MBARI's Coastal Profiling Float: Progress, Science Opportunities and Tech Transfer

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NOAA/PMEL 2024 May 16

Photo: Lori Eanes/Monterey Bay Aquarium

Executive Summary

- **MBARI is finishing the development of a coastal profiling float (CPF) system targeted at better understanding the health of the ocean**

Photo: Lori Eanes/Monterey Bay Aquarium

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- **The CPF is optimized for use in the coastal zones and upper 350 meters of the world's oceans: "where the bugs are"**
  - And can anchor and de-anchor on the bottom

Photo: Lori Eanes/Monterey Bay Aquarium

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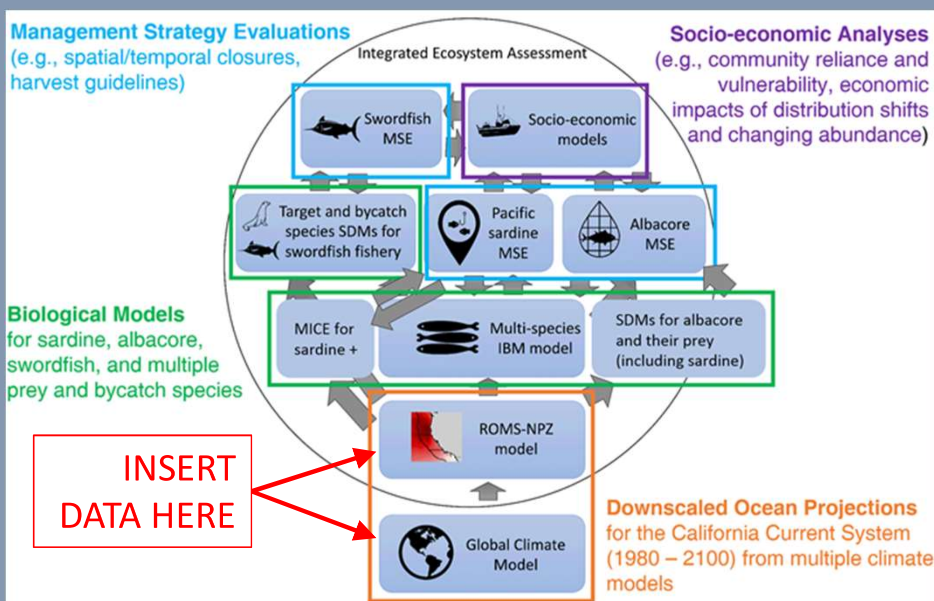
- The CPF supports the GO-BGC suite of biogeochemical sensors: CTD, Oxygen, pH, Nitrate, Fluorescence, Backscatter, Optical Radiation and others
- **We are discussing ways to move the CPF technology out to the greater community**
  - **This seminar, and any follow-up, is part of the conversation**

Photo: Lori Eanes/Monterey Bay Aquarium

NOAA Future Seas



The Initial Motivation

"the widespread pattern of low returns along the West Coast for two species of salmon indicates an environmental anomaly occurred in the California Current in 2005"

A More Current Motivation

[A model based approach] To evaluate the impacts of climate change on US-managed marine species and identify climate-resilient management strategies.

The New Arctic

NSF'S 10 BIG IDEAS

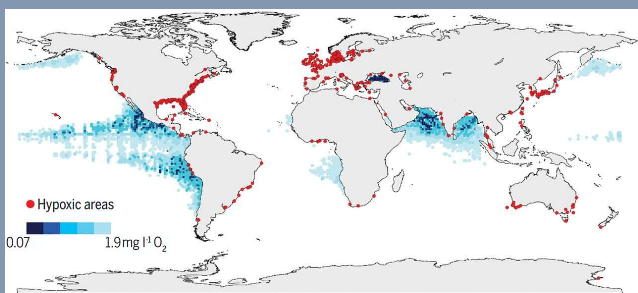
Navigating the New Arctic

"Current Arctic observations are sparse and inadequate for enabling discovery or simulation … to assess their impacts on the broader Earth system"

And Lots More Applications

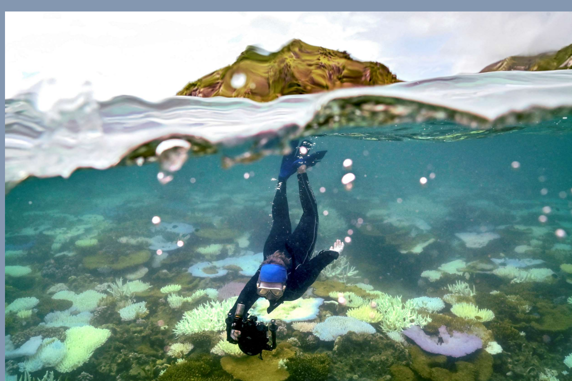
Can we clean up, stop, or end harmful algal blooms?

https://oceanservice.noaa.gov/facts/hab-solutions.html



Ocean scientists call for global tracking of oxygen loss that causes dead zones

Declining oxygen in the global ocean and coastal waters, Denise Breitburg, et.al, SCIENCE, 5 Jan 2018, Vol 359, Issue 6371 https://www.science.org/doi/10.1126/science.aam7240



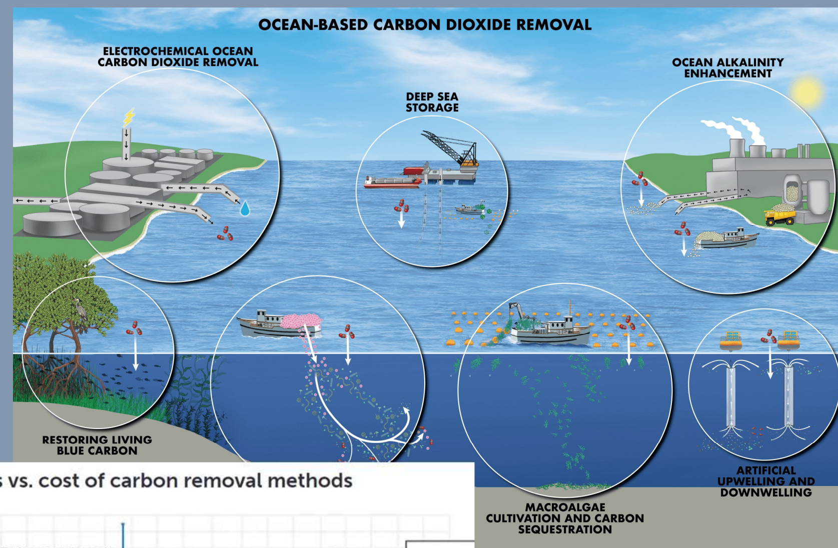
Increasingly Frequent Ocean Heat Waves Trigger Mass Die-Offs of Sealife, and Grief in Marine Scientists

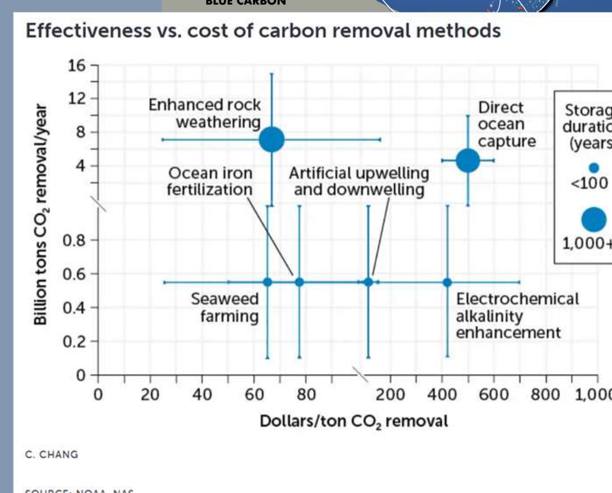
https://insideclimatenews.org/news/01052024/ocean-heat-waves-killing-sealife/

Measurement, Reporting and Validation for mCDR

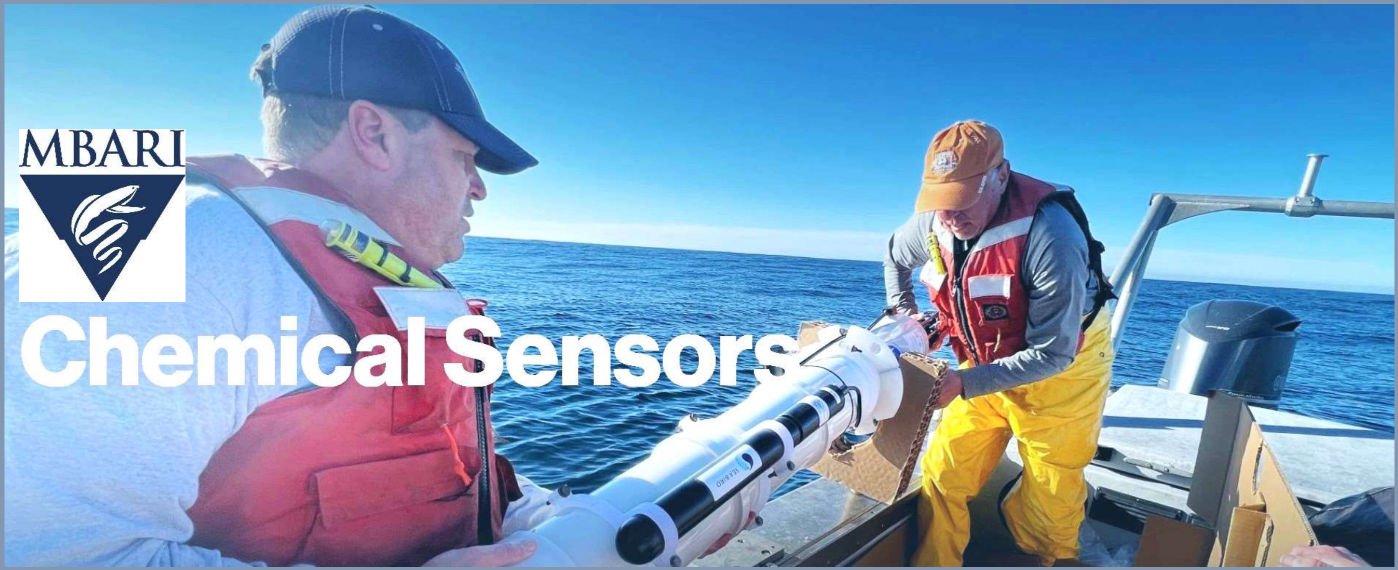
Interesting Conversations

- What are you trying to do?
  - What variables?
  - What spatial scale?
  - What temporal scale?
  - How's the data processed?
  - What's the budget?
- Is it only about quantifying the amount of carbon removed?
- Is it equally, more or less concerned with the effect on the ecosystem?
- Is modelling all that's required now or in the future?





