Preliminary analysis of 2020 vertical mainstem continuous monitoring data

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Modeling Workgroup

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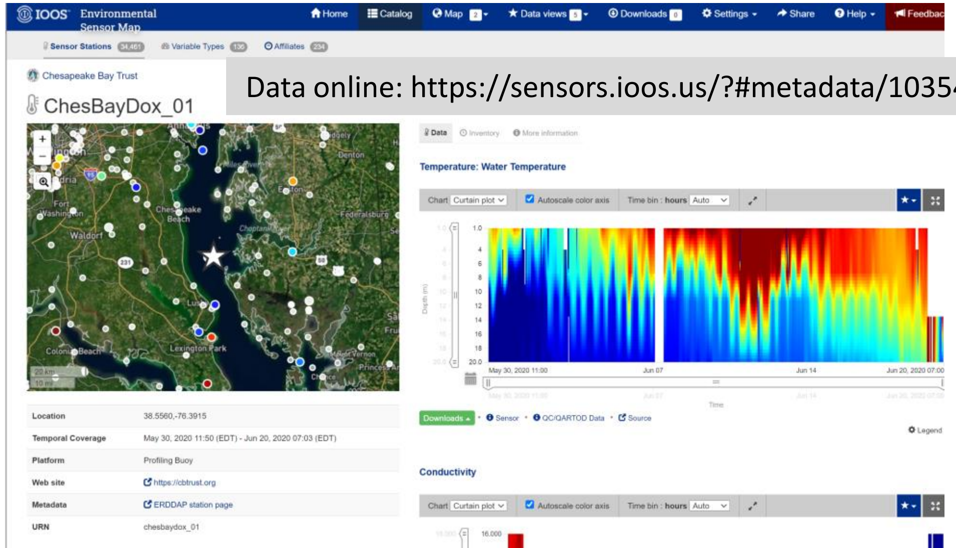
With input from: Peter Tango (USGS), Gary Shenk (USGS), Jeremy Testa (UMCES), Larry Sanford (UMCES)

Prototype vertical deep water DO monitoring

- Chesapeake Bay Trust funding to support STAR and Fisheries GIT
- Pilot project for a cost-effective vertical DO monitoring system for mainstem hypoxia
- Awardee: Doug Wilson, Caribbean Wind, LLC
- Two deployments: May 30-June 19 and Sept 13- Oct 6, 2020



Data online: https://sensors.ioos.us/?#metadata/103543/station

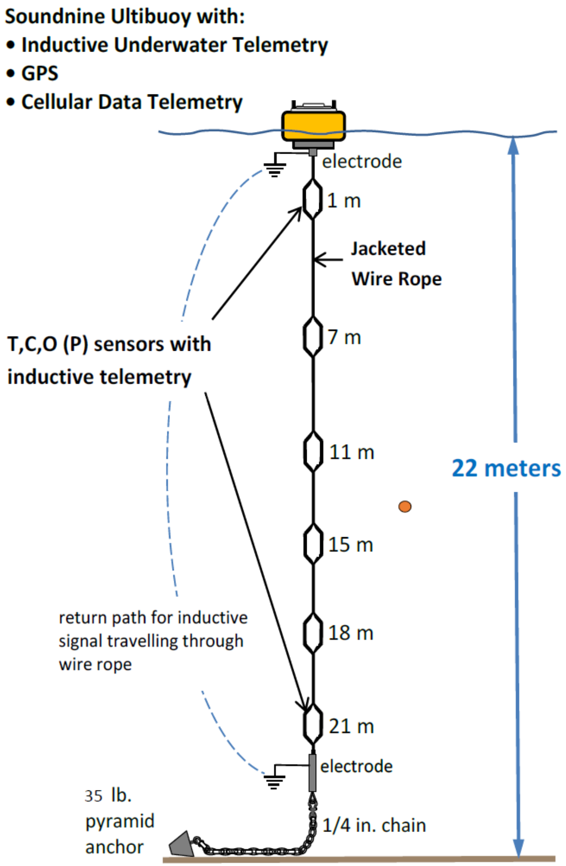
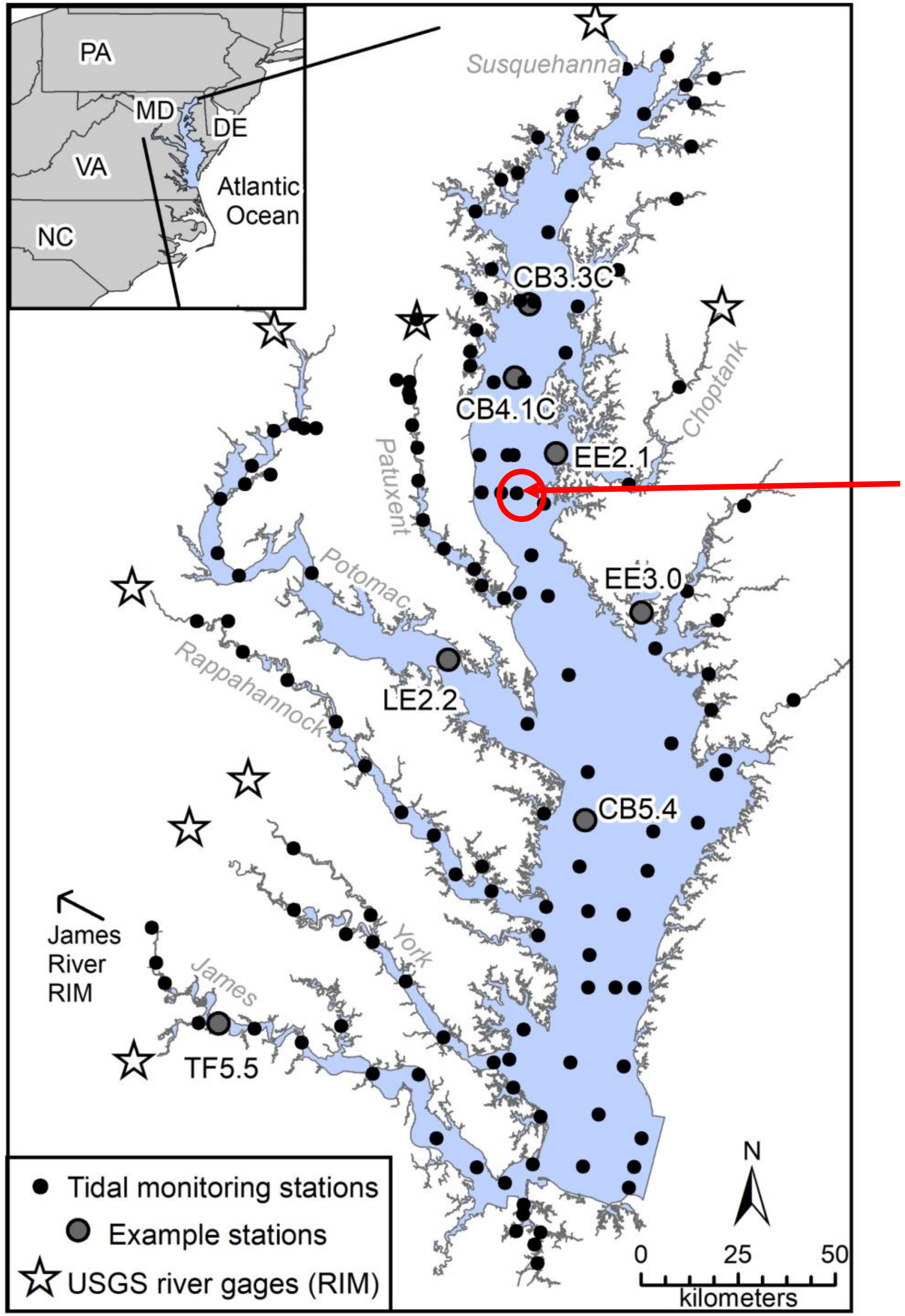


Figure 2. Mooring schematic

From Wilson 2021, Final Report

location



Depth = about 22m

(CB4.3C depth about 28m)

CBP purposes for looking at the data

- Explore the short-term variability in deep waters not captured typically by the long-term monitoring program.
- Use the findings to inform projects: 4D interpolation, criteria-related analyses, etc.
- Compare to estuarine model output.
- Help with future monitoring efforts.

In this presentation

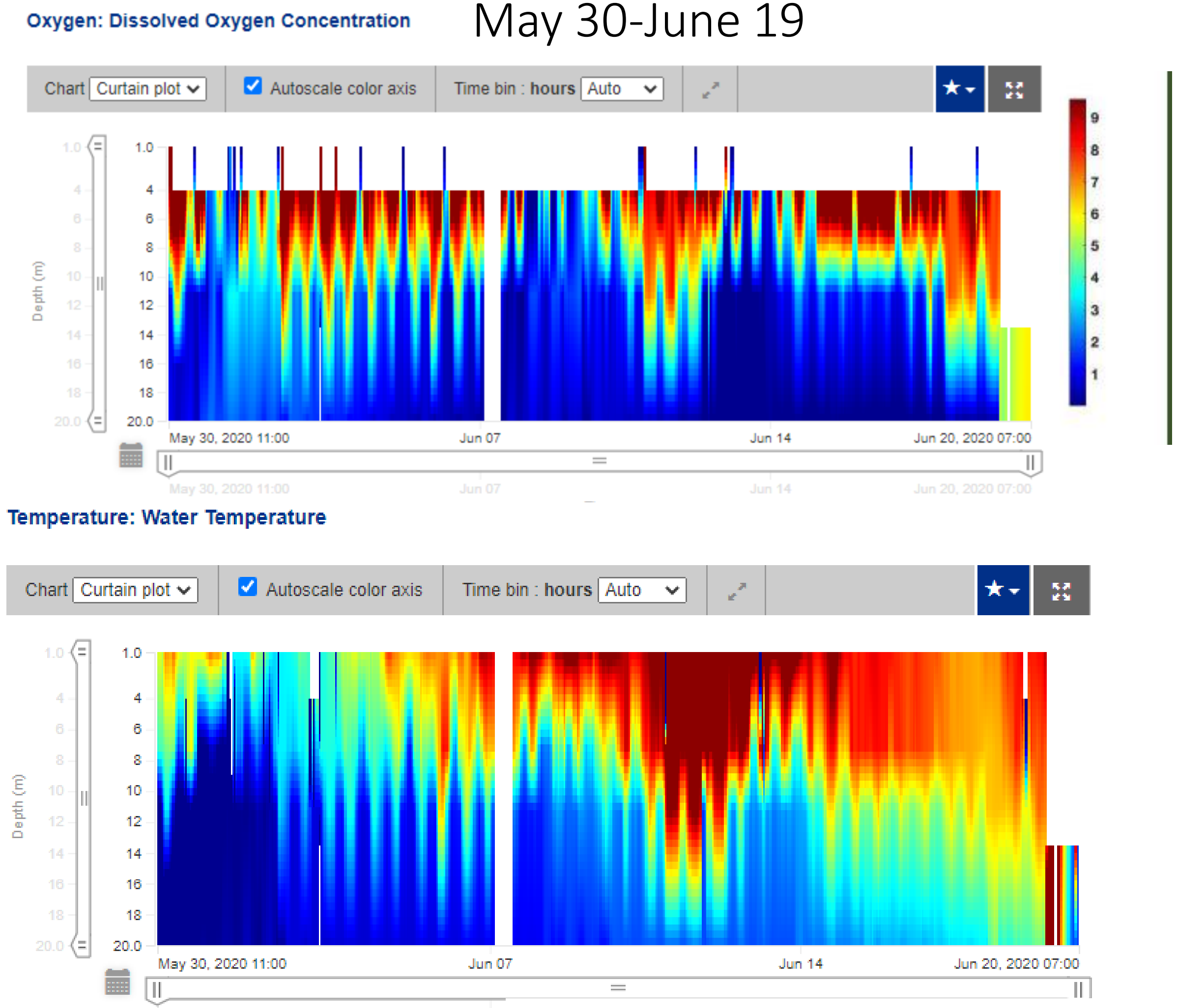
1. Visualize the data and compare to fixed-station monitoring
   - Future work: compare to other continuous monitoring data sets

2. Start to analyze the short-term DO variability
   - Future work: begin to test explanatory variables, as needed
   - Future work: explore how the short-term variability compares to estuarine model

3. Evaluate what impact short-term variability might have on assessing certain WQ criteria
   - Future work: incorporate finding to help predict short-term DO concentrations between observed values (i.e., 4D interpolation)

