Quantifying the impacts of past and future climate and eutrophication on the dynamics of dissolved oxygen in the shallow waters of Chesapeake Bay

PI Team:
Jeremy Testa¹, Damian Brady², Wei Liu¹
¹University of Maryland Center for Environmental Science
²University of Maine

Steering Committee and Collaborators:
Walter Boynton¹, Denise Breitburg, Ming Li¹,
Mark Trice³, Lisa Wainger¹, Carl Friedrichs⁴,
Jeni Keisman⁵, Rebecca Murphy⁶, David Parrish⁴,
Breck Sullivan⁶
³Maryland Department of Natural Resources
⁴Virginia Institute of Marine Sciences
⁵USGS
⁶UMCES/Chesapeake Bay Program
Goals

• Utilize the vast, high-frequency datasets in MD and VA for dissolved oxygen (DO) to understand controlling variables, the time-scale of control, and how controls vary over space

• Discern magnitude and spatial variation in physical influence (salinity, temperature) versus biological influence (Chl-a)

• Develop or enhance statistical and numerical models to be predictive of shallow-water DO
Schematic of Analysis Design

High-Frequency Oxygen Observations

Decompose tidal contribution, isolate residual (biological?) contribution

\[ C_{DO}(t) = \bar{C}_{DO} + \sum_{n=1}^{N} A_n \cos(\omega_n t - \theta_n) + R(t) \]

Use CART to link control variables to non-tidal DO variations

Associate local conditions (load, metabolism, physical setting) with DO variation

- Temp
- PAR
- CHL-a
- Turbidity
- Salinity
- Precip.
- Wind

Chl-a Importance

N Load

?
Quantitative analysis to separate sinusoidal component from non-sinusoidal components in DO time series

\[ C_{DO}(t) = \bar{C}_{DO} + \sum_{n=1}^{N} A_n \cos(\omega_n t - \theta_n) + R(t) \]

“non-tidal” variations

- \( C_{DO}(t) \) is the concentration of DO at time \( t \);
- \( \bar{C}_{DO} \) is the mean concentration;
- \( R(t) \) is non-sinusoidal residual component at time \( t \);
- \( \sum_{n=1}^{N} A_n \cos(\omega_n t - \theta_n) \) is sinusoidal part including tidal induced DO variation for a total of \( N \) tidal constituents;
- \( A_n \) is the amplitude of DO variation due to \( n \)th tidal constituent with a frequency of \( \omega_n \) and a phase of \( \theta_n \).
- Least squares method is used for solving this equation. 35 tidal constituents and their frequencies are considered in solving this equation

(Solved with windows of 1, 7, 14, 30 and 90 days)
DO time series decomposed into tidal and non-tidal components

Susquehanna Flats (XKH0375)

Tidal = 39%, 61% non-tidal

Little Monie Creek (LMN0028)

Tidal = 58%, 42% non-tidal
Example: Regression Tree for **DO residual** (mg/L) at Little Monie Creek

- **At high temp, lower DO**: WaterT $< 20.8395$, WaterT $\geq 20.8395$
  - **N = 60**
    - Mean = 1.51053
    - Std. dev. = 1.32089
    - WaterT $< 13.9138$, WaterT $\geq 13.9138$

- **At low salinity, lower DO**: Salt $< 10.8207$, Salt $\geq 10.8207$
  - **N = 148**
    - Mean = -0.610004
    - Std. dev. = 0.953827
  - **N = 103**
    - Mean = -0.118431
    - Std. dev. = 0.537218

- **N = 45**
  - Mean = -1.73516
  - Std. dev. = 0.714183
  - Salt $< 9.50443$, Salt $\geq 9.50443$

- **N = 44**
  - Mean = 0.905703
  - Std. dev. = 0.805713
  - avgChla $< 7.28351$, avgChla $\geq 7.28351$

- **N = 16**
  - Mean = 3.17382
  - Std. dev. = 0.988776
  - avgChla $< 20.9811$, avgChla $\geq 20.9811$

- **N = 208**
  - Mean = 0.00168962
  - Std. dev. = 1.43902
Importance” of CART Variable Alters with Removal of Tidal Variations
Little Monie Creek

For residual data, multiple variables emerge, including chlorophyll-a

For raw data, salinity variations dominate = tidal variations key
Application of CART Across Stations

Temp
PAR
CHL-a
Turbidity
Salinity
Precip.
Wind
CART Applied Across all Chesapeake ConMon Stations

Cross-station CART analysis: DO-SAT Residual (%)

- CART applied to the entire multi-year time series of DO and predictors to identify the most important predictors at each site.
Most important predictors for DO-SAT residual (%)

• *Many Variables Important*

• Precipitation is important along mainstem fringe

• Upper-western shore wind hotspot

• Salinity key within the tributaries

• Water Temp. is predominant in lower bay
Example Trees Where Wind is the MIP
Vicinity of Patapsco, Annapolis

Lower Residuals (lower DO) with high winds
Histogram of Wind Speed Across Time-Series

![Histogram of Wind Speed Across Time-Series](image)
Most important predictors for DO-SAT residual (%)

- Precipitation is important along mainstem fringe
- Upper-western shore wind hotspot
- Water Temp. is predominant in lower bay.
Example Trees Where Chl-a is the MIP

Higher Residuals (higher DO) with high chlorophyll-a
Most important predictors for duration of ‘hypoxia’

- PAR is an important predictor in upper Bay/trib sites.
- Water Temp. is dominant in controlling DO across all stations.
- Wind is important in the open bay.
Cross-station CART analysis: Hypoxia
Conclusions and Next Steps:

(1) CART suggests that there are many variables that can control oxygen variability, some emerging patterns. Chl-a and temperature are key drivers (also precipitation)

(2) Temperature is a key driver of hypoxia, pushes extremes >24 deg C

(3) Next steps – associate important variables with station-specific variables, such as nutrient load/concentration, salinity, depth, etc.
Questions or Comments?