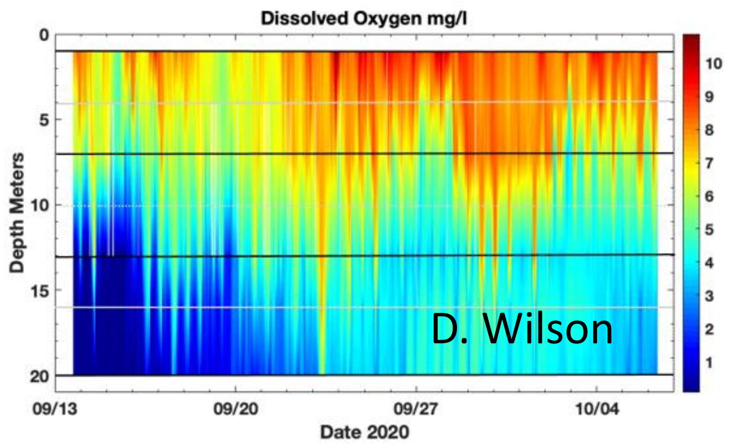
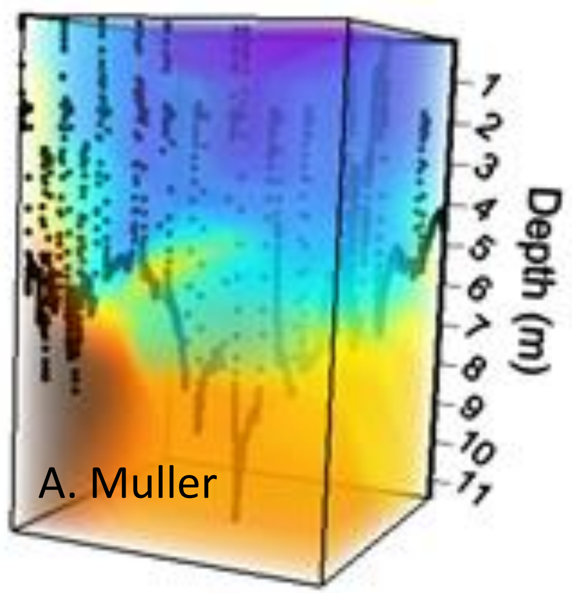
4D BORG
(Bay Oxygen Research Group)
(aka, “Interpolator Innovation Team”)

Peter Tango/Rebecca Murphy

Team Leads

April 2021 Opening Meeting of the BORG





Outline today – 4D BORG getting started

- How did we get here?
- Monitoring Expectations & Challenges
- Setting: Where does this work fit into the big picture?
- Vision
- Timeline
- Meeting schedule
- What is our launch pad? Background and support
- Methods considerations
- Homework assignment for May 2021 – Your requirements for the tool

How did we get here?

The vision for an advanced water quality estimator is not new:
STAC (2008)

Assessing the feasibility of developing a four-dimensional (4-D) interpolator for use in impaired waters listing assessment

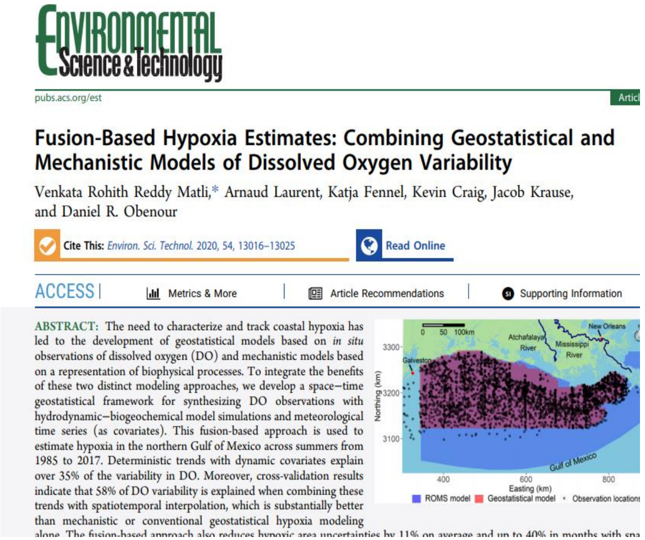
December 2008
STAC Publication 08-008

Recommendations from the STAC Expert Panel
Frank Curriero (Johns Hopkins University)
Eileen Hofmann (Old Dominion University)
Ragu Murtugudde (University of Maryland)
Jian Shen (Virginia Institute of Marine Science)
J. Andrew Royle (U.S. Geological Survey)

Preamble

The Chesapeake Bay Program (CBP) has been collecting environmental data (e.g. temperature, dissolved oxygen) at monitoring sites throughout the Bay since 1985. These data provide the potential for developing data products that can be used to inform and guide water quality decisions and policies for Chesapeake Bay. Thus, several groups within the Chesapeake Bay community have expressed an interest in a four-dimensional (4-D) interpolator, and/or have begun efforts to develop one.