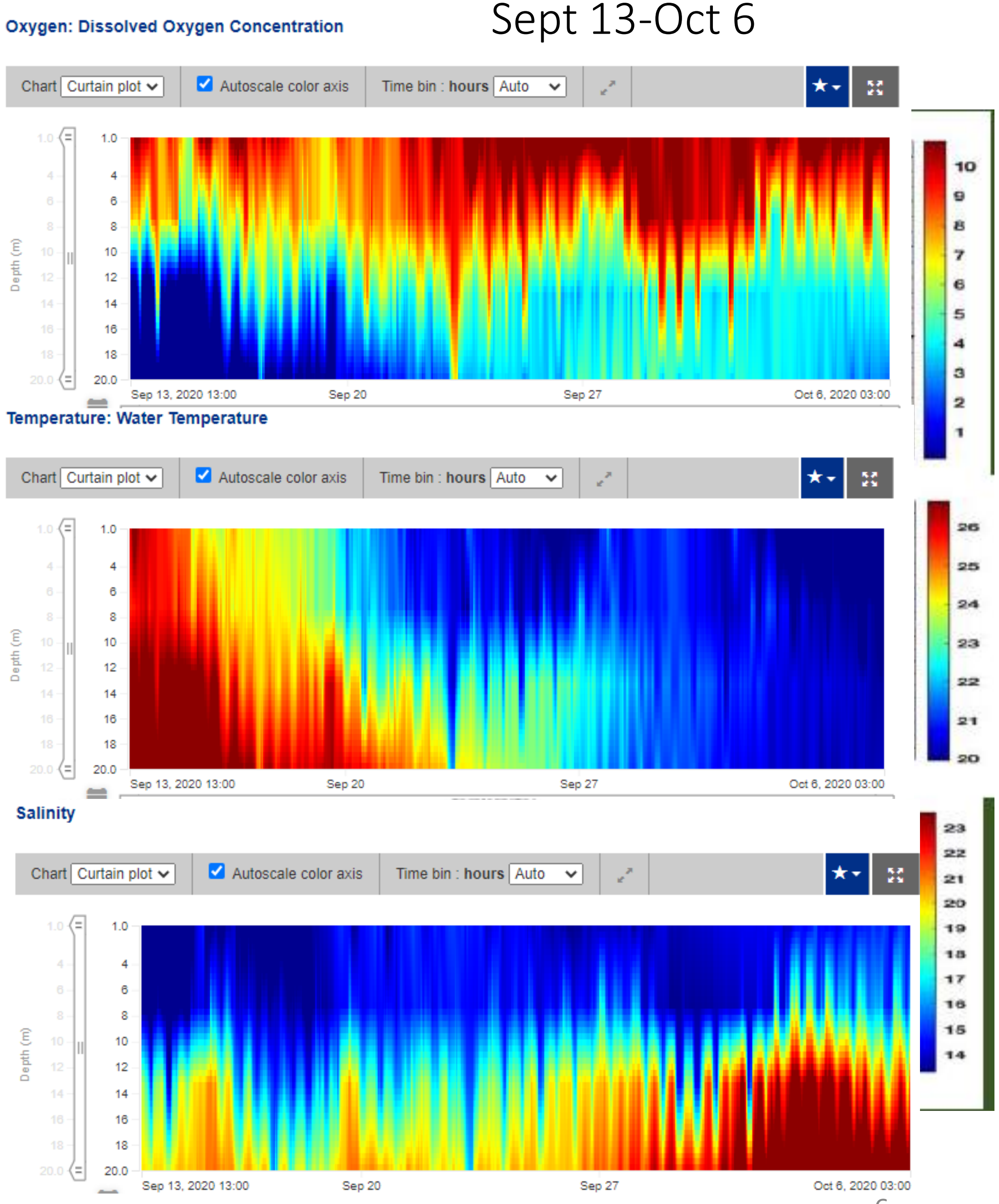
Part 1. Visualize and Compare

May 30-June 19



From: https://sensors.ioos.us/?#metadata/103543/station

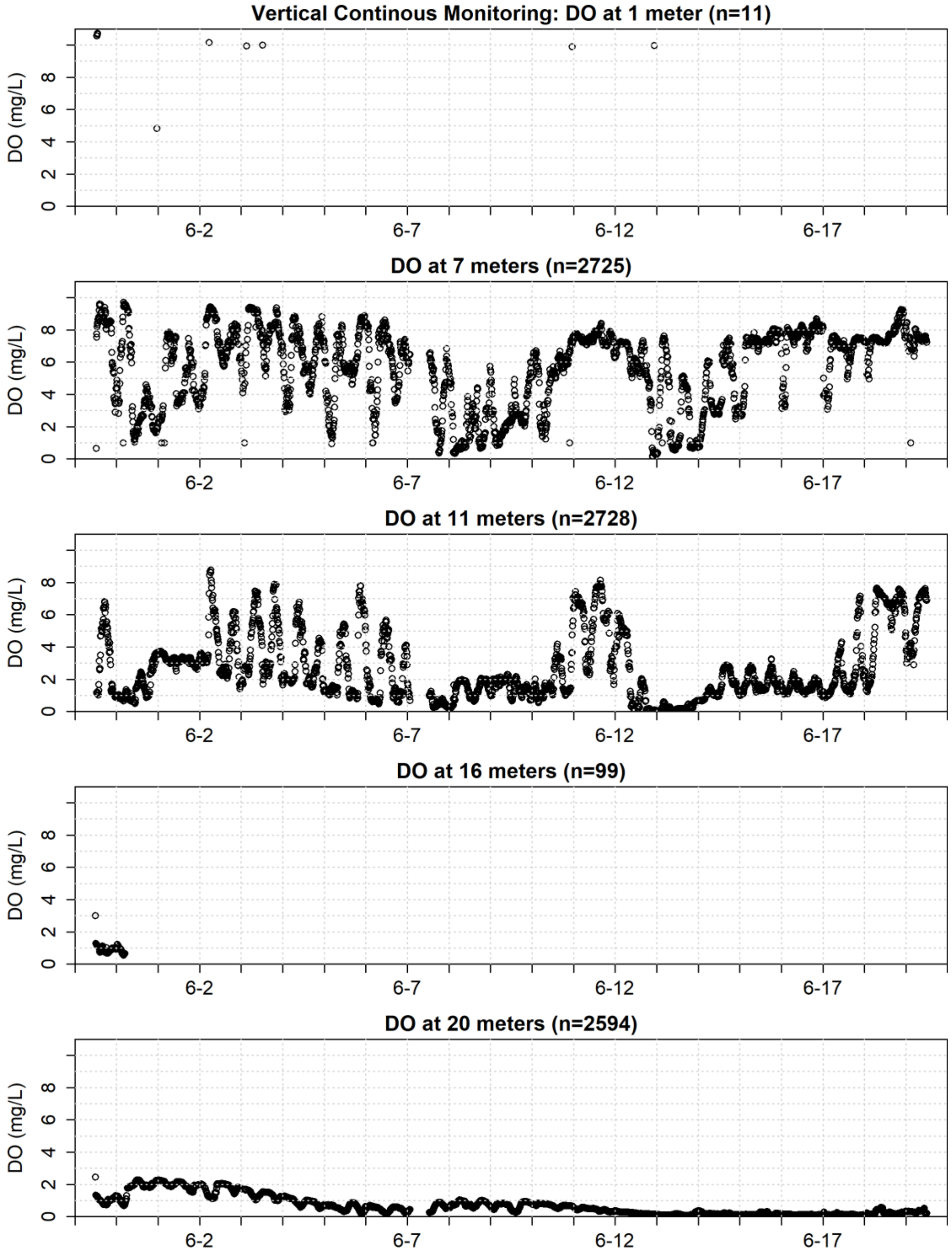
Sept 13-Oct 6



https://sensors.ioos.us/#metadata/105523/station

Observations
May 30-June 19

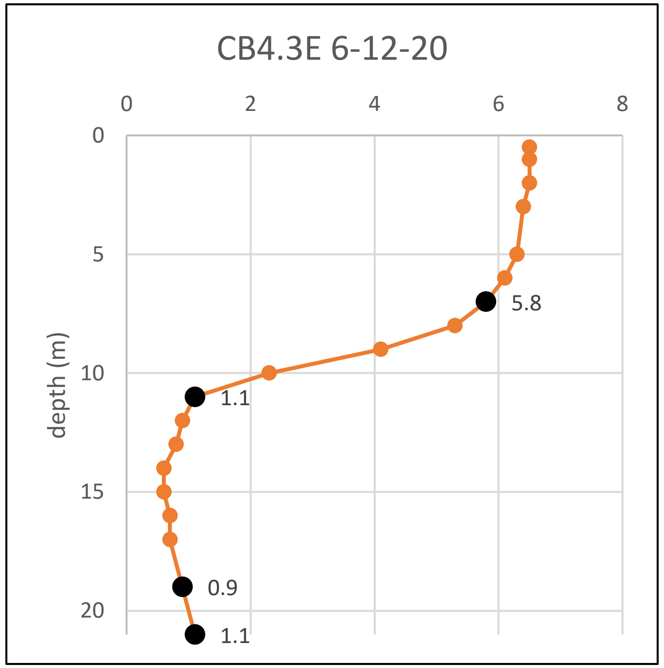
- Depths with QA'ed 10-min DO data:
  - 7m
  - 11m
  - 20m
- Parameters:
  - DO
  - Water temp (also at 1m)
  - Sea water pressure (20m only)

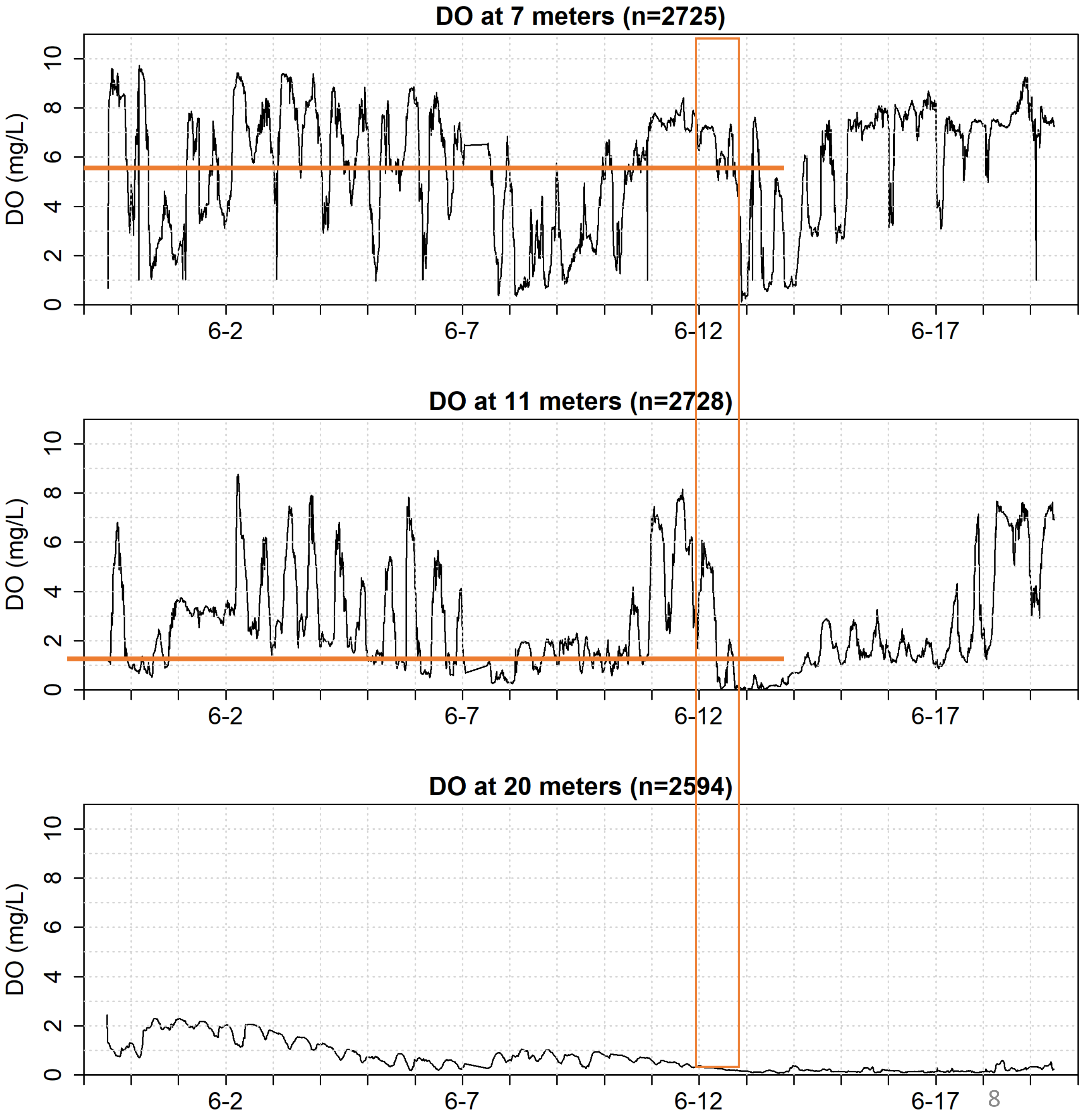


https://sensors.ioos.us/?#metadata/103543/station

Part 1: visualize and compare

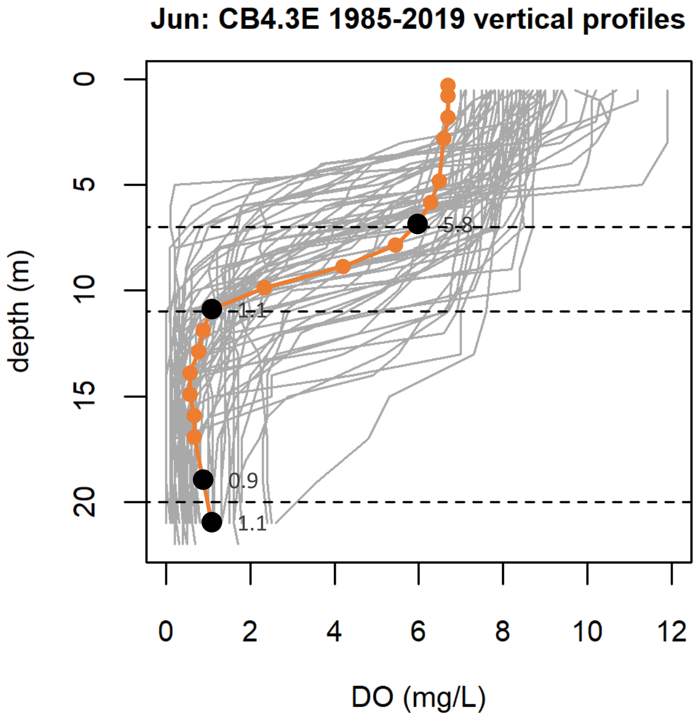
Compare to long-term sampling in the period



