Baywide Trends: Linking estuarine nutrient concentrations to monitored river and point source inputs

For CBP Modeling Workgroup:

April 8, 2020

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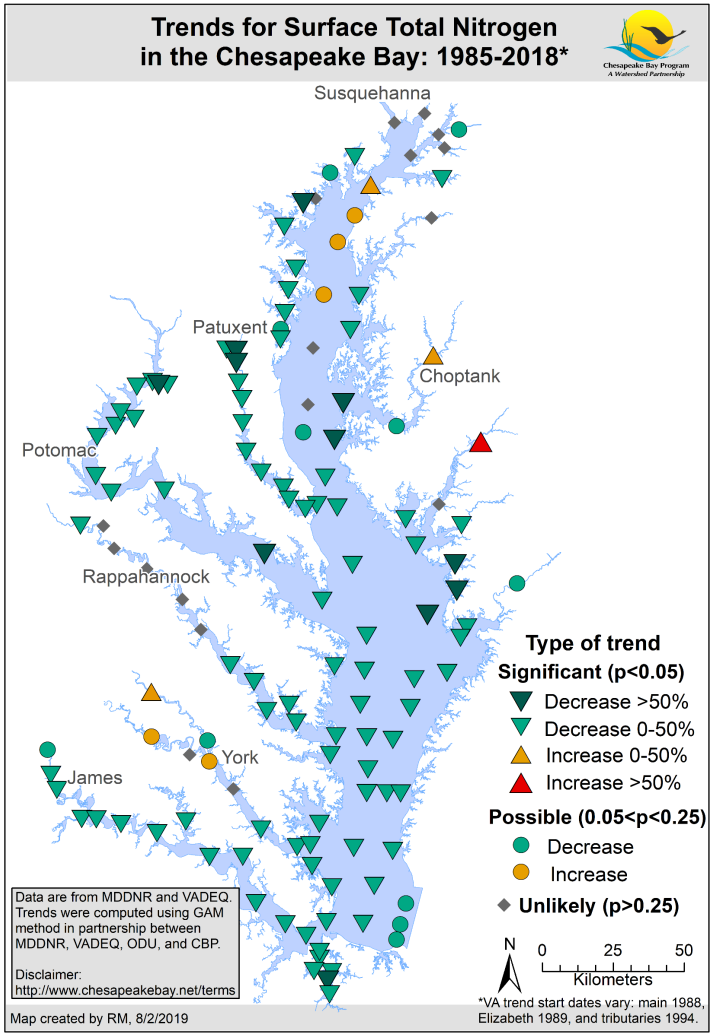
ITAT: What we do

- Work closely with state agency analysts to annually compute and report trends in observed tidal water quality at the 140+ long-term monitoring stations
- Work with collaborators across the CBP partnership, including the states, USGS, academic and research teams, and our consultants to:
  - Explain these trends and how they relate to water quality criteria status,
  - Link them to watershed inputs, and
  - Determine their impact on bay living resources.



http://www.chesapeakebay.net/groups/group/integrated_trends_analysis_team

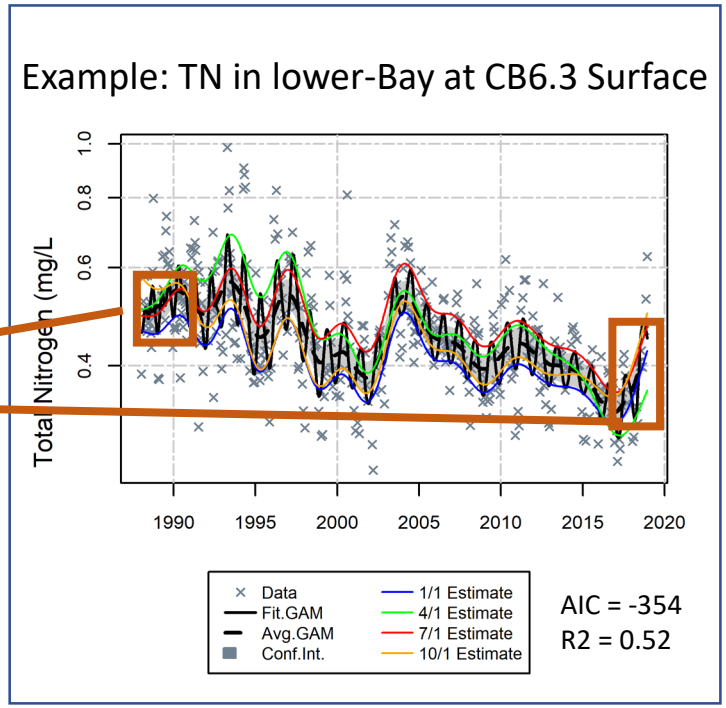
Outline for this study

- Part 1. Document the change in tidal surface TN and surface TP since the 1980s
- Part 2. Identify and process relevant monitored nutrient inputs to the tidal waters
- Part 3. Build statistical models to link/explain the tidal TN and TP concentrations with the river nutrient inputs and below-fall-line point source loads

