Ecological Forecasting Applications for the Chesapeake Bay

Marjorie Friedrichs

Virginia Institute of Marine Science

William & Mary

marjy@vims.edu

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Virginia Institute of Marine Science

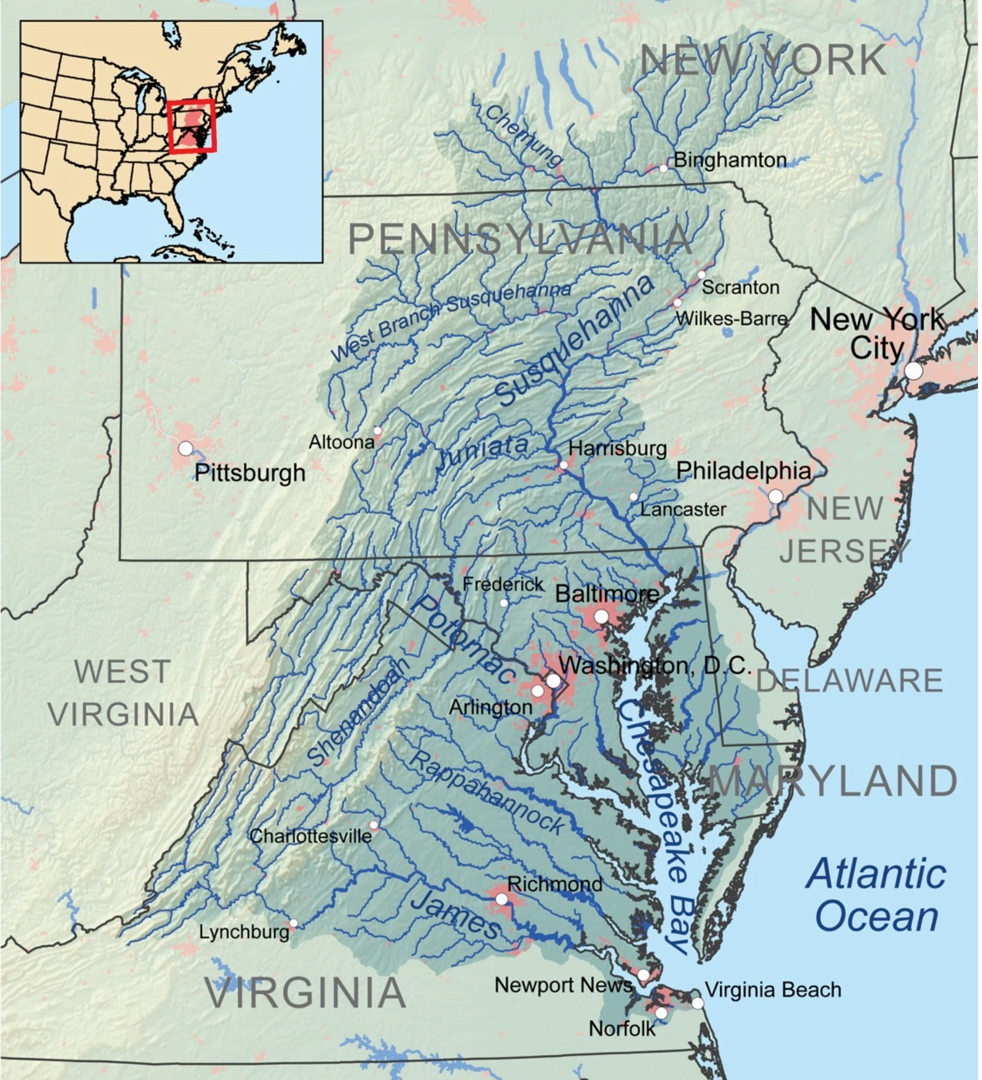
Chesapeake Bay Program

A Watershed Partnership

April 12, 2022

Daily to Decadal Ecological Forecasting

National Oceanic and Atmospheric Administration NOAA U.S. Department of Commerce



Chesapeake Bay:
Background

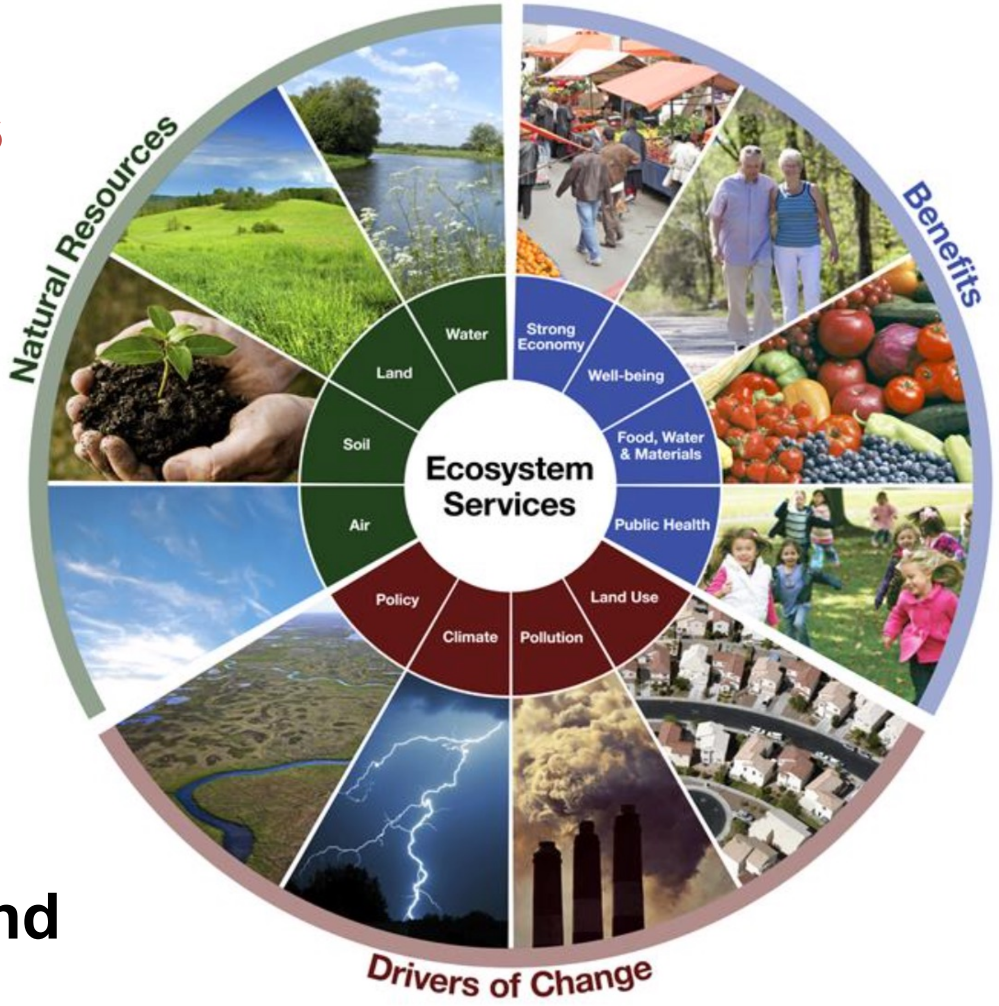
- Largest estuary in continental U.S.; very long coastline
- Population > 18 Million
- Ecosystem services derived from Bay > $100 Billion annually
  - Many fisheries (striped bass, menhaden, shad, oysters, blue crabs, shellfish aquaculture), tourism, etc…

Chesapeake Bay:
Anthropogenic Impacts

But anthropogenic impacts threaten ecosystem services

– NO_3 inputs have doubled since 1950s
– Hypoxia increased by 3x
– pH and omega decreasing

Chesapeake Bay Program (CBP) Partnership leads and directs restoration



Time Scales of Interest for Forecasting of Chesapeake Bay water quality & habitat

- **Daily/weekly forecasts**
  - Anglers and charter boat captains (where are the fish?)
  - Aquaculture industry and hatcheries (do I need to treat Bay intake water?)
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Time Scales of Interest for Forecasting of Chesapeake Bay water quality & habitat

Seasonal Empirical Forecasts:

Scavia et al., 2021.

"Advancing estuarine ecological forecasts: seasonal hypoxia in Chesapeake Bay."

Ecological Applications, 31,

https://doi.org/10.1002/eap.2384

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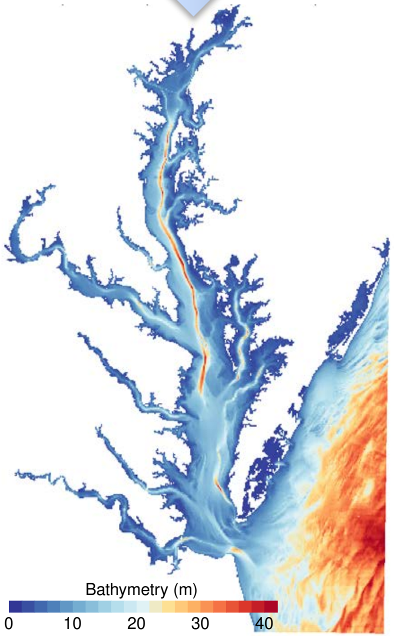
CBEFS: Chesapeake Bay Environmental Forecast System

Atmospheric inputs

Estuarine model framework

- ~600m x 600m
- 20 vertical levels
- Hydrodynamics, tides…
- BGC cycles: C, N, etc…