Since 2008 – new research is making 4D reality


ENVIRONMENTAL Science & Technology

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Fusion-Based Hypoxia Estimates: Combining Geostatistical and Mechanistic Models of Dissolved Oxygen Variability

Venkata Rohith Reddy Matli,* Arnaud Laurent, Katja Fennel, Kevin Craig, Jacob Krause, and Daniel R. Obenour

Cite This: *Environ. Sci. Technol.* 2020, 54, 13016−13025 Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information

ABSTRACT: The need to characterize and track coastal hypoxia has led to the development of geostatistical models based on *in situ* observations of dissolved oxygen (DO) and mechanistic models based on a representation of biophysical processes. To integrate the benefits of these two distinct modeling approaches, we develop a space−time geostatistical framework for synthesizing DO observations with hydrodynamic−biogeochemical model simulations and meteorological time series (as covariates). This fusion-based approach is used to estimate hypoxia in the northern Gulf of Mexico across summers from 1985 to 2017. Deterministic trends with dynamic covariates explain over 35% of the variability in DO. Moreover, cross-validation results indicate that 58% of DO variability is explained when combining these trends with spatiotemporal interpolation, which is substantially better than mechanistic or conventional geostatistical hypoxia modeling alone.

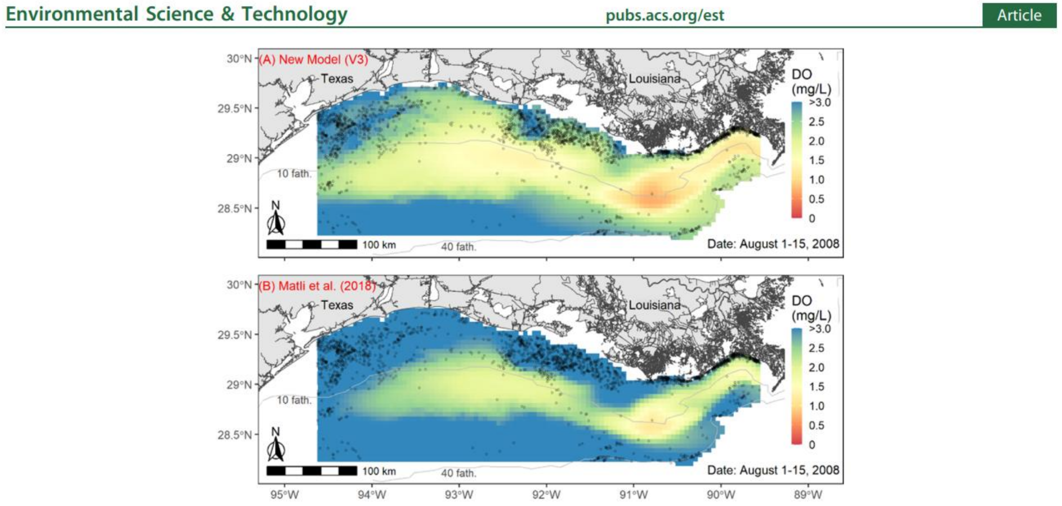


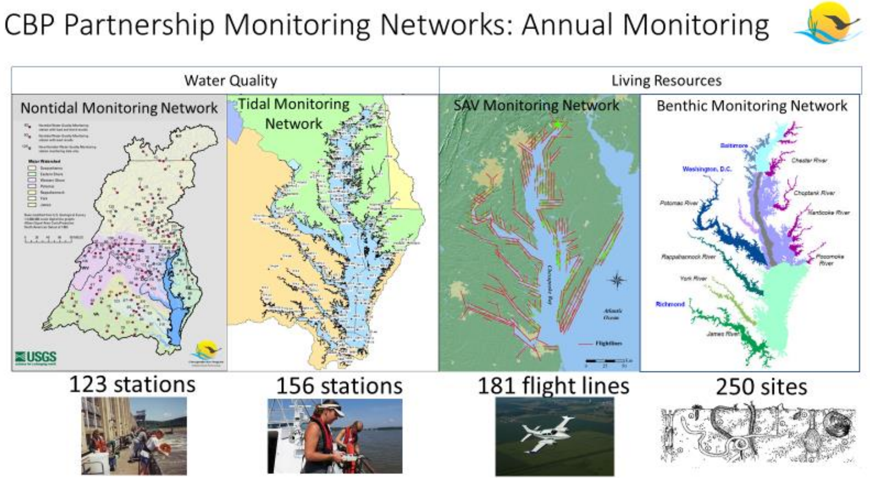
Figure 3. Two week average (August 1−15, 2008) bottom DO estimates from (A) the new model (V3) and (B) Matli et al. (2018) relative to the location of individual shrimp tows during the same period (black circles).[16,39] Note that this period was selected to illustrate a time when there is substantial variation between the two approaches.