Part 1: How we get bay-wide change

Water quality =
s(date) + s(day of year) + ti(date, doy)

change = -27%
p<0.001



Type of trend for annual surface TN

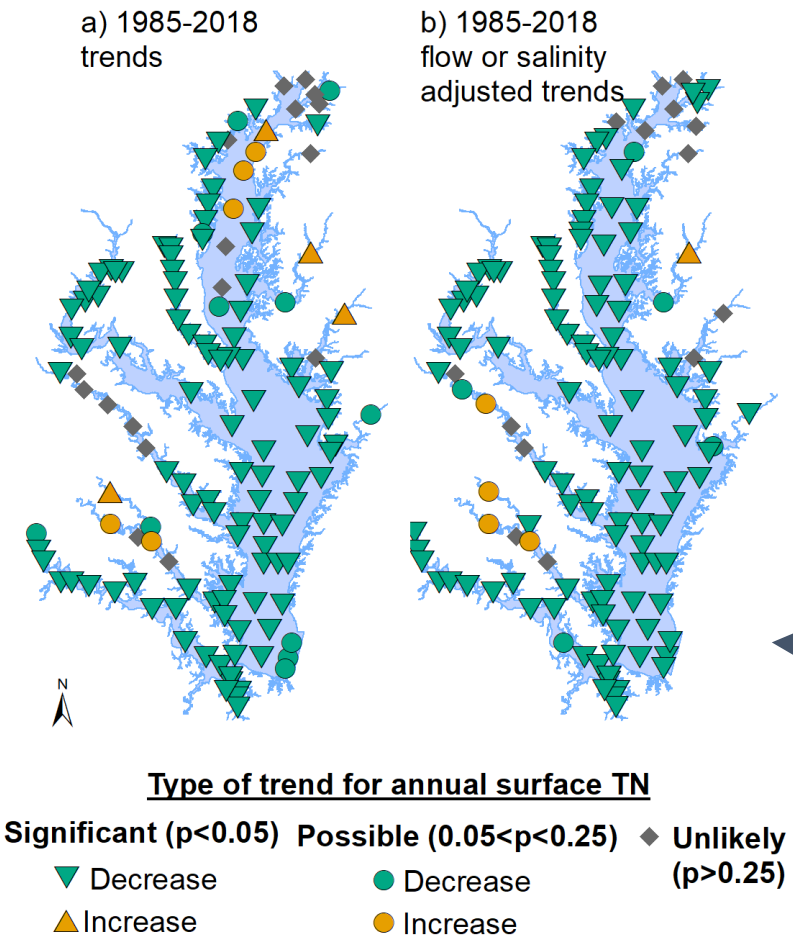
Significant (p<0.05)
Decrease
Increase

Possible (0.05<p<0.25)
Decrease
Increase

Unlikely (p>0.25)

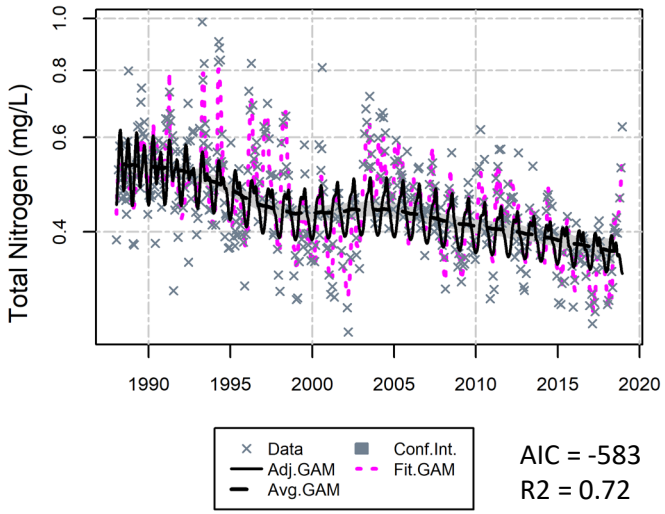
**start dates in VA are 1988 for mainstem, 1994 for tributaries*

Part 1: Add account for river flow



Water quality =
s(date) + s(day of year) + ti(date, doy)
+ s(measure of flow) + …
ti(flow, all date terms)

Example: TN in mid-Bay at CB6.3 Surface



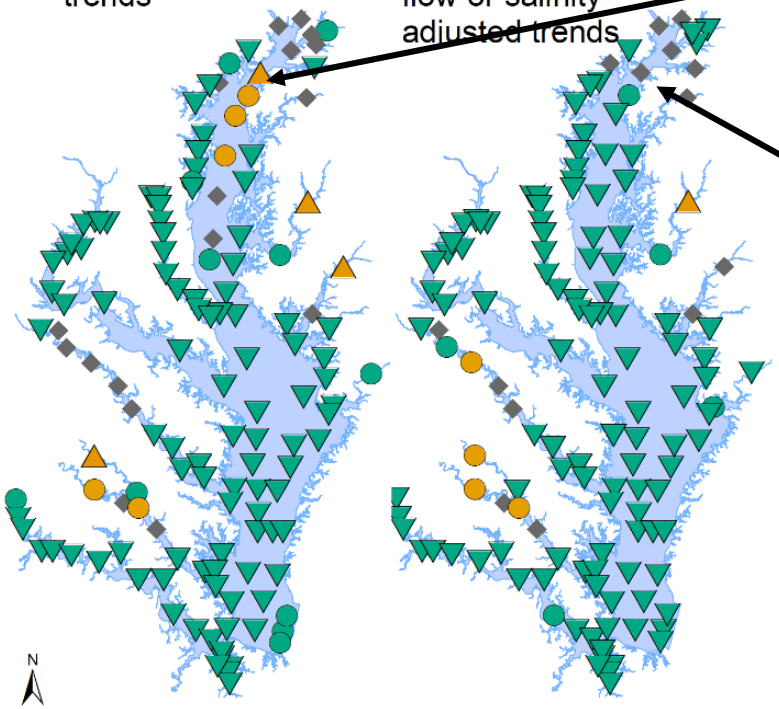
"Measure of flow" is either:

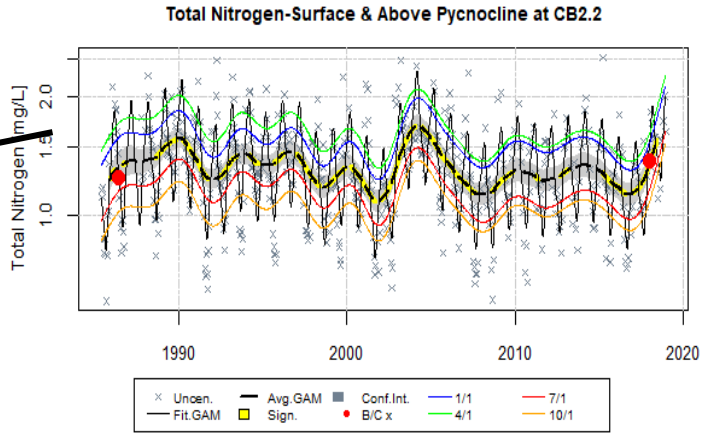
- Salinity at same place & time
- Pre-processed flow from a RIM station averaged over preceding n days (selected by correlation)

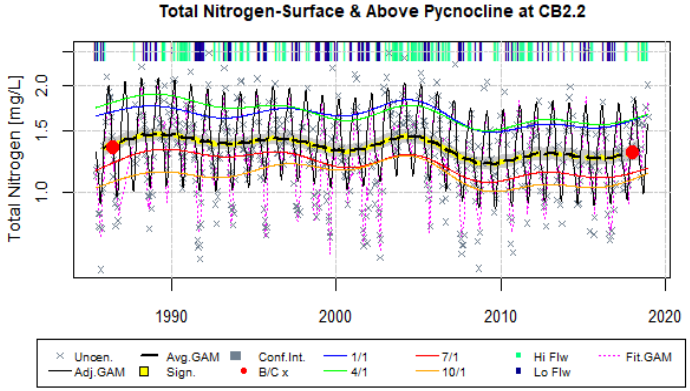
Long-term

a) 1985-2018 trends

b) 1985-2018 flow or salinity adjusted trends







Type of trend for annual surface TN

Significant (p<0.05)

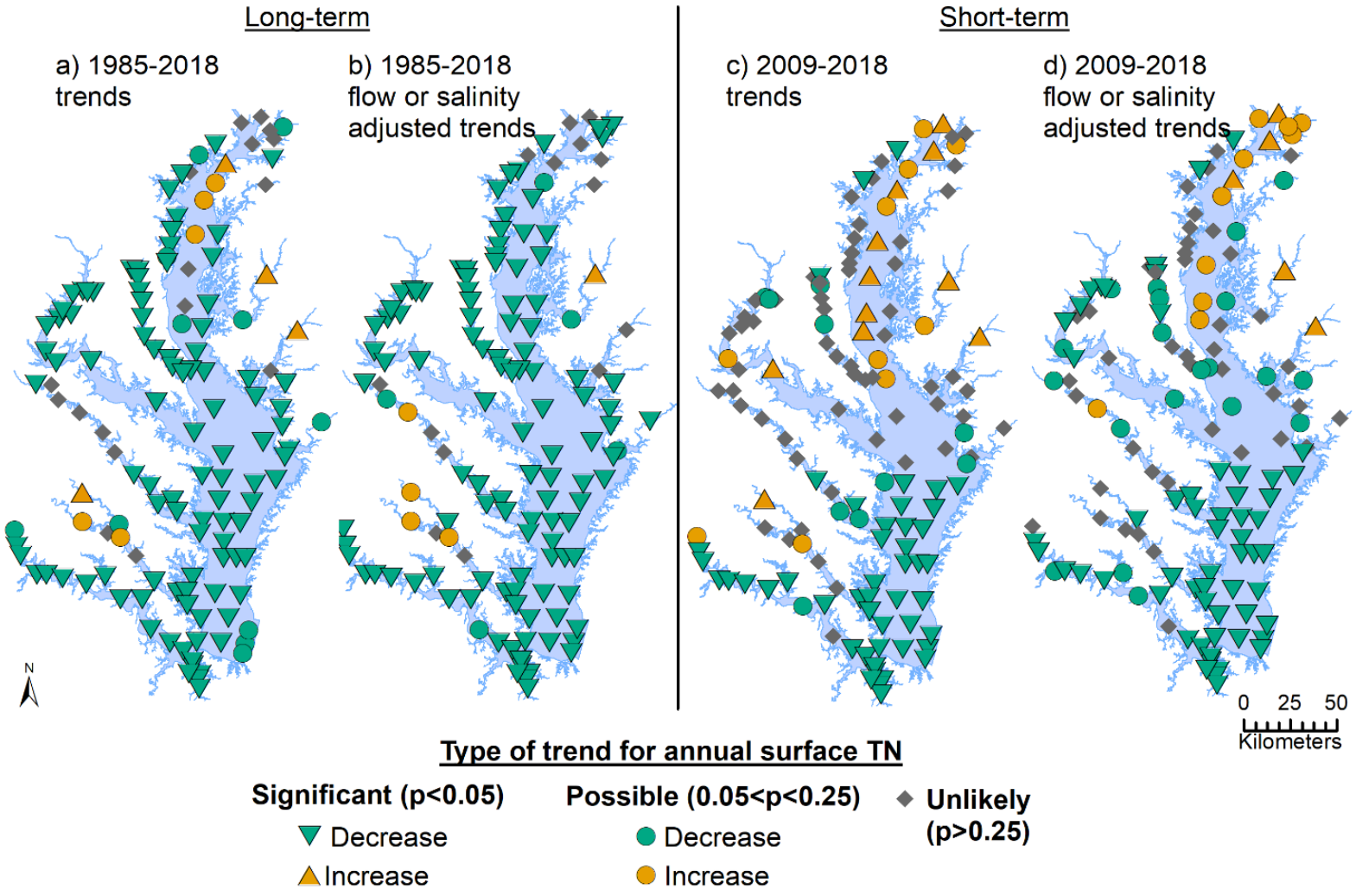
- Decrease
- Increase

Possible (0.05<p<0.25)

