Science, Service, Stewardship

NOAA's Carbon Dioxide Removal Research Interest

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Presented on behalf of the NOAA CDR Task Force

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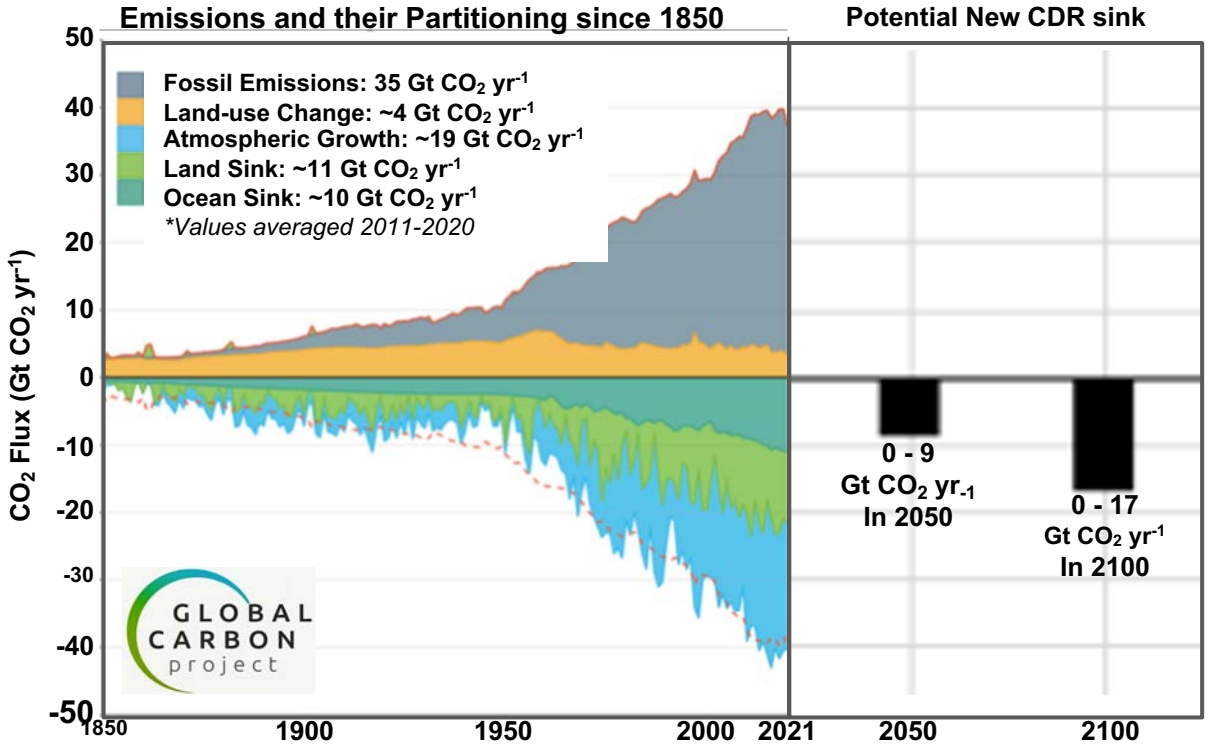
Science at NOAA is the systematic study of the structure and behavior of the ocean, atmosphere, and related ecosystems; integration of research and analysis; observations and monitoring; and environmental modeling…

Service is the communication of NOAA's research, data, information, and knowledge…

Stewardship is NOAA's direct use of its knowledge to protect people and the environment…

NOAA At the Global Scale



From [Friedlingstein et al., 2021]