Science News
April 26, 2024

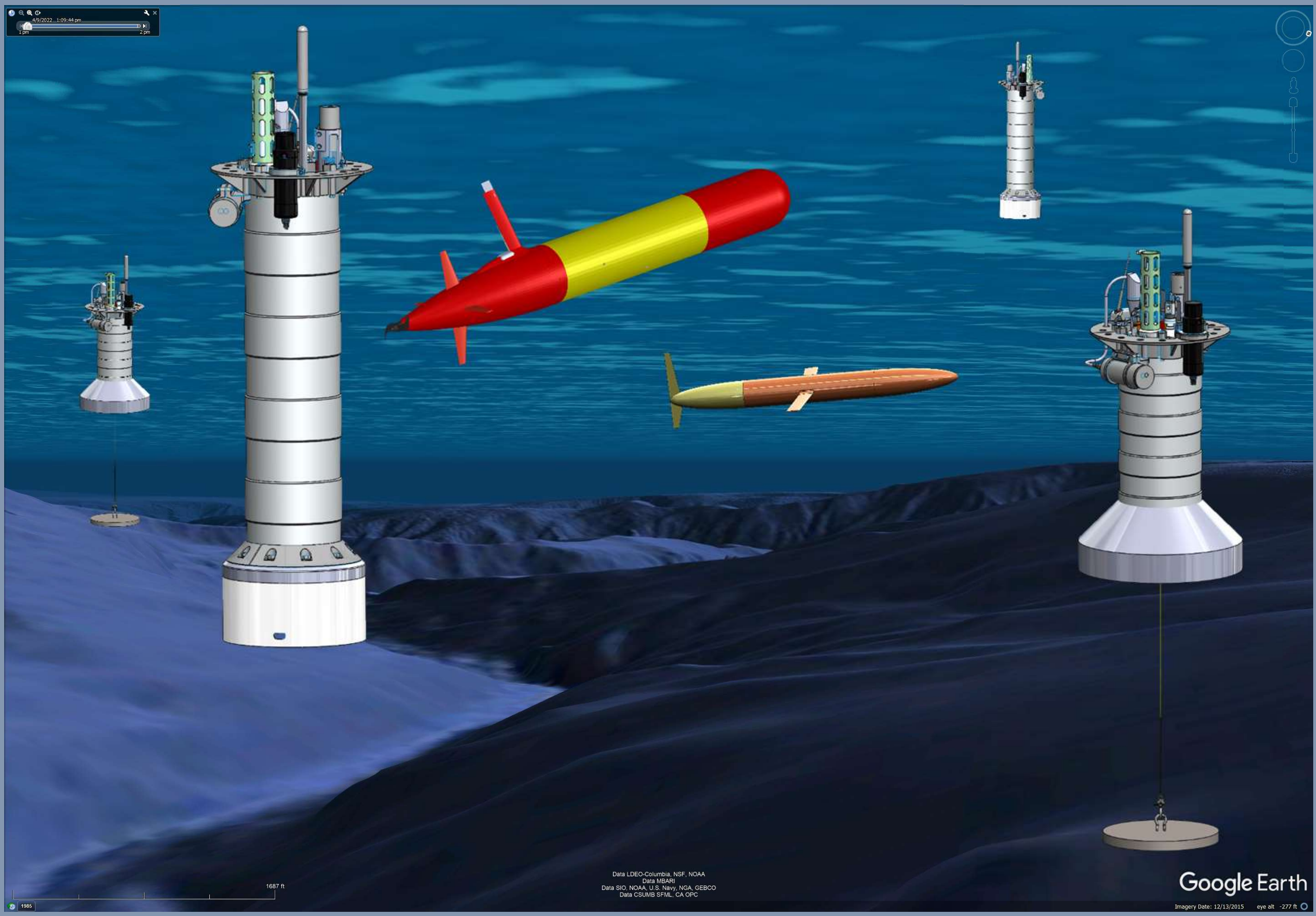


- We develop sensor and float technologies to record fundamental ocean properties
- Our research target is “understanding the health of the ocean”
- THE pH and Nitrate sensors we developed are COTS products
- We are heavily involved in the SOCCOM and GO-BGC projects
  https://soccom.princeton.edu/ https://www.go-bgc.org/

Why Profiling Floats?

- Arguably the most cost effective observing platform for long-term, ecosystem scale applications
  - Capital cost: ~$90K per BGC float
  - Deployment costs: Almost any boat or ship of opportunity that can get to the deployment site
  - Maintenance cost: Near $0 for 5-7 years
  - On-going operations costs: Almost entirely data processing

Profiling Float Array + Friends



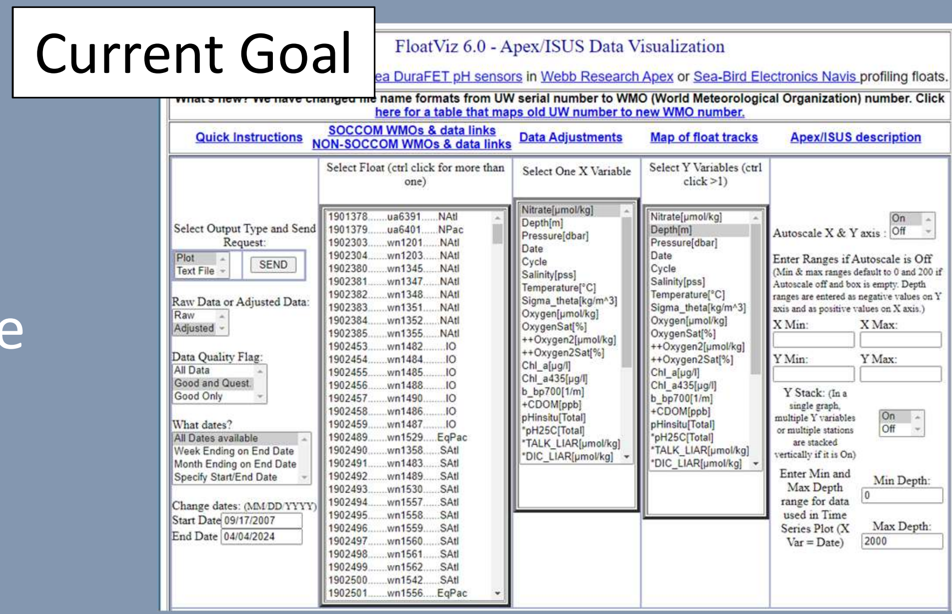
The CPF Data Pipeline

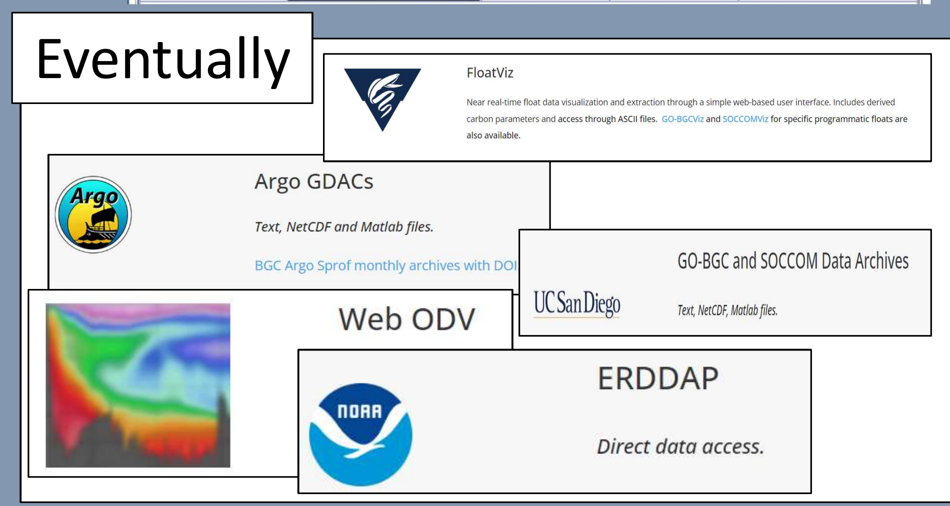
It's The ~~Economy~~ DATA, Stupid

(apologies to James Carville)

- Our "deliverable" is relevant, defensible data products
- Luckily, part of our lab is very involved in the Argo-BGC data processing and QC pipeline
- The CPF generates files that can feed the GO-BGC data pipeline

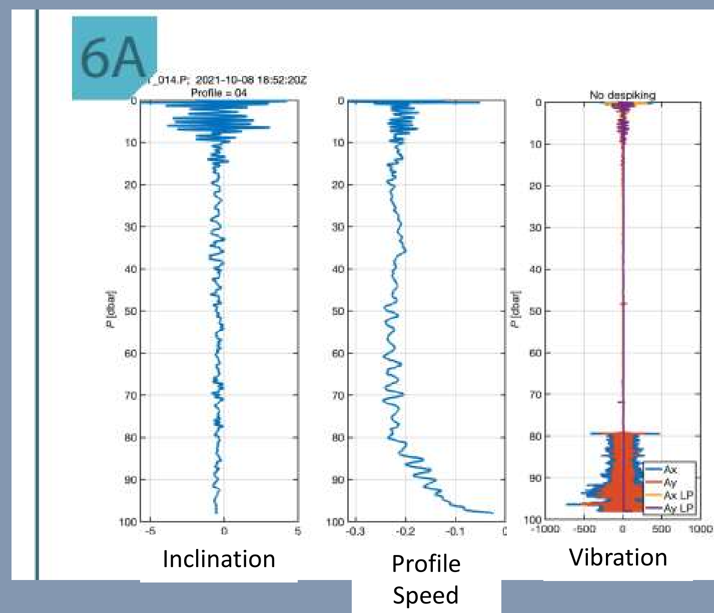
https://www.go-bgc.org/data/access-and-visualization#float-data-access

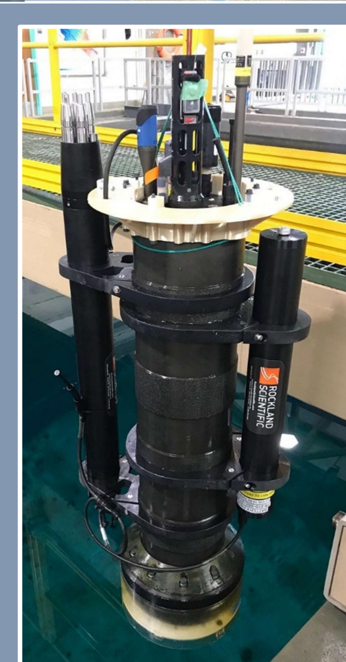




“Other” Science

- Can we infer vertical mixing rates from Argo float ascent rates?
- Use a CPF with turbulence sensor to acquire high quality turbulence data
- See if similar results can be achieved with standard BGC sensors



