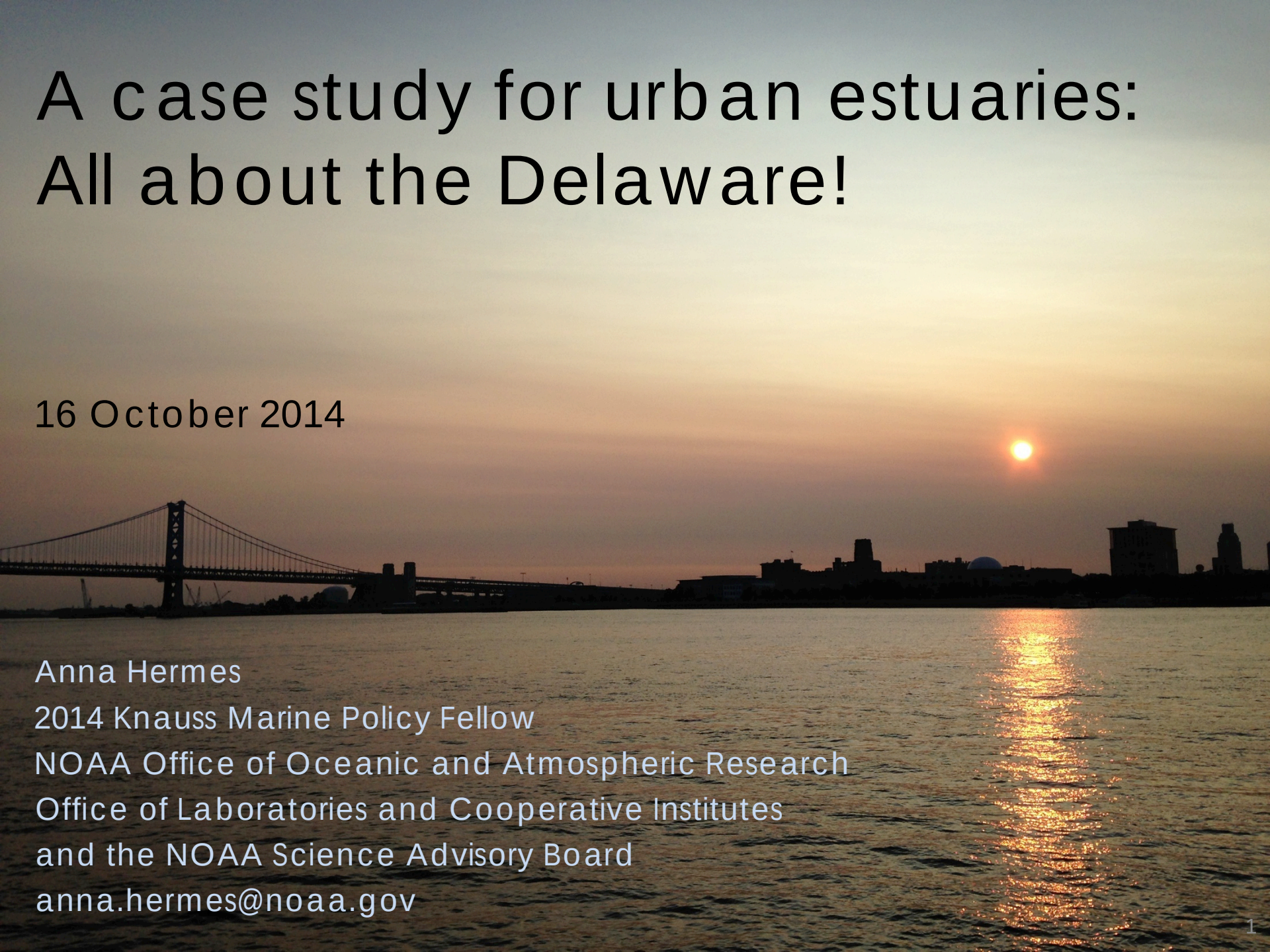
A case study for urban estuaries: All about the Delaware!

16 October 2014



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2014 Knauss Marine Policy Fellow
NOAA Office of Oceanic and Atmospheric Research
Office of Laboratories and Cooperative Institutes
and the NOAA Science Advisory Board
anna.hermes@noaa.gov

Outline

Why we care about estuaries

- The people reason
- The carbon reason
- Estuarine carbon cycling 101
- The Delaware: a model for both!

Sources of Organic Carbon in the Delaware Estuary

- Land-derived organic carbon (OC) is trapped where fresh and saltwater meet, particularly in bottom waters.
- Marsh-derived OC may be a significant proportion of the land-derived OC.
- Lateral circulation connects land, wetland, and sea.

Managing stormwater with *Green City, Clean Waters*

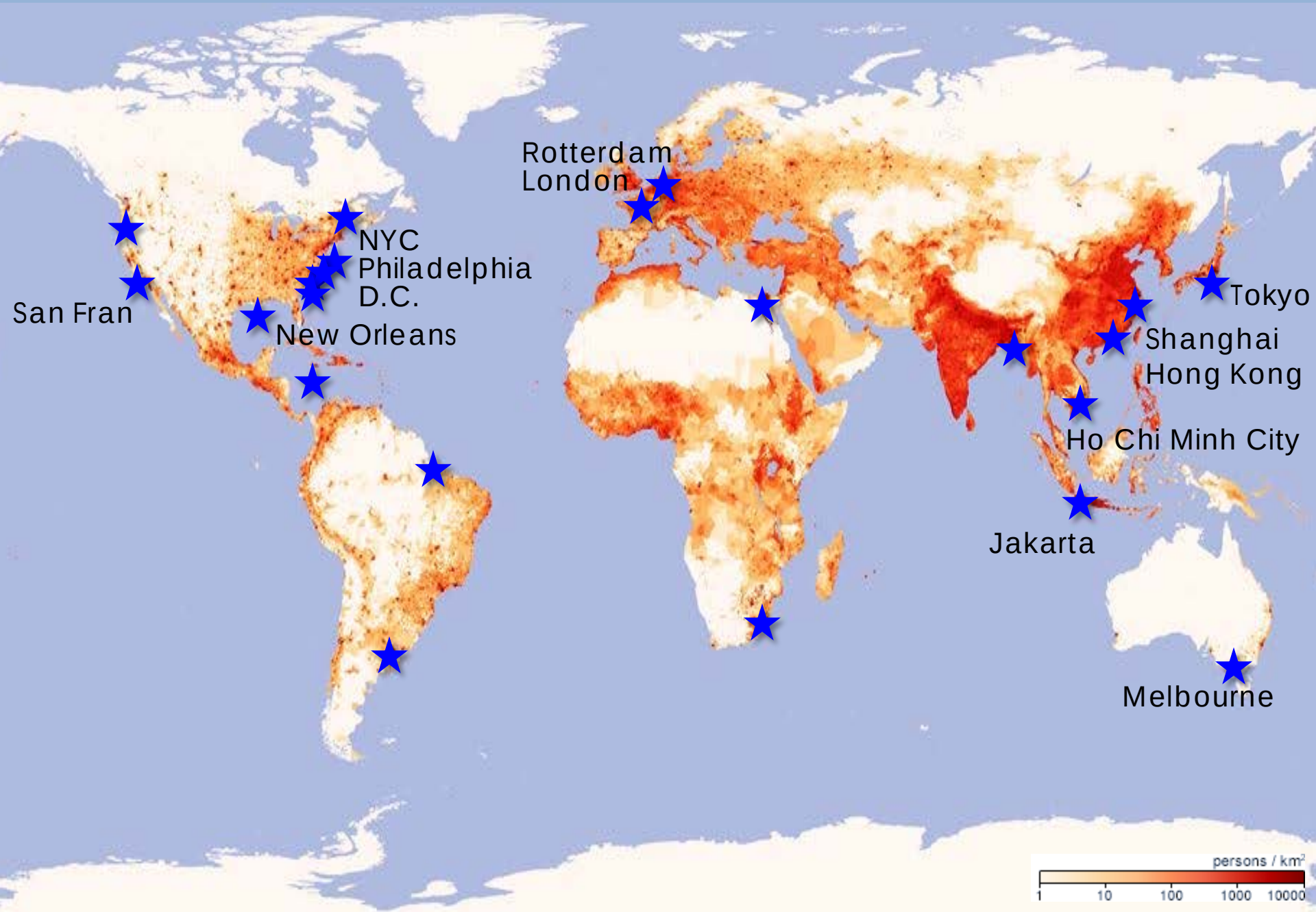
- The Philadelphia Water Department seeks to clean up its waterways with green infrastructure.

Reflections & Future Directions

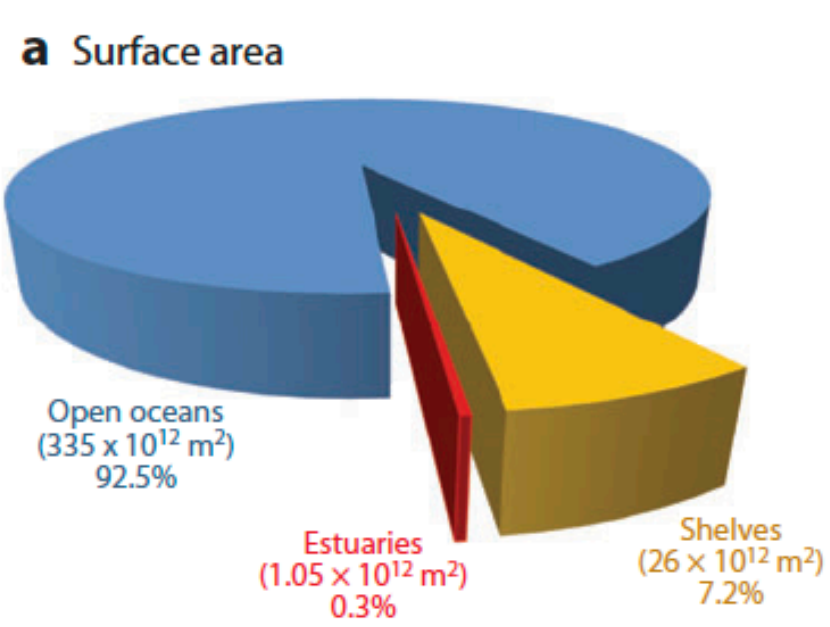
- Thoughts on coastal resilience

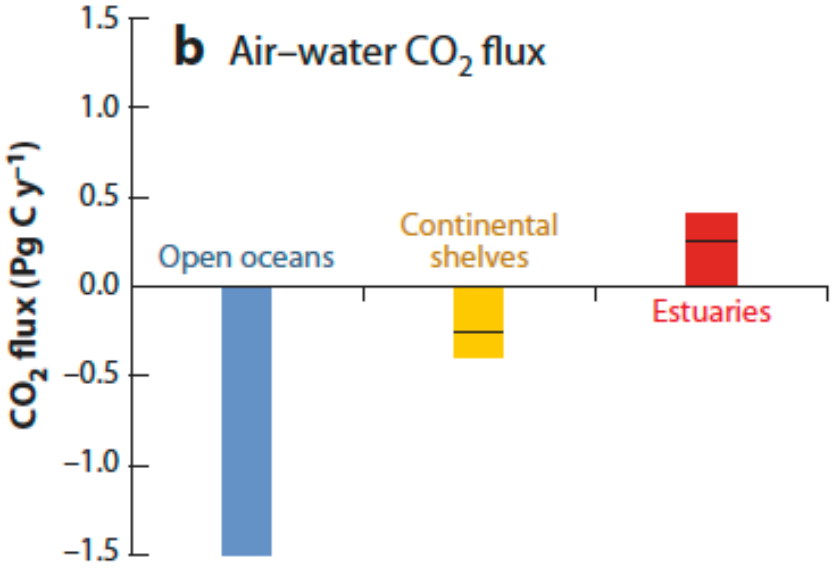

Aker Philadelphia Shipyard


NATIONAL GEOGRAPHIC



http://neo.sci.gsfc.nasa.gov/view.php?datasetId=SEDAC_POP (Nasa Earth Observations, 2000)





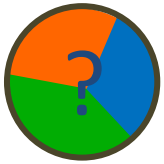
Cai, 2011, *Ann. Rev. in Mar. Sci.*; Bauer et al., 2013, *Nature*

Estuarine OC cycling links land and sea.