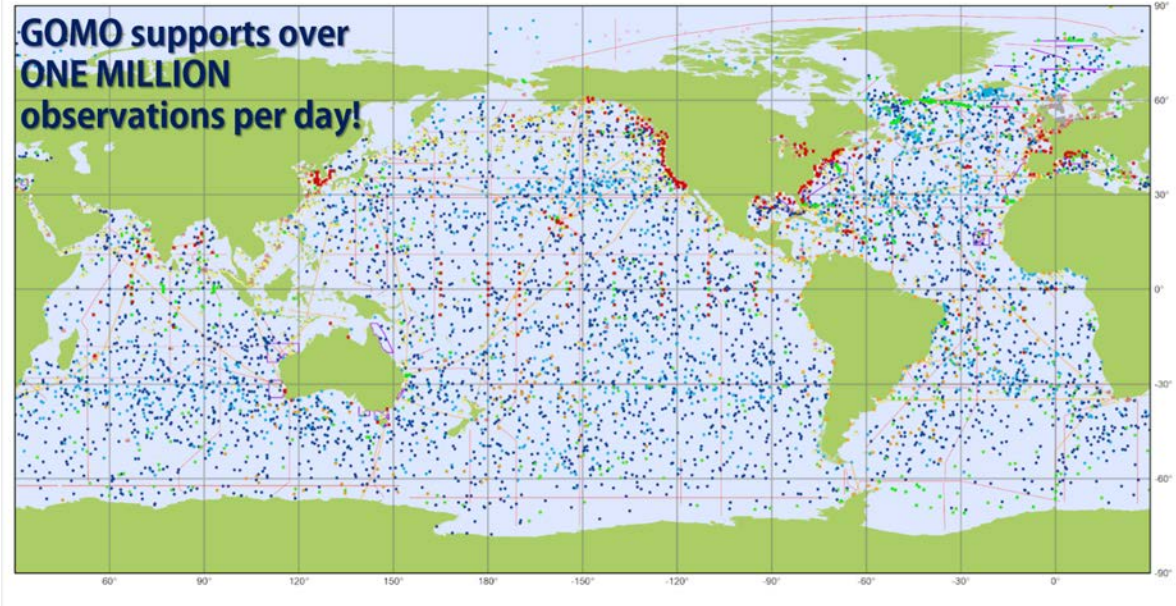
From [Minx et al., 2018]

Mature CDR should be visible on the global scale.

NOAA at the Global Scale

NOAA research collates world-class global and regional carbon measurements. Our **precision carbon observing capacity** is NOAA's most unique and valuable asset for CDR research.

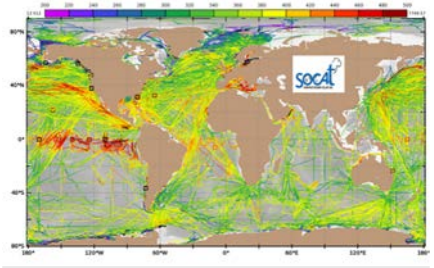
Global Ocean Monitoring and Observing
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

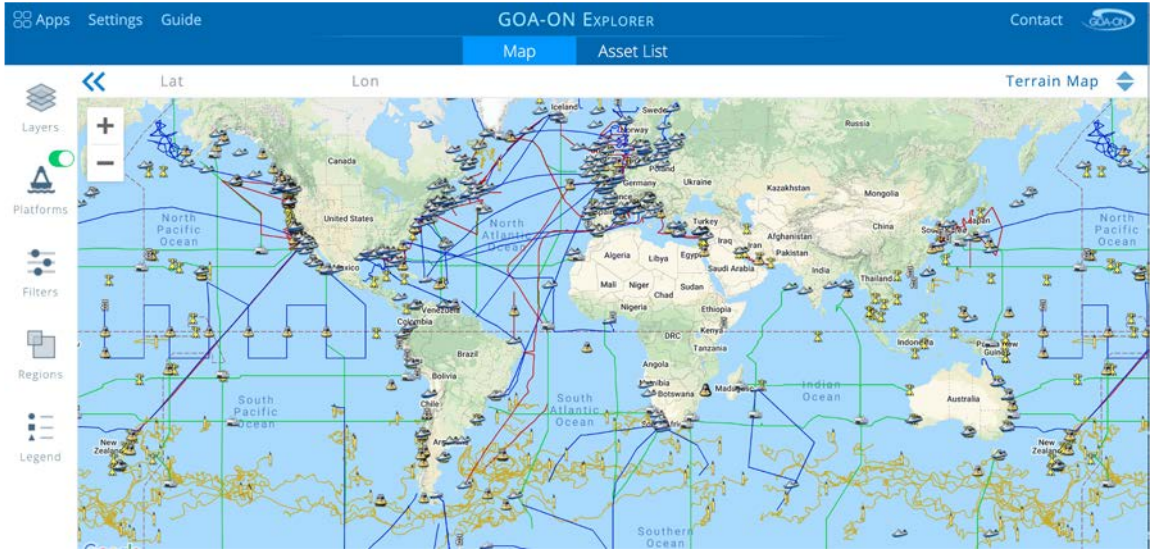


NOAA at the Global Scale

SOCAT
SURFACE OCEAN CO_2 ATLAS

GOA-ON
Global Ocean Acidification Observing Network





NOAA's Global Ocean Carbon Network provides long-term observations of carbon from the sea surface to the ocean interior at a range of spatial and temporal scales.