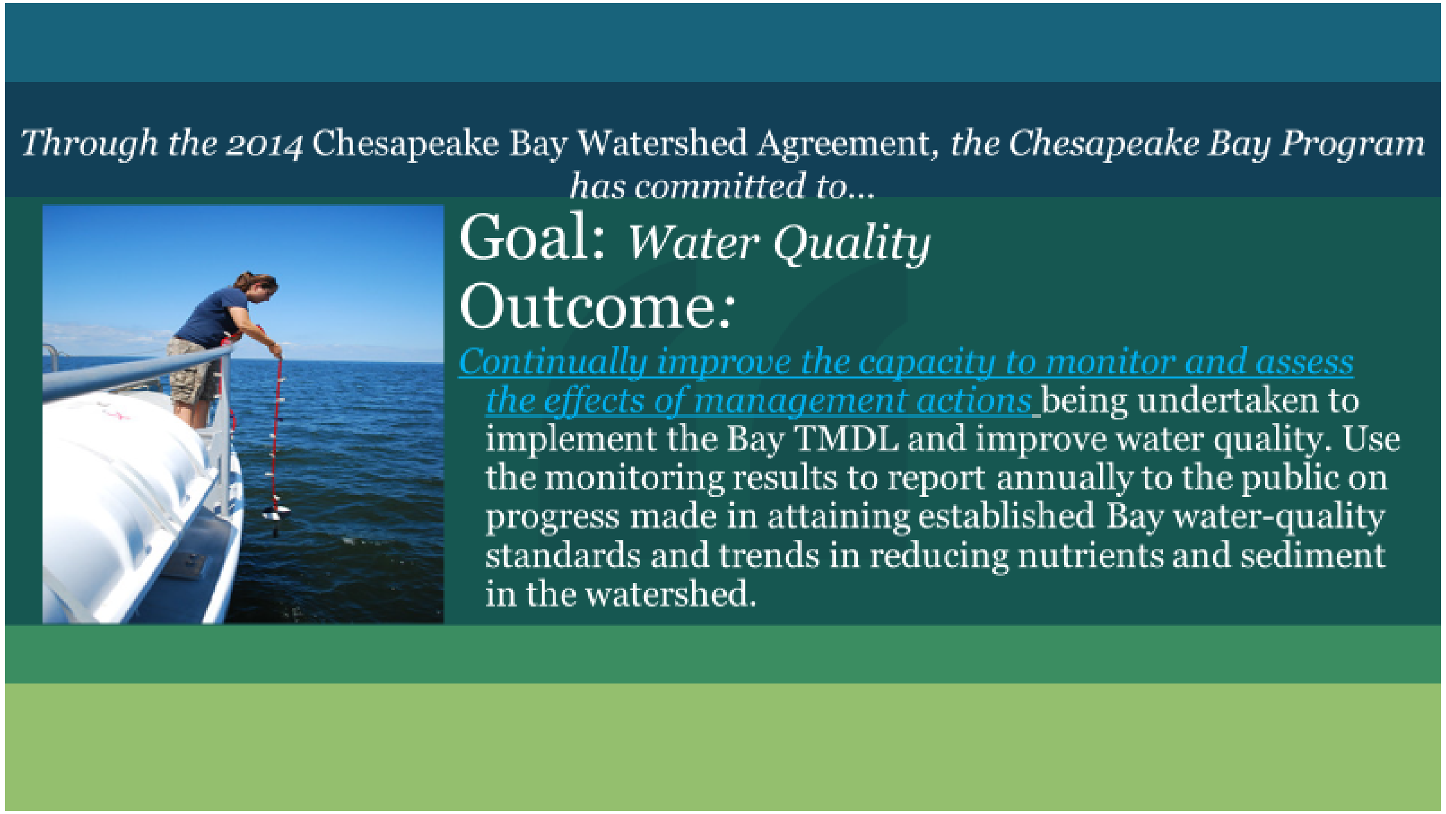
Community interest here continues to support our need to overcome long-stand assessment gaps and resolution on new information needs

- There are stated science needs to address tidal habitat analysis and the full spectrum of dissolved oxygen water quality standards space and time assessment requirements
- The needs align with development of a sophisticated 4-D interpolator
- It will certainly not be an IDW interpolator (our present tool)
- It could be some sort of statistical model that is unbiased relative to the means and distribution of the observed data.
- It should be informed by one or more process models.

Expectations: 2014 Watershed Agreement Maintain & grow monitoring and assessment capacity

