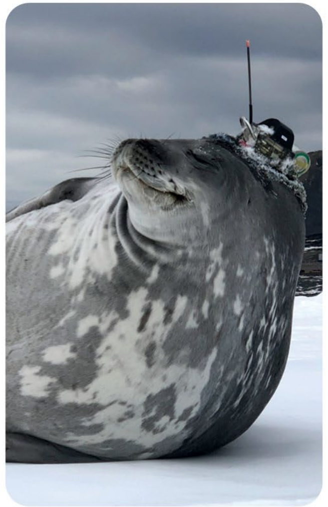
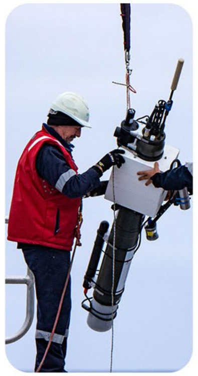
IMOS Integrated Marine Observing System

Marine Carbon Dioxide Removal

Challenges and Opportunities





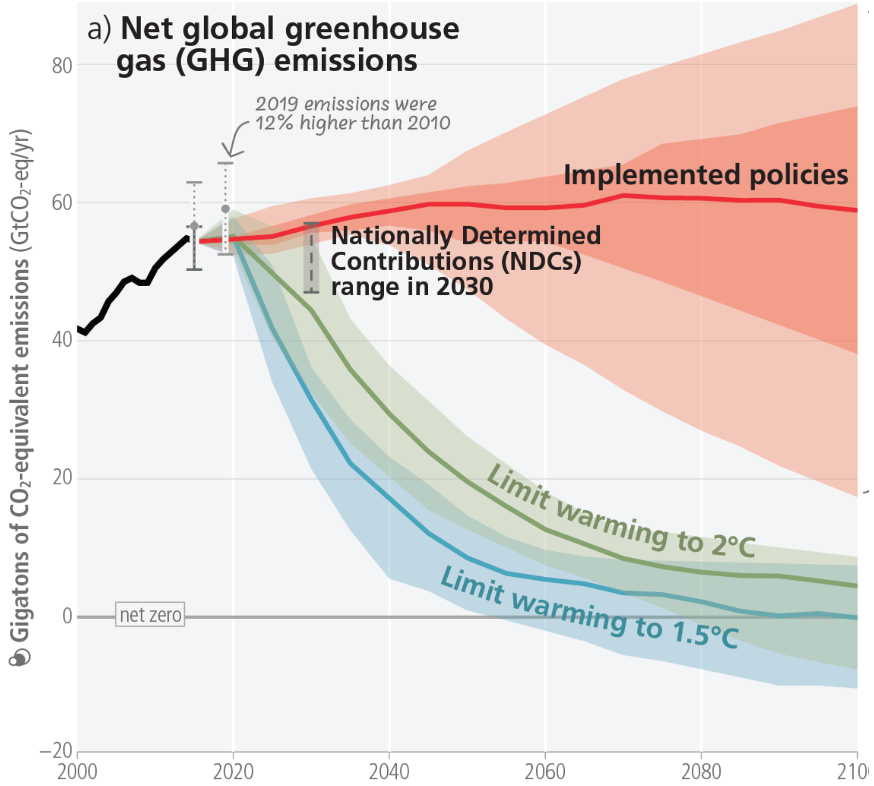
Elizabeth Shadwick | IMOS Annual Planning Meeting | 27 February 2025

https://www.ipcc.ch/report/ar6/syr/

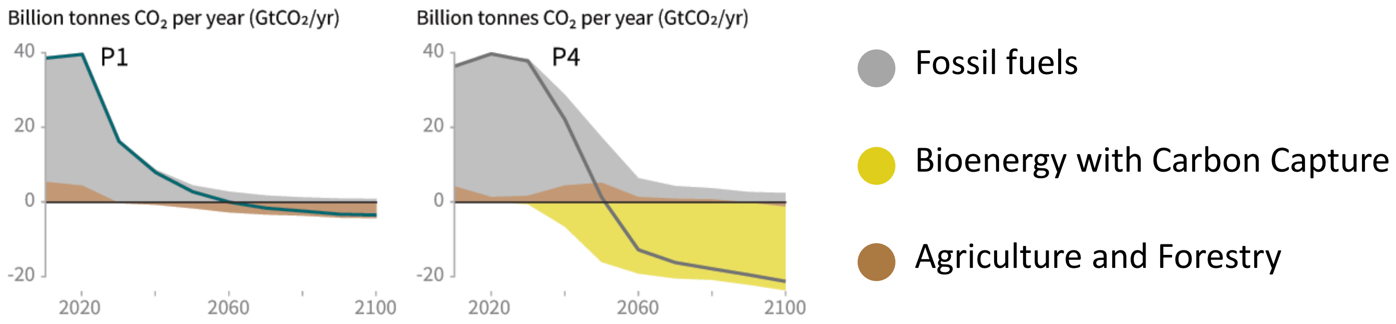
AR6 Synthesis Report ipcc

Pathways Forward

Limiting warming to 1.5°C and 2°C involves rapid, deep and in most cases immediate greenhouse gas emission reductions



Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

All pathways forward require carbon dioxide removal (CDR)

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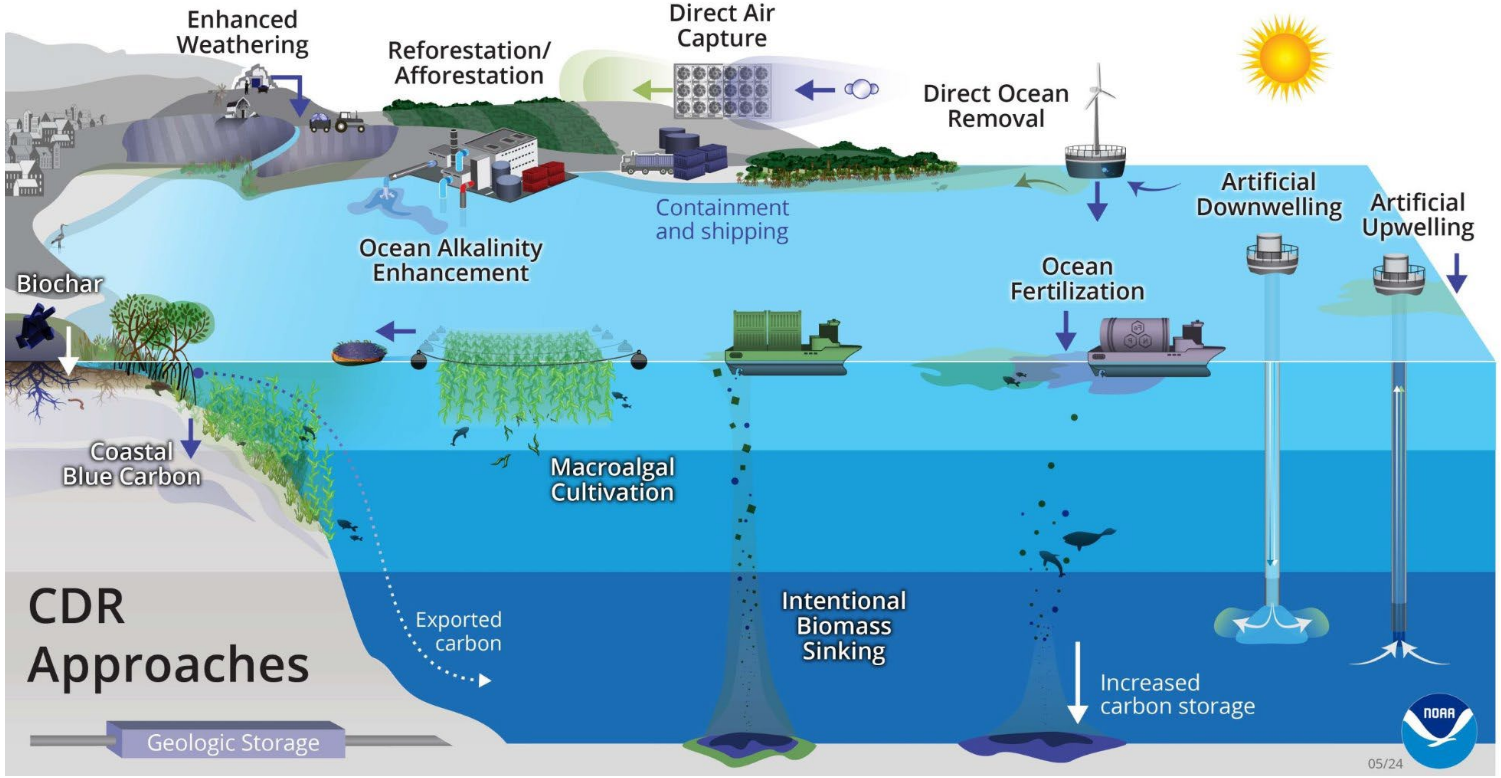
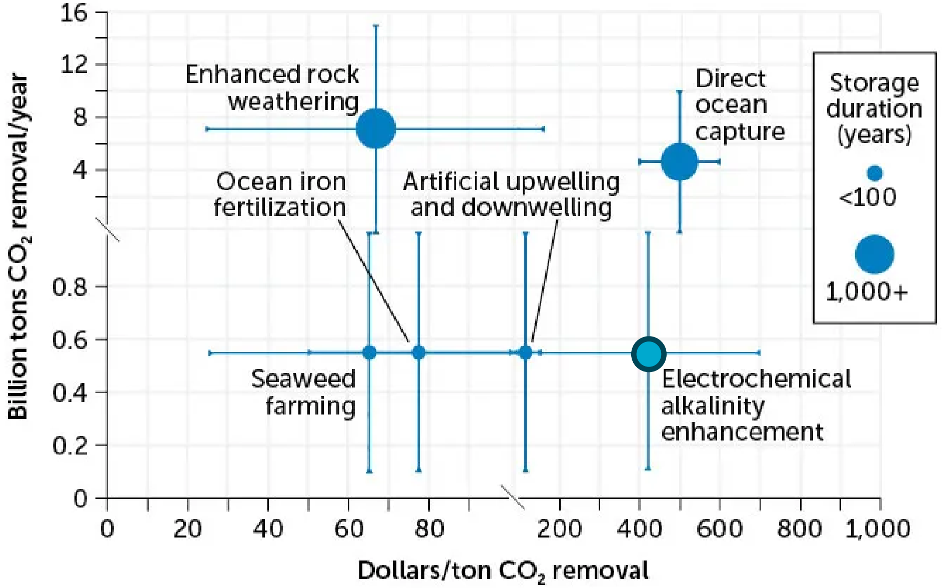
CSIRO

Why use the ocean for CDR?

Effective CDR requires **efficient capture** and **long-term storage** – the ocean has the potential to do both.





The ocean contains ~38,000 Gt* carbon (as dissolved inorganic carbon). Restoring atmospheric CO_2 levels to 280ppm requires removing 270 Gt carbon.