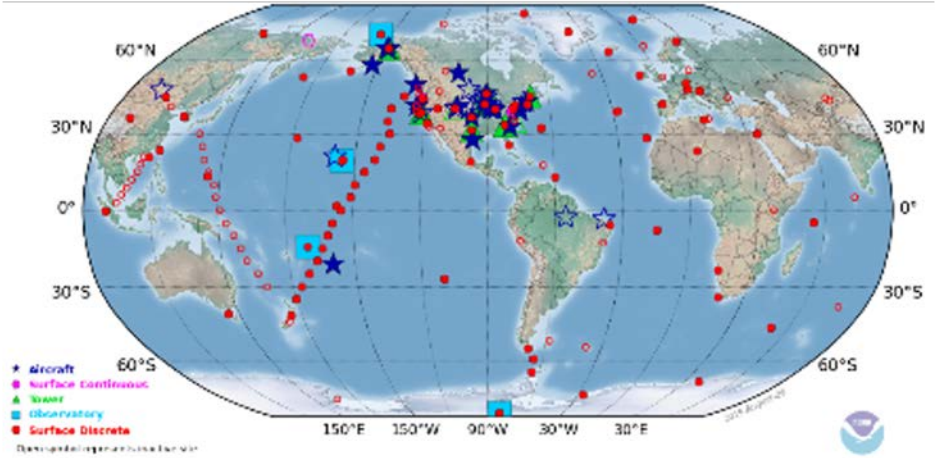
Expanding this network for the scale of CDR will require technology development.

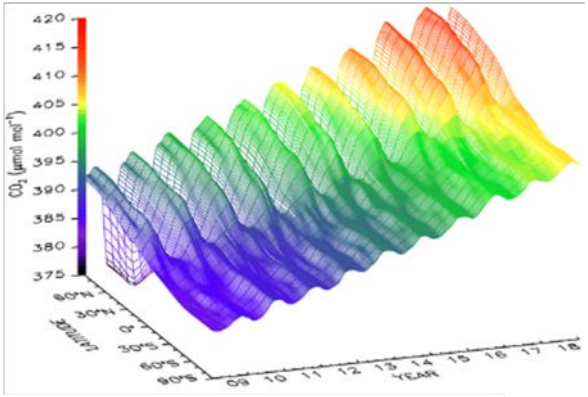
Expanding observing through RDT&E

NOAA builds cost-effective, fit-for-purpose observing systems.

“Fit For Purpose:” A well-defined problem can lead to a revolutionary solution.

Getting to the Local Level





Global Monitoring Laboratory
Earth System Research Laboratories

Virtually everything we know about atmospheric CO_2 comes from the Global Greenhouse Gas Reference Network (GGGRN).

Emission reductions and CDR can be verified with this network.

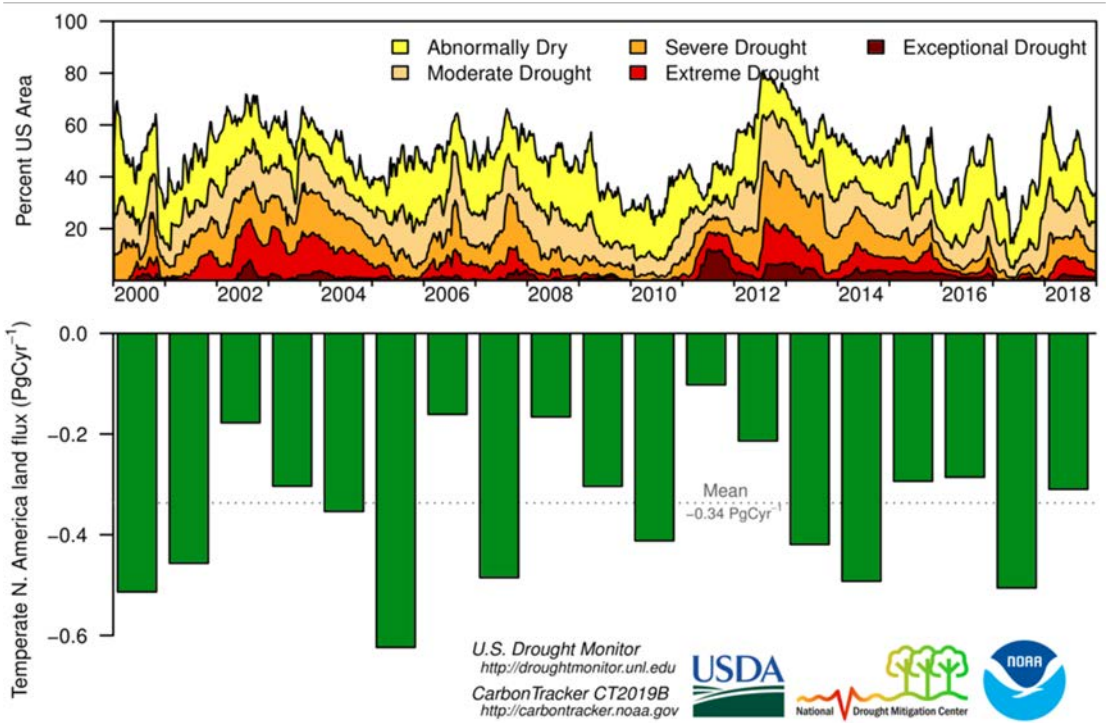
Need to expand the network to provide the granularity needed to detect and assess changes in composition on subcontinental scales.

