Water Clarity Assessment and Update on Satellites and Turbidity

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Criteria Assessment Protocol Workgroup
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CHESAPEAKE BAY NATIONAL ESTUARINE RESEARCH RESERVE VIRGINIA

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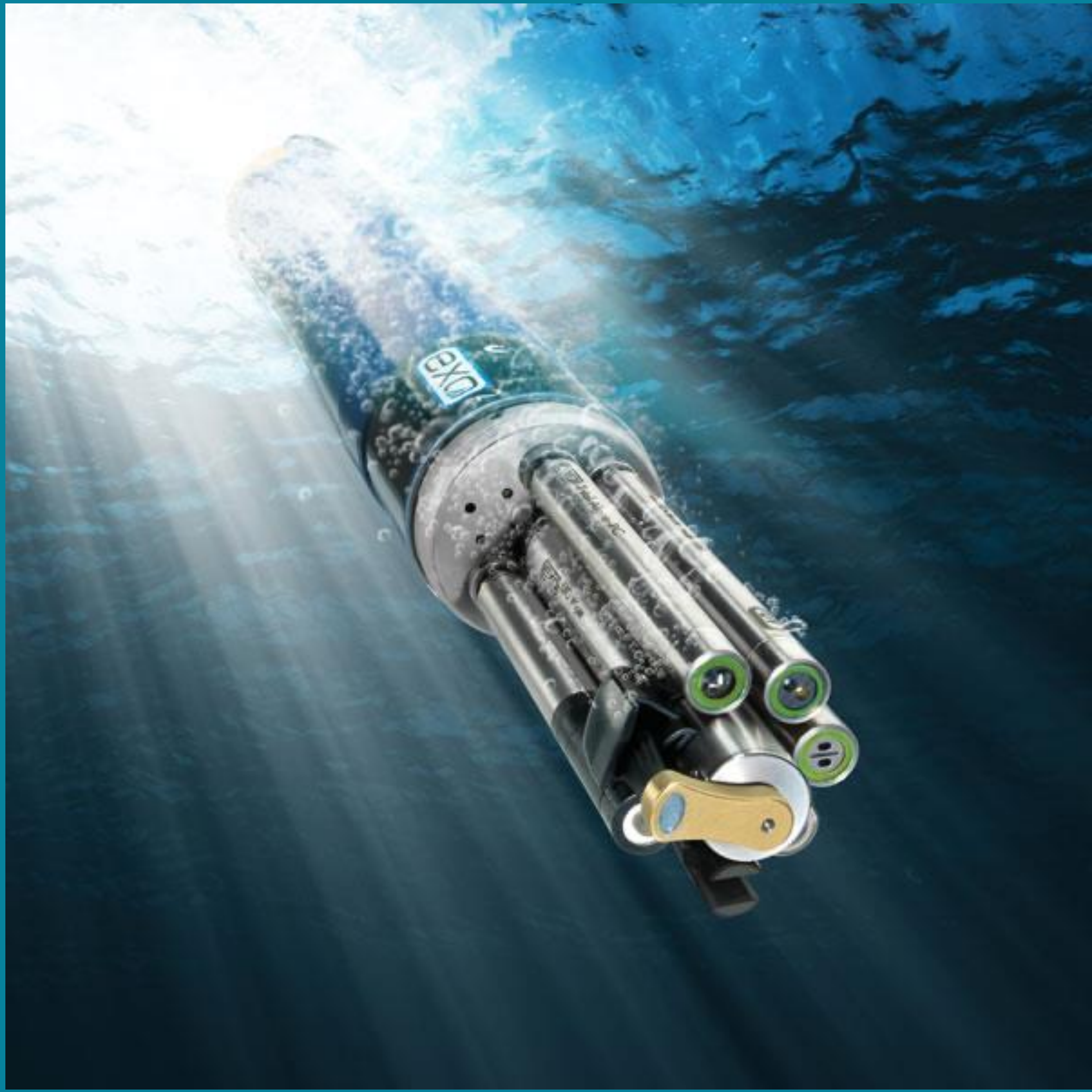
YSI EXO II

- Temperature
- Chlorophyll
- Turbidity
- Salinity
- Specific Conductivity
- pH
- Dissolved Oxygen
- Colored Dissolved Organic Matter (CDOM)