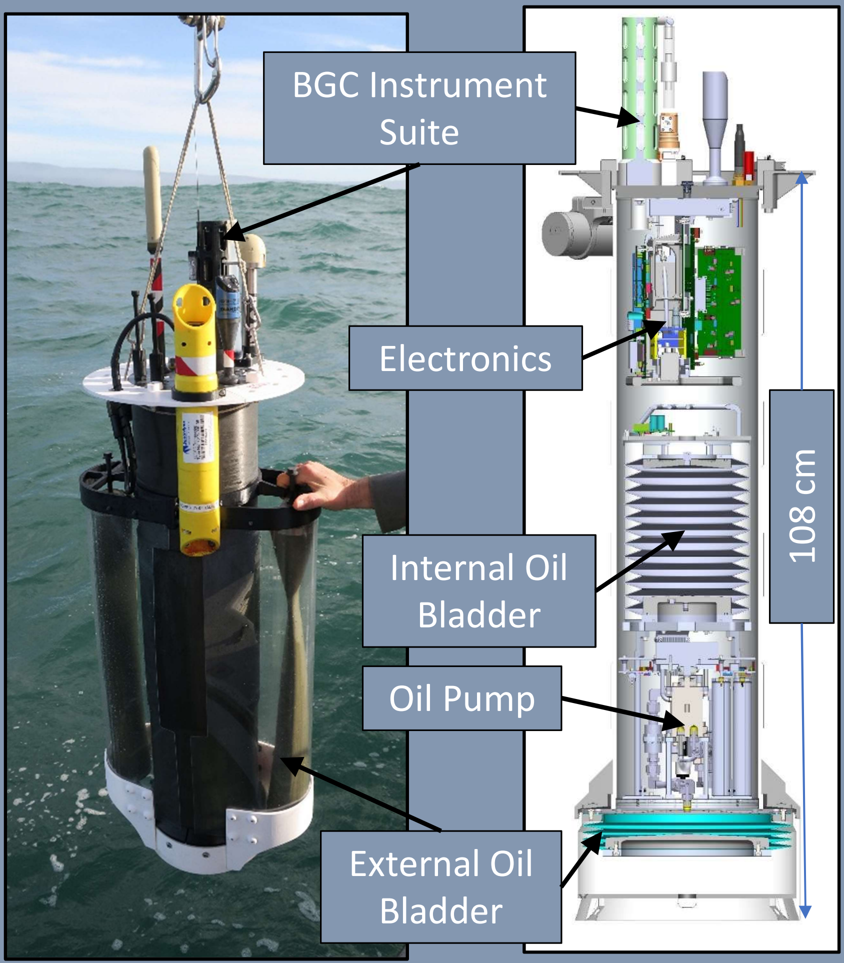


Magdalena M Carranza(1), Gene Massion, Yui Takeshita and Ken Johnson; Presented at the Gordon Research Conference on Ocean Mixing, Mount Holyoke, MA June 5-10 2022

The CPF

CPF Functionality

- **Depth range = 0 to 350 meters**



Lots of Volume Change

- Depth range = 0 to 350 meters

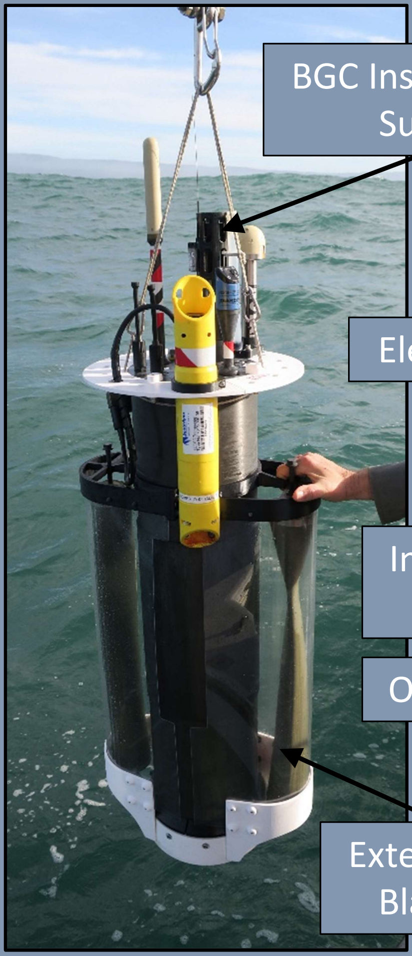
- **Buoyancy engine $\Delta V/V$ = 3.5 liters / 40 liters = 9%**
  - **Profile from freshwater thru 35 psu = 2.5%**
  - **Vertical velocity = zero to ~40 cm/sec**
  - **Ability to anchor and de-anchor**
  - **Reserve buoyancy to offset biofouling-mud buildup**
  - **Easy ballasting**

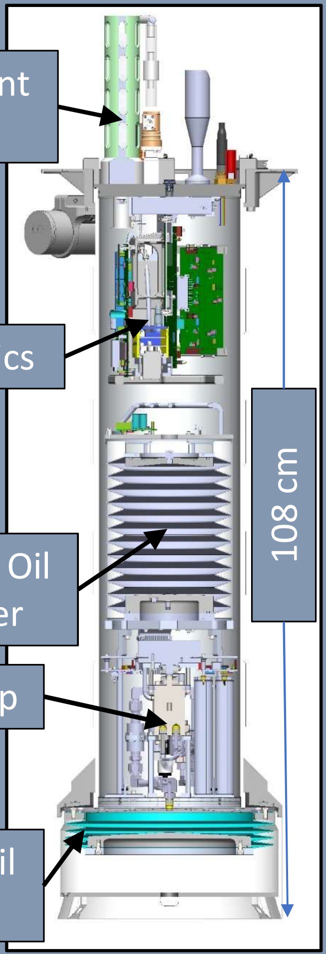
Pickup Truck of the Sea

- Depth range = 0 to 350 meters
- Buoyancy engine ΔV/V = 3.5 liters / 40 liters = 9%
- **Sample recovery** **CPF**
  - **2X Sediment Traps**
  - **Acoustic Modem**

Lots of Instruments

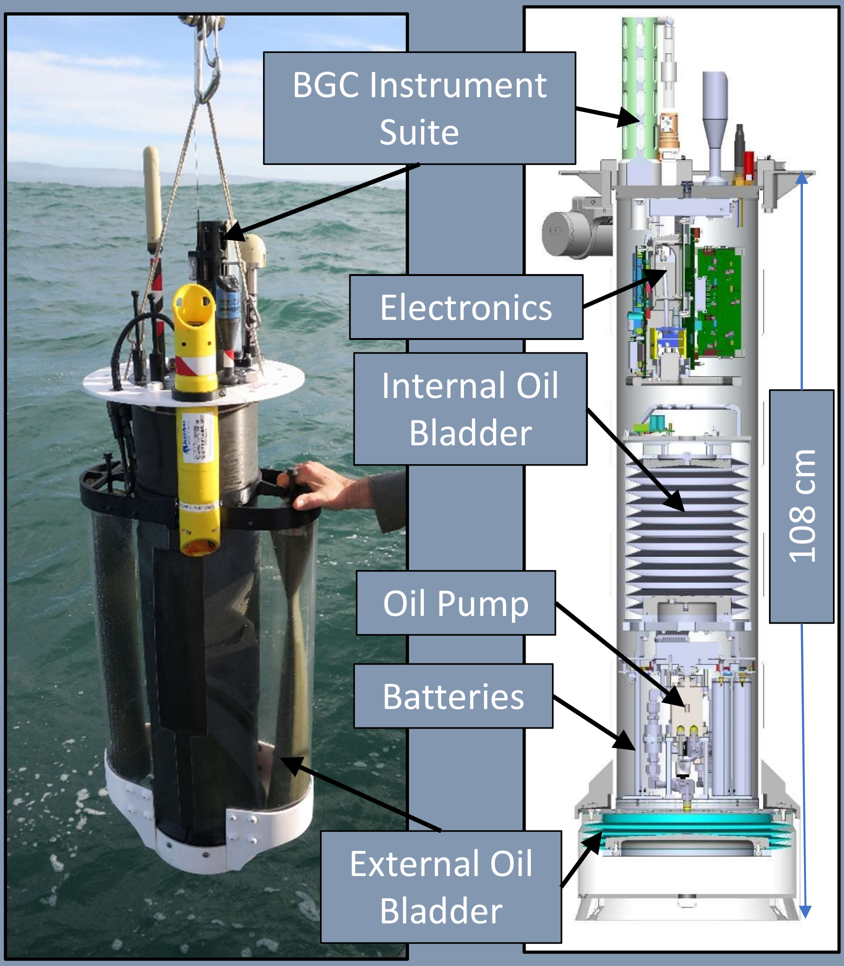
- Depth range = 0 to 350 meters
- Buoyancy engine ΔV/V = 3.5 liters / 40 liters = 9%
- Sample Recovery
- **Science Payload = 9 sensor ports**
  - **6 BGC sensors**
  - **Room for 3 more**