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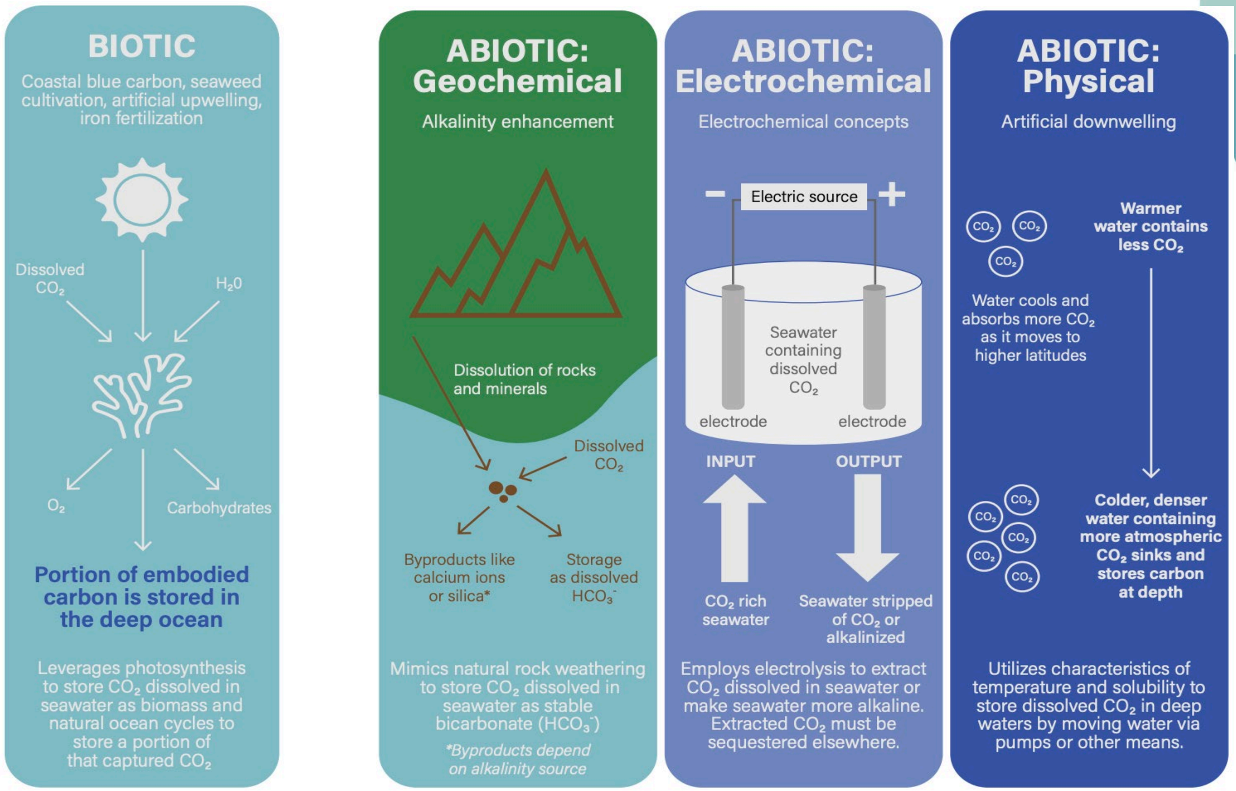
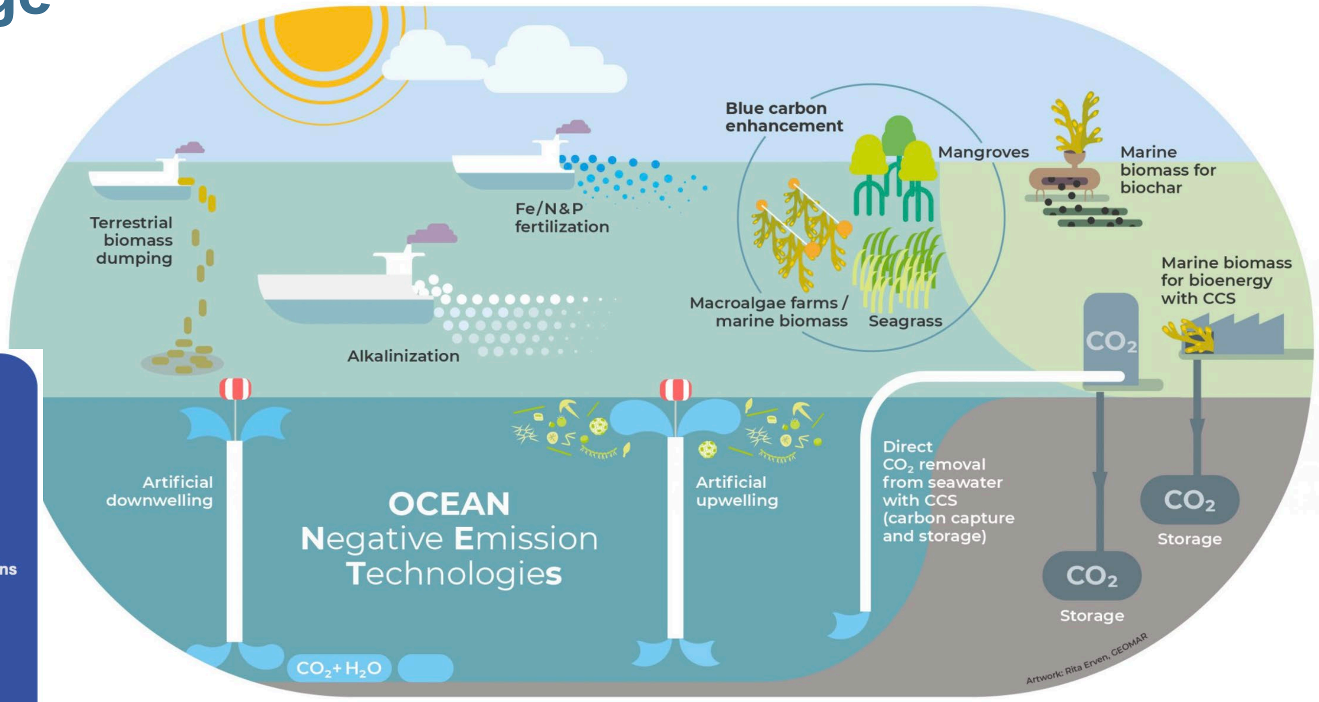
* 1 Gt = 6 million blue whales

mCDR: Enhacing Ocean Carbon Storage



Foundation for Climate Restoration. 2023



https://www.oceannets.eu

OCEAN NETs

Macroalgae Cultivation (*Blue Carbon*)

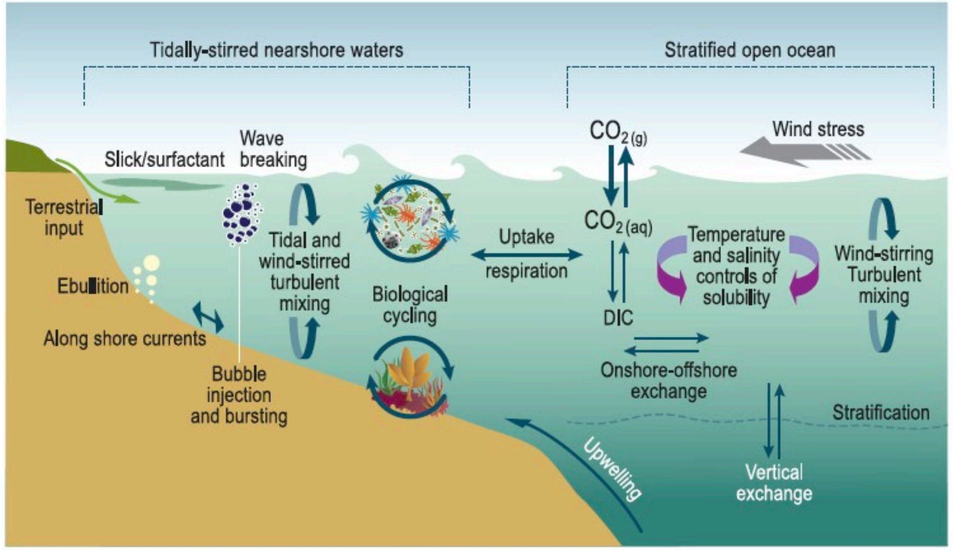
J. Phycol. 58, 347–363 (2022)

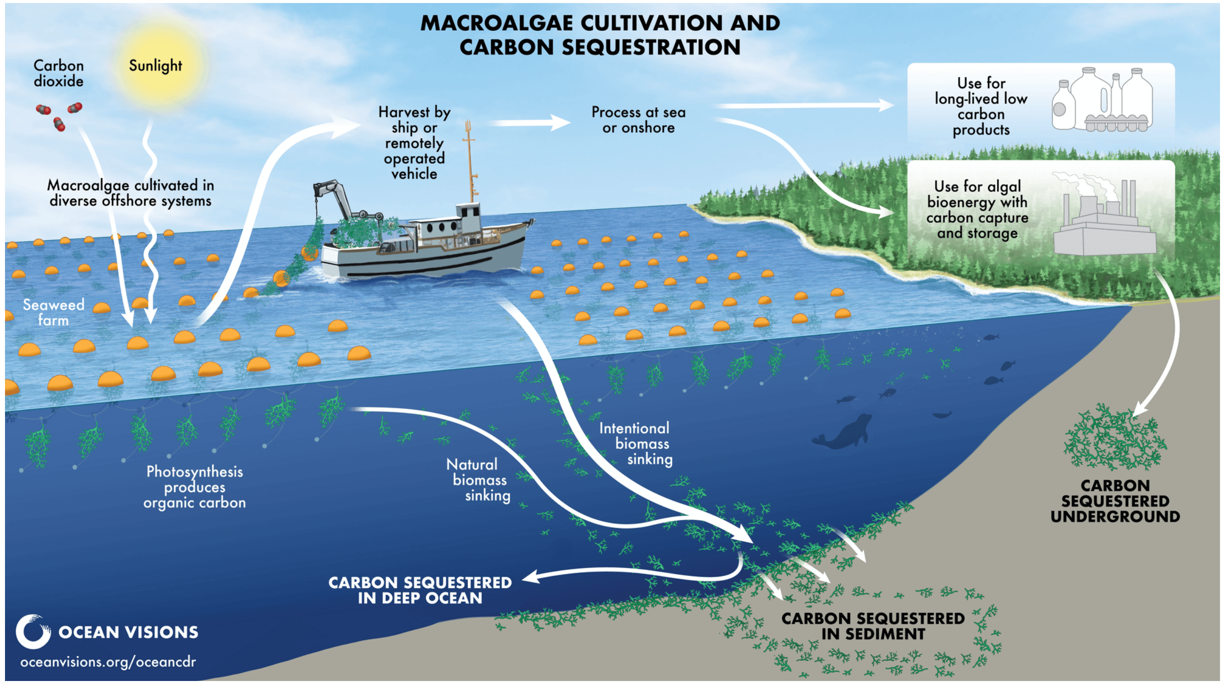
DOI: 10.1111/jpy.13249

PERSPECTIVE

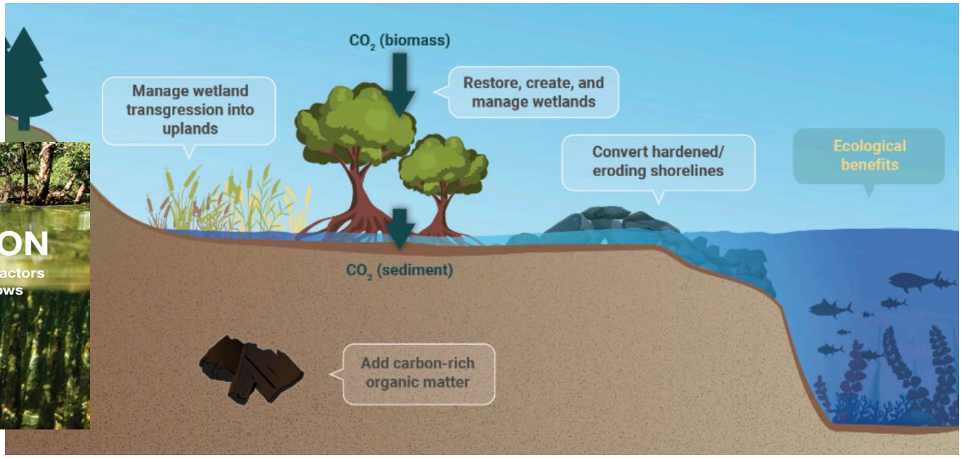
FORENSIC CARBON ACCOUNTING: ASSESSING THE ROLE OF SEAWEEDS FOR CARBON SEQUESTRATION[1]

