



WOODS HOLE  
OCEANOGRAPHIC  
INSTITUTION

EXOIS

# The Climate Hero: Unlocking ocean carbon storage

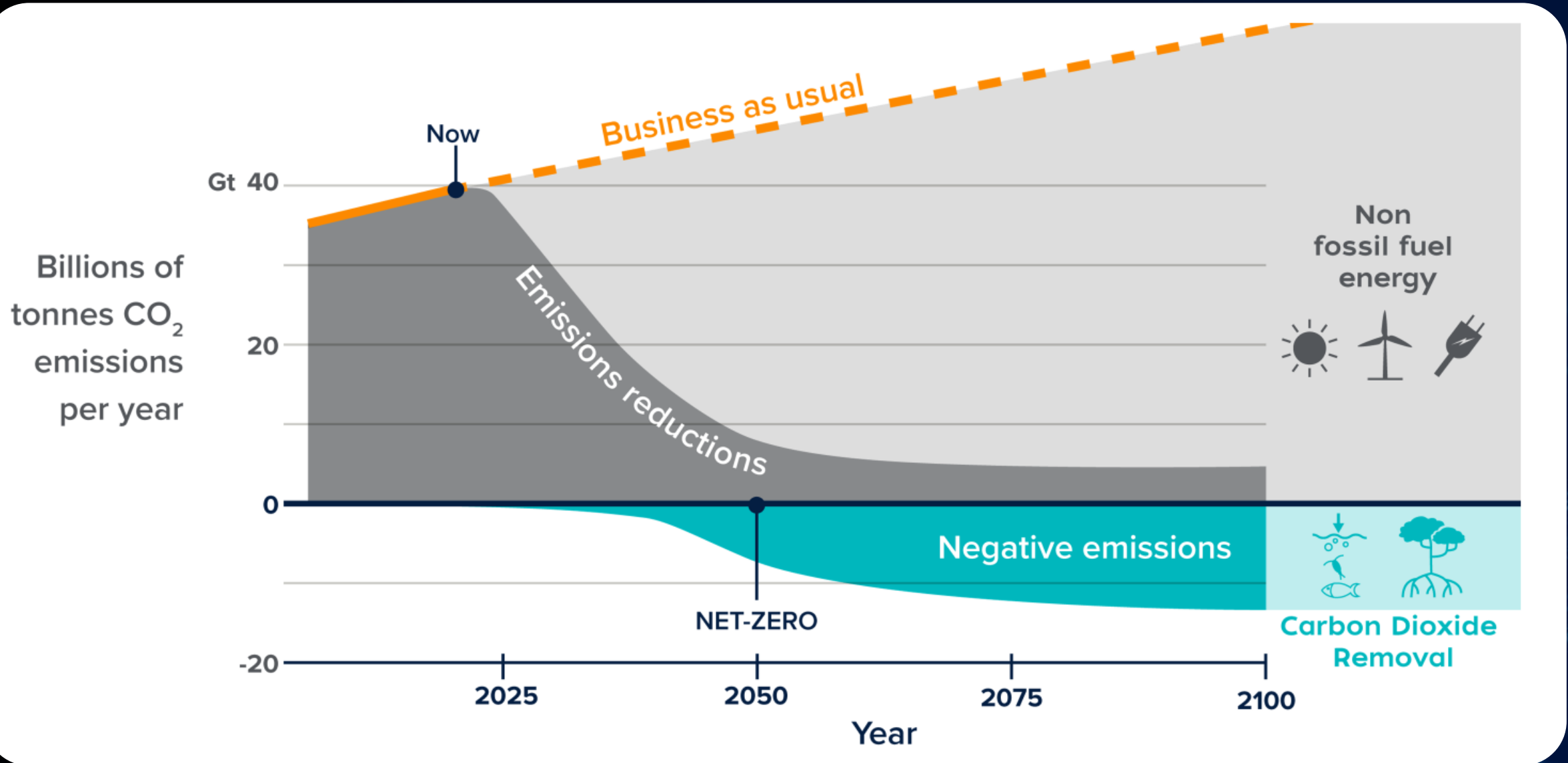
**Paul Morris**

ExOIS Project Manager,  
Woods Hole Oceanographic Institution

**Ken Buesseler**

ExOIS Executive Director,  