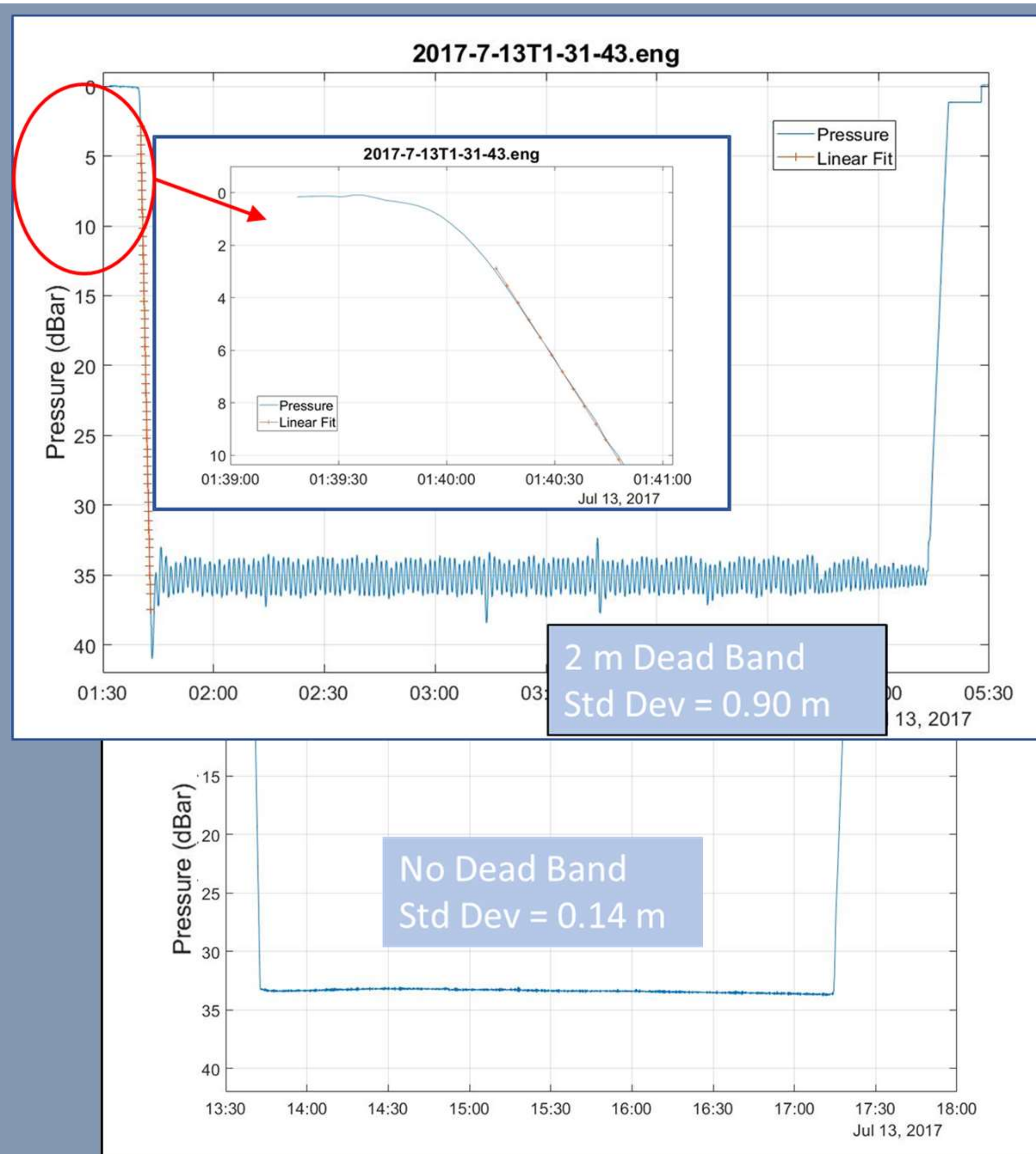
Current CPF Version 2.1 and 2.2

- Depth range = 0 to 350 meters
- Buoyancy engine $\Delta V/V$ = 3.5 liters / 40 liters = 9%
- Sample Recovery
- Science Payload: 9 sensor ports: 6 BGC sensors plus 3 available ports
- **Iridium SBD and (soon) RUDICS communications**



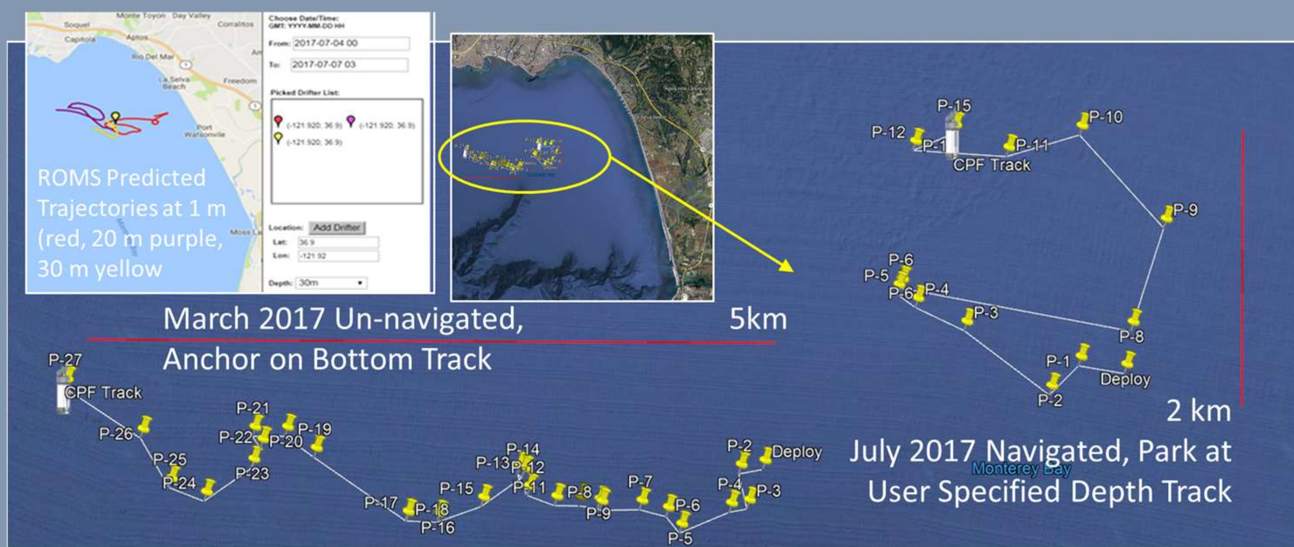
Good Platform Velocity and Depth Control

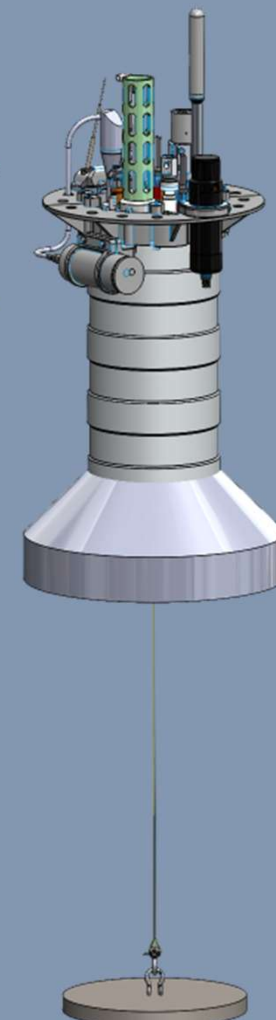
- Depth range = 0 to 350 meters
- Buoyancy engine $\Delta V/V$ = 3.5 liters / 40 liters = 9%
- Sample Recovery
- Science Payload: 9 sensor ports: 6 BGC sensors plus 3 available ports
- **Accurate, closed loop platform velocity and depth control**



Current and Future Work

- Have to do (this year)
  - Finish the power management
    - Goal = 200X 200m profiles over 1 year
  - Finish Iridium RUDICS comms
  - Finish building CPF002 and CPF003
  - Run more MBARI science missions with the FloatViz data pipeline
- Like to do
  - Winched version for non-Lagrangian applications
  - Inertial current meter for float "navigation"
  - Tech transfer





CPF Status Summary

- 1 CPF with dozens of science and engineering missions in Monterey Bay, some with only modest engineering involvement
- 2 CPFs nearing completion, operational Q4 2024
- Data pipeline demonstrated
- 2 early CPF prototypes used routinely by MBARI's BOG group
- 1 BOG CPF being re-purposed for Colleen Durkin's carbon export work

TRL 7 → TRL 8

TRL 9

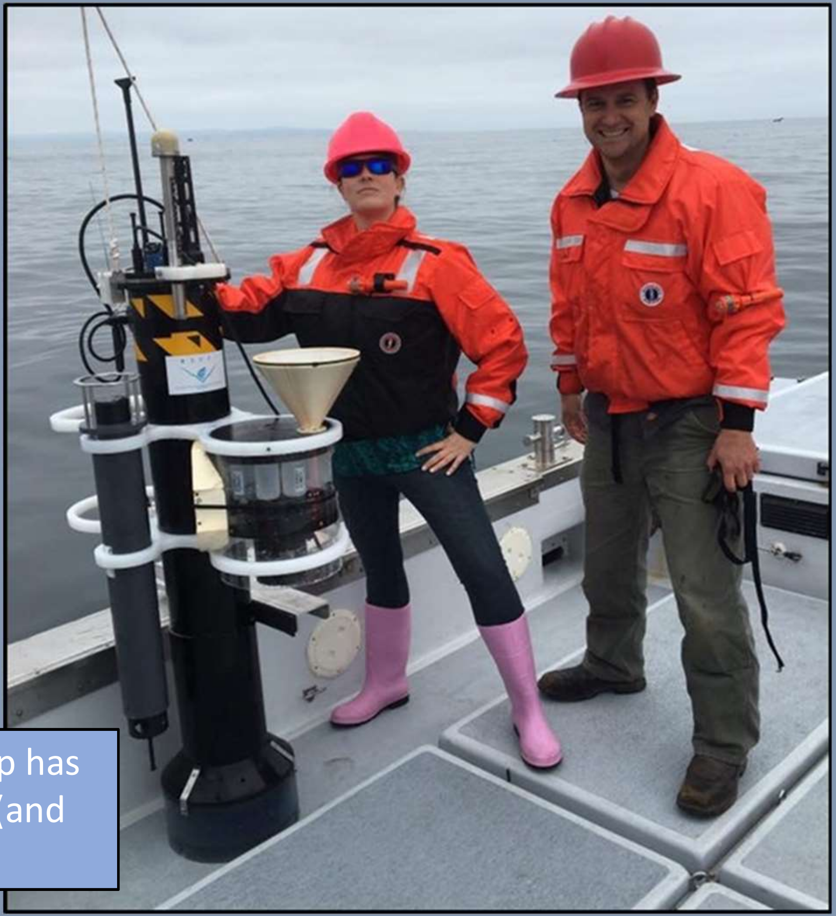
NOAA TRL 7-ish: Prototype system demonstrated in near-real world environment; subsystem components fully integrated into system

8: Finalized system shown to operate within user's environment, training and documentation completed

9: System deployed and used routinely [by non-developers]

Technology Transfer

- Possible tech transfer options:
  - Collaborations
  - Commercialization
  - Open Source
  - Others?



