GROWING OCEANS

# Nitrogen Fixation for Phytoplankton Carbon (Nfix)

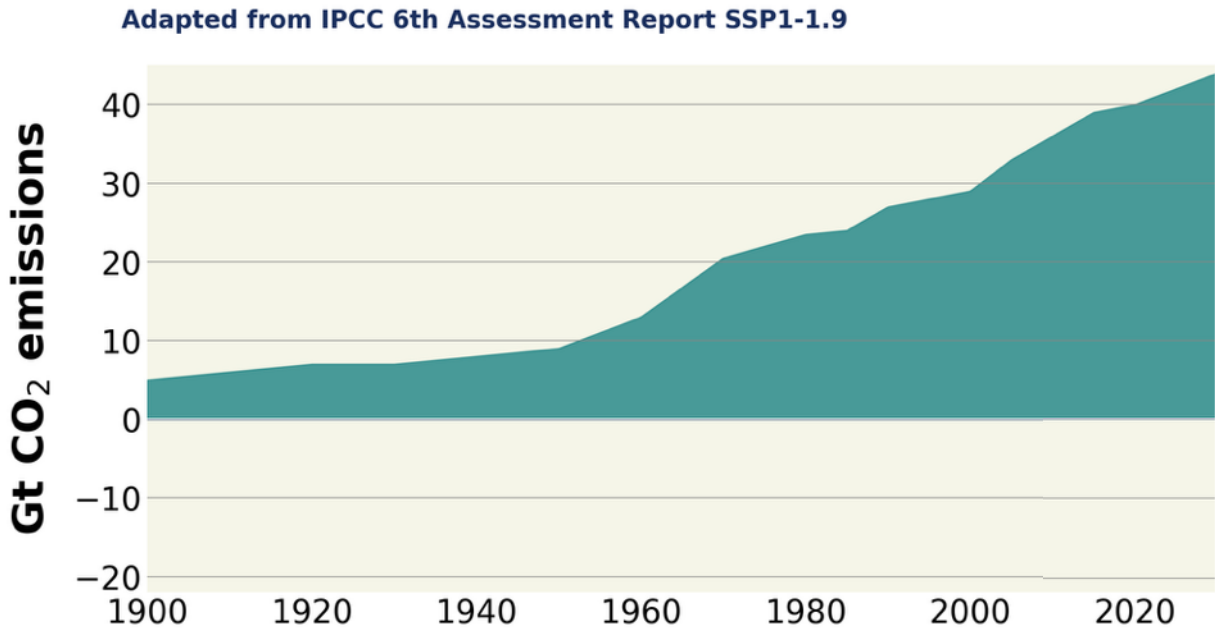
Professor Seth John, *University of Southern California*

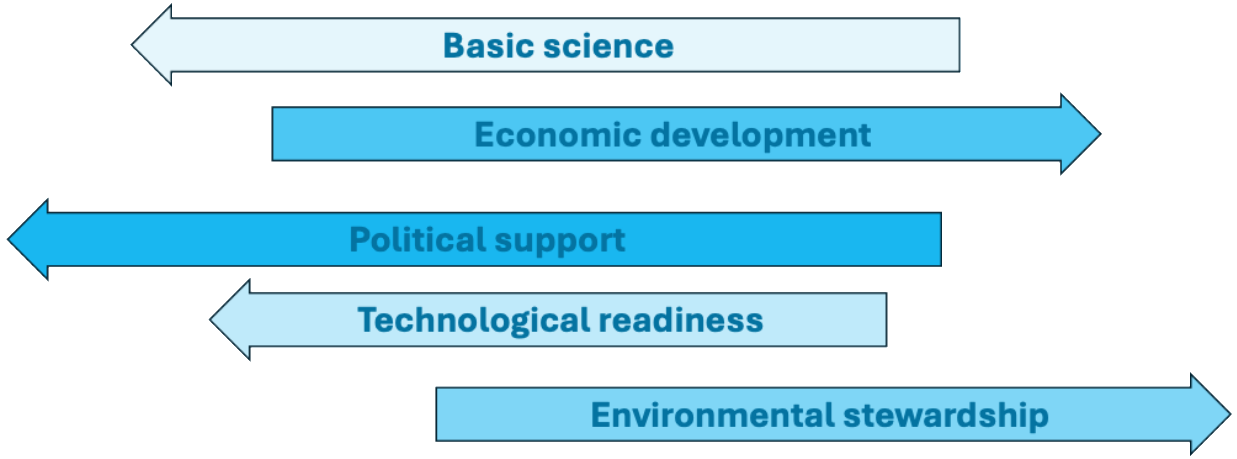
*Growing Oceans*, Director and Chief Scientist

# Outline

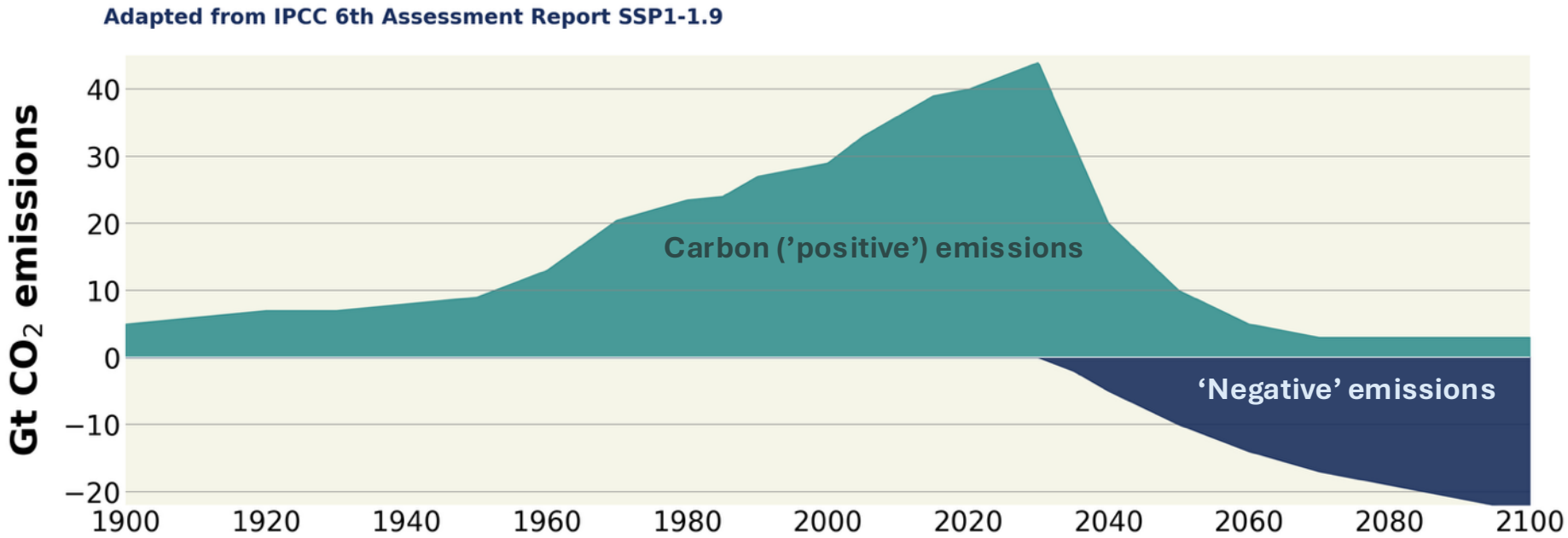
1. Scientific background
2. Recent partnership and fieldwork
3. Recent data

# Historical carbon emissions



# New Approaches Needed




- We need to reduce CO2 emissions…
- …but we also need carbon removal to ensure climate safety.
- Current technologies struggle to achieve reasonable cost (<$100/ton) and scale (Gt CO2) objectives.
- Growing Oceans is studying Nitrogen Fixation for Phytoplankton Carbon (NFix) as a new carbon removal pathway.

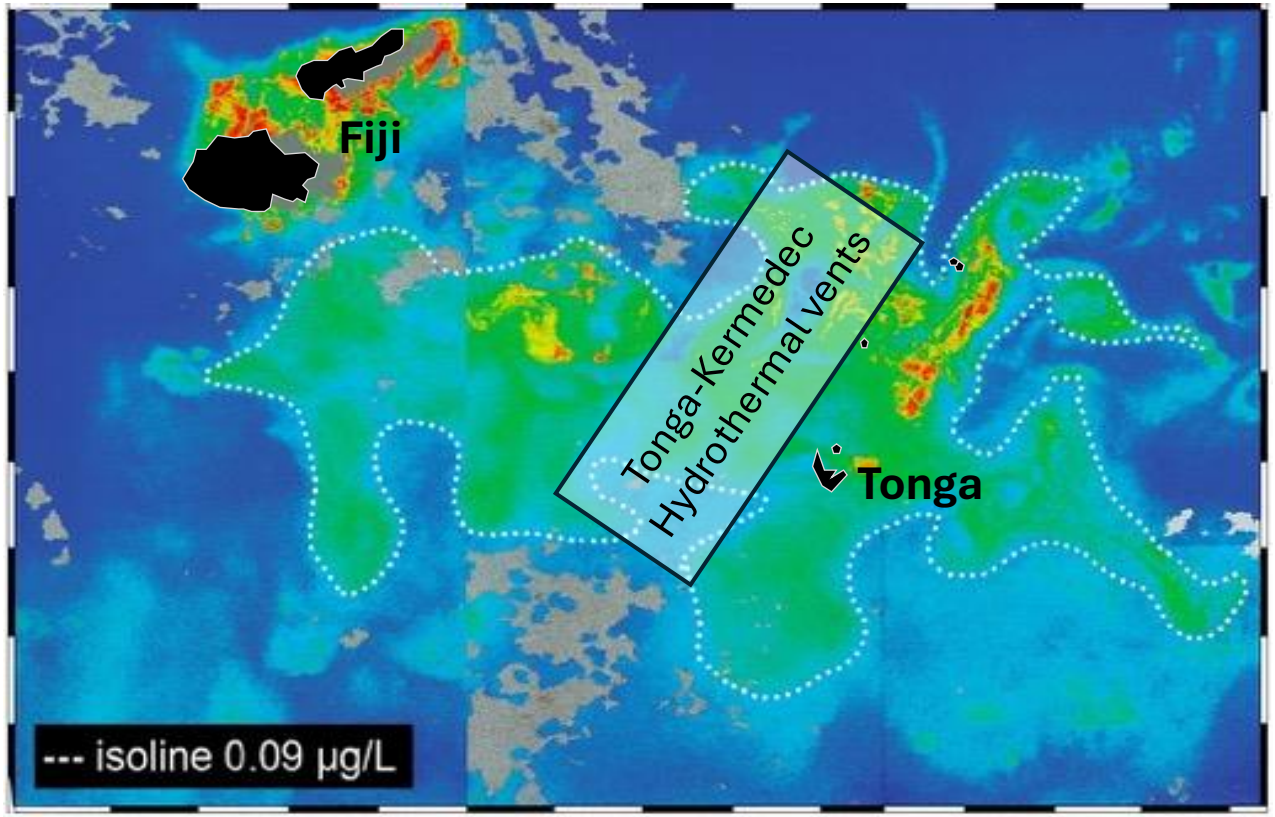
# A Natural Carbon Sequestration Process