Woods Hole Oceanographic Institution

# WE HAVE A PATH FORWARD



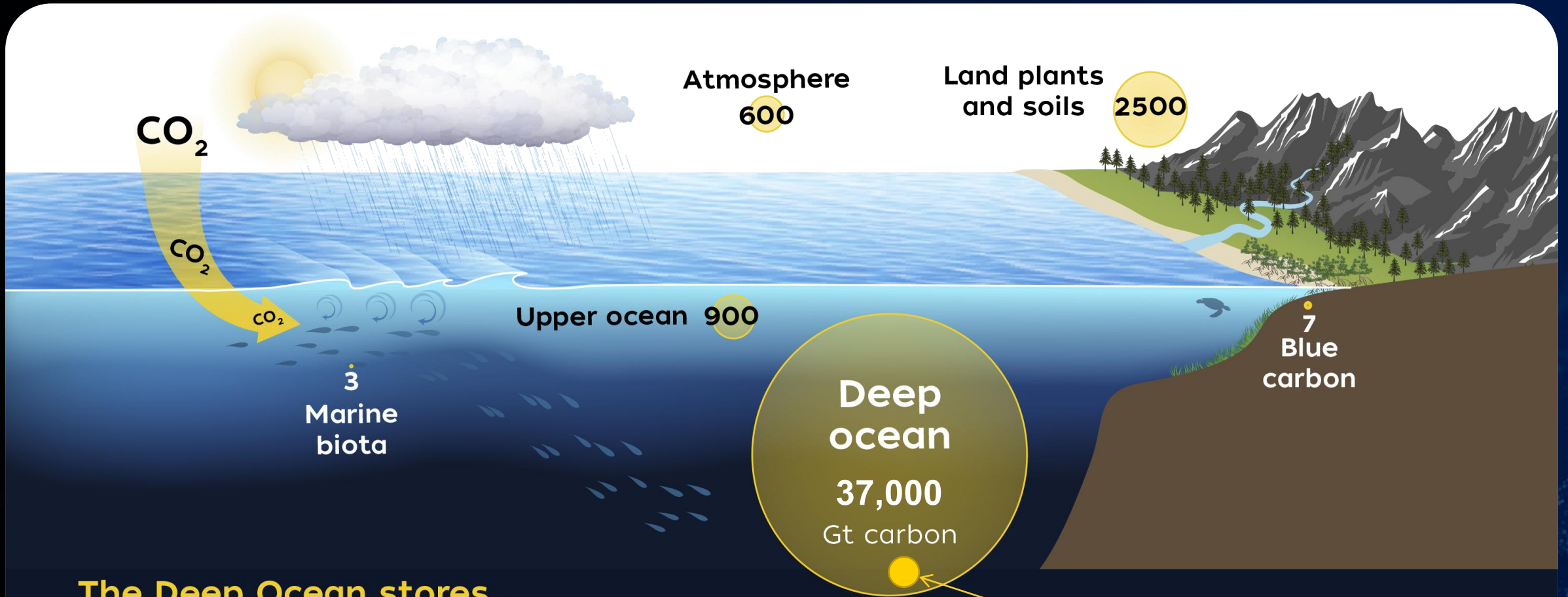
# WHAT IS THE SCALE OF THE PROBLEM?

*Humans have released  
about 400 Gt carbon  
( $\approx 1,500$  Gt CO<sub>2</sub>-eq)*