1. What are the sources of OC through the estuary?
2. How are these sources partitioned through estuarine physical, chemical, and biological gradients?
3. What are their fates?

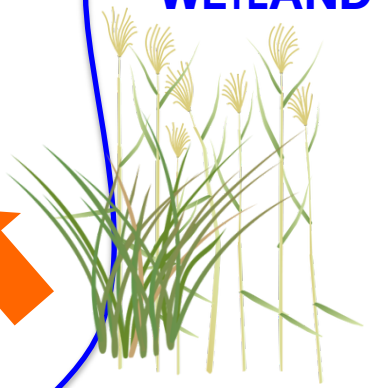
RIVER

POC



WETLANDS

OCEAN



Algal OC:
- **Brought in by tidal pumping**
- **Seasonally produced within the estuary**

Vascular plant (land) OC:
- **Terrestrial from the river**
- **Marsh from fringing wetlands**

E.g. Hedges et al., 1997; Bianchi, 2011, PNAS
Waves, wetlands, and tree from: ian.umces.edu/imagelibrary/

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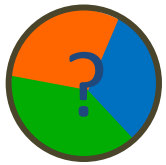


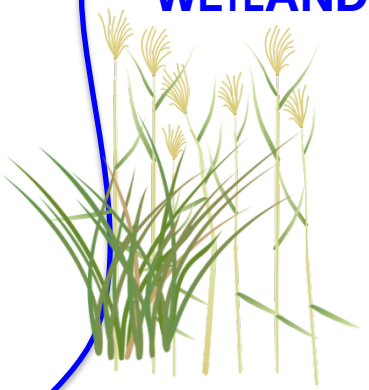
WETLANDS

OCEAN

Export

CO_2

Burial



Remineralization

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RIVER

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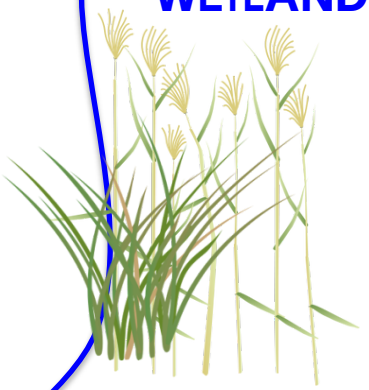
WETLANDS



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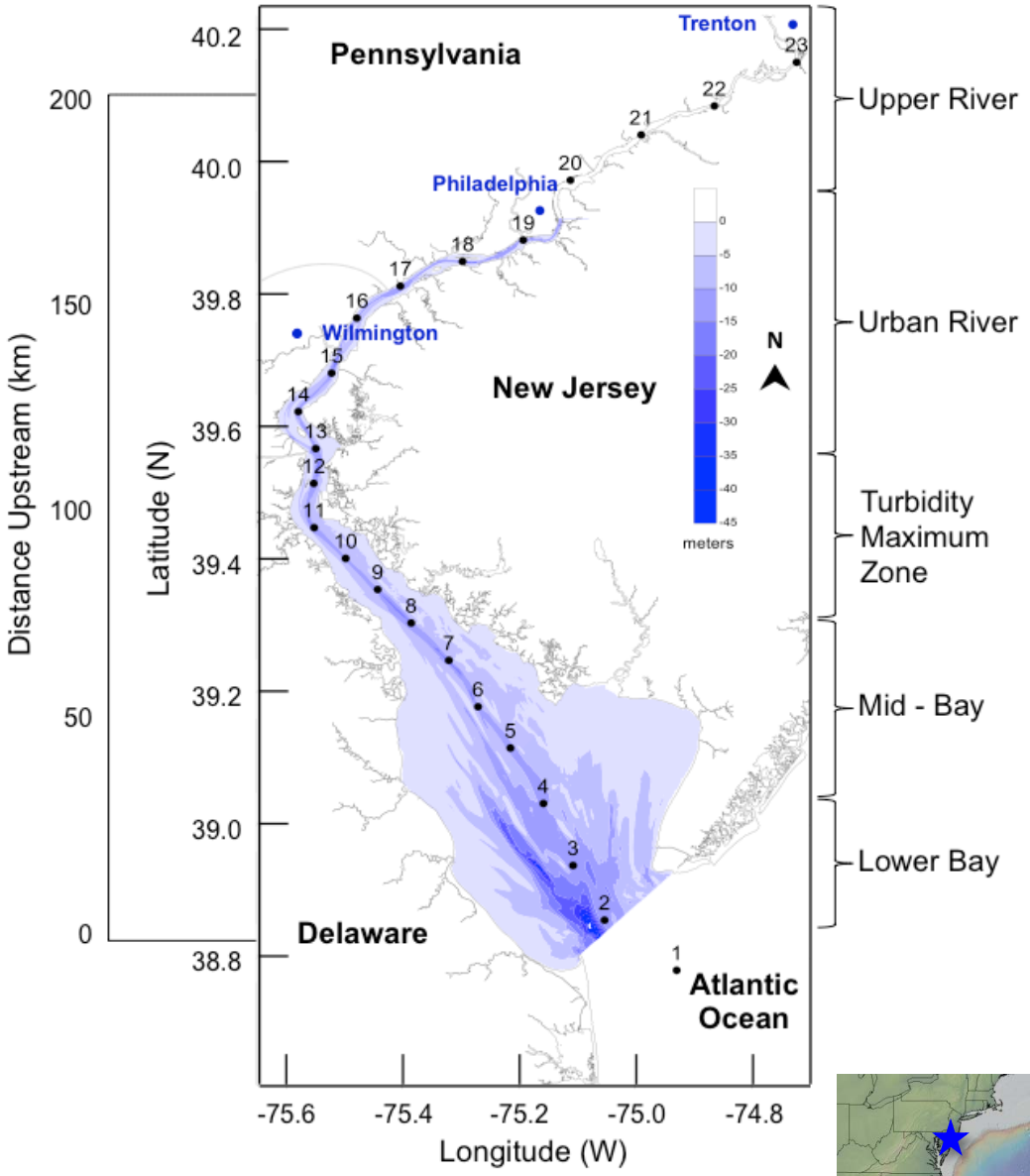
The Delaware Estuary:

A model urban system

- Largest freshwater port in the world (Wilmington, DE is the largest U.S. banana importing port), generating $19 B per yr (2005)
- Receives 70% of oil shipped to U.S. East Coast
- Provides drinking water for 15 million people
- Salem and Hope Creek nuclear power plants

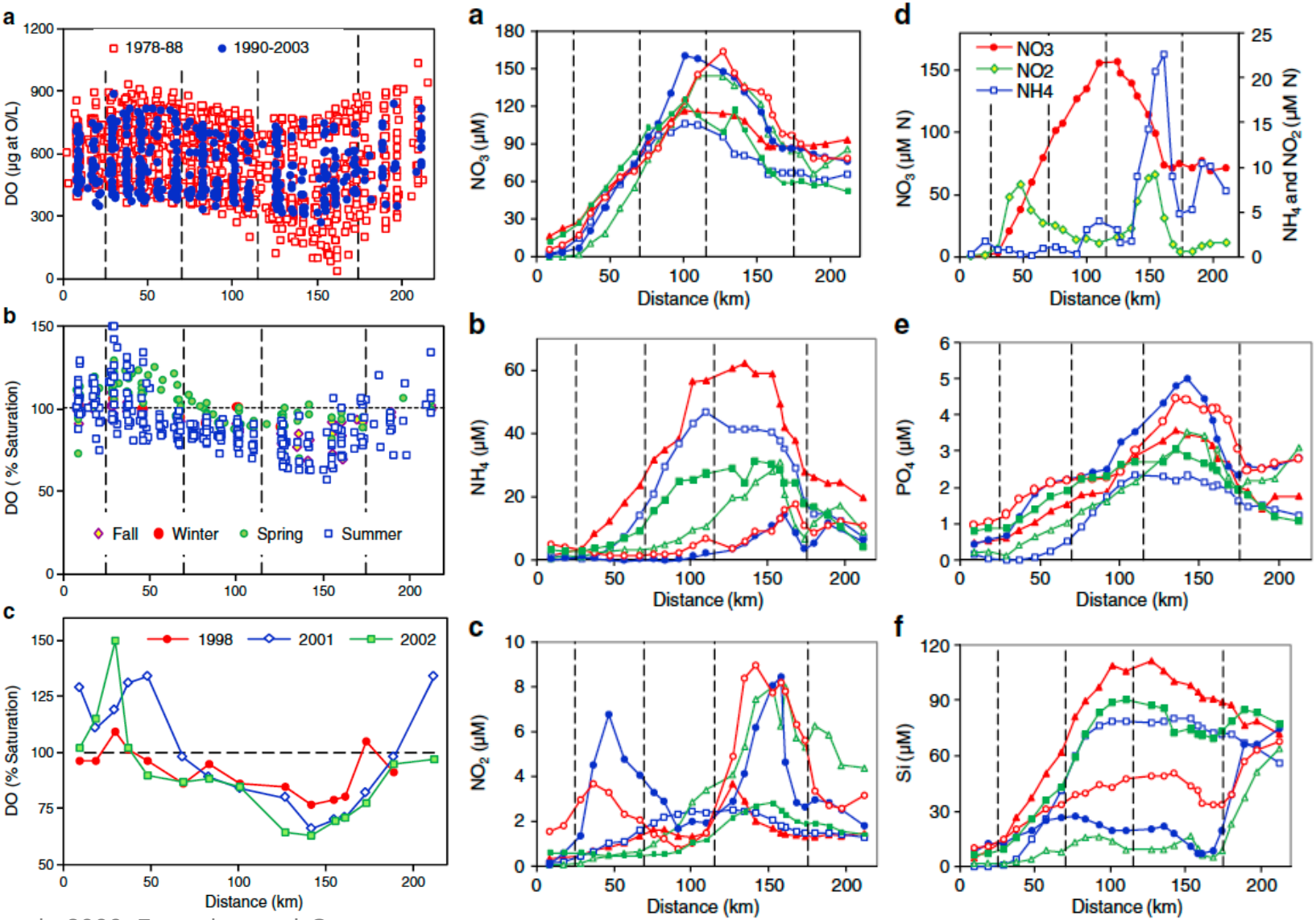


http://delawareestuary.org
http://www.state.nj.us/drbc/basin/

The Delaware Estuary:

