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Sensor Refresh Status

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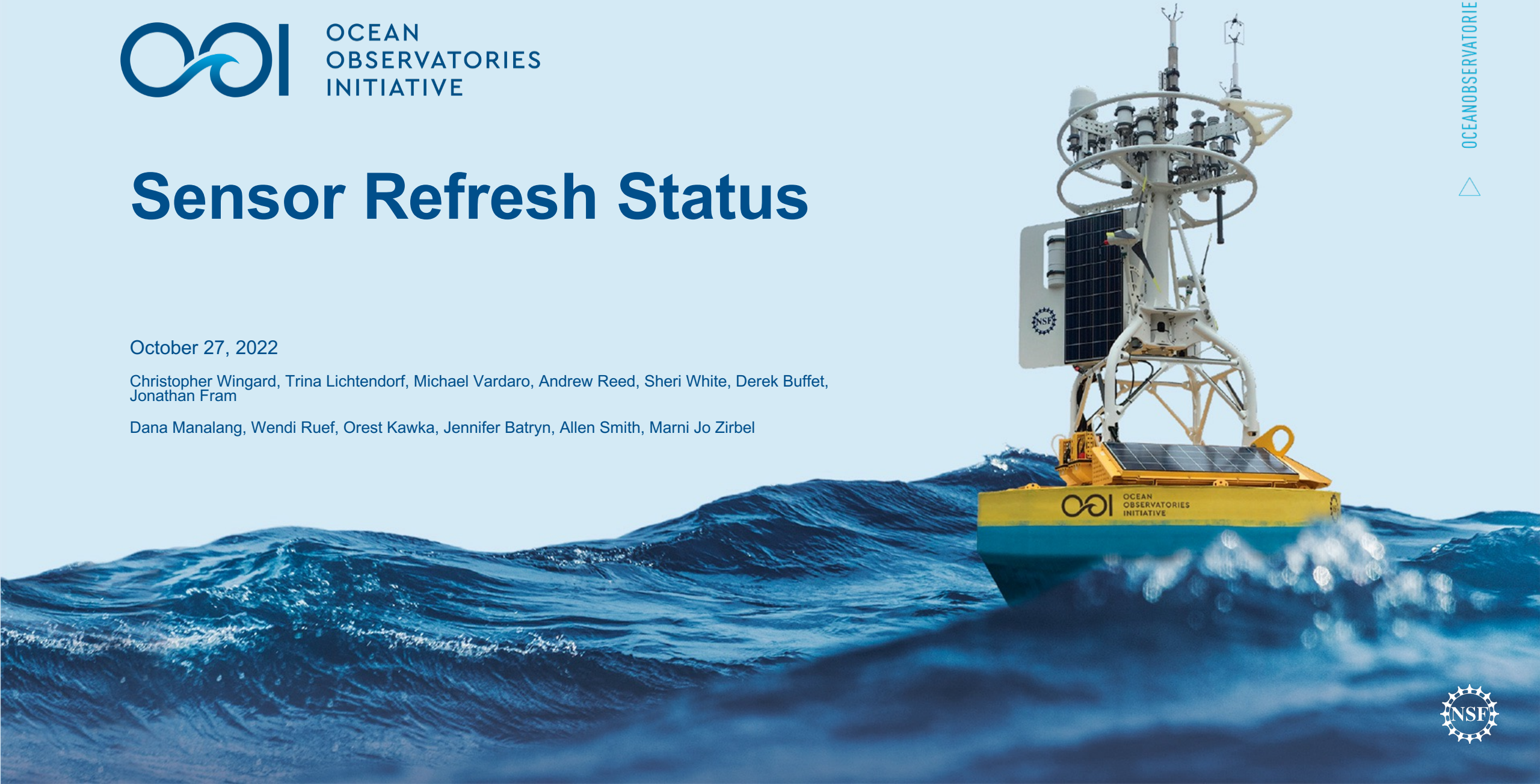