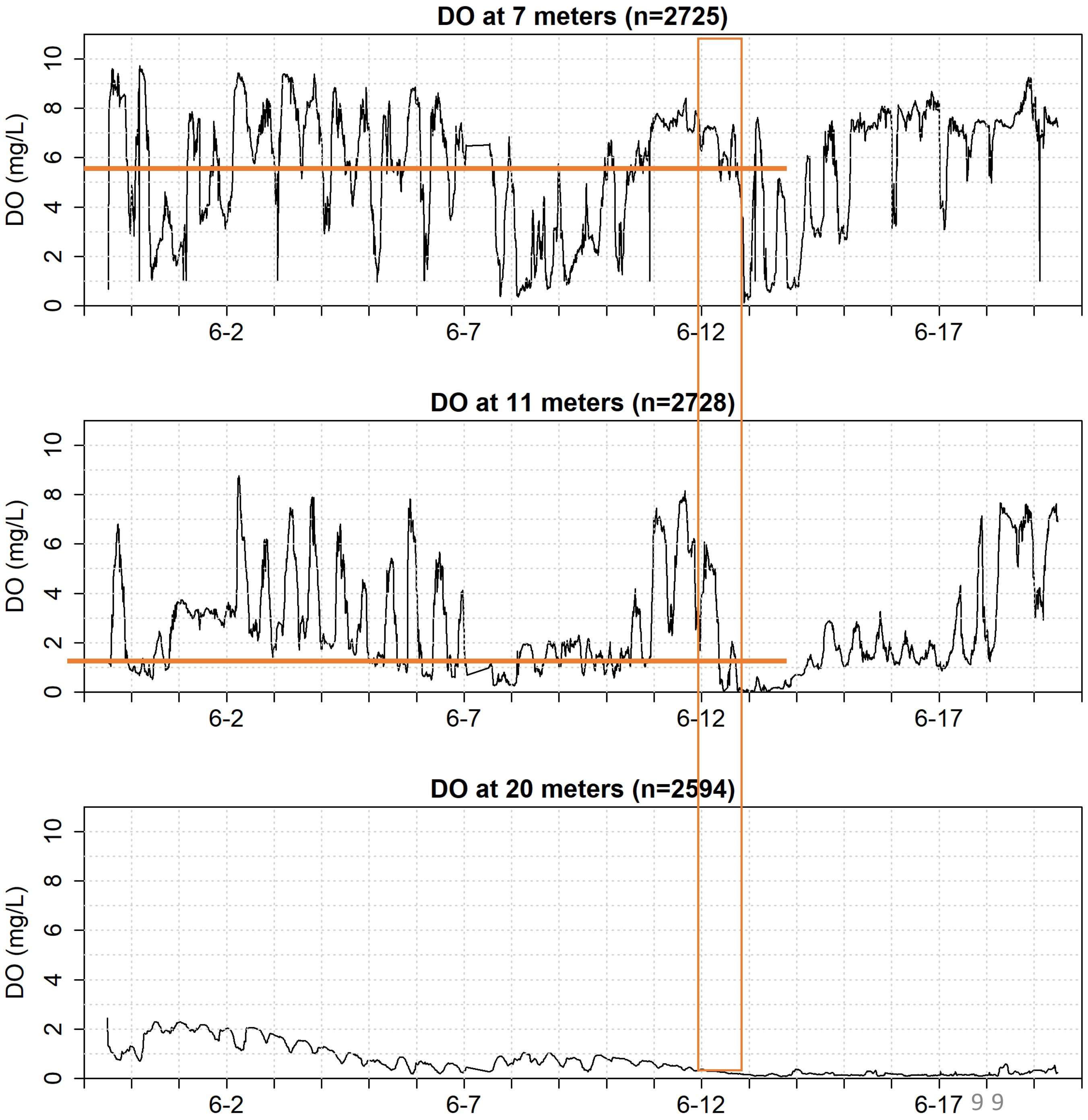


Part 1: visualize and compare

Compare to range of June DO profiles



(note: lower surface observation for June 2020 is because I suspect this is the only sample time was different than usual.)



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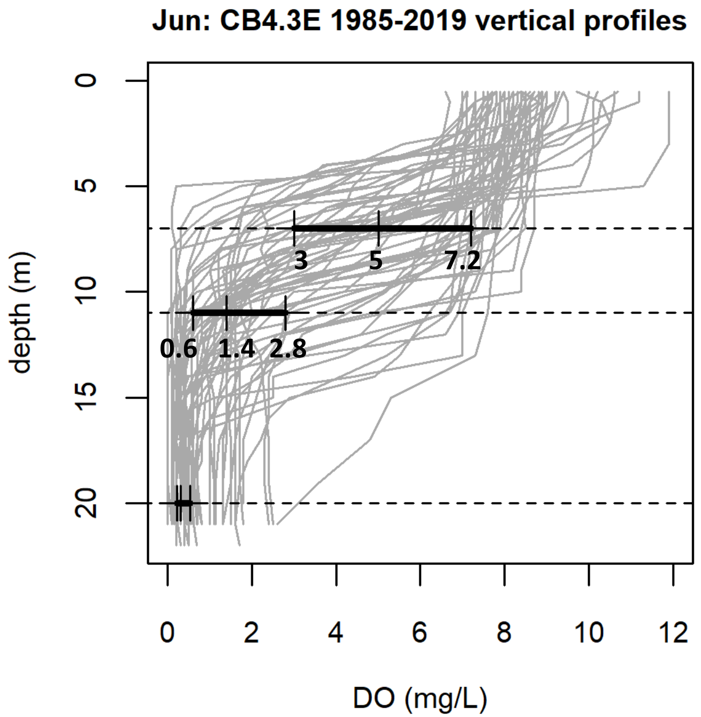
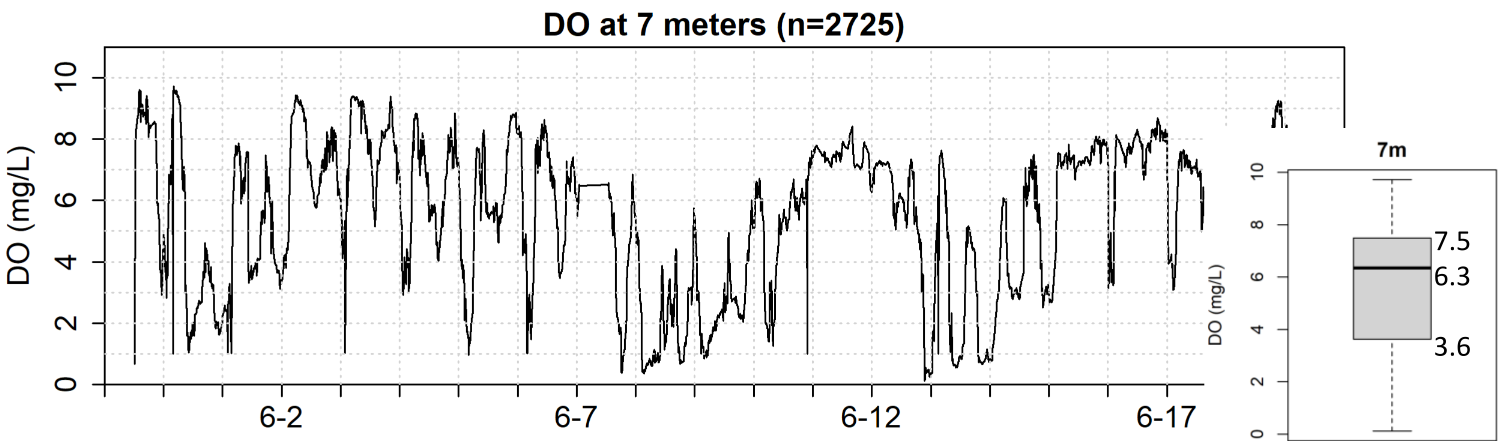
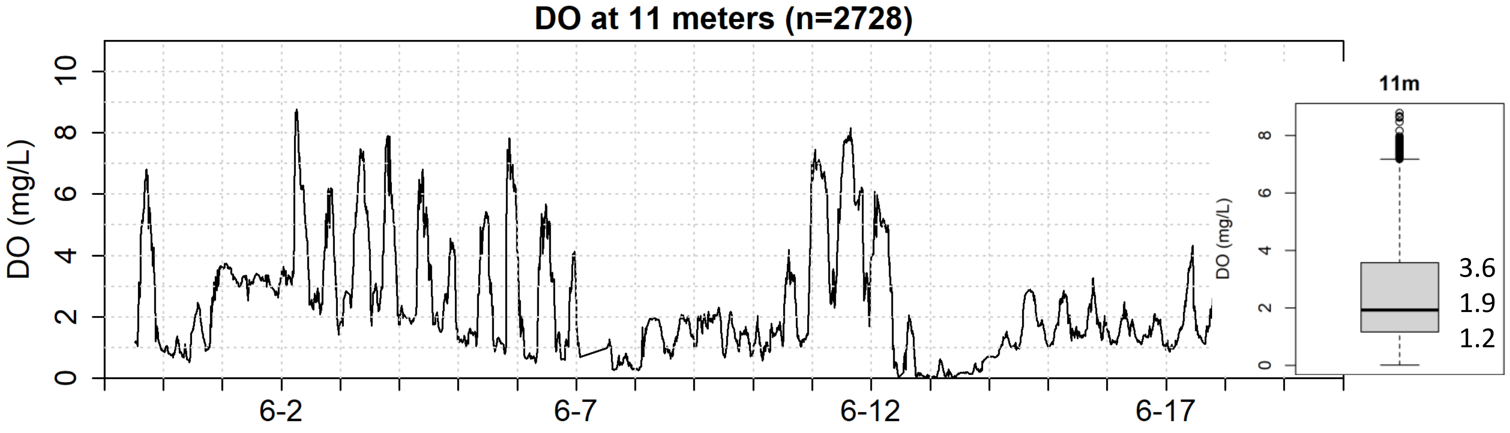
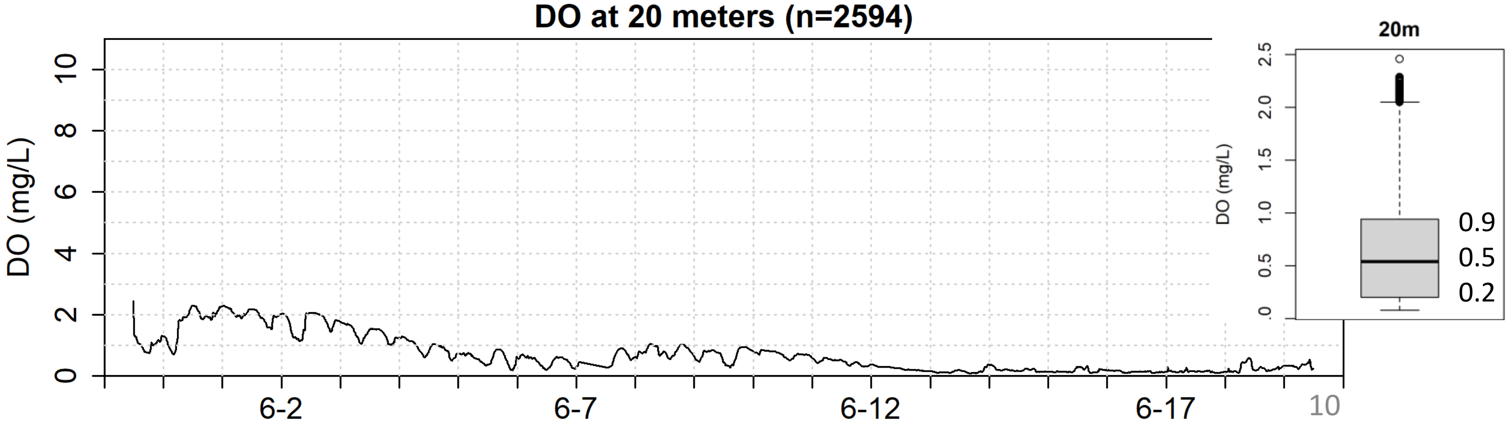