A model study system

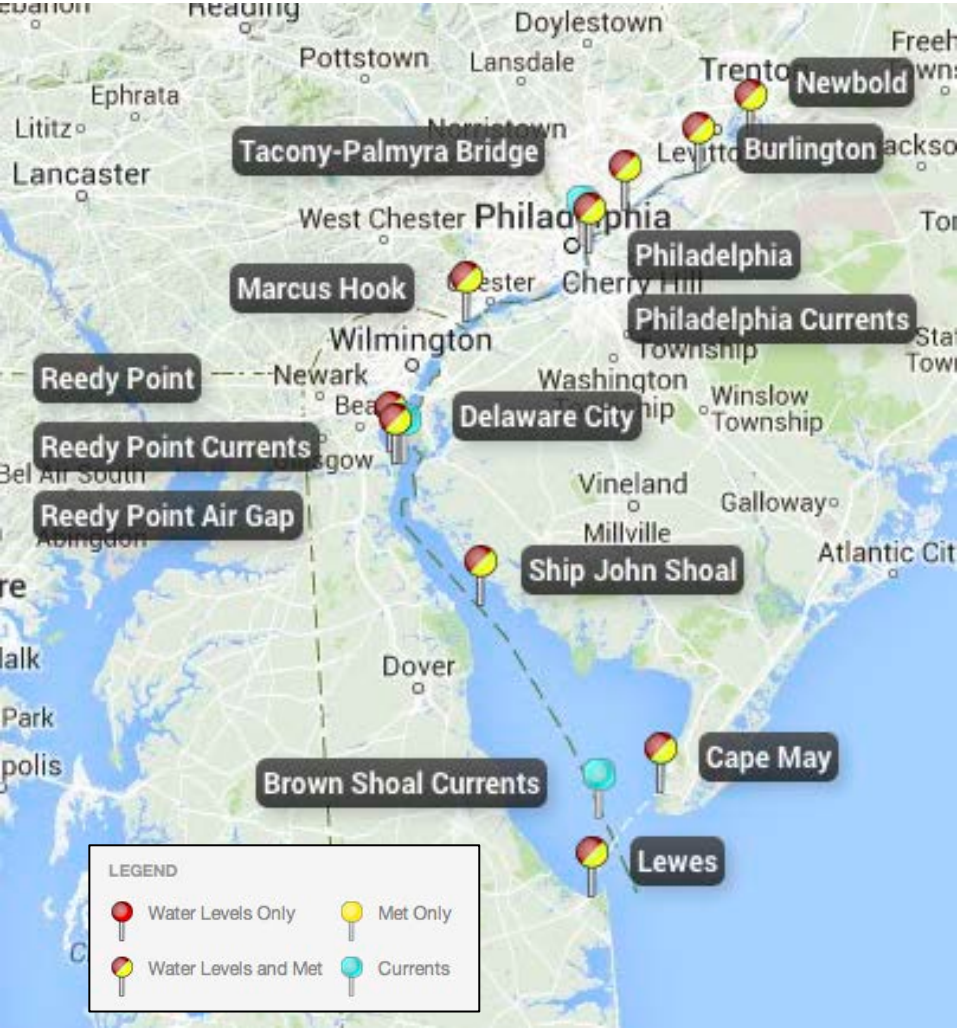
Long-term academic study



Sharp et al., 2009, Estuaries and Coasts

The Delaware Estuary: A model study system

NOAA PORTS, NOAA NDBC,
Delaware River Basin Commission Boat Runs



http://tidesandcurrents.noaa.gov/ports/index.html?port=db

http://www.state.nj.us/drbc/library/documents/BoatRun.pdf

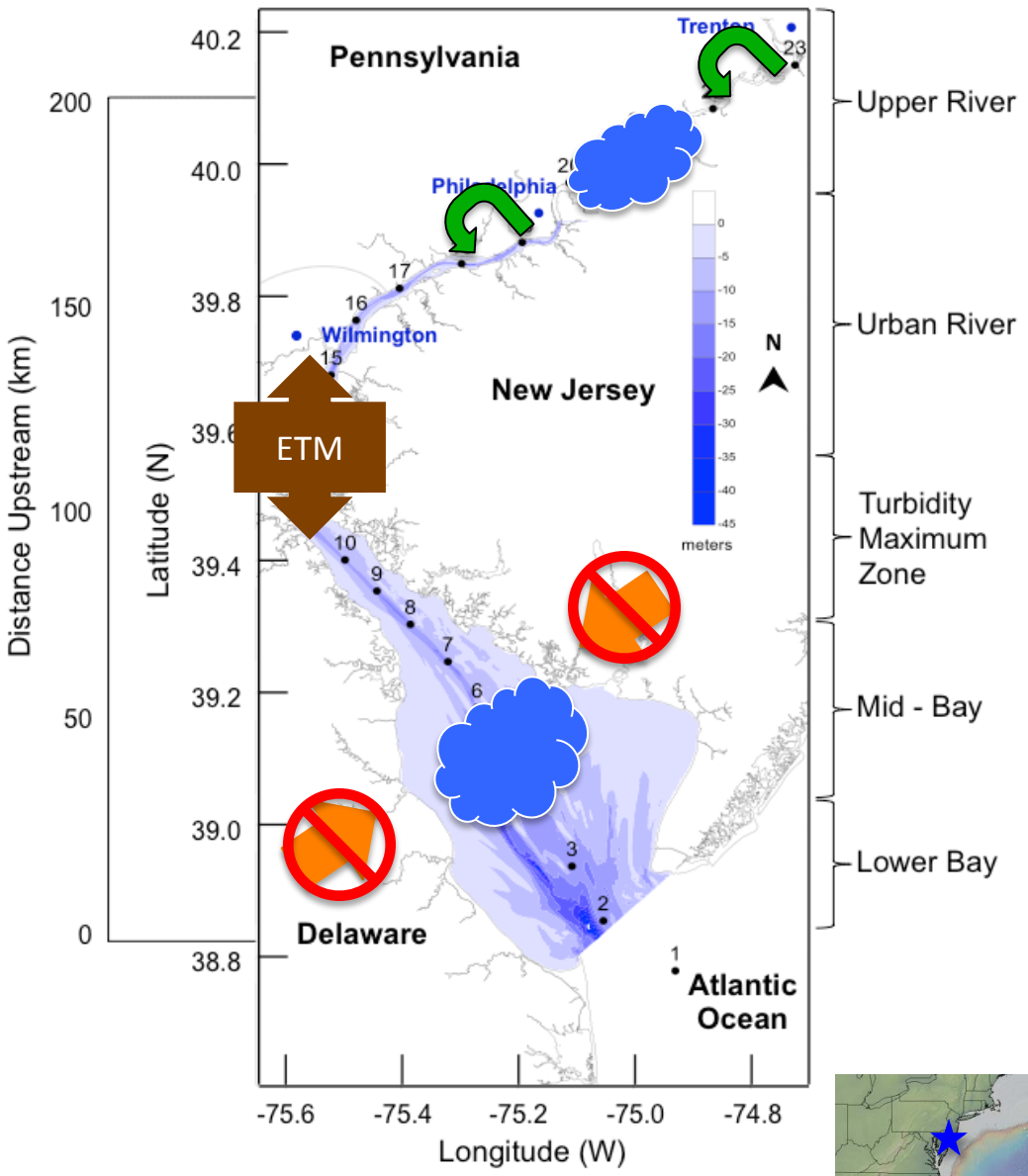
The Delaware Estuary:
A model study system

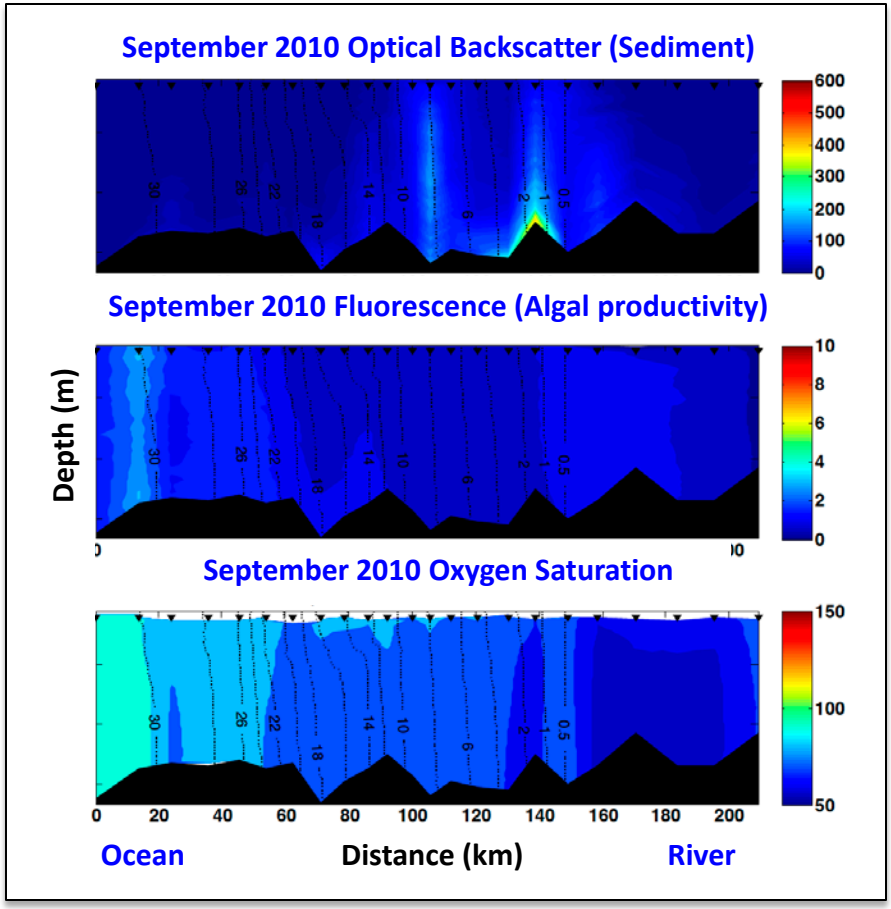
- Model coastal plain estuary: Delaware River is the primary source of freshwater, sediments, and **land-derived OC** *(e.g. Cook et al., 2007; Mannino and Harvey, 1999)*
- Seasonal **algal blooms** occur in Delaware Bay and the upper freshwater river *(e.g. Pennock and Sharp, 1986; Cifuentes et al., 1988)*.
- The **ETM** is a mud trap and mixing zone for OC ~100 km up-estuary *(e.g. Biggs et al., 1983; Sommerfield and Wong, 2011; Mannino and Harvey, 1999)*.
- **Marsh OC** is not significant in the Delaware Estuary *(e.g. Cifuentes, 1991; Mannino and Harvey, 1999).*

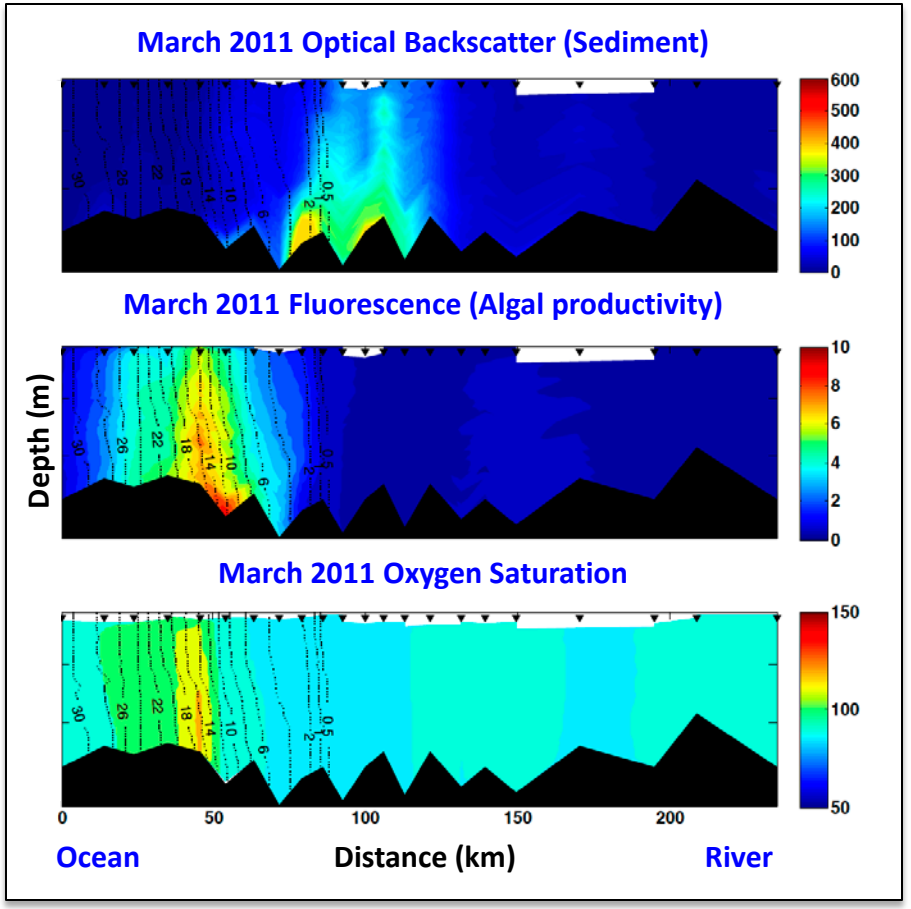
Mismatch between observed wetland erosion and geochemical analyses?

