

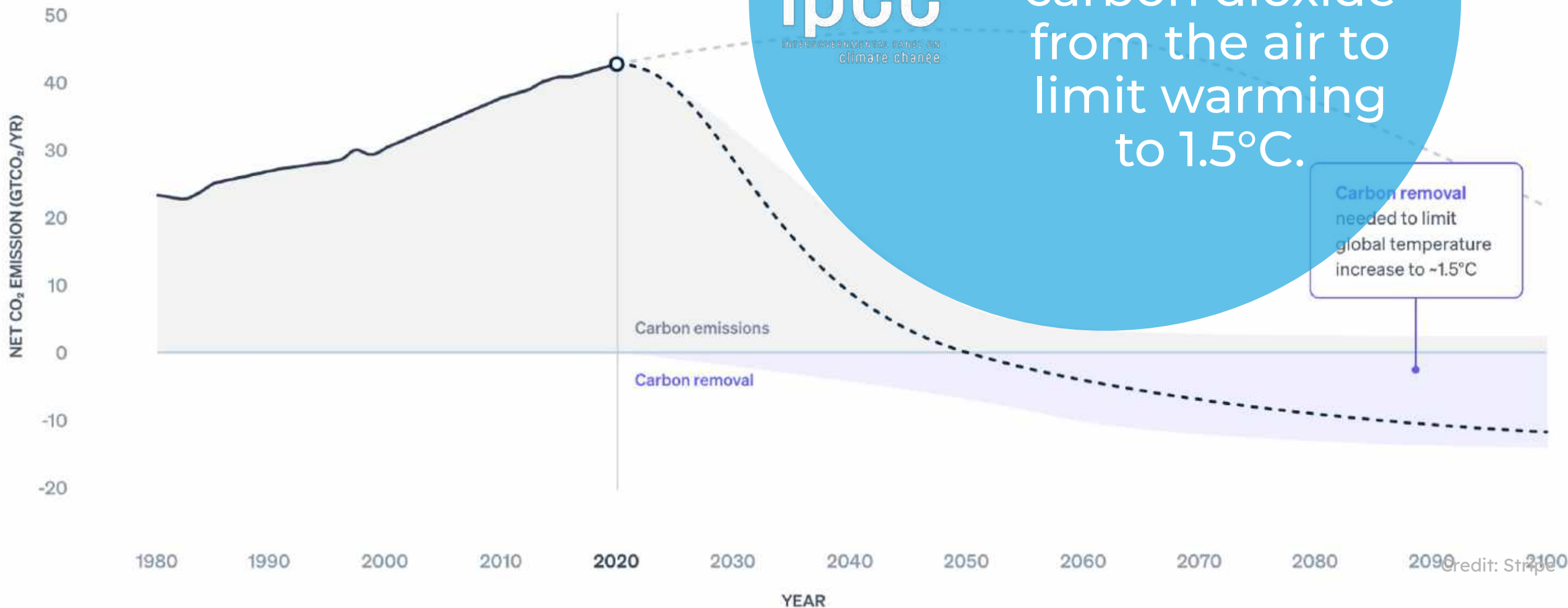
# MRV Development for Electrochemical Ocean Alkalinity Enhancement



Mallory Ringham  
Lead Oceanographer, Ebb Carbon  
Research Associate, Stony Brook University  
[mallory@ebbcarbon.com](mailto:mallory@ebbcarbon.com)

Limit global temperature increase to: **~1.5°C** ~2°C ~3°C (Current path)

— Historical emissions    - - - ~1.5°C path    - - - Current path



ipcc  
INTERGOVERNMENTAL PANEL ON  
climate change

We need to remove 10 gigatons of carbon dioxide from the air to limit warming to 1.5°C.

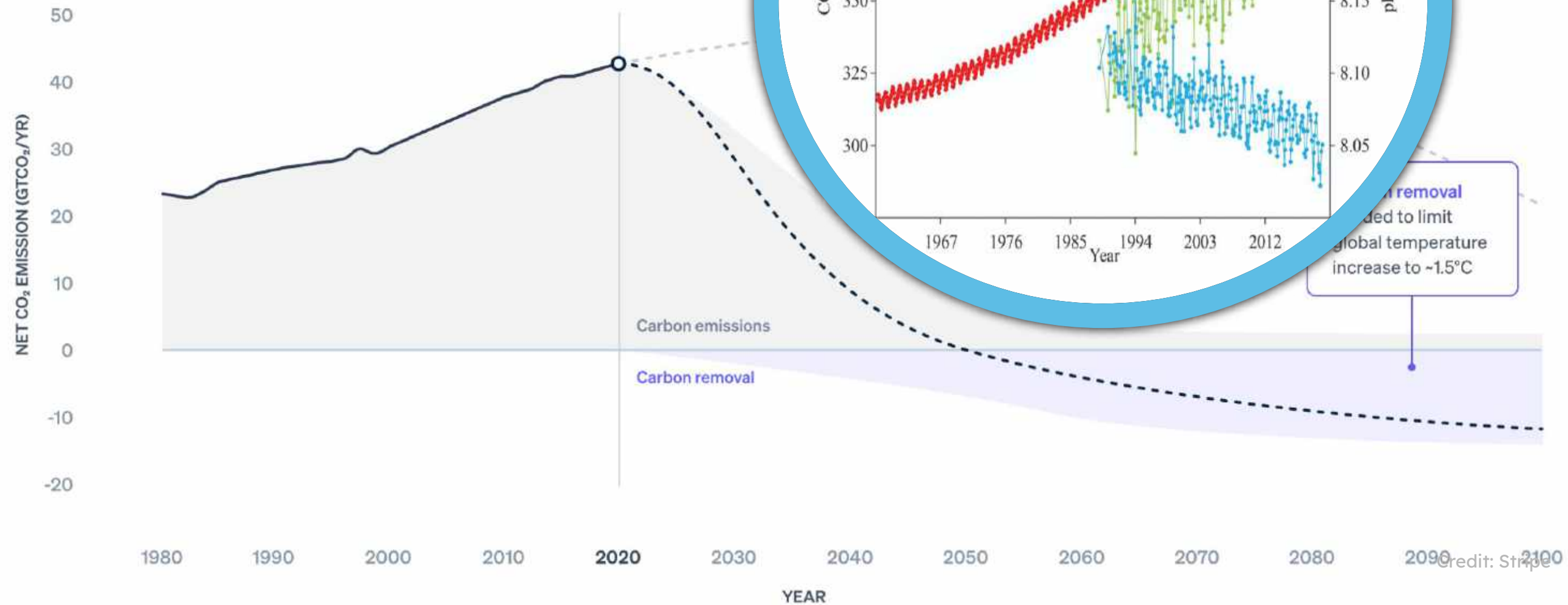
Limit global temperature increase to:

**~1.5°C**

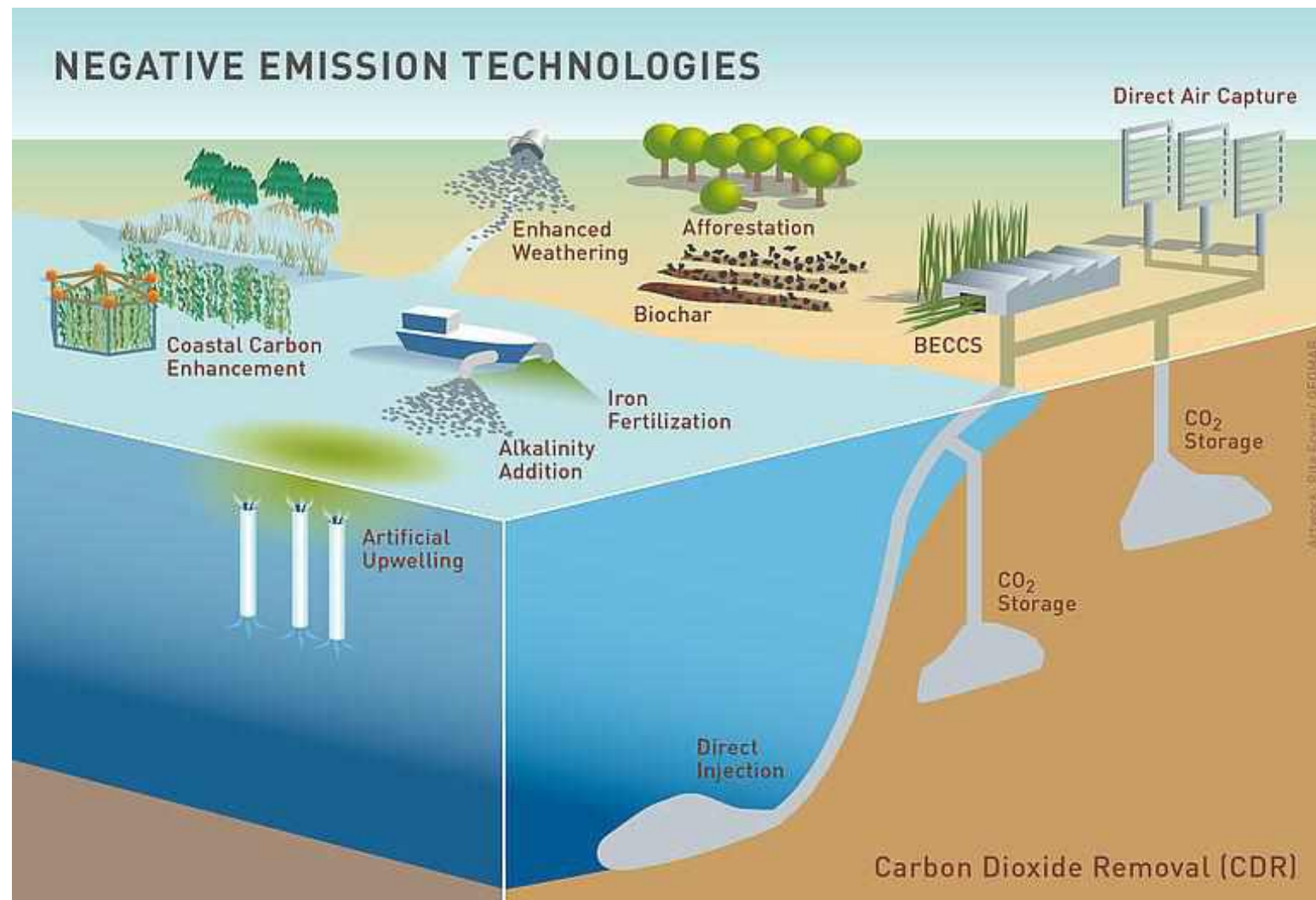
~2°C

~3°C (Current path)

— Historical emissions    - - - ~1.5°C path    - - - Current path



# Portfolio of approaches to scale



## Terrestrial CDR:

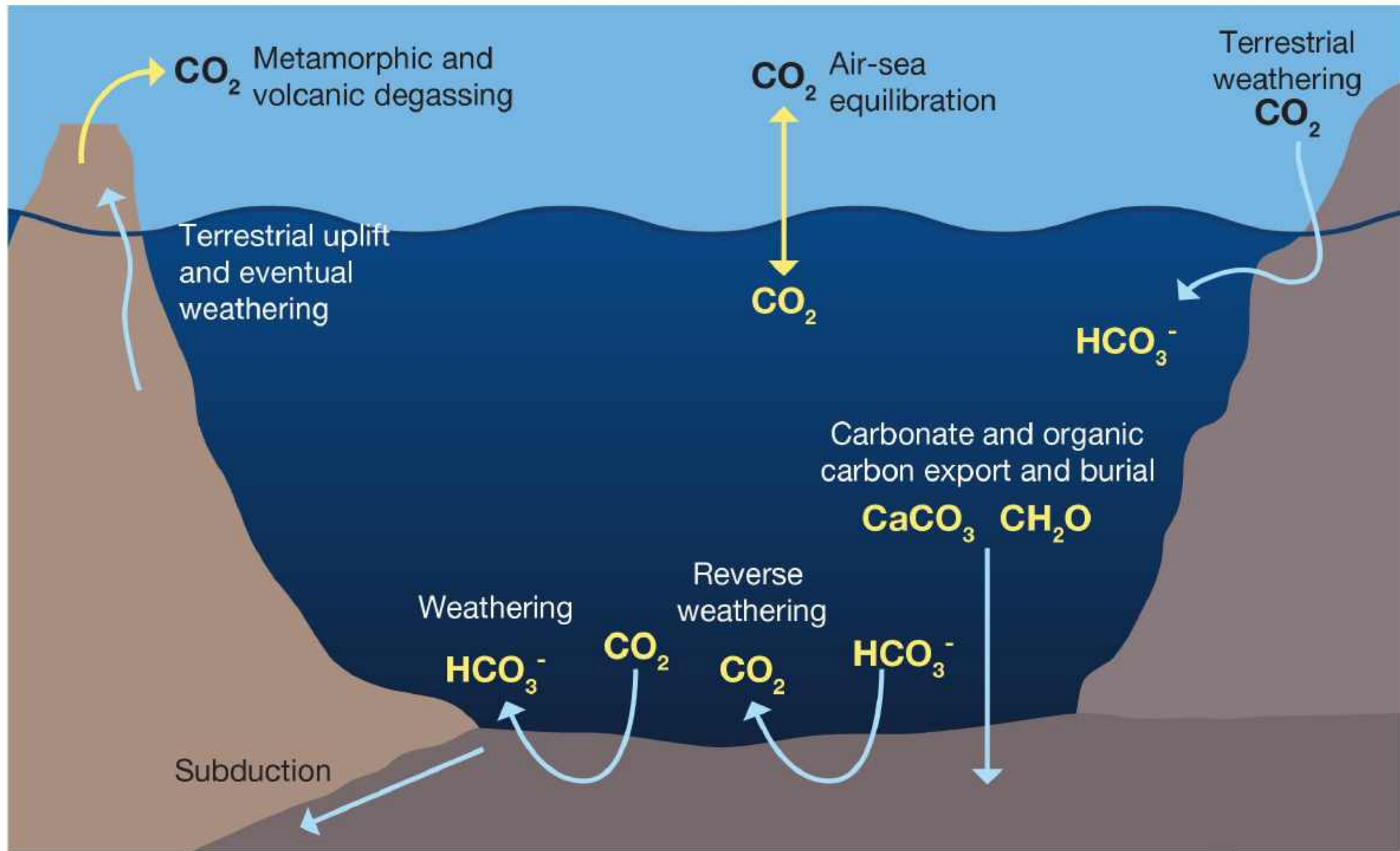
- Direct air capture (DAC)\*
- Bioenergy with carbon capture and storage (BECCS)
- Restoration, management (forests, soils, rangeland)

\*Orca- 4000t/yr

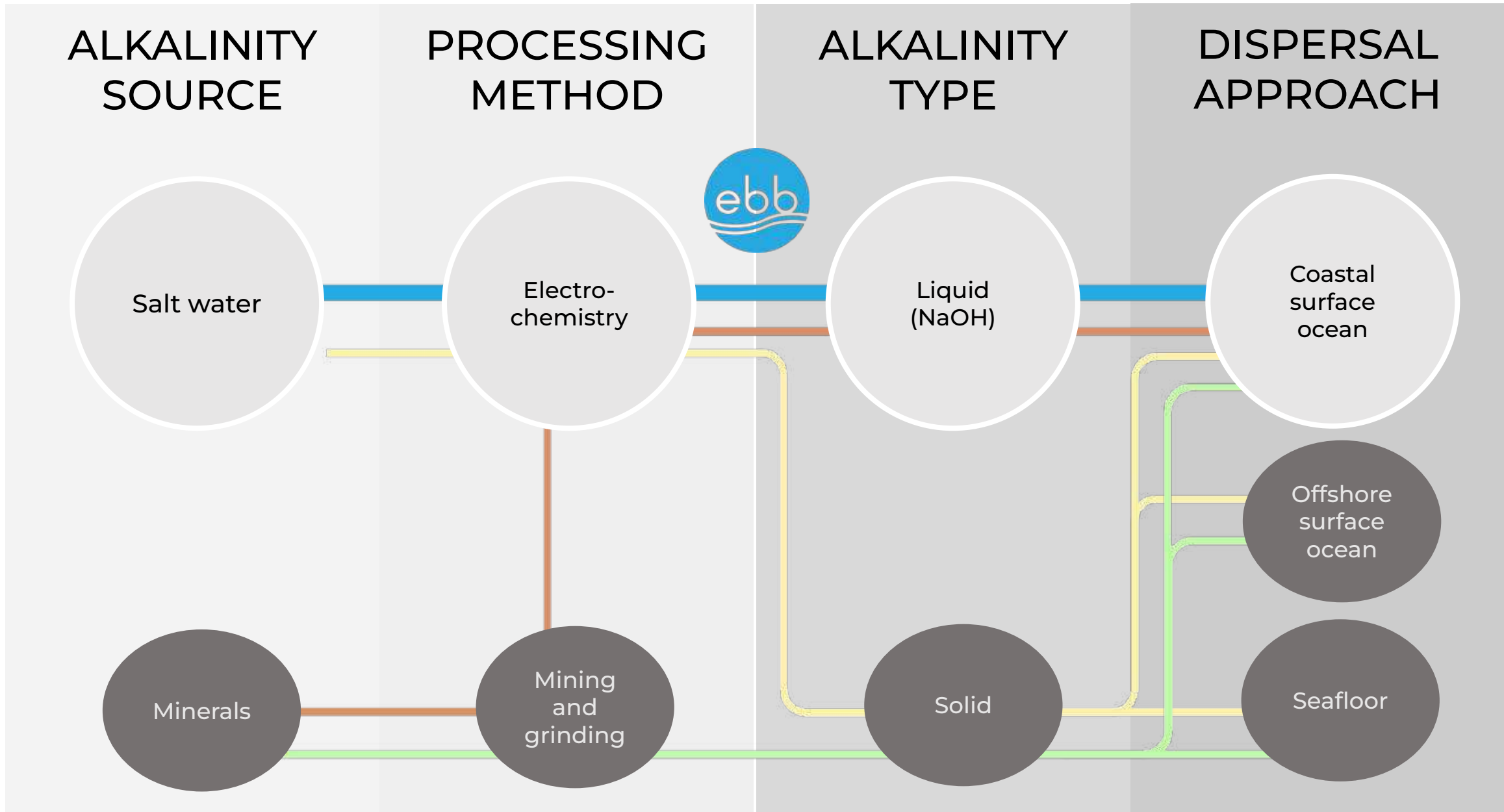
## Marine (mCDR):