MBARI's Biological Oceanography Group has been running 2 CPFs for several years (and setting the fashion standard)

Tech Transfer Options

- Collaborations
  - If a CPF system is interesting to you, please let's talk
- Open Source
  - Pros:
    - The exact opposite of the commercialization cons
  - Cons:
    - It may not be feasible

- Commercialization
  - Pros:
    - Anyone can buy a CPF (theoretically)
  - Cons (based on my experience):
    - CPFs will be expensive
    - Development stagnates
    - Degraded reliability
    - Sole source risks
    - Only provides a product, not the rest of the system required for successful projects
    - Limited (or no) flexibility to address new applications
    - Individual buyers have to cover all the capital costs even if they only deploy CPFs a couple of months a year

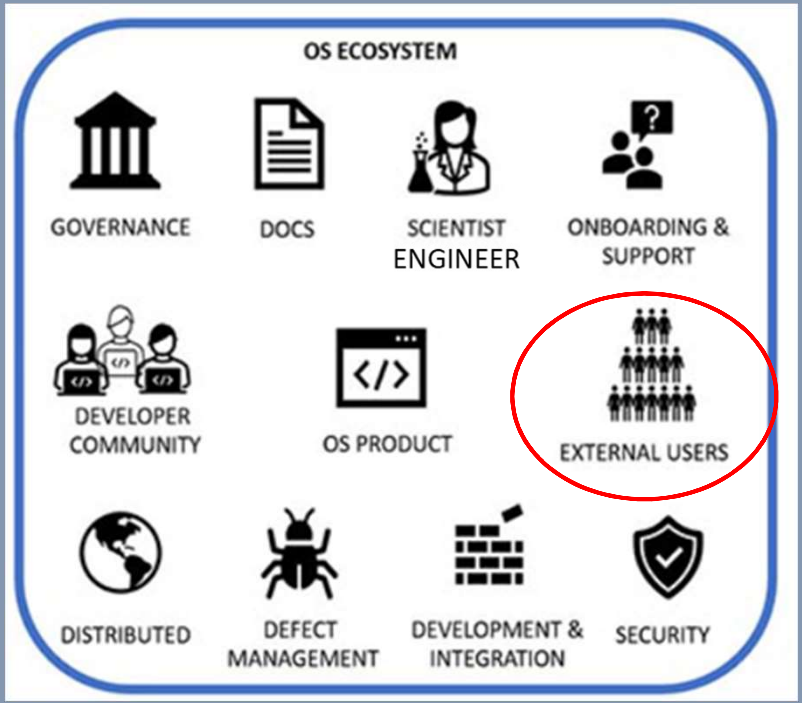
My Preference

CPF Open Source Ecosystem (COSE) Critical Infrastructure

- The critical component is an appropriate size group of users
  - ~10 CPFs a year for a couple of years

  OR
  - 3-5 Projects a year

  OR
  - 1 large volume need and everyone else tags along → MRV for mCDR



Pathways to Enable Open-Source Ecosystems (POSE) PROGRAM SOLICITATION NSF 23-556

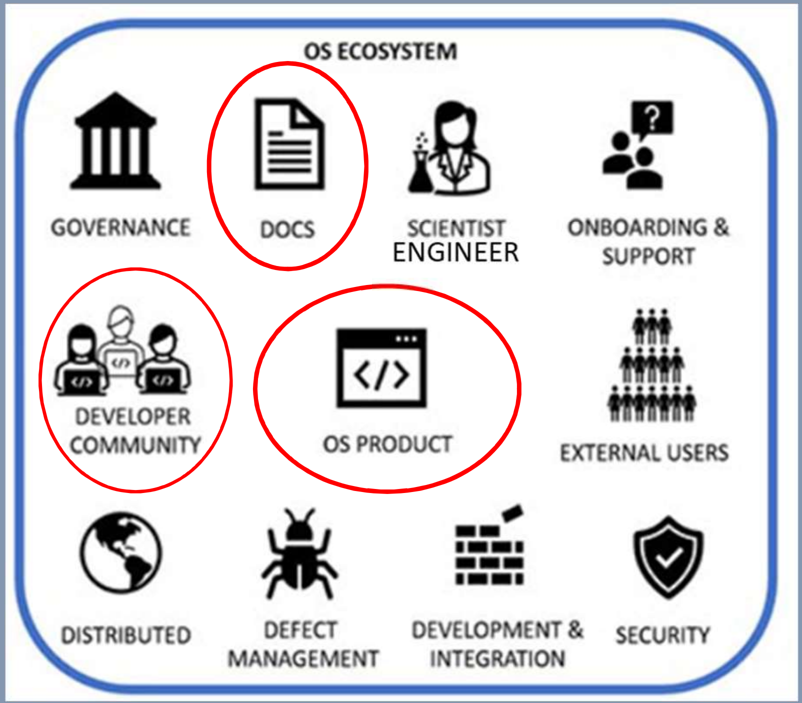
COSE Critical Infrastructure

- 2nd most critical: 1 committed, motivated CPF group

Pathways to Enable Open-Source Ecosystems (POSE)
PROGRAM SOLICITATION NSF 23-556

COSE Critical Infrastructure

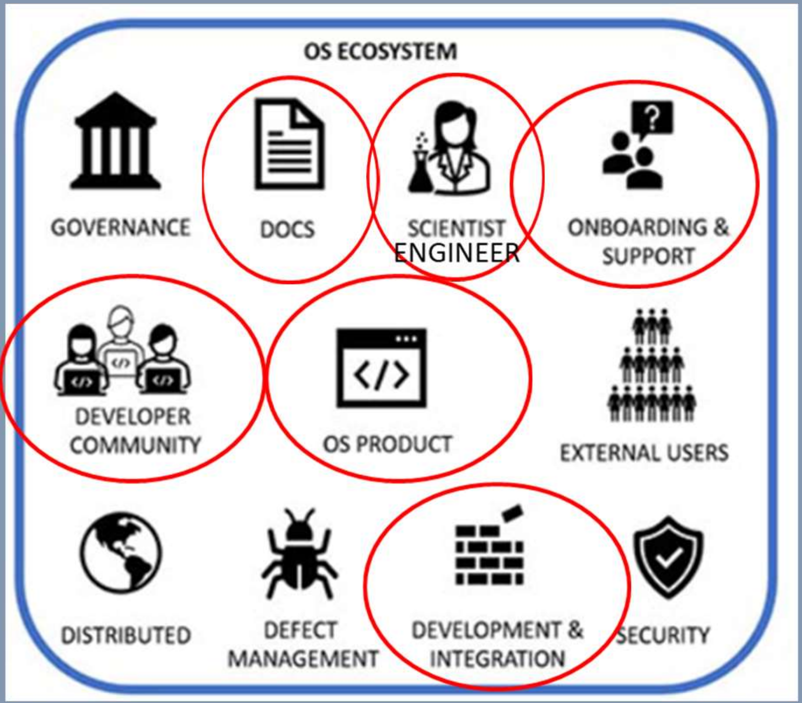
- 3rd most critical: A source of CPFs
  - Contract Manufacturer
  - Equipment supply pool
    - NSF Ocean Bottom Seismograph Instrument Center
    - UNOLS Ships and ROVs
    - Philanthropic Organization
  - Sponsored builder workshops
  - DIY documentation
  - Cooperative CPF-centric groups
  - Non-exclusive licensees



Pathways to Enable Open-Source Ecosystems (POSE)
PROGRAM SOLICITATION NSF 23-556

COSE Critical Infrastructure

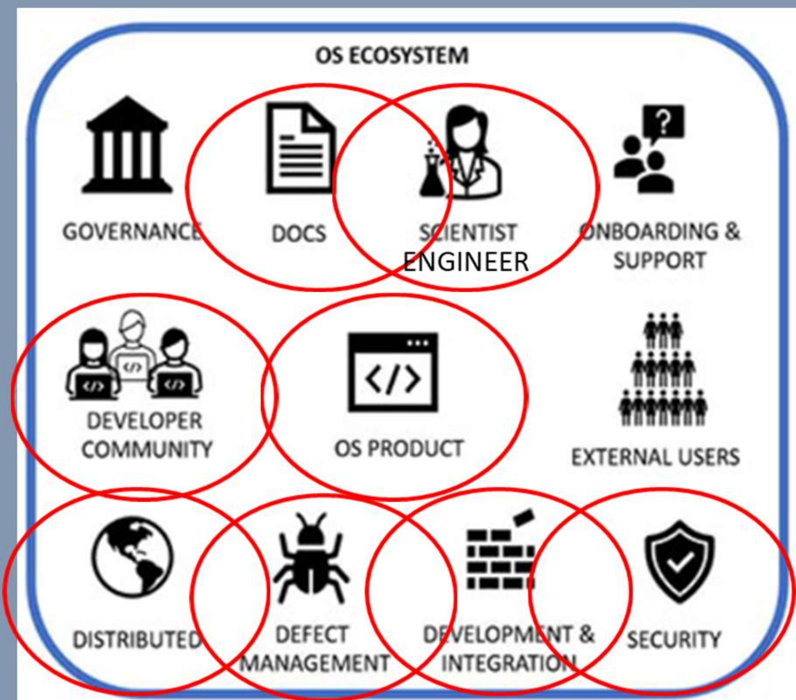
- Also critical: Expertise
  - Proposal development
  - Project planning
  - Project Execution
  - “Rent-a-Tech”
    - Field work design, prep, deploy, operations, recover
  - One-stop-shop providers
    - If there’s a high-volume application



Pathways to Enable Open-Source Ecosystems (POSE) PROGRAM SOLICITATION NSF 23-556

COSE Critical Infrastructure

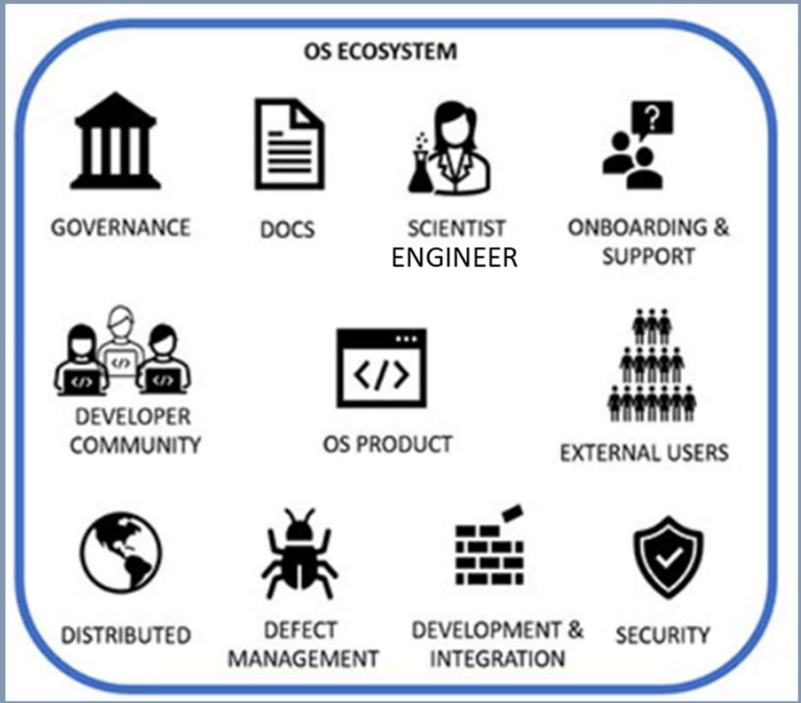
- Open sourcing an appropriate data pipeline is critical
- Argo-BGC is a model for research data
  - Excellent docs but can it be open-sourced?
- Outflow should be scalable, relevant data products
  - Need data product developers
  - NOAA Future Seas might be an example