NOAA atm. forcing

- Winds
- Solar radiation
- Temperature
- Precipitation

Land inputs

Terrestrial inputs from watershed models and USGS data

Coastal inputs

Long-term NOAA data; coastal models

Bever et al., Env Mod & Software, 2021
St-Laurent et al., BG, 2020

Aaron Bever
Anchor QEA

Pierre St-Laurent
VIMS

Raleigh Hood
UMCES

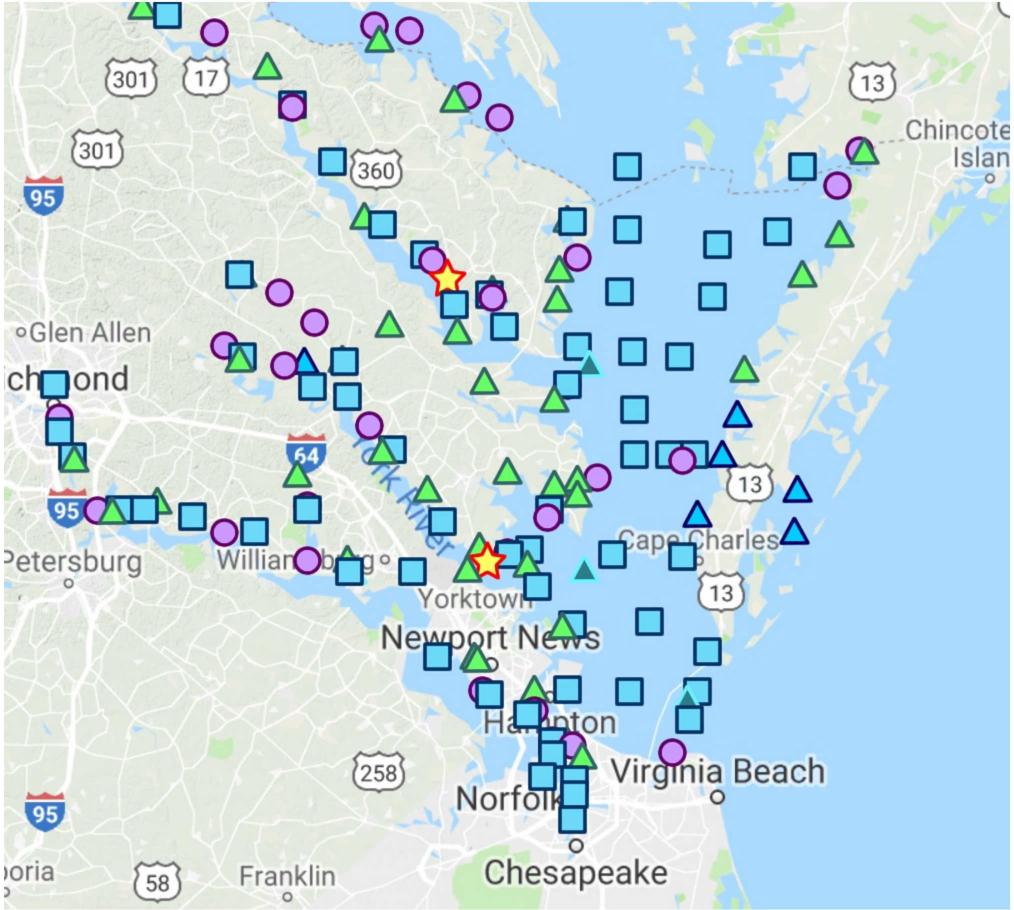
Chesapeake Bay Data

Models evaluated and calibrated extensively with 35+ years of Chesapeake Bay data:

- Temperature
- Salinity
- Oxygen
- pH
- Nutrients
- Chlorophyll

17 cruises per year (> 100 stns)

Multiple estuarine buoys, dataflow, ConMon stations, USGS river gauge data



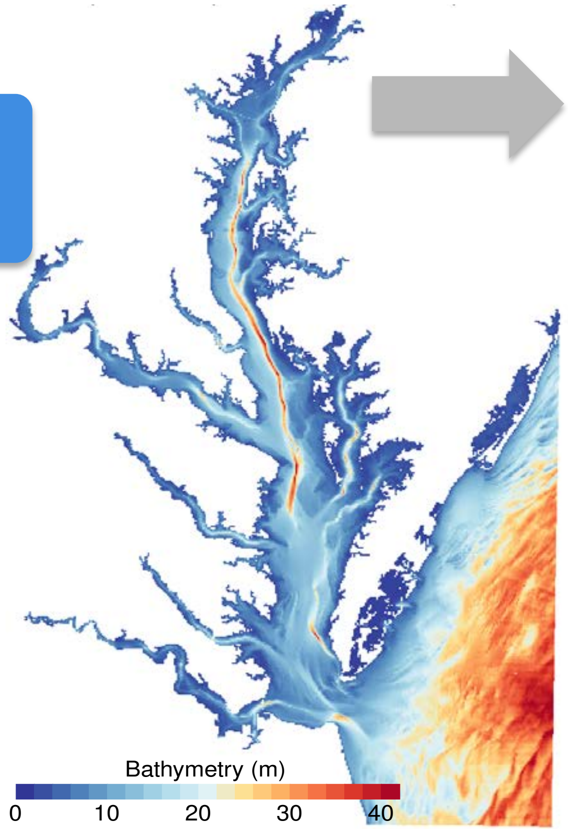
CBEFS: Chesapeake Bay Environmental Forecast System

Atmospheric inputs

Land inputs

Coastal inputs

Evaluate model performance with observational water quality data



Real-time model forecast setup:

- Nowcast and 2-day forecast automatically produced nightly
- Forecasts displayed on the VIMS website and on MARACOOS/IOOS OceansMap portal

www.vims.edu/cbefs

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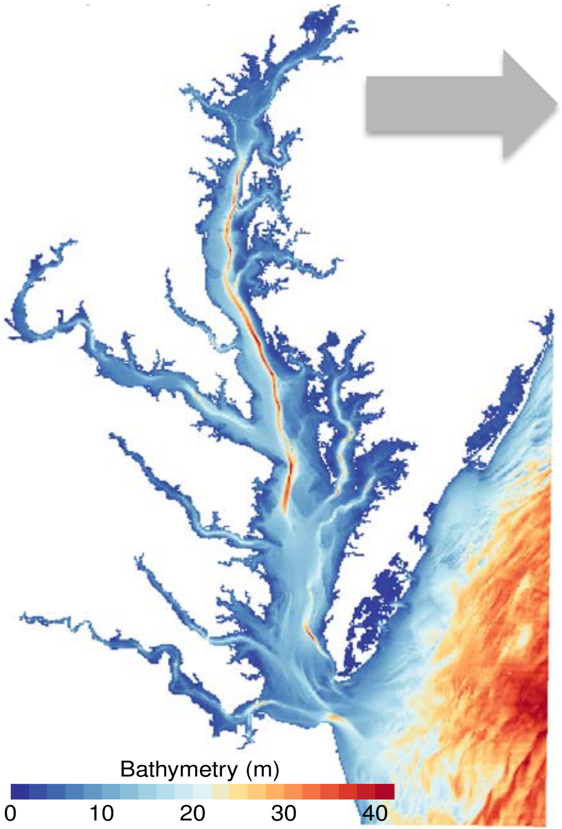

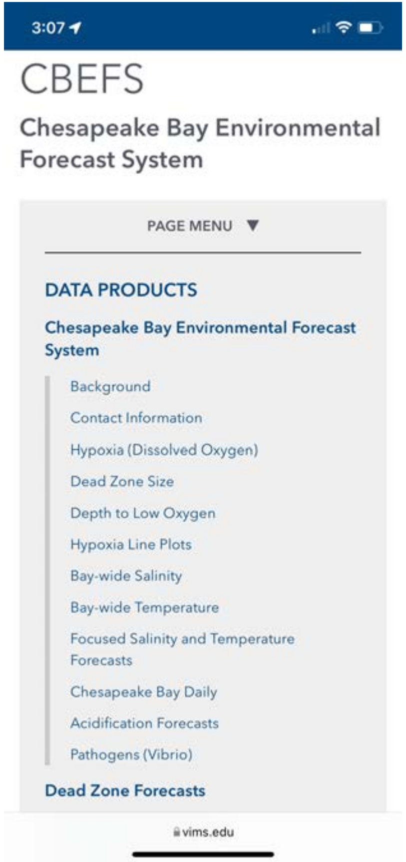

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CBEFS: Chesapeake Bay Environmental Forecast System

Chesapeake Bay Environmental Forecast System

- Background
- Contact Information
- Hypoxia (Dissolved Oxygen)
- Dead Zone Size
- Depth to Low Oxygen
- Hypoxia Line Plots
- Bay-wide Salinity
- Bay-wide Temperature
- Focused Salinity and Temperature Forecasts
- Chesapeake Bay Daily
- Acidification Forecasts
- Pathogens (Vibrio)

Dead Zone Forecasts

Sea-Level Report Cards

Tidewatch

CBEFS

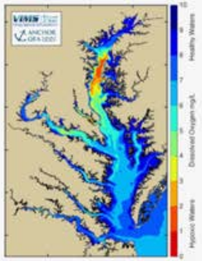
Chesapeake Bay Environmental Forecast System

Use our forecasts and "nowcasts" of temperature, salinity, dissolved oxygen, and other physical and chemical factors within the Chesapeake Bay to help monitor Bay health and plan your on-the-water activities. Based on observations and **computer models** developed by the Virginia Institute of Marine Science and partners, these tools accurately predict the current status of important environmental variables and how they are likely to change in the short-term.

Our Chesapeake Bay Environmental Forecast System simulates 3 conditions for each selected variable:

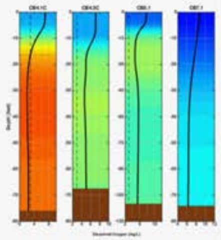
1. **Nowcast**: present-day status of selected variable in Chesapeake Bay
2. **2-Day Forecast**: status of selected variable in the Bay 2 days from now, and
3. **Forecast Trend**: difference between nowcast and forecast (% change over 2 days)

Click a selection below to access the specified simulation.



DISSOLVED OXYGEN (DO)
Discover when and where low-oxygen "dead zone" conditions may form.