- Direct air capture (DAC)
- Macroalgae cultivation
- Ecosystem recovery
- Nutrient fertilization
- Artificial upwelling/downwelling
- **Ocean alkalinity enhancement (OAE)**

# Ocean Alkalinity Enhancement

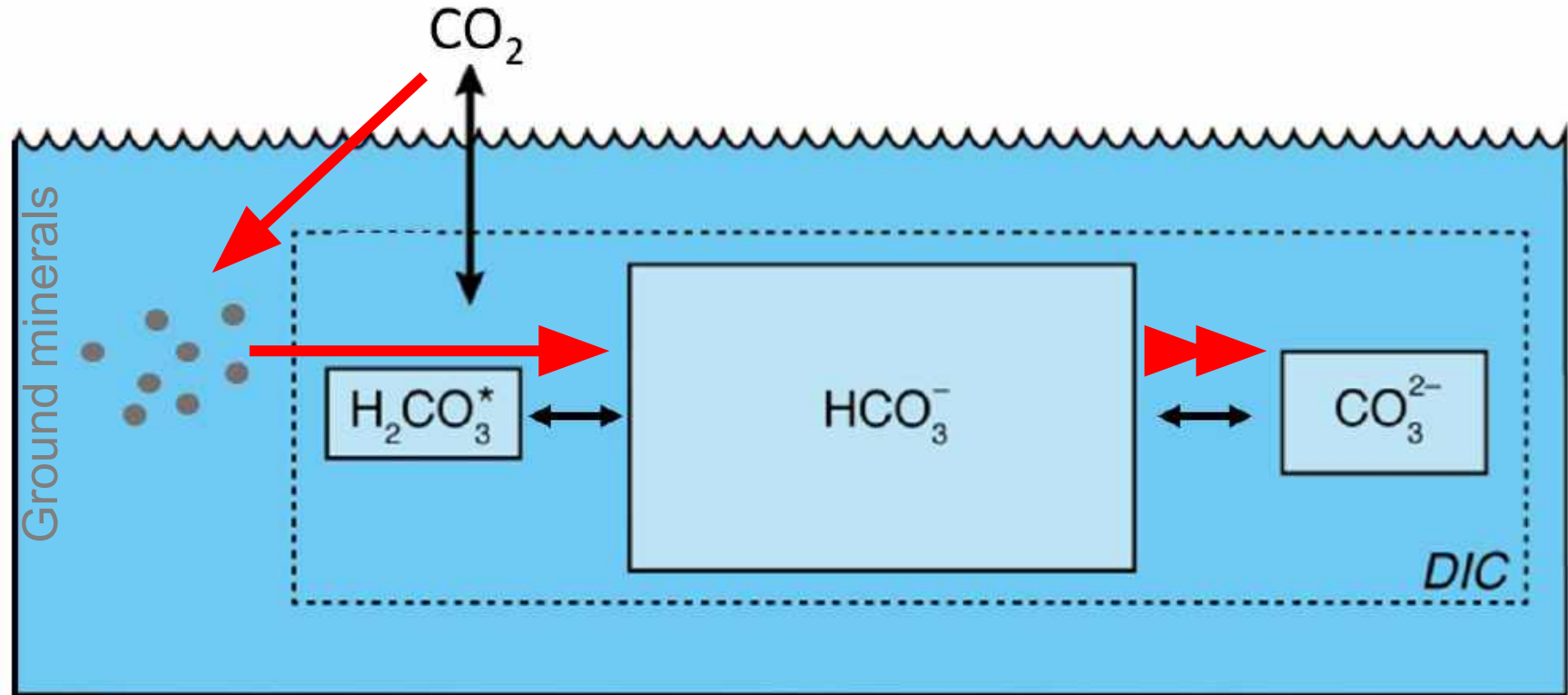
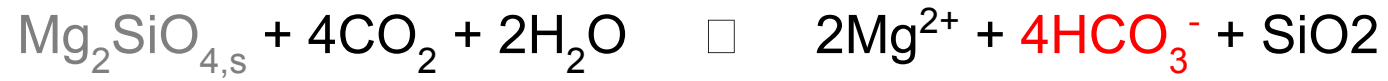
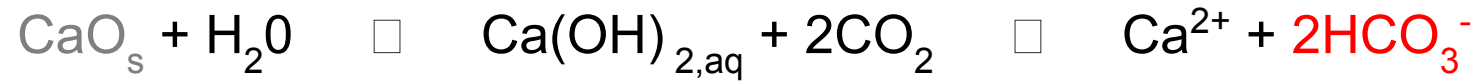


