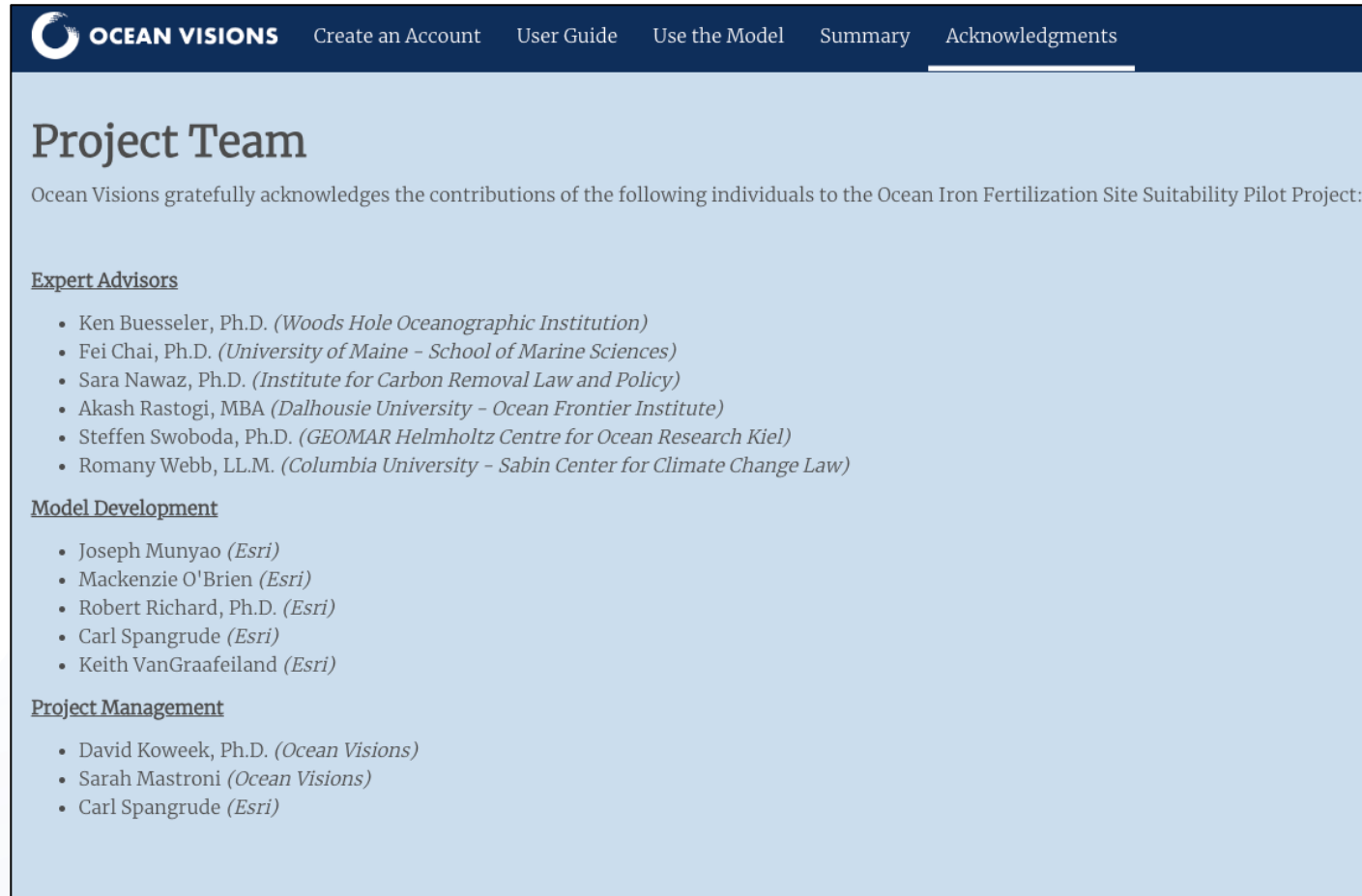
About the Model: [Layers](#) / [Layer Weighting](#) / [Suitability](#)

[Map Experience](#)

[Export Results](#) / [Best Practices](#) / [Resources](#)

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# Complex Climate Solutions Need Diverse Leaders



The screenshot shows the 'Acknowledgments' page of the Ocean Visions website. The page has a dark blue header with the 'OCEAN VISIONS' logo and navigation links: 'Create an Account', 'User Guide', 'Use the Model', 'Summary', and 'Acknowledgments'. The main content area is light blue and features the title 'Project Team'. Below the title, a paragraph states: 'Ocean Visions gratefully acknowledges the contributions of the following individuals to the Ocean Iron Fertilization Site Suitability Pilot Project:'. The page is organized into three sections: 'Expert Advisors', 'Model Development', and 'Project Management', each with a list of names and their affiliations.