Hurd et al., 2022





https://www.thebluecarboninitiative.org



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Iron (or other nutrient) fertilisation

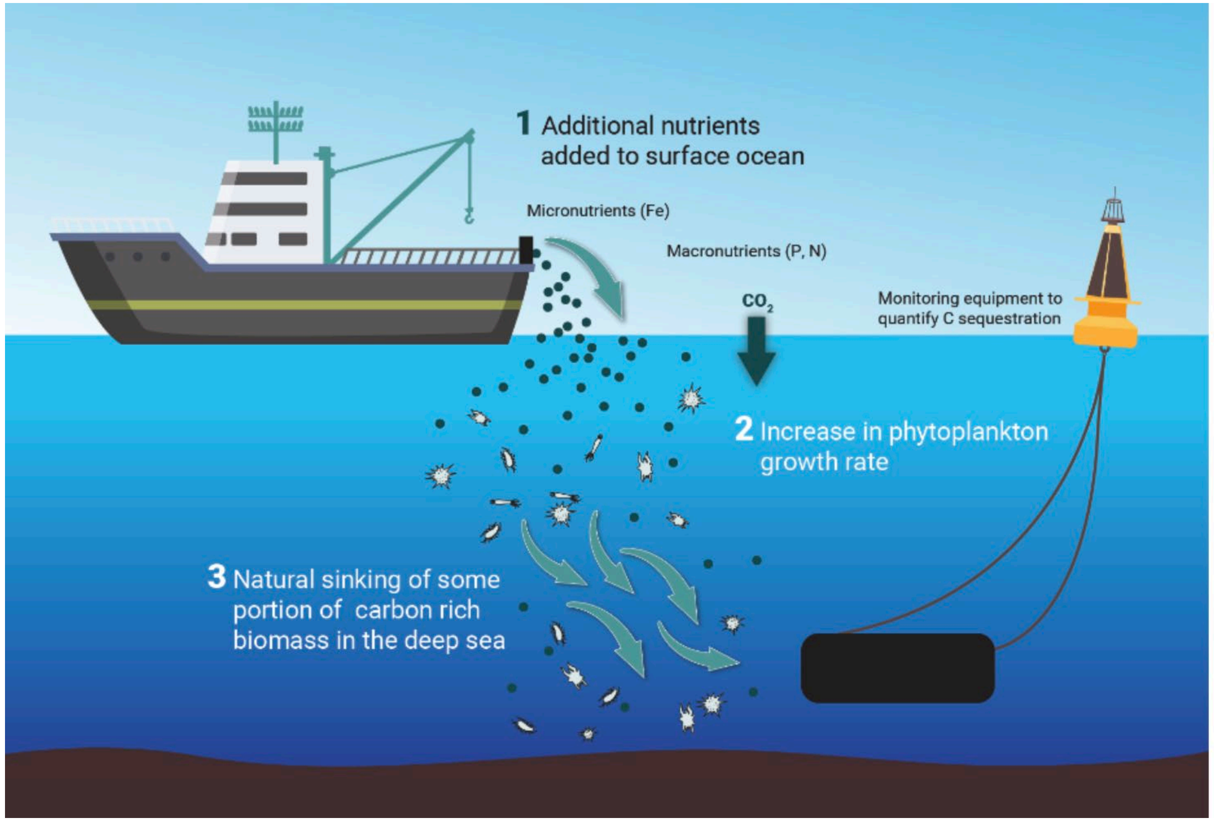


Figure modified from: Energy Futures Initiative (2020)

EXOIS
EXPLORING OCEAN IRON SOLUTIONS

For more info contact info@oceaniron.org
@ExOIS_OceanIron
oceanIron.org

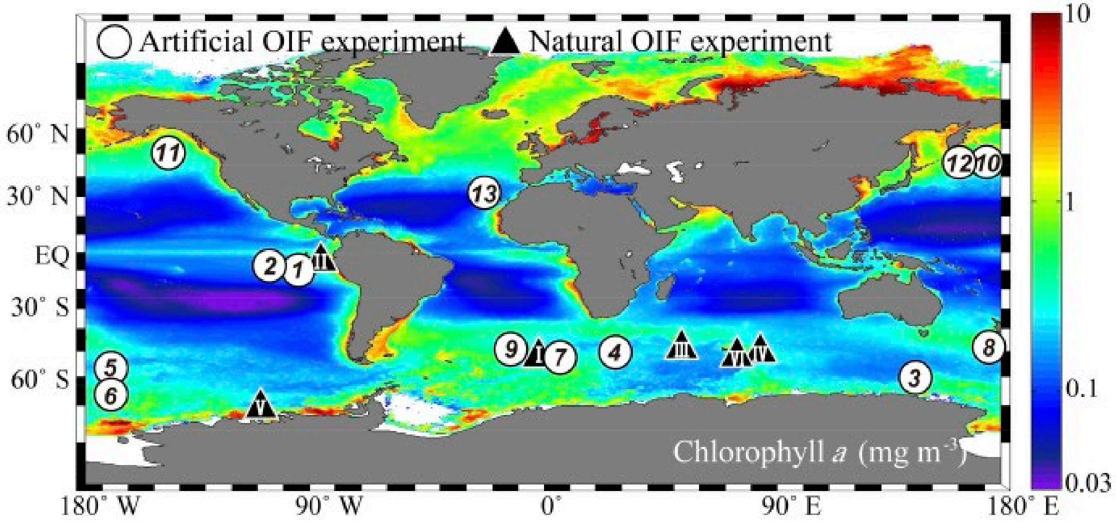
Biogeosciences

Open Access

EGU

Reviews and syntheses: Ocean iron fertilization experiments – past, present, and future looking to a future Korean Iron Fertilization Experiment in the Southern Ocean (KIFES) project

Joo-Eun Yoon[1], Kyu-Cheul Yoo[2], Alison M. Macdonald[3], Ho-Il Yoon[2], Ki-Tae Park[2], Eun Jin Yang[2], Hyun-Cheol Kim[2], Jae Il Lee[2], Min Kyung Lee[2], Jinyoung Jung[2], Jisoo Park[2], Jiyoung Lee[1], Soyeon Kim[1], Seong-Su Kim[1], Kitae Kim[2], and Il-Nam Kim[1]



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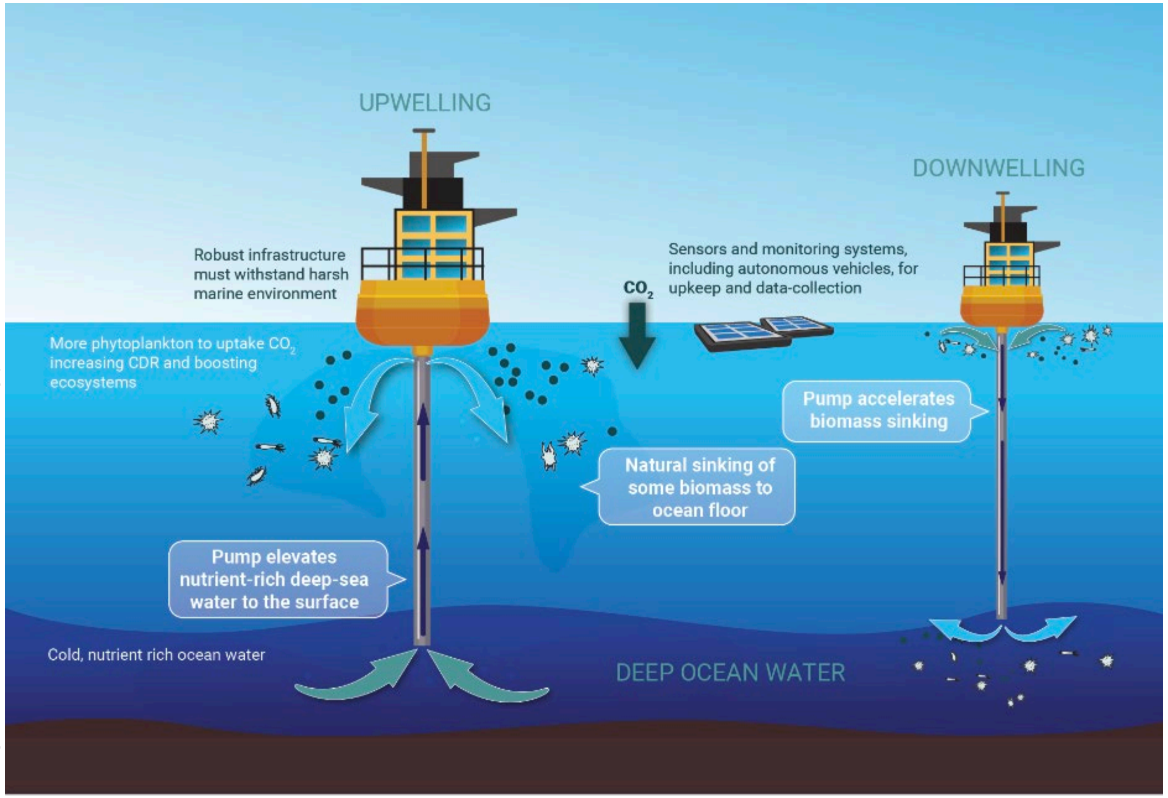
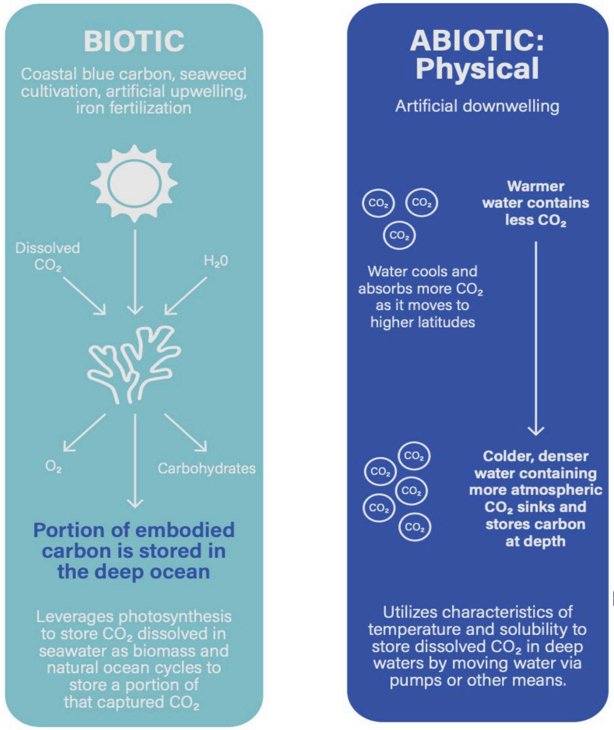
Artificial Upwelling and Downwelling

Figure modified from: Energy Futures Initiative (2020)



Foundation for Climate Restoration. 2023

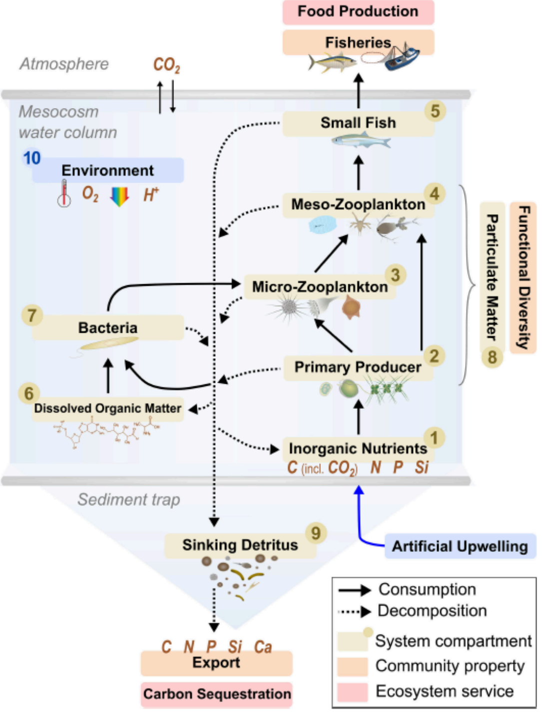


frontiers | Frontiers in Marine Science

TYPE Original Research
PUBLISHED 25 November 2022
DOI 10.3389/fmars.2022.1015188

Nutrient composition (Si:N) as driver of plankton communities during artificial upwelling