RESEARCH ARTICLE

OCEAN NUTRIENTS

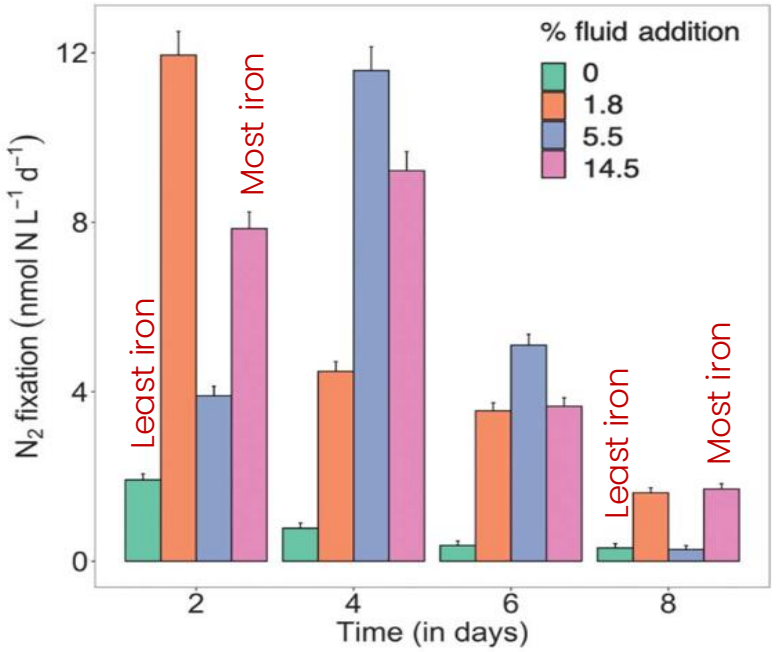
## Natural iron fertilization by shallow hydrothermal sources fuels diazotroph blooms in the ocean

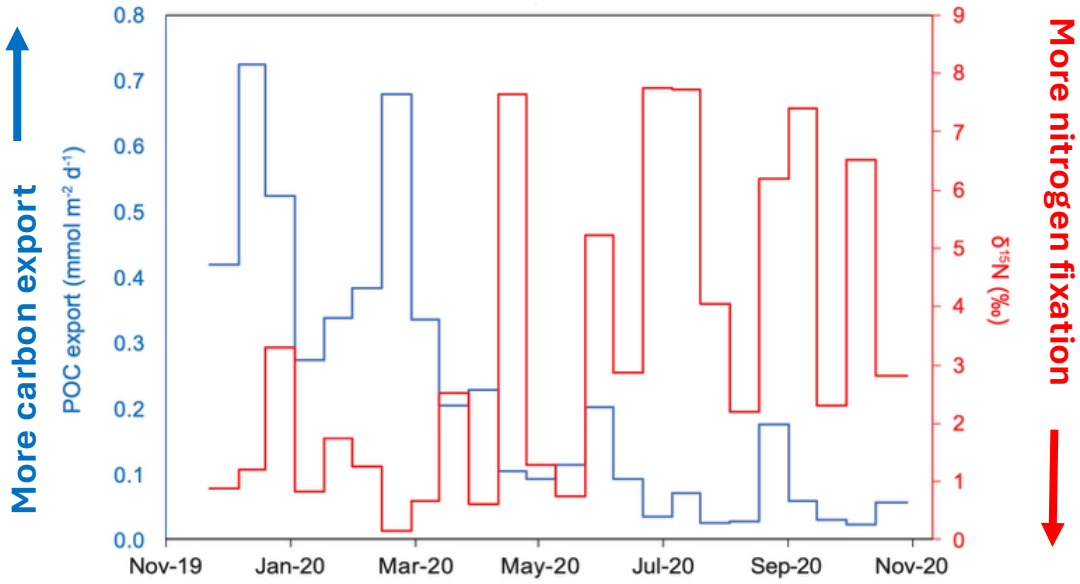
Bonnet *et al.*, *Science* **380**, 812–817 (2023) 26 May 2023




Chlorophyll (µg/L)

# A Natural Carbon Sequestration Process



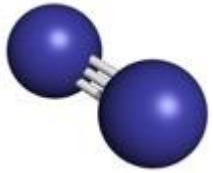

- Incubation data: Iron from hydrothermal fluids stimulates nitrogen fixation.
- Sediment trap data: Nitrogen fixation leads to carbon export.

*Bonnet et al., 2023, Science*

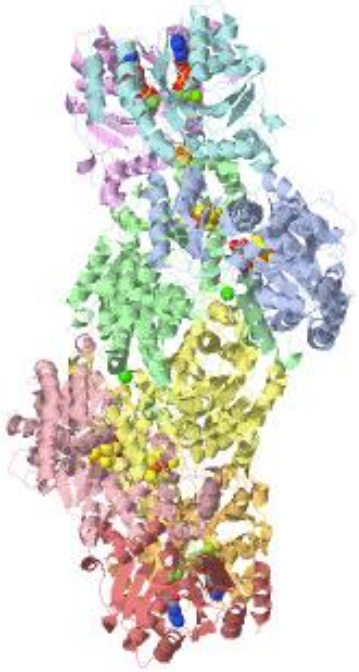
# Nitrogenase: the enzyme which brings life to the oceans