Local Level Products: Carbon Tracker

Global Monitoring Laboratory
Earth System Research Laboratories

Combined with models, the GGGRN can be targeted to specific sinks.

CarbonTracker uses observations of CO2 in the atmosphere to determine the terrestrial sink.



Local-Level CDR Measurements: Lessons Learned

Carbon Dioxide Removal Via Kelp Farming

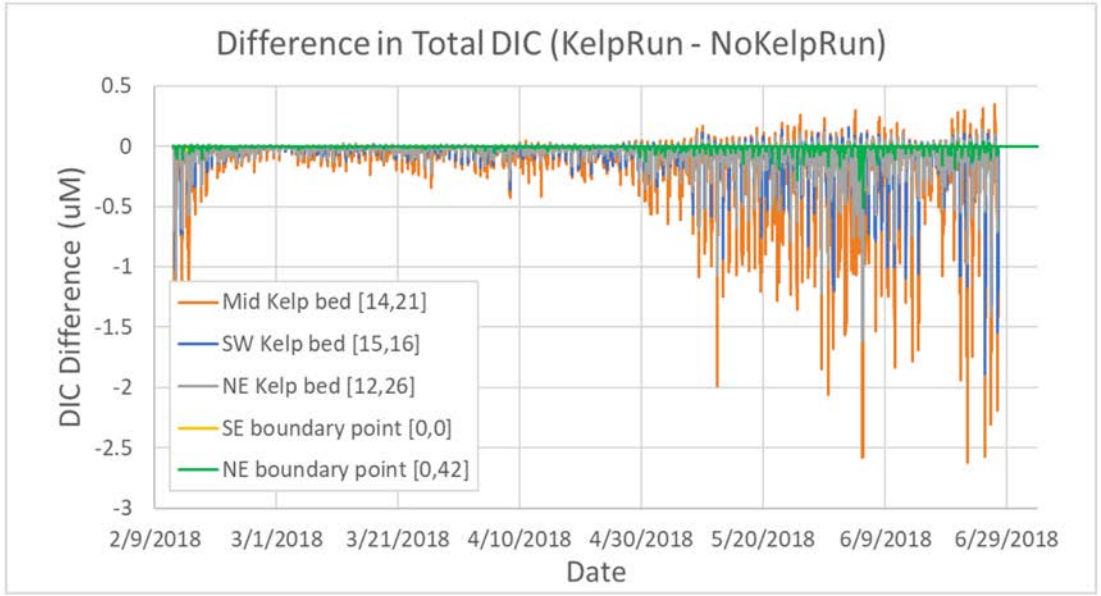


Figure 85. Difference between time series of model output of total DIC of a Year 2 'NoKelp' run and a 'Kelp' run. Plotted lines represent difference in data output from five capture cells.