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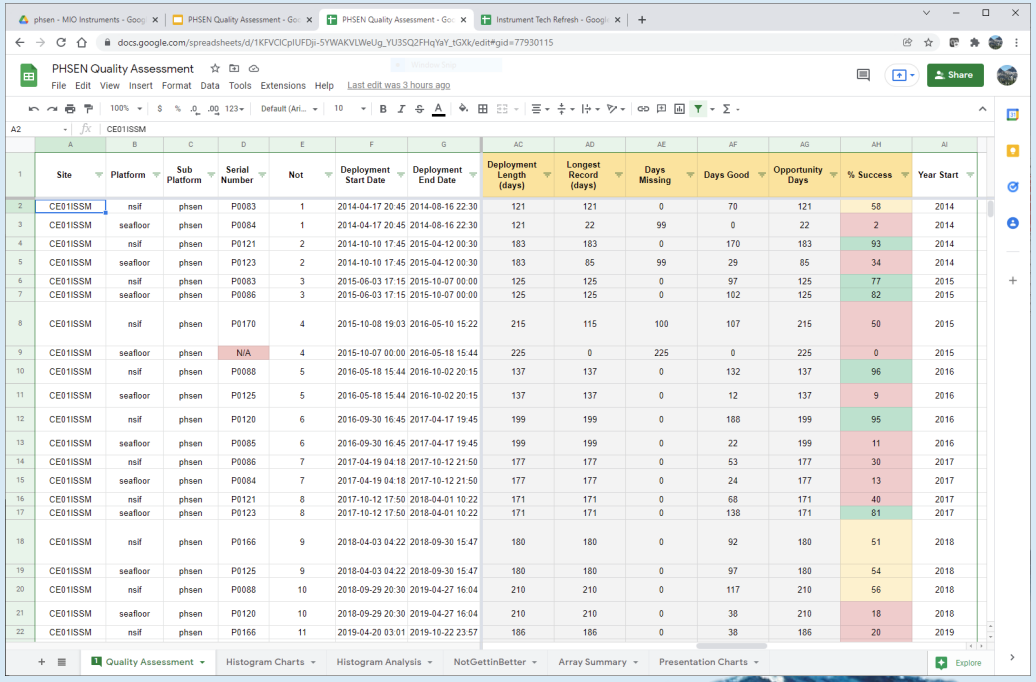
Background

- MIO Instrument Team compiled a list of common instruments, ranking based on data quality, reliability, ease of use, safety, vendor quality, obsolescence, and available alternatives (2017-2019)
- pH sensor (Sunburst Sensors SAMI-pH, PHSEN) was identified as an unreliable sensor. Primary issues were data quality and reliability/vendor quality (flooding, ground faults, battery performance, survivability)
- Rankings were based on experience of the MIO Instrument and Data Team members. Though based on expert opinions, the rankings were anecdotal to a degree
- Beginning in 2019, undertook an effort to develop quantifiable metrics of instrument performance
- Goal was to use the instrument data itself to grade performance (unbiased)
- Secondary goal was to develop a framework and workflow for future reviews

OOI 2.0 – Instrument Tech Refresh		Prioritization									
			1 = good, 2 = adequate, 3 = bad					1 = not anytime soon, 2 = next few years, 3 = now		1 = none, 2 = one, 3 = more than one	
Instrument Class	Model	Vendor	Data Quality	Relia-bility	Ease of Use	Safety	Vendor Quality	Obsolescence	Alternative from same vendor	COTS Alternatives	Alternative within OOI?	Sum
CAMDS		Kongsberg	2	3	3	2	3	3		2	No	18
PHSEN	SAMI-pH	Sunburst	2	2	3	3	3	1	No	3	No	17
PCO2W	SAMI-CO2	Sunburst	2	2	2	3	3	1	No	3	No	16
VEL3D-B	MAVS	Nobska Scientific	2	2	2	1	3	1	No	3	Yes	14
OPTAA	AC-S	WET Labs	2	3	3	1	2	1	No	1	No	13
DOFST	SBE43	Sea-Bird	2	2	2	1	1	1	Yes	3	No	12
ZPLSC/G	AZFP	ASL	2	2	1	1	2	1	No	2	Yes	11
WAVSS	Tri-Axys	Axys Technologies	1	1	2	1	1	3	No	2	No	11
PARAD	QSP	Biospherical	1	1	1	1	1	3	No	3	Yes	11
VEL3D	Aquadopp2	Nortek	2	1	1	1	1	2	Yes	3	Yes	11
VEL3D	Vector	Nortek	1	2	2	1	1	1	Yes	3	Yes	11
VELPT	Aquadopp	Nortek	1	2	2	1	1	1	No	3	No	11
PRESF	SBE26plus	Sea-Bird	1	1	1	1	1	3	No	3	No	11
ADCP	WorkHorse	Teledyne RDI	1	2	1	1	2	1	Yes	3	No	11
FDCHP	DCFS	WHOI	1	3	2	1	2	1	No	1	No	11



