

Tidal Trends to evaluate water quality in the Chesapeake Bay

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Climate Resiliency Workgroup Call

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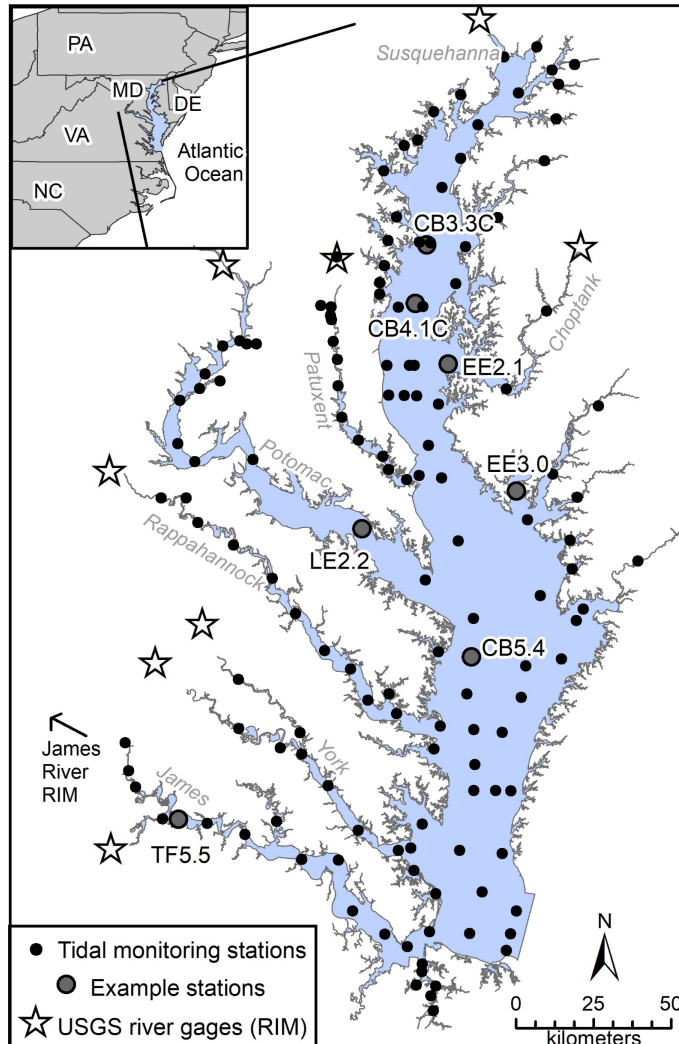


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Chesapeake Bay Program
Science. Restoration. Partnership.

Extensive long-term coordinated tidal water quality monitoring



- MDDNR, VADEQ and others have been sampling at 150+ stations since the 1980s 1-2 times/month
- Nutrients, chlorophyll-*a*, dissolved oxygen, secchi depth, salinity, temperature, and others, all measured at multiple depths



Matt Rath/Chesapeake Bay Program

Tidal Trends Analysis Collaboration

- Since the mid-1990s, coordinated trends efforts have existed as well between MD, VA, and CBP for:
 - Tracking change
 - Visual tool for management audiences
 - Identifying areas for further research
- Recent method revision to use Generalized Additive Models (GAMs)
- Tidal Trends Analysis Team: CBP, MDDNR, VADEQ, ODU, UMCES, USGS, statistical consultants

Approach: Generalized Additive Models (GAMs)

A response variable is modeled as the sum of multiple functions of explanatory variables

$$\text{Water quality} = s(\text{doy}) + s(\text{date}) + \text{Interaction}(\text{doy}, \text{date})$$

Smoothly-varying non-linear “spline” functions

And multi-dimensional smooth functions

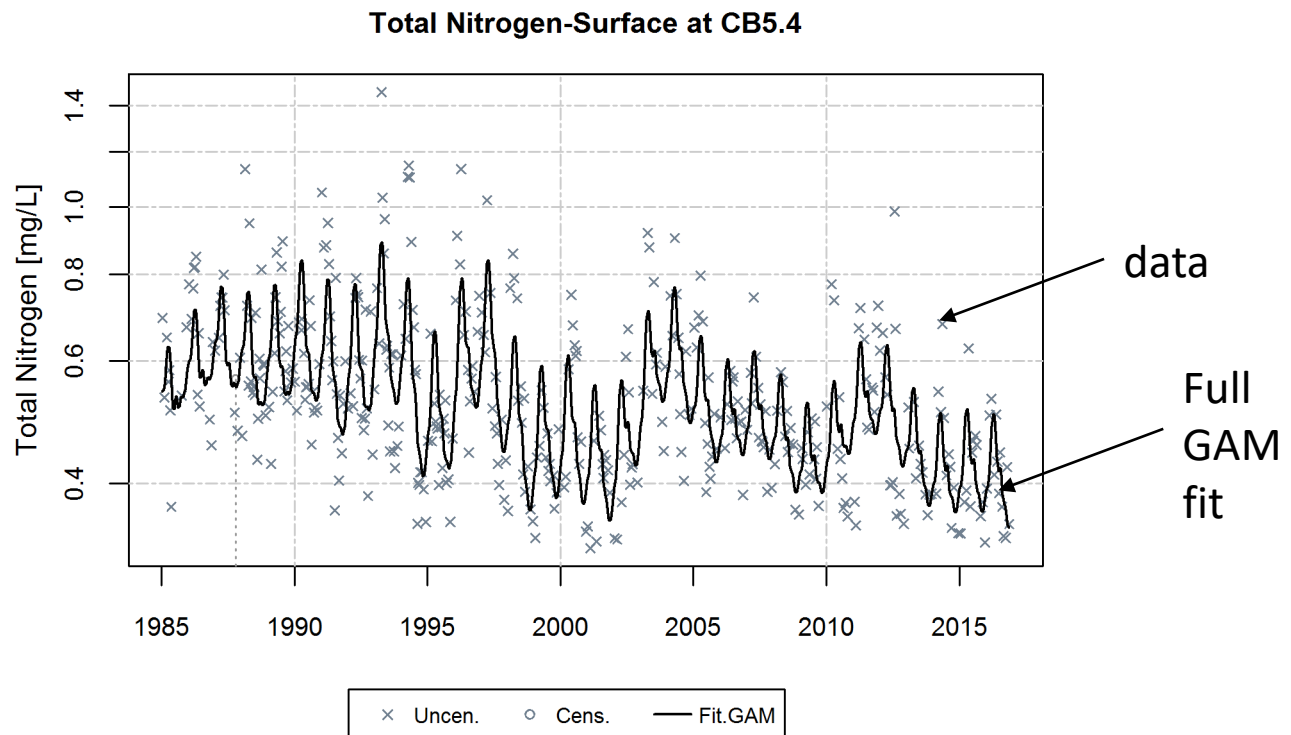
s = spline smooth functions
doy = day of year

We're using: mgcv R package by Simon Wood: (<https://cran.r-project.org/web/packages/mgcv/mgcv.pdf>) and through our separate R package 'baytrends'