CBNERR-VA Monitoring Platforms

Fixed Stations

Near Bottom

Shallow water areas

15-min measurements

Dataflow

Surface

2-3 sec measurements

25 knots -> sample ever 25m

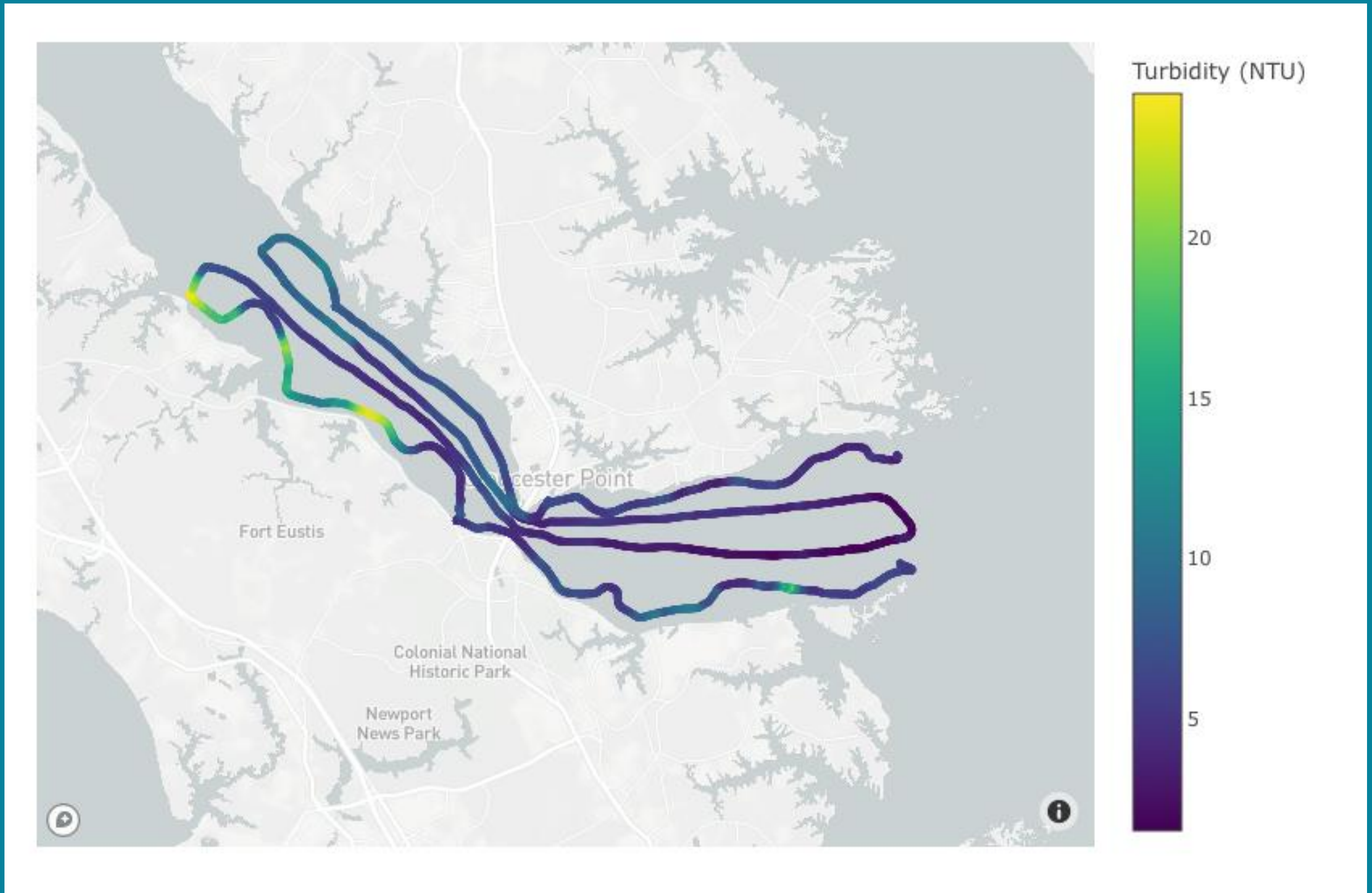
CBIBS Buoy

Surface

Floating buoy

6-min measurements

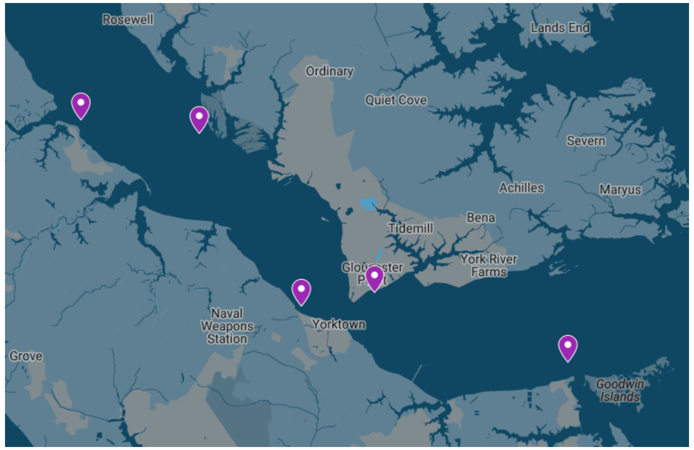
Water Clarity Assessments



York Polyhaline (YRKPH). July 2, 2007.

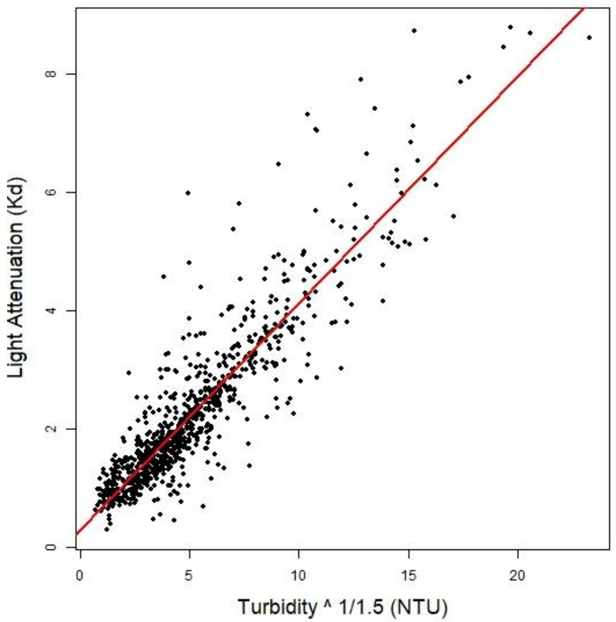
Water Clarity Assessments

Verification and Light Attenuation (Kd) Estimates



York River Polyhaline verification stations

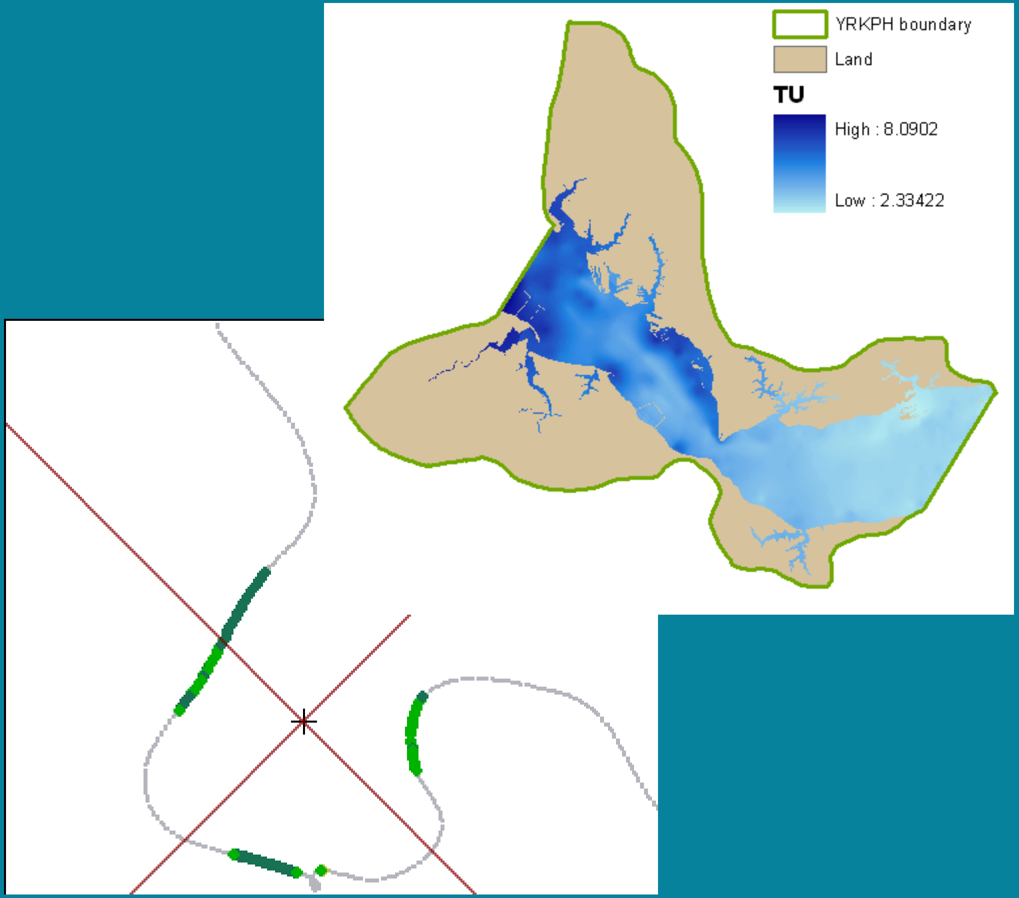
2003 – 2005, York River



$$K_d \sim \mathcal{N}(\mu, \sigma^2)$$

$$\mu = \beta_0 + \beta_1 \cdot \sqrt[1.5]{\text{Turbidity}} + \beta_2 \cdot \text{Chlorophyll} + \beta_3 \cdot \text{Salinity}$$