Silvan Urs Goldenberg[1]*, Jan Taucher[1], Mar Fernández-Méndez[1,2], Andrea Ludwig[1], Javier Arístegui[3], Moritz Baumann[1], Joaquin Ortiz[1], Annegret Stuhr[1] and Ulf Riebesell[1]



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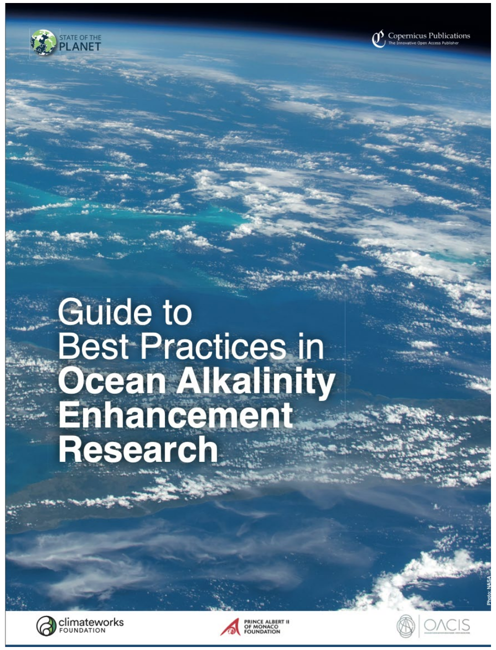
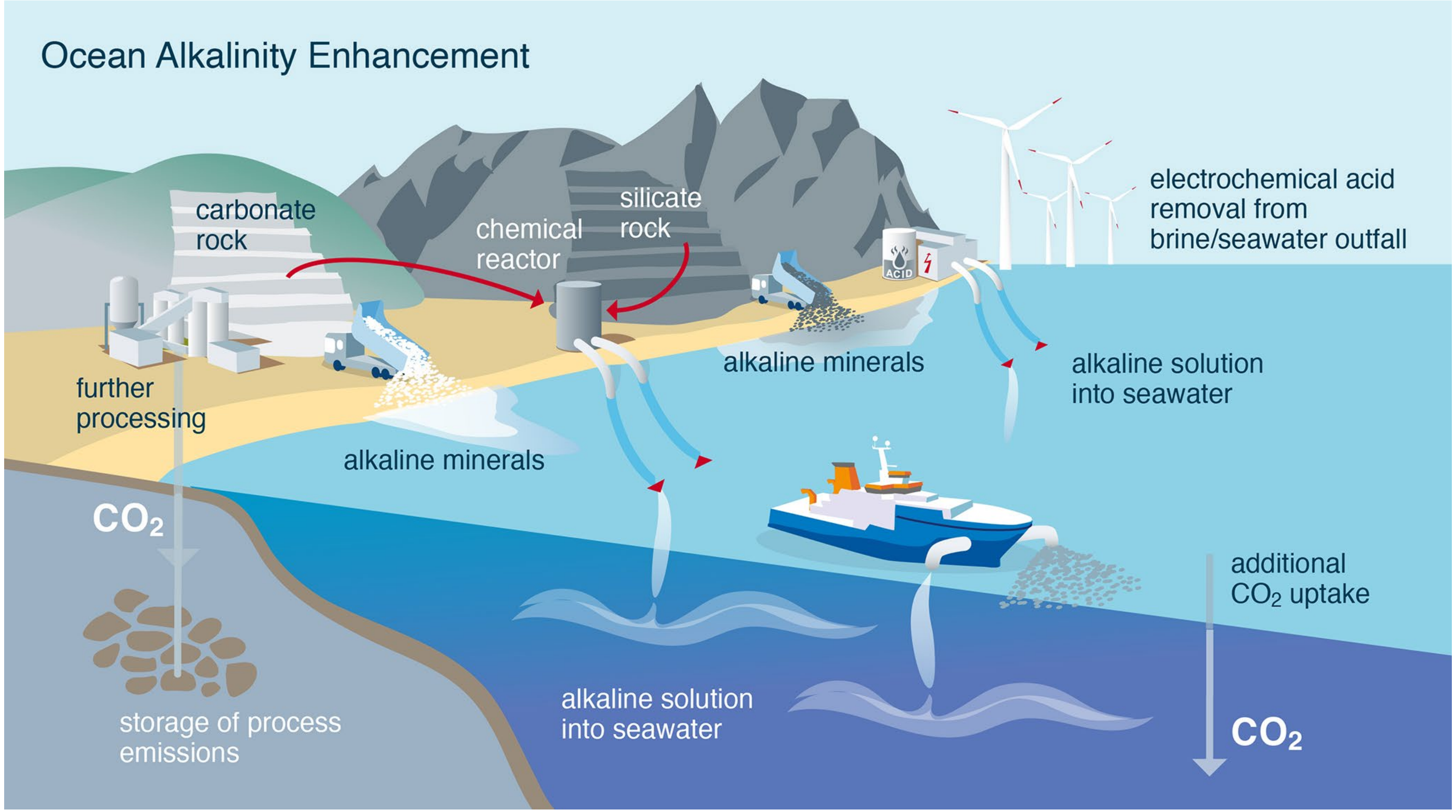
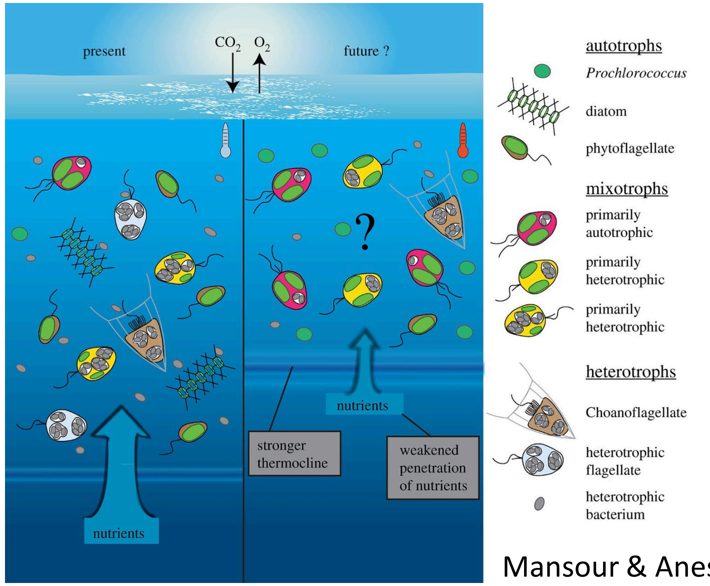
Ocean Alkalinity Enhancement



Oschlies et al. (2023)



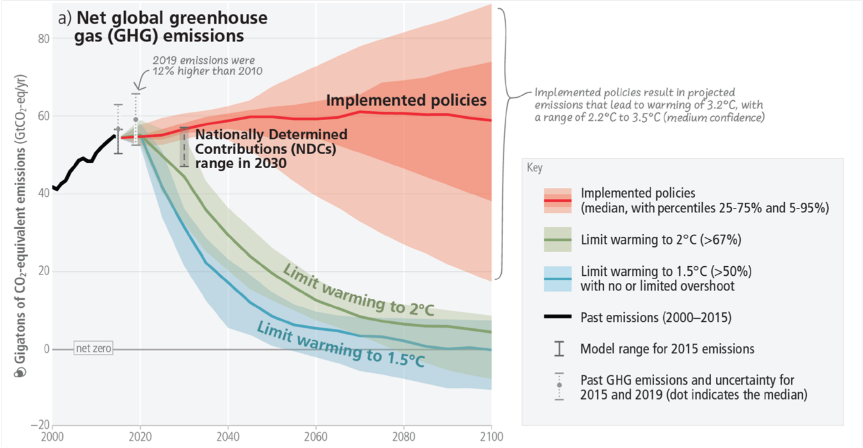
Risks and/or Unintended Consequences



Mansour & Anestis (2021)

AR6 Synthesis Report ipcc

Limiting warming to 1.5°C and 2°C involves rapid, deep and in most cases immediate greenhouse gas emission reductions



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CSIRO

Emerging International Consensus and Ongoing Challenges

IPCC AR6 WGIII: CDR Factsheet

ipcc
INTERGOVERNMENTAL PANEL ON climate change
Working Group III-Mitigation of Climate Change

Carbon Dioxide Removal

CARBON DIOXIDE REMOVAL (CDR) refers to technologies, practices, and approaches that remove and durably store carbon dioxide (CO_2) from the atmosphere. CDR is required to achieve global and national targets of net zero CO_2 and greenhouse gas (GHG) emissions. CDR cannot substitute for immediate and deep emissions reductions, but it is part of all modelled scenarios that limit global warming to 2°or lower by 2100. Implementation will require decisions regarding CDR methods, scale and timing of deployment, and how sustainability and feasibility constraints are managed.

IPCC Expert Meeting

Carbon Dioxide Removal Technologies and Carbon Capture, Utilization and Storage

Report of the IPCC Expert Meeting
1-3 July 2024, Vienna, Austria

Task Force on National Greenhouse Gas Inventories

European MARINE BOARD
Advancing Seas & Ocean Science

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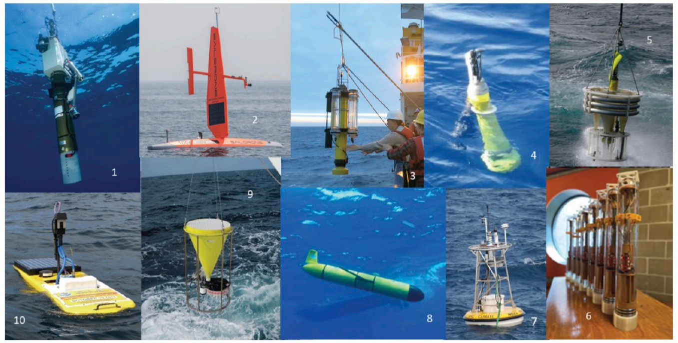
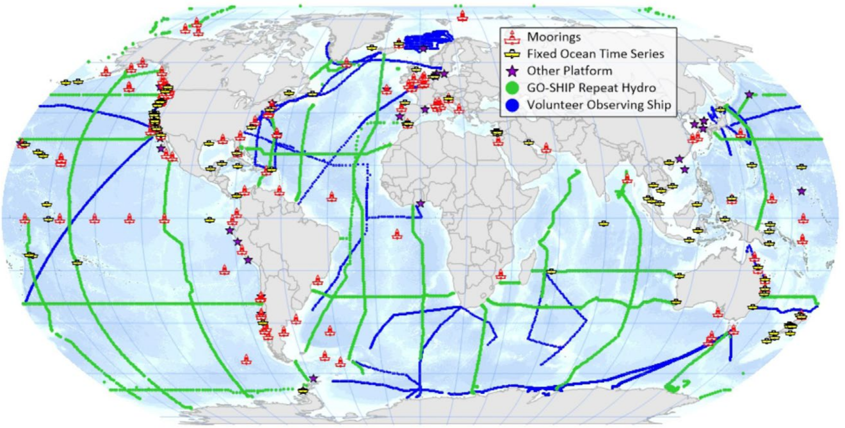
MARINE CARBON DIOXIDE REMOVAL

Reliable monitoring, reporting and verification (MRV) of marine carbon dioxide removal (mCDR) approaches will require accurate quantification of the amount of CO2 removed from the atmosphere, the durab that removal, and non-carbon impacts on the marine environment. Given the vastness of the Ocear slow gas exchange across the sea surface, and the difficulty of defining baselines under ongoing environmental change, accurate estimates are challenging and need to include reliable uncertainty estimates. However, the required measurements, their integration with numerical models and the transparent provision of useful information are critical.