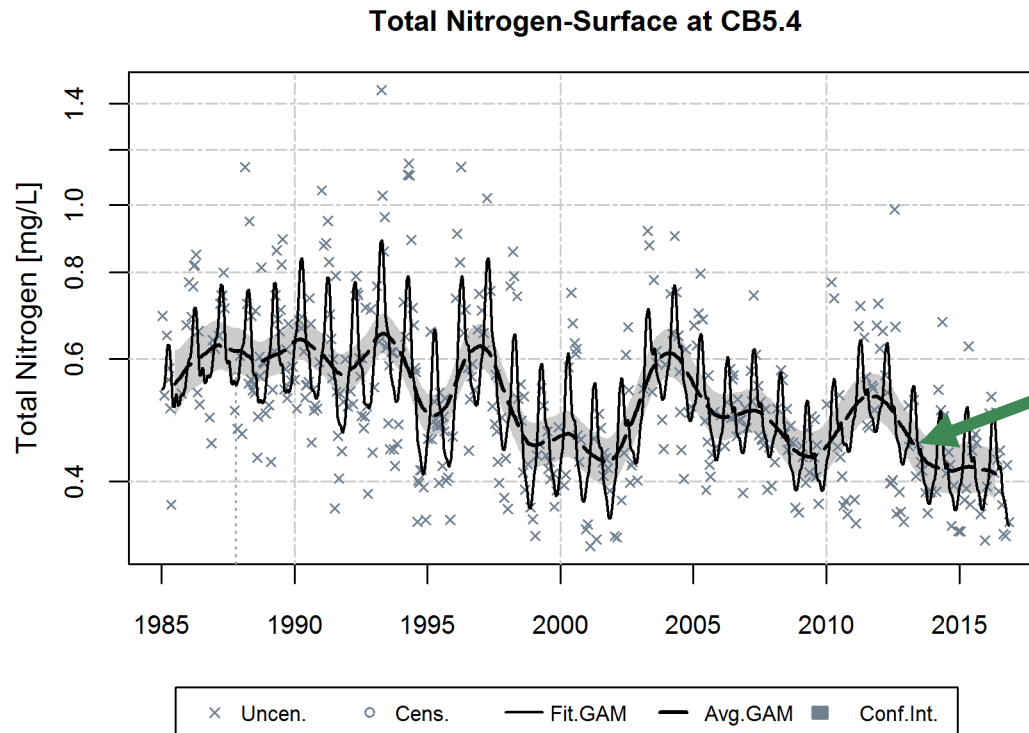
Murphy, R.R., Perry, E., Harcum, J. and Keisman, J. 2019. A Generalized Additive Model approach to evaluating water quality: Chesapeake Bay case study. *Environmental Modelling and Software* 118: 1-13. <https://doi.org/10.1016/j.envsoft.2019.03.027>

GAM Implementation

$$\text{TN} = s(\text{doy}) + s(\text{date}) + \text{interaction}(\text{doy}, \text{date})$$

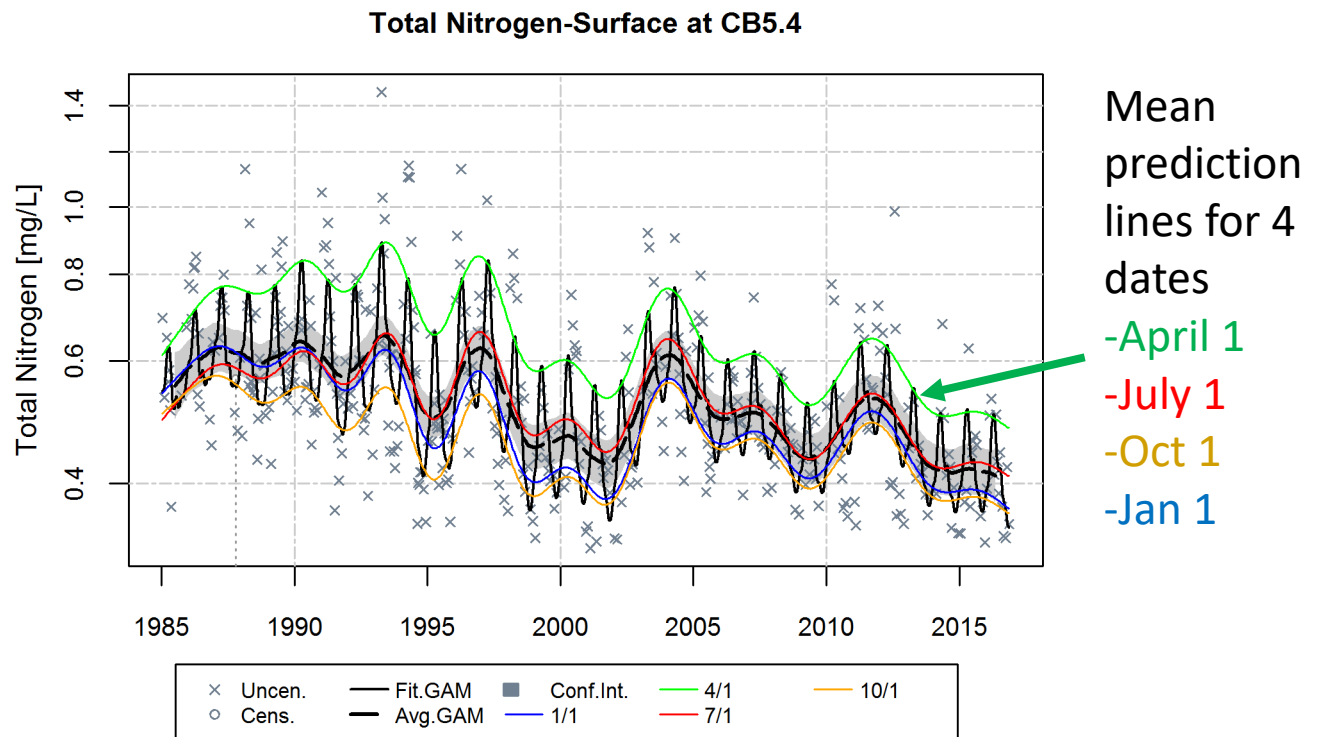


$$\text{TN} = \text{s}(\text{doy}) + \text{s}(\text{date}) + \text{interaction}(\text{doy}, \text{date})$$

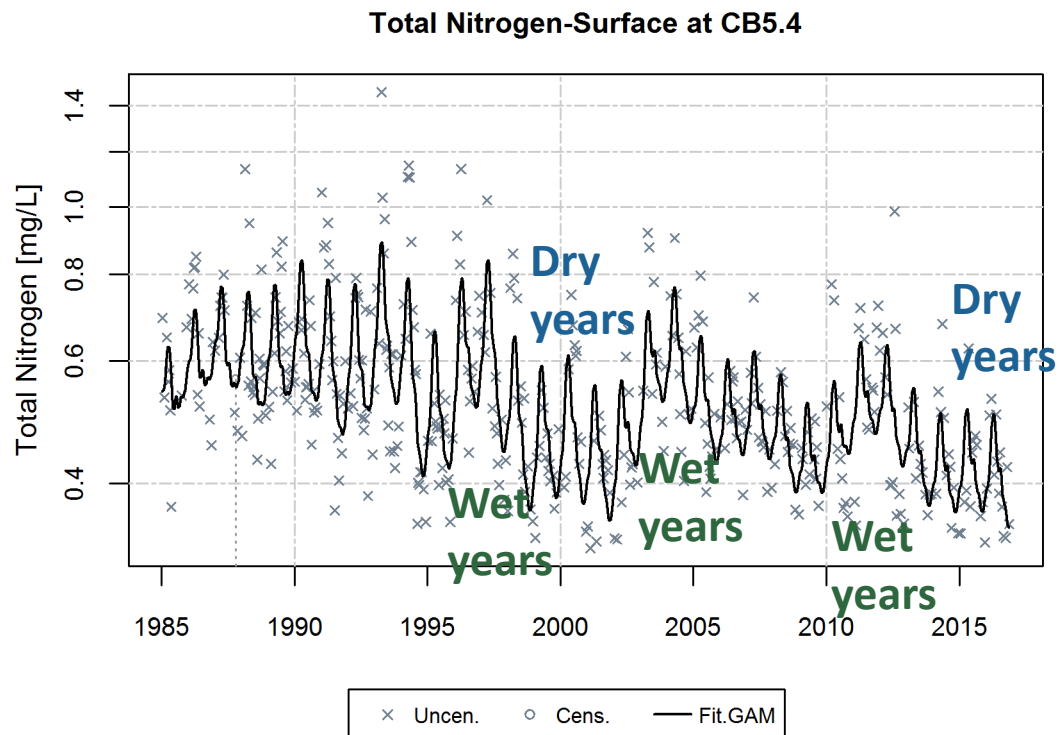


Seasonal mean and 95% confidence interval on the mean

$$\text{TN} = \text{s}(\text{doy}) + \text{s}(\text{date}) + \text{interaction}(\text{doy}, \text{date})$$