**Deep ocean holds  
 $\approx 37,000$  Gt Carbon**

# THE OCEAN'S AND THE CARBON CYCLE



## The Deep Ocean stores...



**15-20x** more C than land plants and soils



**50x** more C than atmosphere

Post-industrial human emissions

# CAN THE OCEAN REMOVE **EVEN MORE CO<sub>2</sub>**?

## Nature-based solutions

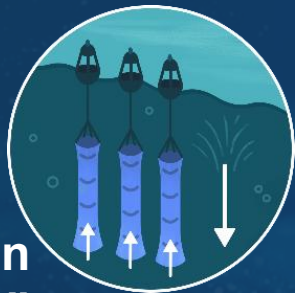
## Engineered solutions



**Phytoplankton heroes**



**Ecosystem recovery**



**Ocean "tubes"**



**Seaweed farming**



**Ocean alkalinity**



**Electro-chemistry**

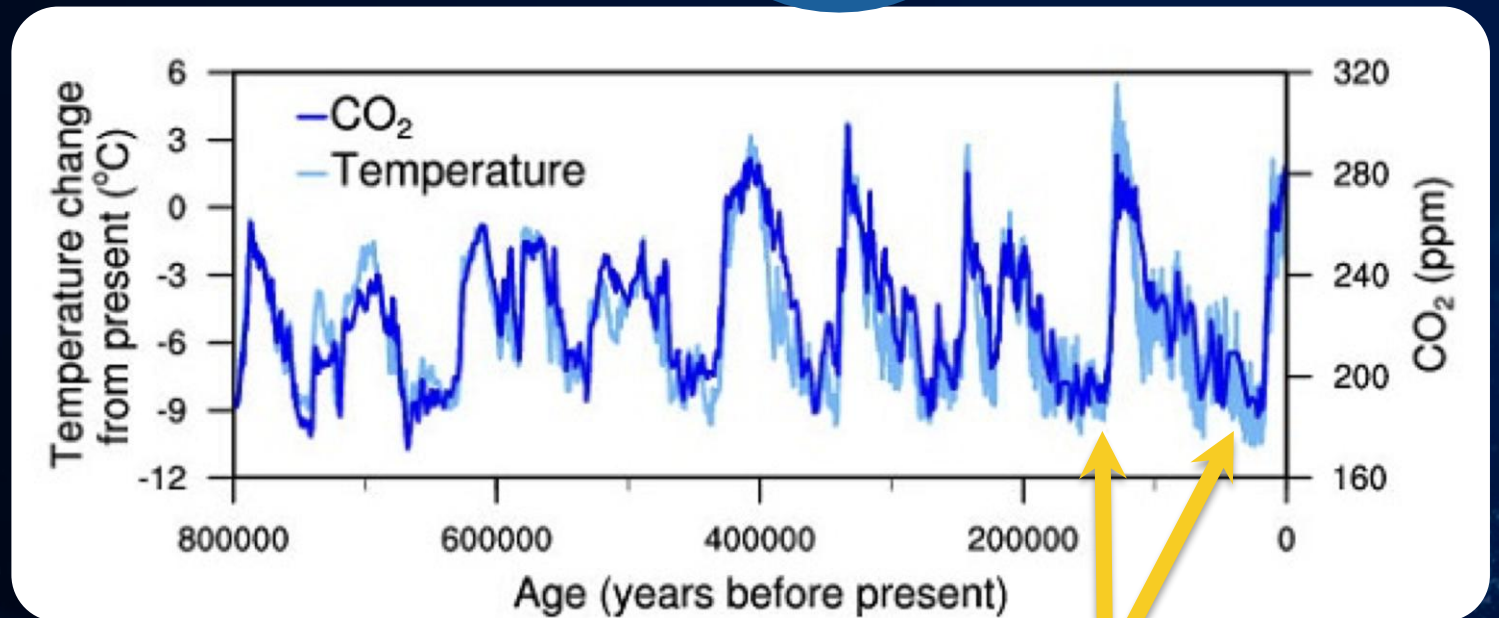
# IRON'S ROLE IN PAST CLIMATE

“Give me half a tanker of iron, and I’ll give you an ice age”