Peabody et al 2019

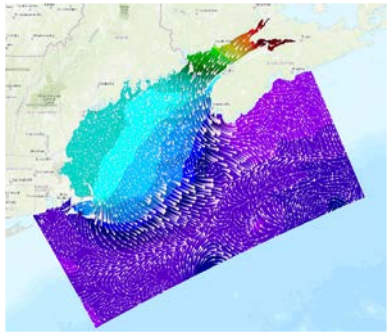
One example of many (PMEL study funded via Paul Allen)

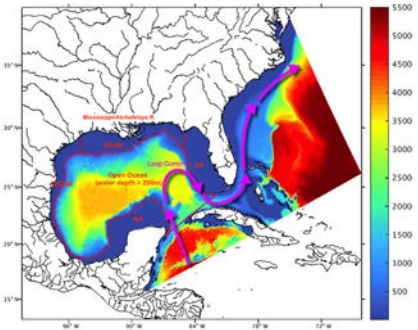
Global and Local Observations are Difficult: Models can help

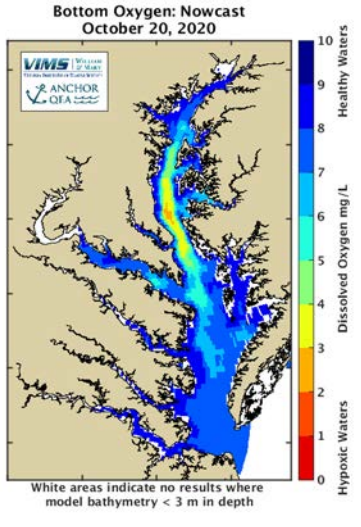
Estimating mCDR efficacy and impacts in the coastal zone will require support from regional modeling efforts.

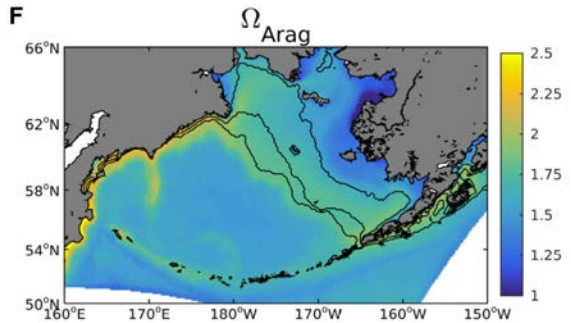
NOAA already supports biogeochemical modeling at the near-coastal zone in many locations.

Pictured here (L-R, top-bottom) are outputs from the Gulf of Maine, Chesapeake Bay, US West Coast, the Gulf of Mexico, and the Bering Sea.



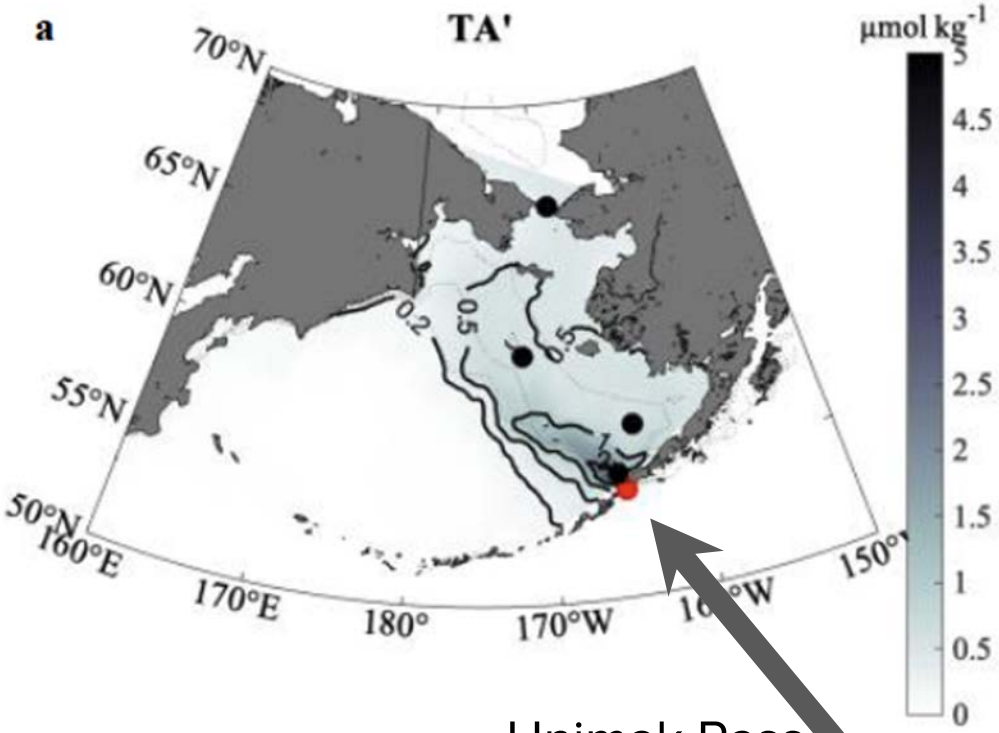






Modeling coastal CDR impacts

In conjunction with our Cooperative Institutes and undergraduate Hollings Scholar program, NOAA is already starting to use these tools to conduct some basic carbon removal projections.