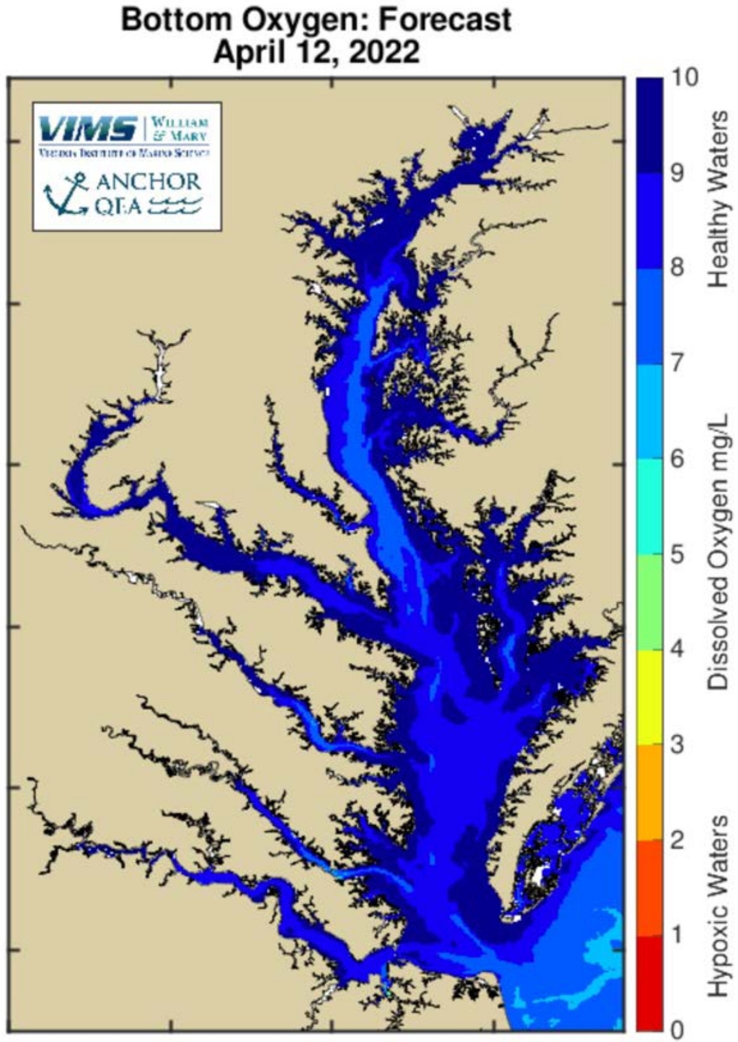
DEAD ZONE SIZE
Track "hypoxia" in the Bay, as measured by the volume of waters where DO levels are below 2 mg/L.



DEPTH TO LOW OXYGEN
Find the depth to fish-unfriendly waters where dissolved oxygen levels fall below 3 mg/L.

- Hypoxia/Dead Zone size
- Acidification metrics
- Bacteria (Vibrio)
- Temperature
- Salinity
- HABS coming coon!

www.vims.edu/cbefs

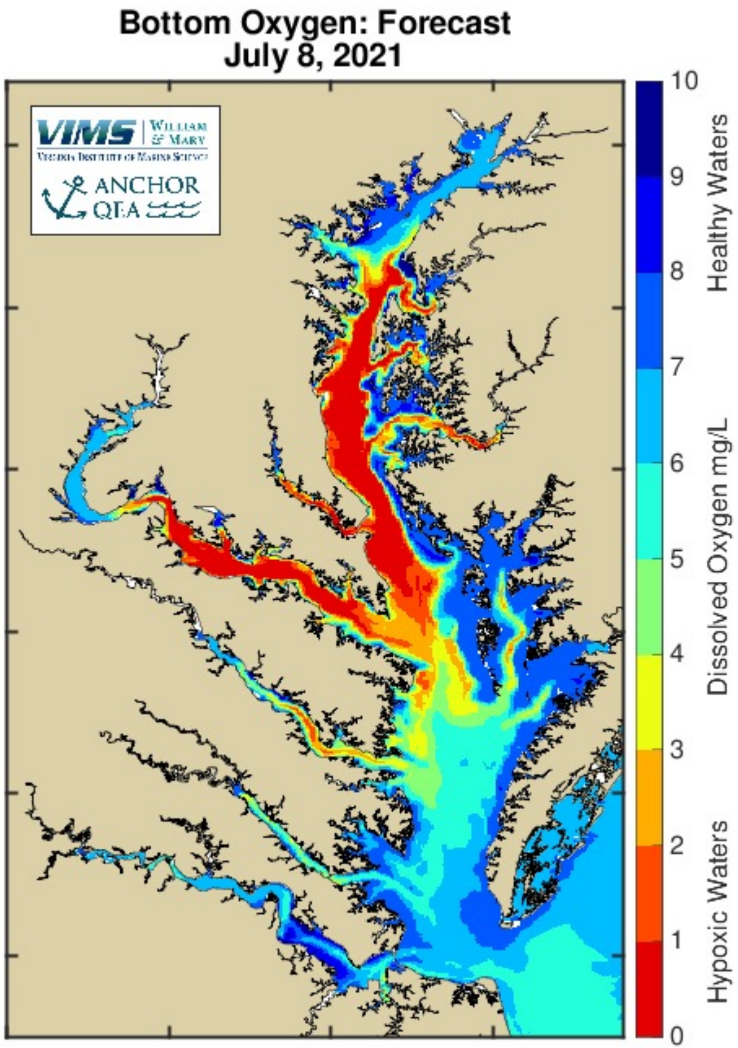


screenshot of April 12th hypoxia forecast

Blues → High bottom oxygen
= Good bottom water
= Bottom fish and crabs

Yellow/green → Moderately low oxygen
= Poor bottom water
= Fewer bottom fish and crabs

Red → Very low bottom oxygen
= Bad bottom water
= No bottom fish or crabs



screenshot of July 8 hypoxia forecast

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Red → Very low bottom oxygen
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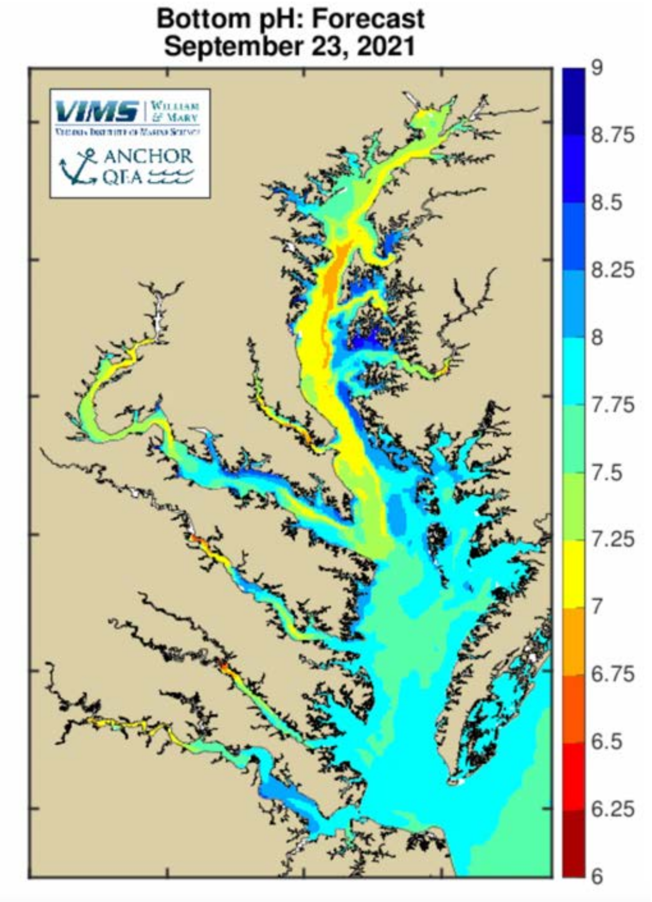
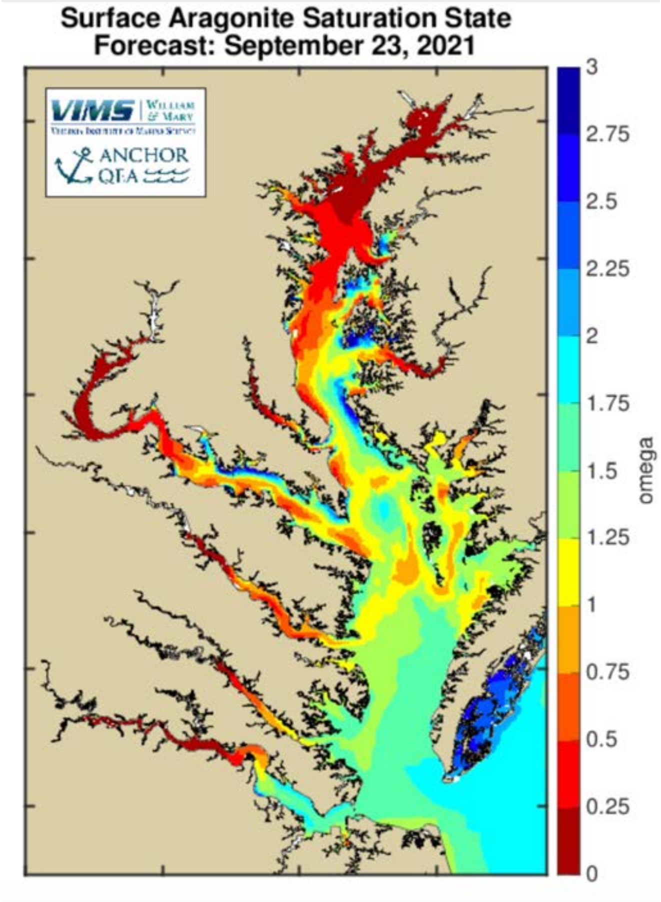
Bottom pH Forecast *(Sept. 23)*