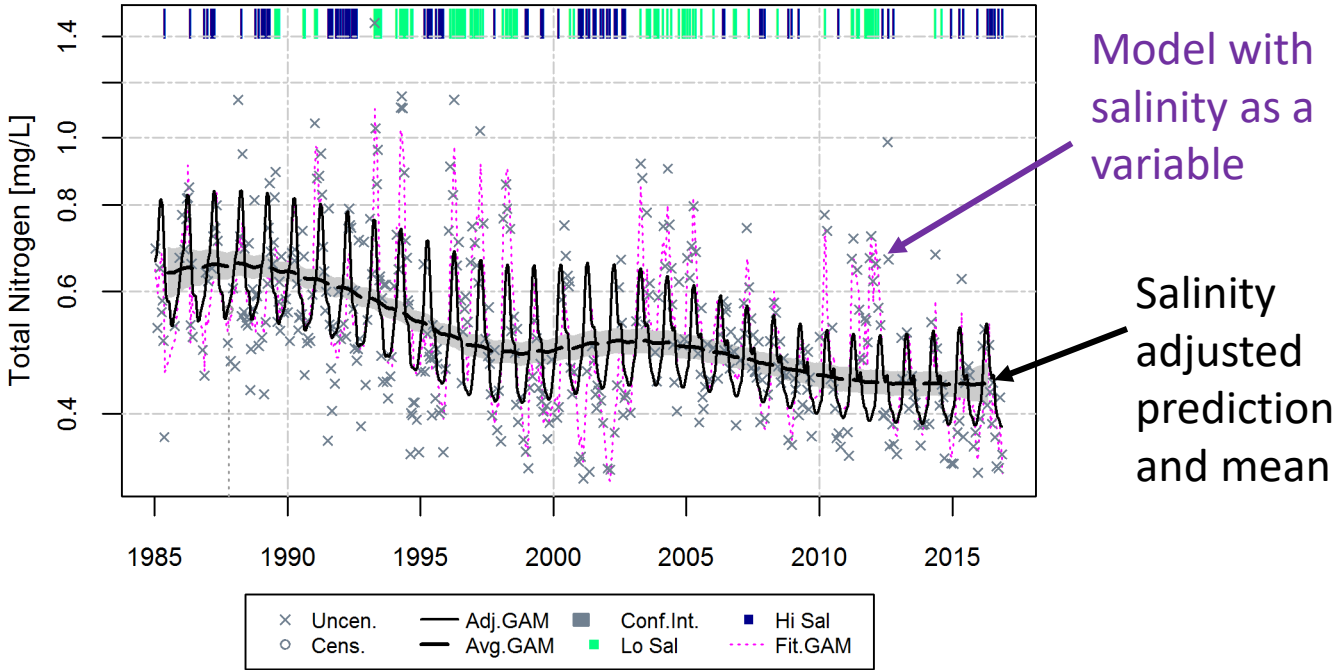


Is variability in river flow the cause of year-to-year fluctuations?



$$\begin{aligned}
 \text{TN} = & s(\text{doy}) + s(\text{date}) + \text{interaction}(\text{doy}, \text{date}) \\
 & + s(\text{sal}) + \text{interaction}(\text{sal}, \text{doy}) + \text{interaction}(\text{sal}, \text{date}) + \text{interaction}(\text{sal}, \text{doy}, \text{date})
 \end{aligned}$$

Total Nitrogen-Surface at CB5.4

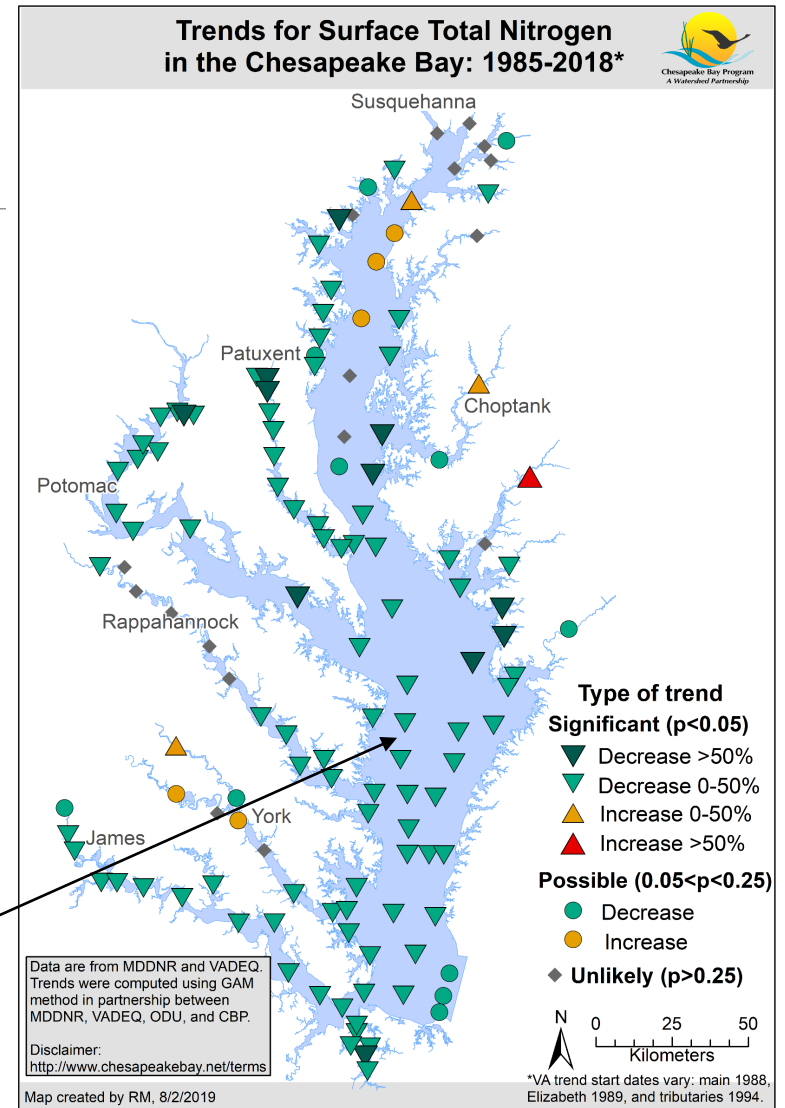
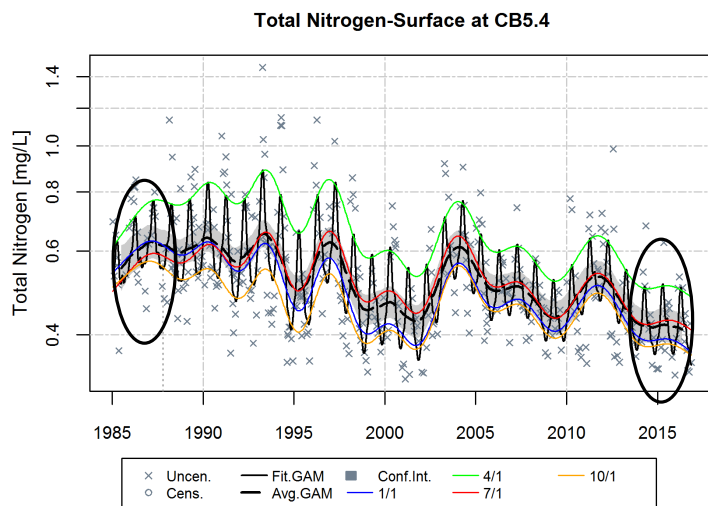