NOAA PMEL Pacific Marine Environmental Laboratory

THE UNIVERSITY OF RHODE ISLAND GRADUATE SCHOOL OF OCEANOGRAPHY

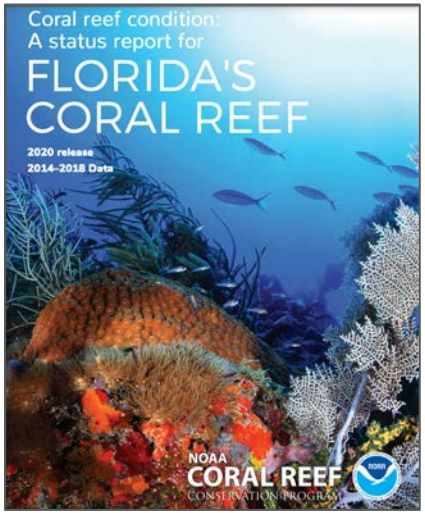
CICOES

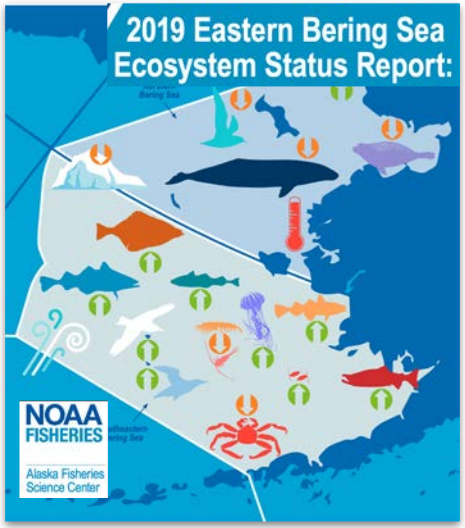
UNIVERSITY OF SOUTH CAROLINA

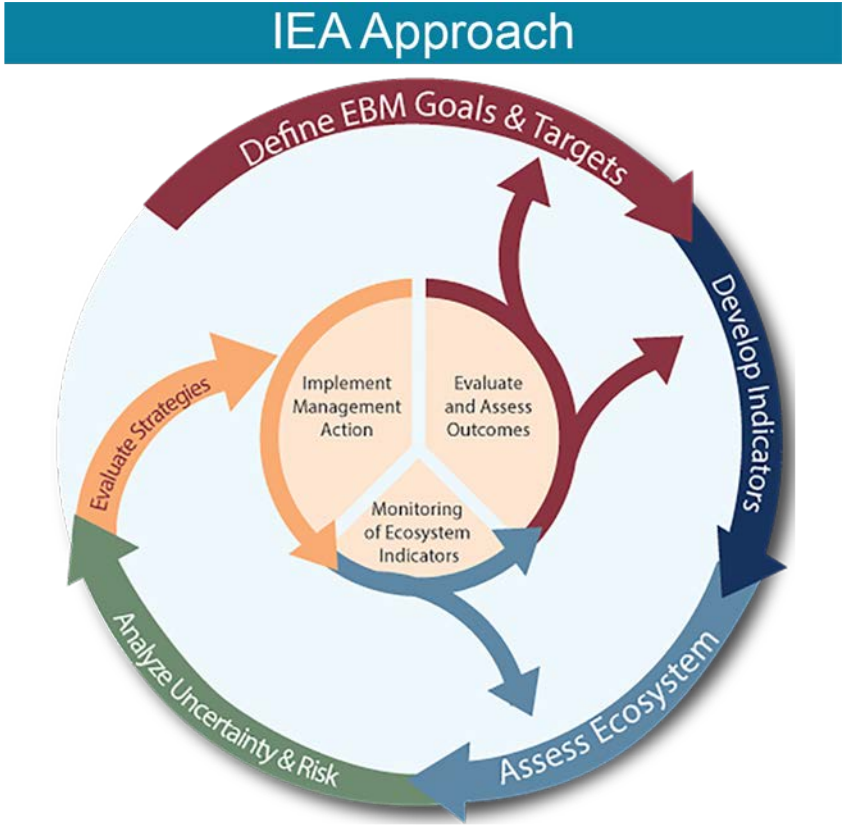
Stony Brook University

Monitoring and modeling ecosystem CDR impacts

NOAA regularly conducts research, monitoring, modeling and forecasting from an **ecosystem assessment** perspective that is critical for understanding potential impacts of CDR techniques.