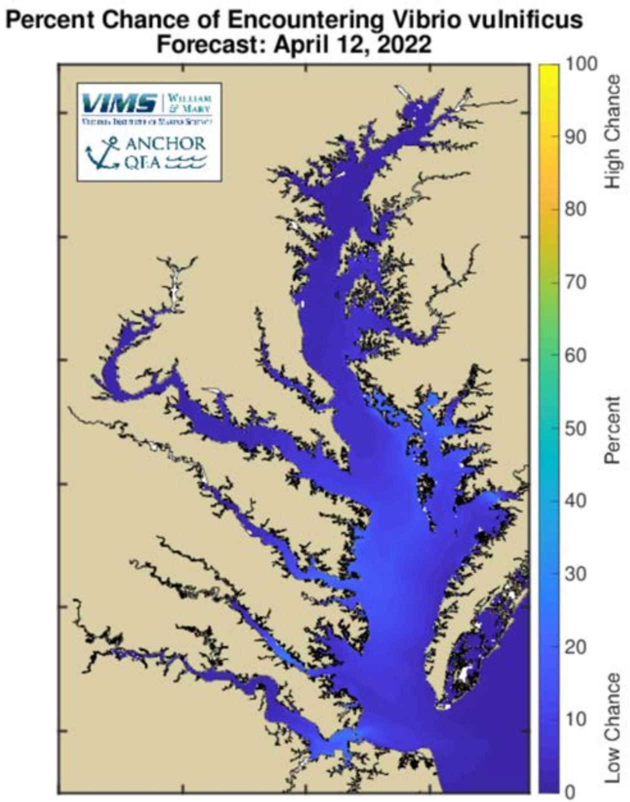


Surface Ω_{AR} Forecast *(Sept. 23)*



% Chance of Encountering Vibrio

April 12, 2022
Forecast



Blues → **Low chance (0-30%)**

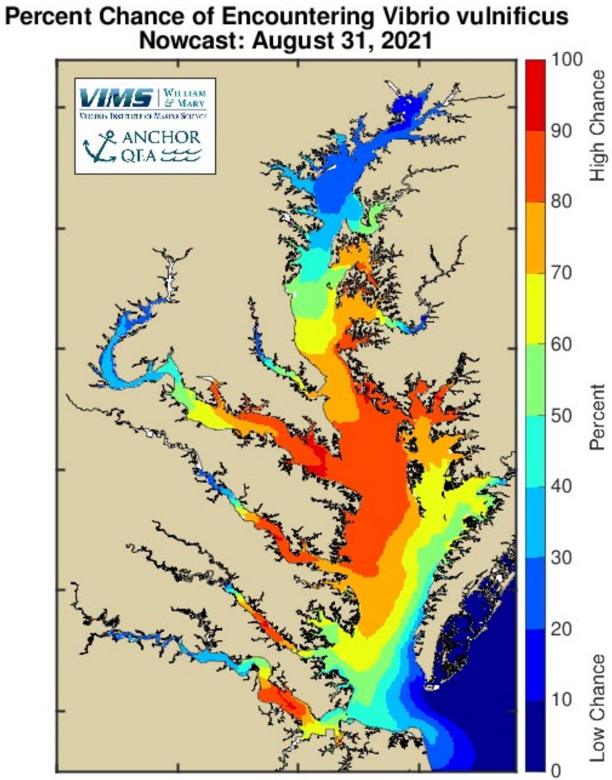
Greens → **Moderate chance**

Oranges → **High chance (70-100%)**

Vibrio is not a concern at this time of year!

% Chance of Encountering Vibrio

August Forecast



But can be in the summer!

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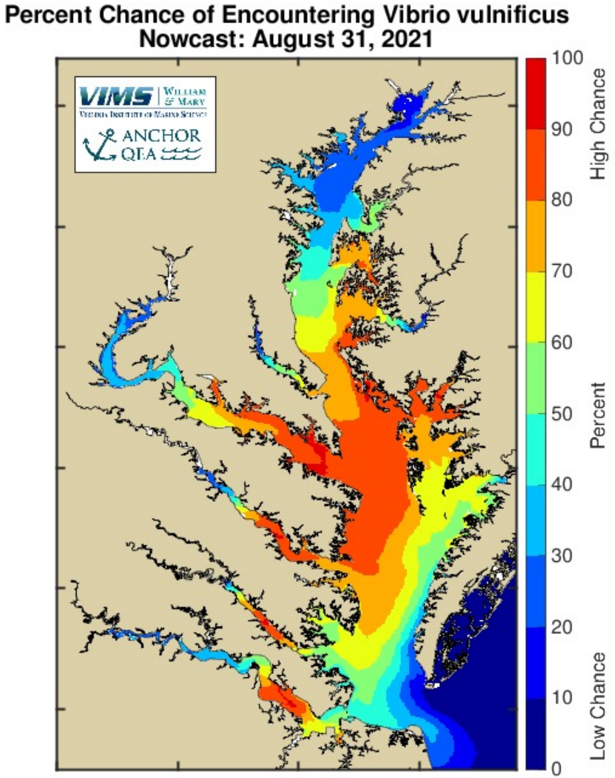
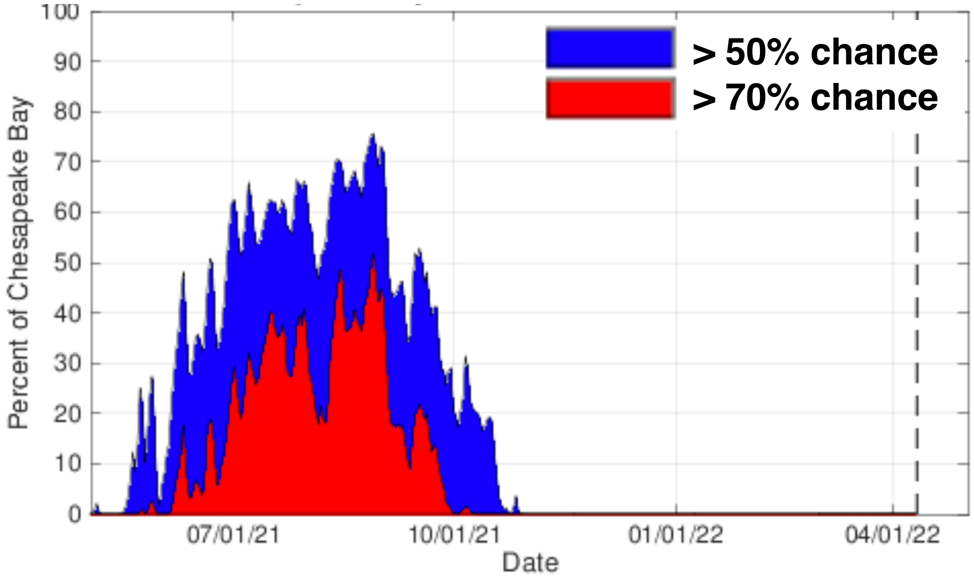


% of Bay with high chance of Vibrio encounter



But it can be a concern in the summer!

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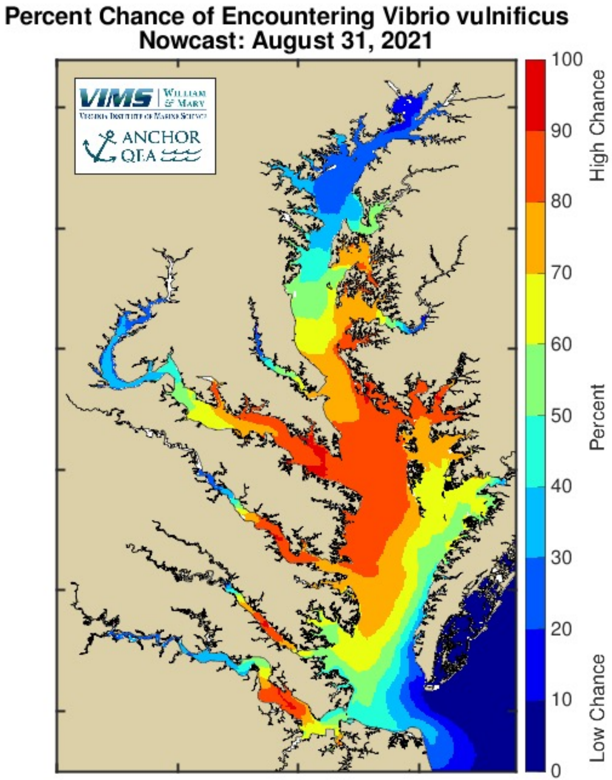

HAB forecasts
coming soon:

Dante Horemans' spotlight talk tomorrow

But it can be a concern in the summer!

Time Scales of Interest
for Chesapeake Bay water quality and habitat

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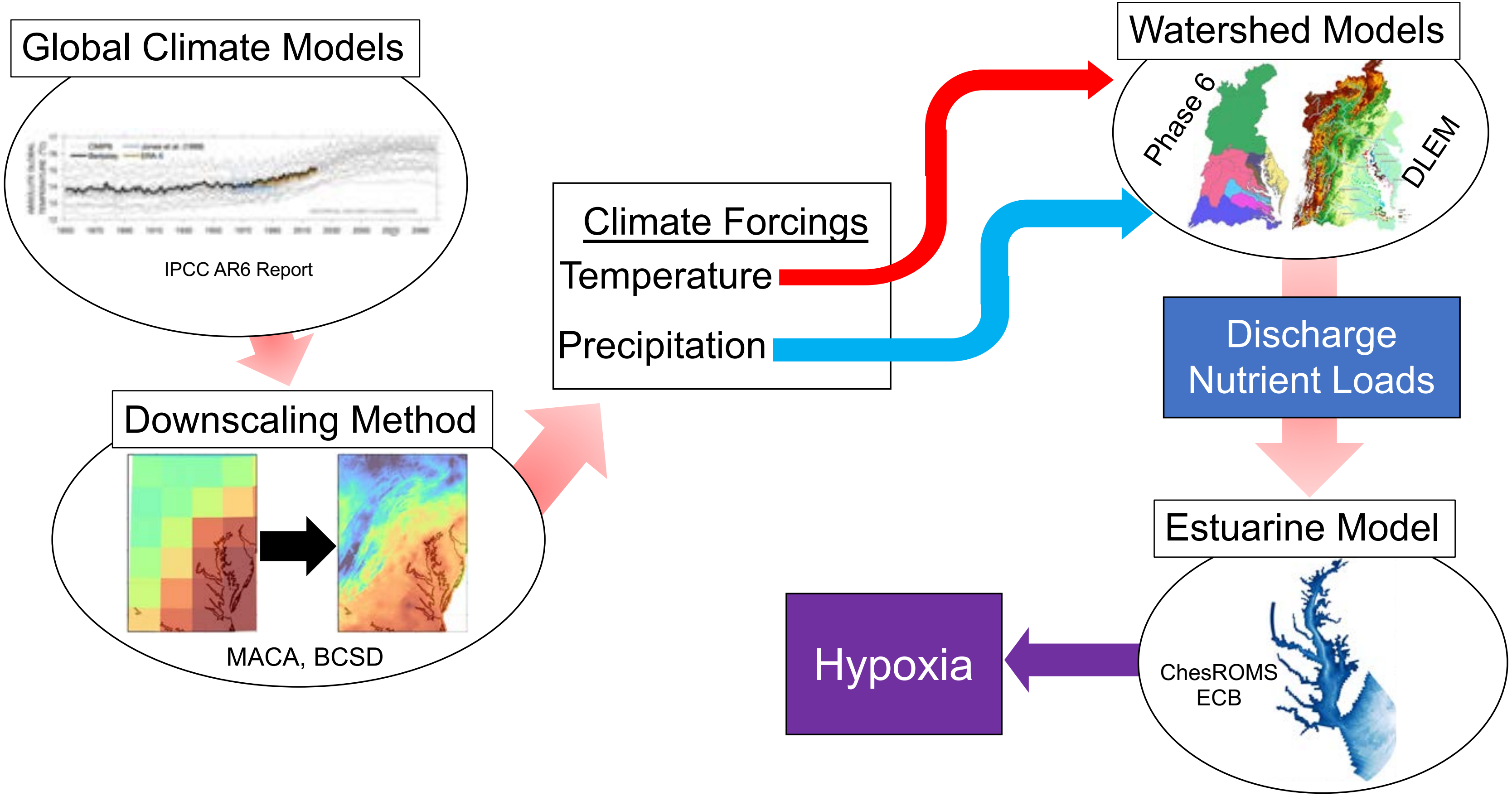
Mid-century projections