- Combined long-term profiles have similar variability to the 10-min data

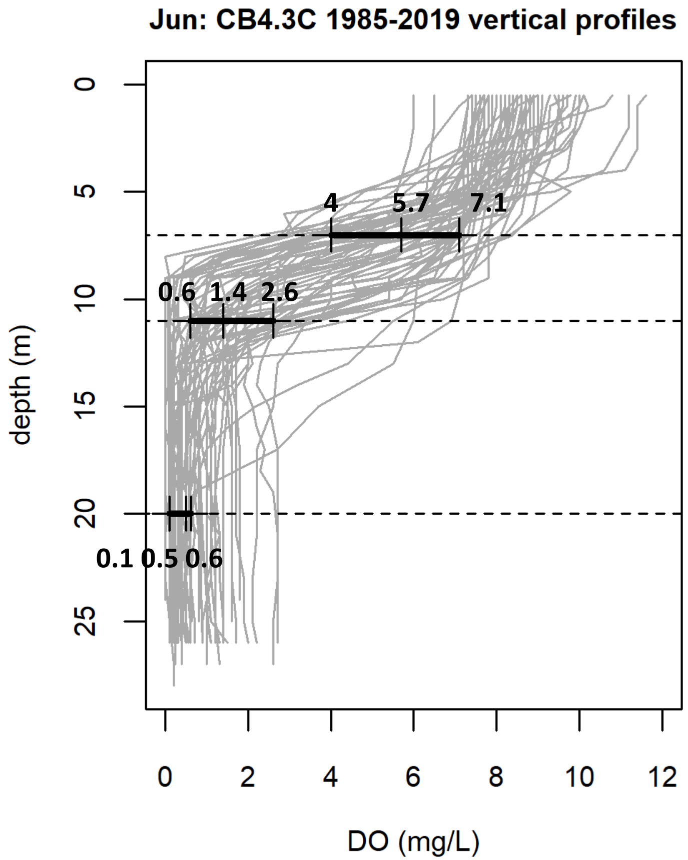


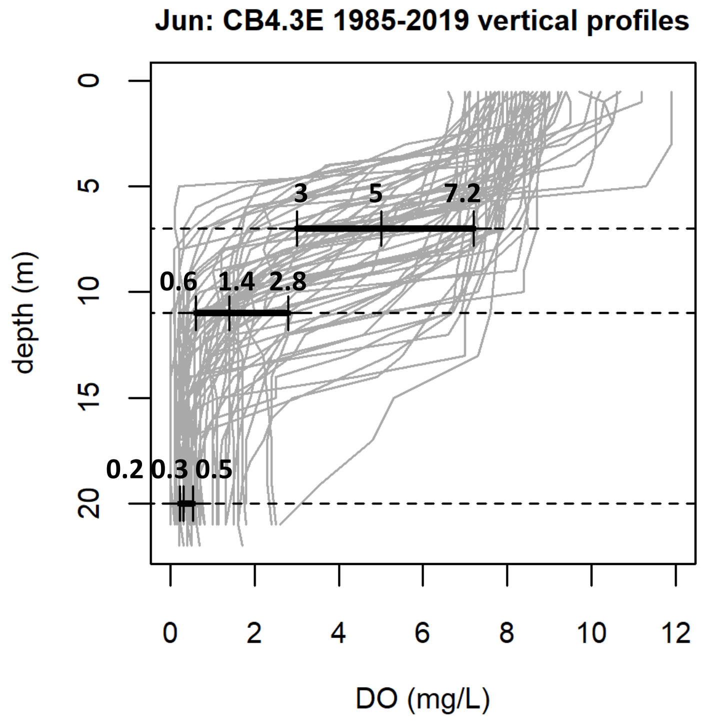




Part 1: visualize and compare

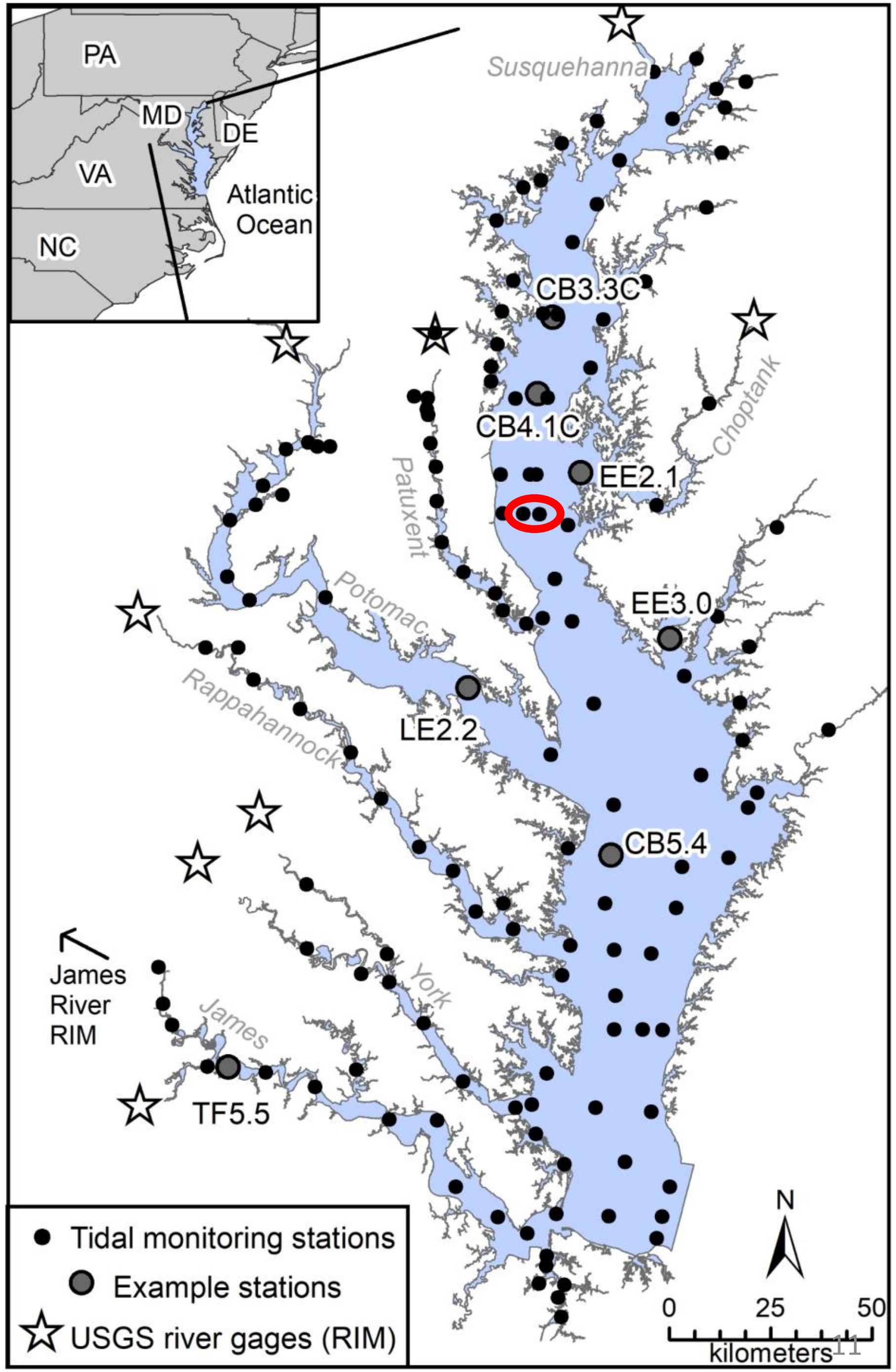
Compare to range of June DO profiles at center channel station





- Surface mixed layer more frequently shallower at E than C.

→ Conclusion: the short-term variability seen this continuous station might not be the same as even at nearby stations.



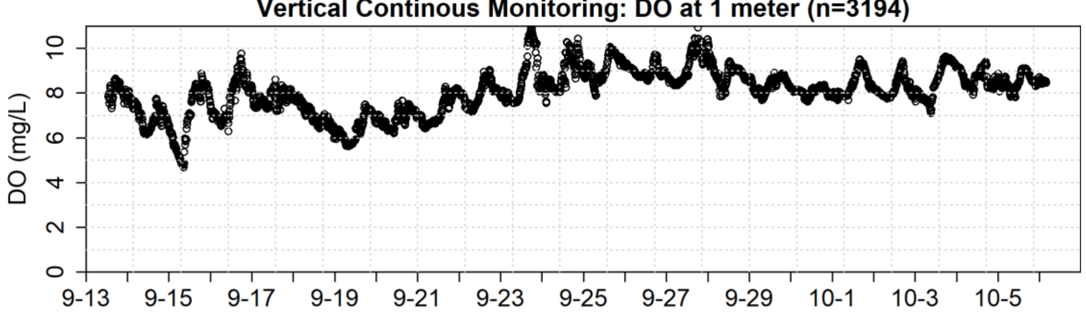
Part 1: visualize and compare

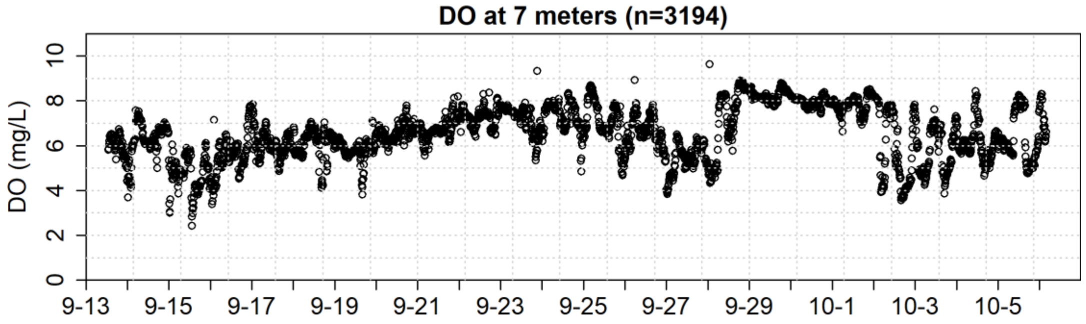
Observations: DO from Sept 13-Oct 6

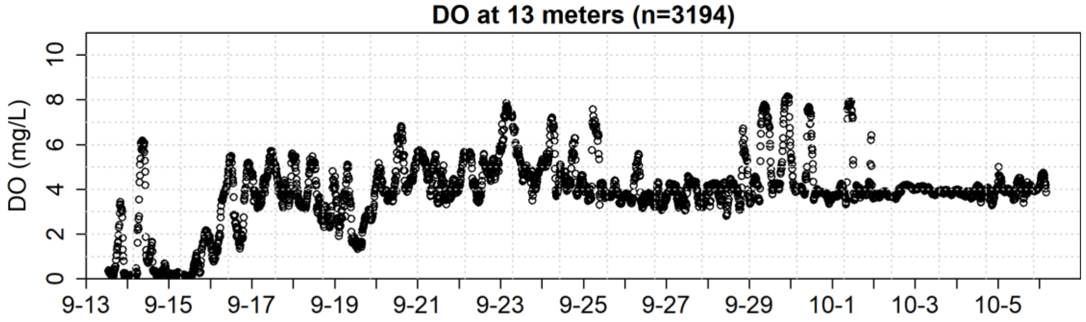
- Depths with 10-min data:
  - 1m
  - 7m
  - 13m
  - 20m
- Parameters
  - DO
  - Water temperature
  - Sea water pressure (13 and 20 only)
  - Conductivity
  - Salinity
- *More analysis in next section…*

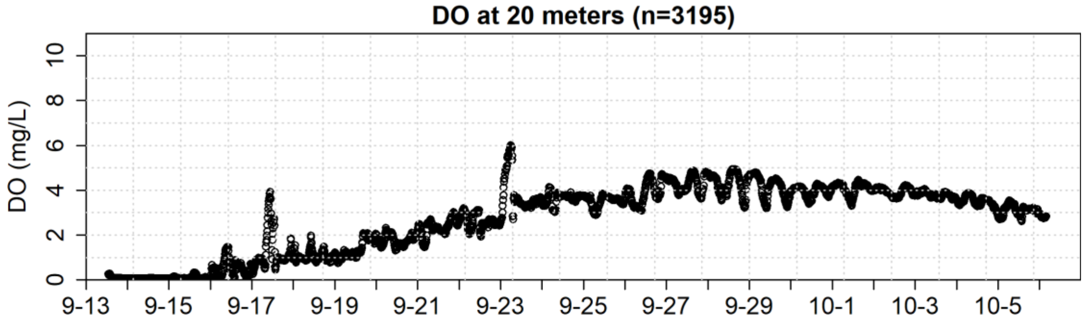
https://sensors.ioos.us/#metadata/105523/station

Part 1: visualize and compare









Part 1. Summary

Take homes:

- A lot of within-day DO variability in the mid-depths.
- Over time, long-term monitoring captures this range.
- There may be important differences by location for certain short-term DO dynamics.