From Tilbrook et al., 2019



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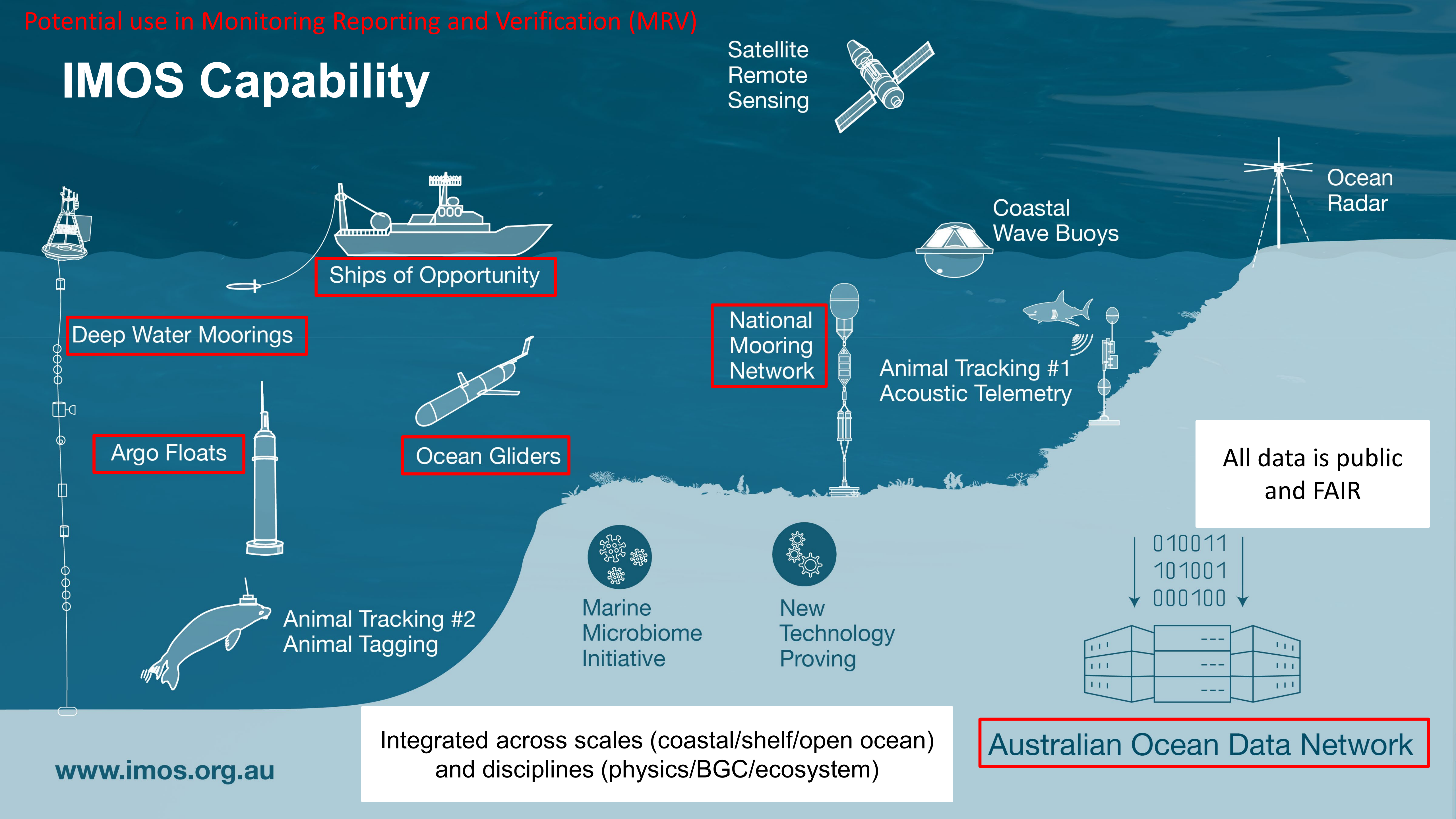
Potential use in Monitoring Reporting and Verification (MRV)
IMOS Capability
Satellite Remote Sensing
Ocean Radar
Coastal Wave Buoys
Ships of Opportunity
Deep Water Moorings
National Mooring Network
Animal Tracking #1 Acoustic Telemetry
Argo Floats
Ocean Gliders
All data is public and FAIR
010011
101001
000100
Animal Tracking #2 Animal Tagging
Marine Microbiome Initiative
New Technology Proving
www.imos.org.au
Integrated across scales (coastal/shelf/open ocean) and disciplines (physics/BGC/ecosystem)
Australian Ocean Data Network

Opportunities for IMOS – examples from overseas

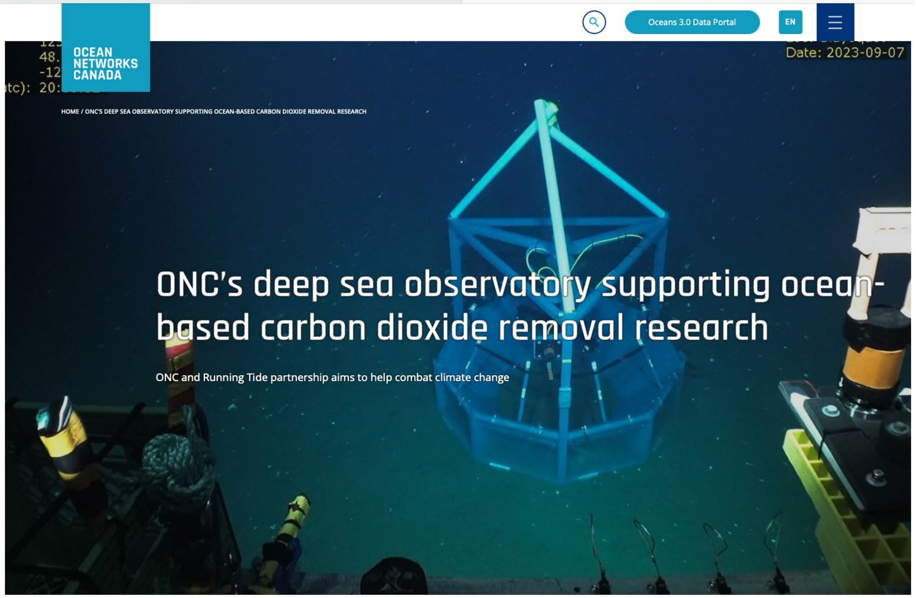

Image credit: Running Tide

Microsoft signs deal with ocean carbon removal project operating on Washington's coast

BY LISA STIFFLER on October 24, 2024 at 8:45 am

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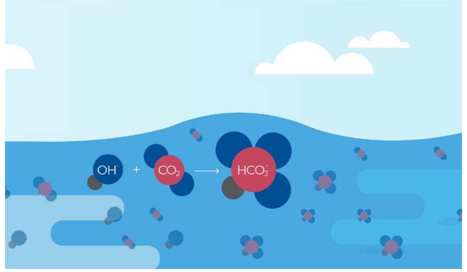
Sustainability: News about the rapidly growing climate tech sector and other areas of innovation to protect our planet. SEE MORE

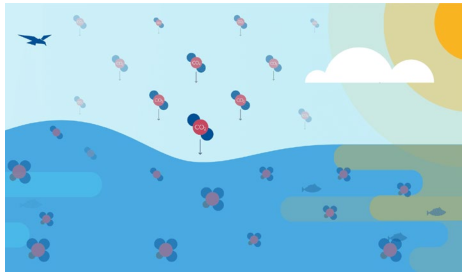
Ebb Carbon is using ocean alkalinity enhancement to remove carbon from seawater. It has a pilot plant in Sequium, Wash. (Ebb Carbon Photo)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

U.S. DEPARTMENT OF ENERGY

ebb carbon





IMOS Integrated Marine Observing System

CSIRO

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

Australia's Integrated Marine Observing System is enabled by the National Collaborative Research Infrastructure Strategy (NCRIS). It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent.

PRINCIPAL PARTICIPANTS

UNIVERSITY of TASMANIA (Lead Agent)

Australian Government | Australian Institute of Marine Science

Australian Government Bureau of Meteorology

CSIRO

Government of South Australia

SARDI South Australian Research and Development Institute

The University of Western Australia

sims sydney institute of marine science

UTS

The University of Sydney

Macquarie University

UNSW Sydney

SIMS is a partnership invoving four universities

ASSOCIATE PARTICIPANTS

Curtin University

Australian Government
Department of Climate Change, Energy, the Environment and Water
Australian Antarctic Division

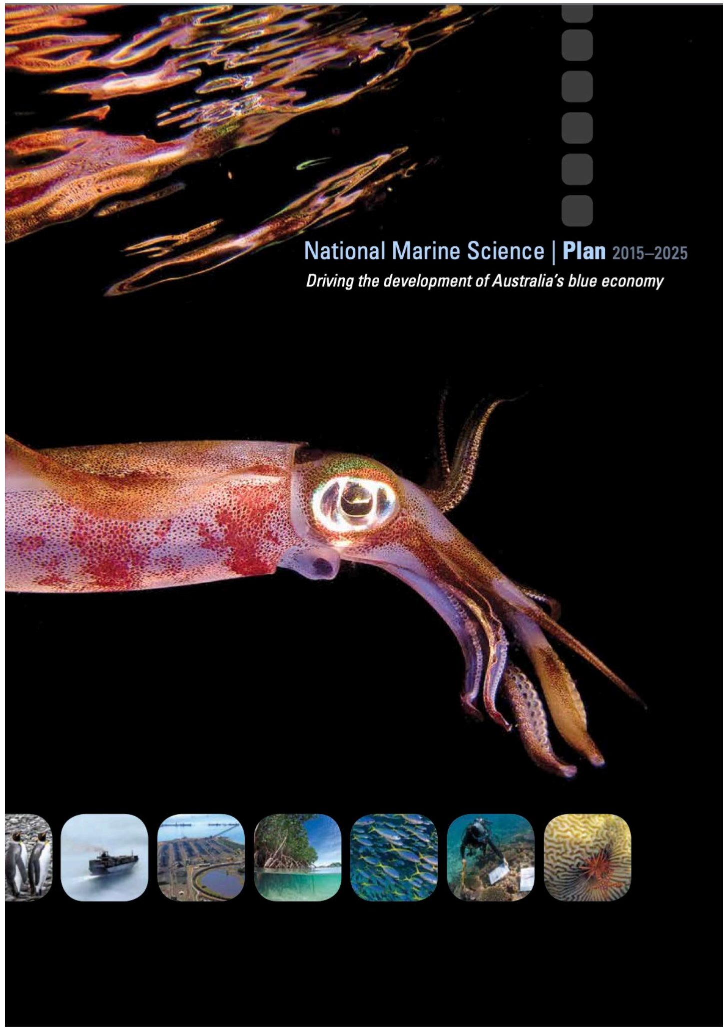
Australian Antarctic Program

Deakin University

The University of Melbourne

IMOS thanks the many other organisations who partner with IMOS, providing co-investment, funding and operational support, including investment from the Tasmanian, Western Australian and Queensland State Governments.