*John Martin during a WHOI seminar in 1988*



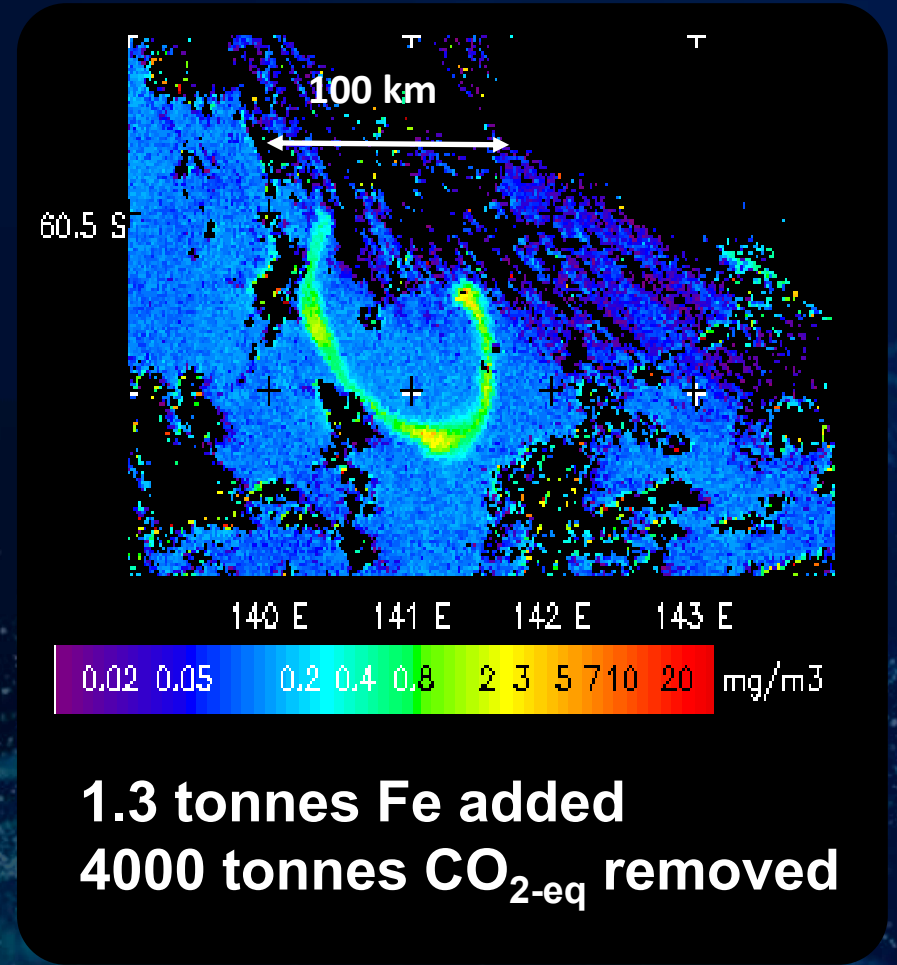
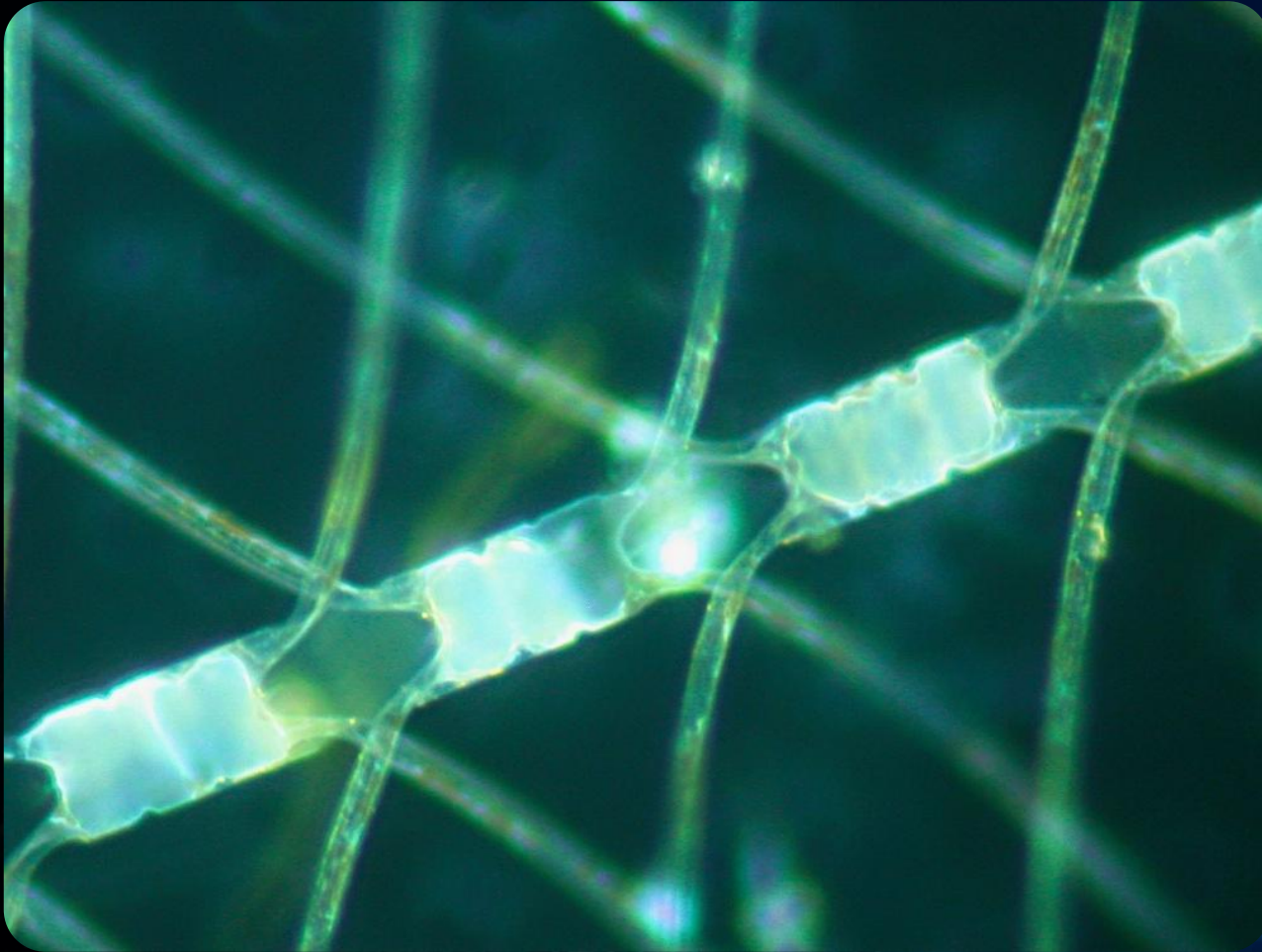
Ice core