1 atom of Iron → 23,000 $CO_2$

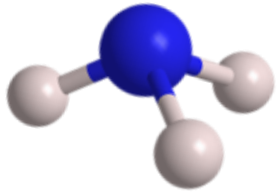
*Iron*



*Inert nitrogen gas*



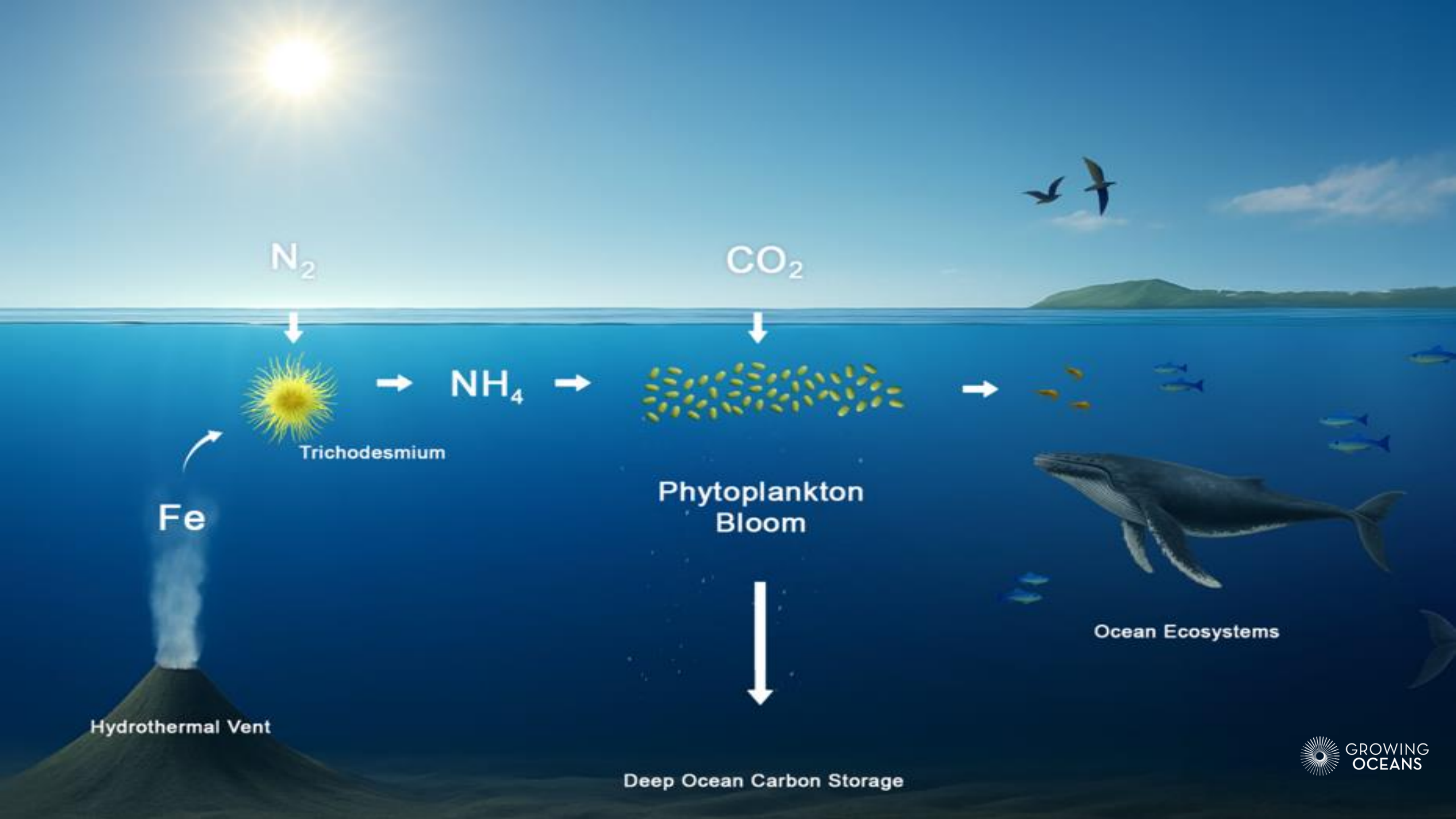
*Nitrogenase*



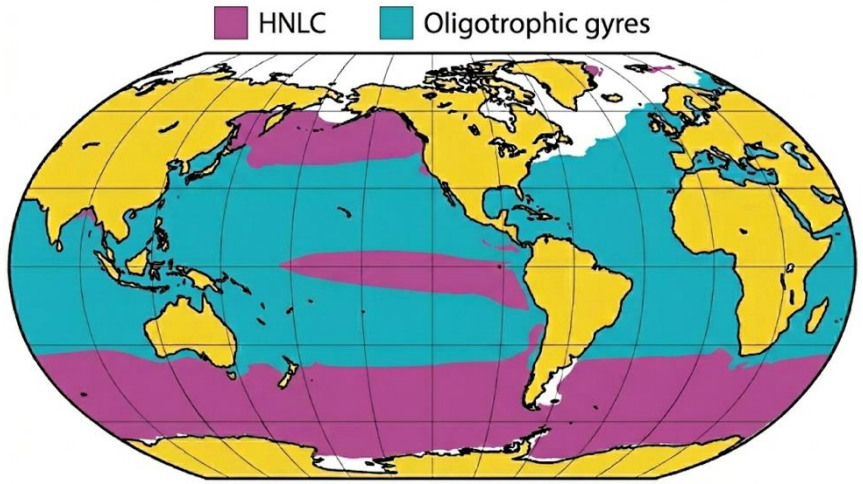
*Biologically available nitrogen*

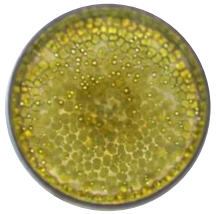
*Phytoplankton*

**23,000 $CO_2$**

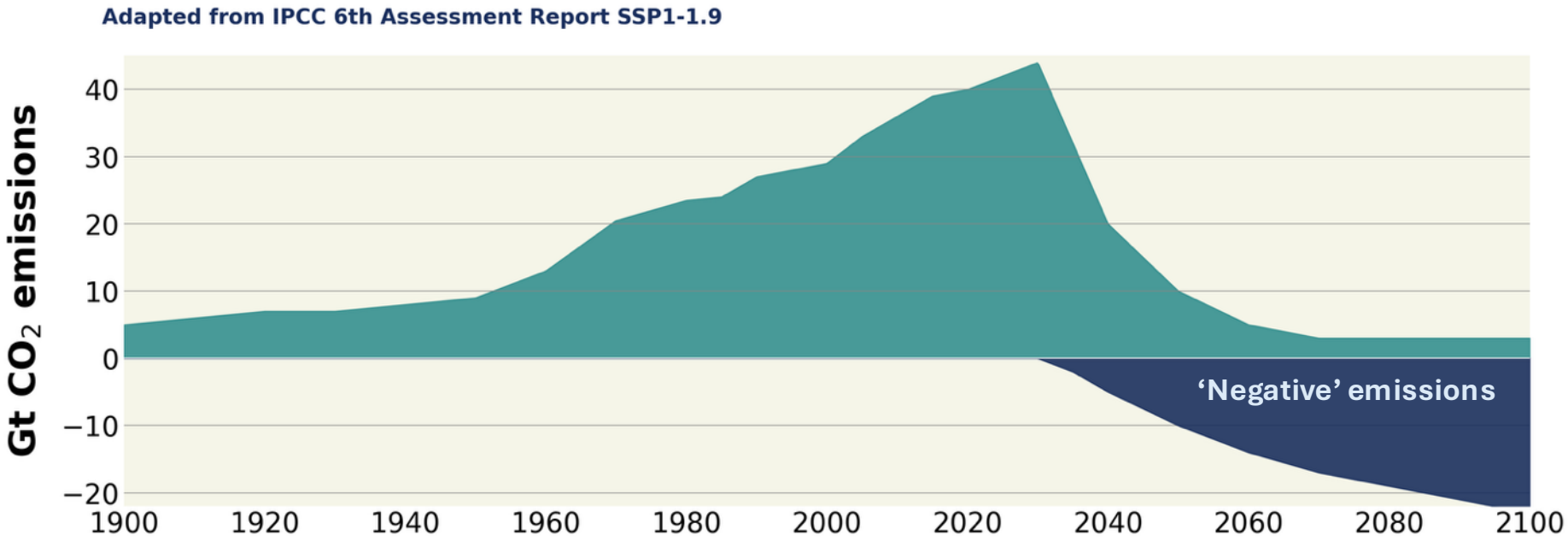

$N_2$
$CO_2$
$NH_4$
Trichodesmium
Fe
Phytoplankton Bloom
Ocean Ecosystems
Hydrothermal Vent
Deep Ocean Carbon Storage
GROWING OCEANS

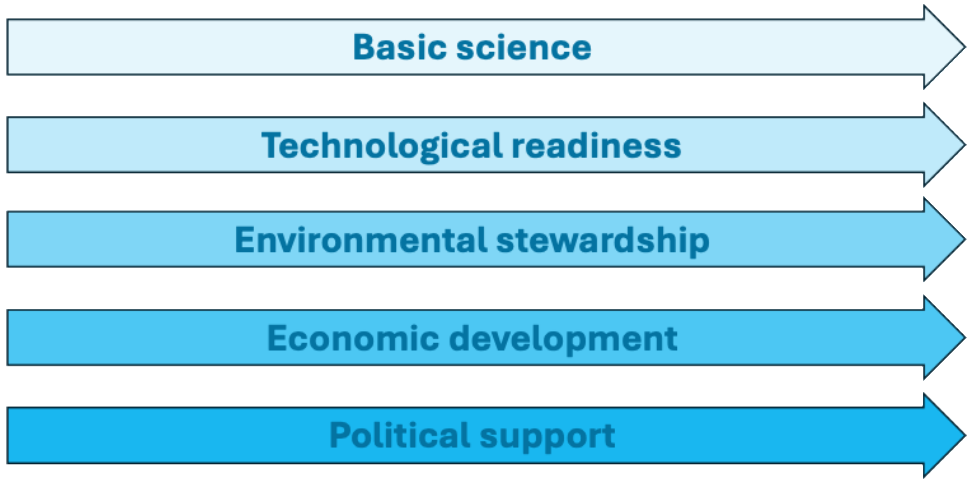
# Traditional' OIF vs. NFix




| Traditional OIF | NFix |
| --- | --- |
| Cool high-latitude oceans<br>HNLC | Warm subtropical oceans<br>Oligotrophic gyres |
| Diatoms (nitrate users)<br>  | Diazotrophs (nitrogen fixers)<br>  |
| Redistributes existing ocean nitrogen | Adds new nitrogen to the oceans |
| Potential 0.5 to 5 Gt annually | Potential > 5 Gt annual storage? |
| Over a dozen *in situ* field trials | Zero *in situ* field trials |
| Better understood | Less well understood |

# Historical carbon emissions



**March 2024**
First travel to the South Pacific

Solomon Islands

**March 2024**
First travel to the South Pacific

American Samoa

**March 2024**
First travel to the South Pacific

Tonga

# June 2024

## Los Angeles workshop

# June 2024

## Los Angeles workshop

# June 2024

## Los Angeles workshop

**June 2024**

Los Angeles workshop

**July 2024**
Tonga again

**July 2024**
Tonga again

**July 2024**

Tonga again

**July 2024**
Tonga again

**Fall 2026**

Japan, New Zealand,
Fiji, Tonga (again)

# Fall 2026

## Japan, New Zealand, Fiji, Tonga (again)

**Fall 2026**

Japan, New Zealand,
Fiji, Tonga (again)

# Fall 2026

## Japan, New Zealand, Fiji, Tonga (again)

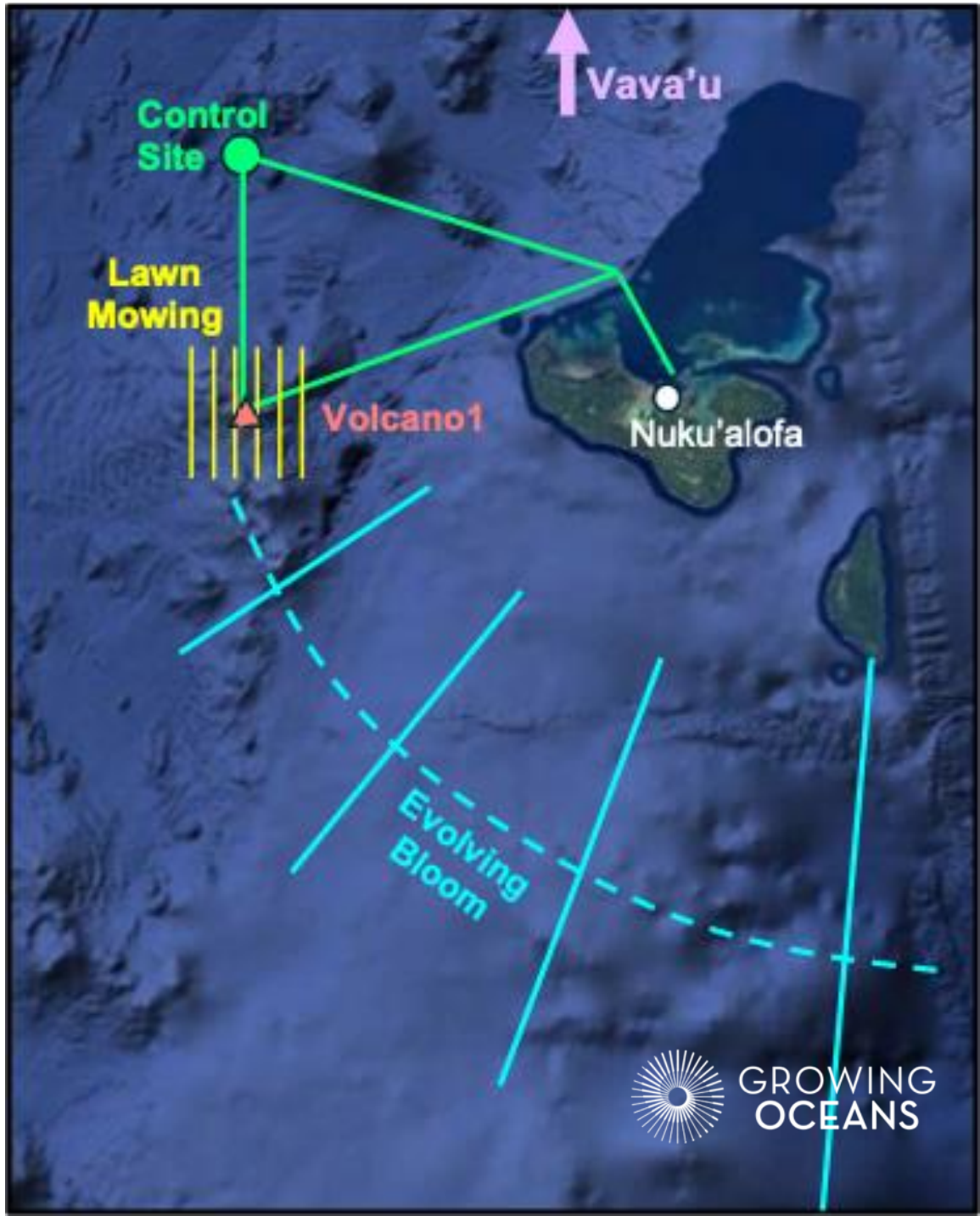
# 2026 Field Season

Pathway verification

- Hydrothermal plume detection
- In-plume vs. out-of-plume comparison
- Nitrogen fixation rates/species
- Bloom evolution