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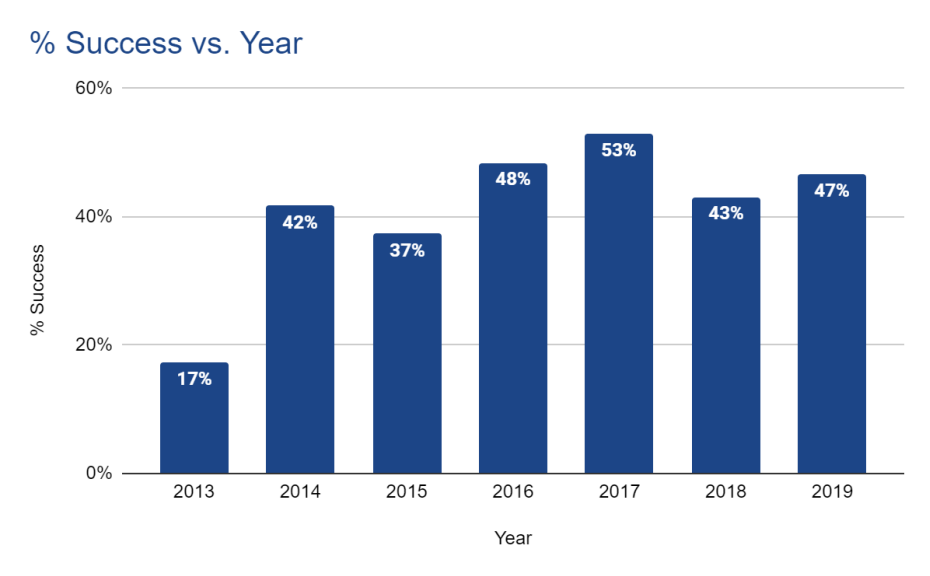
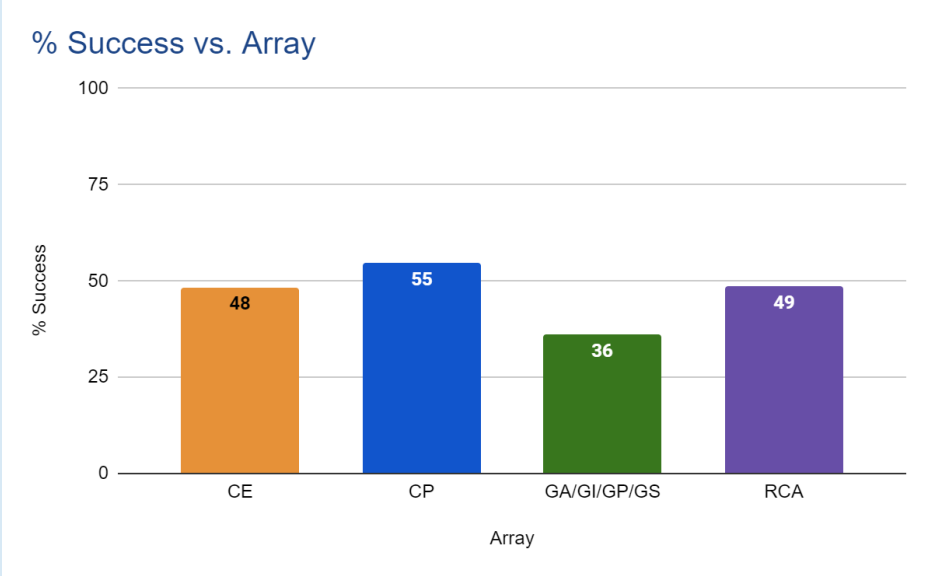
Initial pH Assessment

- Using data collected from deployments ending Fall 2019 (all arrays and data delivery methods, N = 254)
- % Success = Days of Good Data / Opportunity Days = 44%
  - Days of Good Data = % good data * days of longest record
    - % good data = vendor supplied automated tests of data quality (raw signal levels and computed pH)
  - Opportunity Days = days instrument could have operated given the opportunity (excludes days the data logger failed rather than the instrument). Usually, number of days in a deployment
- % Data Collected = Days of Collected Data / Opportunity Days = 71%



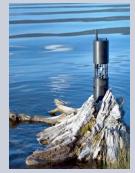
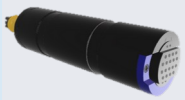


Progress and Path Forward

- COMPLETED TASKS
  - Prioritized and reviewed list of instrumentation for tech refresh
    - Other considerations may take priority (e.g., vendor changes or sensor updates/obsolescence)
  - Updated Common Instrument Specification (1336-00000)
  - Drafted Instrument Tech Refresh Process Document (1100-00007; approved September 2020)
  - Quality assessment of PHSEN data (N = 254)
  - Identified potential pH instrument vendors
  - Evaluate PHSEN requirements
  - Drafted RFI document
  - Issue RFI
  - Assess RFI responses
- NEXT STEPS
  - Analysis of Alternatives
  - ***Generate recommendation plan***