# Ocean Alkalinity Enhancement Pathways

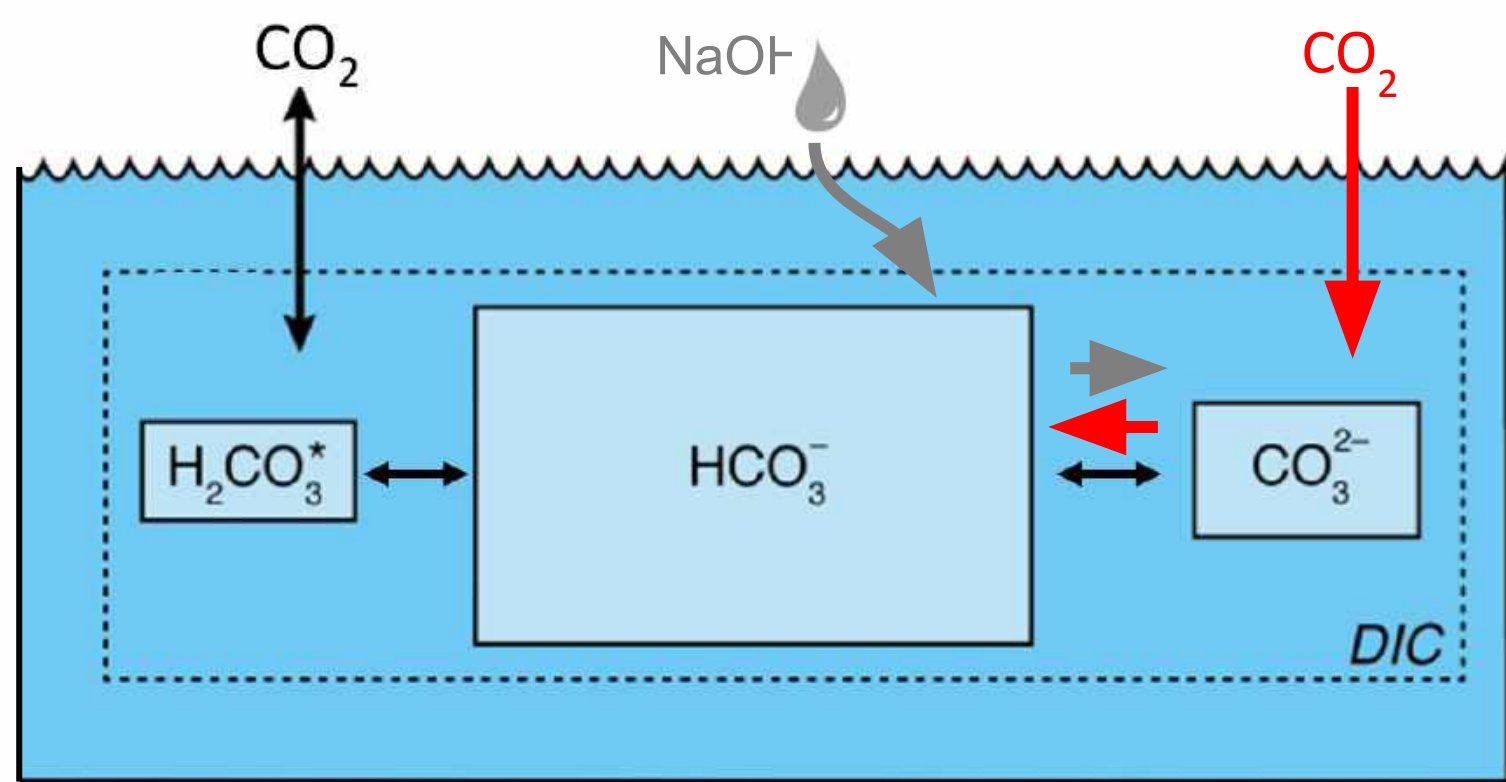
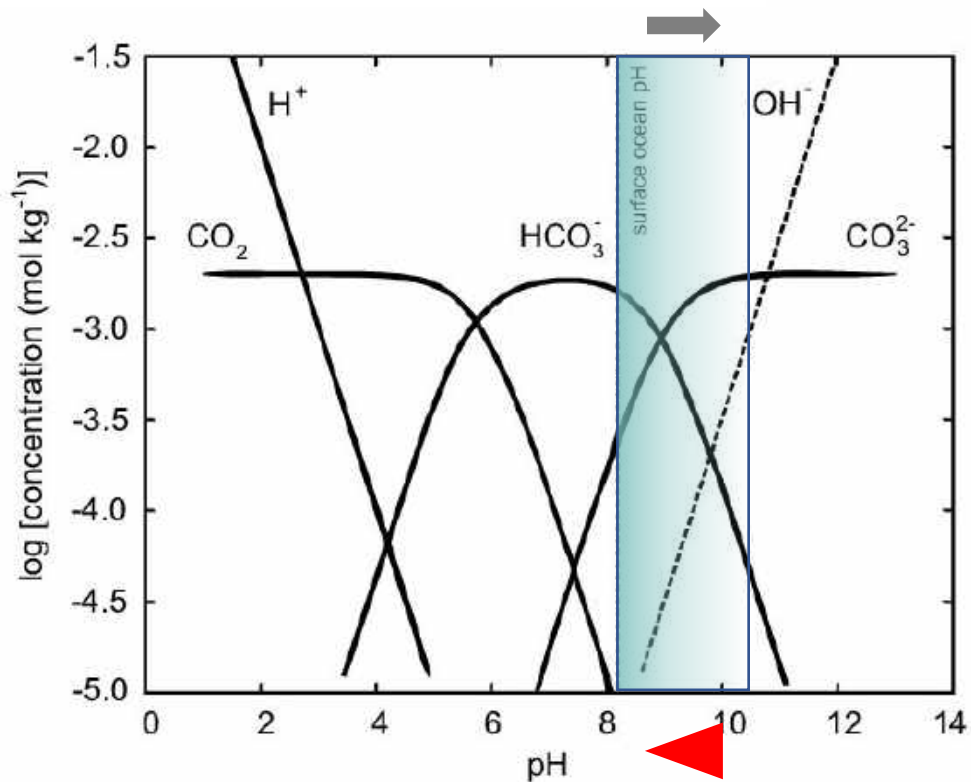
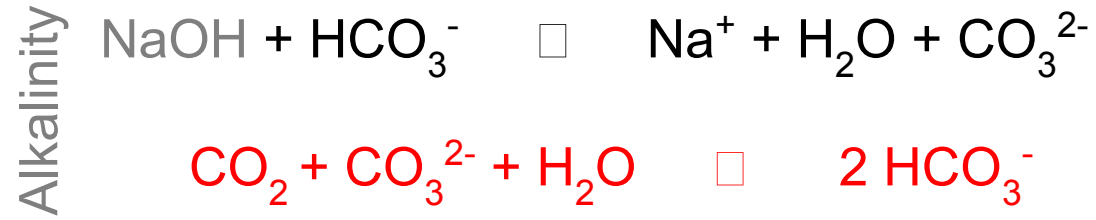