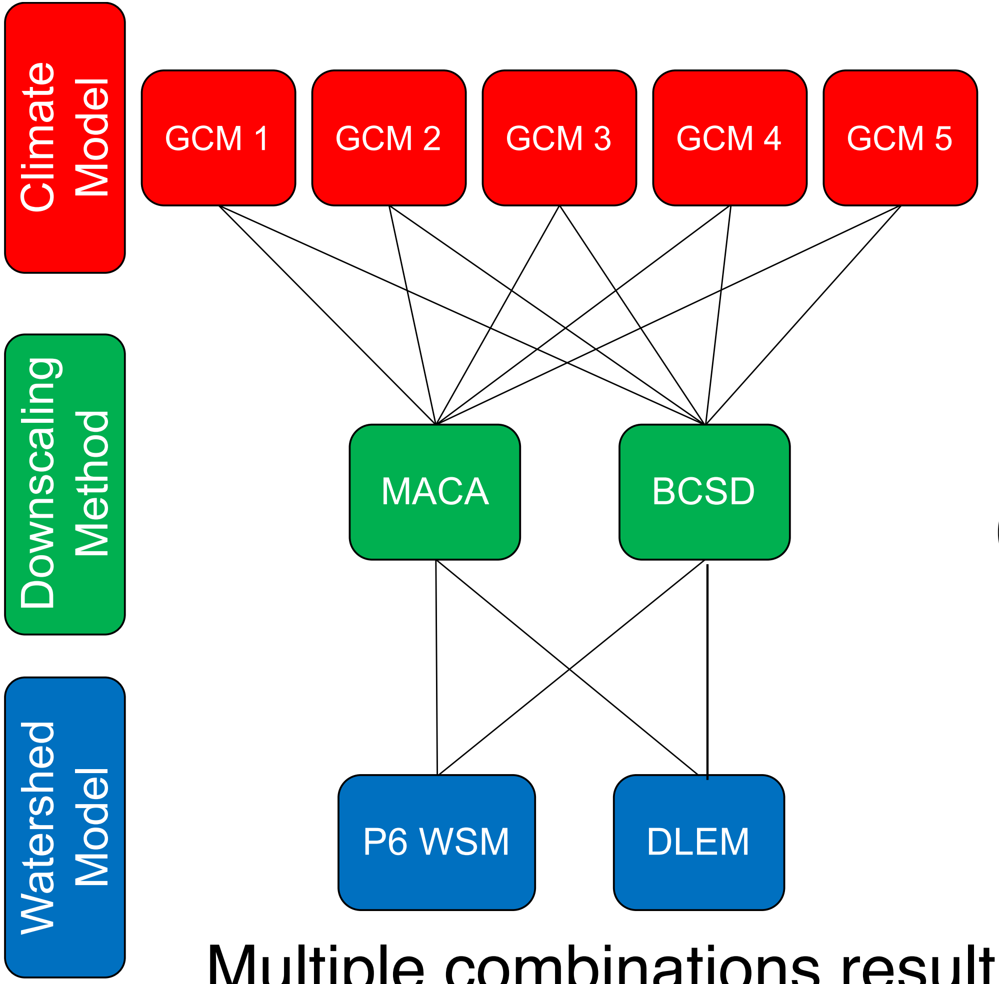
Chesapeake Bay managers want to know:

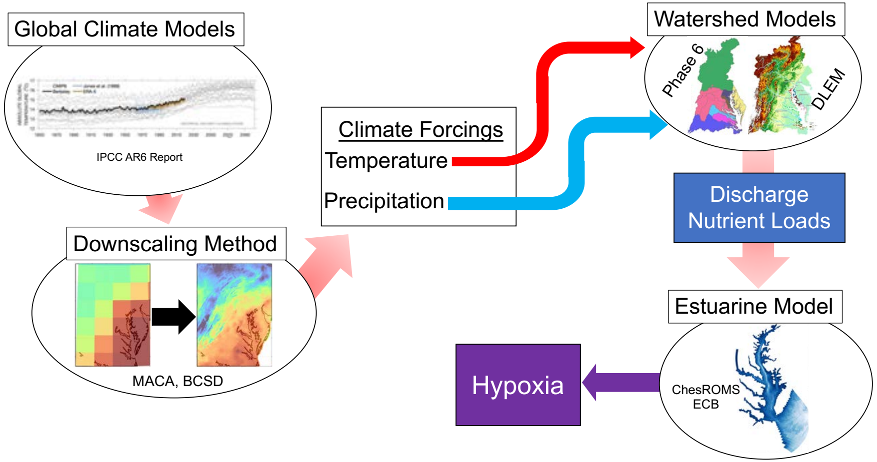
- How will climate change impacts on the watershed (⇧ T_{atm} ⇧ storms) affect terrestrial runoff and hypoxia?
- How confident are we in these estimates?
  (i.e. uncertainty quantification)