Opportunities for the IMOS community



"Climate and Green Engineering" White Paper (WP)

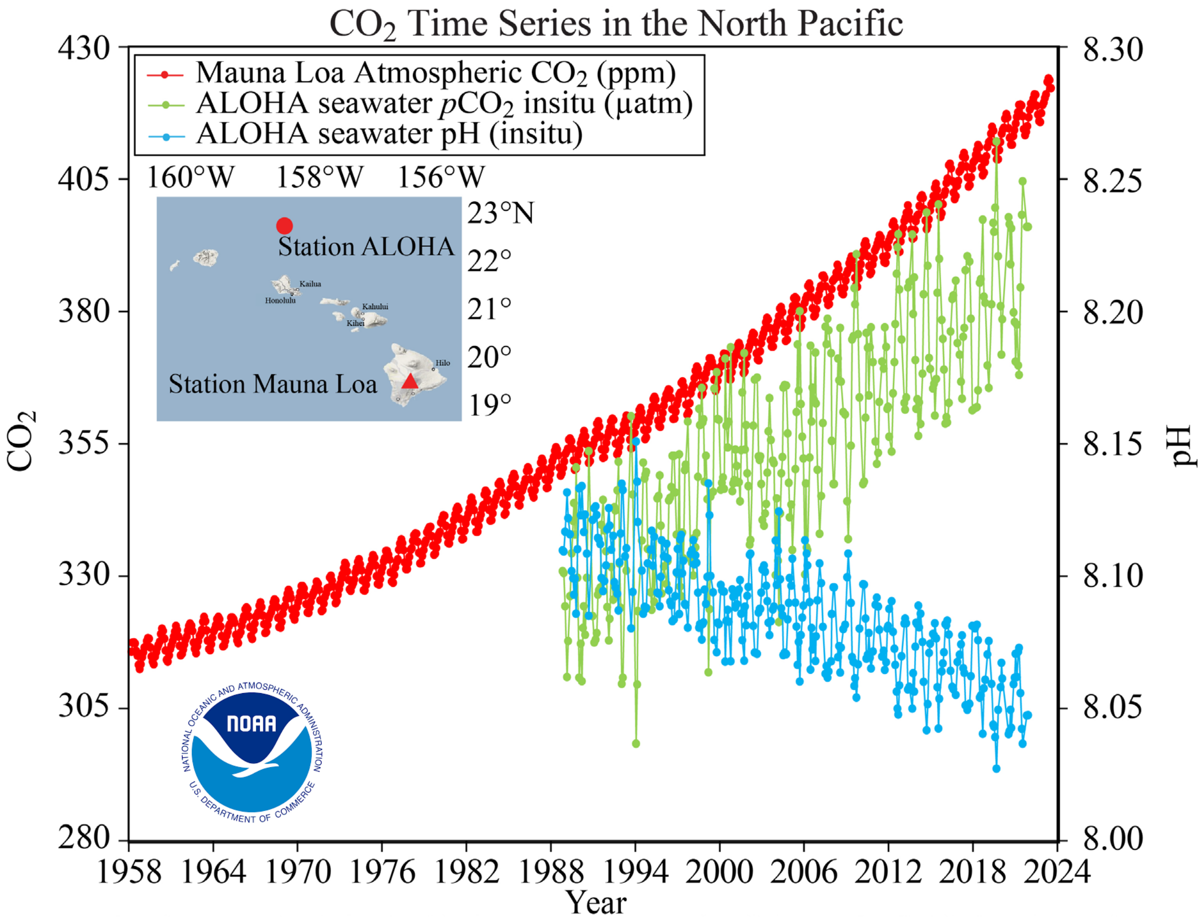
Andrew Lenton
Bronte Tilbrook
Kerryn Brent
Lennart Bach

NATIONAL MARINE SCIENCE COMMITTEE

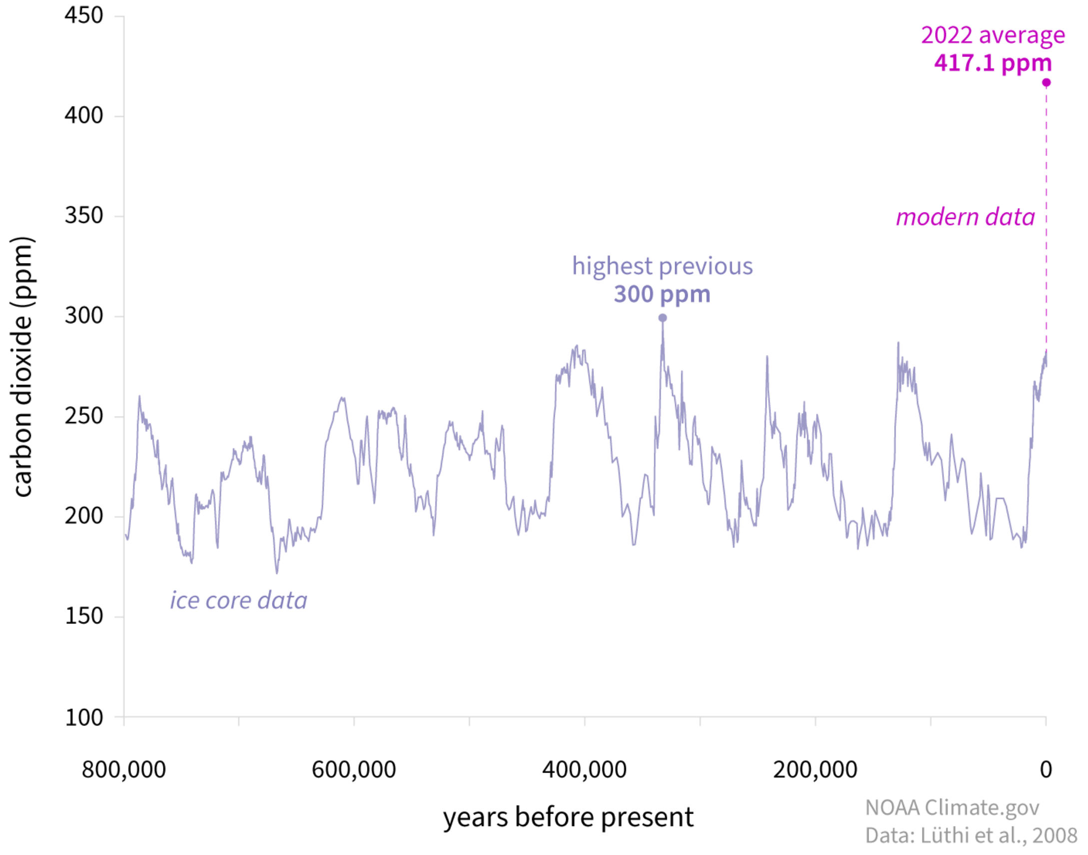
15-20 Sep 2024 | Hobart
AMSA-NZMSS 2024
Navigating uncertainty for a future sustainable ocean

surface ocean solas lower atmosphere study

The Global (Ocean) Carbon Problem



CARBON DIOXIDE OVER 800,000 YEARS



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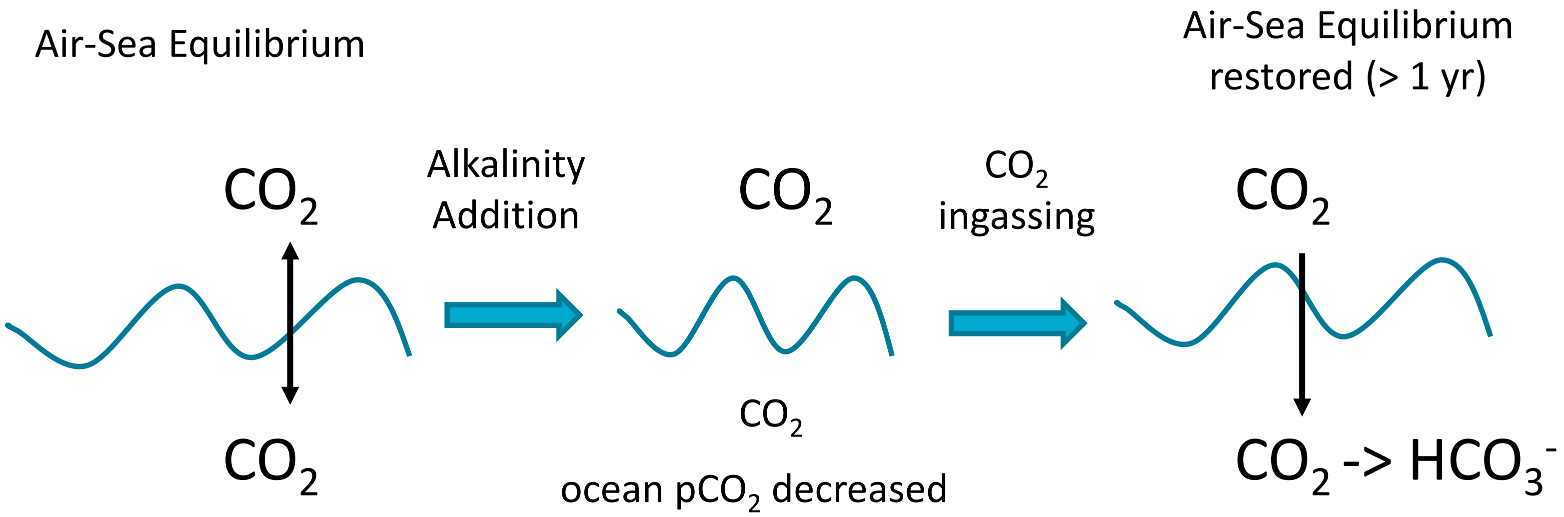
II. Ocean Alkalinity Enhancement (OAE)



This is analogous to the natural process of weathering, which adds (mineral) alkalinity to the ocean regulating atmospheric CO_2 levels over geologic timescales.

CLIMATE CHANGE

Ocean geoengineering scheme aces field test

Alkaline lime powder spread in Florida estuary drew down carbon and reduced acidification

Science, Vol 378, Issue 6626.

WOODS HOLE **OCEANOGRAPHIC** INSTITUTION ABOUT WHOI

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How oceans could be used for carbon capture on a big scale

Dalhousie University researchers take measurements from a boat in Halifax Harbour, after Planetary Technologies added 'antacids' to the water to neutralize dissolved CO2 (a technology called ocean alkalinity enhancement), along with a dye that helps track the dispersion of the antacids. (Planetary Technologies)