Ecological impacts

- Community composition
- Zooplankton abundance
- Coral reef health



# 2026 Field Season

**January 2026**

Partnership

**January 2026**
Partnership

**January 2026**
Partnership

# **January 2026**
# Partnership

# March 2026

## Field Season  Science

# March 2026

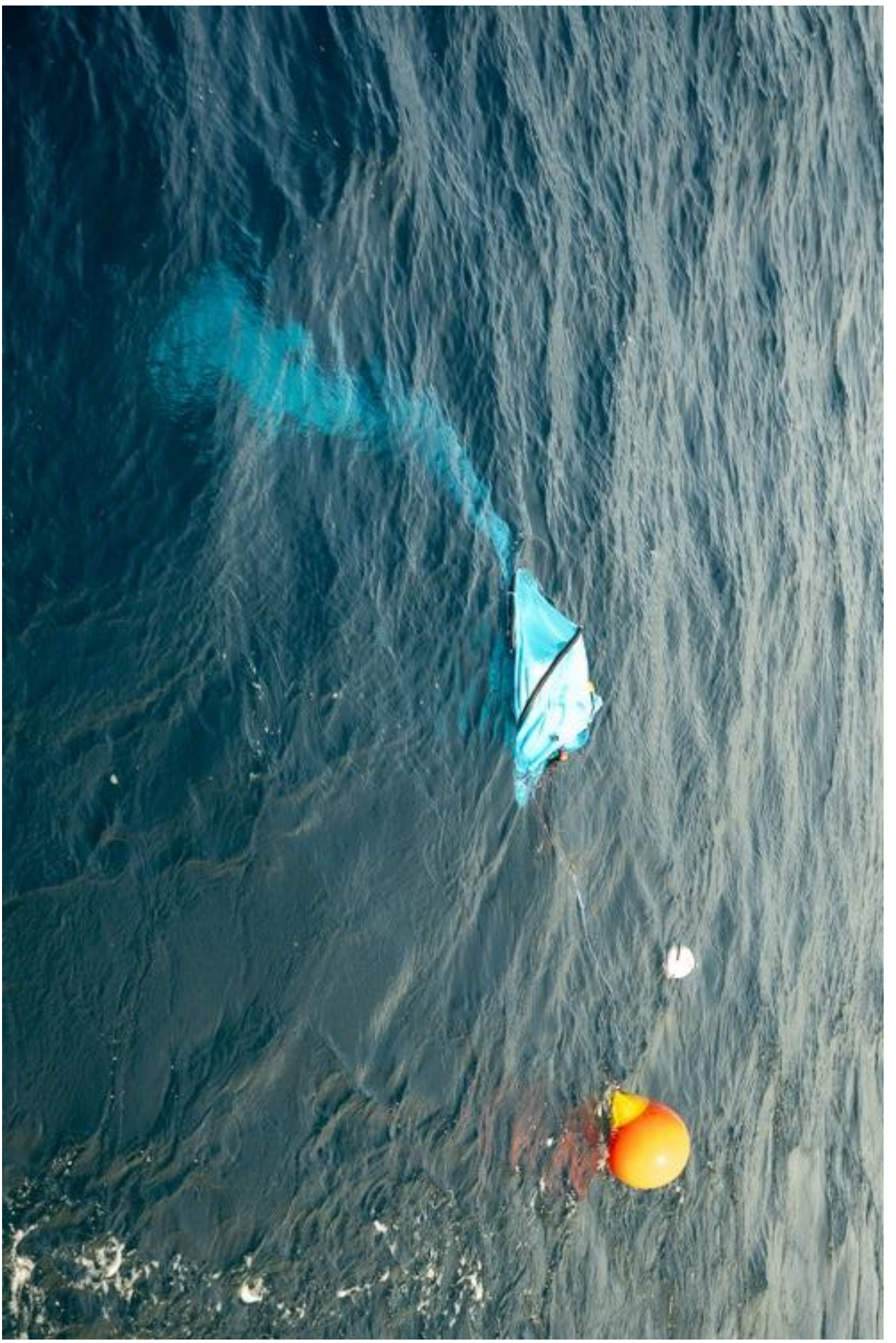
## Field Season  Science

# March 2026

## Field Season  Science

# March 2026

## Field Season  Science



# **March 2026**
# Partnership

**March 2026**
Partnership

**March 2026**
Partnership

# March 2026 Partnership

**Prime Minister's Office, Tonga**
March 26 at 12:51PM ·

Prime Minister Lord Fakafanua was pleased to meet with the Growing Oceans team, a non-profit research initiative focused on understanding how ocean microbes fix atmospheric nitrogen in warm oceans. The Growing Oceans science collaborative is led by Dr. Seth John, a professor at the University of Southern California.

Nitrogen fixation is a vital ecosystem process that supports ocean food webs and enhances the ocean's ability to absorb carbon dioxide. Through studying these natural processes, the initiative aims to support biodiversity while strengthening the ocean's capacity to safely store carbon at scale.

This work is of particular importance to Tonga, as it supports the Government's ongoing efforts to protect our marine environment and address the impacts of climate change.

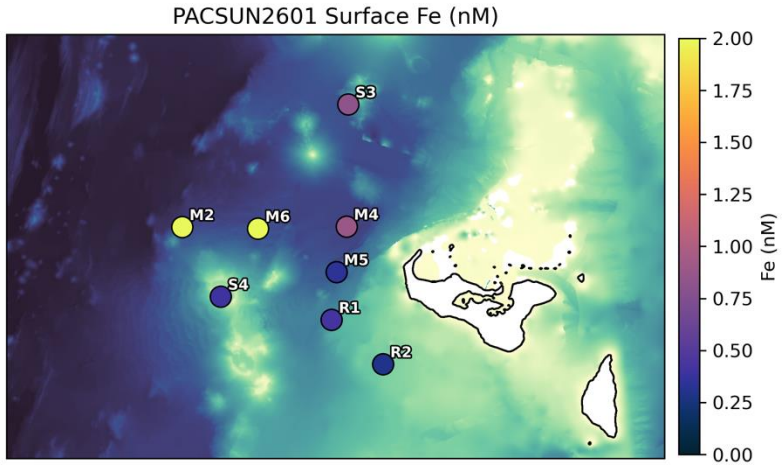
—

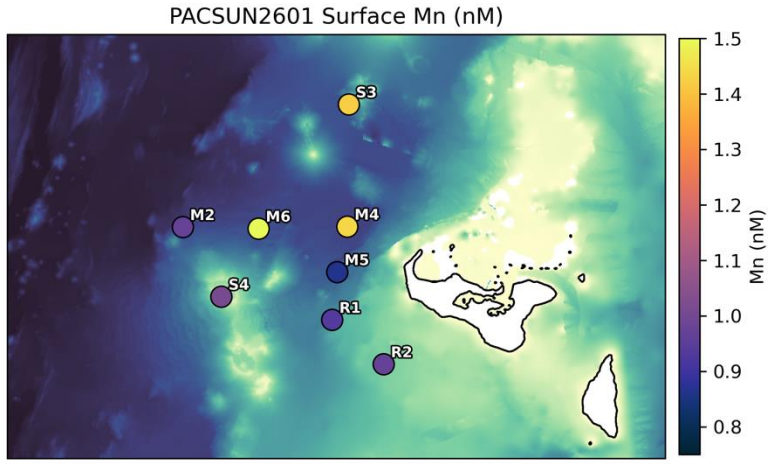
Na'e fiefia 'a e 'Eiki Palemia Lord Fakafanua ke fe'iloaki mo e timi Growing Oceans, ko ha polokalama fakatotolo 'oku 'ikai taumu'a fakatupu pa'anga ka 'oku fakatefito 'i he fakatotolo ki he founga 'oku hanga ai 'e he fanga ki'i me'amo'ui iiki 'o e 'oseni 'o fakalelei'i 'a e kasa naitoloseni (nitrogen) 'i he 'oseni 'oku mafana. 'Oku taki 'a e fengaue'aki fakasaienisi 'a e Growing Oceans 'e Dr. Seth John, ko ha palofesa 'i he 'Univesiti 'o Southern California.

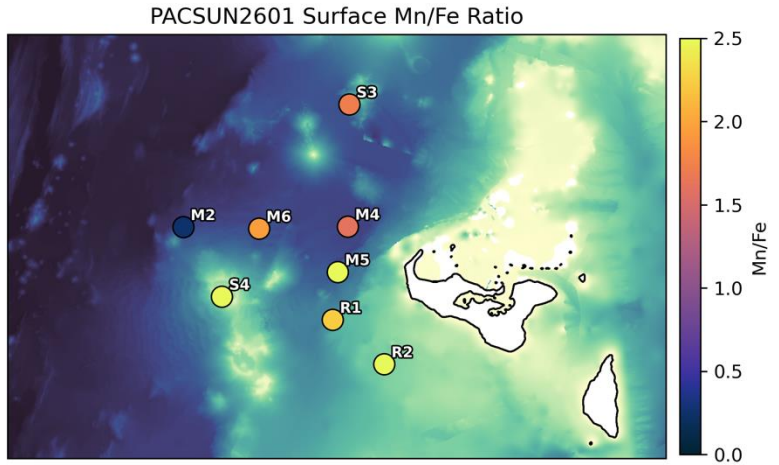
Ko e founga ngaue ki hono ngaue'aki 'o e kasa naitoloseni ko ha founga mahu'inga ia 'o e 'atakai 'oku ne poupou'i 'a e ngaahi kupenga me'akai 'o e tahi mo fakalahi 'a e malava 'a e tahi ke mimisi 'a e kaponi taiokisaiti. 'I hono siofi 'o e ngaahi founga fakanatula ko 'eni, 'oku fakataumu'a 'a e polokalama ke poupou'i 'a e ngaahi me'a kehekehe lolotonga hono fakamalohia 'a e malava 'a e 'oseni ke tauhi malu 'a e kaponi 'i he me'afua ko 'eni.