Previous work – Surface waters

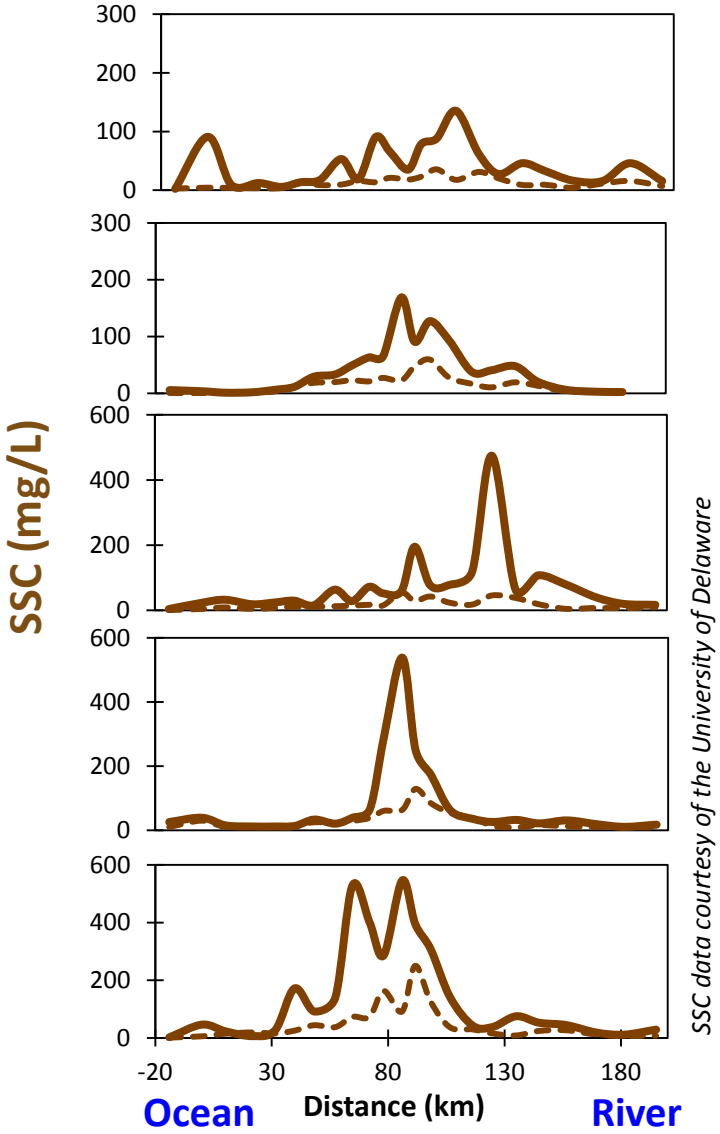
This work – Surface and Bottom waters

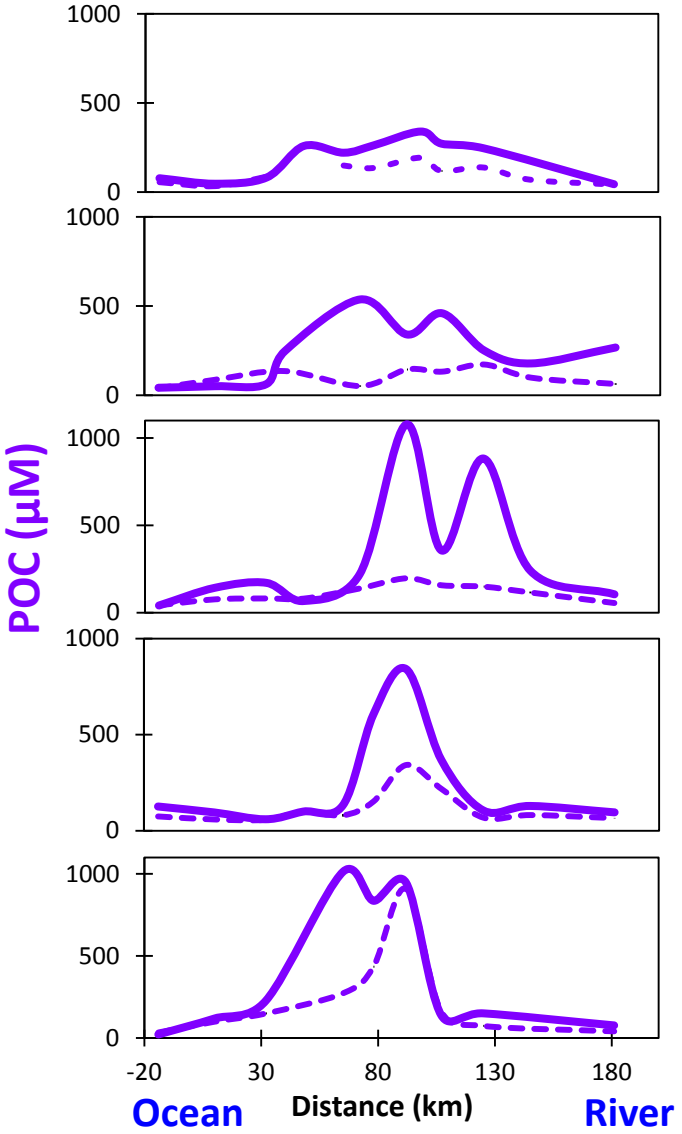






In situ physical and chemical measurements provided "snapshots" of the estuary for each cruise.
(It's fun working with physical and geological oceanographers!)



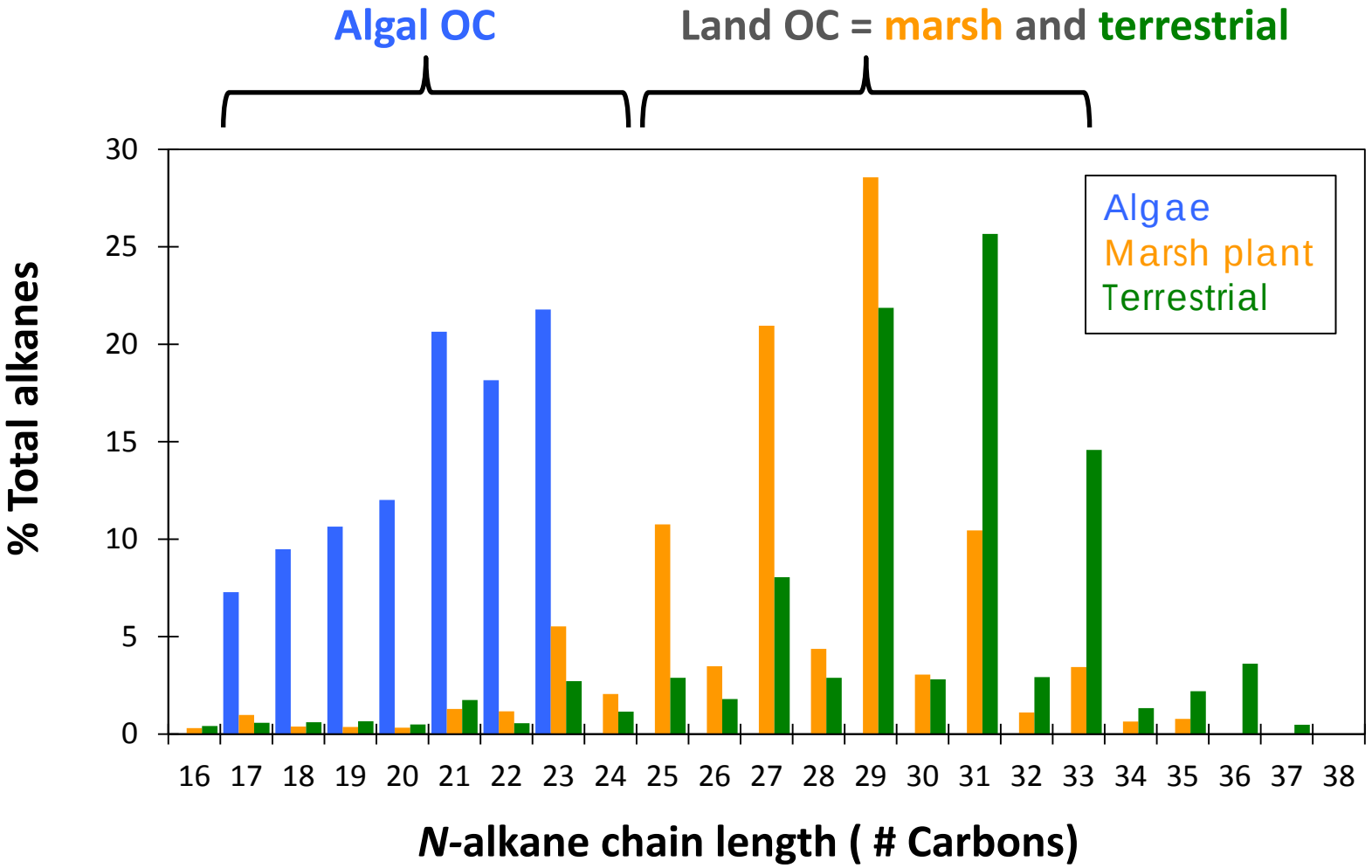


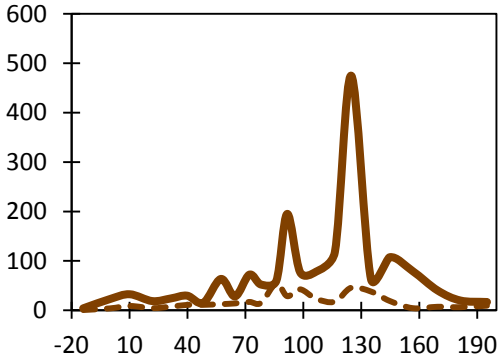
SW R^2 = 0.85
BW R^2 = 0.61

------ Surface water
——— Bottom water

SW R^2 = 0.92
BW R^2 = 0.80

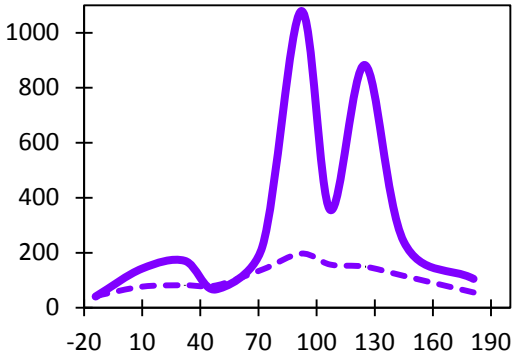
Nonacosane (C_{29}), Eglinton and Hamilton, *Science,* 1967



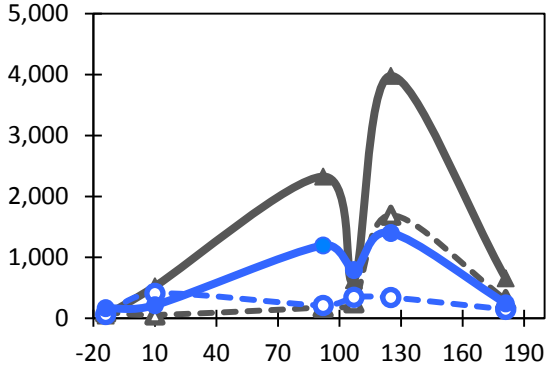


SSC (mg/L)