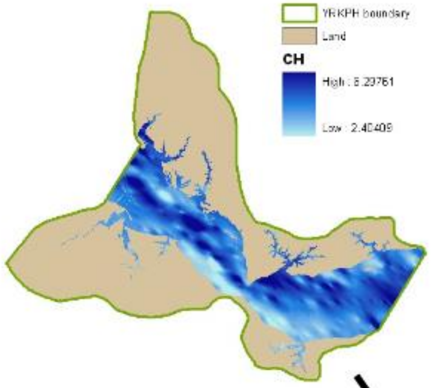
Interpolation: Kriging

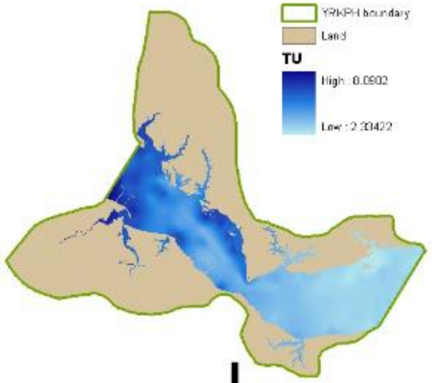


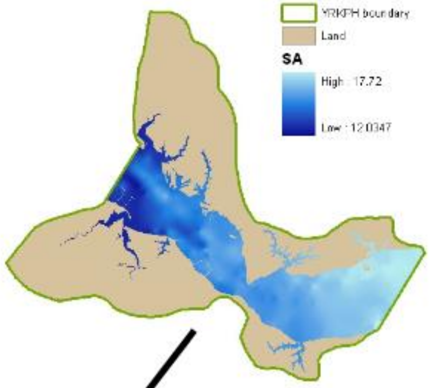
Chlorophyll Fluorescence

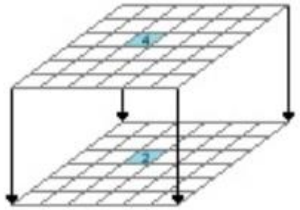
Turbidity

Salinity

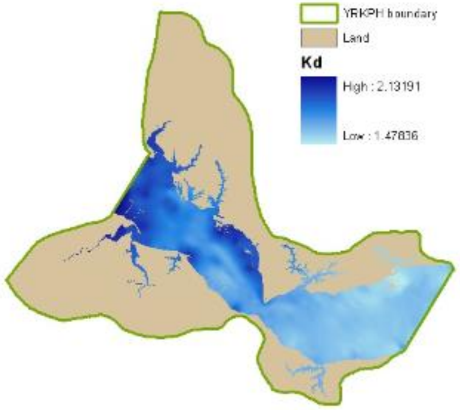








$$Kd = 0.53 + 0.32 \times \sqrt[1.5]{TU} + 0.018 \times SA + 0.027 \times CH$$

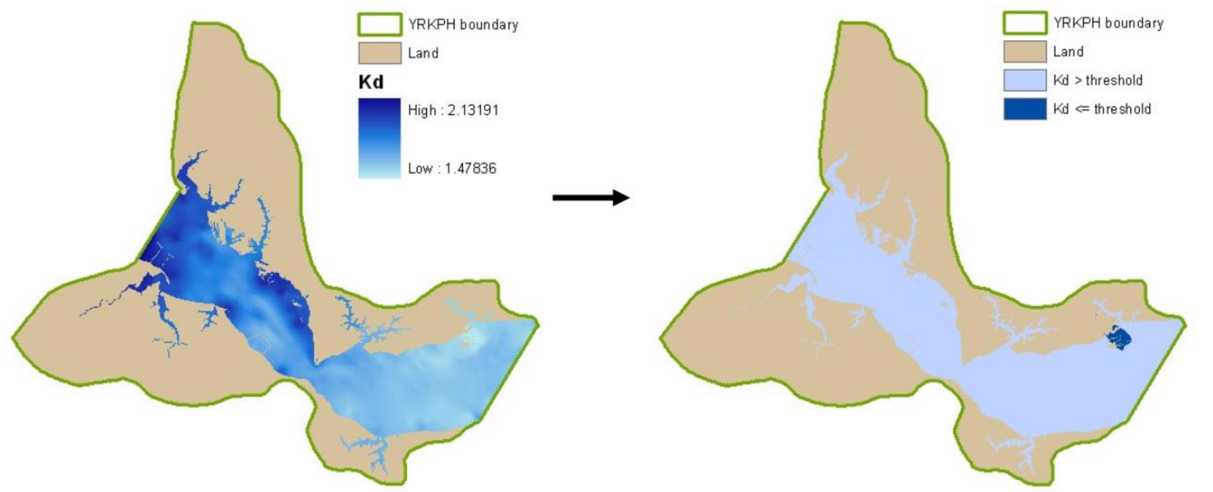


Kd Threshold

PLL	Zones	
	0-1m	**1-2m**
0.22	1.51	0.76
0.13	2.04	1.02

$$PLW = 100 \times e^{-Kz}$$

Polyhaline – Mesohaline: 22% PLL
Oligohaline - Tidal Fresh: 13% PLL



Methodology Challenges

- Segments with low goals can easily pass the water clarity acres goal by having one cruise with good clarity.
- Segments with high SAV goals and moderate/high SAV, may not pass water clarity acres due to insufficient remaining shallow water habitat due to the 2.5 multiplication factor.
- Spatial interpolation and modelling error is not accounted for in methodology
- Spatial and temporal monitoring constraints limit data coverage (1 cruise per month)
- Opportunity for development of Kd models by analyzing at a larger verification dataset (space and time) instead of focusing on current segment could improve models
- Sampling can be biased to good weather
- Opportunity to integrate other existing datasets (ex. fixed stations, satellite)

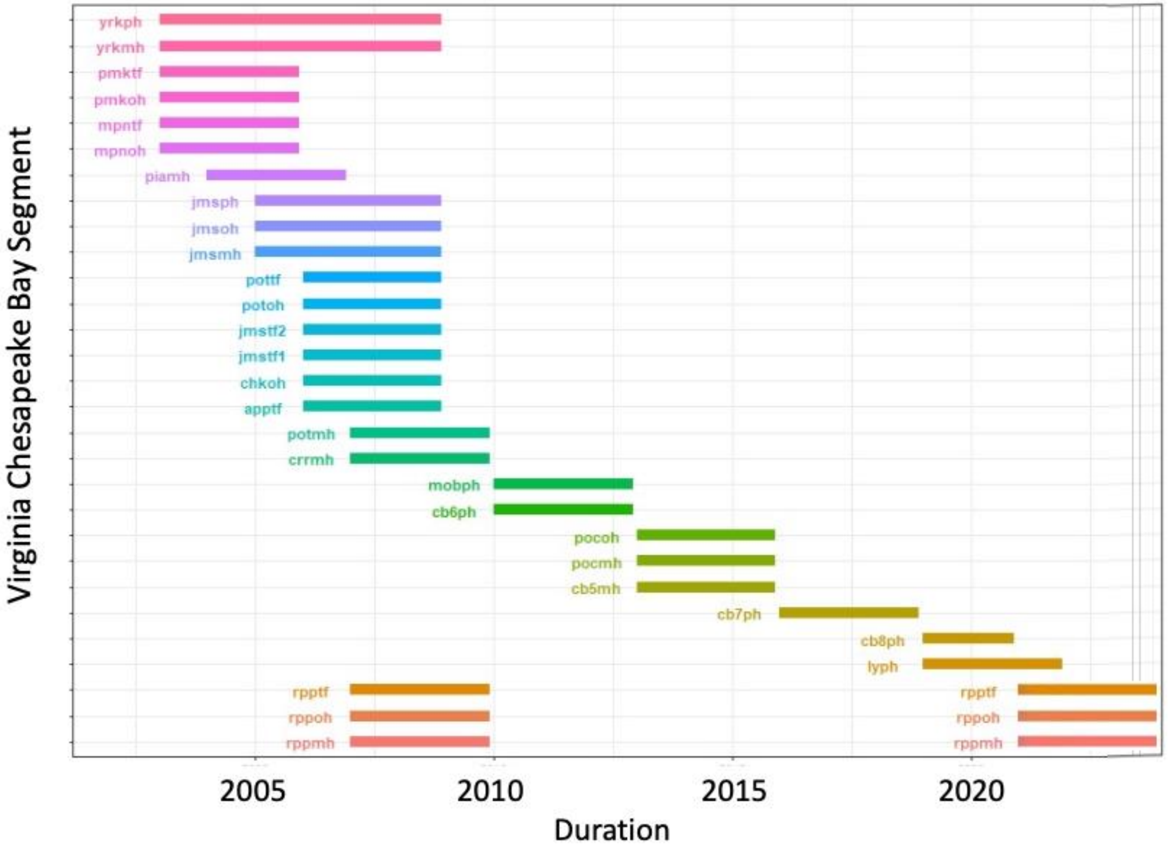
Adapted From Trice & Parrish, 2022, STAC Advanced Monitoring Workshop