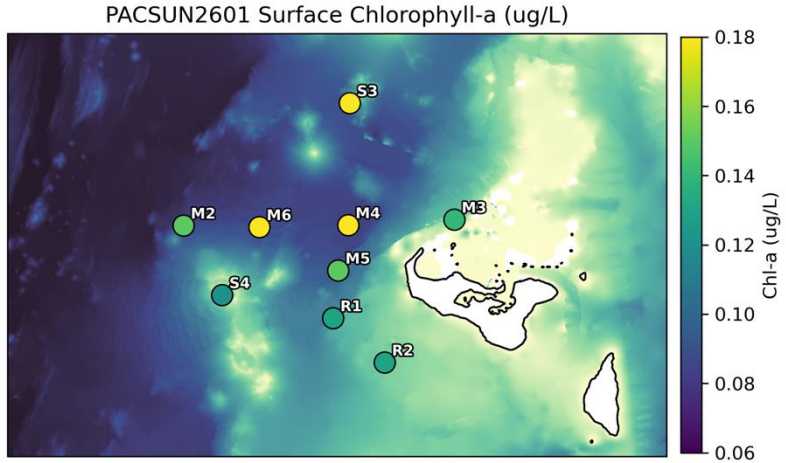
'Oku matu'aki mahu'inga 'a e ngaue ko 'eni ki Tonga, he 'oku ne poupou'i 'a e ngaahi ngaue hokohoko 'a e Pule'anga ke malu'i hotau 'atakai 'i tahi mo tokangaekina 'a e ngaahi nunu'a 'o e feliuliuaki 'o e 'ea.

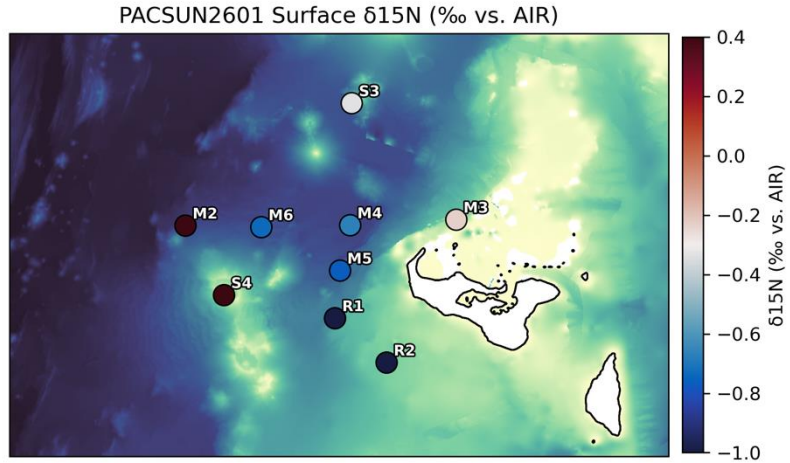
# January (PACSUN 2601)



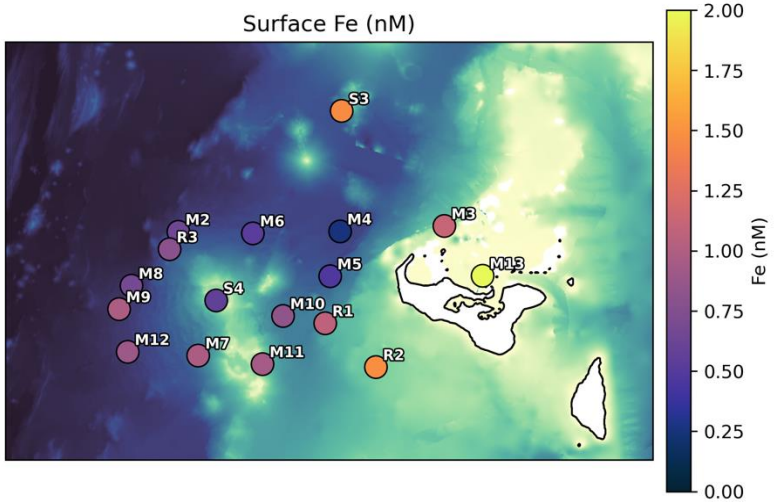



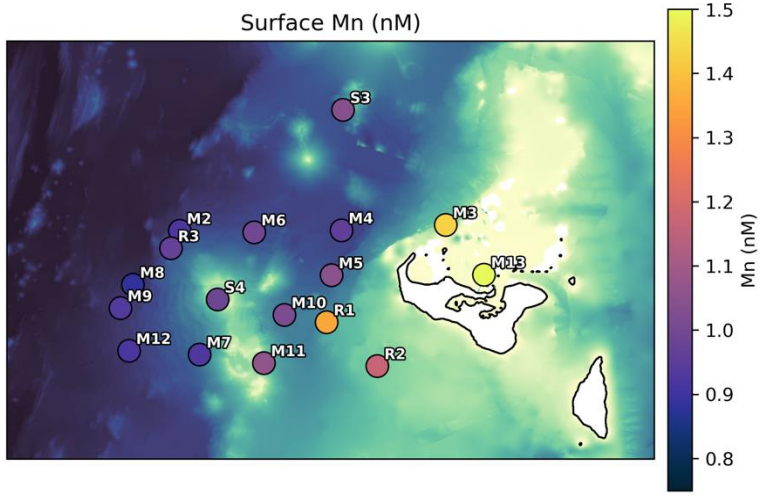



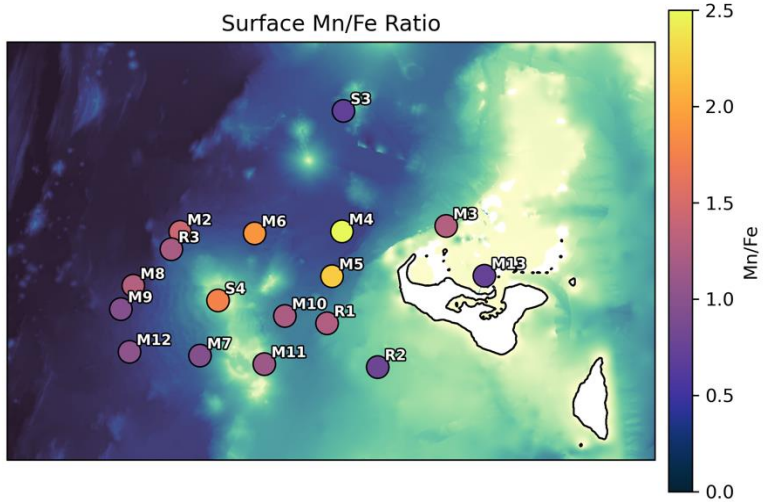



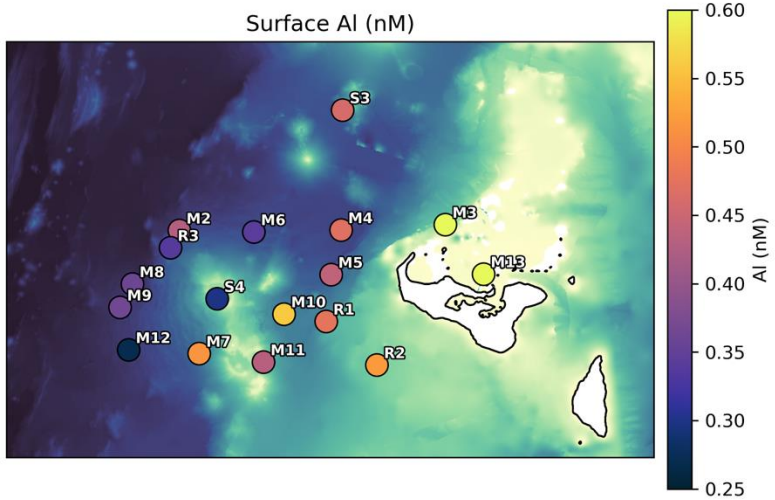



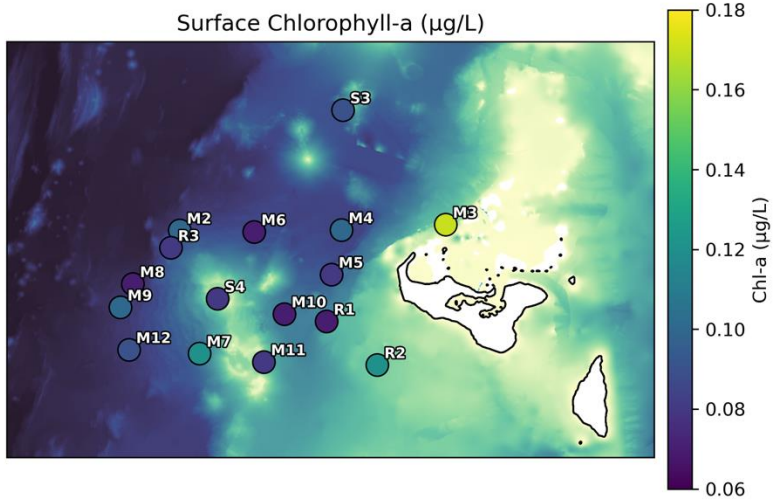
# March (PACSUN 2603)