Next Steps:

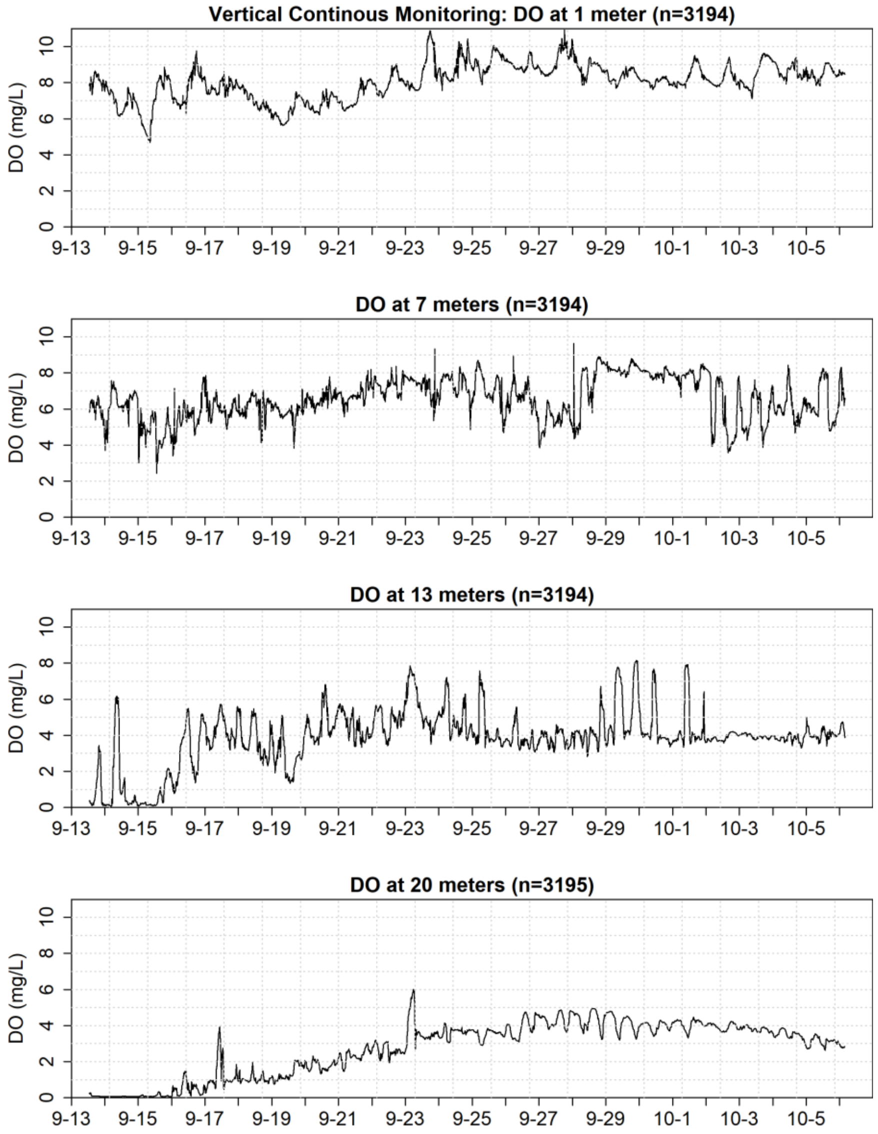
- Compare to continuous monitoring in other parts of the bay (Peter showed some of this).
- Think about how these observations can inform future placement of continuous monitoring.

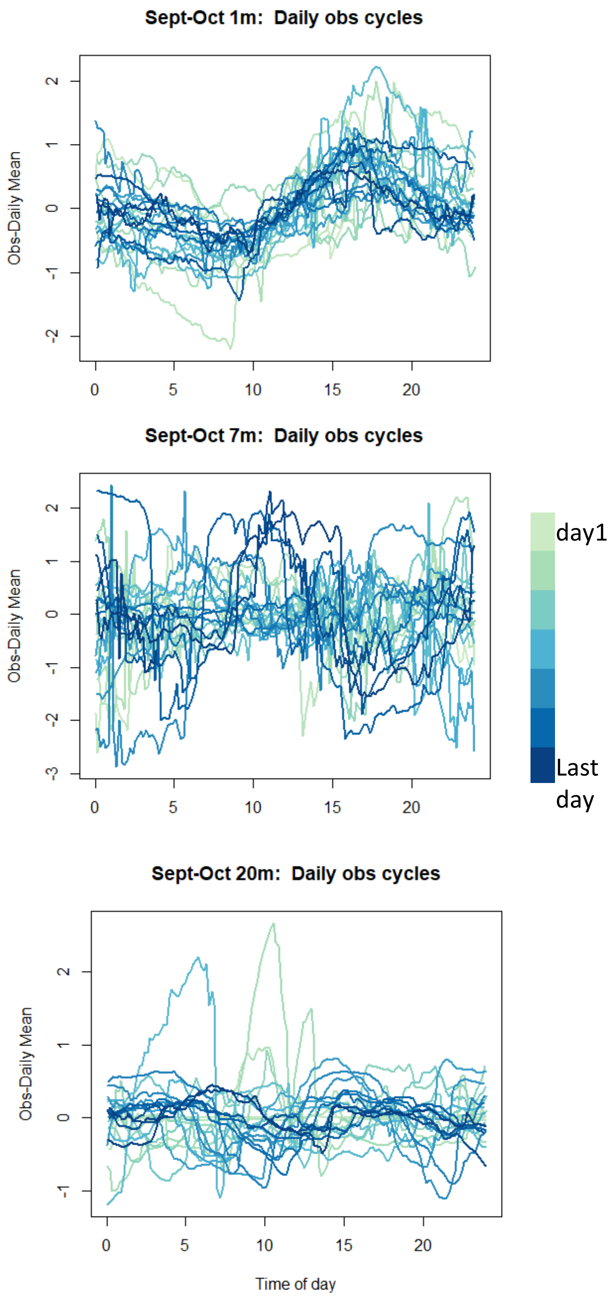
Part 2. Explore the Short-term Variability

- What are the daily cycles like?
- What factors influence variability after accounting for tidal-induced advection?

Daily cycles – Sept DO

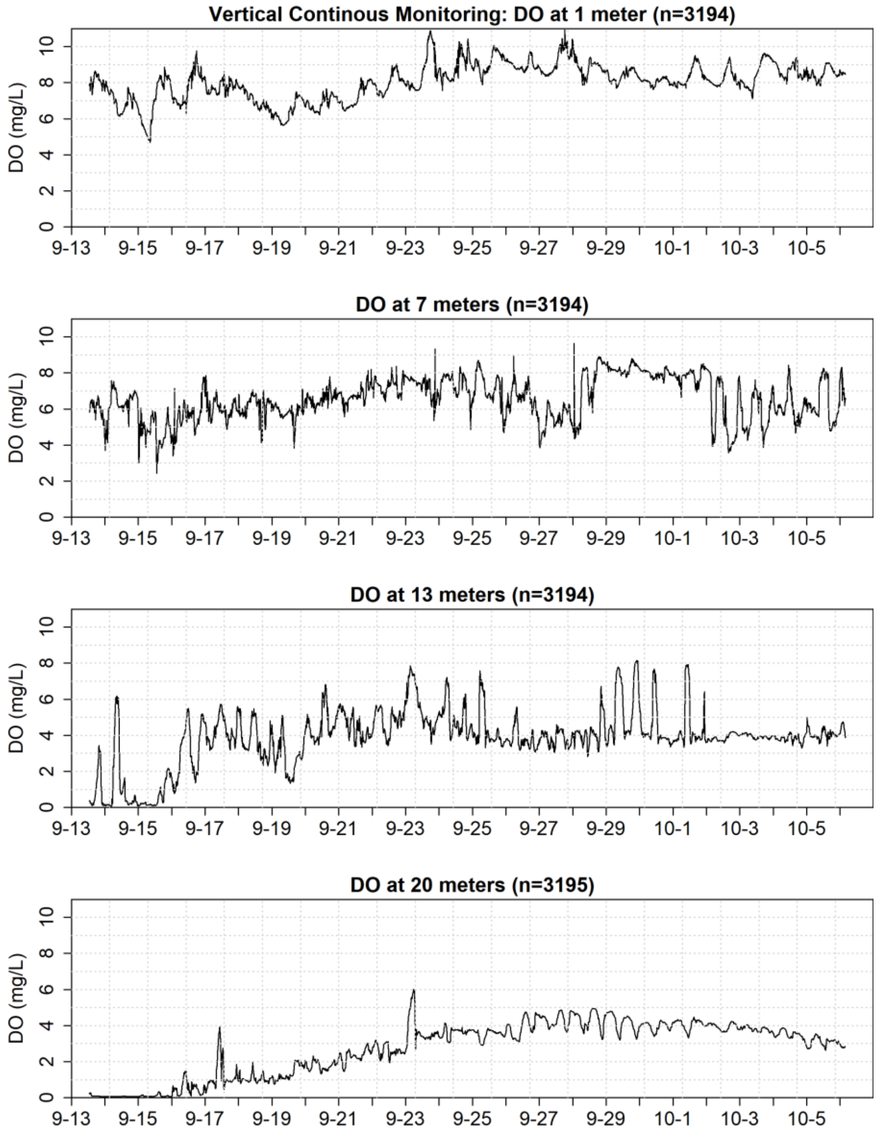
Simply subtracting mean daily avg from each value and plotting by hour





Part 2: Explore Variability

Daily cycles – Sept DO



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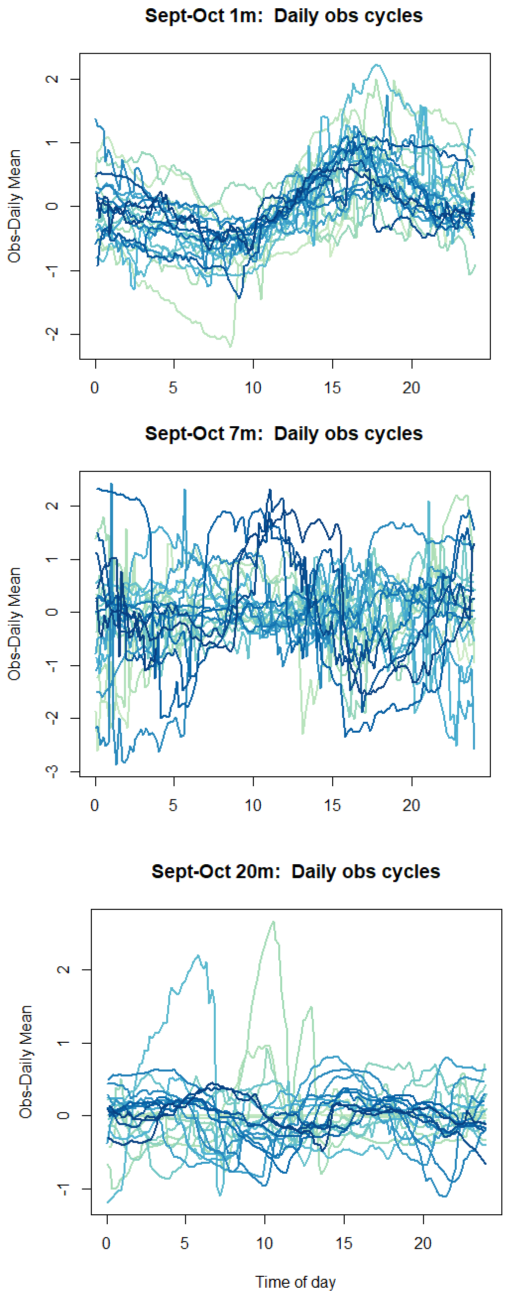
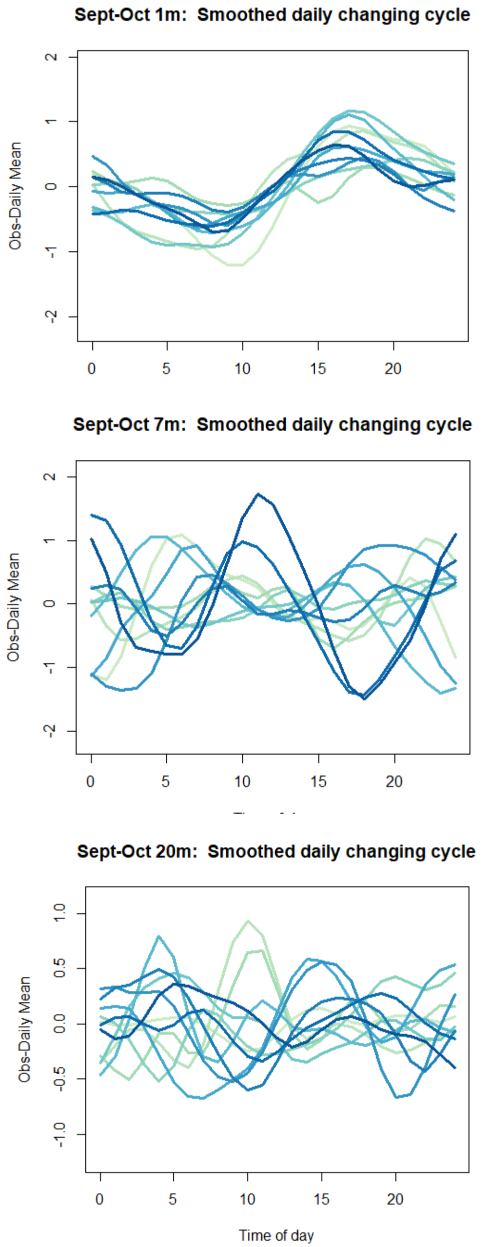


Smoothed with a GAM:
DO = s(time of day) + s(decimal date) + ti(time of day, decimal date)
→ "ti" allows for daily cycle to change over the record
→ (only every other day shown on these plots)