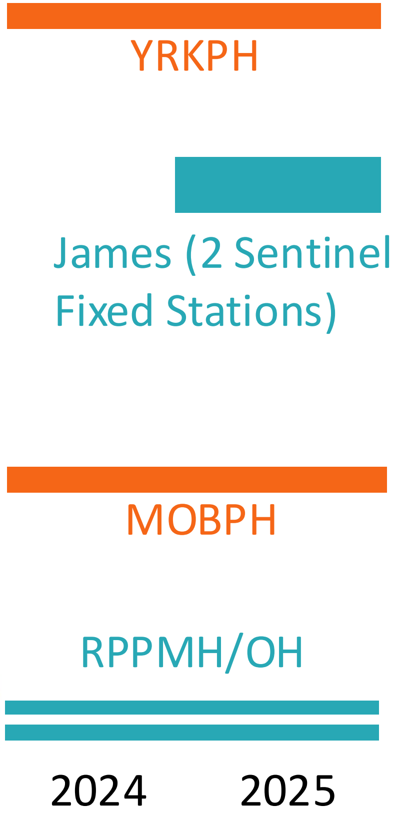
Over 20 years of High-Frequency Water Quality Monitoring

NERRS
CBIBS
Telemetered
VA-DEQ /EPA/CBP
VIMS Water Quality Initiatives
Past CMONs

Fixed

Dataflow





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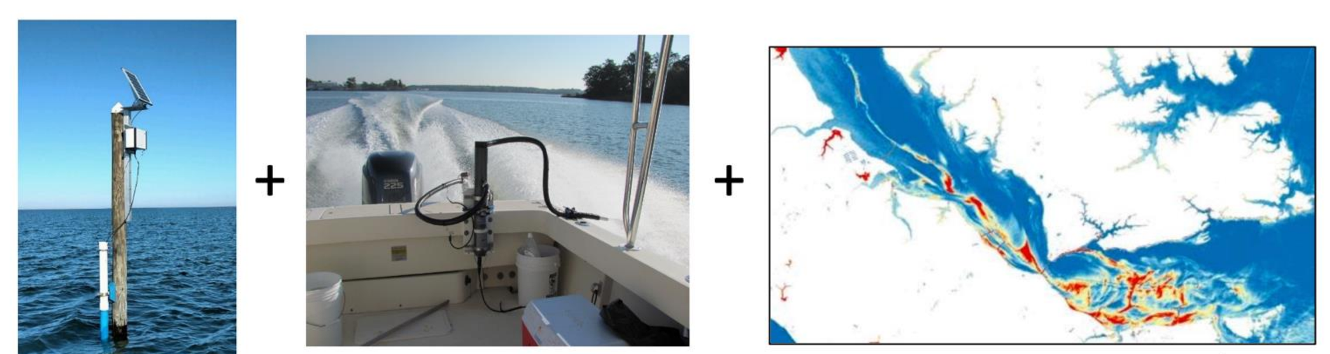
How can we enhance these monitoring program to further capture spatial and temporal water quality variability in surface waters?

- Anchor satellite imagery with CMON and Dataflow monitoring programs
  - Dataflow - 1000's of verification measurements in a single day
  - Fixed Stations - 100's of verification measurements in a year
- Leverage data to optimize predictive models



(Sentinel-2A 705 nm / 665 nm)

Planet SuperDove Satellites

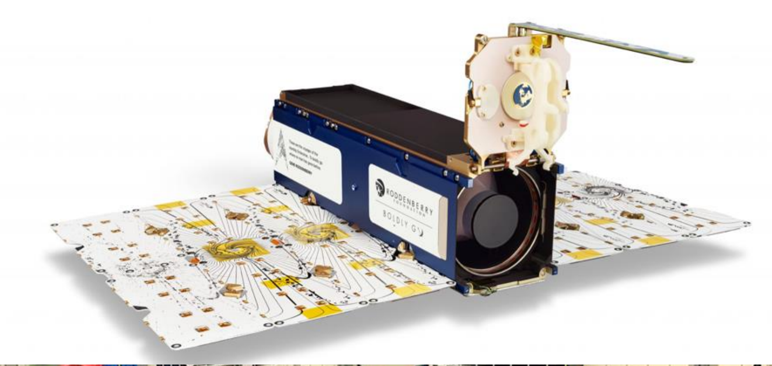
Planet To Launch 36 SuperDove Satellites With SpaceX

Planet Labs PBC | December 31, 2022

AUTHOR PROFILE

PLANET LABS PBC

Curious Planeteer working to make the Earth's changes visible, accessible and actionable.



- 8 band
- ~ 3 m resolution
- Near daily coverage in Chesapeake Bay since 2022

Methods

8 bands -> Surface Reflectance

Source: Vanhellemont, 2023

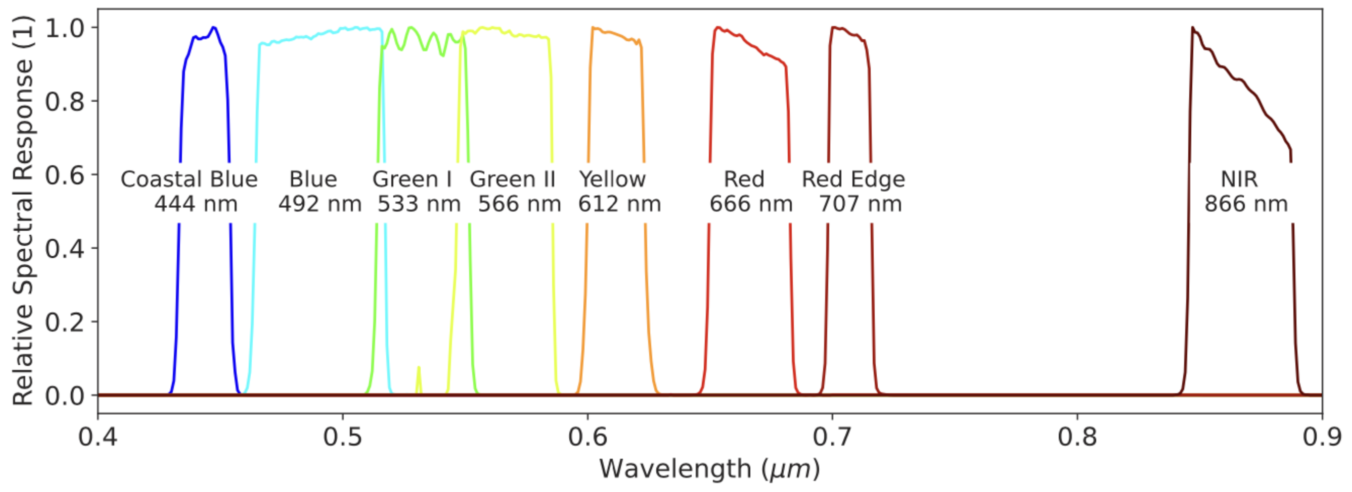
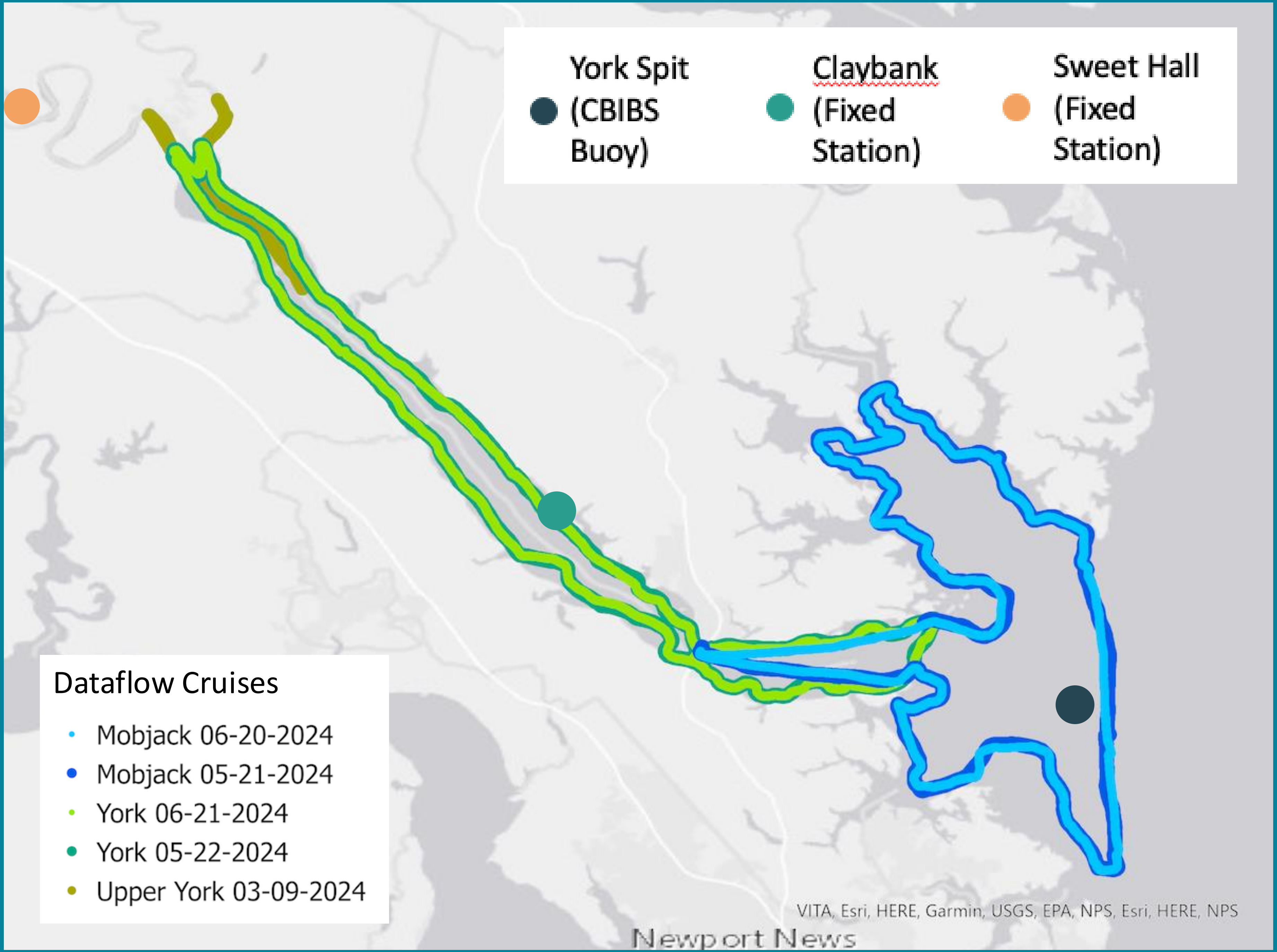