# Ground or precipitated mineral solids

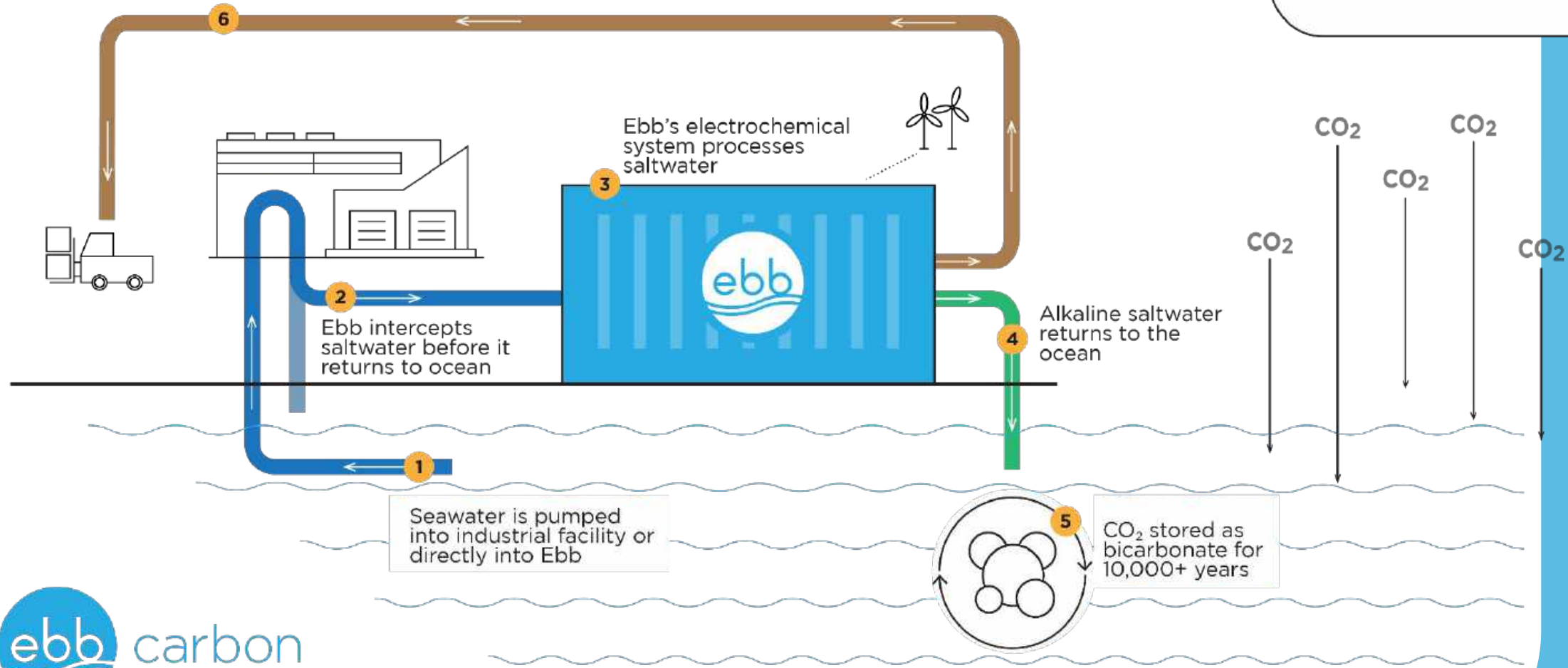
Alkalinity sources



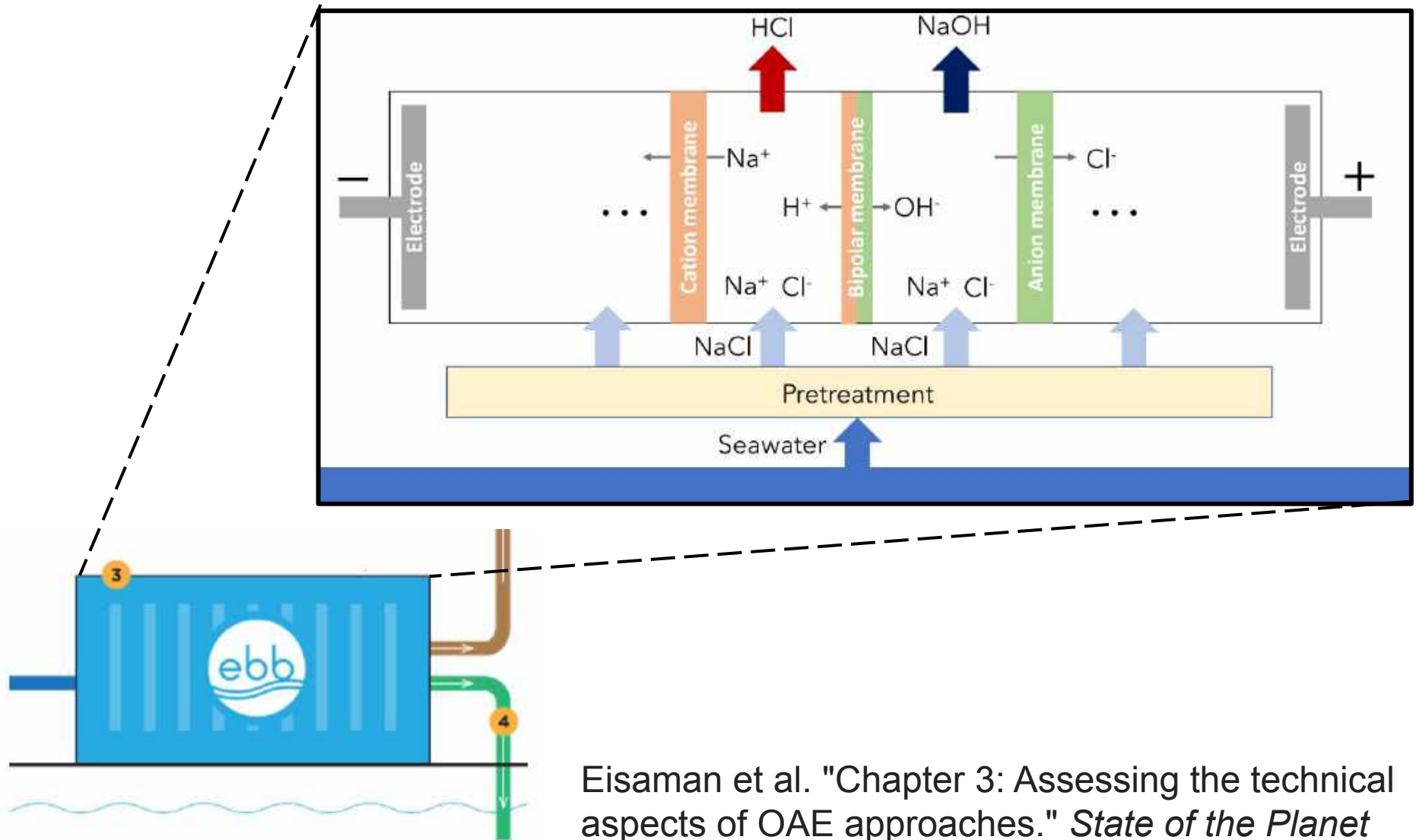
# Aqueous bases



Low carbon footprint acid extracted and utilized for a range of scalable climate-positive purposes



How  
Ebb  
Carbon  
works



How  
Ebb  
Carbon  
works

Eisaman et al. "Chapter 3: Assessing the technical aspects of OAE approaches." *State of the Planet Discussions* 2023 (2023): 1-52.



Ebb Carbon  
SAN CARLOS  
HQ



# R&D

## PNNL SEQUIM



U.S. DEPARTMENT OF  
**ENERGY**



Pacific Northwest  
NATIONAL LABORATORY



# PMEL

**W**  
UNIVERSITY of  
WASHINGTON



<https://www.pnnl.gov/publications/new-technology-removes-acid-ocean-sequester-carbon>

# Laying the scientific groundwork

- ✓ Demonstrate efficacy of CO<sub>2</sub> removal
- Demonstrate safe bounds of alkalinity enhancement
- Understand impacts of OAE on marine species and ecosystems
- Develop new OAE modeling tools