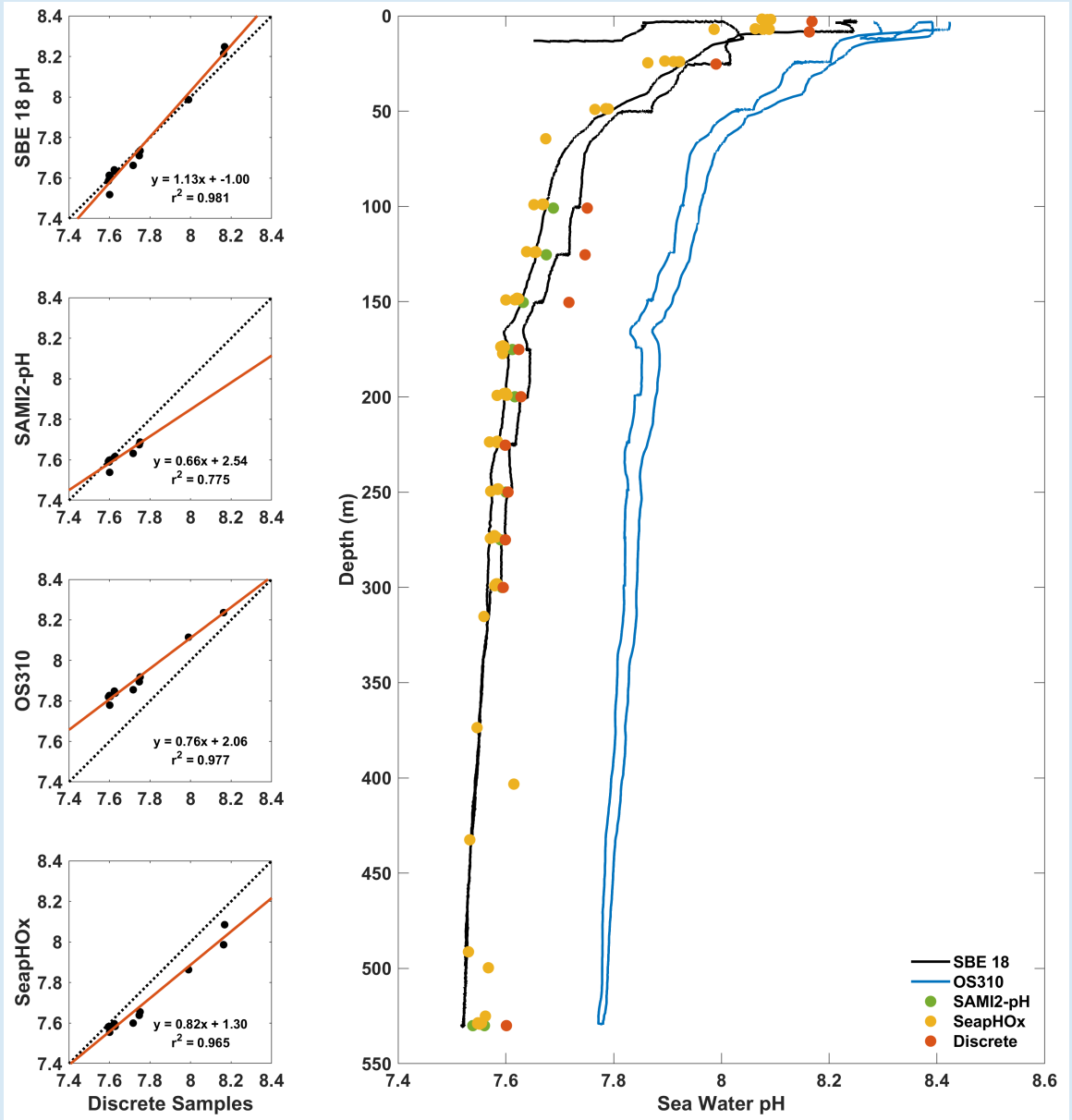
Analysis of Alternatives

- Benchtop testing of the sensors by RCA and EA staff
- Integration and burn-in testing by EA staff
- Side-by-side comparisons of the sensors:
  - Mounted on shipboard CTD rosette, with collection of water samples at multiple depths
  - Long term deployment (Fall 2021 to Spring 2022) on the midwater platform (7 m, NSIF) of the Oregon Shelf Surface Mooring (CE02SHSM); periodic water sampling
  - ANB Sensors is a new start-up, did not have a sensor available for field testing (expected December 2022)