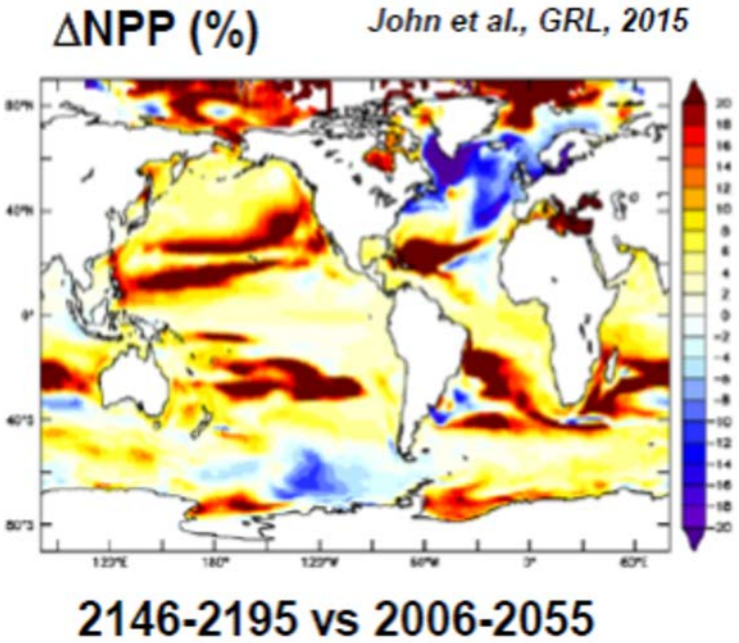






Thinking into the Far Future

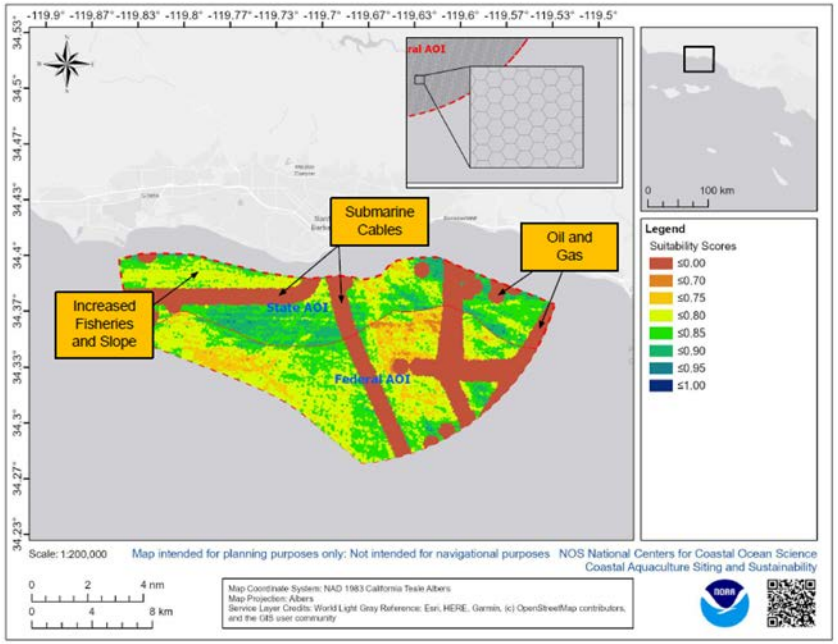
NOAA GFDL Global Modeling Studies explore post-mitigation future



- Marine primary productivity exceeds contemporary values after mitigation
- Legacy subsurface warming increases mixing and enhances surface nitrate

John, J. G., C. A. Stock, and J. P. Dunne (2015), A more productive, but different, ocean after mitigation, *Geophys. Res. Lett.*, 42, 9836–9845, doi:10.1002/ 2015GL066160.

The End Goal: Marine Spatial Planning



NCCOS | NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Evidence-based spatial tools help decision makers explore how to best protect environmental resources and public health, preserve valued habitats, and improve the way communities interact with coastal ecosystems.