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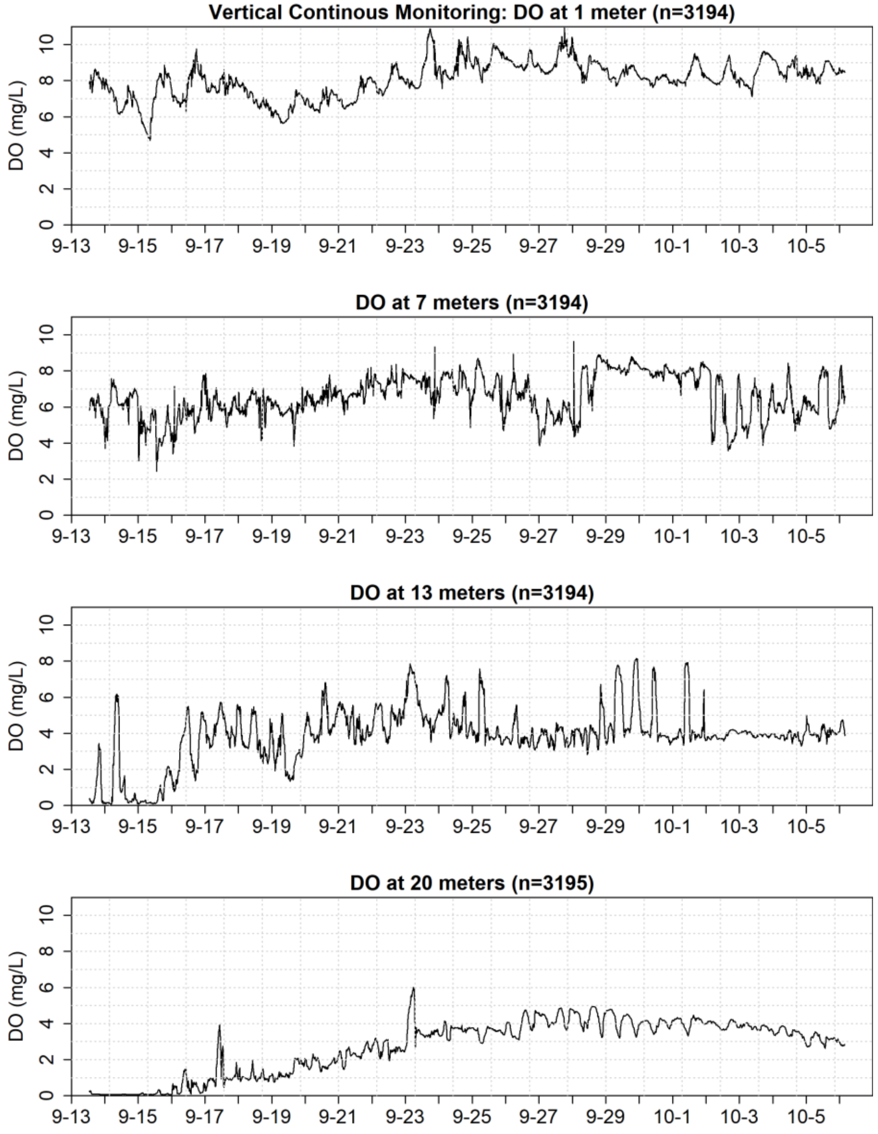
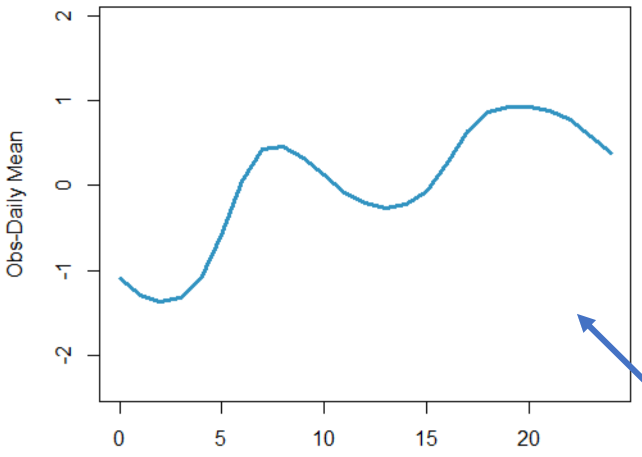
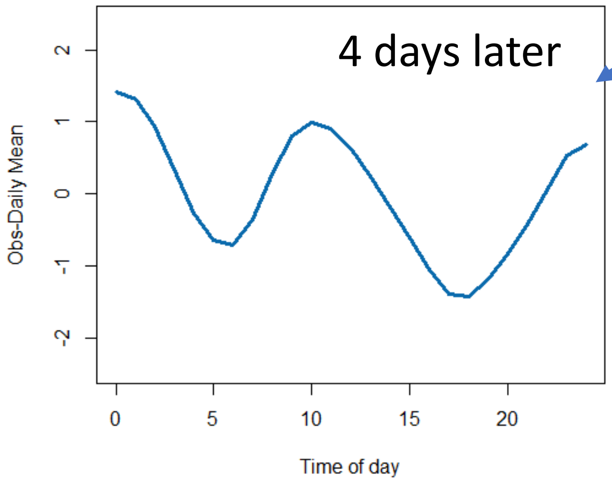
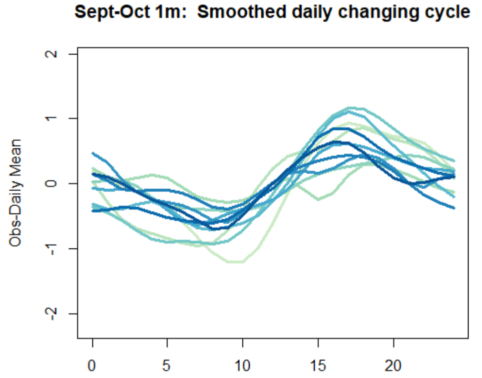
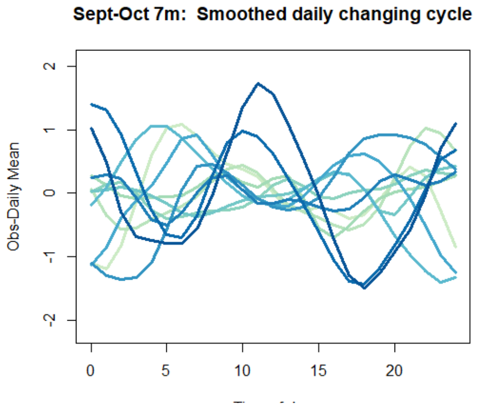
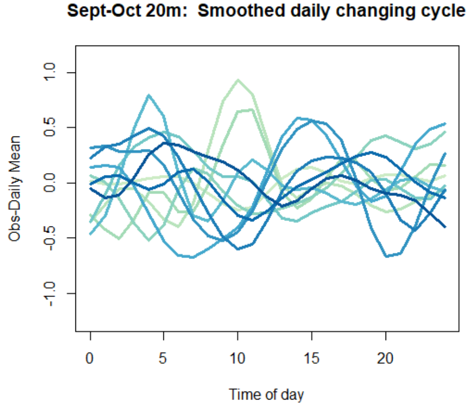






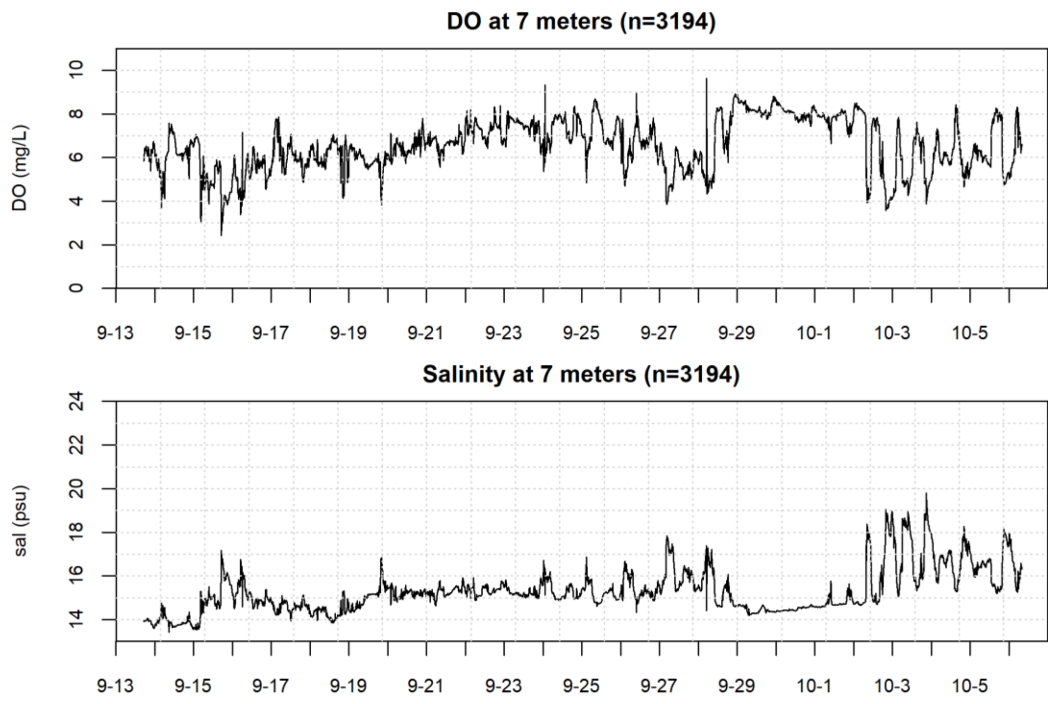






Analyzing relationships

- Tidally-induced advection likely plays a big role in the DO variability



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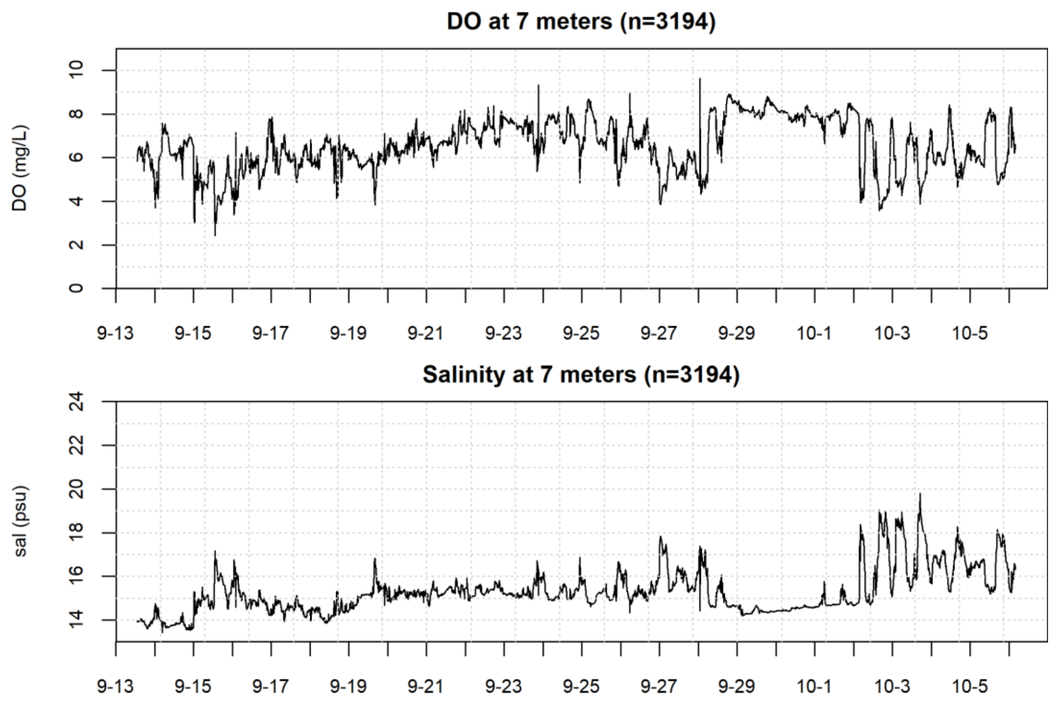
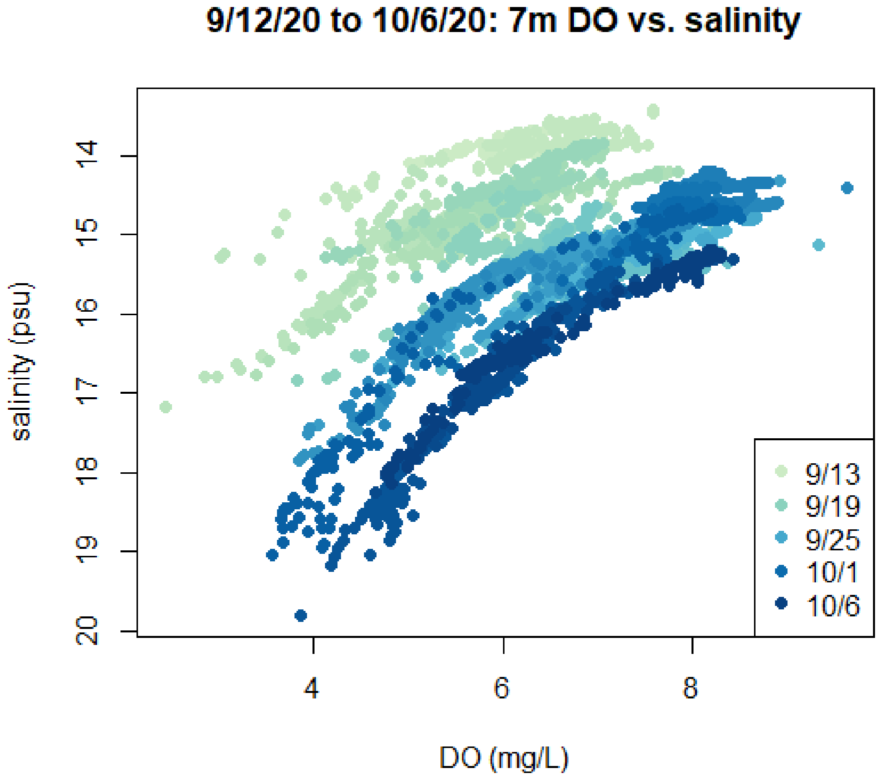
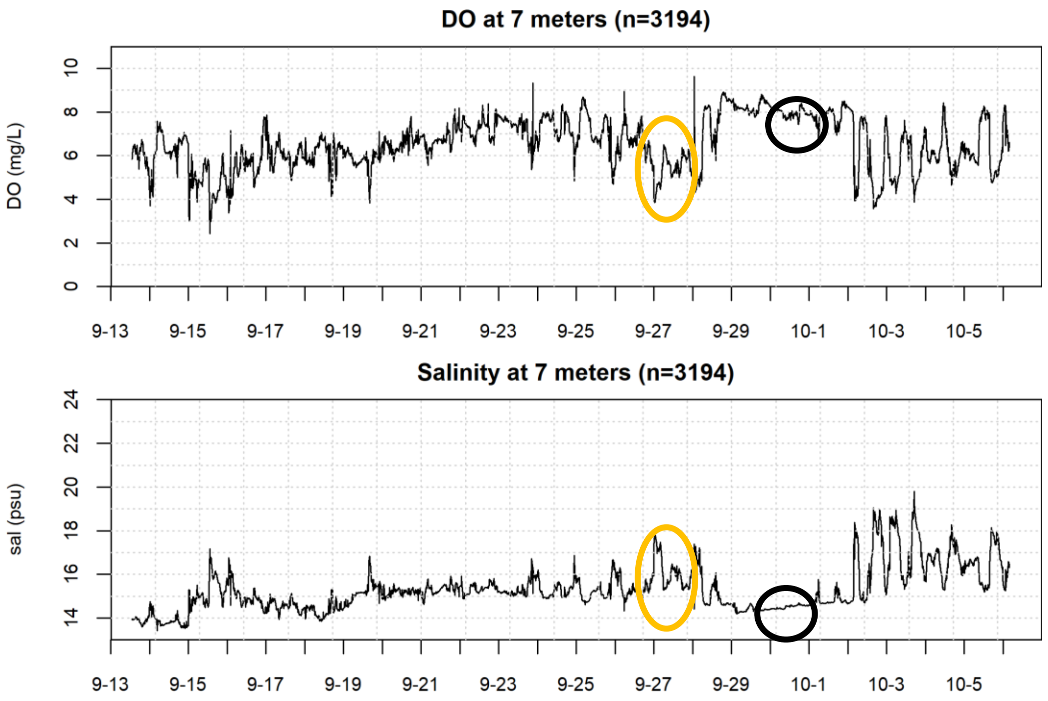