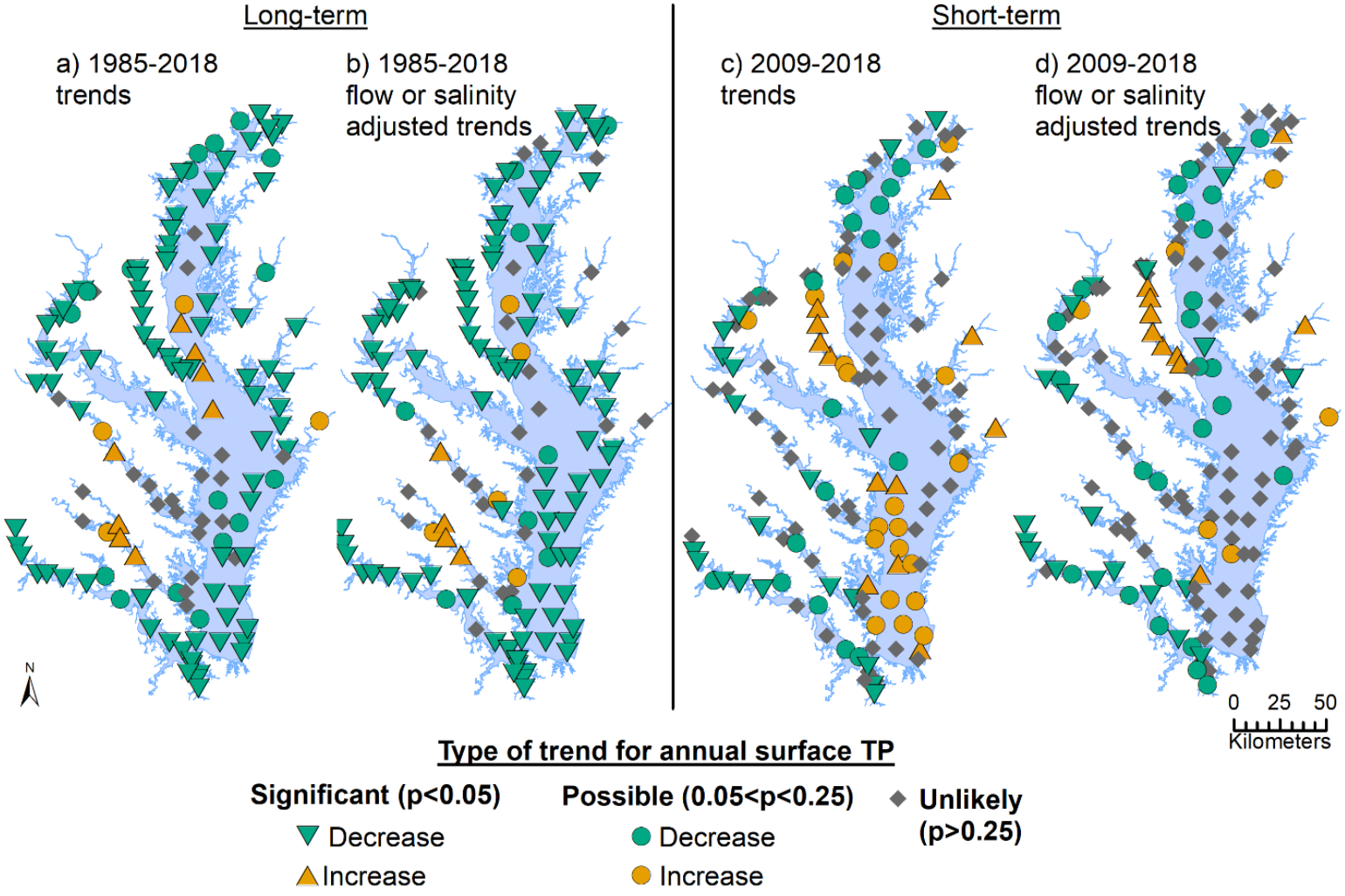
- Decrease
- Increase

Unlikely (p>0.25)