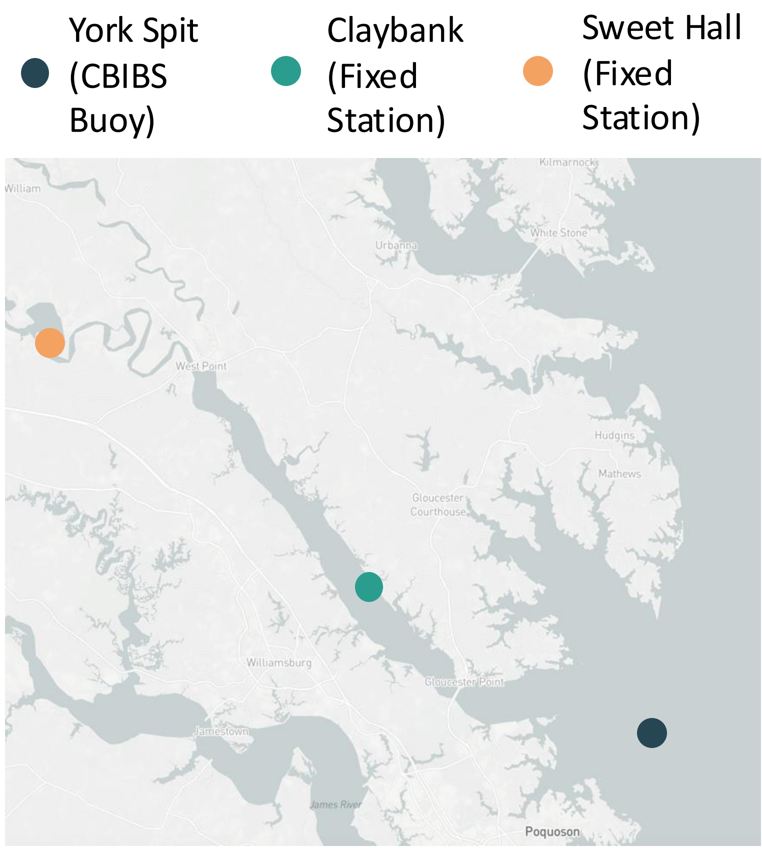
Fig. 3. SuperDove eight band relative spectral response function as provided by Planet.

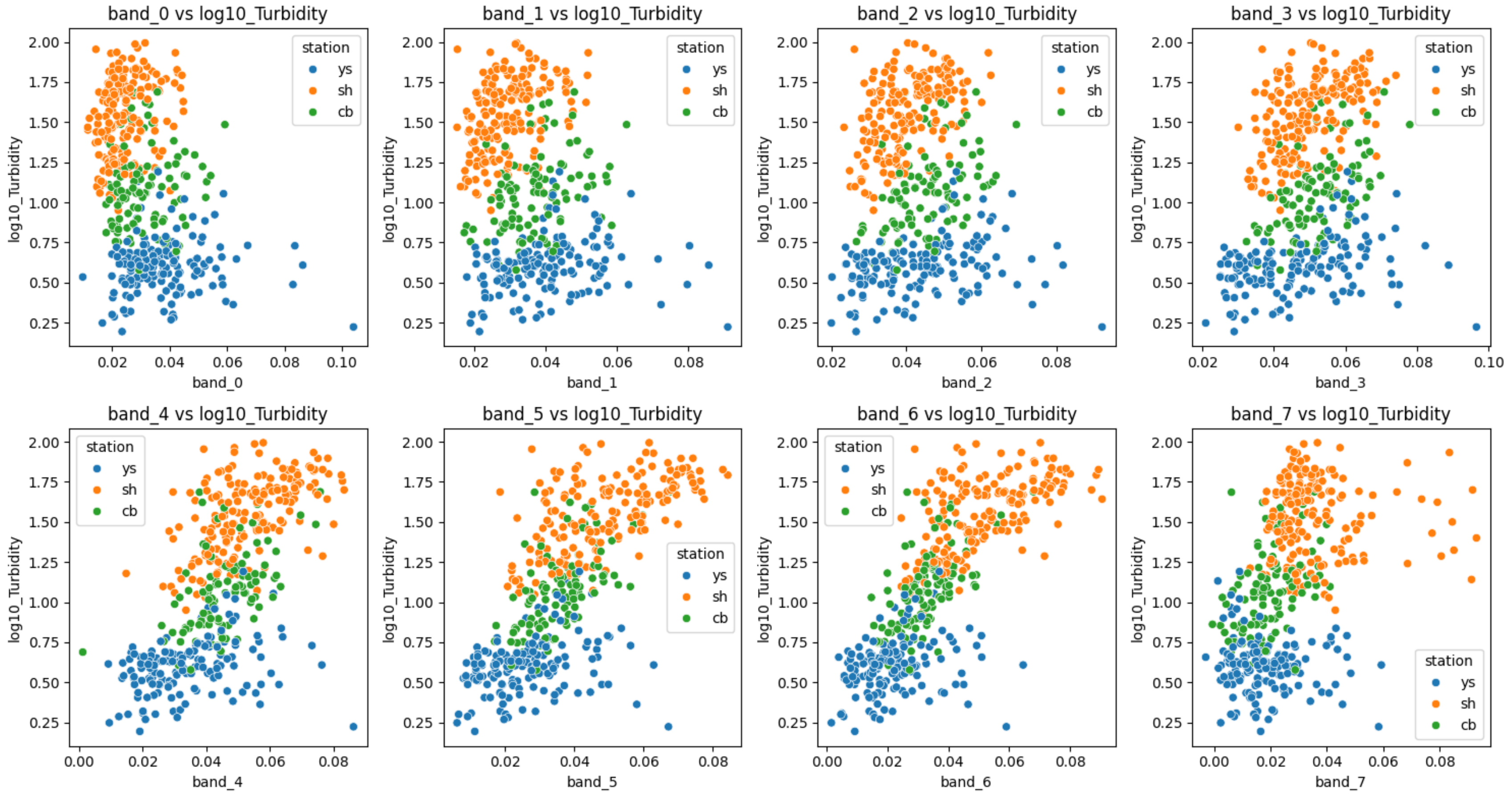
- Acquire imagery from Planet (since 2022)
- Atmospheric correction (ACOLITE) -> 8 surface reflectance bands
- Match surface reflectance to CBNERR-VA fixed station and Dataflow turbidity measurements
- Develop predictive models to estimate turbidity from 8 bands + depth