Kyle Hinson, VIMS

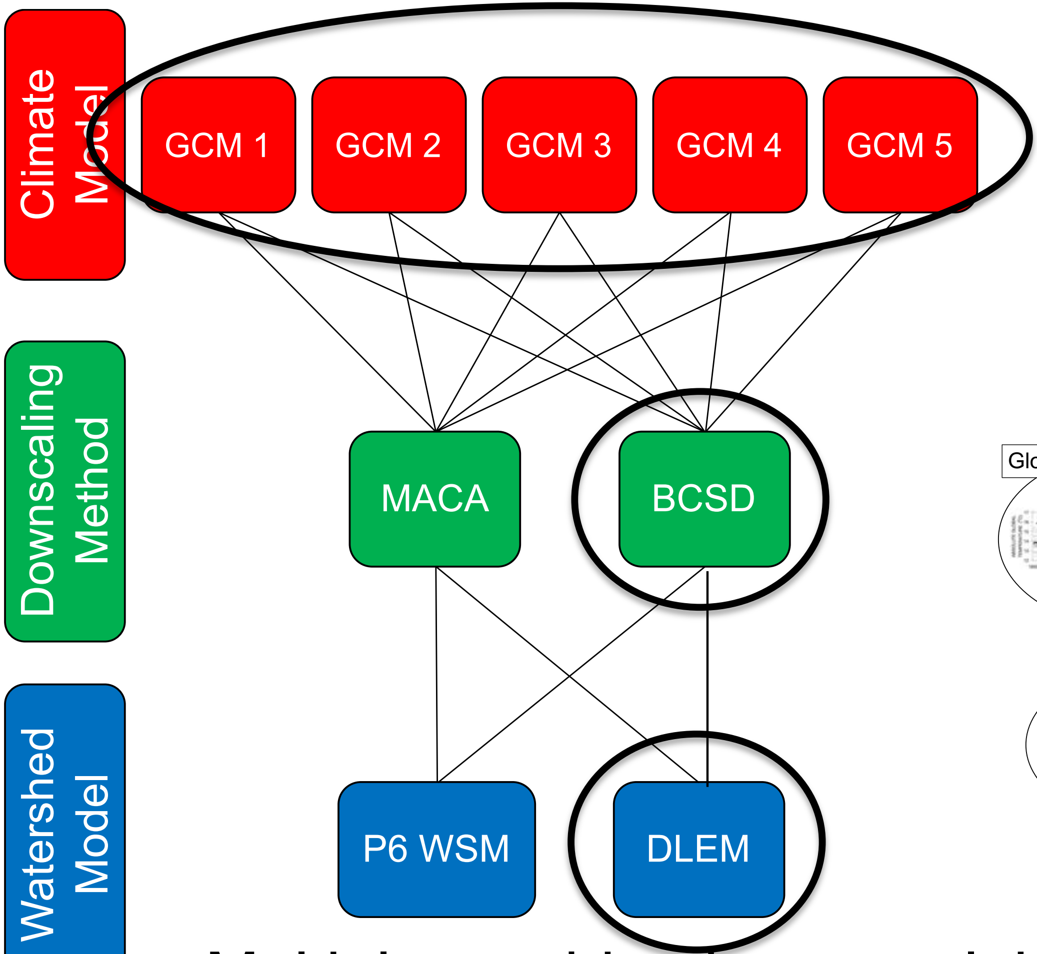
Mid-century projections

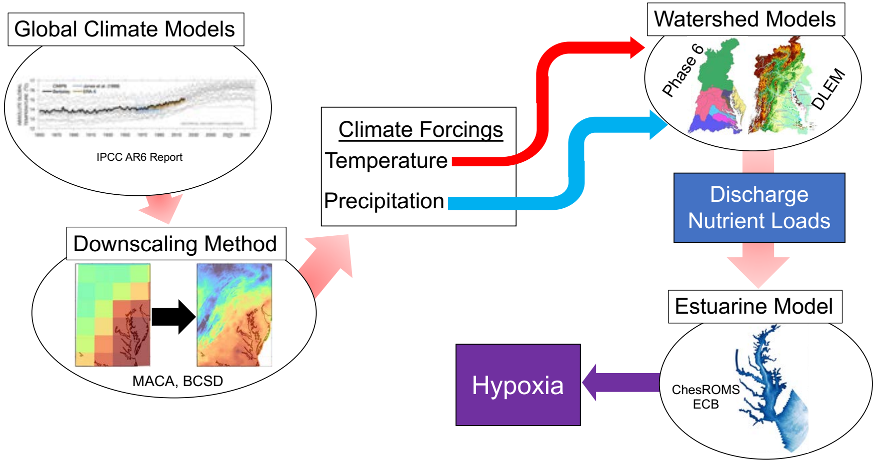






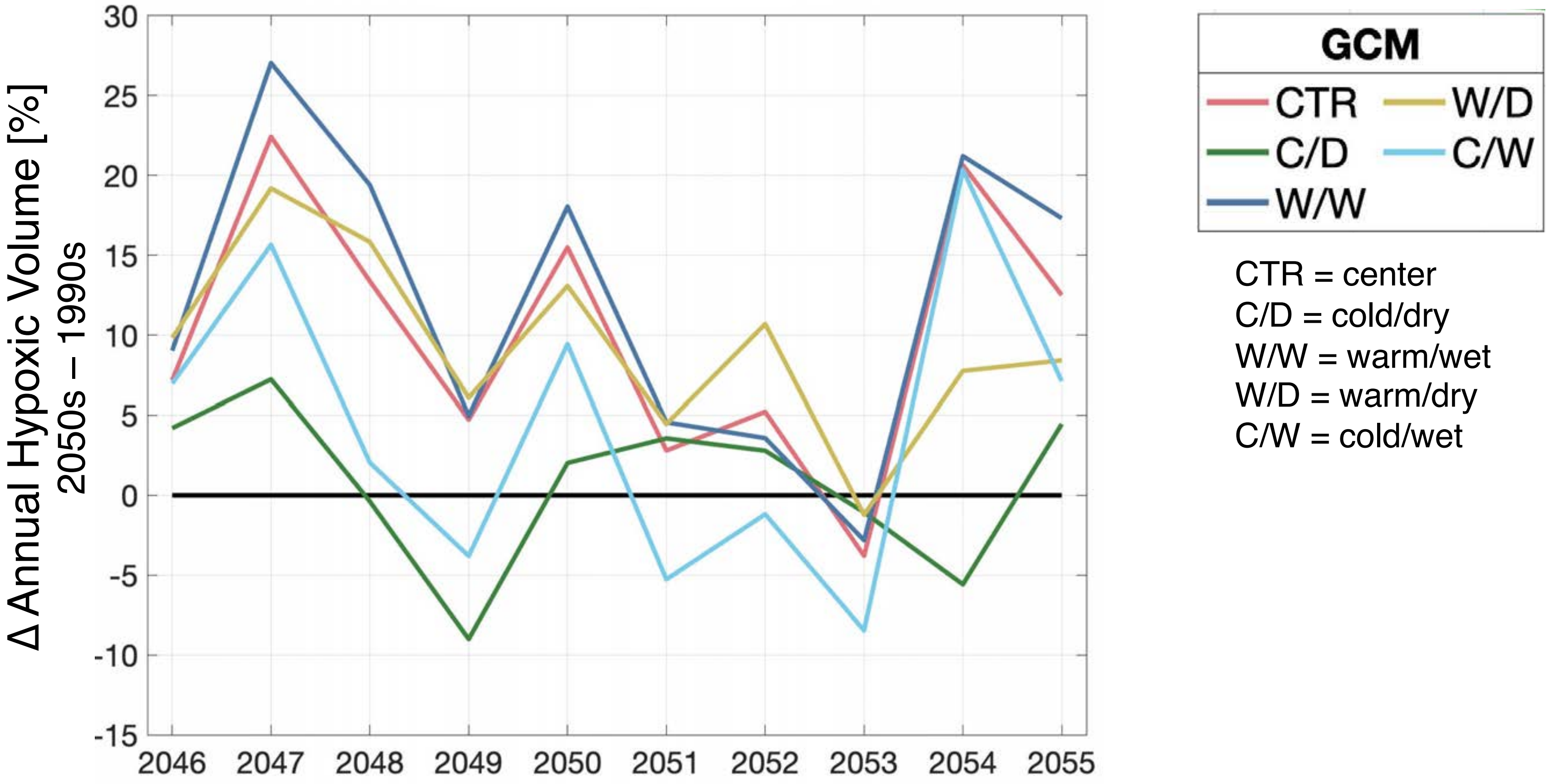
Multiple combinations result in 20 climate scenarios





Multiple combinations result in 20 climate scenarios

Future hypoxia depends on GCM choice: -5 to +25%



CTR = center
C/D = cold/dry
W/W = warm/wet
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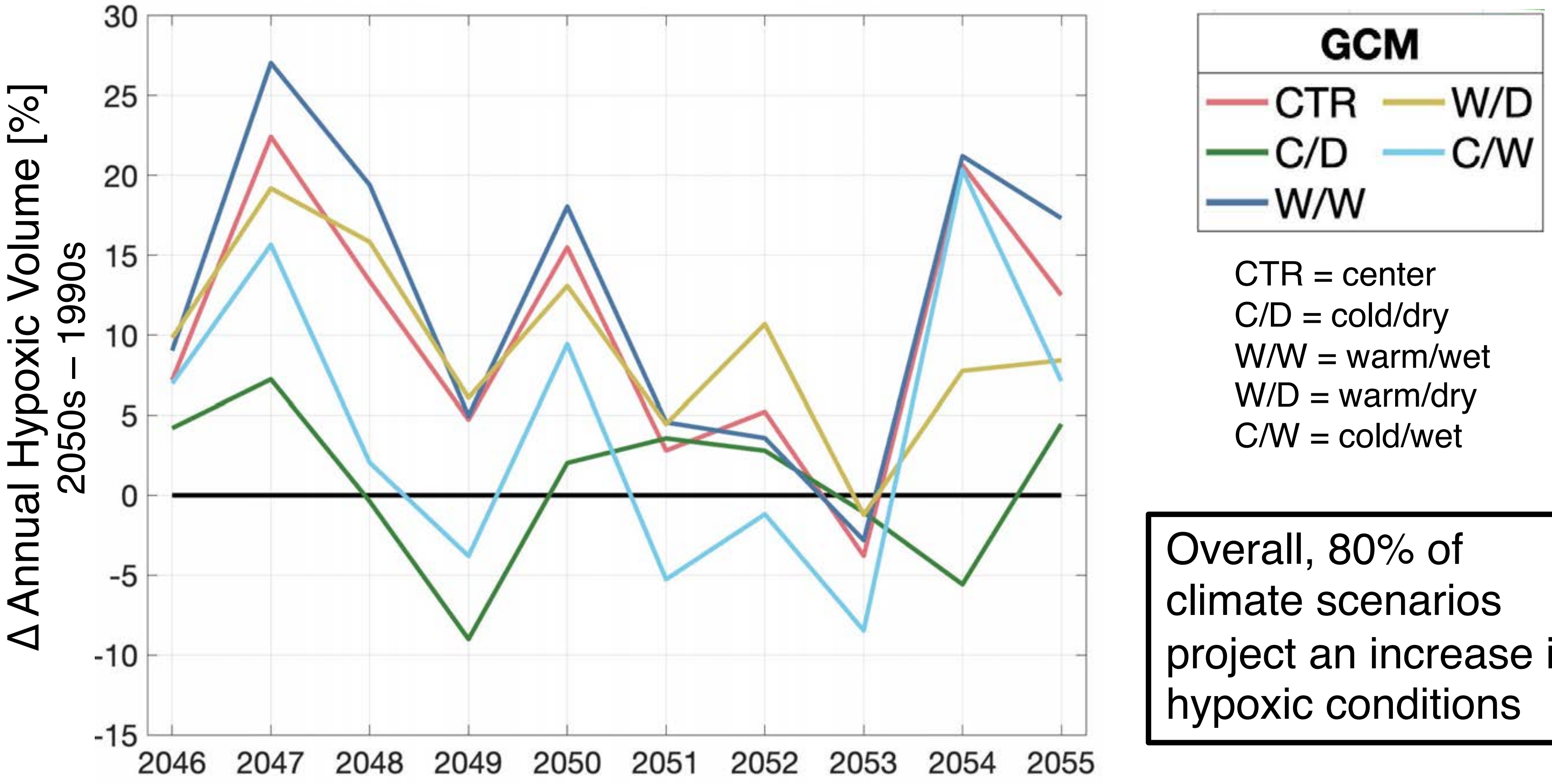
C/W = cold/wet

Future hypoxia depends on GCM choice: -5 to +25%



CTR = center
C/D = cold/dry
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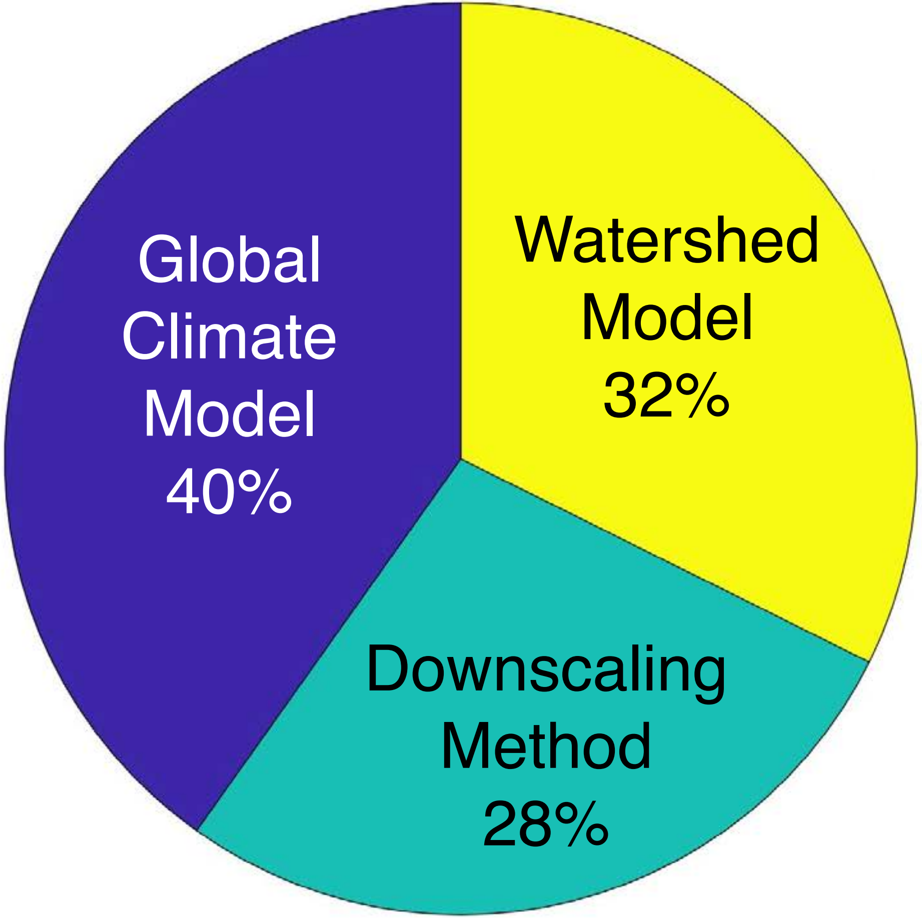
C/W = cold/wet