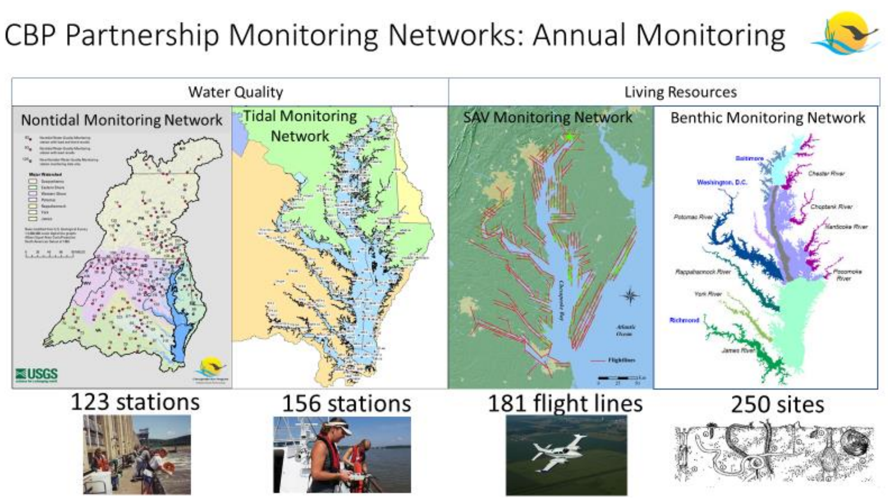
Traditional networks





Challenges

Traditional networks

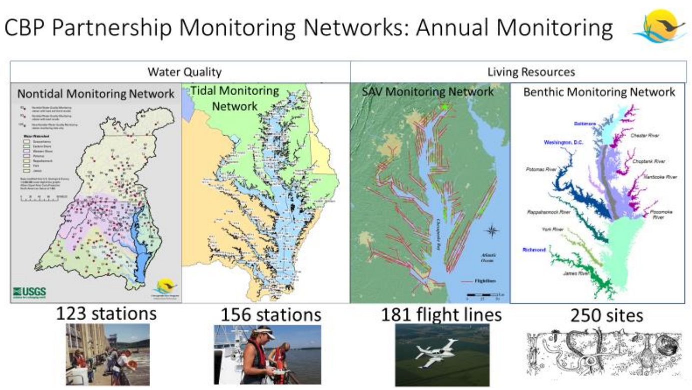


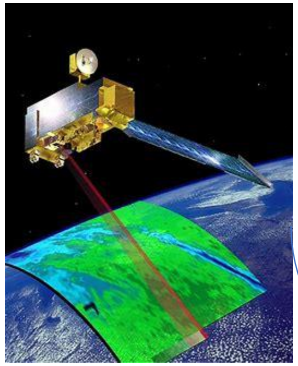
- **Water quality standards** – **0 of 92** segments have ever been fully assessed with our existing investments in traditional monitoring and evaluation tools since the publishing of USEPA (2003) Chesapeake Bay criteria on dissolved oxygen, SAV/Water Clarity and Chlorophyll *a*.

- We need to address capacity.
- We need to adapt our program.

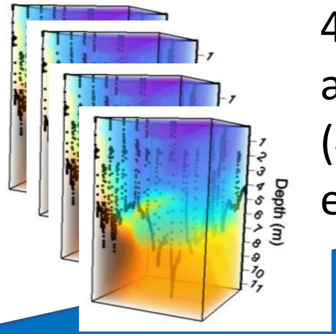
Setting: We need to leverage successful research, adopt and adapt to address capacity shortfalls

Traditional networks





2. Adapt to baywide satellite-based data (SAV, Kd, CHLA)



4. Improve assessment tools (4D water quality estimator)

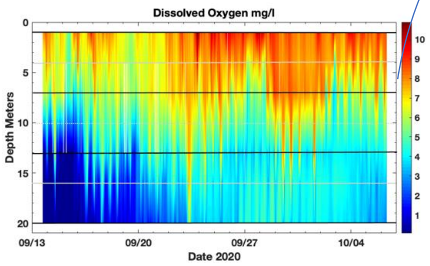
Expanded capacity

Monitoring and assessment capacity building beyond traditional monitoring

Expanded capacity

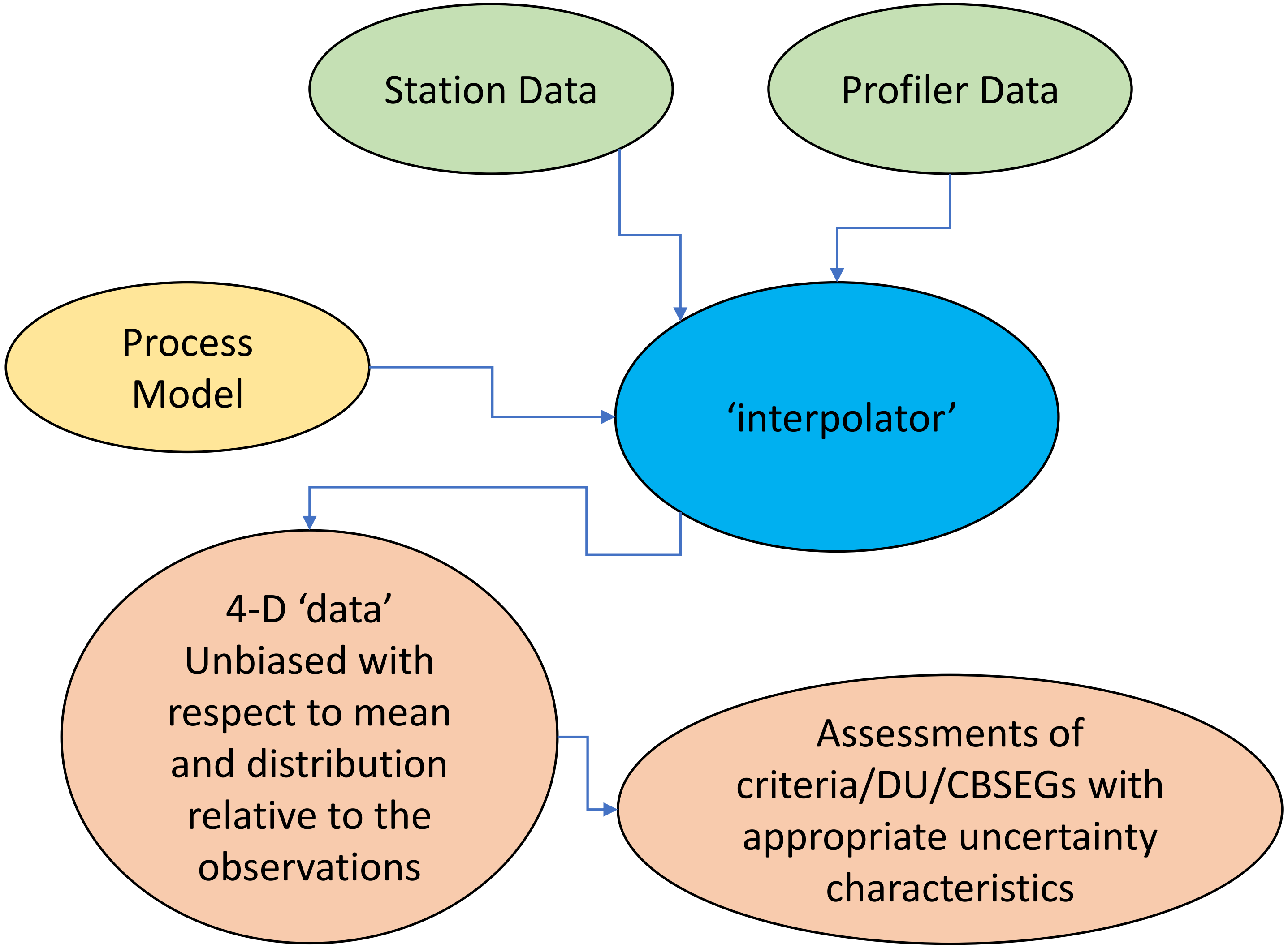
Full Water Quality Standards Attainment Assessment for Chesapeake Bay + CrossGIT Benefits