PLANETARY

DALHOUSIE UNIVERSITY

CSIRO

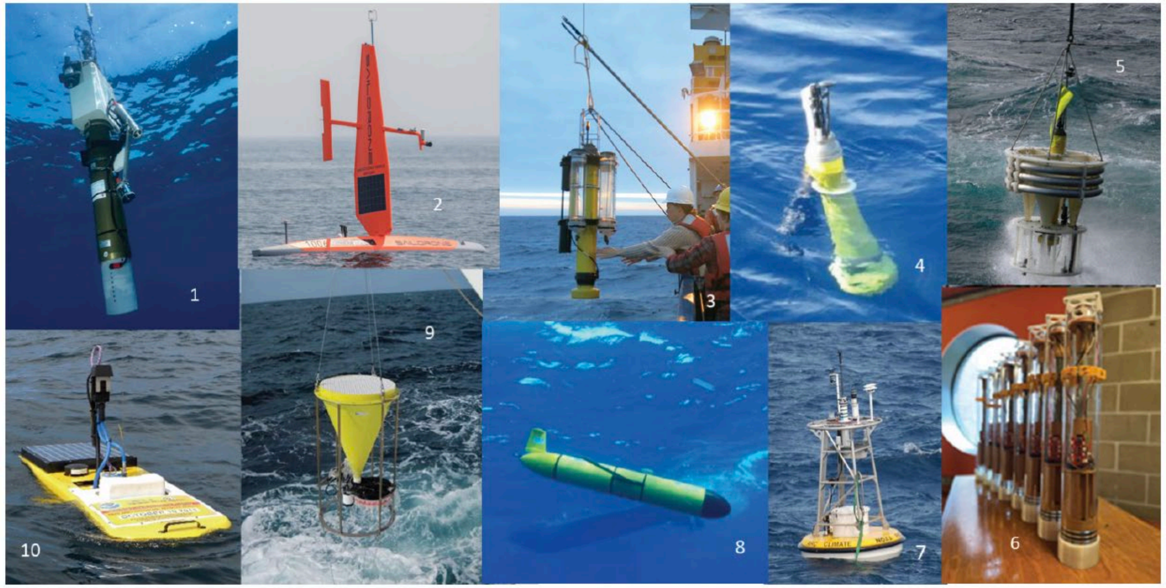
Research and Development Needs

Monitoring and Measurement

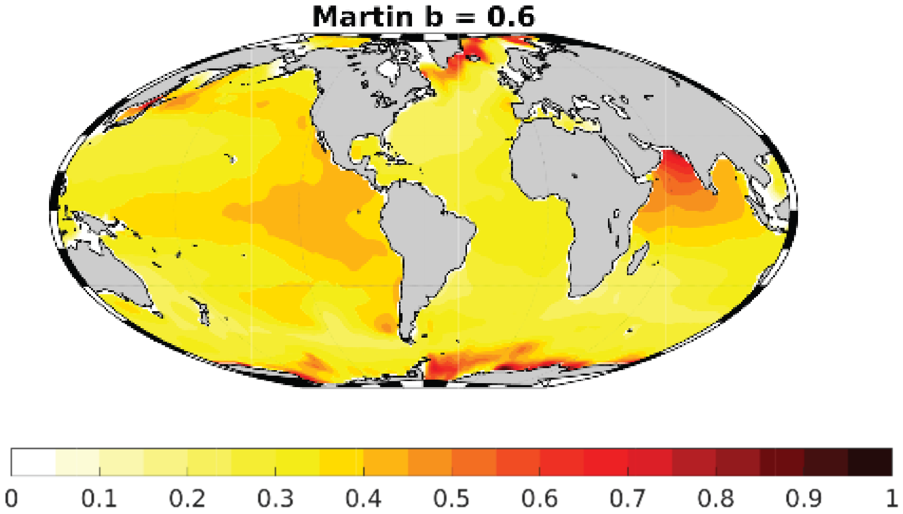
Lifecycle Analysis

Mapping/Planning

Modeling

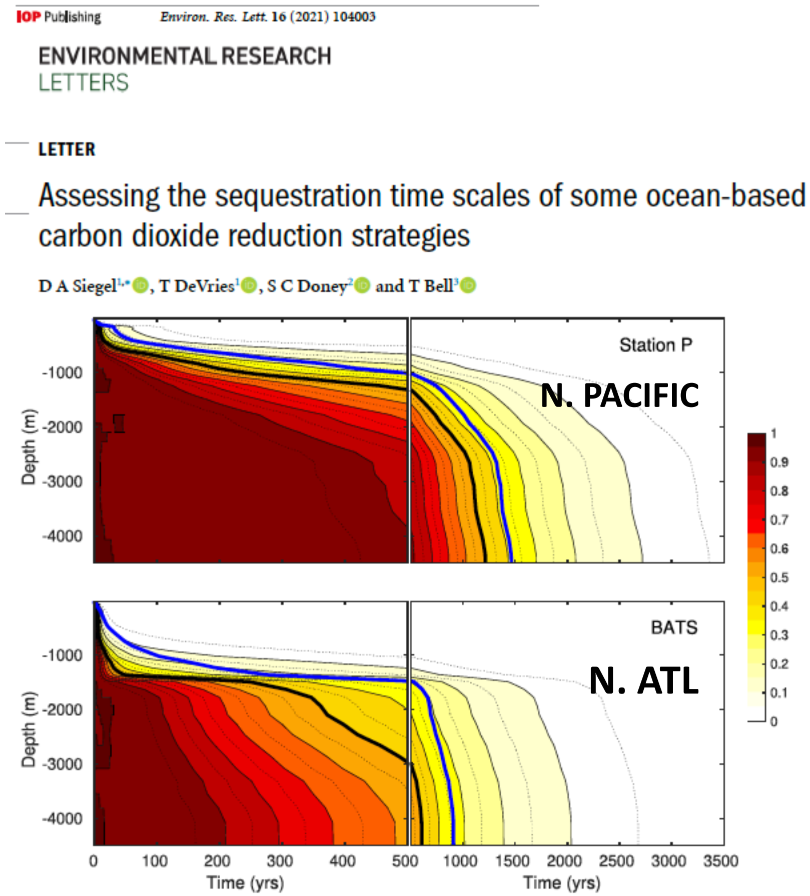


Existing platforms for (carbon) monitoring at sea



Fraction of CO_2 retention for 100yr or more in response to a surface bloom (modified from Seigel et al., 2021)

Southern Ocean (carbon) Observations

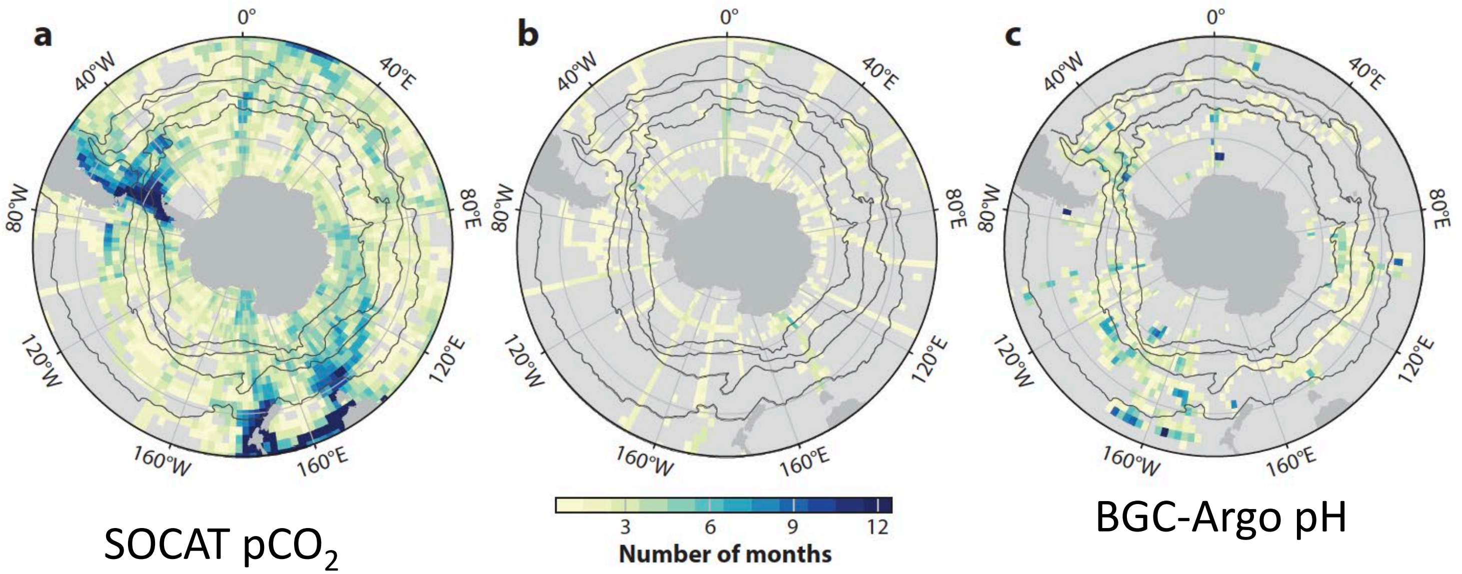


Amount of carbon that remains sequestered as a fraction of time after injection.

Sequestration times are decades to centuries, except for where C is injected to the abyss. Different basins, different sequestration times

GLODAP DIC

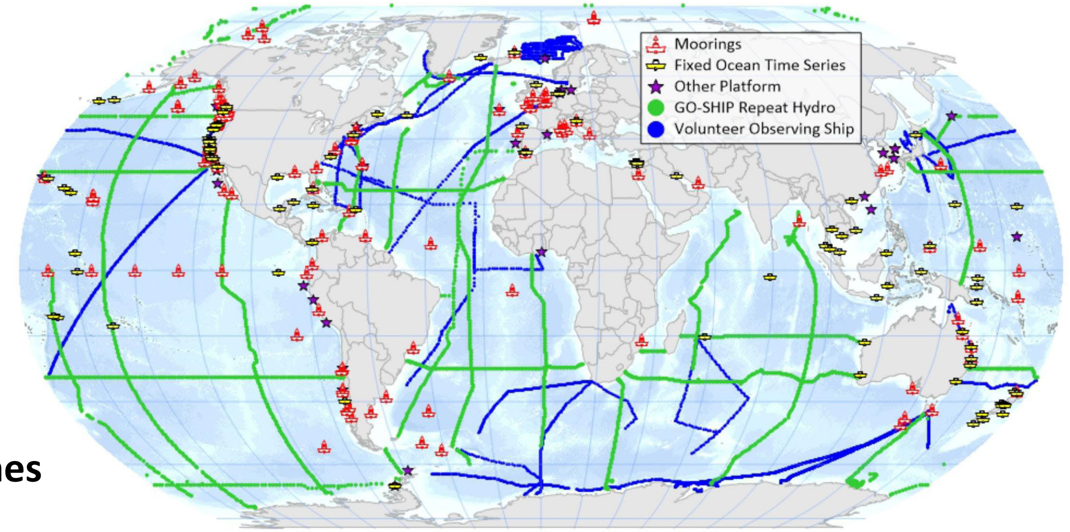
Modified from Gray (2023)