Annual trend products

- MDDNR and ODU/VADEQ fit GAMs like this for every station, surface & bottom:
 - Nutrients: Total Nitrogen, Dissolved Inorganic Nitrogen, Total Phosphorus, Orthophosphate
 - Chlorophyll-a, Dissolved Oxygen, Total Suspended Solids, Secchi Depth
 - Temperature, Salinity

Annual trend products

- Post-process analysis to compute change at each station for time periods and seasons
 - Long-term (ideally 1985-present)
 - Short-term (last 10 years)
 - Spring & Summer chlorophyll-a, summer bottom DO



Annual trend products

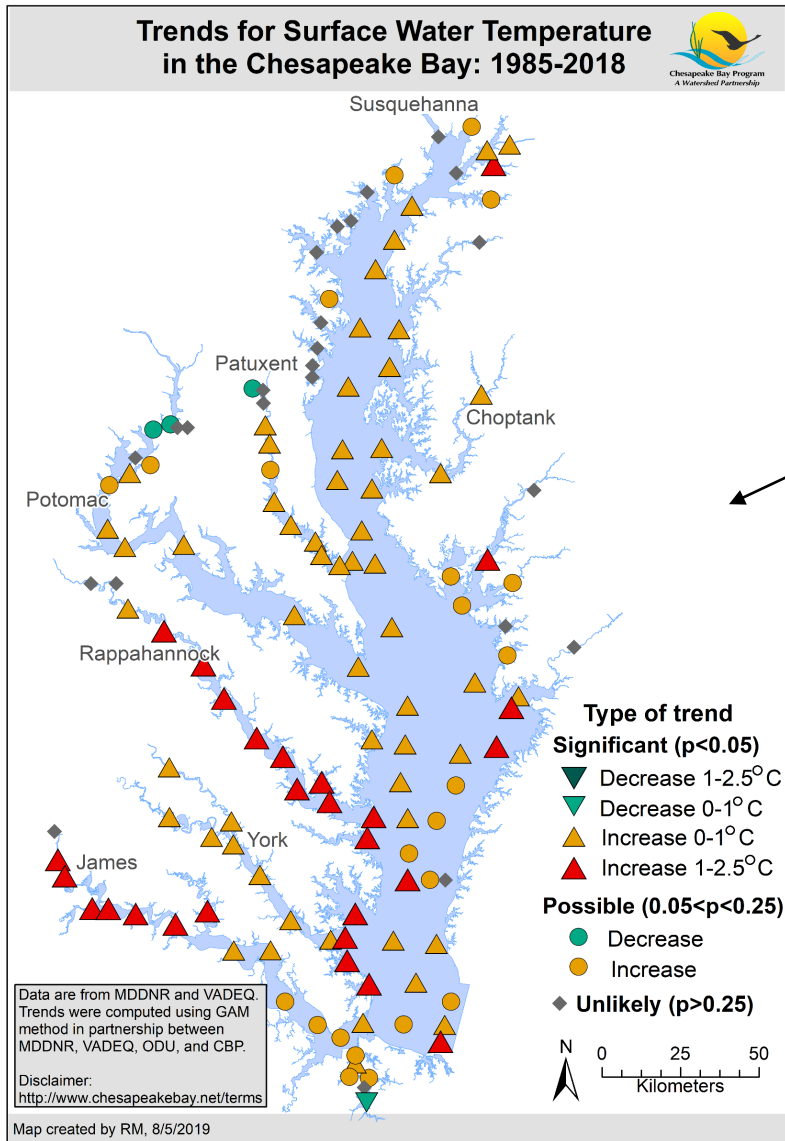
- Combined summaries generated at CBP
 - Maps
 - Graphics on data dashboard
 - Interactive mapping tool (available soon)
 - Basin summaries (in the works)

The screenshot shows the website for the Chesapeake Bay Program, specifically the Integrated Trends Analysis Team page. The header includes the program's logo and tagline: "Chesapeake Bay Program Science. Restoration. Partnership." Below the header are navigation links: "Discover the Chesapeake", "Learn the Issues", and "State of the Chesapeake". The main content area features the team name "Integrated Trends Analysis Team" with social media icons for Facebook, Twitter, and Email. Underneath, there are three sections of "Maps of 2018 Tidal Trends":

- 1. Long-Term Tidal Trends**
 - Surface TN, Annual, 1985-2018 (973.2 KB)
 - Surface TP, Annual, 1985-2018 (971.33 KB)
 - Secchi Disk Depth, Annual, 1985-2018 (970.68 KB)
 - Surface Total Suspended Solids, Annual, 1999-2018 (971.52 KB)
 - Surface Water Temperature, Annual, 1985-2018 (972.6 KB)
 - Surface Chlorophyll-a, Spring, 1985-2018 (971.77 KB)
 - Surface Chlorophyll-a, Summer, 1985-2018 (971.8 KB)
 - Bottom Dissolved Oxygen, Summer, 1985-2018 (971.96 KB)
- 2. Long-term Flow-Adjusted Tidal Trends**
 - Surface TN, Annual, 1985-2018 (973.97 KB)
 - Surface TP, Annual, 1985-2018 (971.69 KB)
 - Secchi Disk Depth, Annual, 1985-2018 (972.09 KB)
 - Surface Total Suspended Solids, Annual, 1999-2018 (972.33 KB)
 - Surface Water Temperature, Annual, 1985-2018 (973.76 KB)
 - Surface Chlorophyll-a, Spring, 1985-2018 (972.87 KB)
 - Surface Chlorophyll-a, Summer, 1985-2018 (973.13 KB)
 - Bottom Dissolved Oxygen, Summer, 1985-2018 (973.24 KB)
- 3. Short-term Tidal Trends**
 - Surface TN, Annual, 2009-2018 (972.06 KB)
 - Surface TP, Annual, 2009-2018 (971.64 KB)
 - Secchi Disk Depth, Annual, 2009-2018 (970.98 KB)

The screenshot shows the "Tidal Water Quality" monitoring interface. It features a map of the Chesapeake Bay area with various monitoring stations marked by colored icons (triangles, circles, squares). A "Quick Start Information" pop-up window is open, providing instructions and background information. The instructions state: "Click on a monitoring station to open more information about that station and to access a chart of the monitoring trend. Click on the 'Layer List' widget at the bottom of the map to change the water quality parameter displayed on the map. Use the other widget icons at the bottom of the map to access additional features." The background section explains: "The Chesapeake Bay tidal water quality monitoring program is carried out in partnership with Maryland, Virginia and EPA. Water quality parameters including temperature, salinity, dissolved oxygen, clarity, chlorophyll-a, nitrogen and phosphorus are measured at over 100 stations at least once a month. Trends in water quality parameters are analyzed by state agency and Chesapeake Bay Program partners using a Generalized Additive Model (GAM) statistical approach. More information on the tidal water quality monitoring program can be found here. More information on the GAM methods can be found here." The interface also includes a search bar, a "Find address or place" input, and a "Layer List" widget at the bottom.