Part 1: Compare with recent TN change



Part 1: Comparable set for TP



Part 1. Summary of tidal nutrient patterns

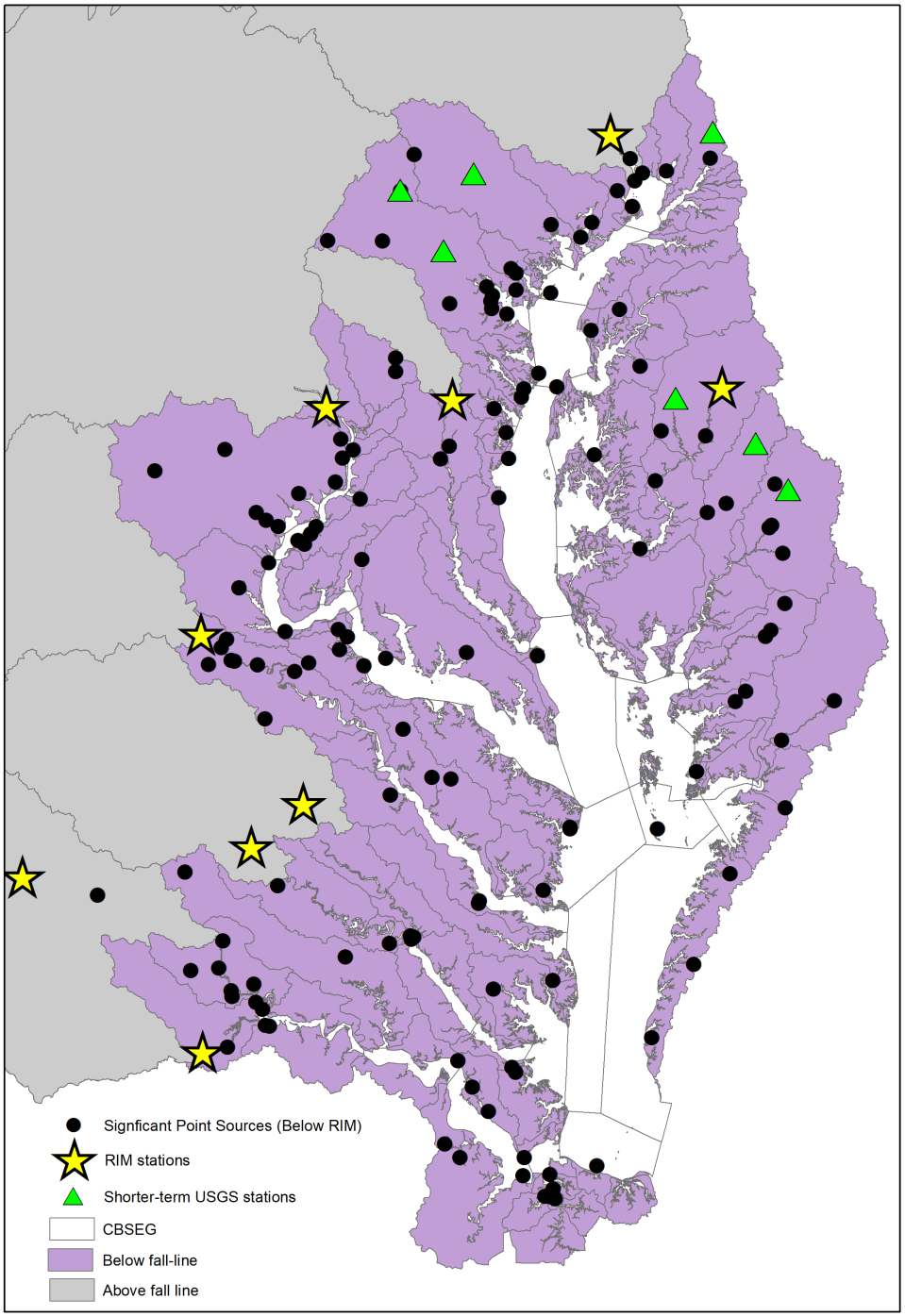
- The majority of the stations have significant long-term improvements. After flow adjustment:
  - 82% of the stations for TN
  - 68% of the stations for TP
- Over the short-term many patterns have leveled-out, and some locations stand-out as degrading:
  - TN: the upper mainstem and eastern shore tributaries
  - TP: Patuxent, lower mainstem and some eastern shore tributaries
- The York and Rappahannock River seems to have less consistent temporal patterns over space and time than the other major tributaries.

→ *We will aim to investigate these patterns, as well as others, with the watershed-link analysis*

Part 2. Identify and process relevant monitored nutrient inputs to the tidal waters

Part 2. Nutrient inputs used

- RIM stations – using monthly loads ★
- Also loads from shorter-term USGS NTN stations ▲
- Point source monthly loads – selected NPDES with discharges that were significant at any time in the record ●