Establish efficacy of electrochemical OAE in the laboratory

**Stony Brook  
SEA MATE**

Demonstrate performance & safety of Ebb Carbon commercial system

**Ebb Carbon HQ  
Sequim**

Demonstrate performance under real world conditions

**Readiness  
testing**

Establish MRV methodology & deliver verified CO<sub>2</sub> removal

**Piloting**

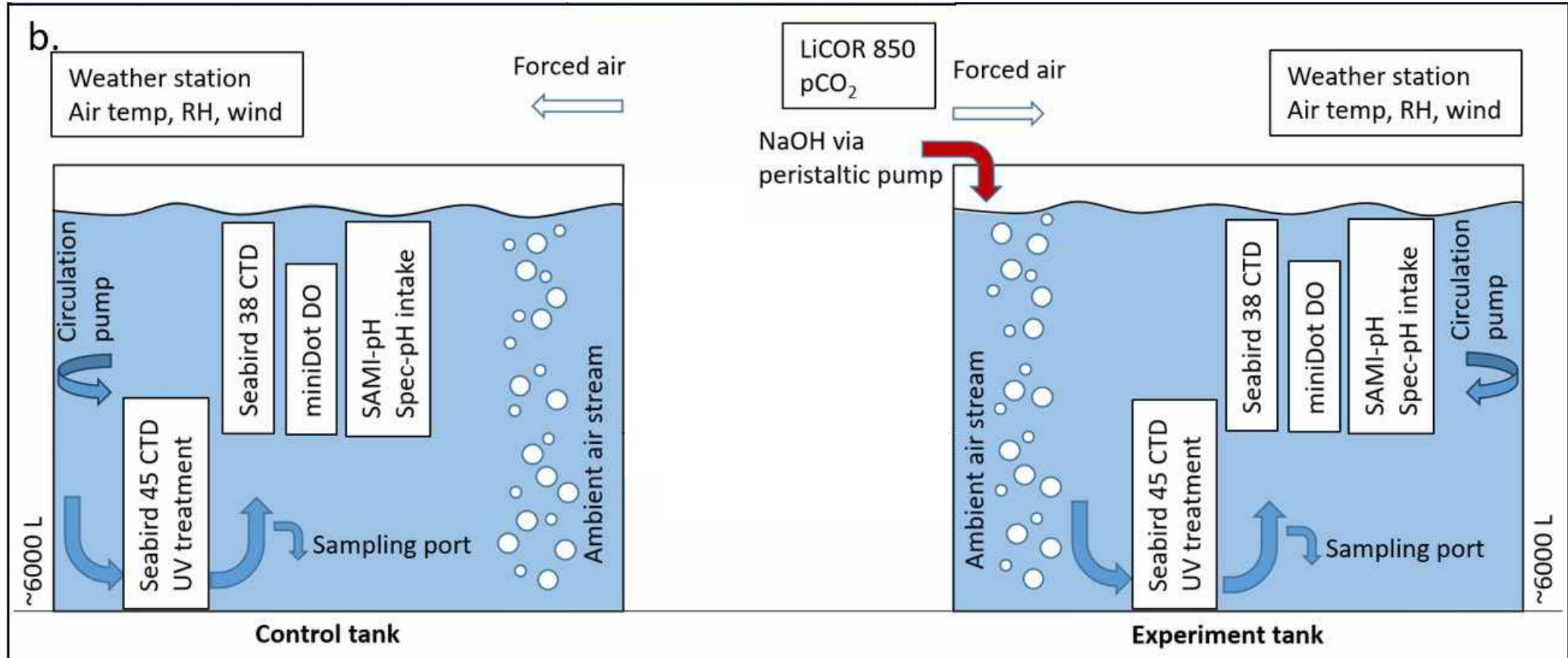
# R&D

SUNY  
STONY BROOK



# R&D

SUNY  
STONY BROOK

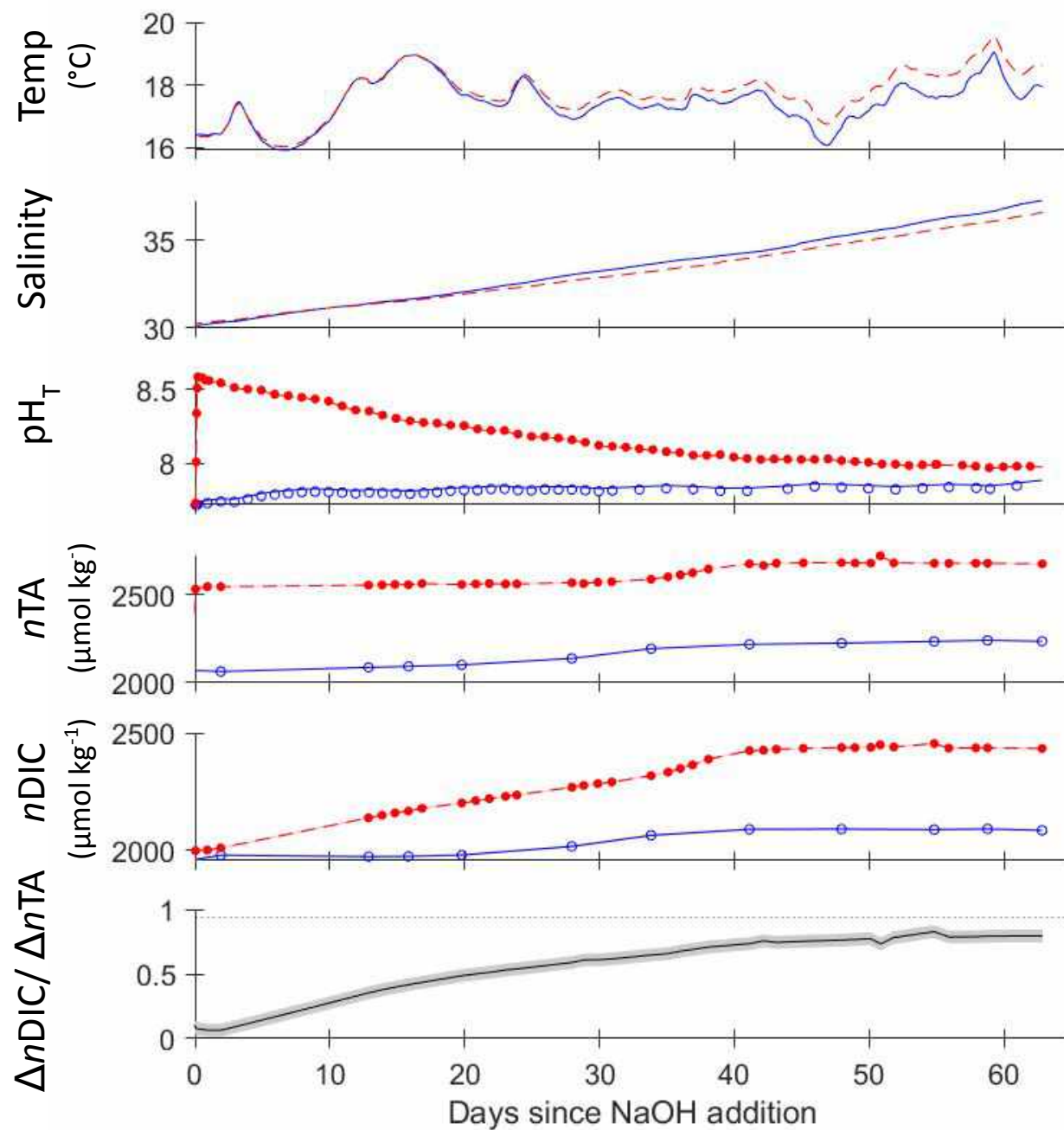


# Preliminary Results

*Example of single experiment*

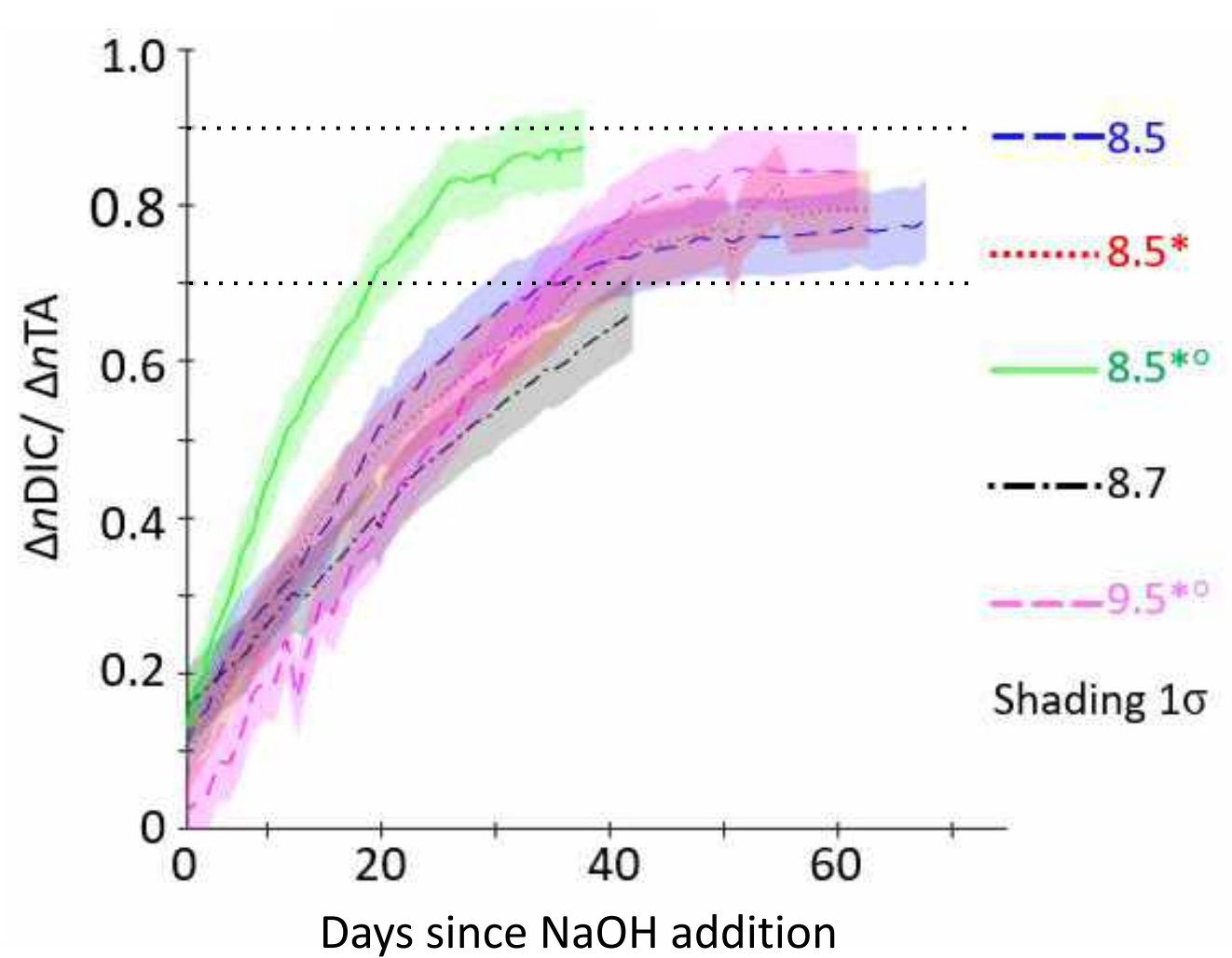
NaOH added to experiment tank until bulk pH is 8.5.