Overall, 80% of climate scenarios project an increase in hypoxic conditions

Multiple sources (nearly equivalent) of uncertainty in future hypoxia estimates (2050s)



Mid-century projections

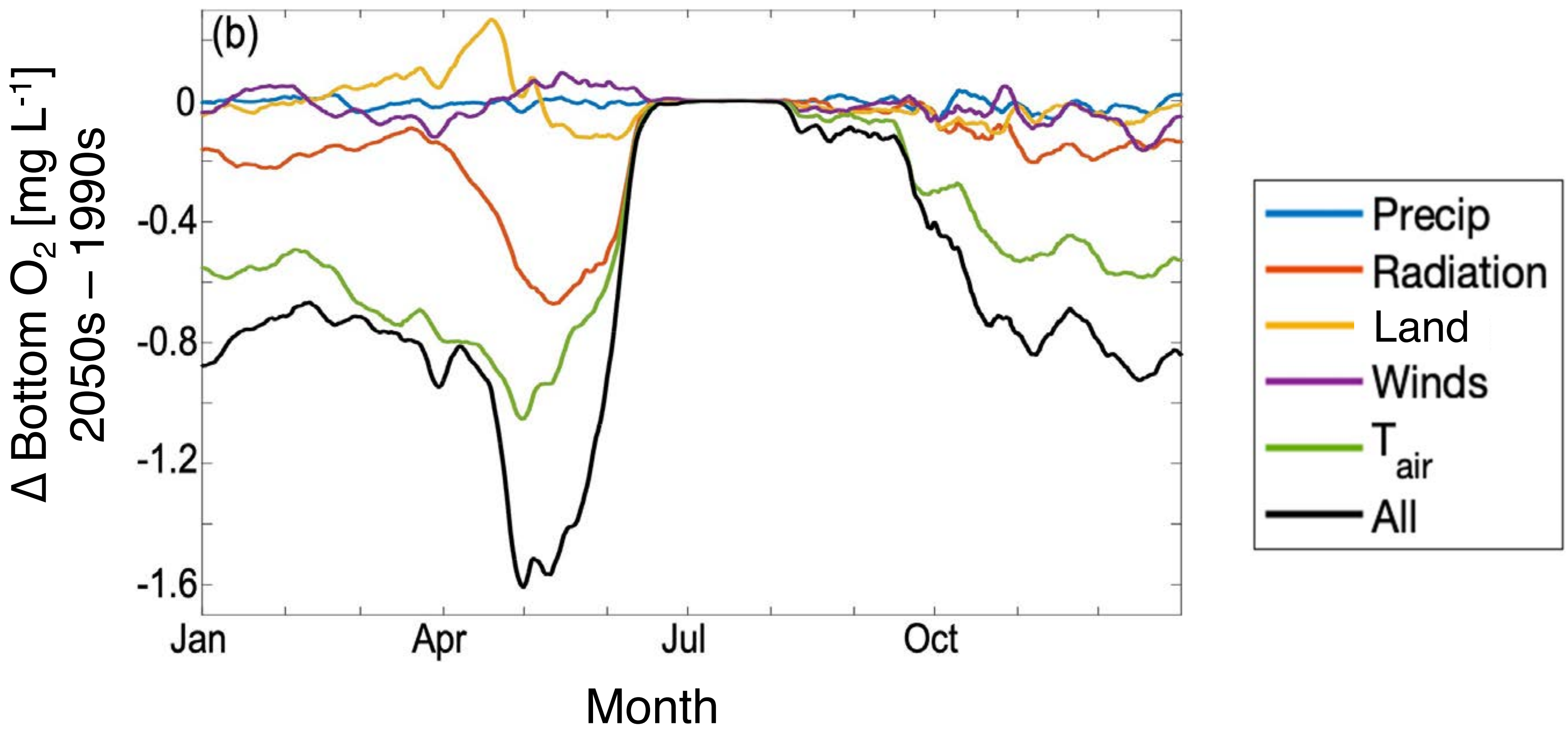
Chesapeake Bay managers want to know:

- How does this impact of changing runoff on hypoxia compare to the direct effects of changing atmospheric conditions?

- Where in the Bay will the greatest effects be seen?

Colin Hawes, VIMS

Direct impacts of atmospheric change >> indirect impacts from land



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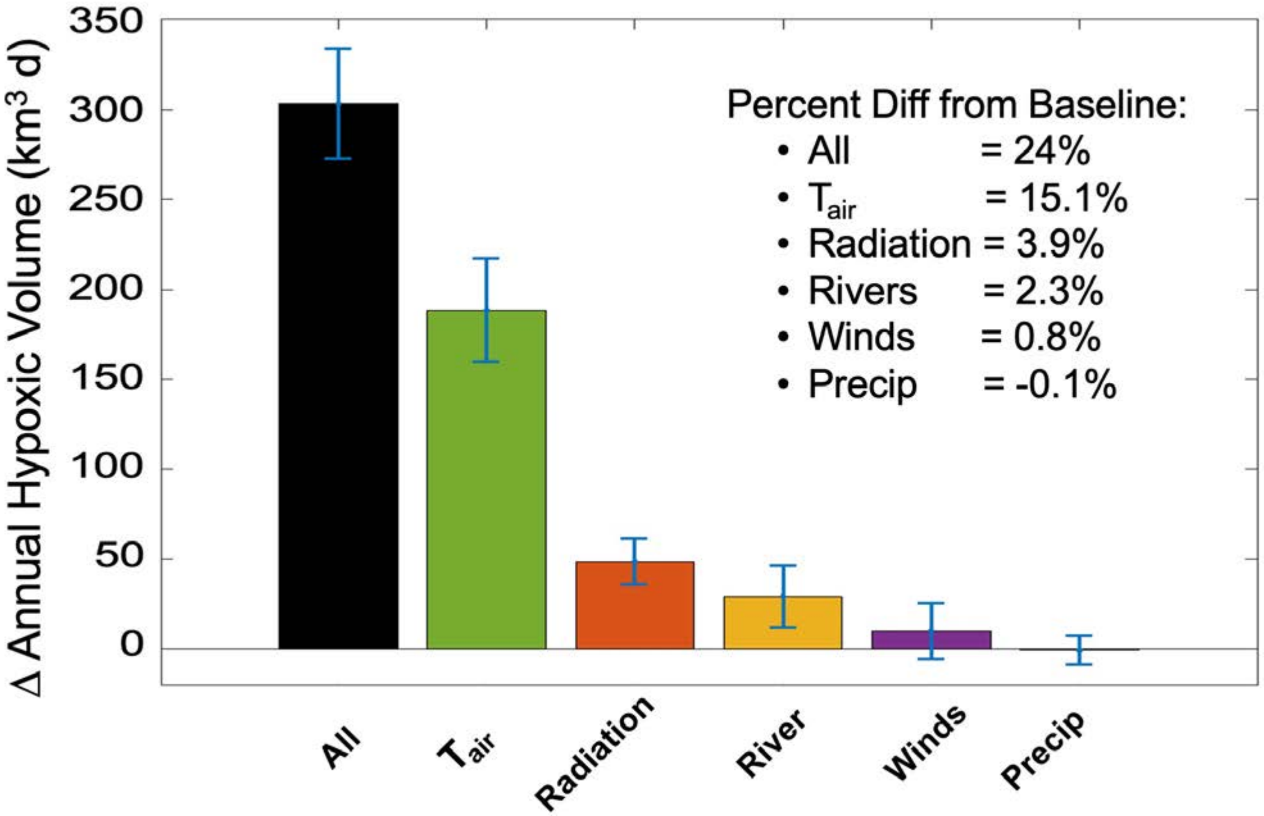
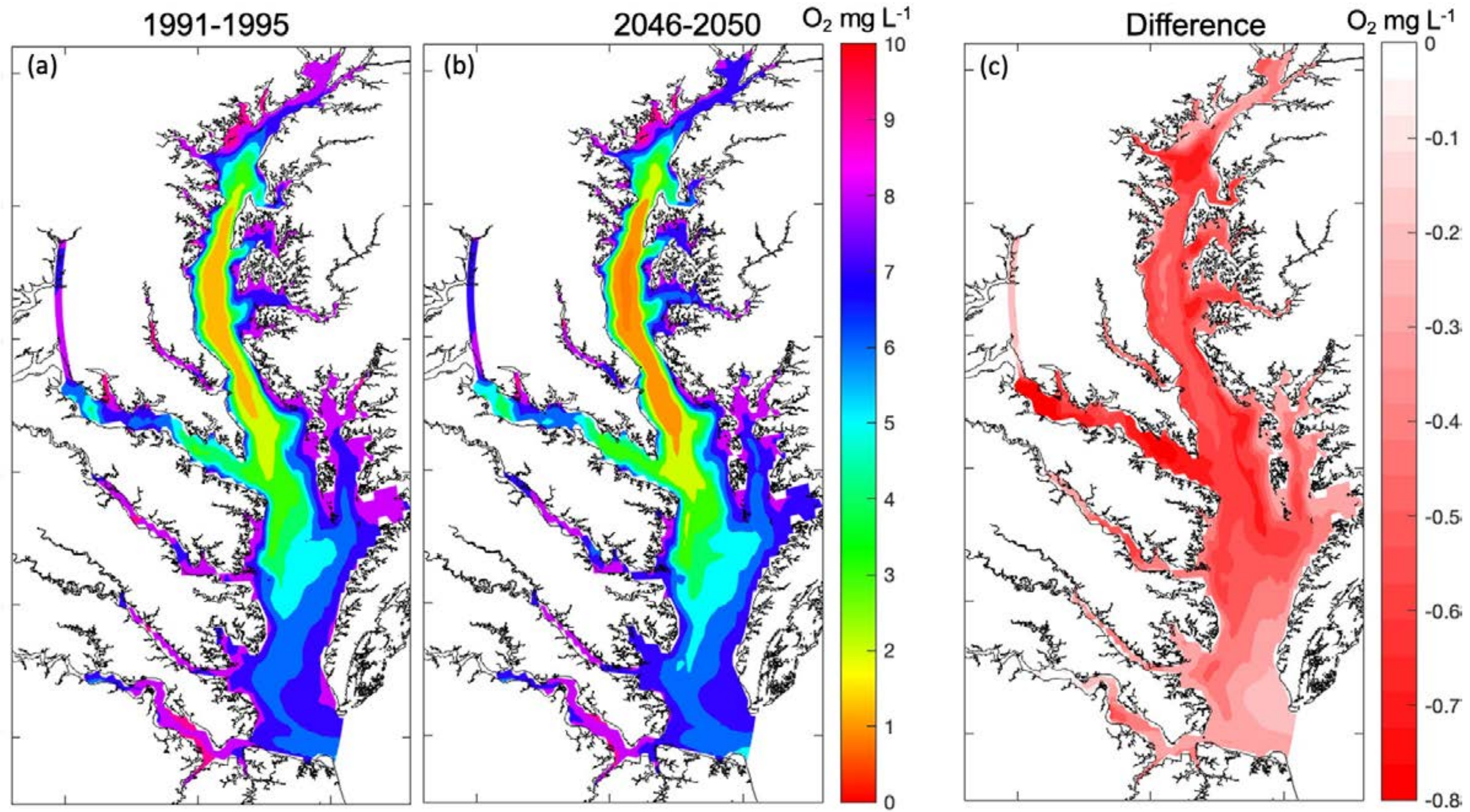