Vendor	Instrument	
Sunburst Sensors http://www.sunburstsensors.com/index.html (colorimetric)	SAMI-pH Ocean pH Sensor	
Idronaut https://www.idronaut.it/ (glass electrode)	Ocean Seven 310 Multiparameter CTD (OS310)	
Sea-Bird Scientific https://www.seabird.com/ (Ion Sensitive Field Effect Transistor, ISFET)	Deep SeapHOx V2 Ocean CT(D)-pH-DO Sensor	
ANB Sensors https://www.anbsensors.com/ (solid state?)	*OC300 pH Sensor*	

Shipboard CTD Cast

- 2021-09-14, Cast #06 (Washington Offshore)
  - Ship's CTD included an SBE 18 pH Sensor calibrated 2020-12-01.
  - OS310 configured to sample at 1 Hz (fastest rate possible). Sampling started immediately after powering on via magnetic switch. Sampled during down and upcast.
  - SAMI-pH configured to sample every 5 minutes (every 4 minutes is the fastest rate possible) with sampling delayed (timed to start when CTD was near the bottom of the cast). Upcast sampling only.
  - SeapHOx configured to sample every minute (*fastest rate possible?*) with sampling delayed (timed to start when CTD was near the bottom of the cast). Upcast sampling only.
  - Water samples collected during upcast at 530, 300, 275, 250, 225, 200, 175, 150, 125, 100, 50, 25, 7, and 2 m
  - Water sampling results posted to Alfresco 2021-11-10
- Issues and results
  - Noticeable OS310 offset even with bench top calibration prior to deployment
  - SAMI-pH "clogged" during last 4 sampling depths (primary failure mode)
  - All three sensors show evidence of hysteresis in response curves, seeming to lag the SBE 18 during the upcast
  - None of the 3 sensors performed well (designed for moored applications, not profiling)



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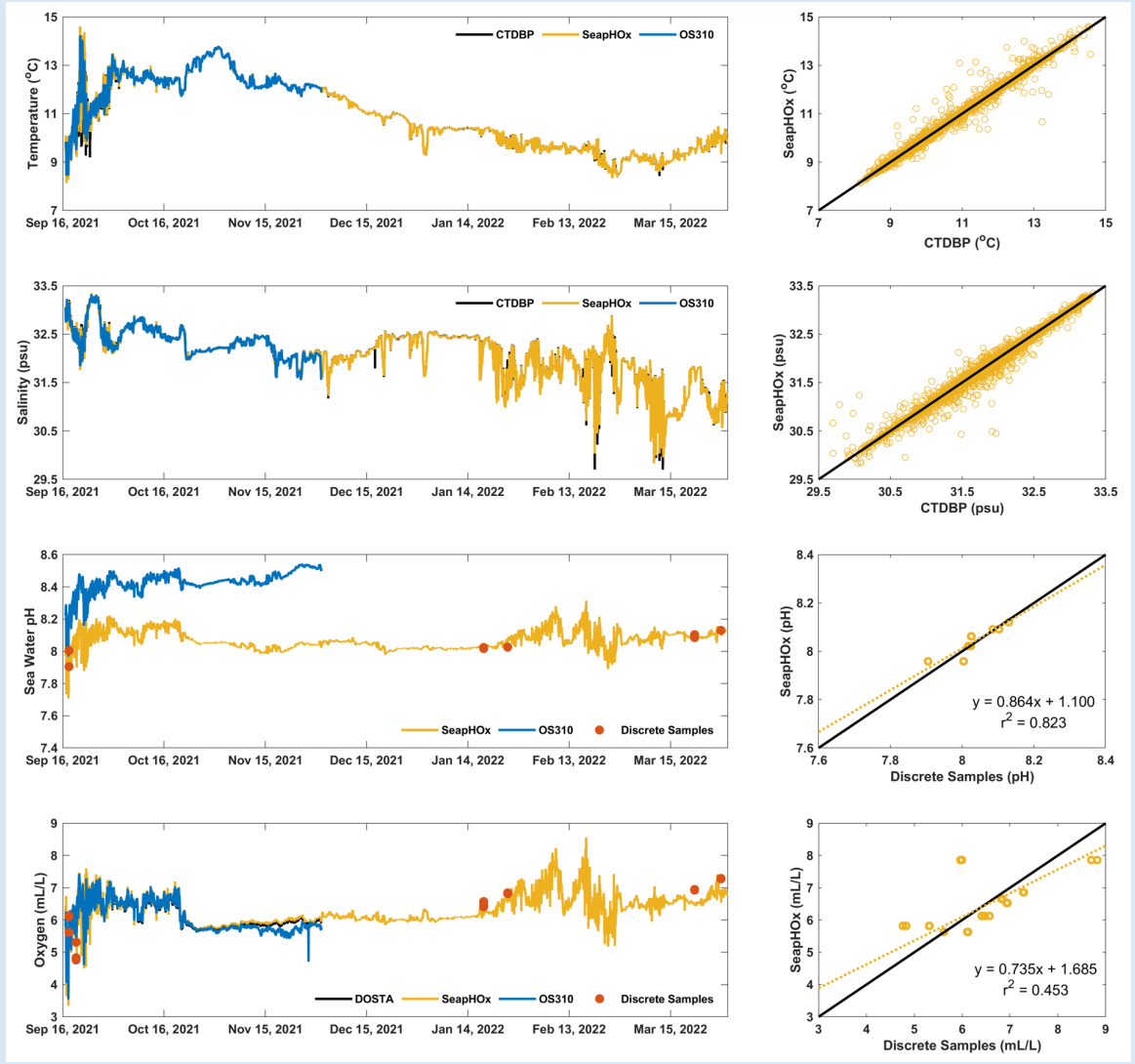
Mooring Deployment