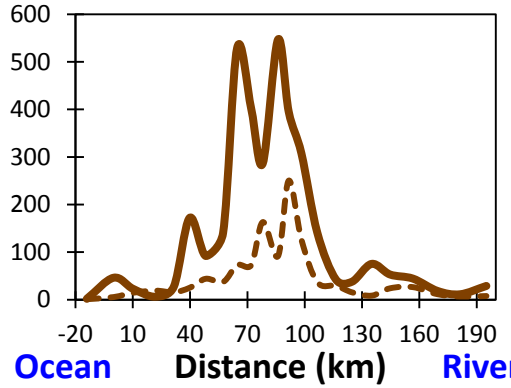
S'10



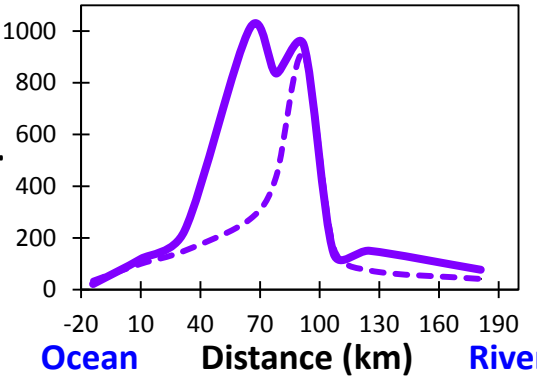
POC (µM)

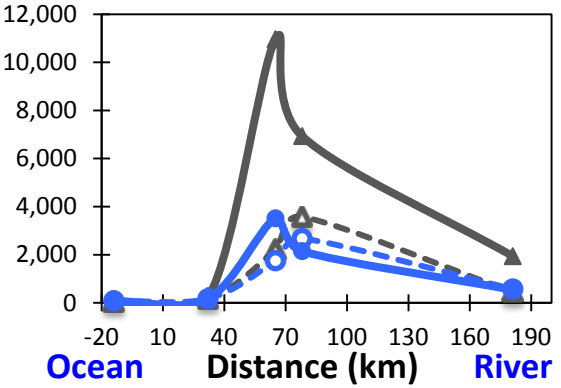


Alkane abundance (ng/L)



M'11





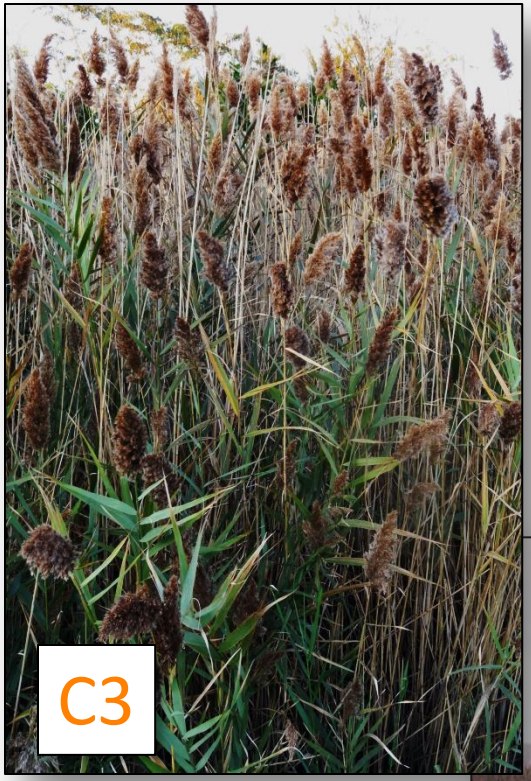
SSC data courtesy of the University of Delaware