1. Apply Citizen-based observations (MOU 2018)



3. Innovate and adopt new WQ and living resource monitoring at needed data scales (CBT 2020 work, Bever et al. sampling design insights)

Vision: WQ Criteria Assessment (Habitat Assessment)



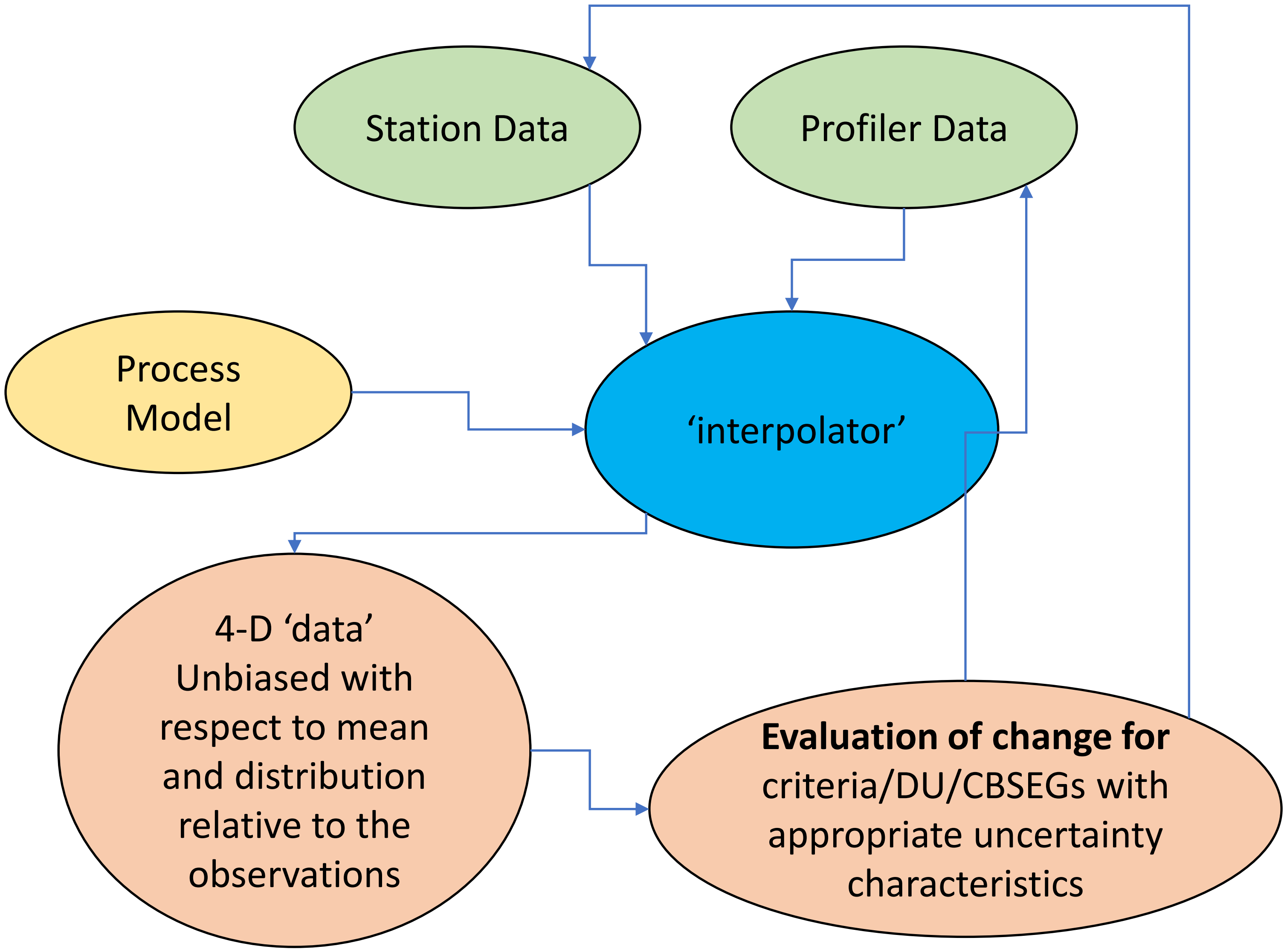
An 'interpolator' would take inputs from station data, profiler data, and process models to produce a complete historical hourly record of DO on perhaps a 200x200x1 meter cell framework.

We would want to specify that the resulting history was unbiased relative to several different distribution metrics

Assessments would be carried out in those areas and times-scales when uncertainty estimates are within acceptable ranges.