Ice-ages are colder, dryer, and dustier.  
More dust (iron) boosts productivity, which lowers atmospheric **CO<sub>2</sub>**

# PHYTOPLANKTON – NEED IRON IN HNLC REGIONS

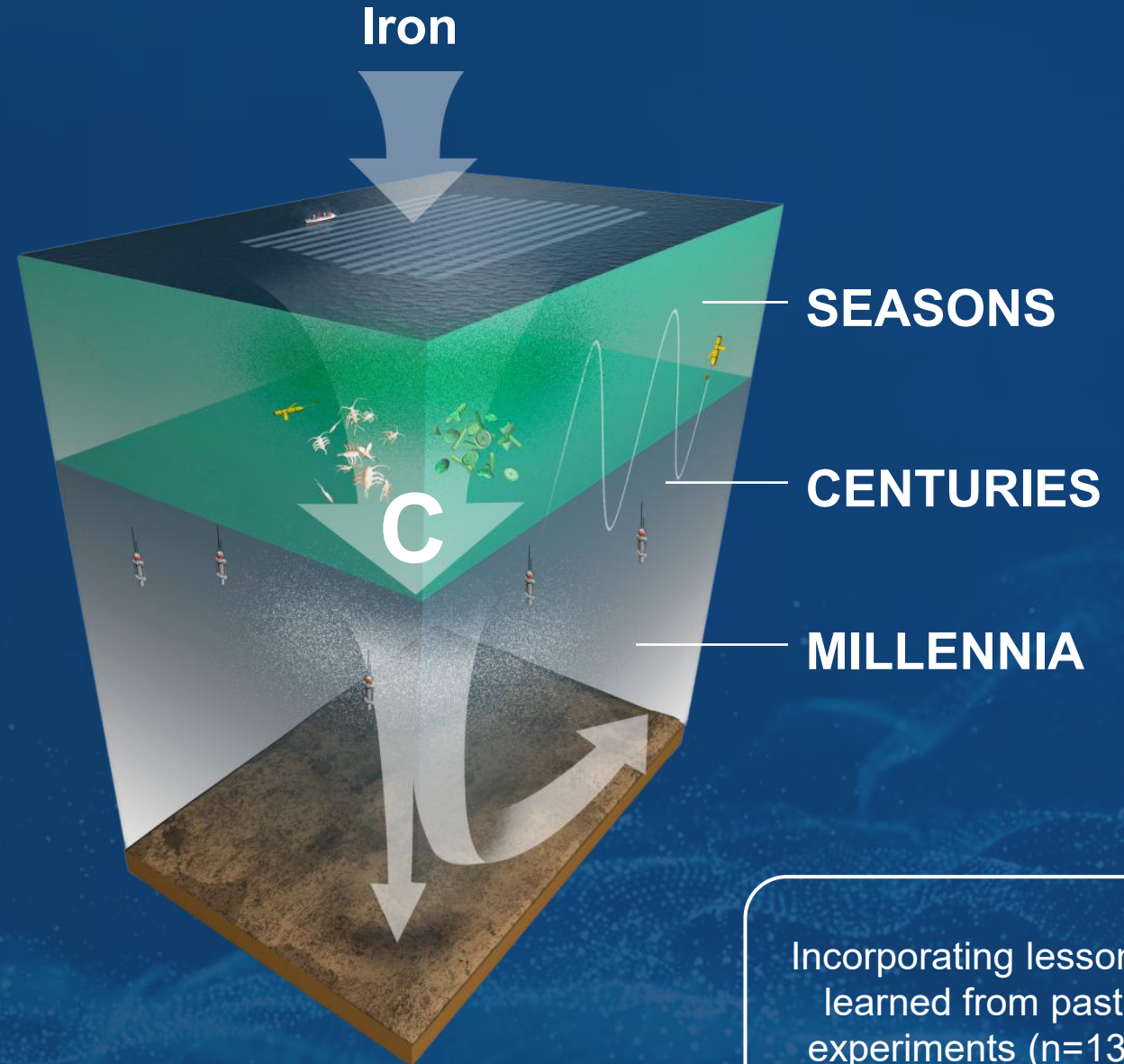
“Just add iron” 13 ocean experiments 1993-2009



How much carbon reaches depth to be sequestered for >100 years?