Both tanks are left to evolve while carbonate chemistry is monitored

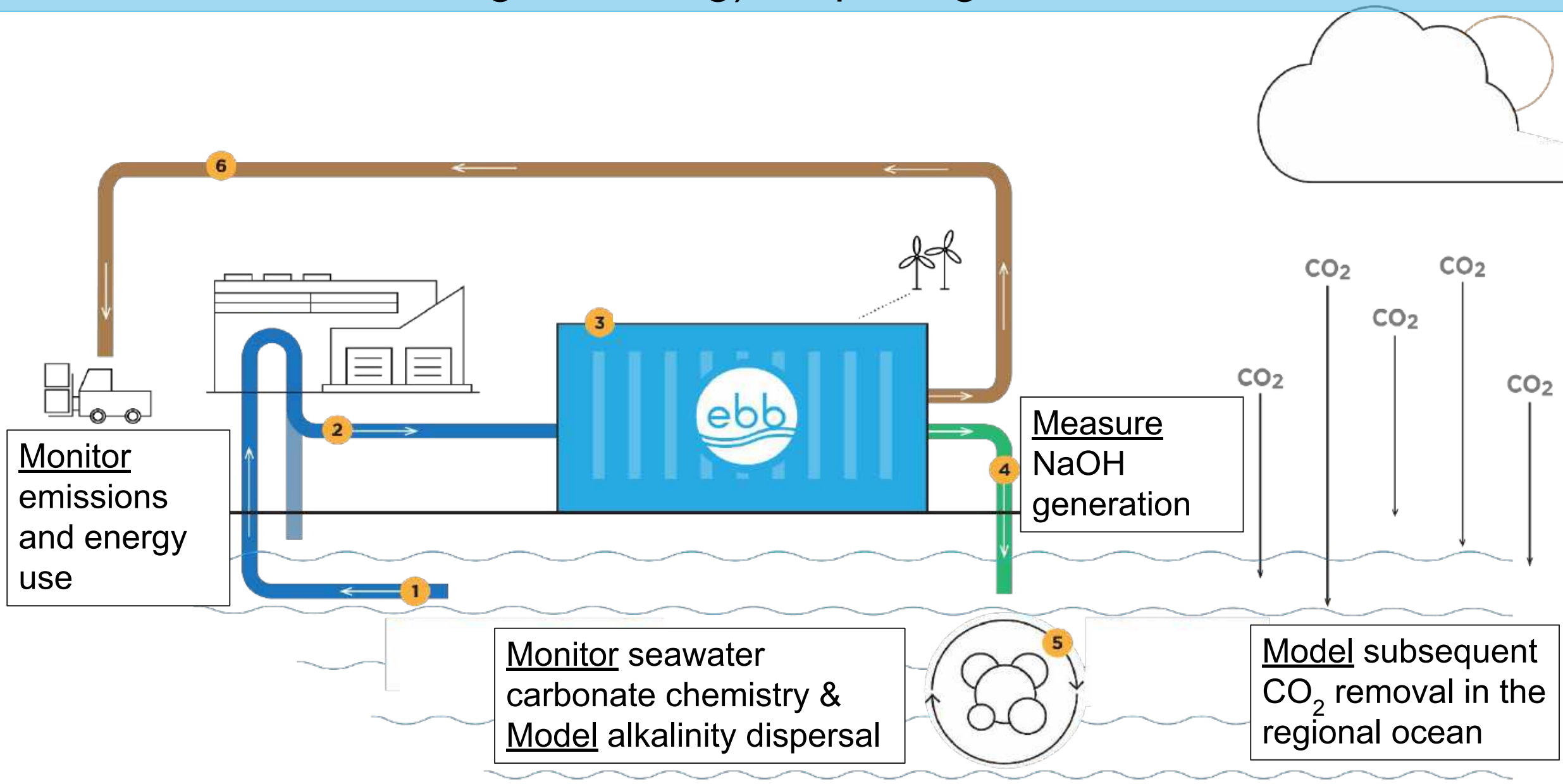


# Preliminary Results

Ratio of increased moles of DIC to moles of added alkalinity approaches the expected ratio  $\sim 0.8$



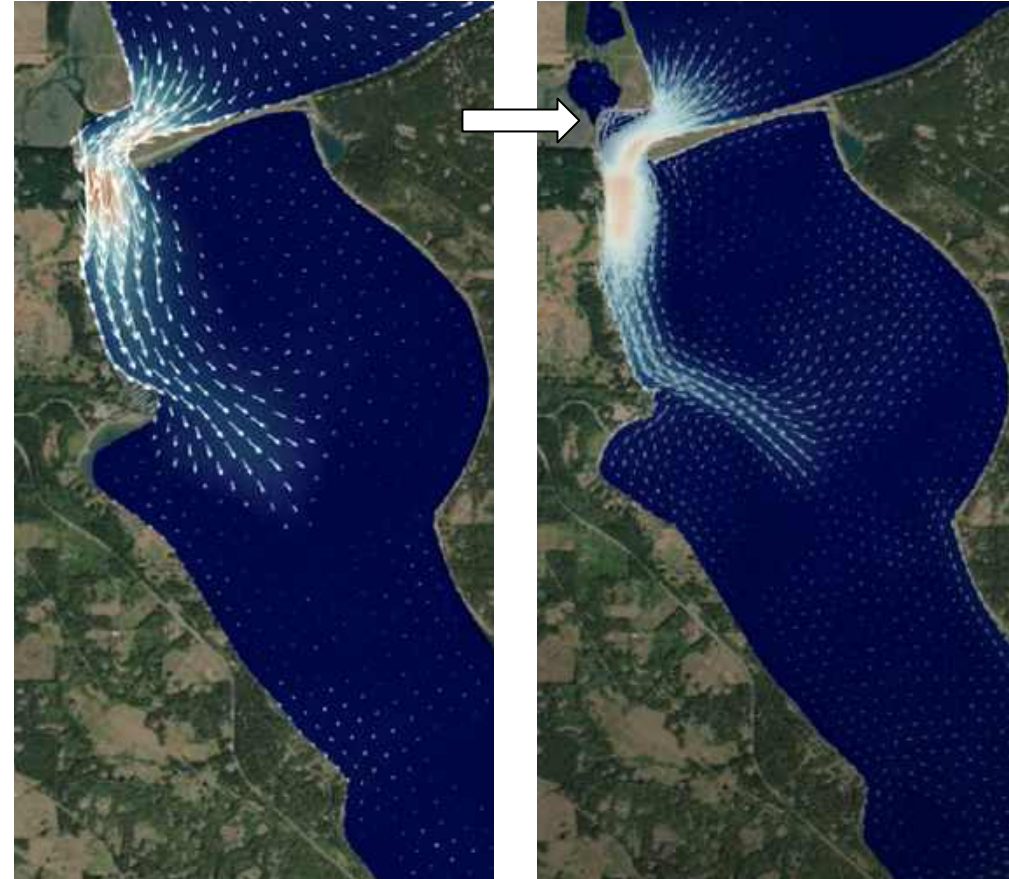
# (Measurement, Monitoring, Modeling), Reporting, and Verification



# Sequim Phase I: Ex-situ demonstration

1. Monitoring temperature, salinity, dissolved oxygen, chlorophyll, turbidity, pH through sensor deployments and bottle sampling
2. Ex-situ (tank) OAE experiments and demonstration
3. Near-field dilution modeling with environmental consultants
4. Adapting regional ocean models to simulate alkalinity release
5. Oyster and eelgrass epifauna response experiments