- 2021-09-16 through 2022-04 (Oregon Shelf)
  - OS310 configured to collect 5 samples every 15 minutes
  - SAMI-pH configured to collect 1 sample every hour per OOI sampling plan (reagent limited)
  - SeapHOx configured to collect 1 sample every 15 minutes
  - Discrete samples collected at beginning/end of deployment with additional samples collected during winter/early spring glider and CSPP cruises
  - Water sampling results posted to Alfresco 2021-11-10
- Issues and results to date
  - SAMI-pH "clogged" immediately upon deployment (data not shown)
  - OS310 was offset by +0.246 from the SeapHOx (based on difference between the sensors averaged over the first 48 hours of the deployment) with a noticeable linear drift (r^2 = 0.9688) in the OS310 data compared to the SeapHOx over the rest of the time period (drift is a key issue for glass electrode pH sensors)
  - Mooring lost power late November, ending OS310 sampling. SeapHOx and CTDBP continued sampling, ***internally recording***
  - Excellent agreement between SeapHOx and CTDBP throughout the deployment (OS310 as well, while it ran)
  - Excellent agreement with SeapHOx pH measurements and the discrete samples (r^2 = 0.823)
  - Good(?) agreement with the SeapHOx DO measurements and the DOSTA and discrete samples (uncertainty regarding DO unit conversions). OS310 showing evidence of DO sensor biofouling.



Summary

- Issues common to all sensors
  - Documentation (inconsistent, copy-paste errors, language barriers)
  - Biofouling control (none to limited)
- OS310 is not a viable alternative (significant offsets and drift)
- SeapHOx outperformed the other two sensors as a *moored* sensor
  - However, Honeywell has discontinued manufacture of the Durafet pH sensor used in the SeapHOx
    - Currently unable to proceed with SeapHOx purchase
    - Path Forward
      - SeaBird has identified a supplier for a DuraFET replacement
      - Qualification and testing of new chips expected to begin spring 2023
      - OOI will participate in field testing, expected late 2023
      - ANB pH sensor will be added to field testing (expected delivery December 2022)