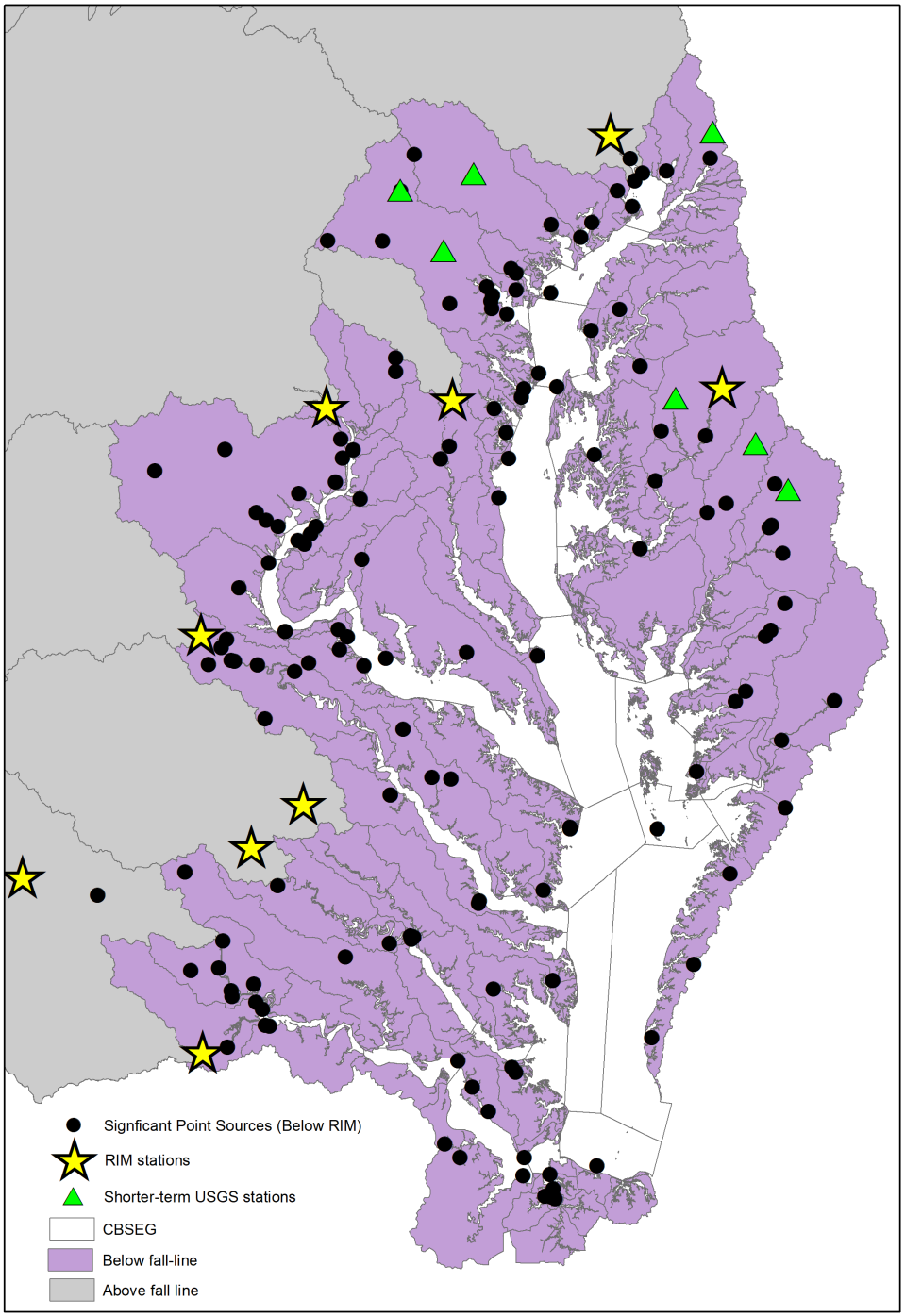
Thanks to Jess Rigelman and Doug Moyer for source data!

Part 2.
Some of the Considerations

a. Which loads to combine for each estuarine location?

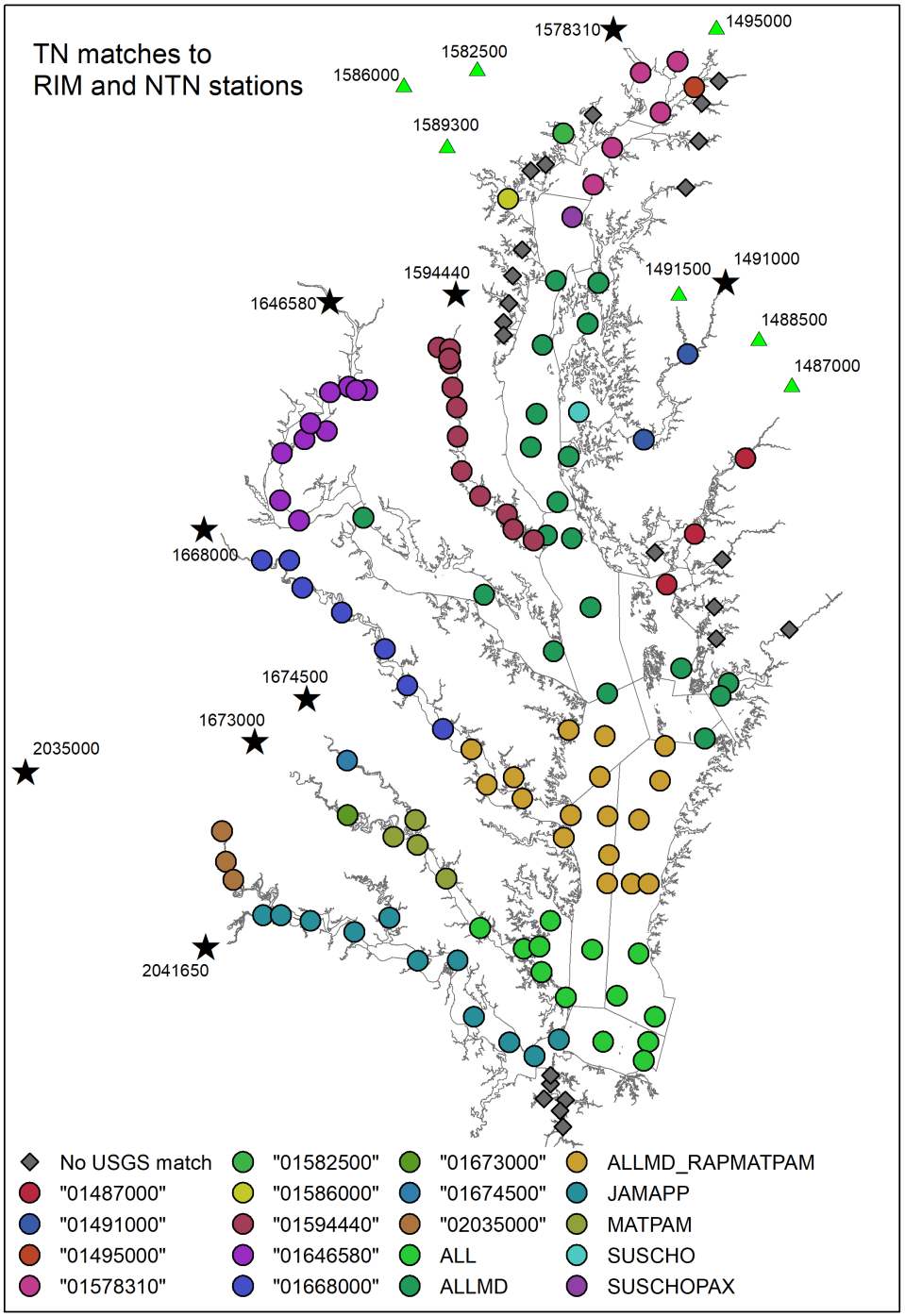
b. How long to lag/average the loads?