$SOCAT\ pCO_2$

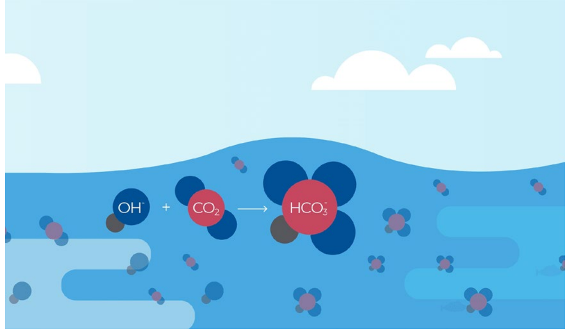
BGC-Argo pH

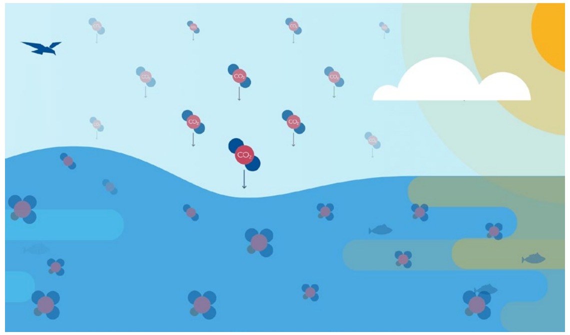
From Tilbrook et al., 2019



Emerging Efforts

ebb carbon





NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

PNNL

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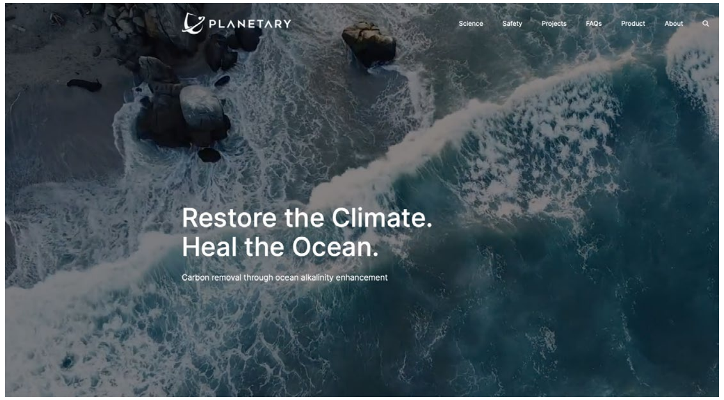
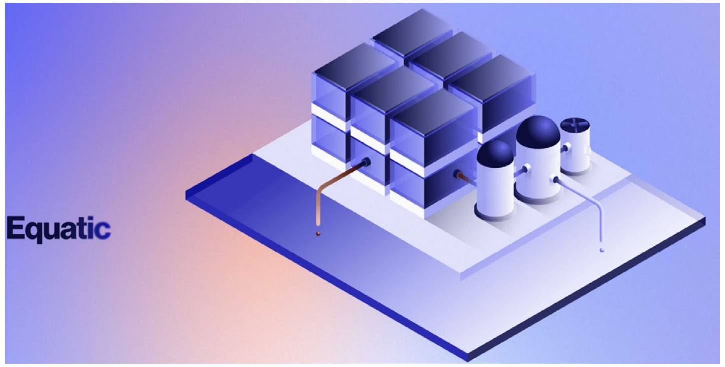
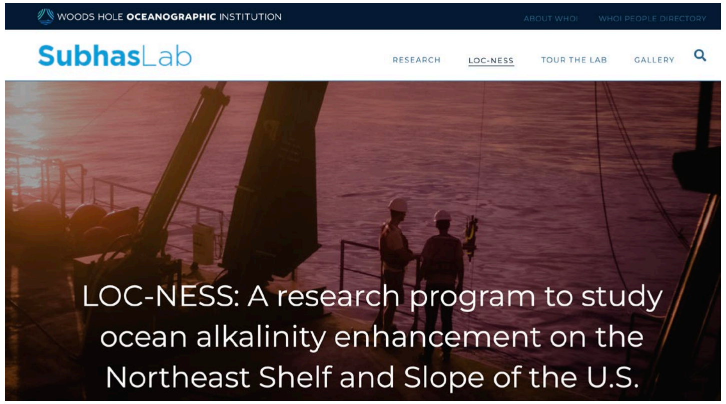
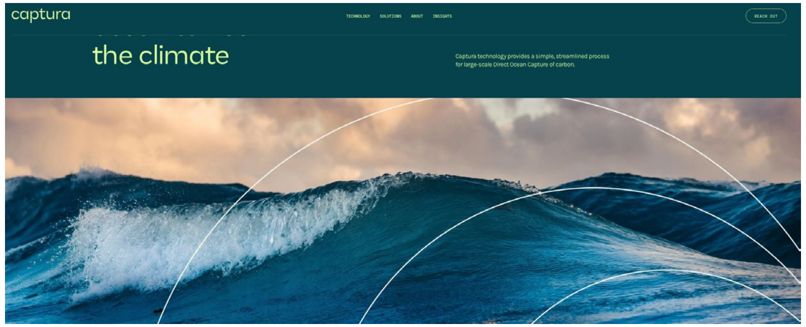
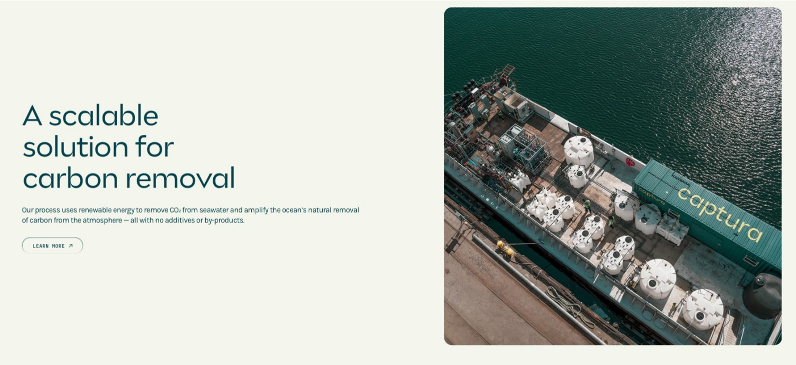










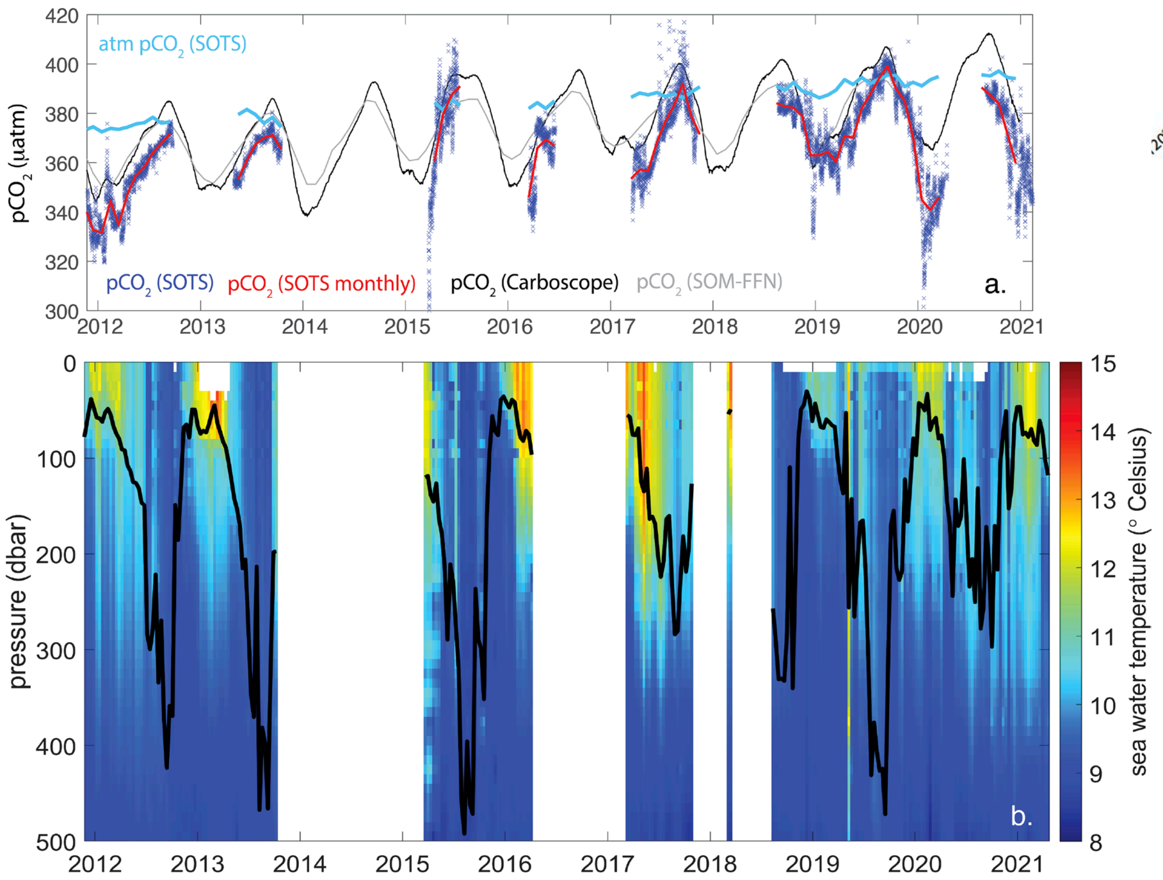
OCEAN NETs

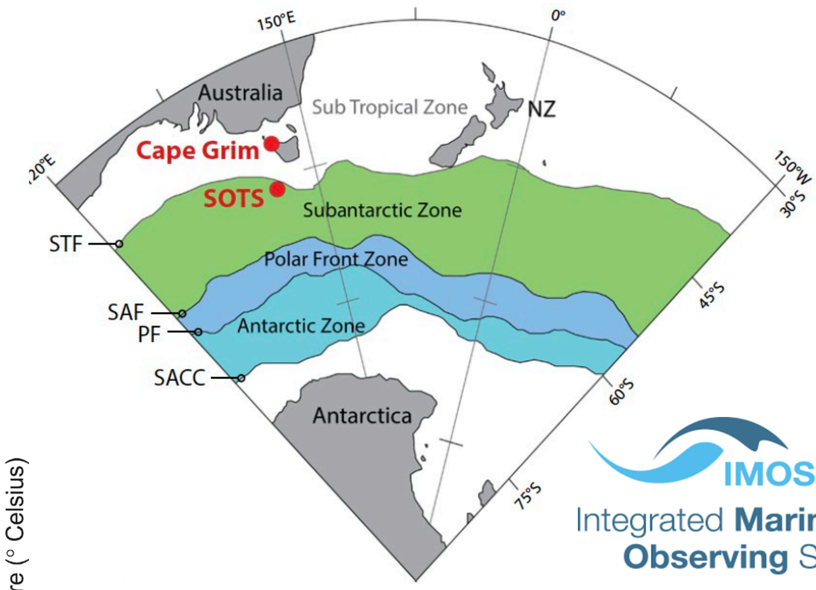
Carbon to Sea Initiative

OCEAN VISIONS

CSIRO

The Southern Ocean Time Series





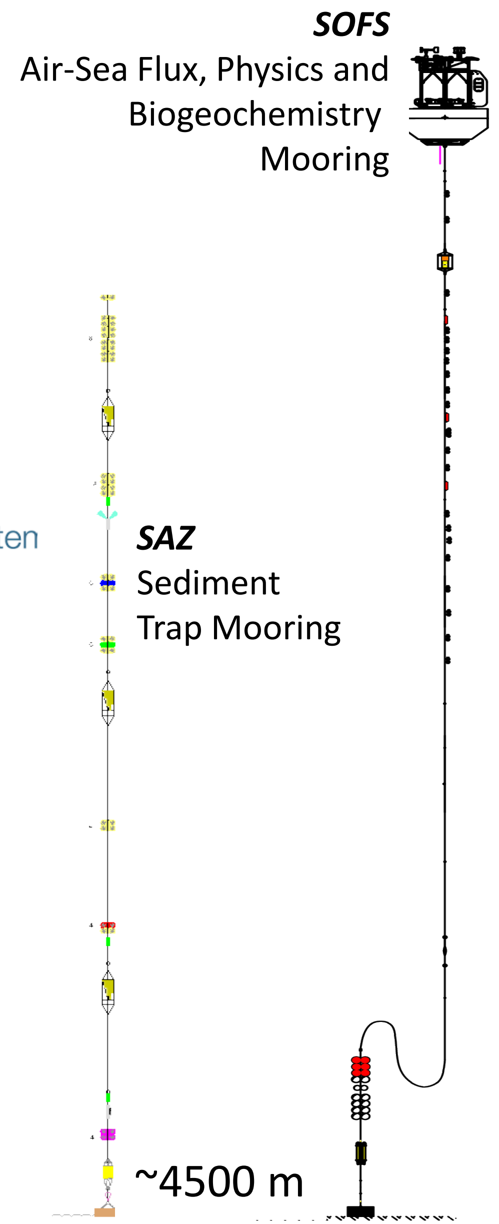
IMOS
Integrated Marine Observing Systen

frontiers | Frontiers in Marine Science

TYPE Original Research
PUBLISHED 13 October 2023
DOI 10.3389/fmars.2023.1281854

Observed amplification of the seasonal CO_2 cycle at the Southern Ocean Time Series

Elizabeth H. Shadwick[1,2]*, Cathryn A. Wynn-Edwards[1,2], Richard J. Matear[1], Peter Jansen[1], Eric Schulz[3] and Adrienne J. Sutton[4]



Australian Antarctic Program Partnership
CSIRO
Australian Government
Bureau of Meteorology