Salish Sea model resolution updates



## Measurement

Sensing and sampling near alkalinity dispersal and throughout mixing zone

Evolving laboratory experiments

Modeling on near and regional scales

Emissions accounting and full CO<sub>2</sub> life cycle analysis

## Reporting

Open conversation with stakeholders on all levels

Public MRV methodology under development

Publically accessible oceanographic and CDR data

Peer-reviewed publications with academic and federal partners

## Verification

Third party validation of all CO<sub>2</sub> data

Participation in third party CDR databases

Engaging with scientific community on model analyses and sensor development

# Many thanks

mallory@ebbcarbon.com

## Advisors



Ellen Briggs  
U of Hawaii



David Ho  
U of Hawaii



Kristy Kroeker  
UC Santa Cruz



Heather Kim  
WHOI



Todd Martz  
UCSD



William Tarpeh  
Stanford



David Koweek  
Ocean Visions



OCEAN VISIONS



Brad Ack  
Ocean Visions



22+ others



## Collaborators



Brendan Carter  
University of  
Washington



Carbon  
Program  
NOAA/PMEL



Honjie Wang  
University of  
Rhode Island



Ben Tutolo  
U. Calgary



Mike Tyka  
Google Research



Pete Psarras  
University of  
Pennsylvania



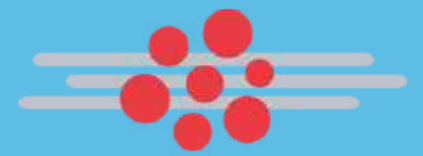
Débora  
Iglesias-Rodriguez  
UCSB



Noah Planavsky  
Yale



Jo Katchinoff  
Yale



Center for Functional Nanomaterials  
Brookhaven National Laboratory

## Funding



## Stony Brook University



Xi Lu  
Postdoc



Mallory Ringham  
Research  
Associate



Nathan Hirtle  
PhD Student



Cody Shaw  
PhD Student



Katherine Hillis  
Undergrad

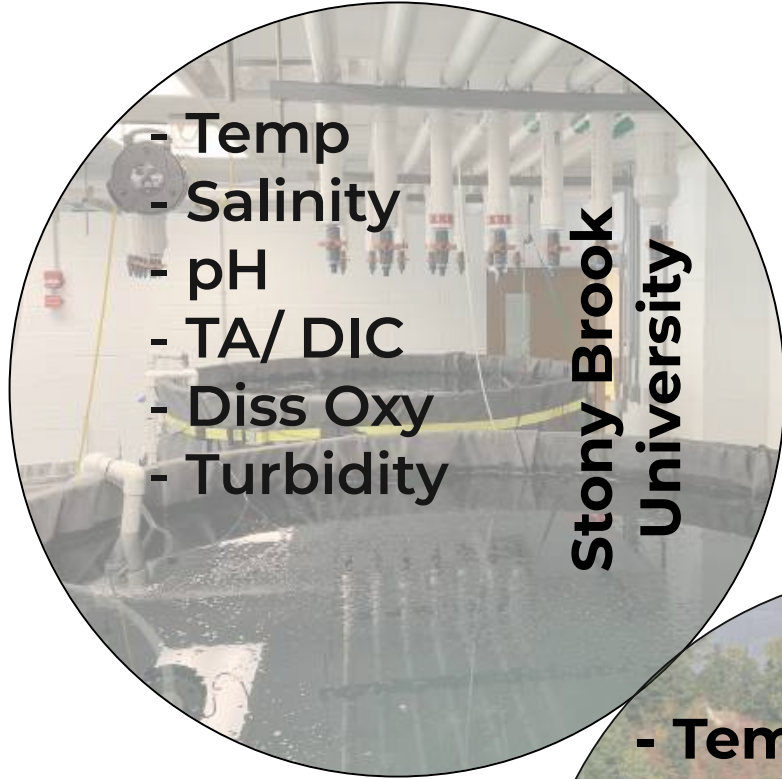


Steve Abrams  
Flax Pond Lab  
Manager



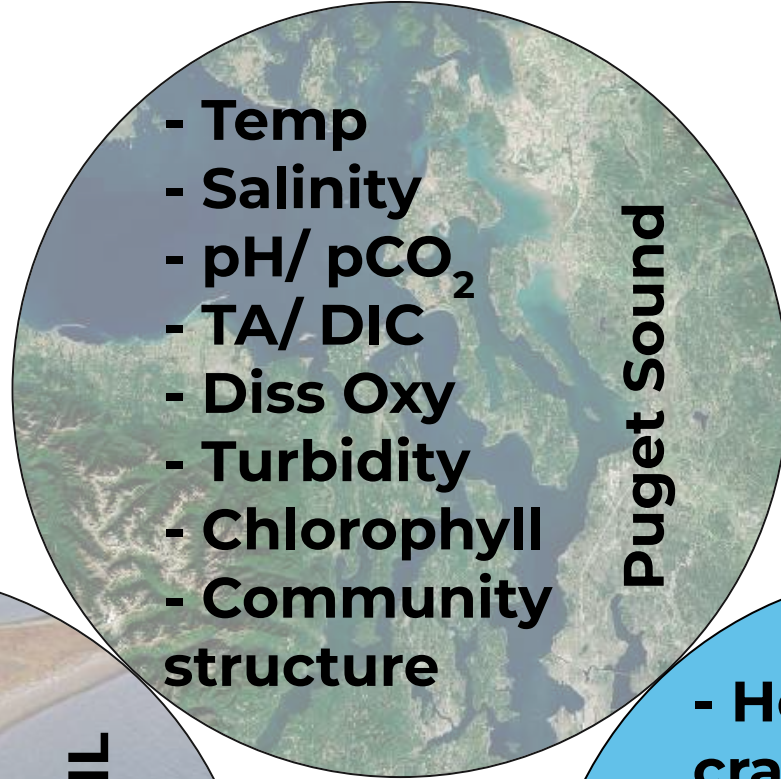
Tom Wilson  
Flax Pond Lab  
Instrument  
Engineer





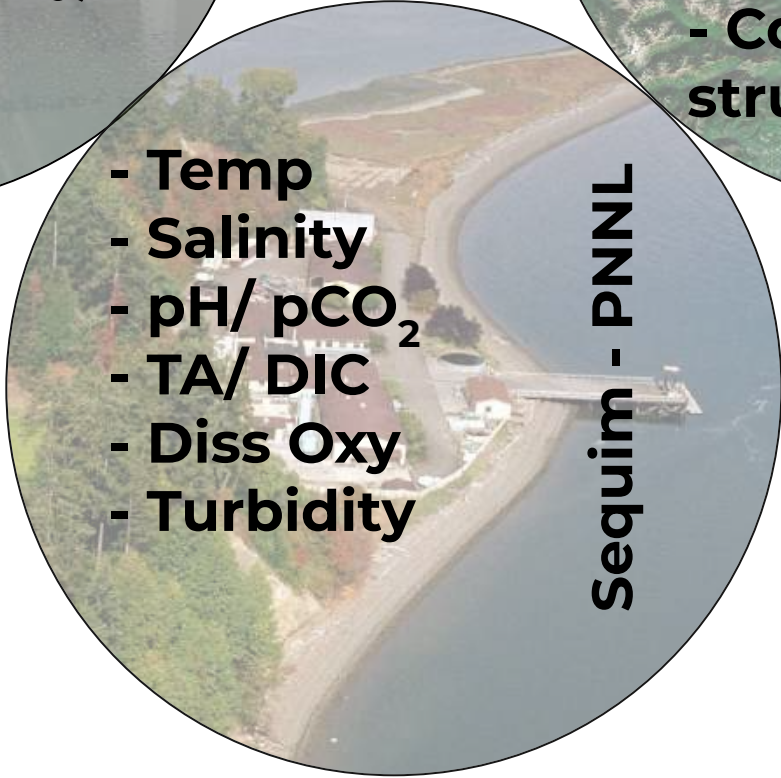
- Temp
- Salinity
- pH
- TA/ DIC
- Diss Oxy
- Turbidity

**Stony Brook University**



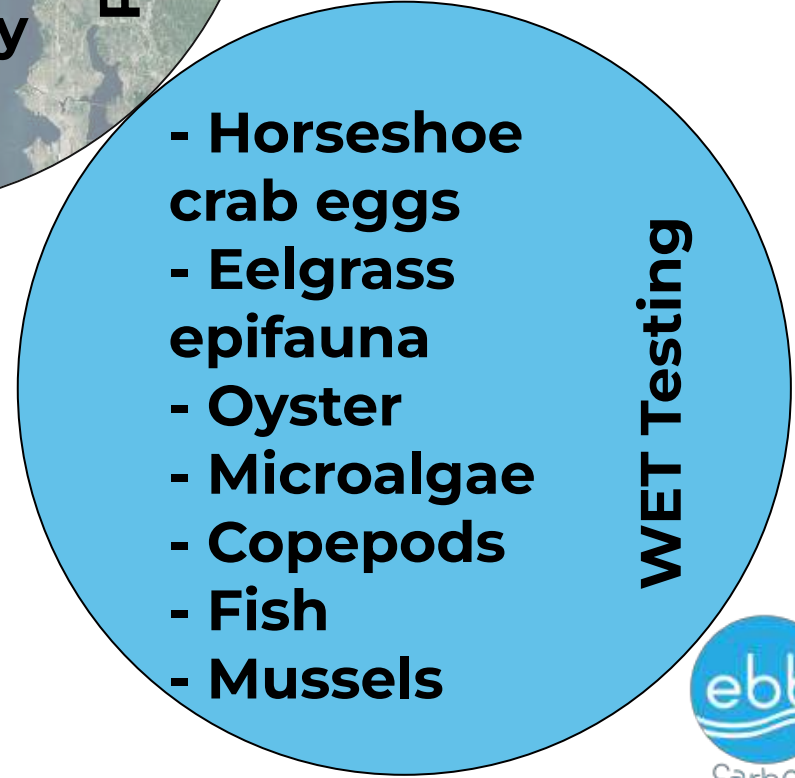
- Temp
- Salinity
- pH/ pCO<sub>2</sub>
- TA/ DIC
- Diss Oxy
- Turbidity
- Chlorophyll
- Community structure

**Puget Sound**



- Temp
- Salinity
- pH/ pCO<sub>2</sub>
- TA/ DIC
- Diss Oxy
- Turbidity

**Sequim - PNNL**



- Horseshoe crab eggs
- Eelgrass epifauna
- Oyster
- Microalgae
- Copepods
- Fish
- Mussels

**WET Testing**