Pathways to Enable Open-Source Ecosystems (POSE)
PROGRAM SOLICITATION NSF 23-556

COSE Risks

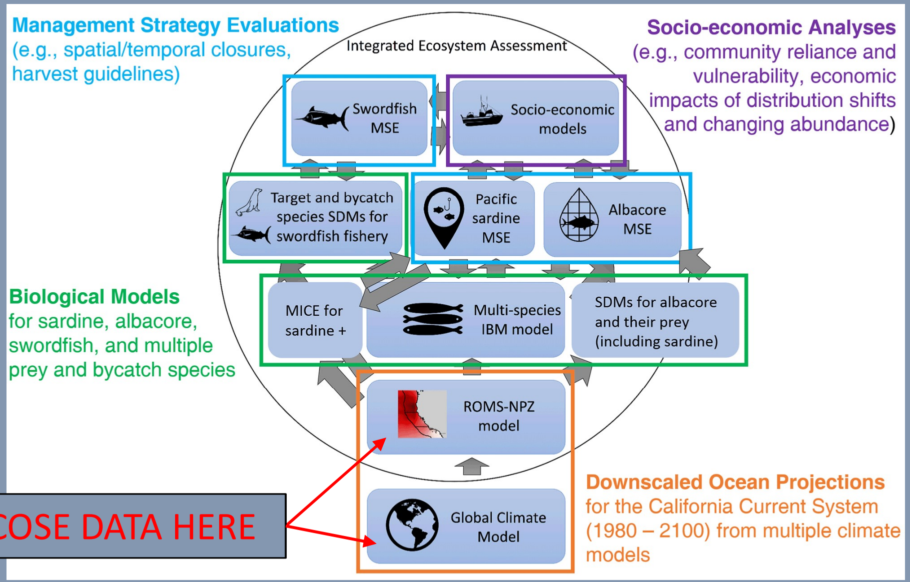
- Sensor maturity
  - e.g., Measuring pH in the ocean requires significant expertise
  - Interpreting FLBB and OCR data is an active conversation
- Argo data centers probably don't have the bandwidth to support non-Argo data streams
- The problem with TRLs is they don't capture who's doing the demo
  - Demo by the system developers is one thing, demo by others is an entirely different kettle of fish



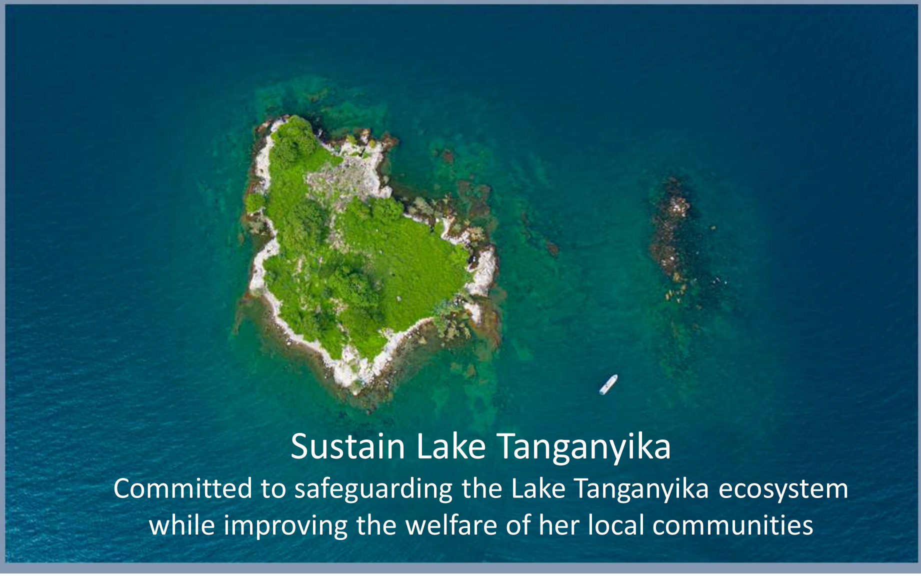
Pathways to Enable Open-Source Ecosystems (POSE) PROGRAM SOLICITATION NSF 23-556

COSE Targets

- US Regional Fishery Management Councils
- NOAA Integrated Ecosystem Assessment program
  - Future Seas "Physics to Fisheries" projections and predictions
- mCDR MRV mandated by the government
- Non-MBARI research groups
- NGOs



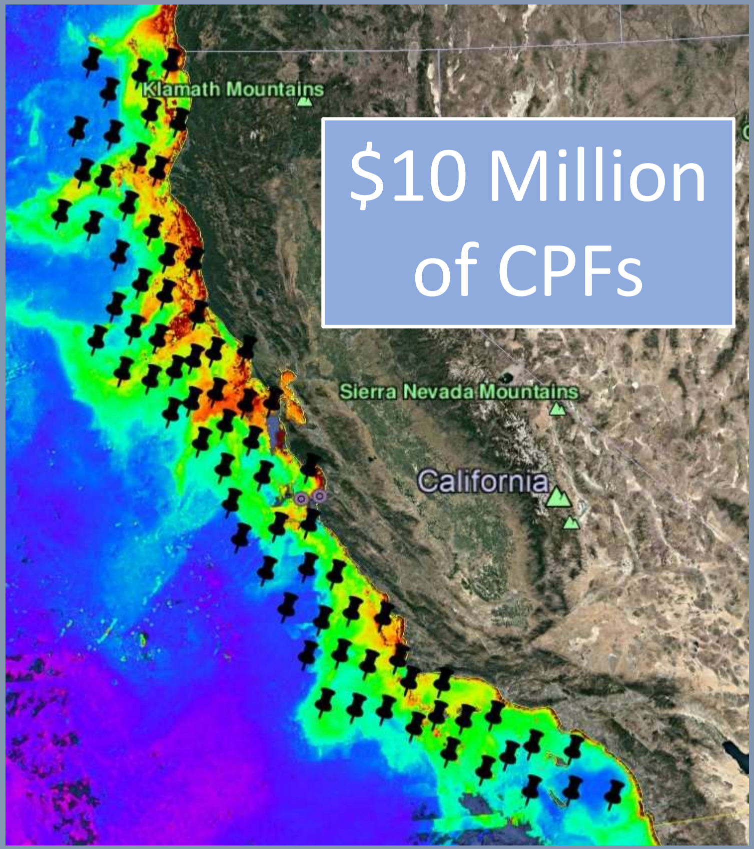
INSERT COSE DATA HERE



Is a COSE a Realistic Possibility?

- Step 1: POSE Phase I
  - are for open-source research products with a small community of external users .. may not necessarily have external content developers. The objectives are (1) enable scoping activities 2) **provide training to teams interested in building such an OSE** (<1 Year and <$300K)
  - Develop risk mitigation plan
- Step 2: Simultaneously find funding to support a pilot project with existing CPF assets
- If (POSE Phase 1 == success) then
- Step 3: Pose Phase II
  - transition into a sustainable and robust OSE (<2 Years and <$1.5M)
  - Execute risk mitigation plan
- Step 4: Execute POSE Phase II with the pilot project as the case study

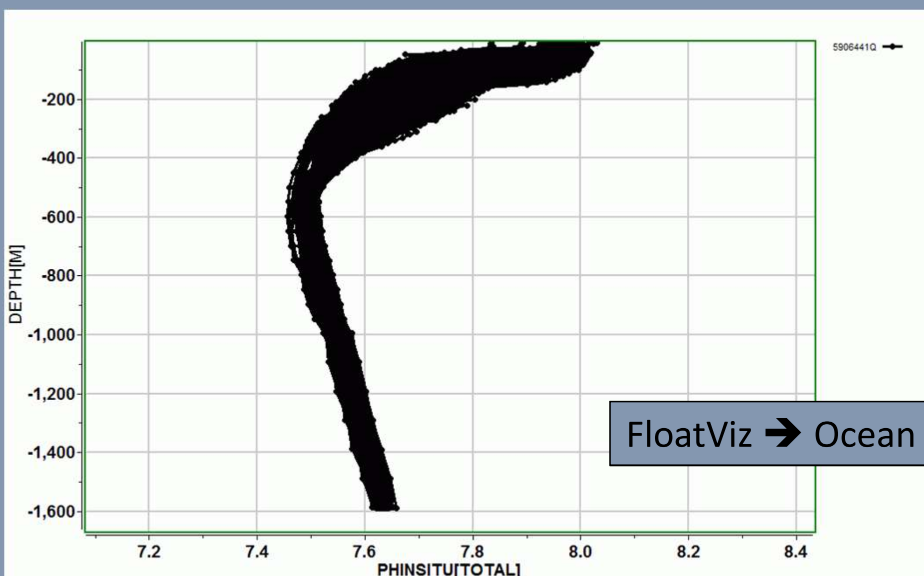
- The CPF Village includes: Jerry Allen, Magdalena Carranza, Paul Conen, Jared Figurski, Chad Kecy, Eric Martin, Tanya Maurer, James McClure, Jim Montgomery, Josh Plant, Jose Rosal, Aaron Schnittger, Ray Thompson, Mark Tynes, Joe Warren and others
- This work has been generously supported by the David and Lucille Packard Foundation