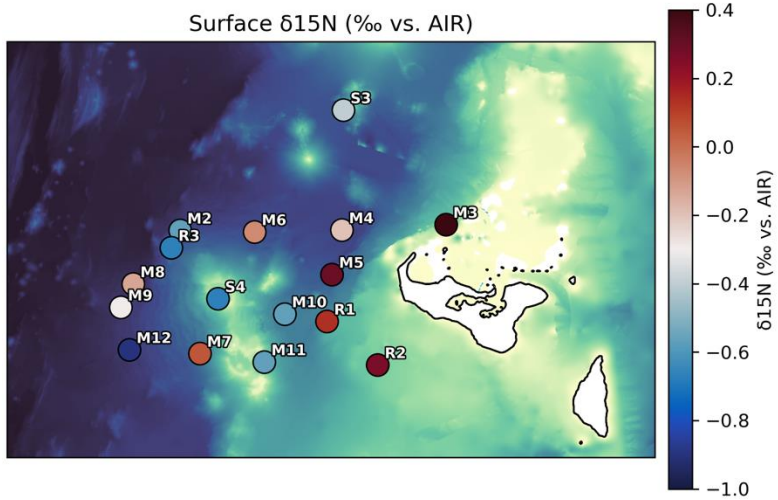


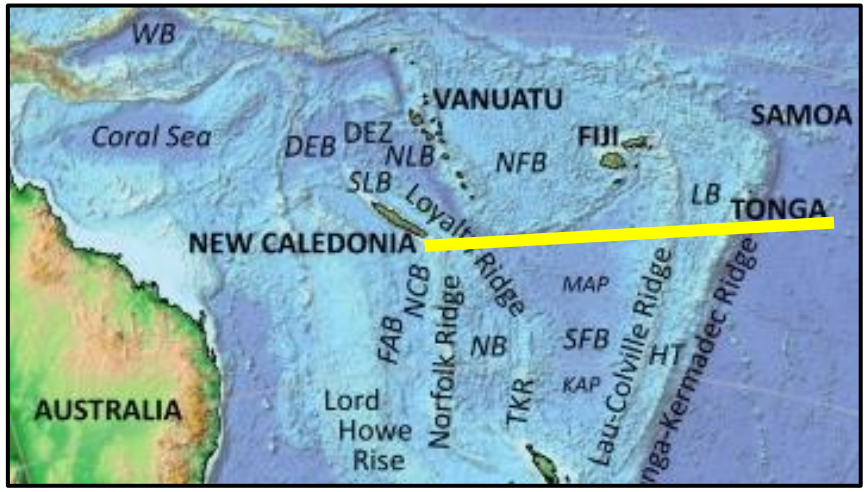



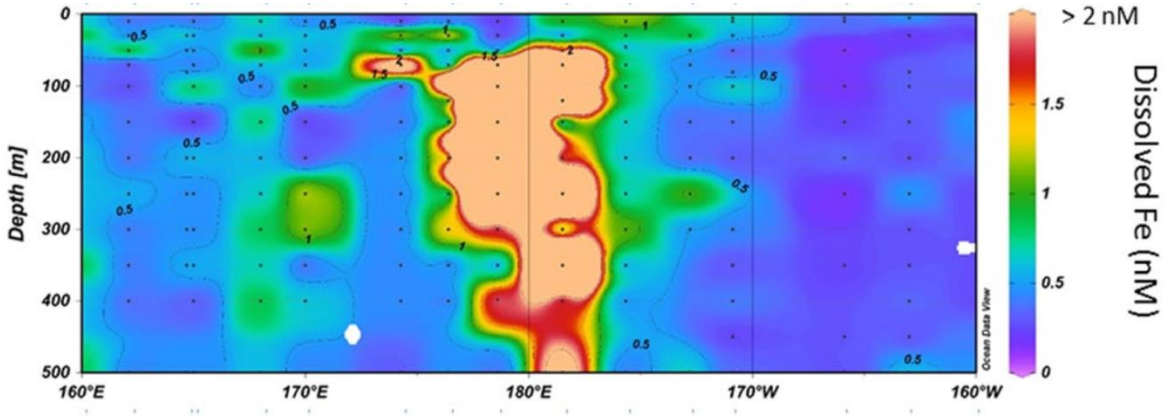



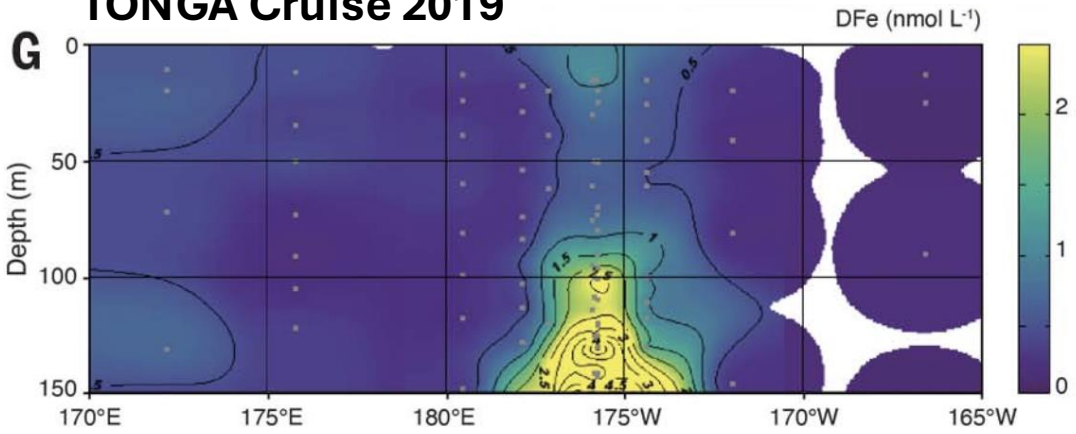
# Previous observations of Tonga hydrothermal plumes