Annual trend products



Integrated Trends Analysis Team

chesapeakebay.net/who/group/integrated_trends_analysis_team

Apps Google Google Scholar IntroLinks Monitoring CBP UMD examples trends R paper

Chesapeake Bay Program
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WHO WE ARE > HOW WE'RE ORGANIZED > INTEGRATED TRENDS ANALYSIS TEAM

Integrated Trends Analysis Team

f t e

Maps of 2018 Tidal Trends

1. Long-Term Tidal Trends

- Surface TN, Annual, 1985-2018 (973.2 KB)
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2. Long-term Flow-Adjusted Tidal Trends

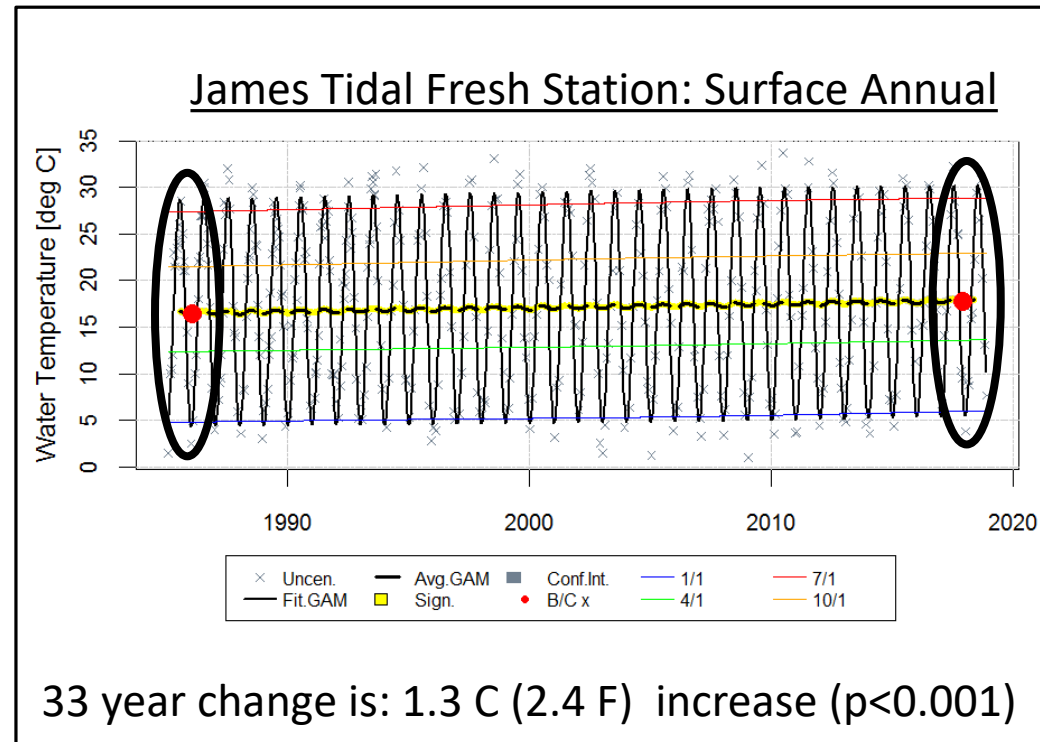
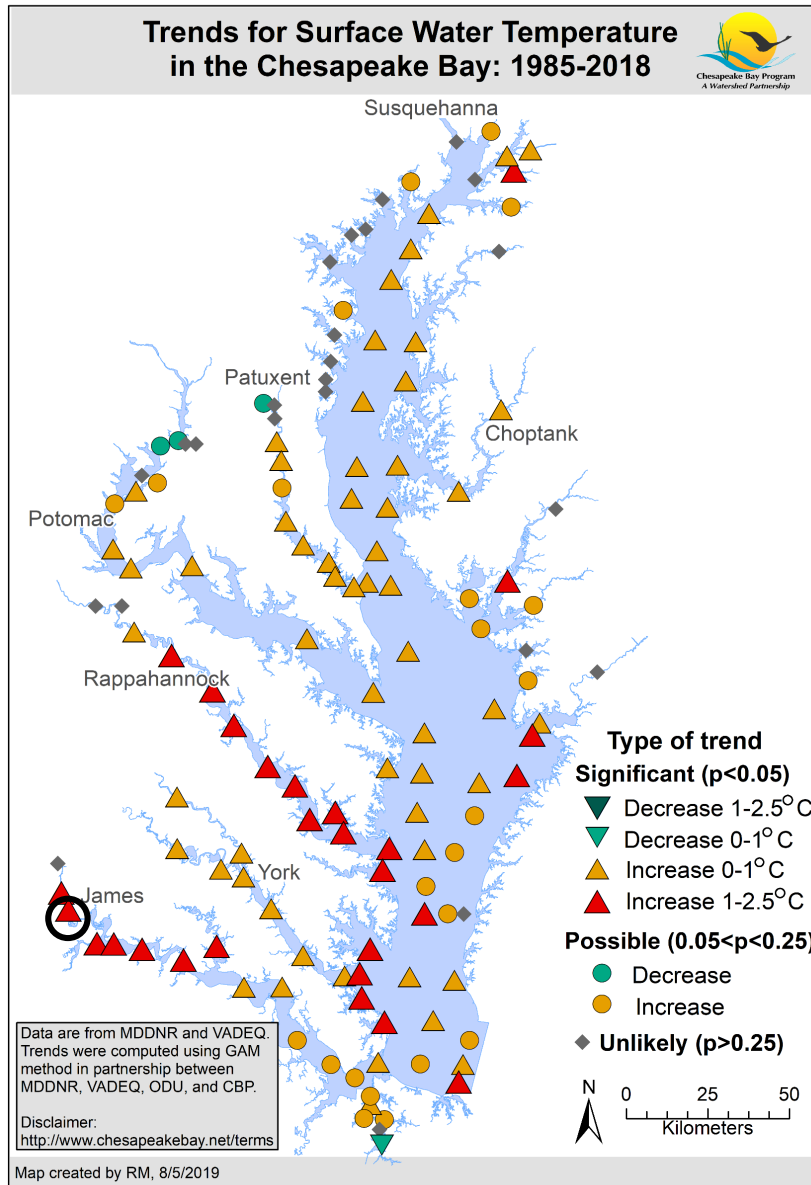
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- Surface Chlorophyll-a, Spring, 1985-2018 (972.87 KB)
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3. Short-term Tidal Trends

- Surface TN, Annual, 2009-2018 (972.06 KB)
- Surface TP, Annual, 2009-2018 (971.64 KB)
- Secchi Disk Depth, Annual, 2009-2018 (970.88 KB)