------ **Surface water**

Bottom water

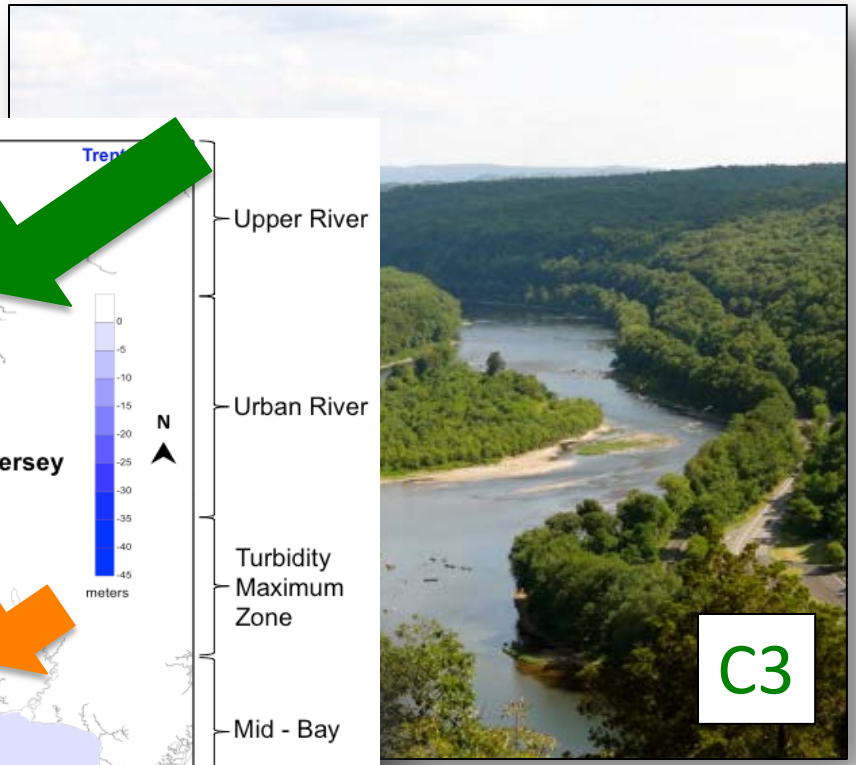
Algal OC

Land OC = marsh & terrestrial

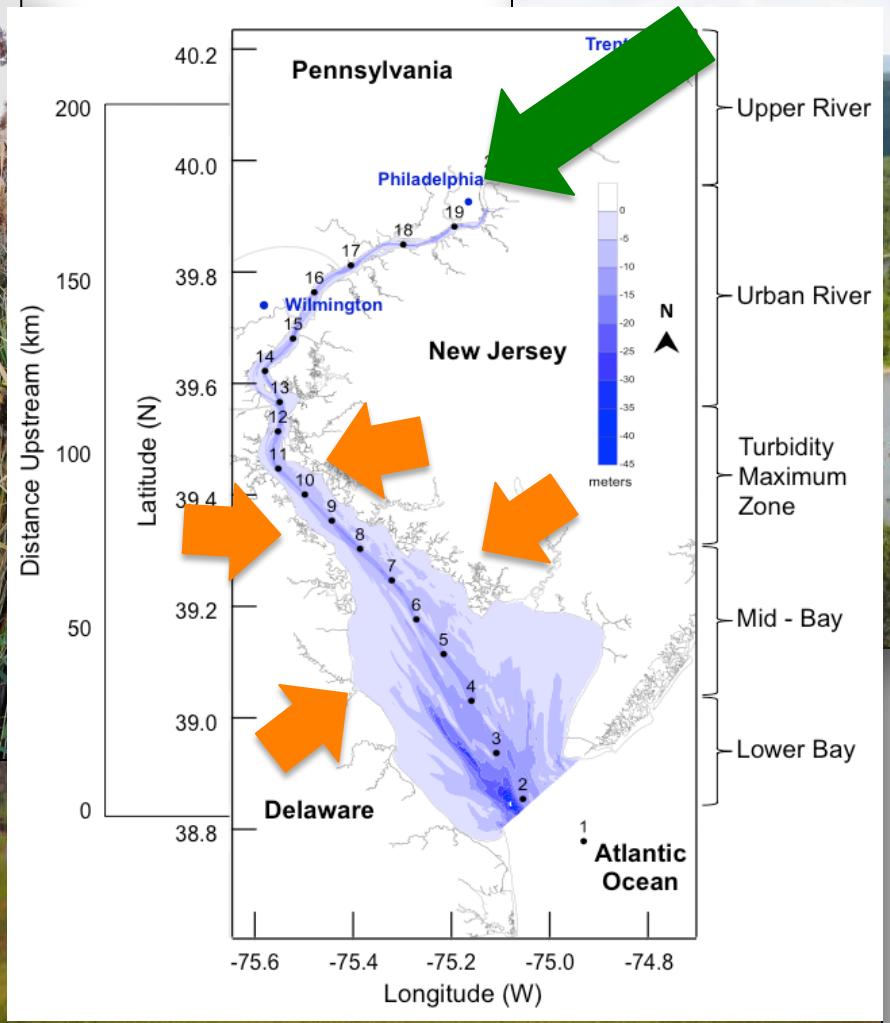


Terrestrial

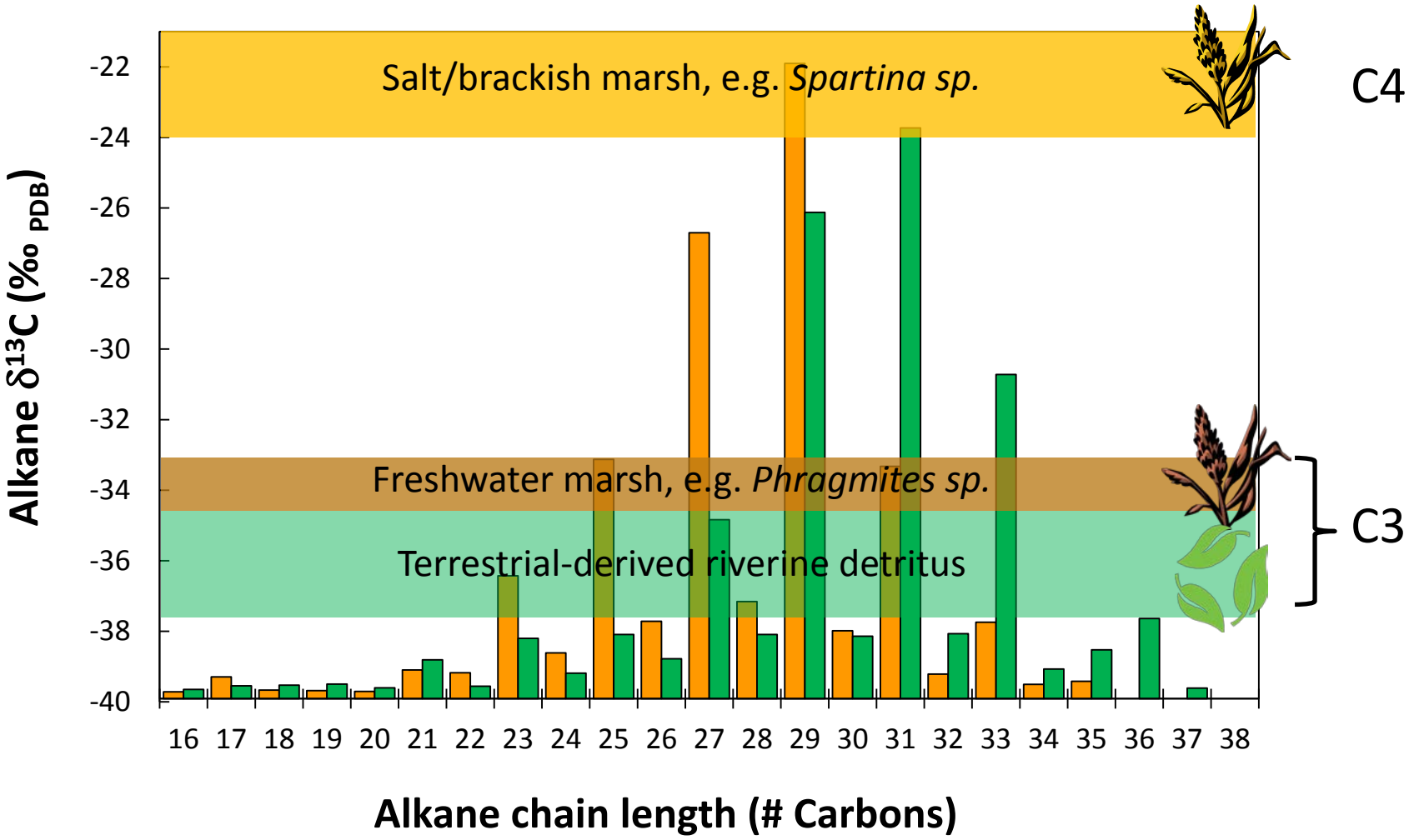
Marsh

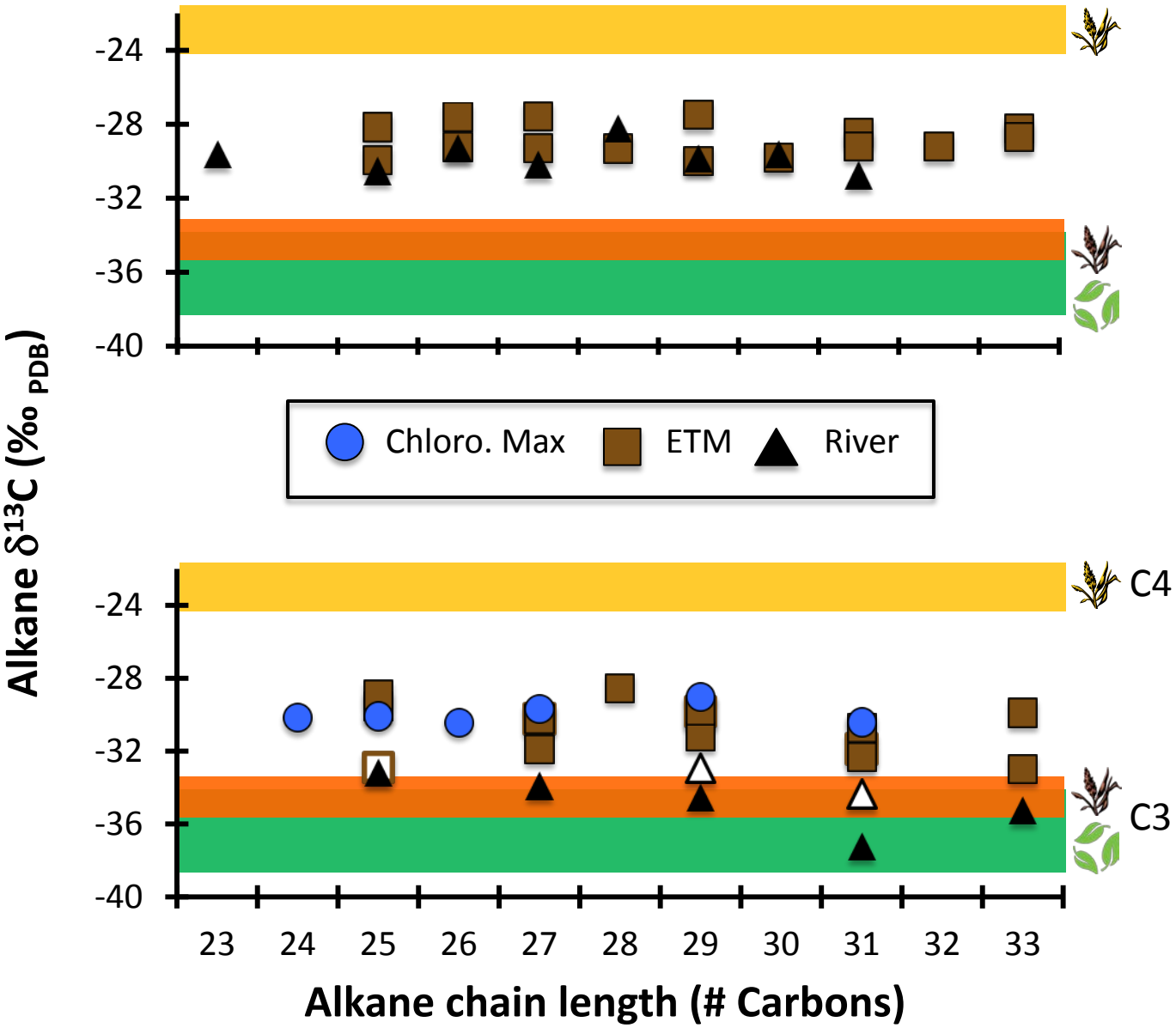


Terrestrial



Marsh


Salt/brackish marsh, e.g. Spartina sp.
Freshwater marsh, e.g. Phragmites sp.
Terrestrial-derived riverine detritus
C4
C3
Alkane δ13C (‰ PDB)
-22
-24
-26
-28
-30
-32
-34
-36
-38
-40
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Alkane chain length (# Carbons)



S'10 - Dry

~35-65% of land plant OC is from C4

M'11 - Wet

~15-50% of land plant OC is from C4

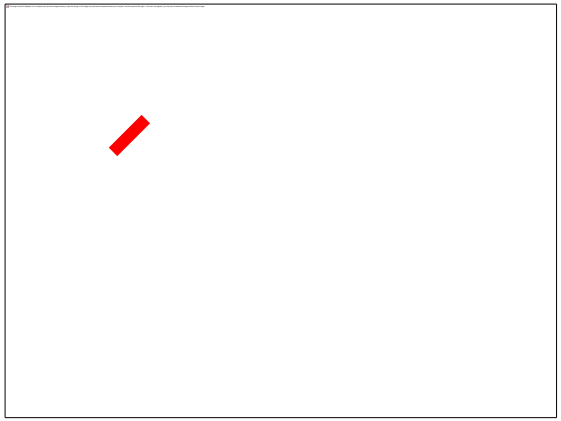
DB - ~32-49% C4

ETM - ~15-47% C4

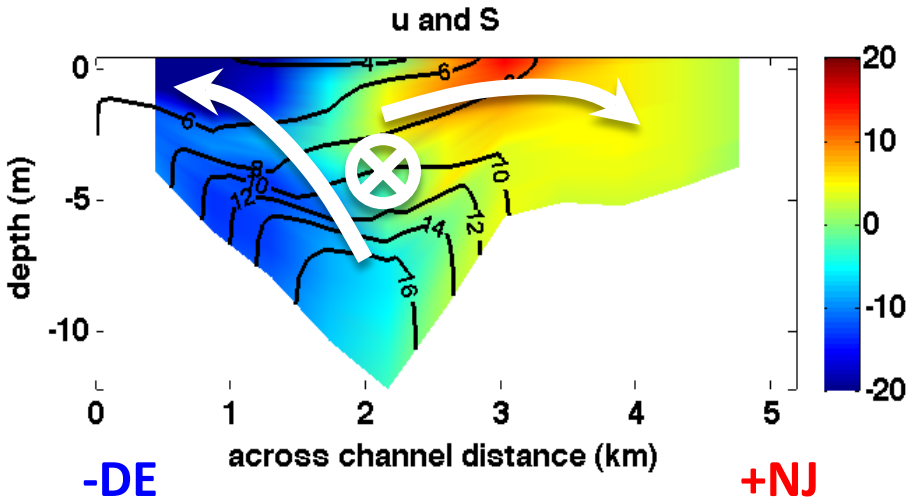
River - 100% C3

Bianchi et al., 2009, Aq. Geochem.; Bristow et al., 2013, Biogeochemistry

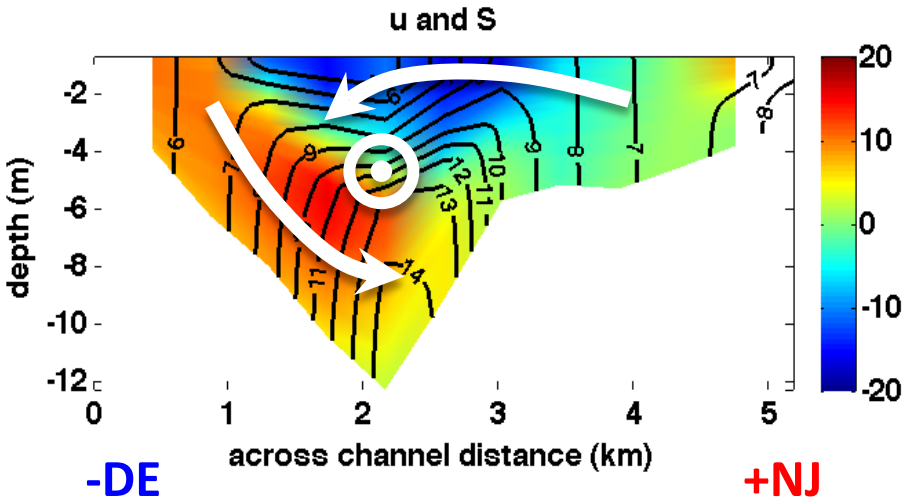
How does wetland organic carbon reach the main channel of the estuary?



Flood



Ebb



u (colorscale) is cross-channel velocity (cm/s)
S (isohalines) is salinity (PSU)

Physical oceanography to the rescue!

Aristizabal and Chant, 2013, J. Phys. Oce.; Aristizabal and Chant, 2014, Ocean Dynamics

Summary

There is more carbon in bottom waters than surface waters in the Delaware Estuary.

Bottom water POC is geochemically distinct from surface waters, particularly within the ETM.

Alkane compound-specific carbon isotopes allow us to assess the role of wetlands in the Delaware Estuary.

Wetland OC influences the geochemical signature of OC pools in Delaware Bay and in the ETM.

Lateral circulation may provide an exchange mechanism between the main channel and adjacent wetlands.