Hypoxic zone spreads farther south by 2050s



For Workshop Discussions

- **Time horizons of interest**
  - Depend on stakeholders: daily/weekly, seasonal, interdecadal, century
- **Modeling approaches**
  - Mechanistic vs. empirical
- **Data/inputs needed**
  - Terrestrial BGC inputs (terrestrial/watershed models?)
  - Improved high resolution weather forecasts (winds)
  - Downscaled climate model forcing

Thanks!

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Virginia Institute of Marine Science

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A Watershed Partnership

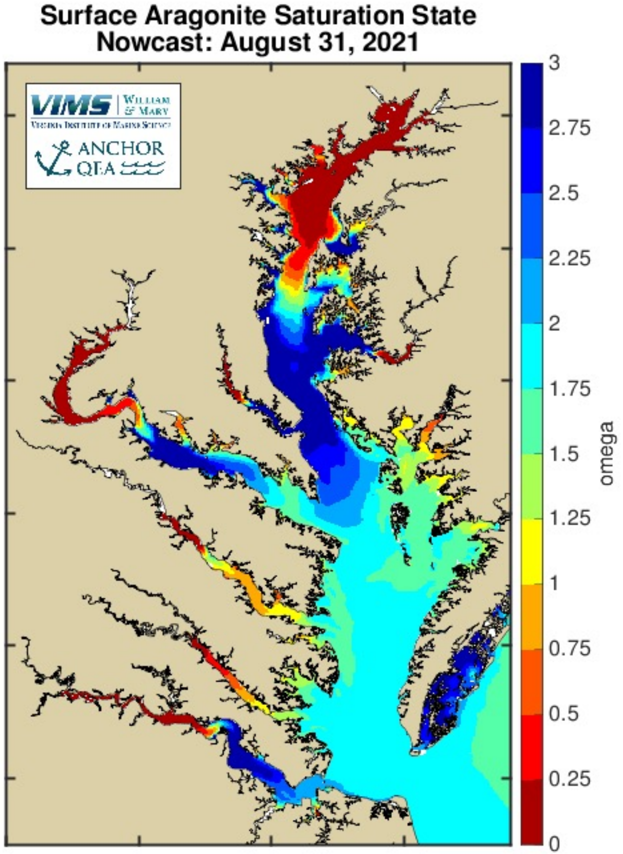
NOAA

National Oceanic and Atmospheric Administration

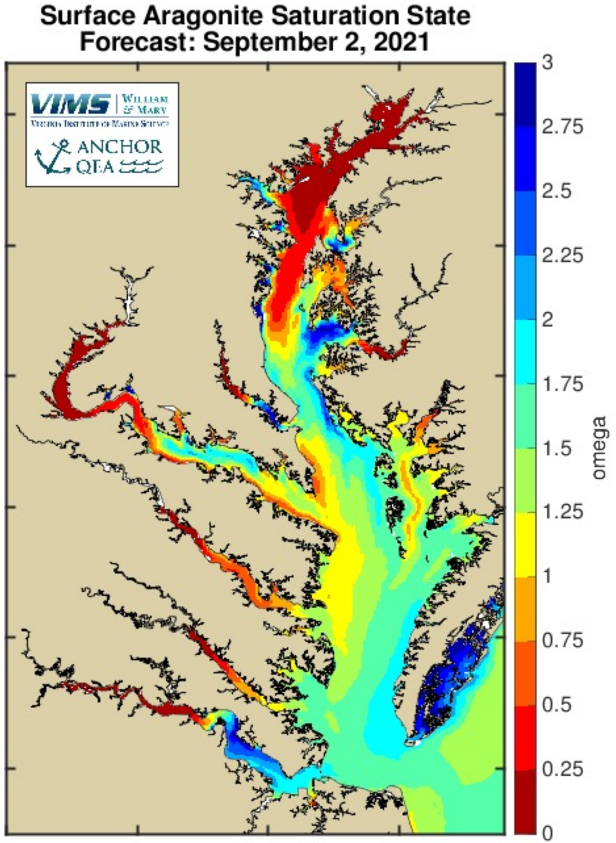
U.S. Department of Commerce

Two day change:
before storm (8/31/21)
to after storm (9/2/21)

Surface Ω_{arag} pre-Ida



Surface Ω_{arag} post-Ida



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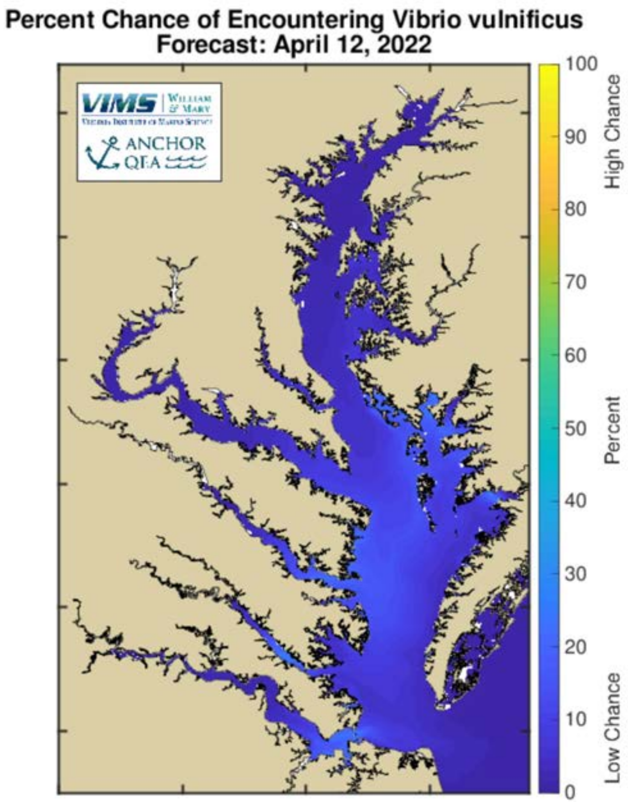

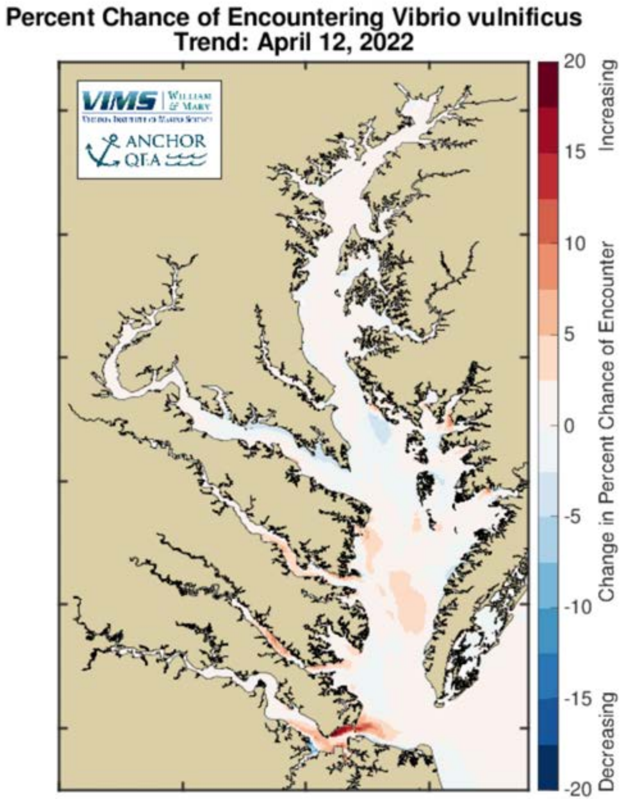

April 12, 2022
Trend

Vibrio is not a concern at this time of year!