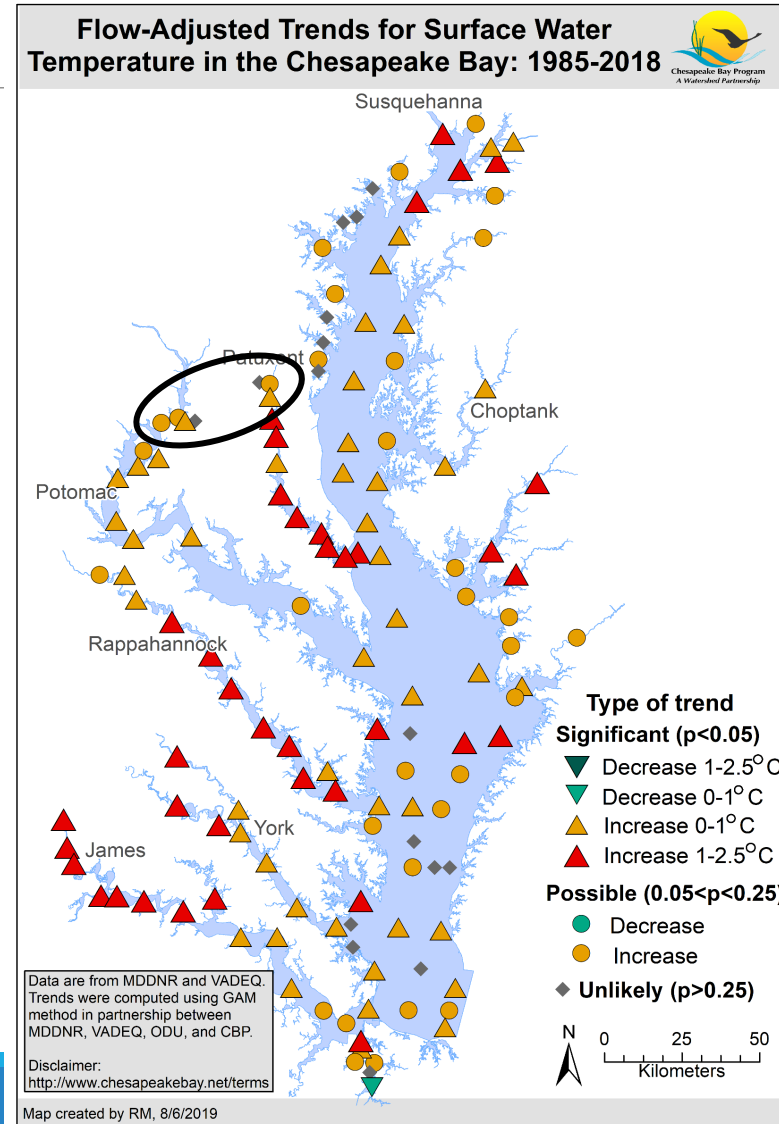
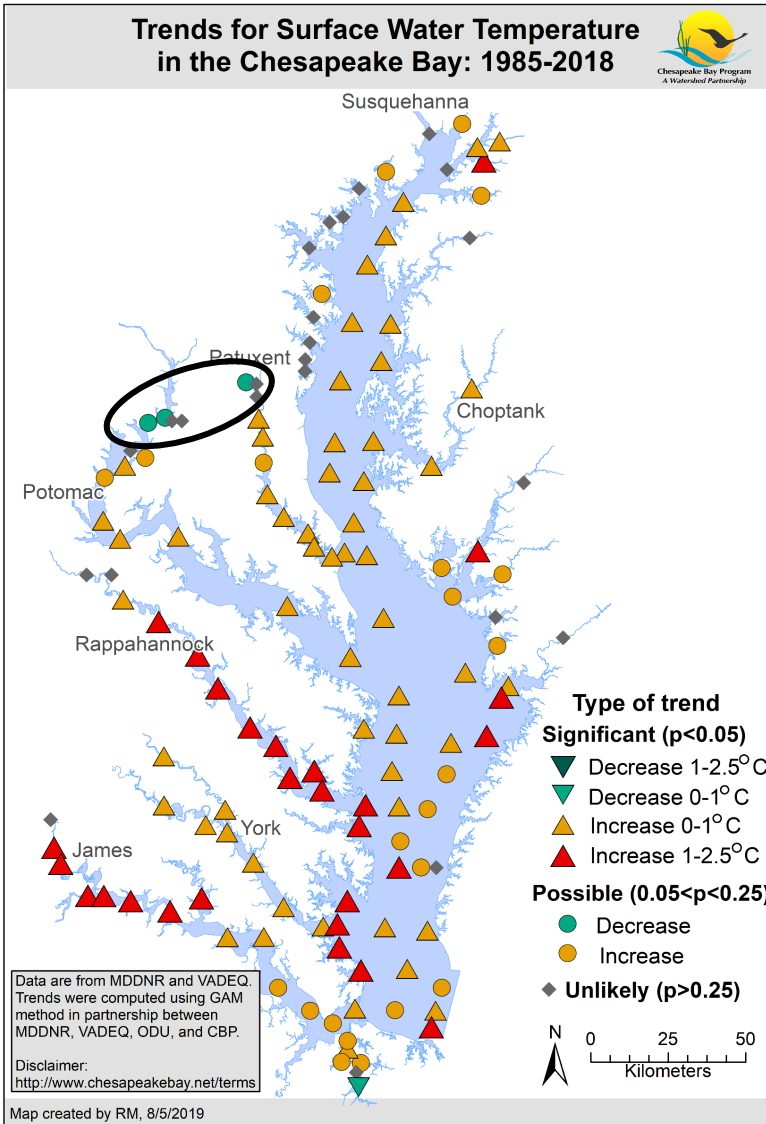
Can extract relevant info, such as:

1. Detailed graphics of the data, model, and computed change



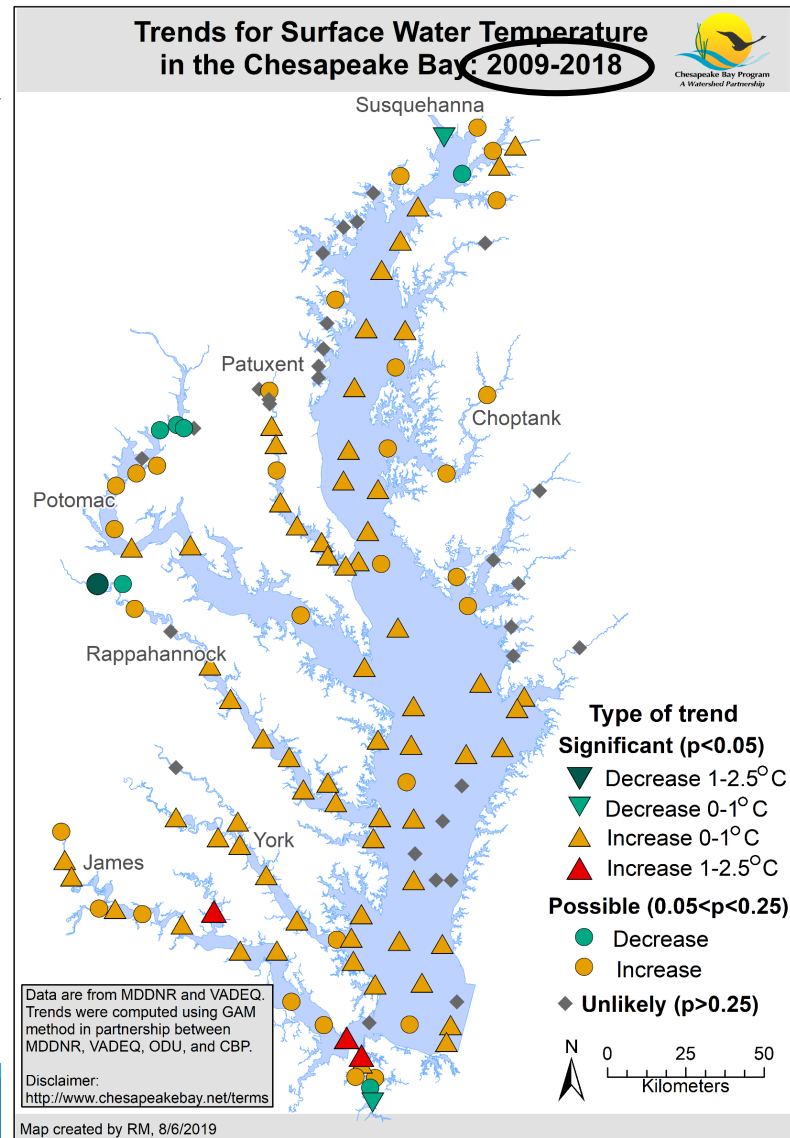
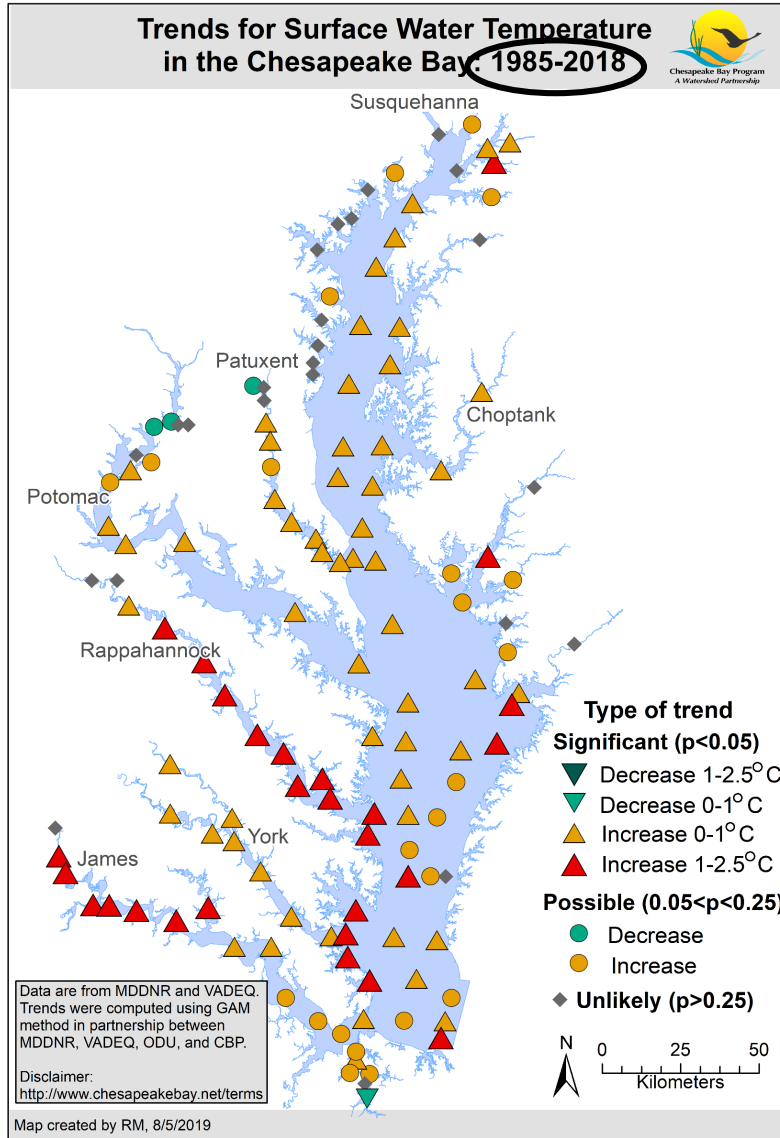
Can extract relevant info, such as:

2. Estimates of change after accounting for flow variability



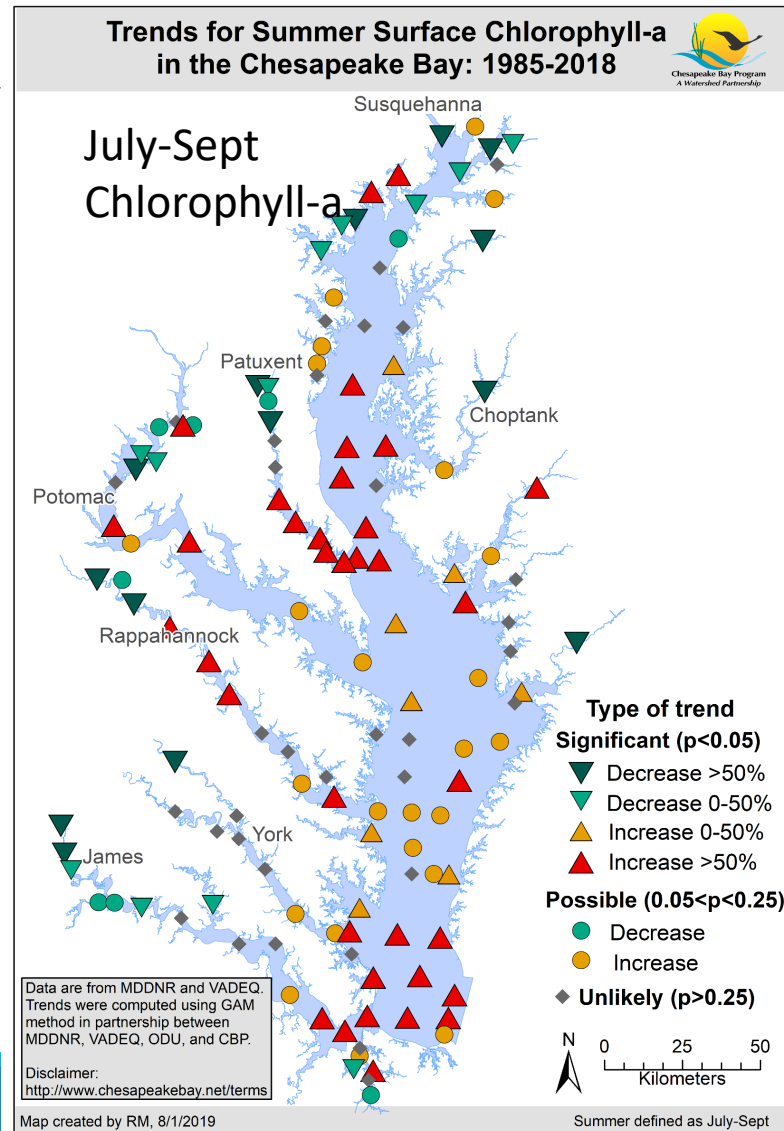
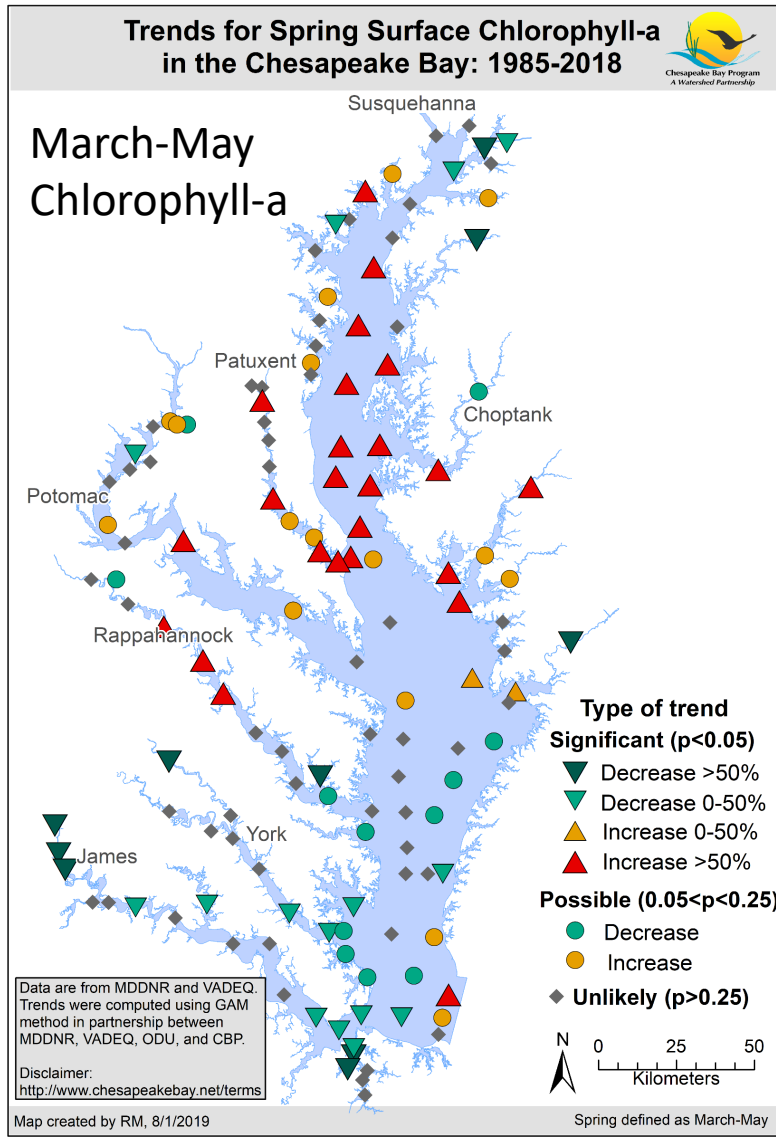
Can extract relevant info, such as:

3. Shorter-term changes



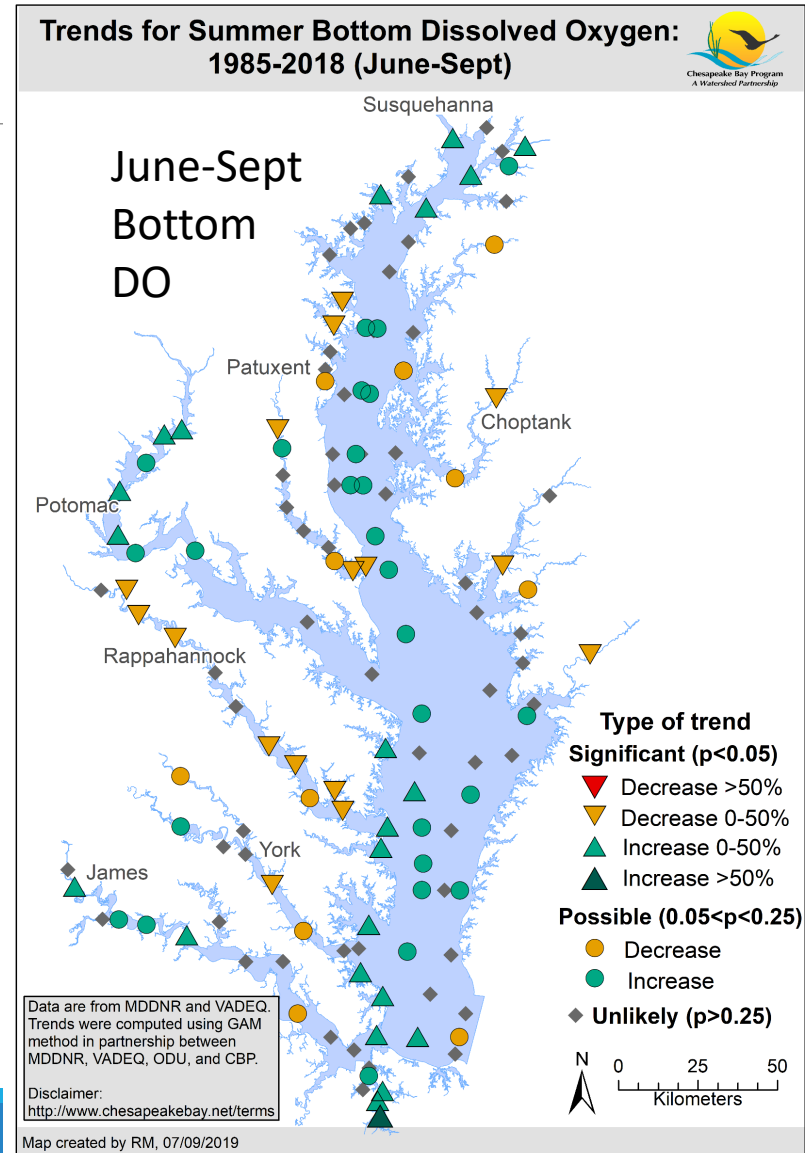
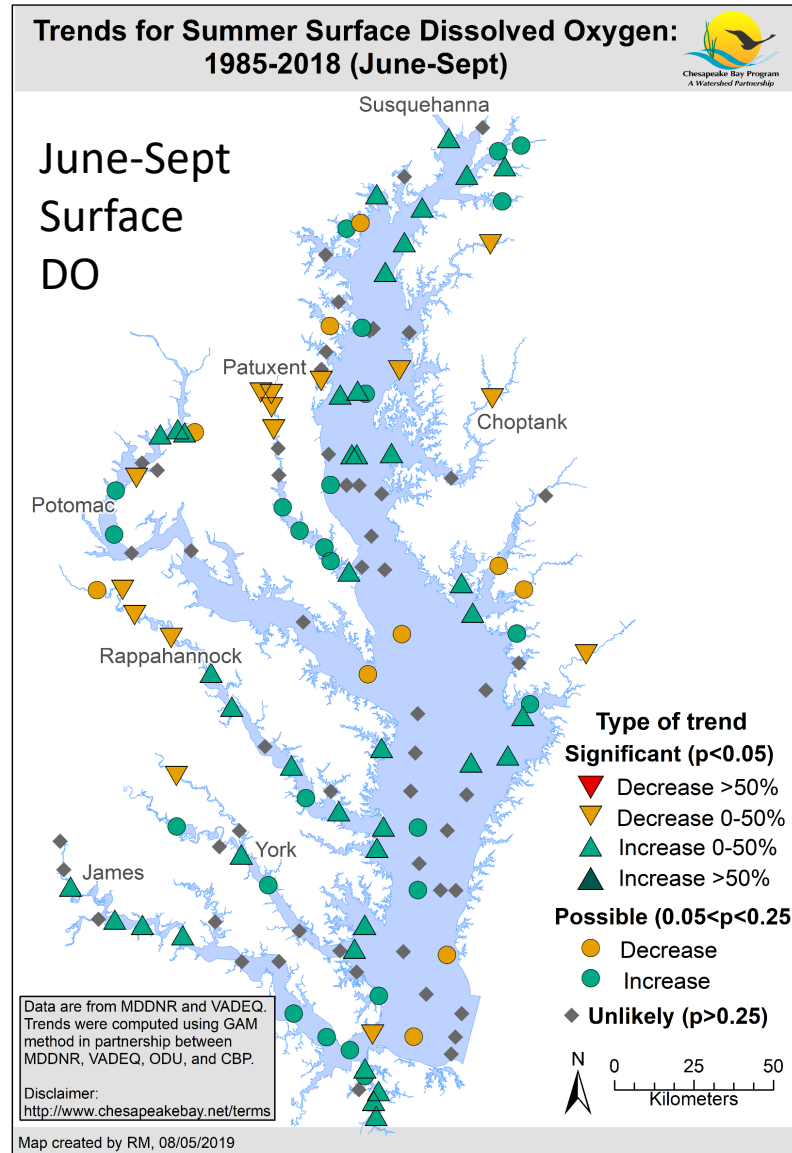
Can extract relevant info, such as:

4. Changes for certain seasons



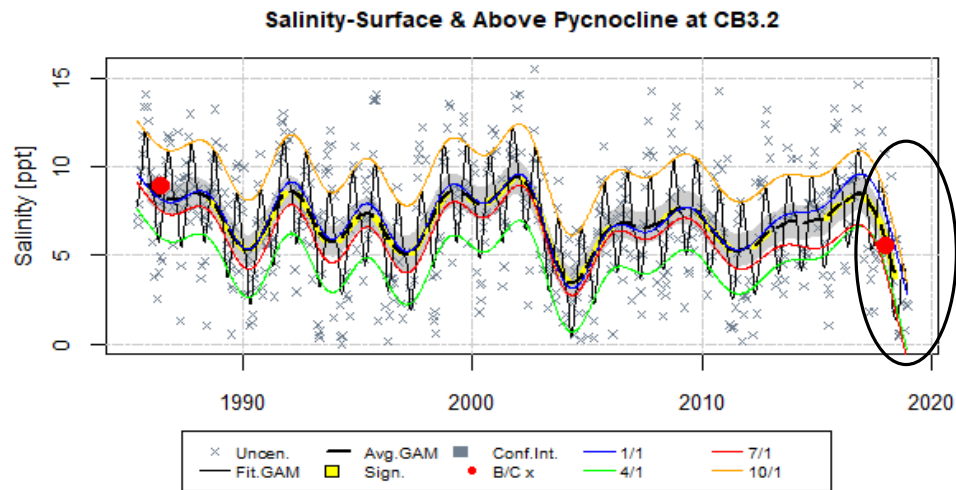
Can extract relevant info, such as:

5. Depth comparison



Can extract relevant info, such as:

6. Graphics to examine flow impacts on salinity



Summary

- Multiple trend analysis products might be of interest to climate resiliency: water temperature, DO, chlorophyll-a, other water quality variables
- Long-term trends are currently being computed through 2019 at MDDNR and ODU, they are submitted to CBP in the summer and combined into various products by the fall

https://www.chesapeakebay.net/who/group/integrated_trends_analysis_team

Tidal trends contributors:

- Jeni Keisman (USGS)
- Renee Karrh (MDDNR)
- Mike Lane (ODU)
- Elgin Perry
- Jon Harcum (Tetra Tech)
- Cindy Johnson and Amanda Shaver (VADEQ)

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