c. Will TN and TP links and lags be the same?



Part 2. River loads

- Computed combined tributary inputs where applicable by summing loads
- Tested multiple options and selected combined loads with most explanatory power & spatial consistency
- Averaging periods were also tested and selected in a similar way



Part 2. Point

- Point sources were matched to the land-river segment and then estuarine CBSEGs to which they drain. Point loads where then summed going down the major tributaries.
- Averaging periods were selected with a similar process to the river input loads

Example point sources linked to Patuxent segments

Segment with station	Linked point source segments
WBRTF	WBRTF
PAXTF	WBRTF
	PAXTF
PAXOH	WBRTF
	PAXTF
	PAXOH
PAXMH	WBRTF
	PAXTF
	PAXOH
	PAXMH
CB5MH_MD	Joined to all these, plus more

Part 3. Build statistical models to link/explain the tidal TN and TP concentrations with the river nutrient inputs and below-fall-line point source loads

Part 3. Statistical models

Remember our temporal trend model with flow

TN= s( ) + s(day of year) + ti(doy)
+ s(measure of flow) + … ti(flow, all terms)

New models

Model 1: Has no date term.

TN= s(day of year) + s(measure of flow) + ti(flow,doy)

Model 1 residuals: See if they are trending over time

Residuals1 = $\beta 0 + \beta 1(\text{date}) + \varepsilon$

Model 2: Add in the loads.

TN= **s(RiverLoad) + s(Pt)** + s(doy) + s(measure of flow) + ti(flow,doy)

Model 2 residuals: Did the loads explain the change over time?

Residuals2 = $\beta 0 + \beta 1(\text{date}) + \varepsilon$

Part 3. Example
TF1.6 Patuxent TN

Our temporal trend model with flow

TN= s(date) + s(doy) + ti(date,doy) + s(flw_sal) + ti(flw_sal,doy) + ti(flw_sal, date) + ti(flw_sal,doy,date)

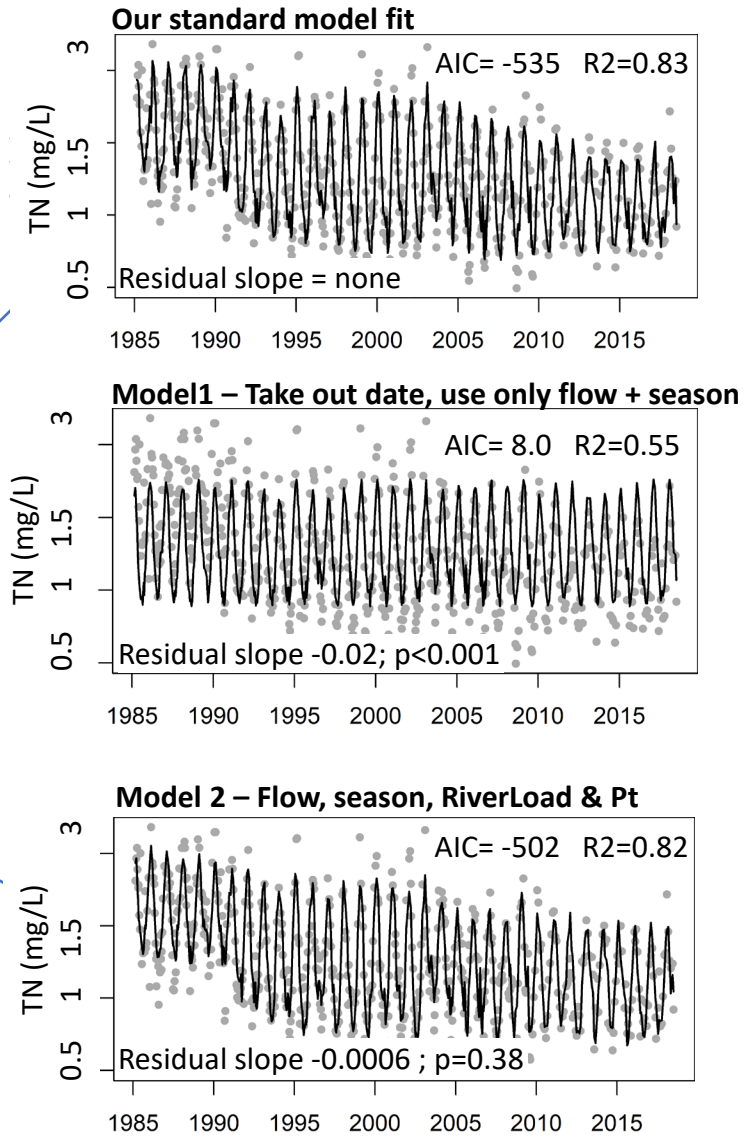
<u>New models</u>

Model 1:

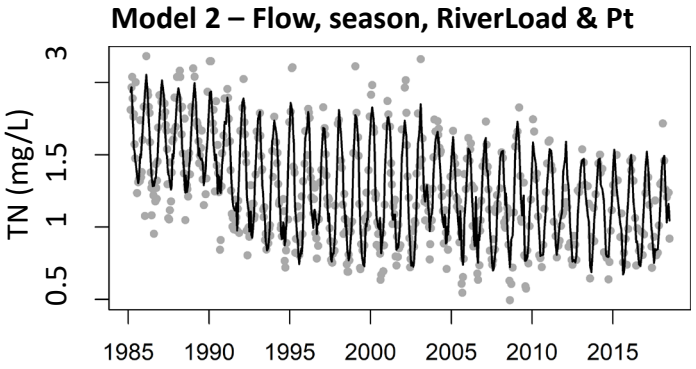
TN= s(doy) + s(flw_sal) + ti(flw_sal,doy)

Model 2:

TN= **s(RiverLoad) + s(Pt)** + s(doy) + s(flw_sal) + ti(flw_sal,doy)

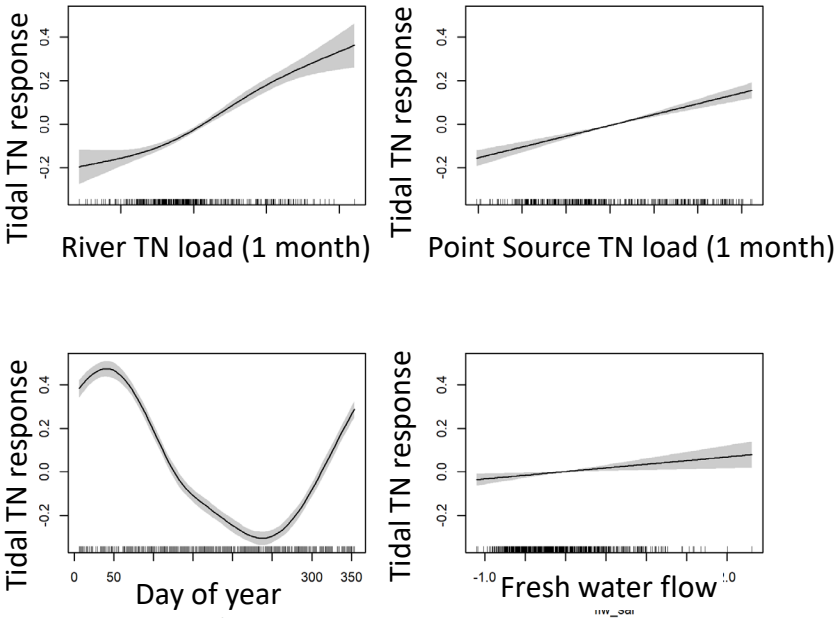


Part 3. Example
TF1.6 Patuxent TN



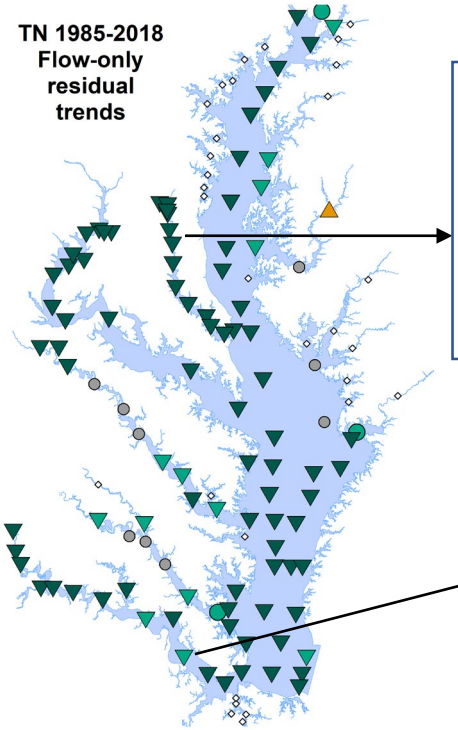
TN= **s(RiverLoad) + s(Pt)** + s(doy) + s(flw_sal) + ti(flw_sal,doy)

Examine the components of the GAM fit:



Currently: Finalizing models for all stations and summarizing bay-wide

- Is temporal change explained by monitored loads?
- Which loads explain more of the change (river or point)?
- How are TP and TN different?



No residual trend after combined model

No residual trend from river load-only model

Residual decrease after BFL point-only model

No residual trend after combined model

Possible remaining trend from river load-only mod

No residuals trend from point-only model

Summary/next steps

- In some places, trends will not be explained. Will discuss:
  - Uncertainties in approach
  - Below-fall-line non-point inputs
  - Atm deposition to tidal waters
  - In-estuary processing and removal
  - Inevitable differences between TN and TP
- Relevance to understanding chl-a, DO, criteria trends

Thank you!

- Renee Karrh (MDDNR), Mike Lane (ODU) for annual trends
- Jon Harcum and Erik Leppo (Tetra Tech) for baytrends package
- Elgin Perry for GAM implementation
- Doug Moyer (USGS) for preliminary NTN loads
- Jess Rigelman for compiling point source loads

- Questions? rmurphy@chesapeakebay.net