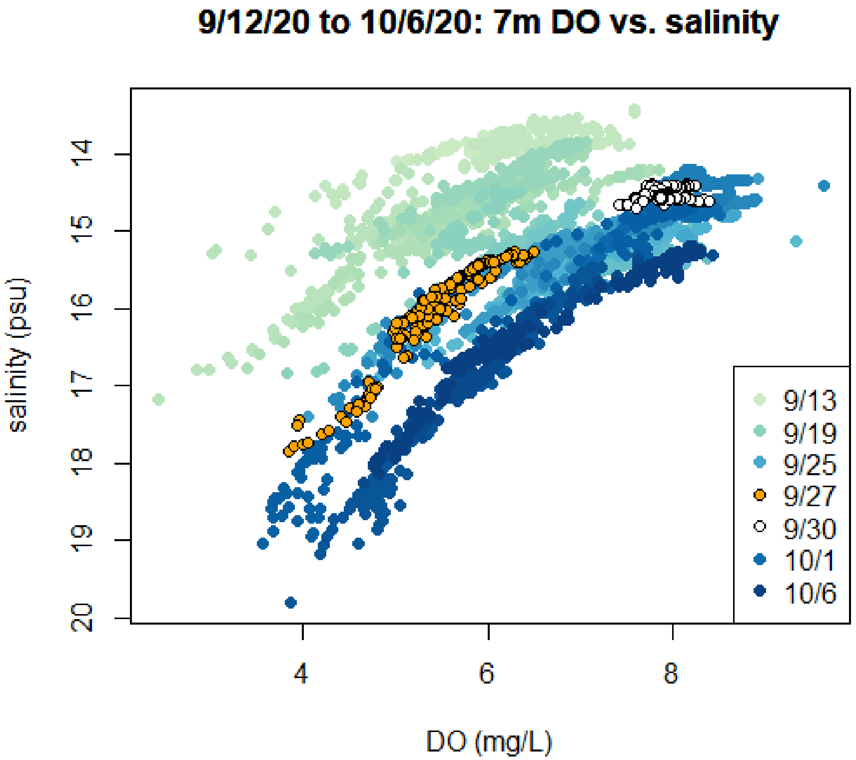
- Tidally-induced advection likely plays a big role in the DO variability
- Advective variability vs. other causes of variability can be identified with salinity-DO plot
- Over this Sept period, salinity increases

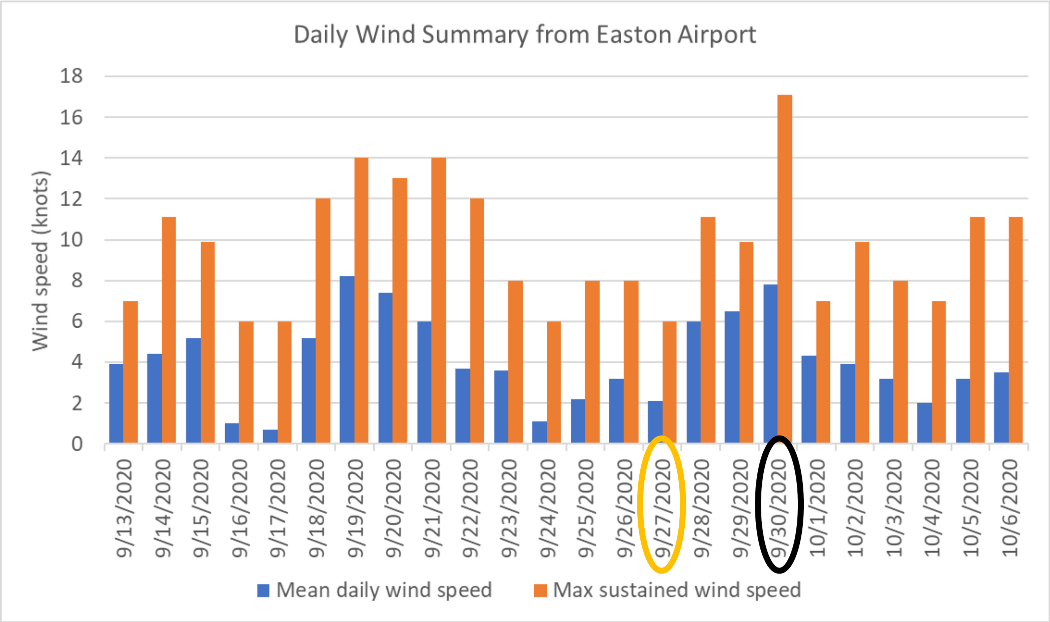


Example

- Compare two days close in time with high variability vs. little variability (at 7m)
- Can see the difference on the DO-salinity plot

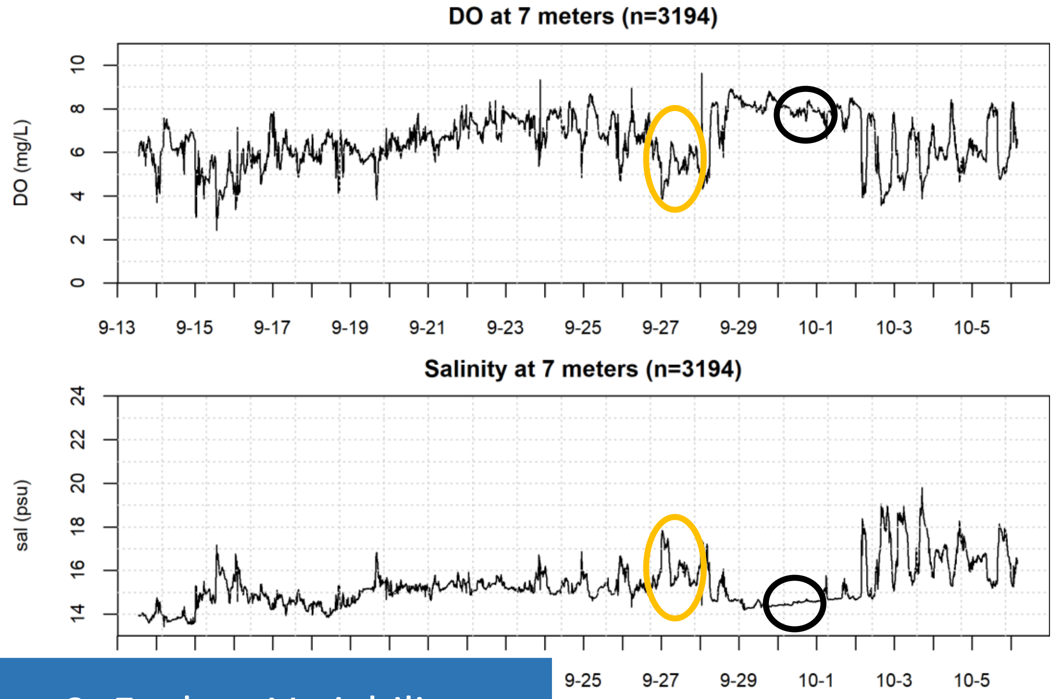


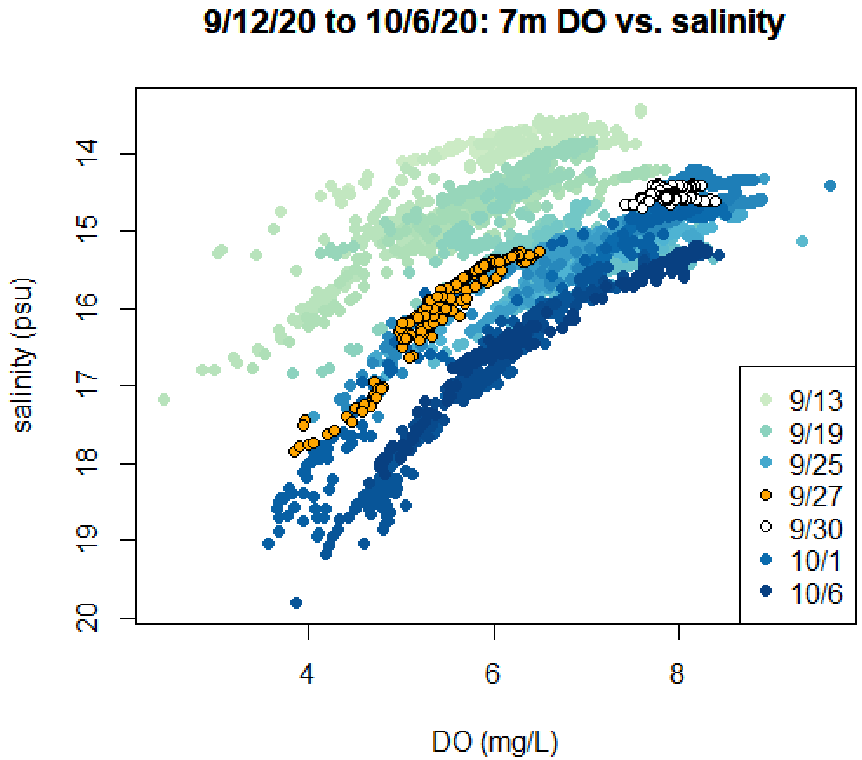




Possible factor: Wind

- Lower winds = surface mixing is low, therefore 7m is below the pycnocline and tidally influenced
- Higher winds = deeper surface layer including 7m





Part 2. Summary

- Tides influence the mid-depth daily fluctuations of DO.
- Examining temporally changing relationships (e.g., DO vs. salinity) can help us hypothesize about factors impacting DO variability.

Next Steps:

- Make similar (DO vs. Sal, Sal vs. Temp) plots for other depths and June time period.
- Set up some tests (e.g., CART) to test explanatory factors for short-term variability.
- Compare to estuarine model output.

Part 3. Insights into criteria analysis

- What do these data tell us about the uncertainty around criteria assessment, particularly the assumption that two observations represent the monthly mean?

Table 1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	7-day mean ≥ 6 mg $liter^{-1}$ (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species.	February 1 - May 31
	Instantaneous minimum ≥ 5 mg $liter^{-1}$	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean ≥ 5.5 mg $liter^{-1}$ (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean ≥ 5 mg $liter^{-1}$ (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean ≥ 4 mg $liter^{-1}$	Survival of open-water fish larvae.	
	Instantaneous minimum ≥ 3.2 mg $liter^{-1}$	Survival of threatened/endangered sturgeon species.[1]	
Deep-water seasonal fish and shellfish use	30-day mean ≥ 3 mg $liter^{-1}$	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean ≥ 2.3 mg $liter^{-1}$	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum ≥ 1.7 mg $liter^{-1}$	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum ≥ 1 mg $liter^{-1}$	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

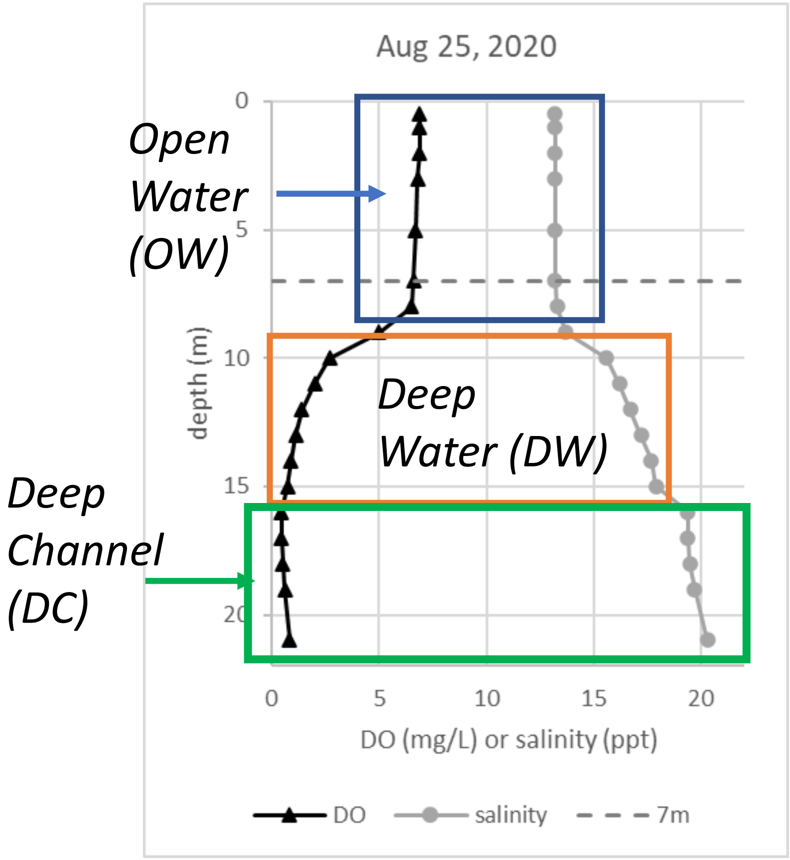
[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg $liter^{-1}$ will protect survival of this listed sturgeon species.

