Ecological Forecasting Applications for the Chesapeake Bay

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Daily to Decadal Ecological Forecasting
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…
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?)
  - Beach managers and beach goers (are beach waters safe?)

- **Seasonal forecasts**
  - Fisheries managers (are limits needed this season?)

- **Mid-century projections**
  - Coastal resource managers (will planned nutrient reductions lead to attainment of water quality standards, in spite of climate change?)
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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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Estuarine model framework

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

Atmospheric inputs

- Winds
- Solar radiation
- Temperature
- Precipitation

Land inputs

Terrestrial inputs from watershed models and USGS data

NOAA atm. forcing

Coastal inputs

Long-term NOAA data; coastal models

CBEFS: Chesapeake Bay Environmental Forecast System

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

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

Evaluate model performance with observational water quality data

www.vims.edu/cbefs
Land inputs
Coastal inputs
Atmospheric inputs

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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.

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

www.vims.edu/cbefss
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
Blues → High bottom oxygen
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Yellow/green → Moderately low oxygen
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   = Bad bottom water
   = No bottom fish or crabs
Vibrio is not a concern at this time of year!

April 12, 2022

Forecast

% Chance of Encountering Vibrio

Blues  →  Low chance (0-30%)

Greens  →  Moderate chance

Oranges  →  High chance (70-100%)
% Chance of Encountering Vibrio

But can be in the summer!

August Forecast

Blues → Low chance (0-30%)
Greens → Moderate chance
Oranges → High chance (70-100%)
% Chance of Encountering Vibrio

August Forecast

But it can be a concern in the summer!
% Chance of Encountering Vibrio

August Forecast

But it can be a concern in the summer!

HAB forecasts coming soon:
Dante Horemans’ spotlight talk tomorrow
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Mid-century projections

Chesapeake Bay managers want to know:

• How will climate change impacts on the watershed ($\uparrow T_{atm} \uparrow$ storms) affect terrestrial runoff and hypoxia?

• How confident are we in these estimates? (i.e. uncertainty quantification)
Mid-century projections

Global Climate Models
- IPCC AR6 Report

Downscaling Method
- MACA, BCSD

Climate Forcings
- Temperature
- Precipitation

Watershed Models
- Phase 6
- DLEM

Discharge Nutrient Loads

Estuarine Model
- ChesROMS
- ECB

Hypoxia
- ChesROMS
- ECB
Multiple combinations result in 20 climate scenarios
Multiple combinations result in 20 climate scenarios
Future hypoxia depends on GCM choice: -5 to +25%
Future hypoxia depends on GCM choice: -5 to +25%
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?
Direct impacts of atmospheric change >> indirect impacts from land
Direct impacts of atmospheric change

>> indirect impacts from land

Percent Diff from Baseline:
- All = 24%
- $T_{air}$ = 15.1%
- Radiation = 3.9%
- Rivers = 2.3%
- Winds = 0.8%
- Precip = -0.1%
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!
Two day change: before storm (8/31/21) to after storm (9/2/21)
Vibrio is not a concern at this time of year!