- Habitat mapping
- Aquaculture Siting and Sustainability
- Risk Assessment
- Restoration

What does NOAA Need?

- **Scalable** new technologies that can work both on the local scale, and when networked together provide a regional or global picture.
- **Interdisciplinary** systems that explore both the carbon system as well as environmental impacts.
- **Maps** are key**.** Products that can be easily spatially indexed are integral for decision support systems.

Research Pathways for CDR

It is essential that a CDR research strategy include strong relationships with the private sector and with NGOs to accelerate basic and applied research. The Task Force is also scaling up interdisciplinary research opportunities through NOPP that will include multiple agencies, nonprofits, academia, and industry.

We can do more together.

NOPP

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

NSF

Executive Office of the President Office of Science and Technology Policy United States

BOEM Bureau of Ocean Energy Management

NASA

climateworks FOUNDATION

NOAA's Key Assets

Current NOAA Assets		Development Necessary for CDR	Potential Impact of new NOAA CDR Research
Observing Networks	Global Atmospheric and Ocean Observing (e.g., GGGRN; GO-SHIP; Argo; GOAON)	Fill regional gaps; develop deep-sea monitoring network	NOAA continues to verify global Carbon Budget at necessary scales to identify CDR
	Local Atmospheric and Ocean Observing (e.g., CarbonTracker; IOOS RAs; NOA-ON)	Expand to many more sites for comprehensive local-scale monitoring at CDR installations	NOAA verifies, monitors impact of single CDR projects
	Technology Development Programs (e.g., DART; ITAE)	Early investment and partnerships with industry, other agencies	NOAA catalyzes global CDR monitoring and verification potential (e.g., trading accredited offsets)
Modeling, Scaling, and Projection of CDR Pathways	Earth System Models (e.g., CMIP6) and regional models (e.g., ROMS)	New CDR-specific modeling packages	NOAA projects near-term and long-term CDR impacts to identify changes, risks, cobenefits for earth system
	Process study models	Development of virtual "testbeds" for CDR research	NOAA designs quality process studies for investigating the impacts of experimental CDR methods
Environmental Impacts	National ecosystem monitoring programs	Expand to many more sites for comprehensive local-scale monitoring at CDR installations	NOAA verifies, monitors environmental impacts of single CDR projects
	Ecosystem modeling	Modify ecosystem models to evaluate the effect of CDR	NOAA projects impacts of CDR on marine ecosystems
	Laboratory research	Design and implement CDR-specific experimental studies for key species	NOAA identifies environmental risks, cobenefits of single CDR projects
Ocean Planning & Socio-Economic Considerations	Marine Spatial Planning (e.g., NCCOS, OCM)	Apply new CDR knowledge using existing spatial planning tools	NOAA resolves use conflicts, enhances decision support for CDR implementation requests
	Aquaculture Research, Development, and Policy	Development of sustainable farming methodology; expanded permitting support	NOAA maximizes sustainable coastal marine services
	Collaborative Research and Stakeholder Engagement (e.g., SeaGrant)	Improve pathways for stakeholder participation in NOAA CDR Research	Research reflects stakeholder needs
	Blue Carbon Conservation (e.g., CCAP)	Fill local gaps; conserve existing natural carbon storage sinks	NOAA protects and restores existing natural carbon sinks

NOAA's expertise and infrastructure can advance ocean and land CDR science from multiple perspectives– and on multiple scales.

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RESOURCES:

- **Review Article of ocean CDR:** https://www.frontiersin.org/articles/10.3389/fclim.2020.575716/full
- National Academies Studies
  - General CDR (completed): https://www.nationalacademies.org/our-work/developing-a-research-agenda-for-carbon-dioxide-removal-and-reliable-sequestration
  - Ocean Specific (ongoing): https://www.nationalacademies.org/our-work/a-research-strategy-for-ocean-carbon-dioxide-removal-and-sequestration
- EFI Reports:
  - https://energyfuturesinitiative.org/efi-reports
    - 2019: "Clearing the Air: A Federal RD&D Initiative and Management Plan for Carbon Dioxide Removal Technologies"
    - 2021: "Accelerating Underexplored Solutions to the Climate Crisis"
- CDR Primer: https://cdrprimer.org/
- OceanVisions roadmaps: https://www.oceanvisions.org/task-force-ocean-cdr
- Columbia Law database: https://cdrlaw.org/