Turbidity


York Spit (CBIBS Buoy)
Claybank (Fixed Station)
Sweet Hall (Fixed Station)
Dataflow Cruises
Mobjack 06-20-2024
Mobjack 05-21-2024
York 06-21-2024
York 05-22-2024
Upper York 03-09-2024
VITA, Esri, HERE, Garmin, USGS, EPA, NPS, Esri, HERE, NPS
Newport News

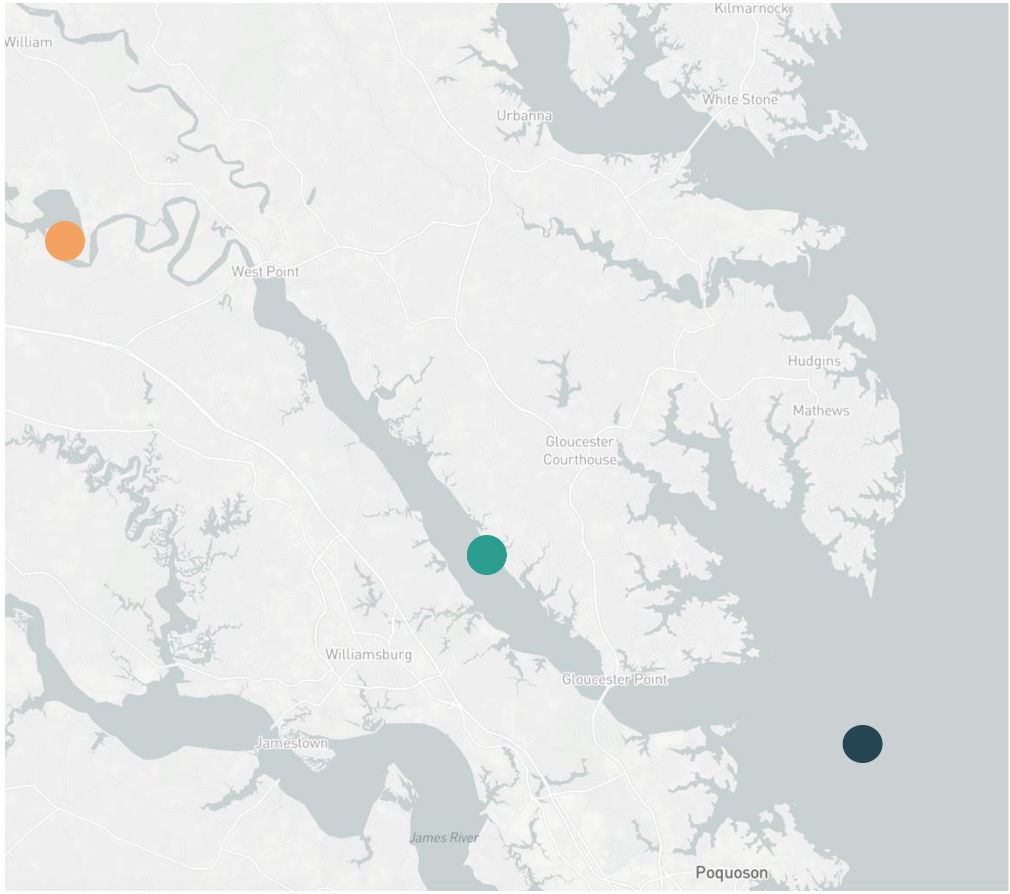
Using Fixed Stations and CBIBS Buoy to Estimate Turbidity From Satellite Images





Using Fixed Stations and CBIBS Buoy to Estimate Turbidity From Satellite Images

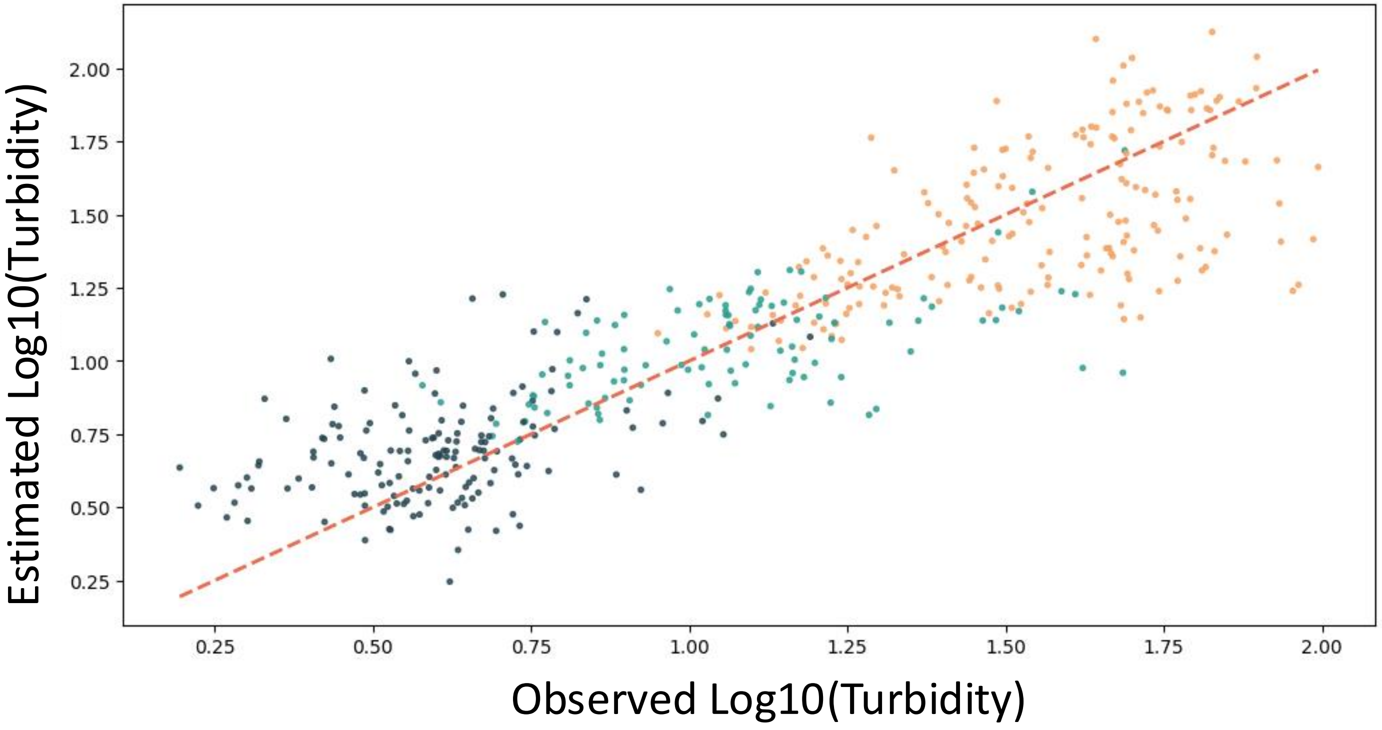
York Spit (CBIBS Buoy) | Claybank (Fixed Station) | Sweet Hall (Fixed Station)