Is OIF effective, durable, scalable, and reproducible?

What are the impacts on marine ecosystems?



# WHY IS OCEAN IRON SUCH A PROMISING CLIMATE SOLUTION?

## SCALING

Up to 4 billion tonnes CO<sub>2</sub> per year, considering only HNLC areas

## A LITTLE IRON GOES A LONG WAY

**1 : 1,000** iron:carbon ratio from (inefficient) field experiments

**1 : 100,000** in nature

## COST

<\$50 tonne CO<sub>2</sub> - lower than any other marine CDR approach, iron is cheap

Leverages a natural process, energy from sunlight

## EXPERIENCE

**13 prior field** experiments; no observed/direct harm

**Already studied after** volcanic eruptions, forest fires, island plumes

**Removed** ≈4,000 tonnes CO<sub>2</sub> in a 1-month ocean iron experiment

# MONITORING, REPORTING, VERIFICATION

*Oceanographers have access to a large range of technology that can be used for the monitoring blooms and carbon removal*



# WHAT POTENTIAL RISKS NEED CONSIDERATION

## AREAS OF CONCERN

## DESCRIPTION

## CONSIDERATIONS

Harmful  
algal blooms

Harmful algae such as Pseudo-nitzschia may bloom and produce domoic acid

Deoxygenation

Additional organic carbon will be respired at depth, depleting oxygen via respiration

Non-CO<sub>2</sub> GHG's

Production of other GHGs (CH<sub>4</sub> and N<sub>2</sub>O) will offset CO<sub>2</sub> removal

“Nutrient robbing”

Nutrients used by the bloom won't be available elsewhere

In addition to carbon accounting, future field trials must monitor these environmental and ecological concerns – **eMRV**

Low magnitude on experimental scale, but small-scale trials can inform what might happen at larger scale deployments

# HIGH-INTEGRITY, INDEPENDENT SCIENCE MUST LEAD

- Conclusions of research must be independent and driven by the data
- There cannot be any inference – real or perceived – that the research outcomes are biased by the source of the funding
- This is especially true during the initial research, and especially if the research guides us to bigger scale pilot studies
- Scientific independence can be maintained by not selling carbon credits



# EXPLORING OCEAN IRON SOLUTIONS – EXOIS

International consortium of experts dedicated to studying ocean iron fertilization for carbon dioxide removal (CDR)

- 60 members
- 37 institutions
- 9 countries

## STEERING COMMITTEE



**Ken Buesseler**  
Woods Hole  
Oceanographic  
Institution



**Kilaparti  
Ramakrishna**  
Woods Hole  
Oceanographic  
Institution



**Joo-Eun Yoon**  
Korea Polar  
Research Institute



**Mark Wells**  
University of Maine



**Sarah Smith**  
Moss Landing  
Marine Laboratories



**Fei Chai**  
Xiamen University



McConnell Family Foundation



OCEAN VISIONS  
Advancing Solutions for  
Ocean-Climate Restoration



The  
Navigation  
Fund

Small financial donations



In-kind and pro bono support



# EXPLORING OCEAN IRON SOLUTIONS – EXOIS

International consortium of experts dedicated to studying ocean iron fertilization for carbon dioxide removal (CDR)

- 60 members
- 37 institutions
- 9 countries



McConnell Family Foundation



Small financial donations



In-kind and pro bono support



# HOW WE CONDUCT SCIENCE MATTERS

*Guiding principles for  
responsible mCDR studies*



**Prioritize** benefit for humans  
and the environment



Perform iterative and  
independent **assessments**



Establish clear lines  
of **responsibility**



Engage the **public**



Commit to **open research**  
and risk assessments

*Ken Buesseler, Kilaparti Ramakrishna,  
Margaret Leinen, Nature Correspondence, 2022*

**ExOIS is not seeking C credits**



Learn more at  
[OceanIron.org](https://oceaniron.org)