EPA 2003. Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries EPA 903-R-03-002

Assigning each sample to a layer/designated use (DU)

- Based on historical CB4.3E data:
  - 7m: mix of OW and DW
  - 11 and 13m: mix of DW and DC
  - 20m: Always DC
- Approach: Compare temperature or salinity between 7m and 1m and between 11 (or 13) and 20m.
- Decide on cutoffs to assign each 10 min sample a DU/layer.

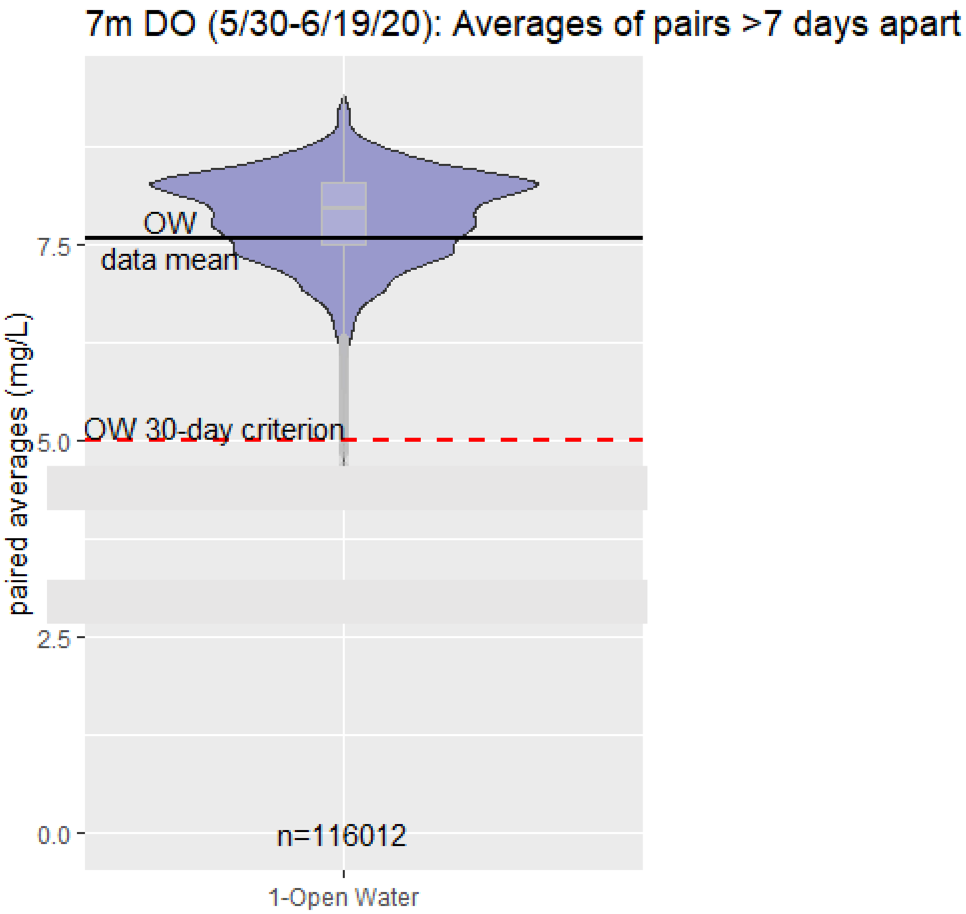
Example of Designated Uses (DU)



Analysis

1. Assign each sample a DU.
2. Compute average DO in each DU-depth combination.
3. Sub-sample the 10-minute data to get all pairs of 2 samples >7 days apart within each DU-depth.
4. Compute the average of every one of these pairs.
5. Answer: How often would 2 samples give the same conclusion as the continuous data for meeting the criteria in each DU?

Results: May-June data, 7m

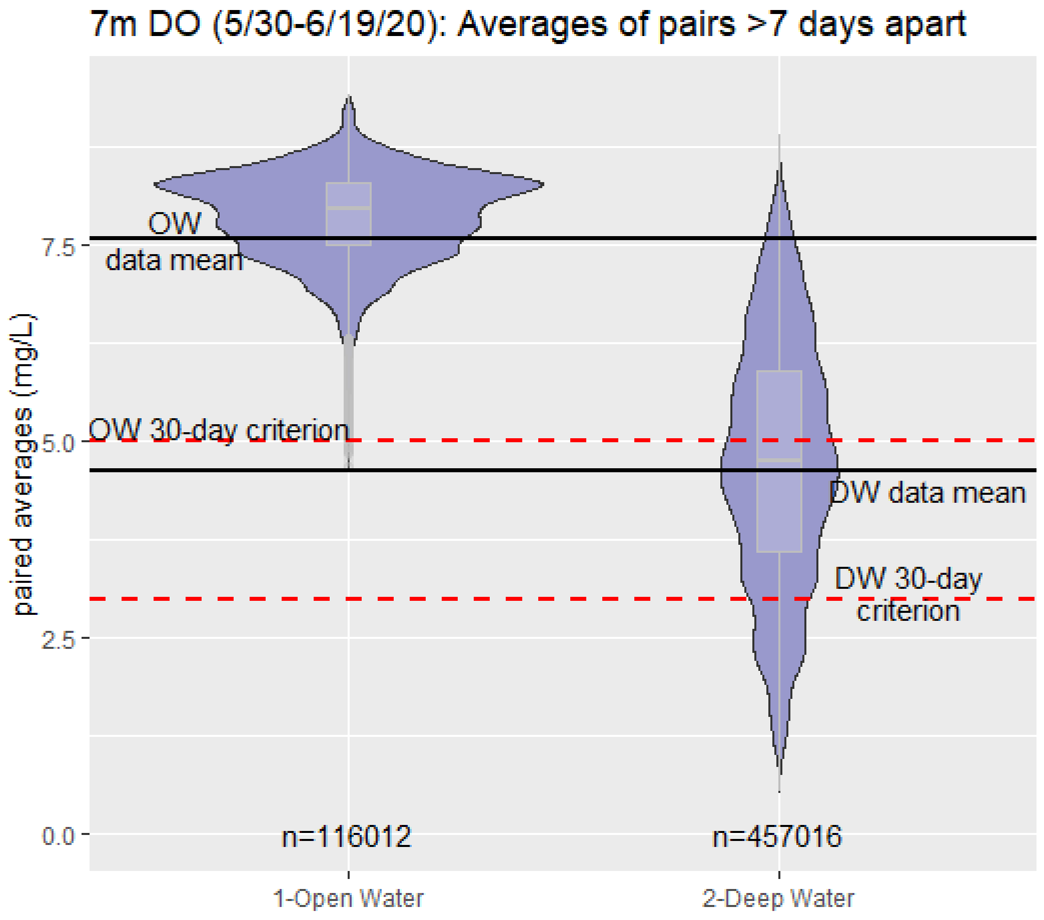


	Open Water (30-day criterion is 5 mg/L)
Average of all 10 min samples	7.59 mg/L
Percent of paired averages < the criterion	0.015 %

If sampled only twice:

→ *During **Open Water** conditions: continuous average is well above 5mg/L, and there is almost no chance we'd think the 30-day mean OW criterion was not met.*

Results: May-June data, 7m



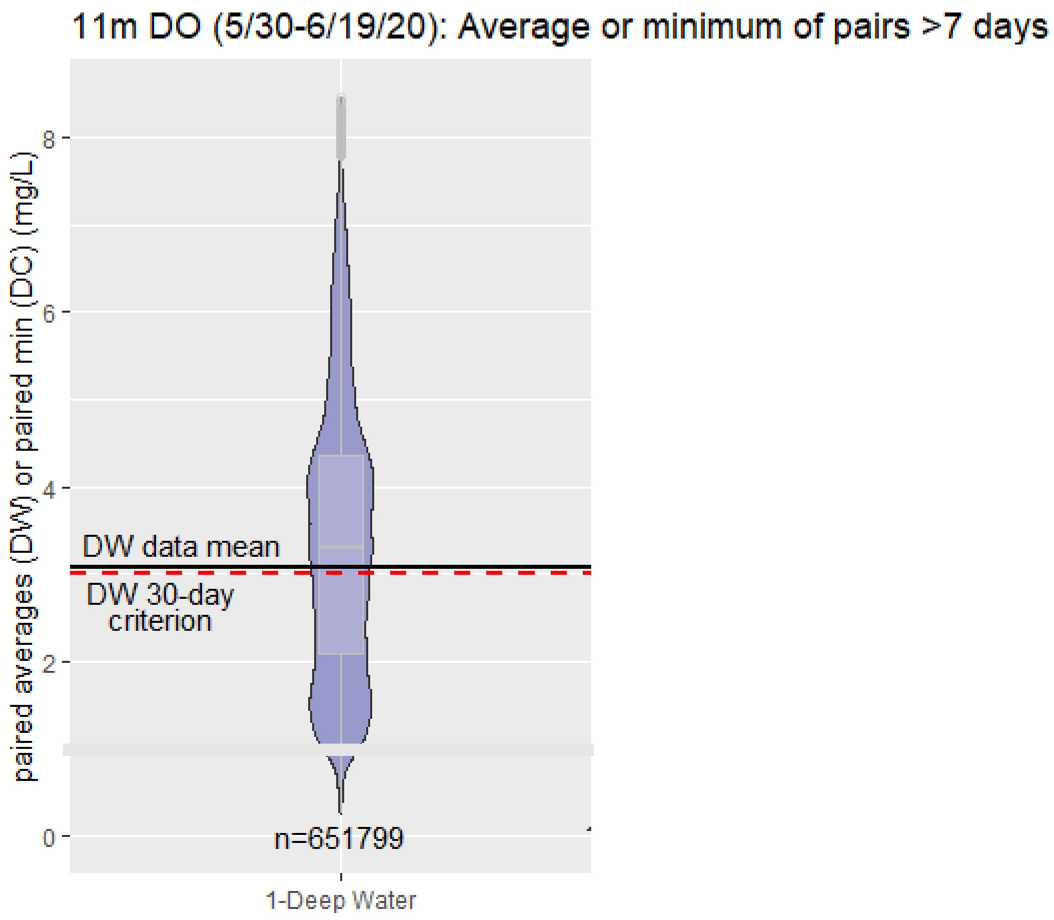
	Open Water (30-day criterion is 5 mg/L)	Deep Water (30-day criterion is 3 mg/L)
Average of all 10 min samples	7.59 mg/L	4.62 mg/L
Percent of paired averages < the criterion	0.015 %	14.9 %

If sampled only twice:

→ *During **Open Water** conditions: Continuous average is well above 5mg/L, and there is almost no chance we'd think the 30-day mean OW criterion was not met.*

→ *During **Deep Water** conditions: Continuous average is above 3mg/L criteria, and there is a 15% chance we'd think this criterion was not met from the pairs of continuous data.*

Results: May-June data, 11m



	Deep Water (30-day criterion is 3 mg/L)
Average of 10 min samples	3.09 mg/L
Percent of paired averages < the criterion	43.0 %

If sampled only twice:

→ *During **Deep Water** conditions: The continuous average is just slightly above the criterion, and 43% of the time we would think we did not meet the criterion.*

Part 3. Summary

- For this simple test -- most of the time we would make the “right” decision for OW and DW with just 2 samples at 7m.
- The 11m-DW continuous average is very close to the criterion, and as expected about half of the time the paired averages would suggest not meeting the criterion.

→*BUT this is just one spot, the criteria analysis needs to include space as well.*

<u>Next Steps</u>

- Could sample model output with this same evaluation.

Summary of some future work ideas

- Compare to other continuous monitoring data sets around the bay.
- Begin to test explanatory variables, if helpful.
- Explore how the short-term variability compares to estuarine model output.
- Incorporate finding from this into 4D interpolator project.

Thank you!

- **Team:** Gary Shenk (USGS), Larry Sanford (UMCES), Jeremy Testa (UMCES), Peter Tango (USGS), and Isabella Bertani (UMCES-CBP)
- Mark Trice (MDDNR) for CB4.3E long-term preliminary data and helpful info
- Doug Wilson, Caribbean Wind team and GIT-Trust funding
- MDDNR sampling team