This could perhaps be tested using ChesROMs as the profiler data and WQSTM as the process model.

Vision: Monitoring Designs



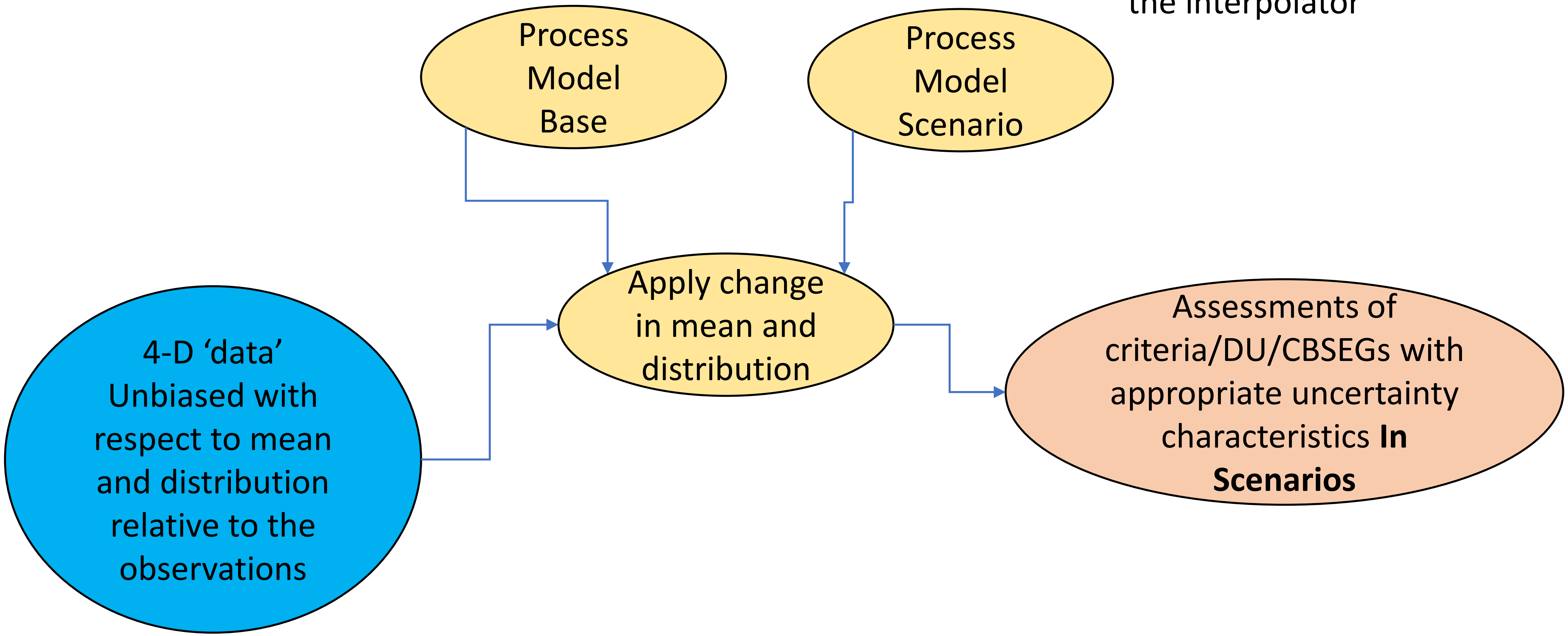
A system like this could give us very clear guidance on how to optimize the collection of station and profiler data.

We could test different spatial and temporal schemes to see which are cost effective

Vision: Mgt Scenario Assessment

For management scenarios, we could continue altering the observations as we do now, but that might cause issues since the interpolator would only be partially based on observation

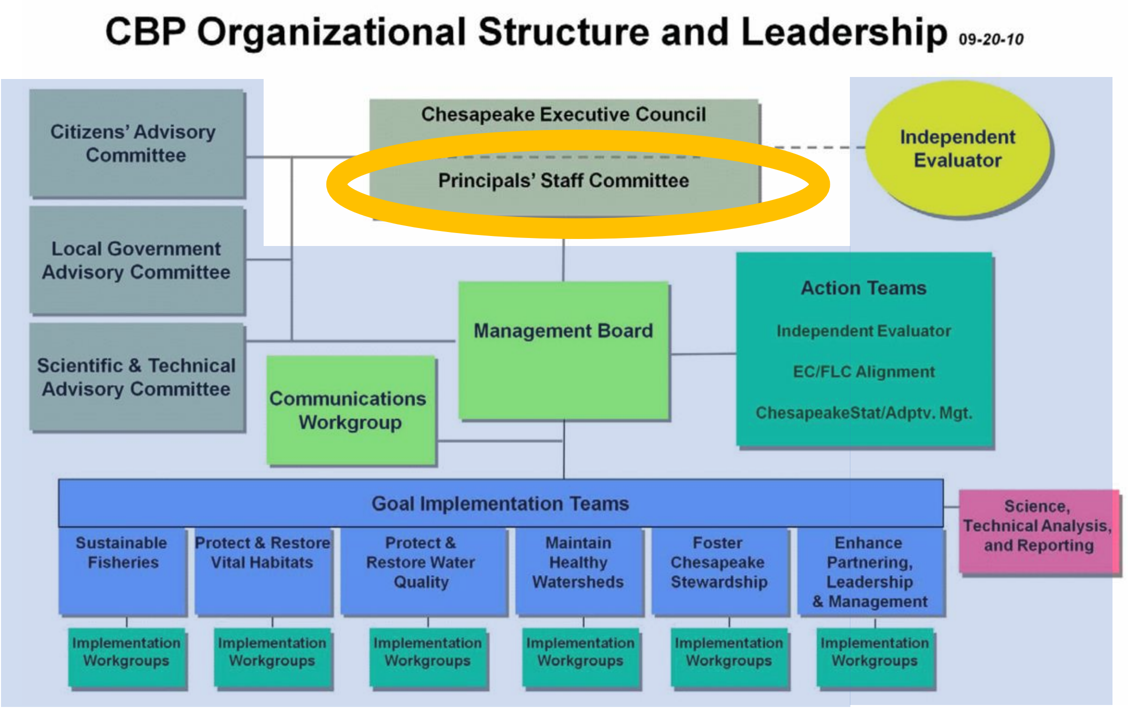
An alternative would be to apply the change to the 4-D data directly and not go back to the interpolator