**OCEAN VISIONS** Create an Account User Guide Use the Model Summary Acknowledgments

## Project Team

Ocean Visions gratefully acknowledges the contributions of the following individuals to the Ocean Iron Fertilization Site Suitability Pilot Project:

### Expert Advisors

- Ken Buesseler, Ph.D. (*Woods Hole Oceanographic Institution*)
- Fei Chai, Ph.D. (*University of Maine - School of Marine Sciences*)
- Sara Nawaz, Ph.D. (*Institute for Carbon Removal Law and Policy*)
- Akash Rastogi, MBA (*Dalhousie University - Ocean Frontier Institute*)
- Steffen Swoboda, Ph.D. (*GEOMAR Helmholtz Centre for Ocean Research Kiel*)
- Romany Webb, LL.M. (*Columbia University - Sabin Center for Climate Change Law*)

### Model Development

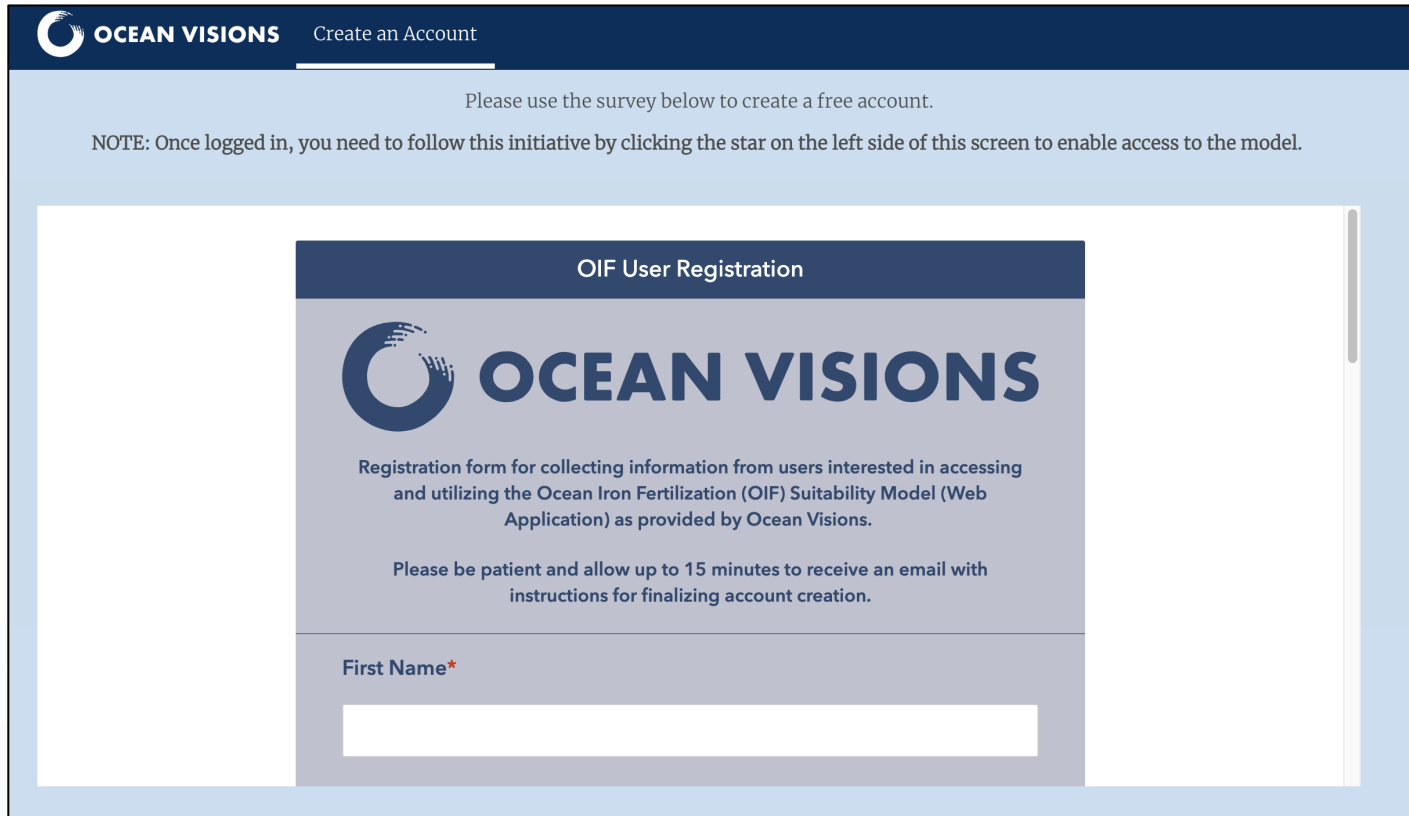
- Joseph Munyao (*Esri*)
- Mackenzie O'Brien (*Esri*)
- Robert Richard, Ph.D. (*Esri*)
- Carl Spangrude (*Esri*)
- Keith VanGraafeiland (*Esri*)

### Project Management

- David Koweek, Ph.D. (*Ocean Visions*)
- Sarah Mastroni (*Ocean Visions*)
- Carl Spangrude (*Esri*)

Ocean Visions worked with ESRI and a team of advisors who spanned disciplines, sectors, and geographies to bring this project forward

# Open Access for Global Widespread Use




**OCEAN VISIONS** Create an Account

Please use the survey below to create a free account.

NOTE: Once logged in, you need to follow this initiative by clicking the star on the left side of this screen to enable access to the model.

### OIF User Registration



## OCEAN VISIONS

Registration form for collecting information from users interested in accessing and utilizing the Ocean Iron Fertilization (OIF) Suitability Model (Web Application) as provided by Ocean Visions.

Please be patient and allow up to 15 minutes to receive an email with instructions for finalizing account creation.

First Name\*

Once live, all you will need to do is sign up for a free account to get started using this tool yourself

Scheduled for March 2024 public release





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# Join us

[oceanvisions.org/join](https://oceanvisions.org/join)  
[info@oceanvisions.org](mailto:info@oceanvisions.org)

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