**OUTPACE Cruise 2015**

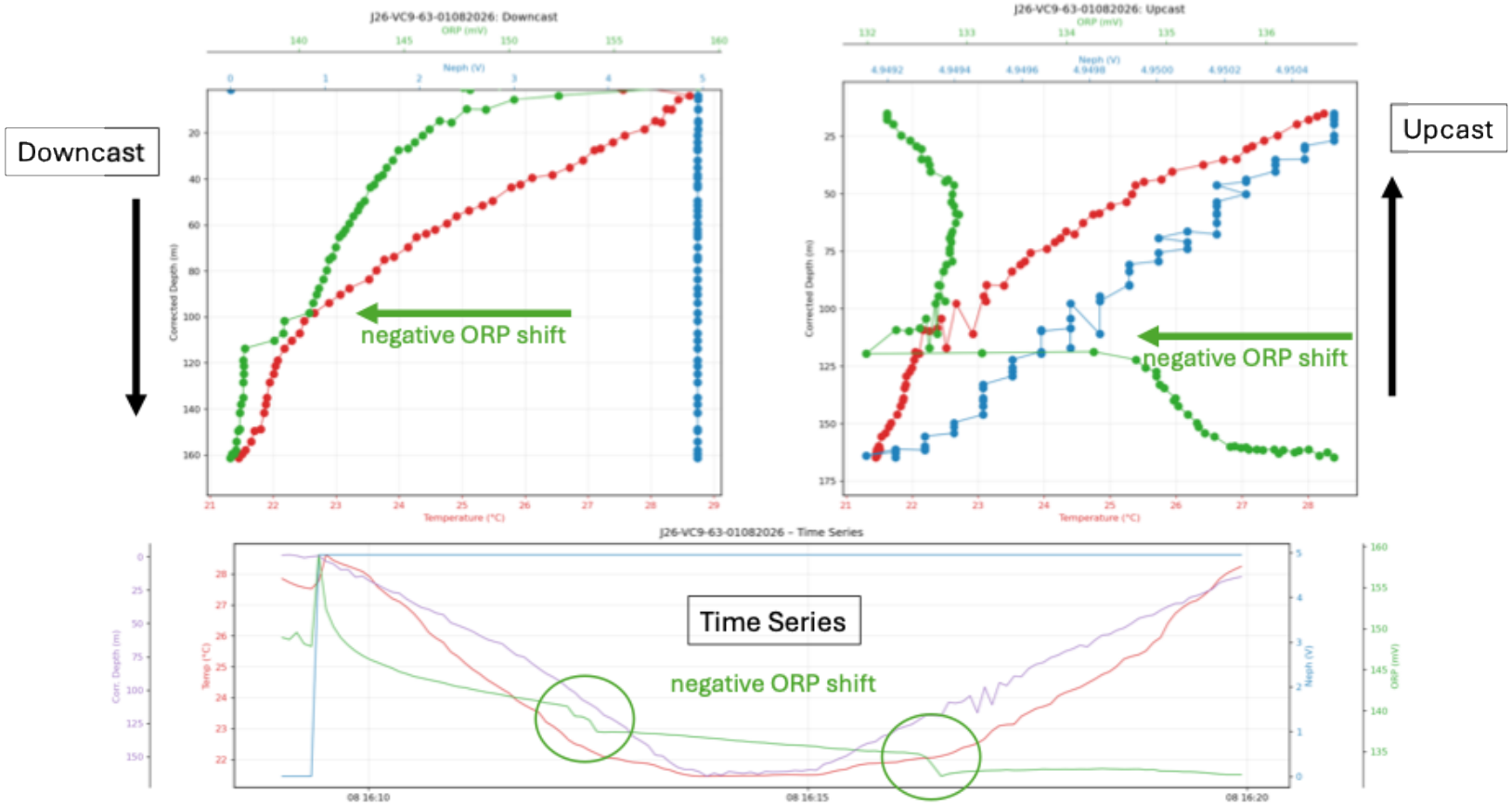



**TONGA Cruise 2019**

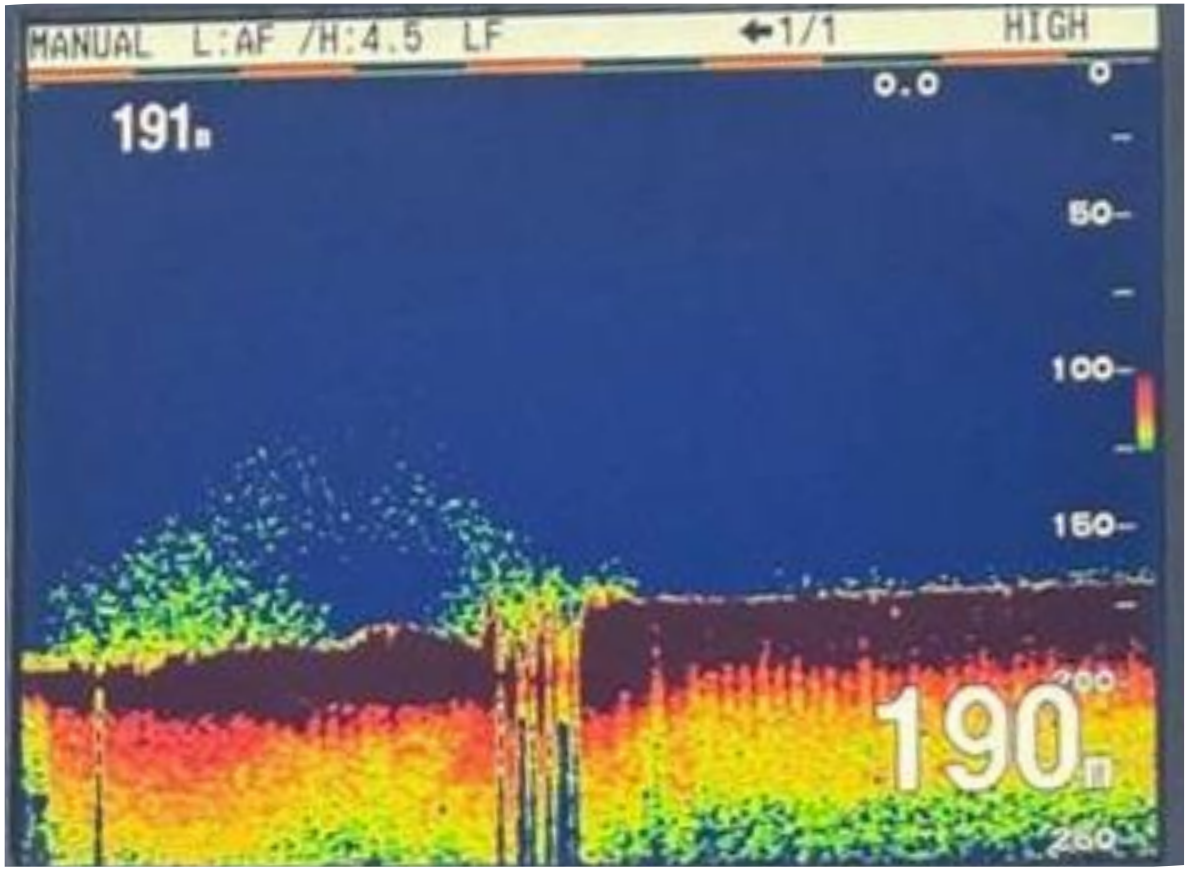


# Hydrothermal plume MAPR data


*Outside view of the Miniature Autonomous Plume Recorder.*



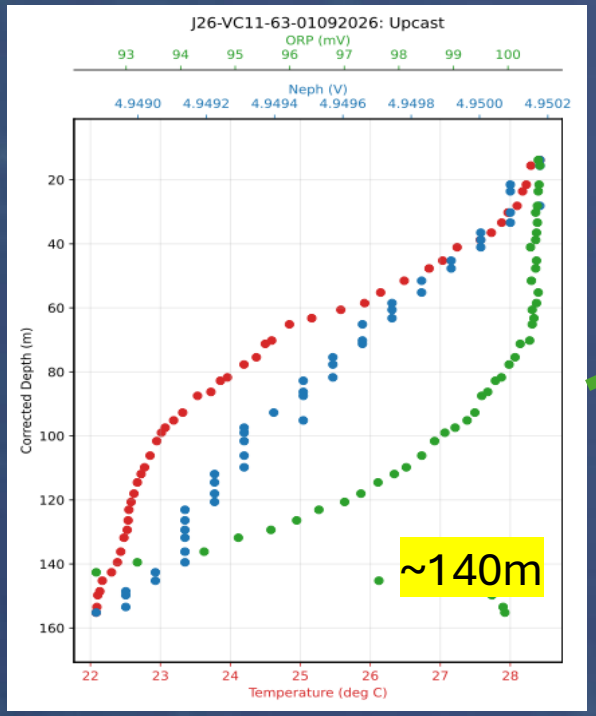
# Hydrothermal venting at ‘Volcano 1’

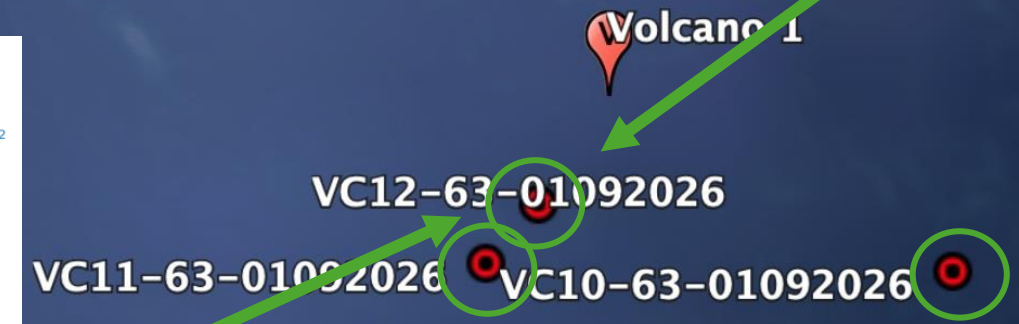


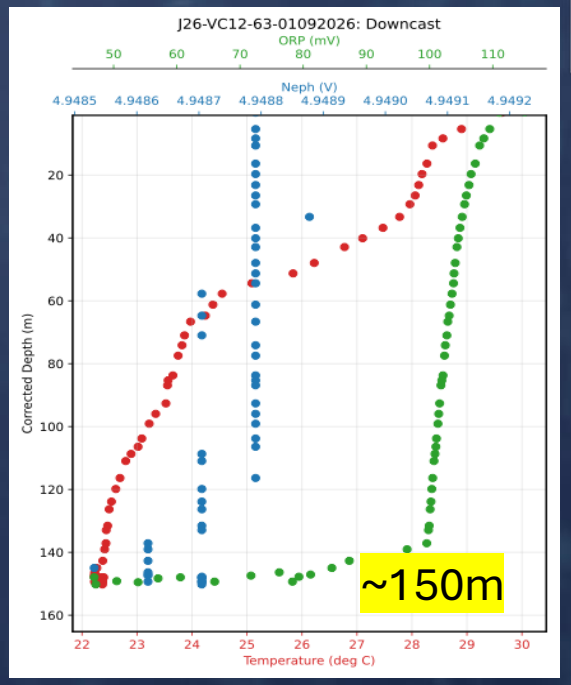

**Cruise 1**

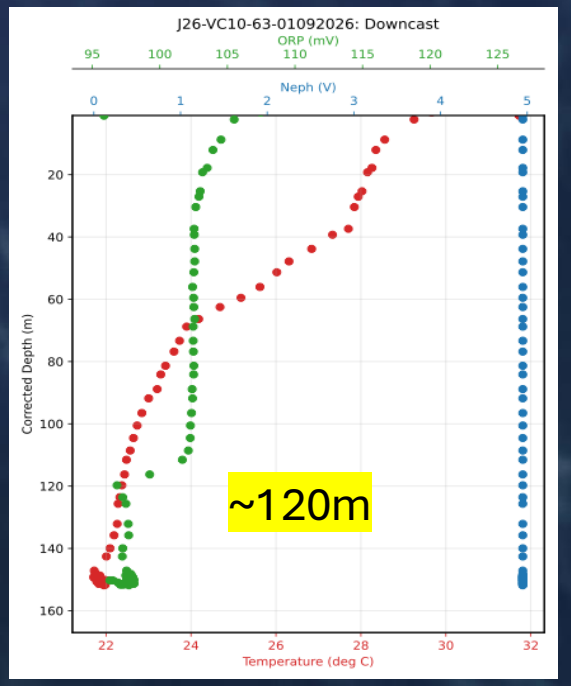
The objective of Cruise 1 was to survey the hydrothermal vent via MAPR vertical casts to determine the depth at which we encoutner a plume signal