$$y_i = X_i\beta + \varepsilon_i, \quad \varepsilon_i \sim N(0, \sigma^2)$$

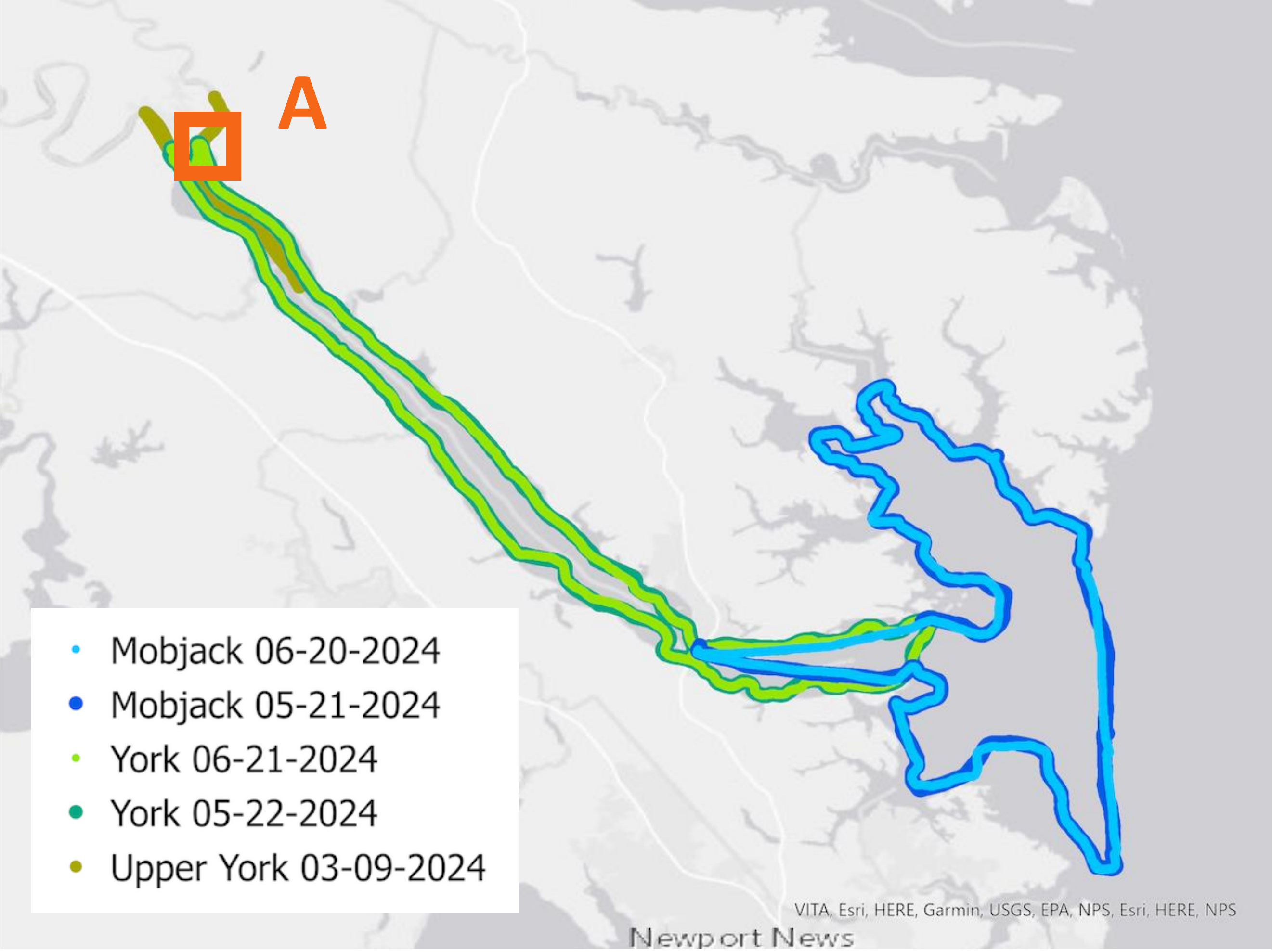
$$y_i = \log_{10}(turbidity)$$

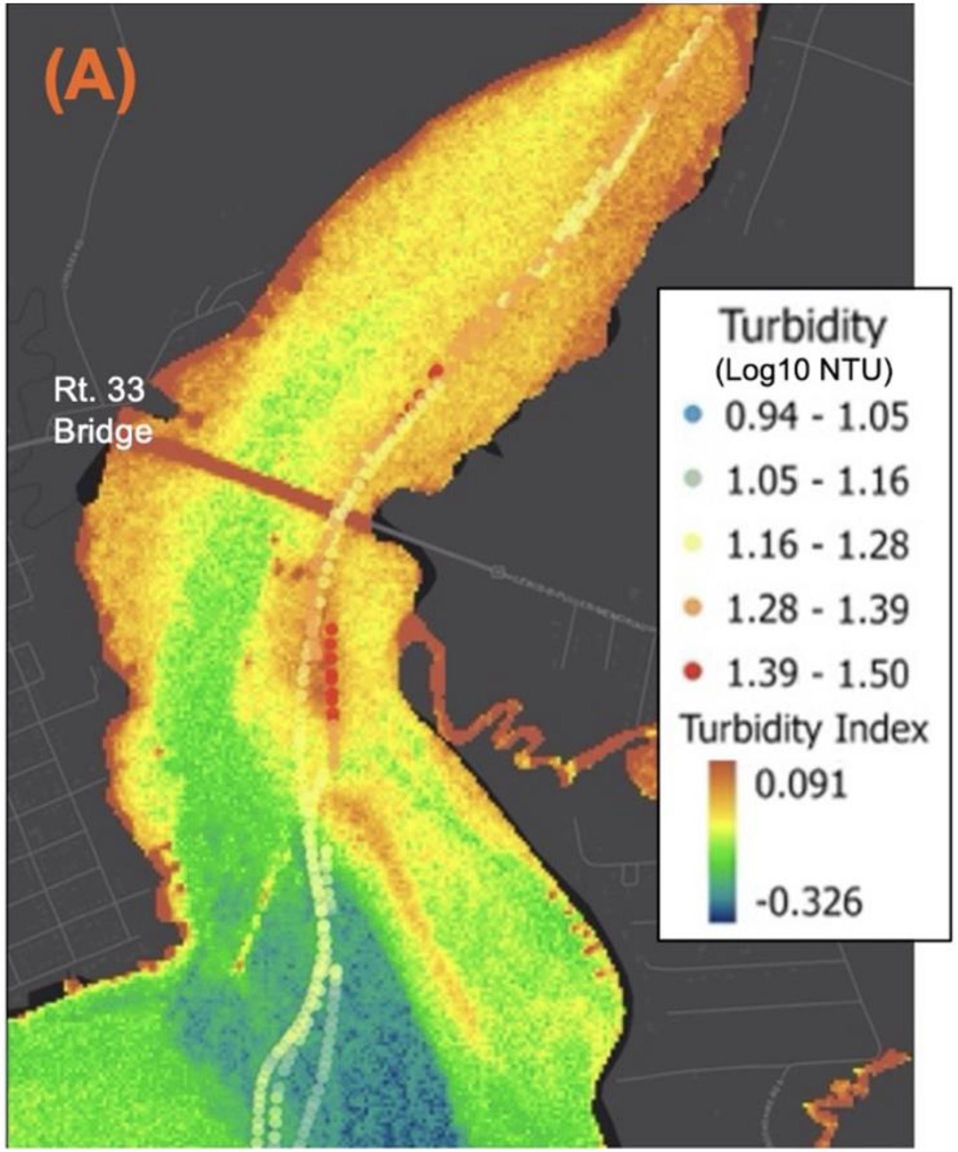
$$X_i\beta = \beta_0 + \beta_0 \cdot band_0 + \beta_4 \cdot band_4 + \beta_6 \cdot band_6$$