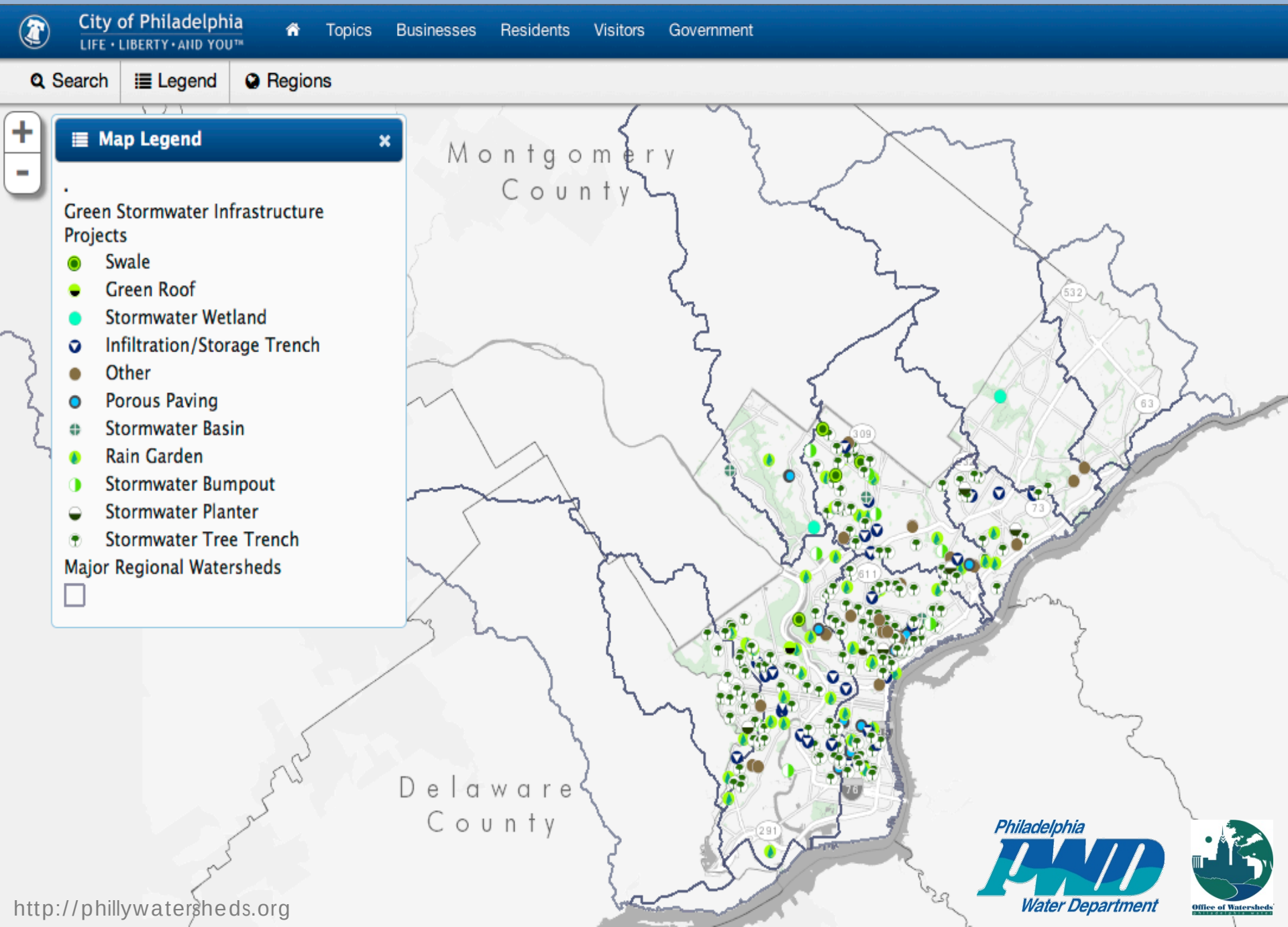
Exported land-derived OC may have a different reactivity and/or identity than expected because of it's multiple delivery pathways.

Green City, Clean Waters

Clean Water Act 1972

The Safe Drinking Water Act 1974

PA Act 167 Stormwater Management Planning 1978

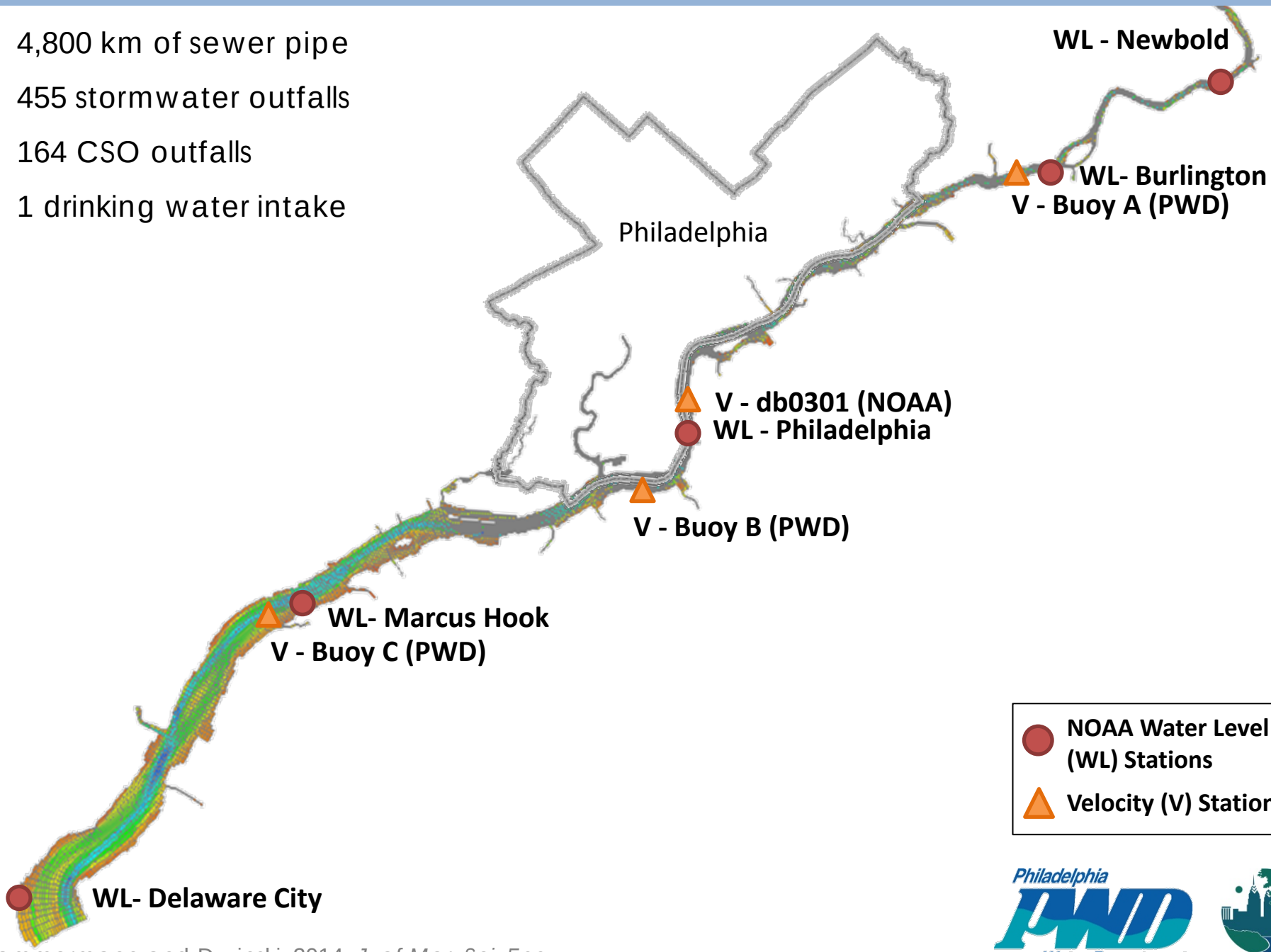

City of Philadelphia
LIFE • LIBERTY • AND YOU™
Topics
Businesses
Residents
Visitors
Government
Search
Legend
Regions
Map Legend
Green Stormwater Infrastructure Projects
Swale
Green Roof
Stormwater Wetland
Infiltration/Storage Trench
Other
Porous Paving
Stormwater Basin
Rain Garden
Stormwater Bumpout
Stormwater Planter
Stormwater Tree Trench
Major Regional Watersheds
Montgomery County
Delaware County
Philadelphia
Water Department
Office of Watersheds

4,800 km of sewer pipe

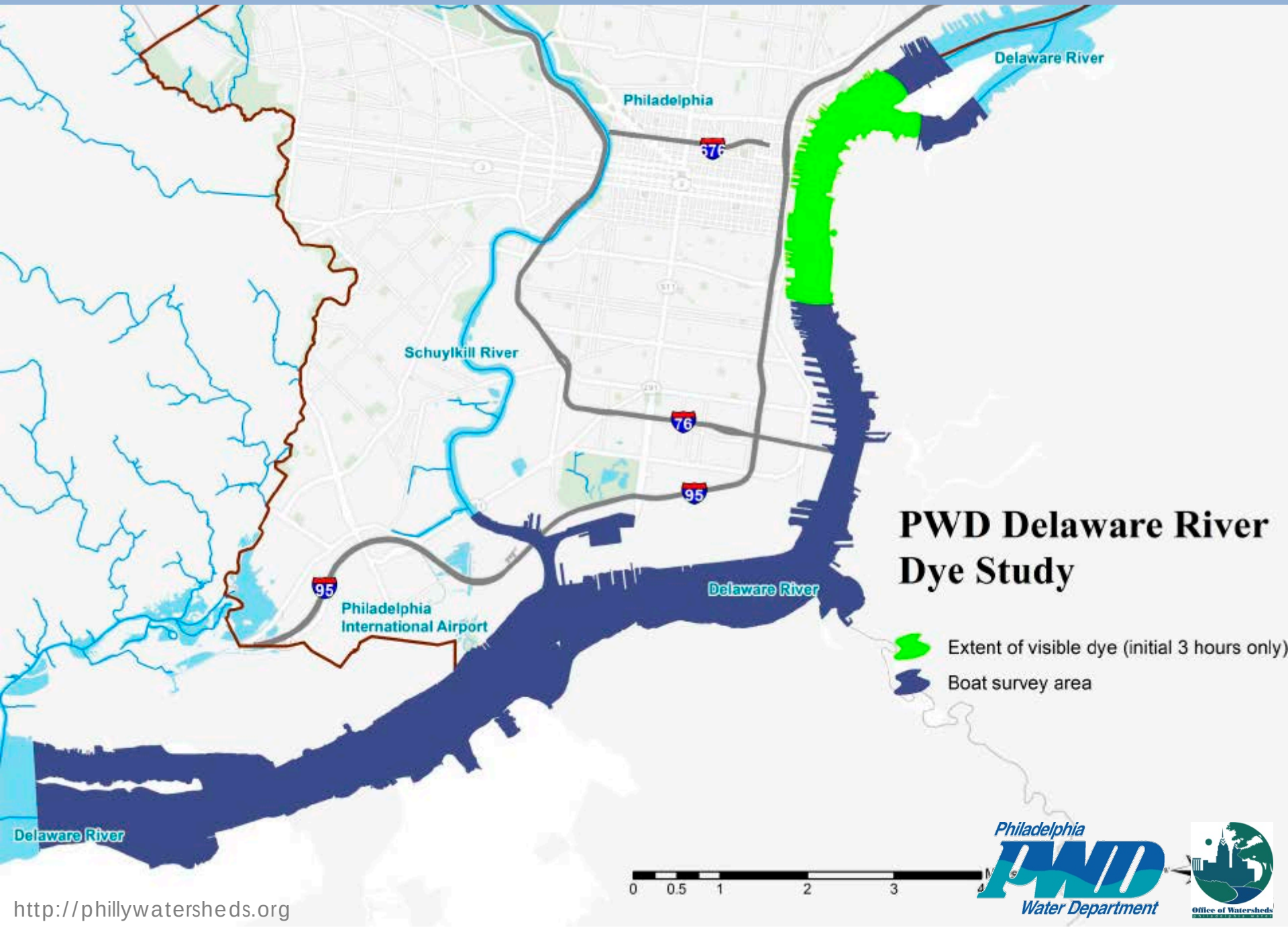
455 stormwater outfalls

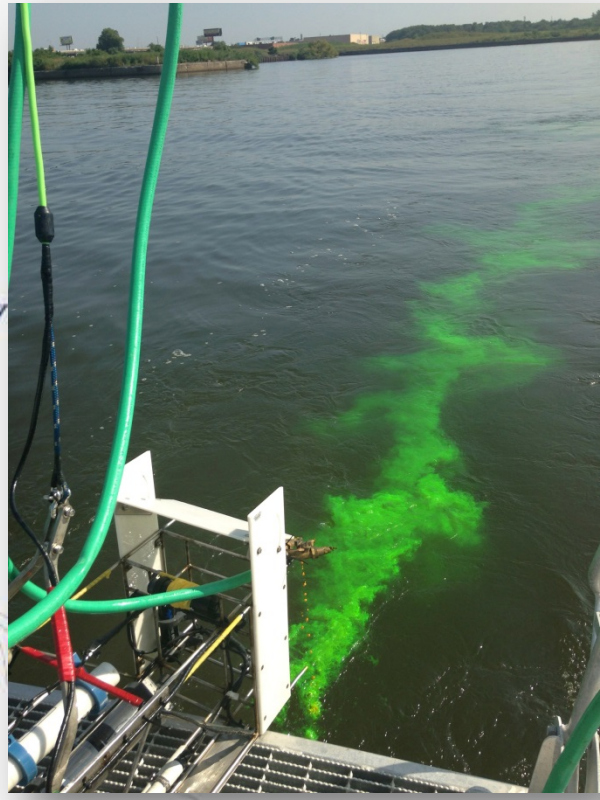
164 CSO outfalls

1 drinking water intake



Stammermann and Duzinski, 2014, *J. of Mar. Sci. Eng.*


Delaware River
Philadelphia
676
Schuylkill River
76
95
95
Philadelphia
International Airport
Delaware River
Delaware River
PWD Delaware River
Dye Study
Extent of visible dye (initial 3 hours only)
Boat survey area
0
0.5
1
2
3
Philadelphia
PWD
Water Department
Office of Watersheds



adelphia
Delaware River
676
76
95
95
Philadelphia
International Airport
Delaware River
Delaware River
0
0.5
1
2
3