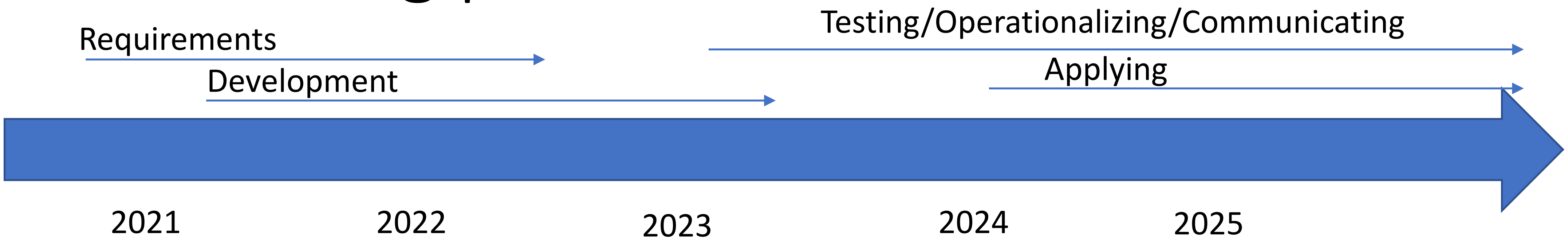
Timeline insights:

2021 Monitoring Review: 9 months.
Define programming to fully address WQ Stds assessments and watershed WQ trends

- **March 2, 2021. Principal Staff Committee request:**
  - Provide information to improve CBP monitoring networks, including: (1) Current status and threats to the networks, (2) what is needed to improve the monitoring networks.



Timeline: Big picture



- **PSC request: 9 months (December 2021)** for understanding data requirements – what more do we need from our monitoring program to feed the 4D WQE? Manage expectations (spatially, temporally).

- **2 Year (2023)** – target development timeline for a working WQE.

- **4 Years (2025)** – operational, implemented in decision-support for the CBP

- **Beyond 2025** - applications

What is our launch pad? Meeting Schedule?

- <u>January-February 2021</u>:
  - A small group at CBP explored the feasibility of creating a 4D Water Quality Estimator at this time.
    - 4D water quality estimation with a geostatistical approach has been used in Gulf of Mexico using diverse data sets to feed the estimator (D. Obenour, NC State)
    - Machine Learning is a feasible but not necessary the right path at this time
    - GAMs + simulation successfully explored as a 4D foundation (Perry, Murphy)
- <u>March-April 2021</u>:
  - EPA Year 1 pilot investment provided to the team to move forward on research and development (EPA-CBPO)
  - 4D-BORG membership invitations for stakeholder participation in shaping the development of the future estimator.

<u>Thank you:</u>

Gary Shenk
Isabella Bertani
Elgin Perry
Rebecca Murphy
Jeni Keisman
Breck Sullivan
Lee McDonnell

- **Meeting Schedule proposed**
  - **Propose monthly meetings for spring-summer 2021**.
  - Target a day meeting for STAC Workshop autumn 20201 on development, insights and directions.
  - Consider schedule needed after STAC Workshop to allow time for work and reconvene at other intervals (e.g., every other month?) to review and guide development, evaluate outputs, interface, product targets.

Methods considered

From late 2020 to early 2021, a small team at CBPO explored options, opportunities and cost considerations, late 2020/early 2021 and found:

- **Machine Learning** approach may be conceptually feasible but is not presently considered a suitable, efficient option
- **Bayesian approach** (e.g., D. Obenour, NC State) is a viable framework, used for 4-D assessment of hypoxia in the Gulf of Mexico. Starting from scratch in Chesapeake Bay represents a feasible but cost/time intensive option to involve experts in the technique at this time.
- **General Additive Models (non-Bayesian)** – exploratory work using GAMs for 4D water quality estimation (e.g., Perry, Murphy) demonstrates the feasibility of applying this approach to the problem.
  - We have local expertise familiar with the bay system, bay data sets, applications and directions of the CBP.
  - Insights suggest hybridizing data assessment informed by model processes can improve habitat condition estimates.
  - DO spatial and temporal variability will be captured through simulations based on geostatistical methods (e.g., kriging) and time series analysis.
  - Cost and time efficient.