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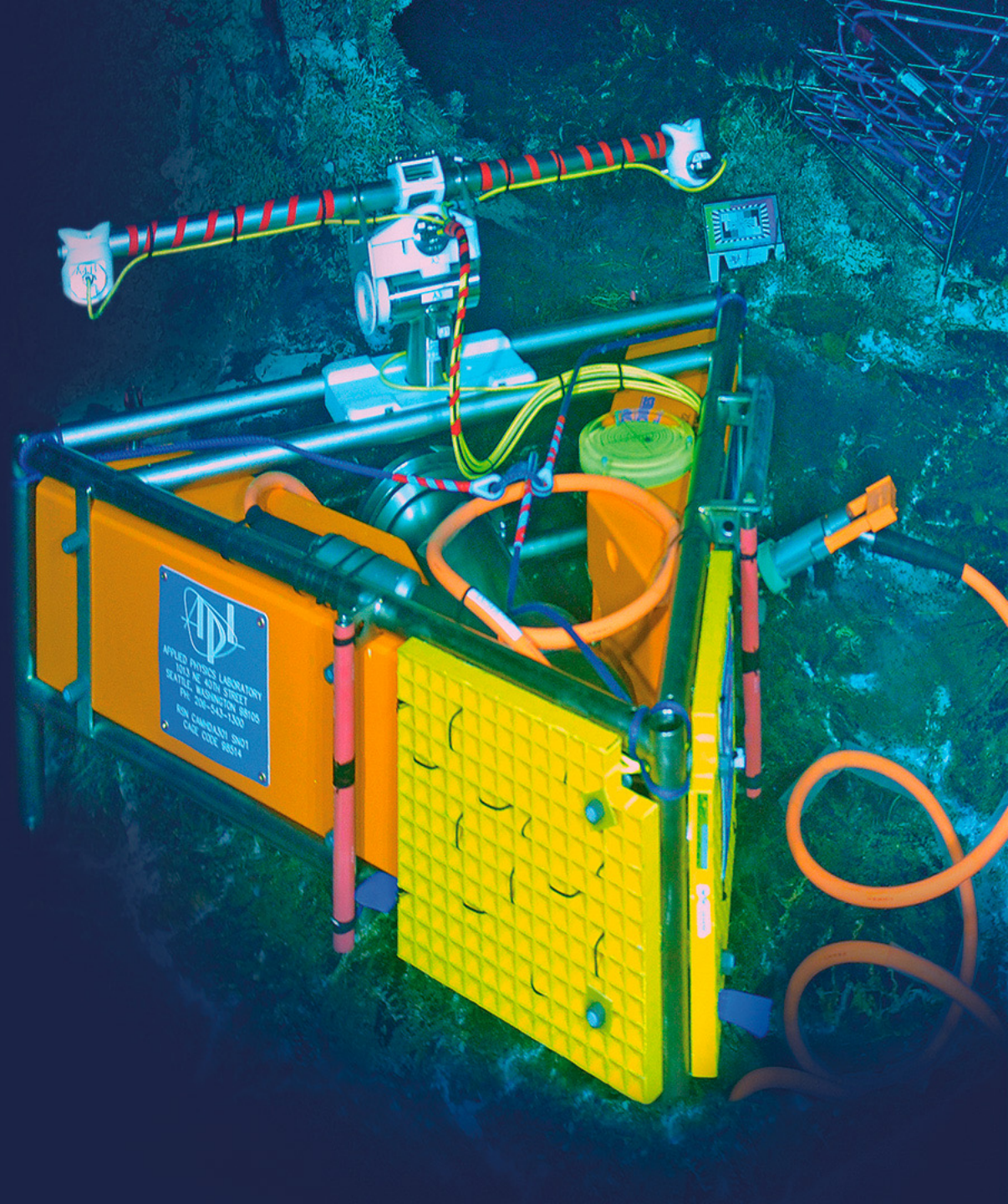
Questions?