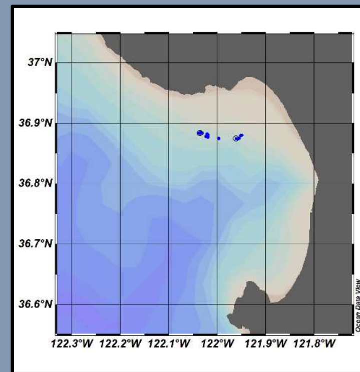
Thanks for listening

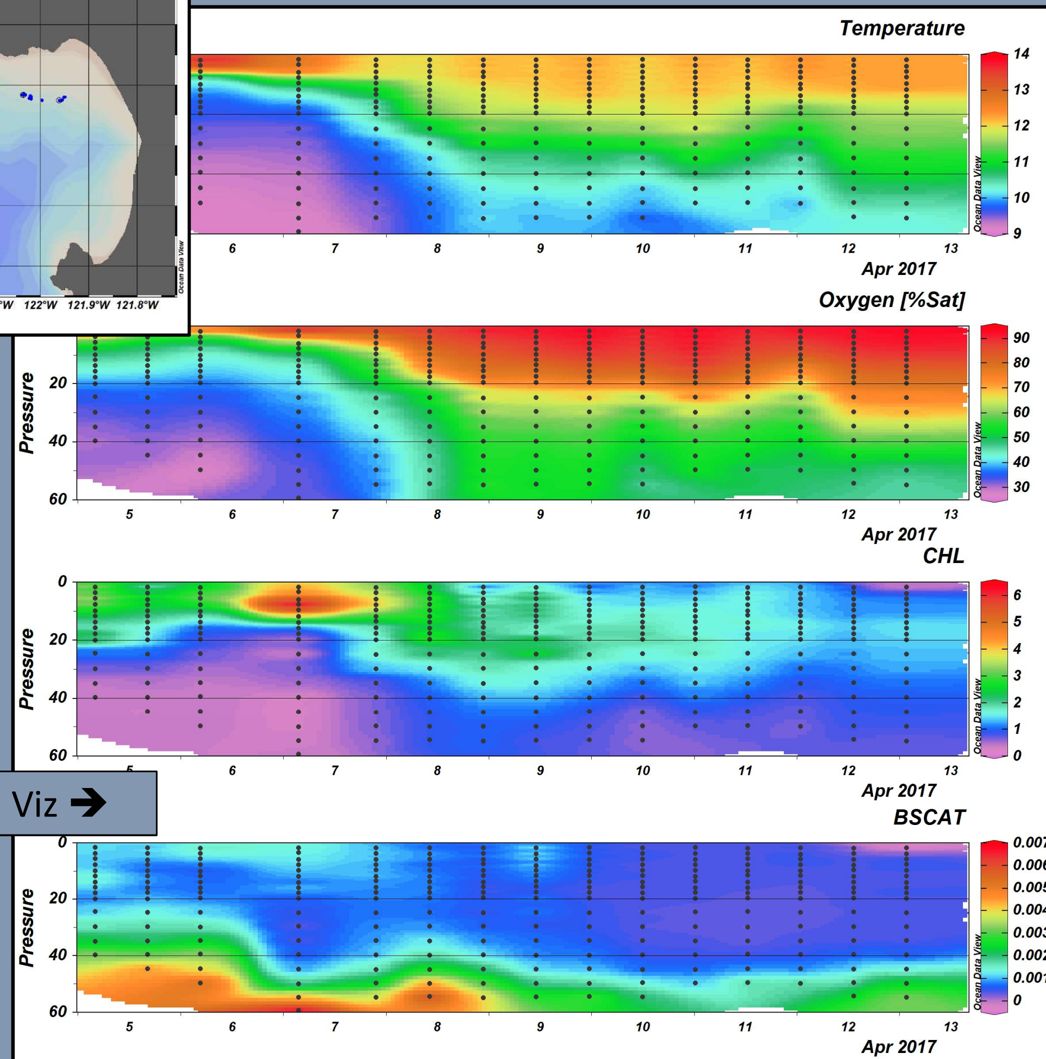
magene@mbari.org

Float Viz

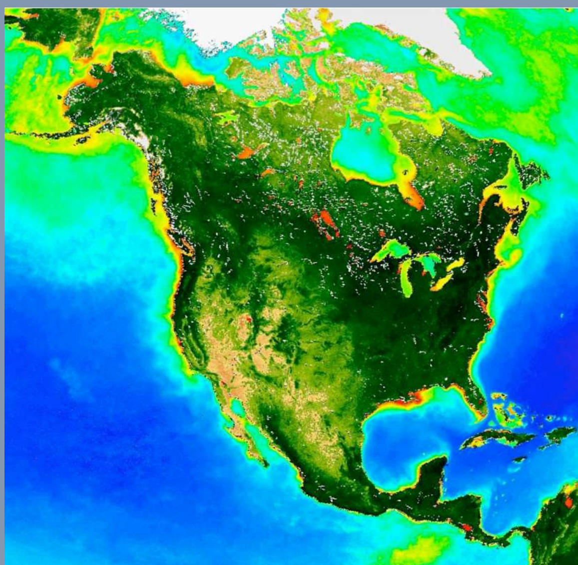


FloatViz → Ocean Data Viz →



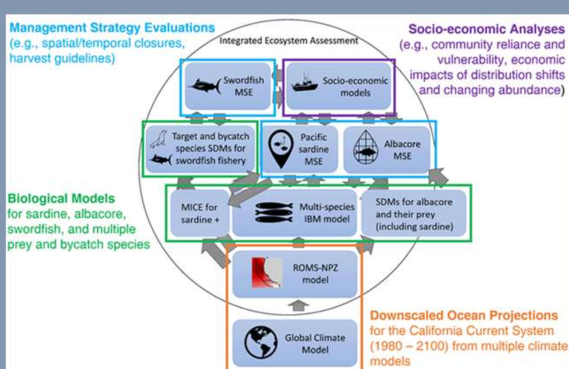


More Motivation



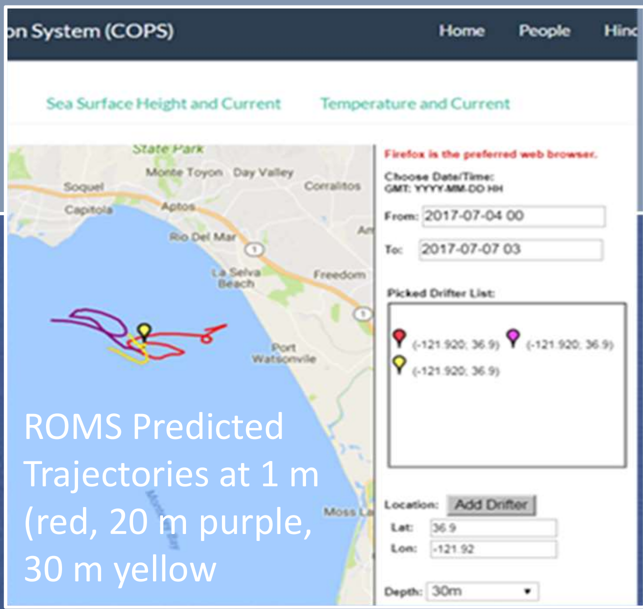
"Further development of <u>event-scale observing capacity (e.g., novel autonomous platforms) in all continental margin systems</u> to better quantify impacts of episodic events on coastal carbon budgets"

A Science Plan for Carbon Cycle Research in North American Coastal Waters 2016, Ocean Carbon and Bio. Program and NA Carbon Program

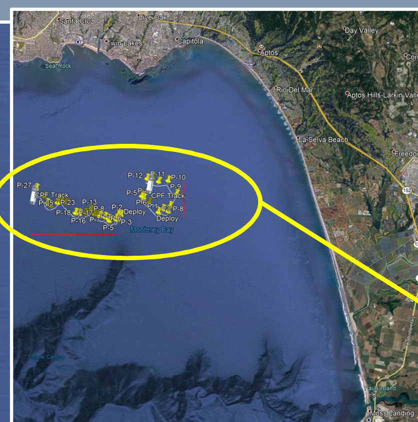


Float Navigation

- Experiment: Park the CPF at various depths and compare track to ROMS nowcast and previous missions that anchored on the bottom after every profile