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Method suggested and **First homework assignment**

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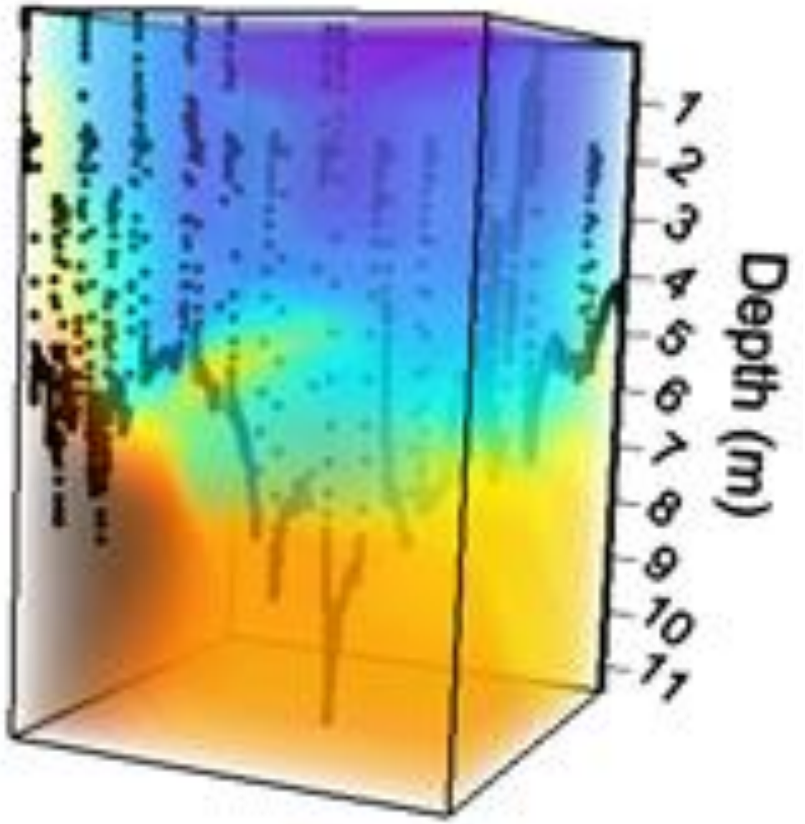
* However, your **first homework assignment** –
Action: if any of you have another idea, an alternative method,
and want to bring that forward for presentation and consideration by the community in the next meeting,

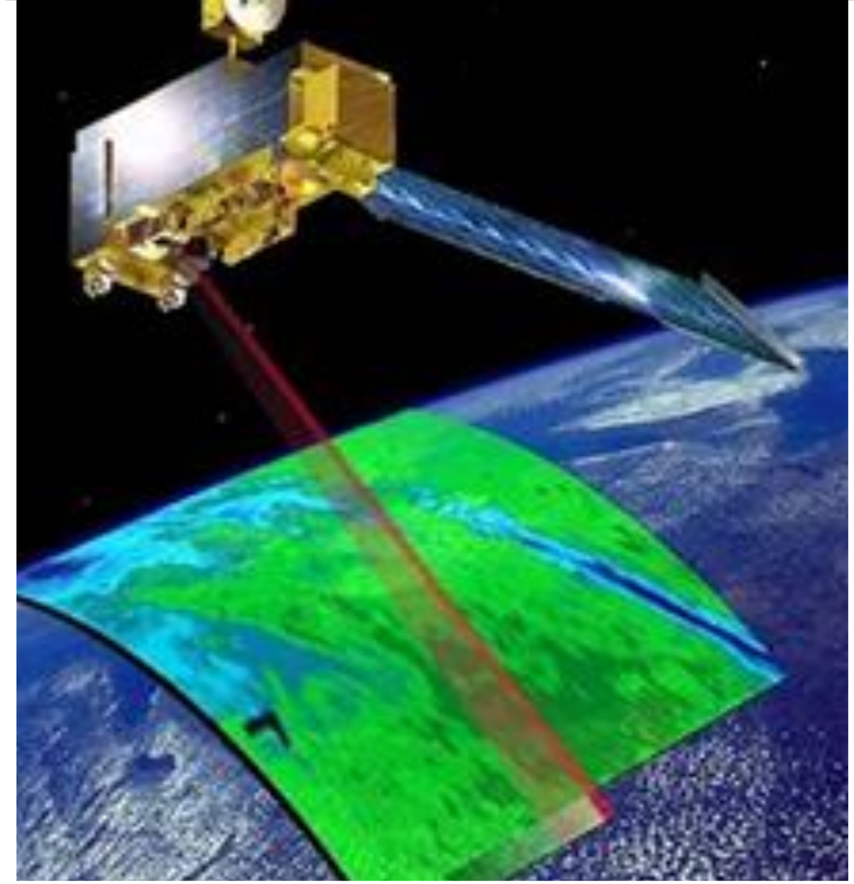
This is the time for exploration as we set up the launch pad on a method to invest in and move forward on.

Homework #2 – first cut thinking due May 2021 meeting, follow-up thinking June and July 2021.

Action: We need your feedback on system requirements – what do we, as a community, need for structure and function, from a 4-D water quality estimator?

- **Statistically** – what data sources are available?
  - Team discussion on which are viable and necessary among the many assets we have and those being developed?
- **Functionally** – what requirements do you suggest as most useful for the user interface development?
- **Communications** – what do outputs, products need to look like for effective communication on habitat status?
- **Other requirements**, needs?





Thank you!