Bio-Acoustic Sonar Data Issues

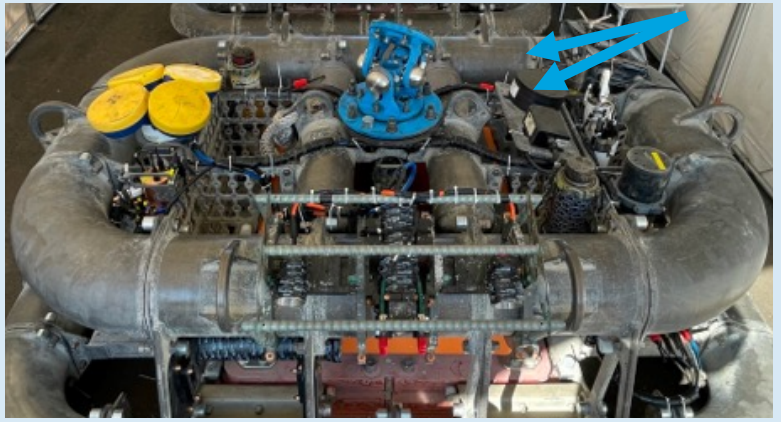
Sensor Models and Hardware Issues

- ASL AZFP (uncabled)
  - ZPLSC (Coastal) and ZPLSG (Global) transducer replacement.
    - The multi-frequency transducers were prone to failures in the field for deep sites at coastal Pioneer and Endurance
    - OOI worked with the manufacturer on “rolling upgrade”
    - Most currently deployed ZPLS have the transducer upgrade
    - Early results are encouraging, awaiting multiple deployment cycles
  - ZPLSC signal interference
    - Pioneer MFN-mounted instruments showed noise that degraded data quality
    - Revisions to cable routing were tested and implemented
    - Early results are encouraging, awaiting recovery of Pioneer-18
  - ZPLSC range and sensitivity
    - Some frequencies (e.g. 38 kHz) showed less range than expected
    - Tests were conducted by an SME on Pioneer 15 and 17
    - Results were shared with the vendor; assessment in progress
  - ZPLSC, ZPLSG clock drift
    - Drift can be order 5 minutes over a deployment (temperature dependent)
    - Sample times can also change over a deployment (independently of clock drift) could cause overlap in ZPLSC/ADCP sampling times
- Kongsberg Simrad EK60 (cabled)
  - No known hardware issues, but will need to be upgraded to EK80 due to model obsolescence

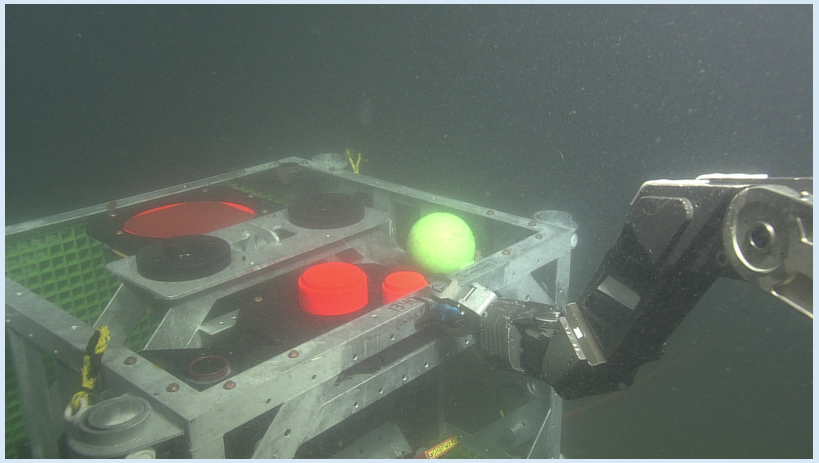
Array	Model	Site	Depth	Issues
Coastal Endurance	AZFP	Oregon Inshore	25 m	clock drift
Coastal Endurance	EK60	Oregon Shelf	80 m	obsolete
Coastal Endurance	EK60	Oregon Offshore	200 m	obsolete
Coastal Endurance	AZFP	Washington Inshore	29 m	clock drift
Coastal Endurance	AZFP	Washington shelf	87 m	clock drift
Coastal Endurance	AZFP	Washington Offshore	542 m	transducers, clock drift, range
Coastal Pioneer	AZFP	Inshore Surface Mooring	95 m	signal interference, clock drift
Coastal Pioneer	AZFP	Central Surface Mooring	135 m	signal interference, clock drift
Coastal Pioneer	AZFP	Offshore Surface Mooring	450 m	transducers, signal interference, clock drift, range
Global Argentine Basin	AZFP	Apex Profiler Mooring	150 m	clock drift
Global Irminger Sea	AZFP	Apex Profiler Mooring	150 m	clock drift
Global Station Papa	AZFP	Apex Profiler Mooring	150 m	clock drift
Global Southern Ocean	AZFP	Apex Profiler Mooring	150 m	clock drift

Calibration Issues

- AZFP
  - Calibrated at the factory in a small tank. Unknown accuracy *in situ*
- EK60
  - Calibrated *in situ* with 38.1-mm tungsten-carbide reference sphere (Urmy *et al* 2012)
  - Limited to Oregon shelf site only due to technical constraints
- Shipboard surveys
  - Not all vessels are equipped with bio-acoustic systems (in situ calibrations)
  - Time and site constraints



Washington Offshore MFN showing instruments including bioacoustic sonar transducers (arrows). Note oblique mounting.



ROPOS releasing the tungsten carbide calibration sphere on the Endurance Array Oregon Shelf bioacoustic sonar platform. The transducer heads are orange. Credit: NSF-OOI/UW/CSSF; Dive R1792; V14

Going Forward

- *In situ* calibrations are preferred, however …
- Technical issue without an identified cross-site/cross-array solution
  - RCA calibration
    - Feasible for the Oregon Shelf seafloor platform
      - Timescale
      - Marine debris (plastic float and monofilament line)
    - Difficult for Oregon Offshore shallow profiler. Primary concern is entanglement with the profiler system
  - CGSN and EA calibration
    - Primary concern is entanglement with mooring riser elements
    - Secondary issue is that oblique angling of the transducers makes it difficult to suspend a sphere directly in the path.
  - Resources
- Discussion