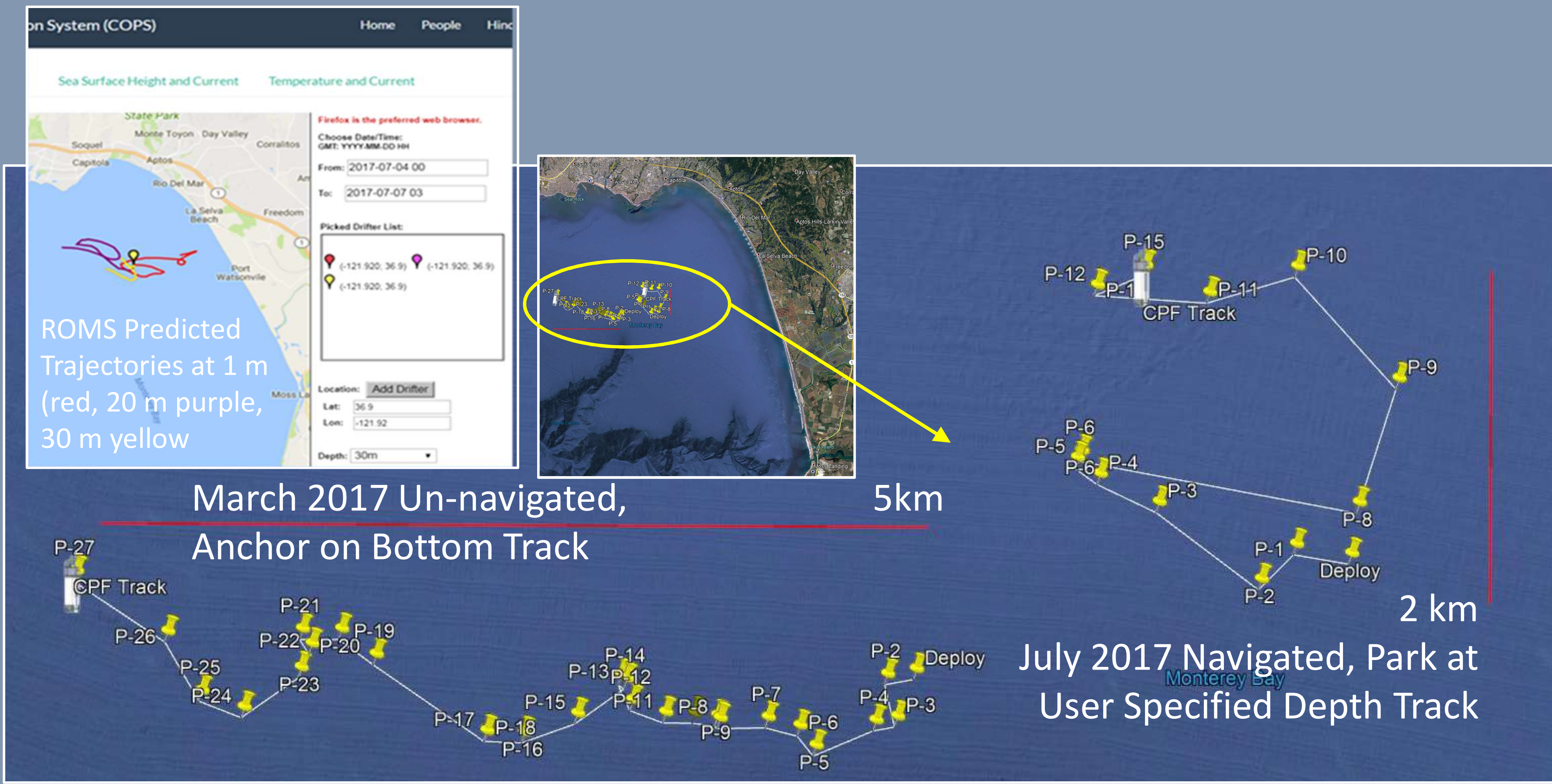


ROMS Predicted Trajectories at 1 m (red, 20 m purple, 30 m yellow



March 2017 Un-navigated, Anchor on Bottom Track

July 2017 Navigated, Park at User Specified Depth Track


on System (COPS)
Home
People
Sea Surface Height and Current
Temperature and Current
Firefox is the preferred web browser.
Choose Date/Time:
GMT: YYYY-MM-DD HH
From: 2017-07-04 00
To: 2017-07-07 03
Picked Drifter List:
Location: Add Drifter
Lat: 36.9
Lon: -121.92
Depth: 30m
ROMS Predicted Trajectories at 1 m (red, 20 m purple, 30 m yellow
March 2017 Un-navigated, Anchor on Bottom Track
5km
P-27
CPF Track
P-26
P-25
P-24
P-23
P-22
P-21
P-20
P-19
P-17
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P-14
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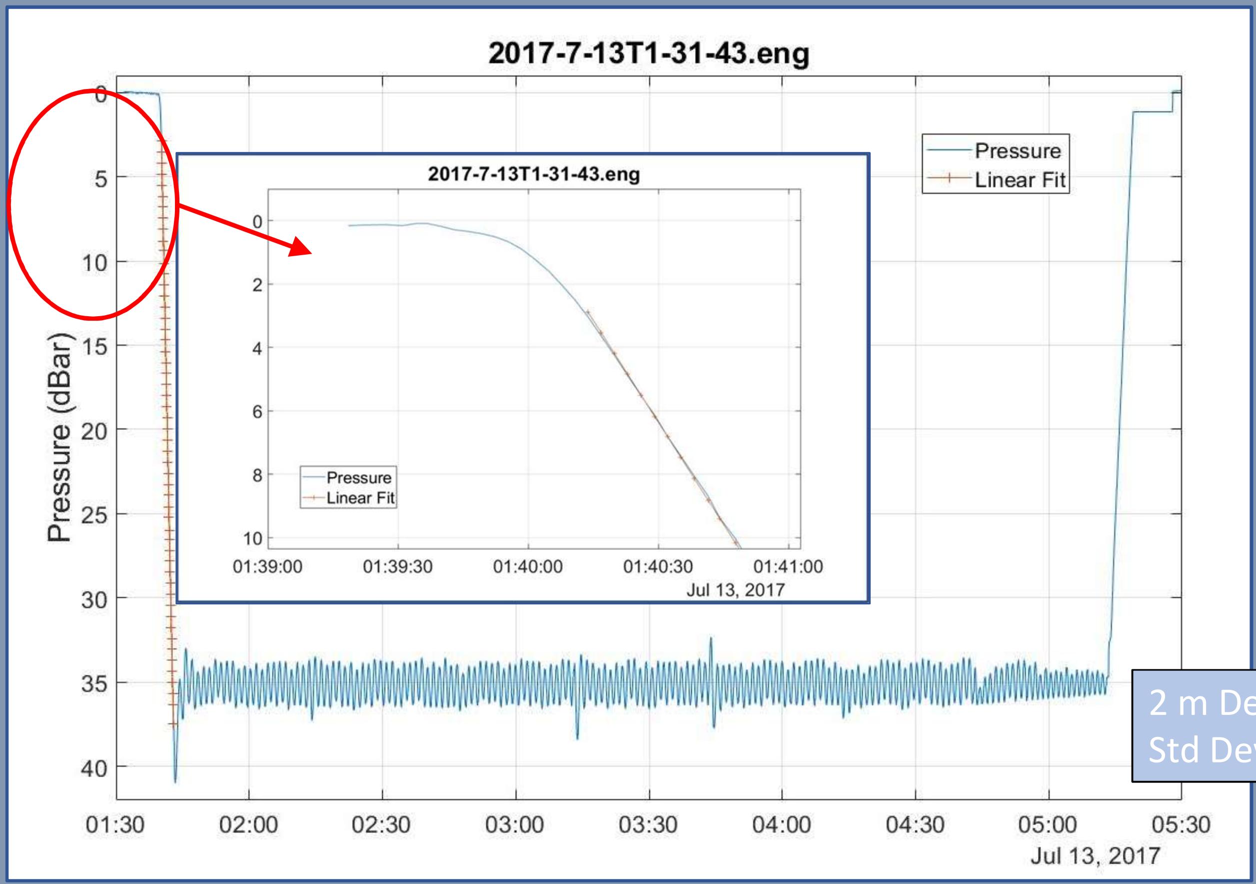
P-12
P-11
P-8
P-9
P-7
P-6
P-5
P-4
P-3
P-2
Deploy
P-15
P-12
P-1
P-11
P-10
CPF Track
P-9
P-6
P-5
P-6
P-4
P-3
P-8
P-1
Deploy
P-2
2 km
July 2017 Navigated, Park at User Specified Depth Track
Monterey Bay

Can a COSE Become a Reality?

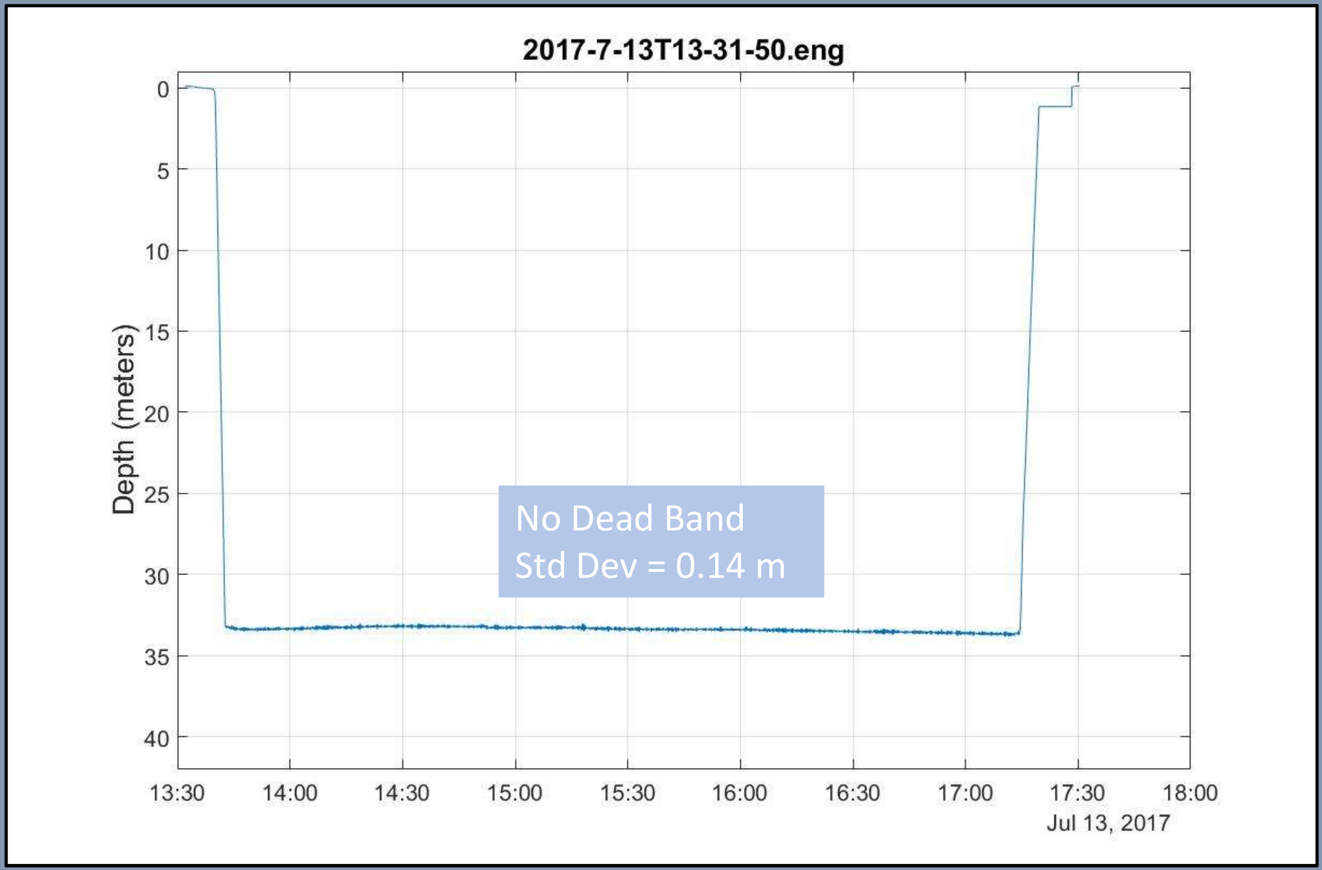
- Step 1:
  - POSE Phase 1: “The objectives of Phase I projects are … enable scoping activities that will inform the transition of promising research products … into sustainable and robust OSEs that will have broad societal impacts .. provide training to teams interested in building such an OSE” (<1 year <$300K)
- Step 2:
  - POSE Phase 2: “projects are for open-source research products with a small community of external users and external content developers. The objective of Phase II projects is to support the transition of a promising open-source product into a sustainable and robust OSE” (<2 years <$1.5M)
- Step 3:
  - In parallel with POSE Phase 1 and 2: Win a grant for a marine CO2 removal MRV system pilot project (or ?) using the COSE developed through POSE

Engineering Results



2 m Dead Band
Std Dev = 0.90 m

More Engineering Results



Here's a first pass at the energy in Joules from one profile from the March 20-24 deployment (3.5 hour profile period) and a wild guess at what might be achievable in the future. I made my guesses and didn't change them even after I saw the pretty unrealistic total just for fun.

	Actual	Wild guess for future
Surface Ops	216	216
Retract Fast	2684	100
Retract Slow	734	500
Descend	1972	1500
Park	0	0
Anchor	49771	500
Start CP Mode	133	133
DeAnchor	1747	2500
Ascend	4737	1500
Init Profile	2	2
Surface Ops Set Bellows	5648	1500
Dump CP Data	193	193
Total	67837	8644

Our current packs have about 3000 kJoules which would suggest we should get 3000/67.8 = 44 profiles. We stopped the mission after 26 profiles with a battery voltage of 29.75. That's about half the energy available so we might have been able to get 52 profiles which is at least in the same order of magnitude as 44.

Without any derating, the new battery pack should have about 4600 KJoules. 4600 / 8.6 = 535 or so 50 meter-ish profiles. Which would be an optimistic upper limit if you believe any of these numbers.

Here's Dana's data which includes 3 kJ of energy for the ISUS

Subsystem:	percent	mean	stdDev	min	max
(257 profiles)	%	kJ	kJ	kJ	kJ
Apex(260ml):	26.5	4.02	0	4.02	4.02
Apf9i:	13.7	2.08	0	2.08	2.08
Iridium/GPS:	14.1	2.14	0.054	2.06	2.24
Isus:	19.6	2.97	0	2.97	2.97
Optode:	0.6	0.09	0	0.09	0.09
Sbe41cp:	18.9	2.86	0	2.86	2.86
Self-Discharge:	6.6	1.01	0.597	0	2.06
Total:	100	15.16	0.6	14.1	16.22