# January 2026



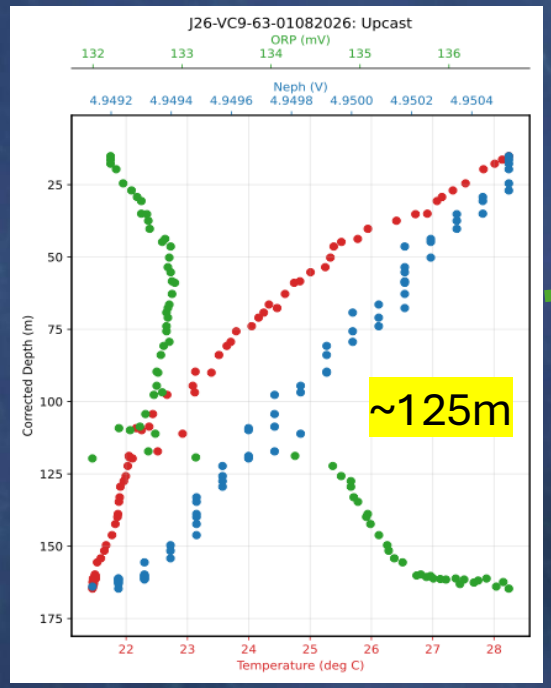



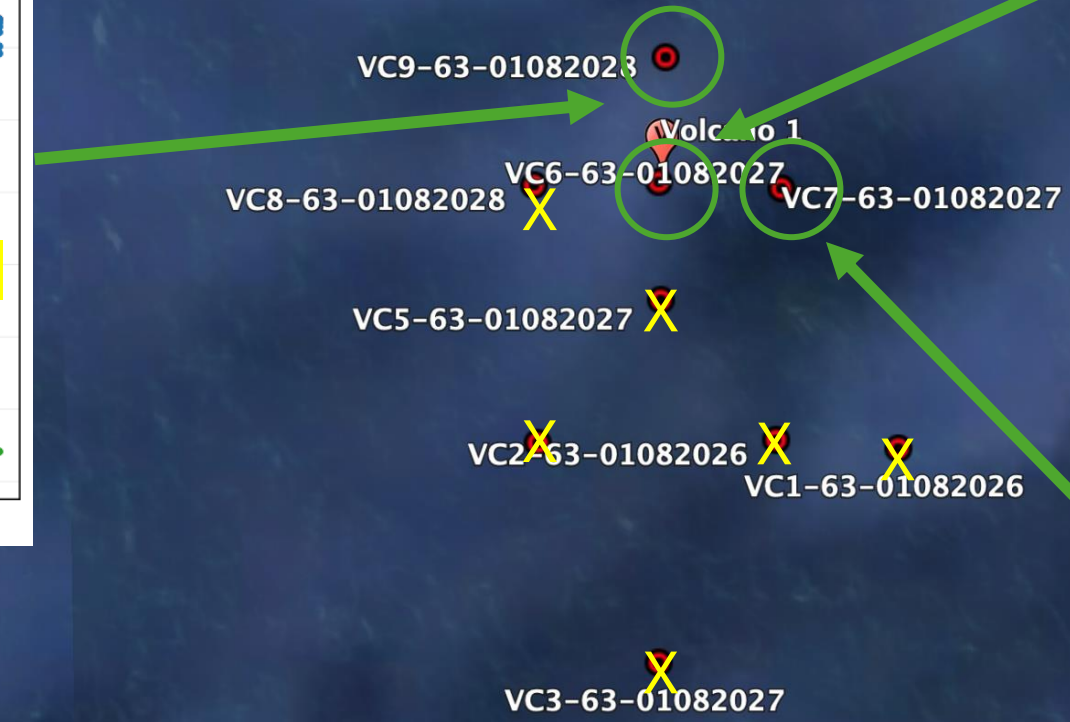

Note: Floating Glass Bubbles observed

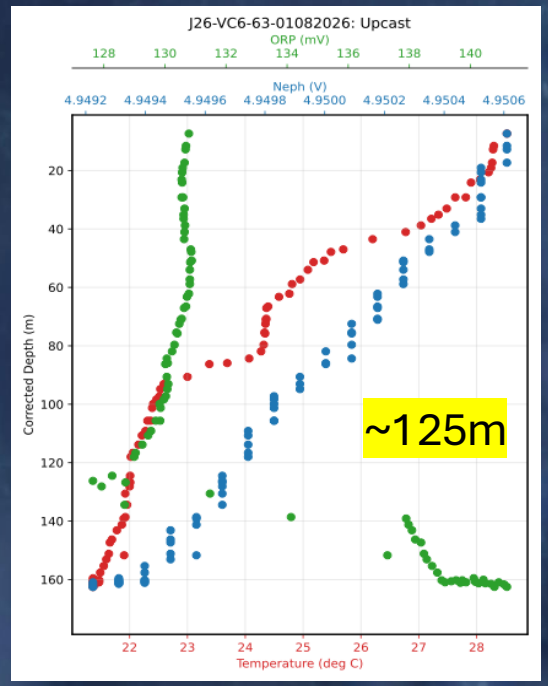
**Cruise 1**

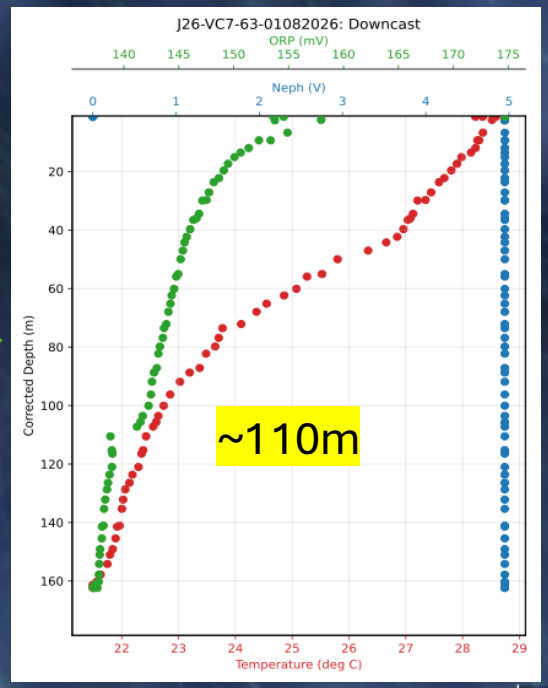
The objective of Cruise 1 was to survey the hydrothermal vent via MAPR vertical casts to determine the depth at which we encoutner a plume signal

# March 2026



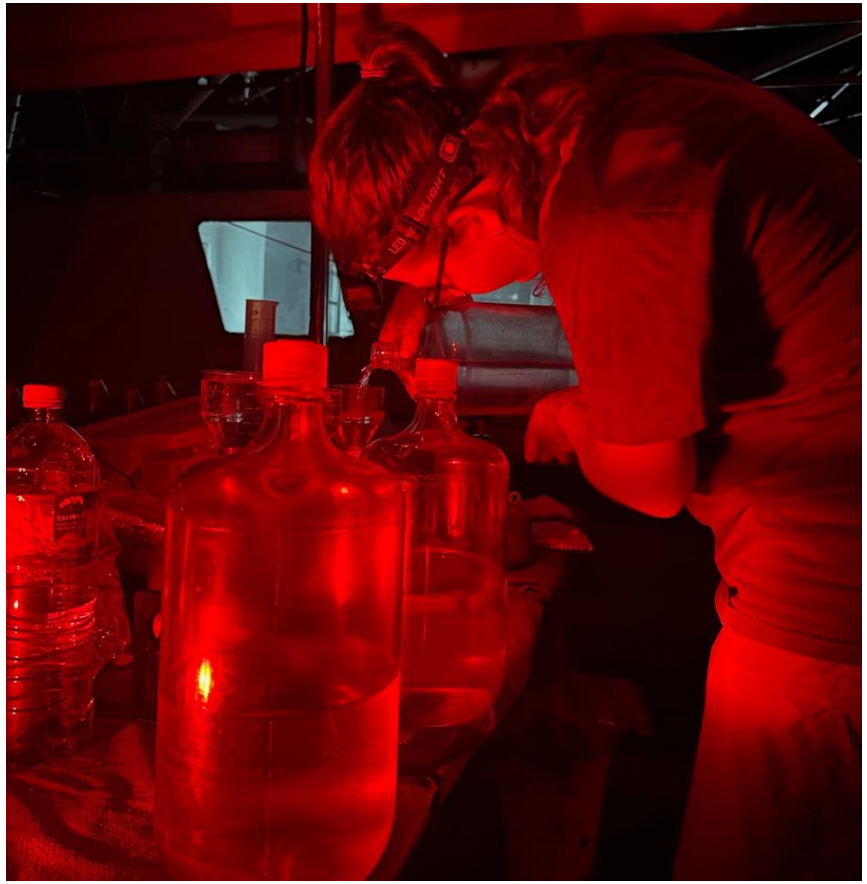



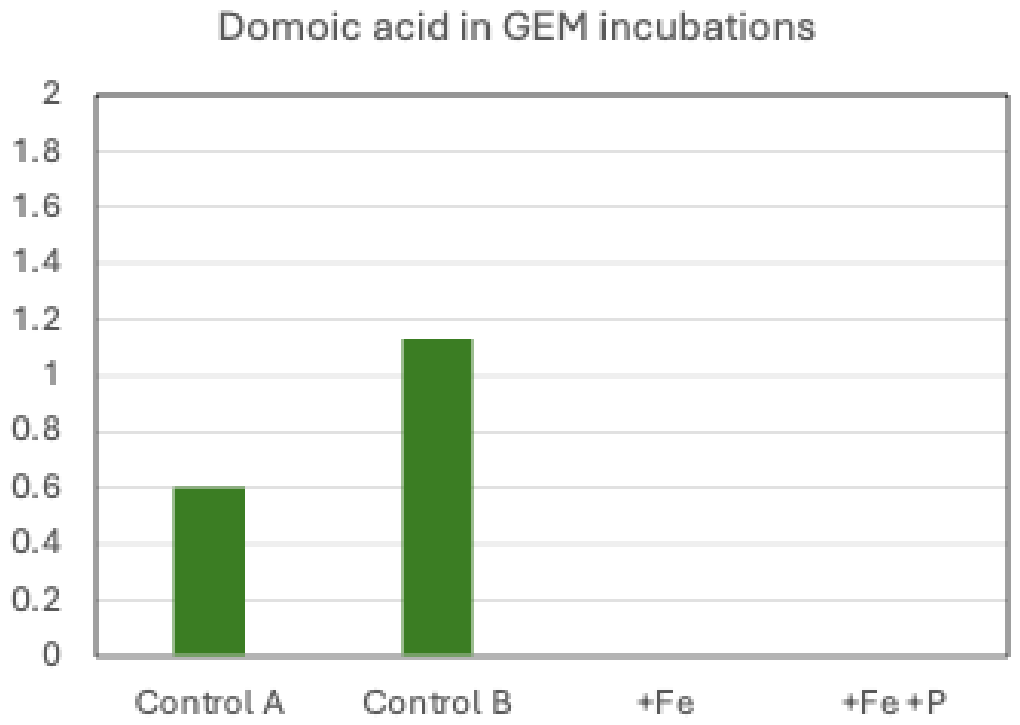




Legend
Feature 1
Volcano 1

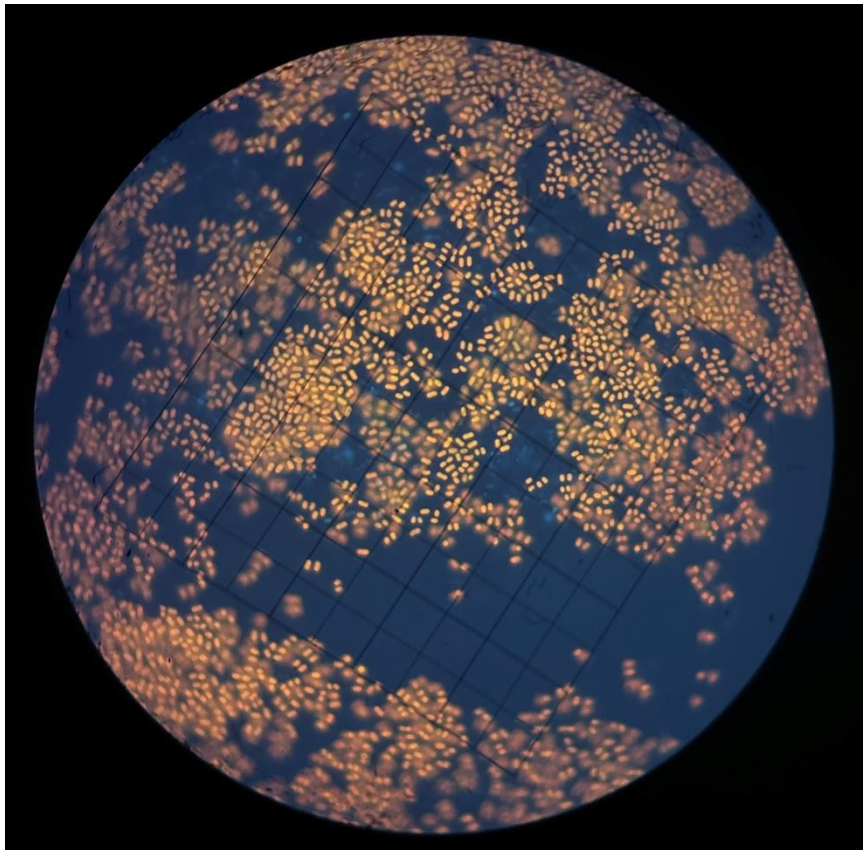
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
1 mi

# Checking for harmful algal toxins





# A new *Crocosphaera* in cuture



*Crocosphaera*-like cells viewed in 40X magnification. Image credit: Caitlyn Parente

- *Crocosphaera*-like cells isolated from Tongan waters in November 2025 (left)
- First known cultured isolate of *Crocosphaera* from the South Pacific
- Cells are rod-shaped like the recently characterized *Crocosphaera waterburyi*... if this is *C. waterburyi*, it would only be the second isolate of the species

# Thanks!

GROWING
OCEANS