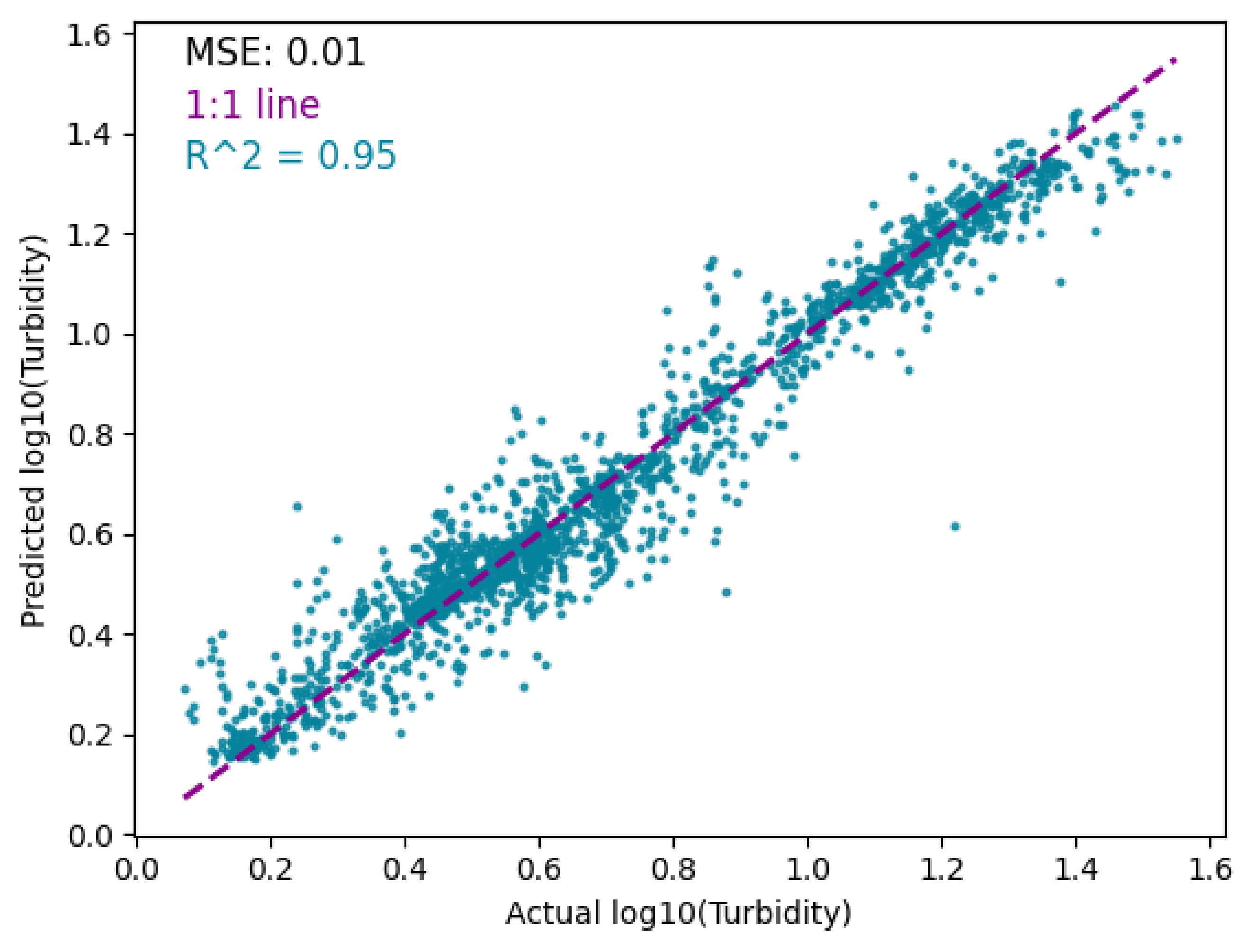
2022-2024

Dataflow and Satellites

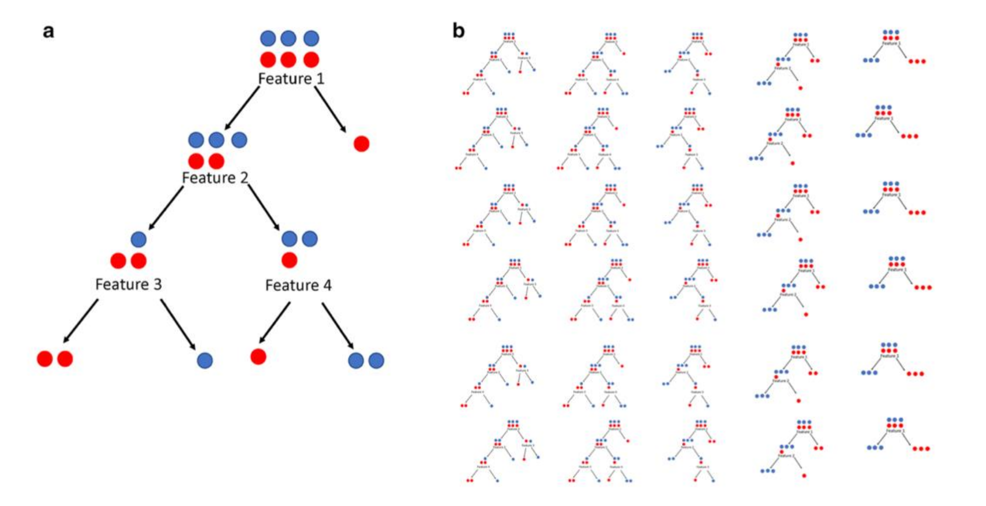




Random forest regression model results fitting 5 Dataflow cruises in York and Mobjack



Dataflow: 03/29/2023, 05/21/2024, 05/22/2024, 06/20/2024, 06/21/2024



Source: Musolf et al., 2022

Integrating Satellite Data for Water Clarity Assessment

- Early data exploration shows promise for anchoring satellite imagery with dataflow and CMON monitoring platforms to estimate surface turbidity
- Kd can be modelled using monitoring data paired with verification measurements – a similar idea to current assessment methodology
- Using a hierarchical model we could potentially estimate a Kd surface whenever there is a clear satellite image (~ 100 estimates a year)
- Kd surface estimates could be compared to Kd thresholds as with the current methodology

Summary

- Early data exploration shows promise for anchoring satellite imagery with dataflow and CMON monitoring platforms to estimate surface turbidity

Next Steps

- Continue expanding datasets
- Merge dataflow and fixed station datasets for modeling effort
- Add turbidity measurements from fixed station as a predictor in
  Turb ~ bands model
- Tune model for extrapolation between monitoring datasets
- Assess use of these models for water clarity standards assessment – compare results with previous methods
- Leverage supporting datasets to interpolate in time b/w satellite estimates

VECOS

Virginia Estuarine & Coastal Observing System

vecos.vims.edu

190,000,000 water quality samples

8,000,000 sampling locations

21 years of high frequency monitoring

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Chesapeake Bay National Estuarine Research









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