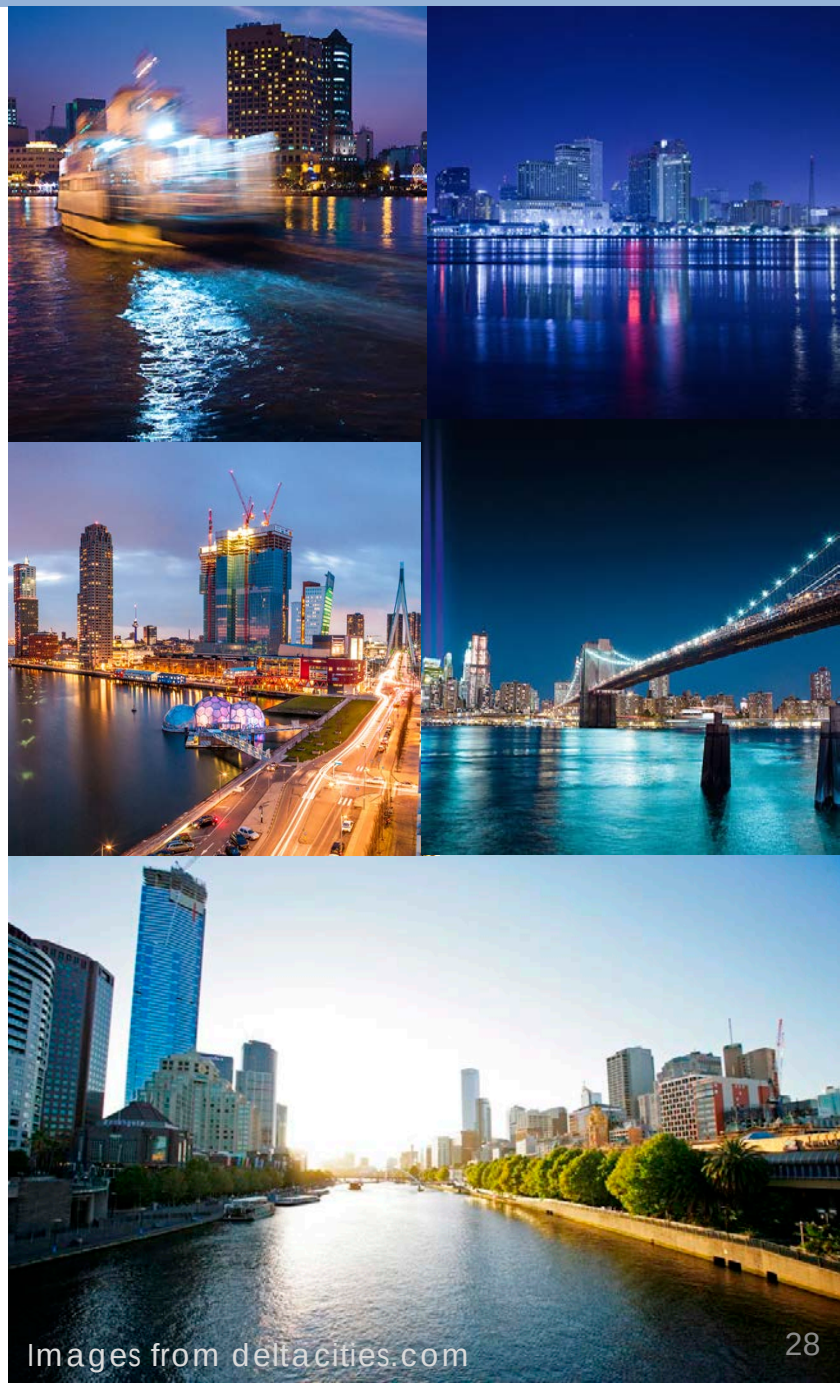
Reflections and Future

We can't address the complexities of estuarine systems alone. Inter- and multi-disciplinary studies get the conversation started.

Long-term data sets are essential for developing understanding of the underlying dynamics on multiple spatial and time scales (e.g. John Sharp, DRBC boat runs; NOAA PORTS and NOAA NDBC).

Regional and local management and decision making can be informed by underlying physical, chemical, and biological dynamics.
E.g. What are the effects of dredging? How do land use changes impact the biogeochemistry of estuaries?

Resilience scales up but can take a long time. We're changing culture.



Images from deltacities.com

Acknowledgements

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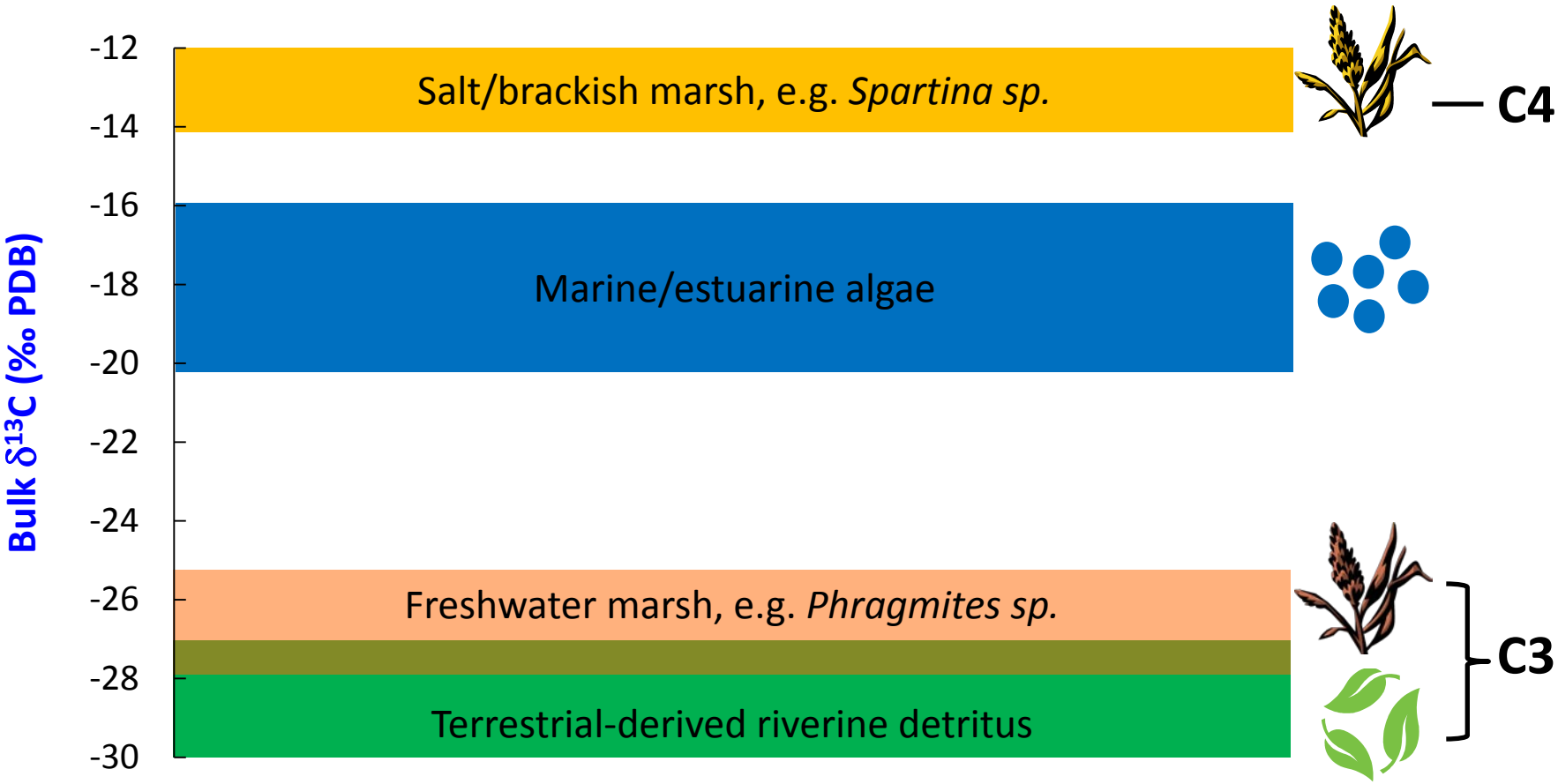
Liz Canuel (MS committee; VIMS)
Eli Hunter
Cap'n and crew of the *R/V Hugh Sharp, Tina IV, Caleta* etc.
Gear assistance
Lab and Cruise assistance
Philadelphia Water Department Office of Watersheds
Sci-Tek Consultants, Inc.
Woods Hole Group, Inc.
UMCES, Academy of Natural Sciences, NOAA, DRBC



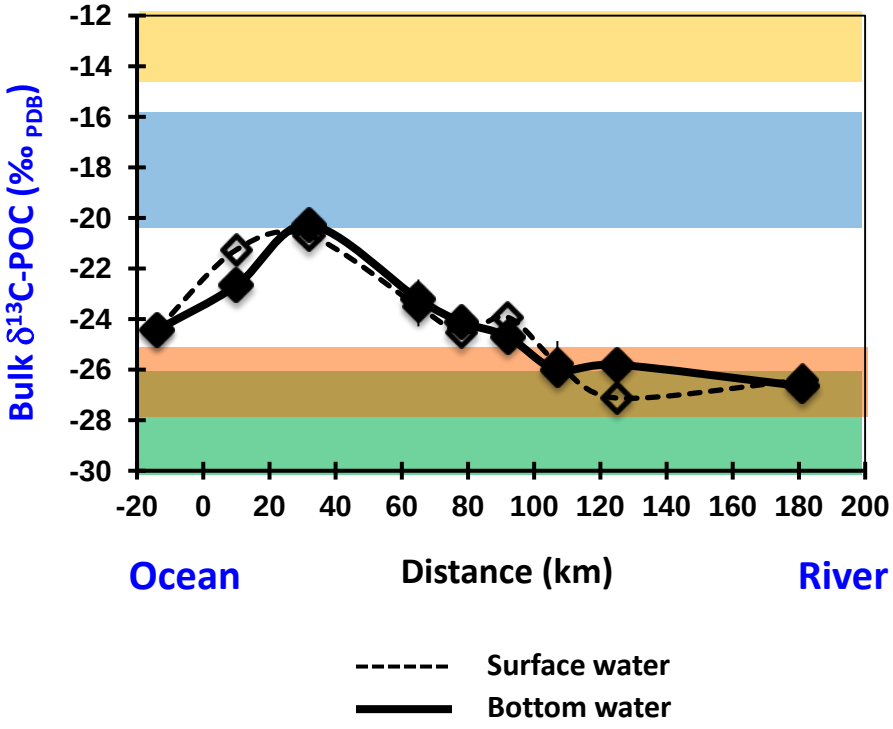

Questions?

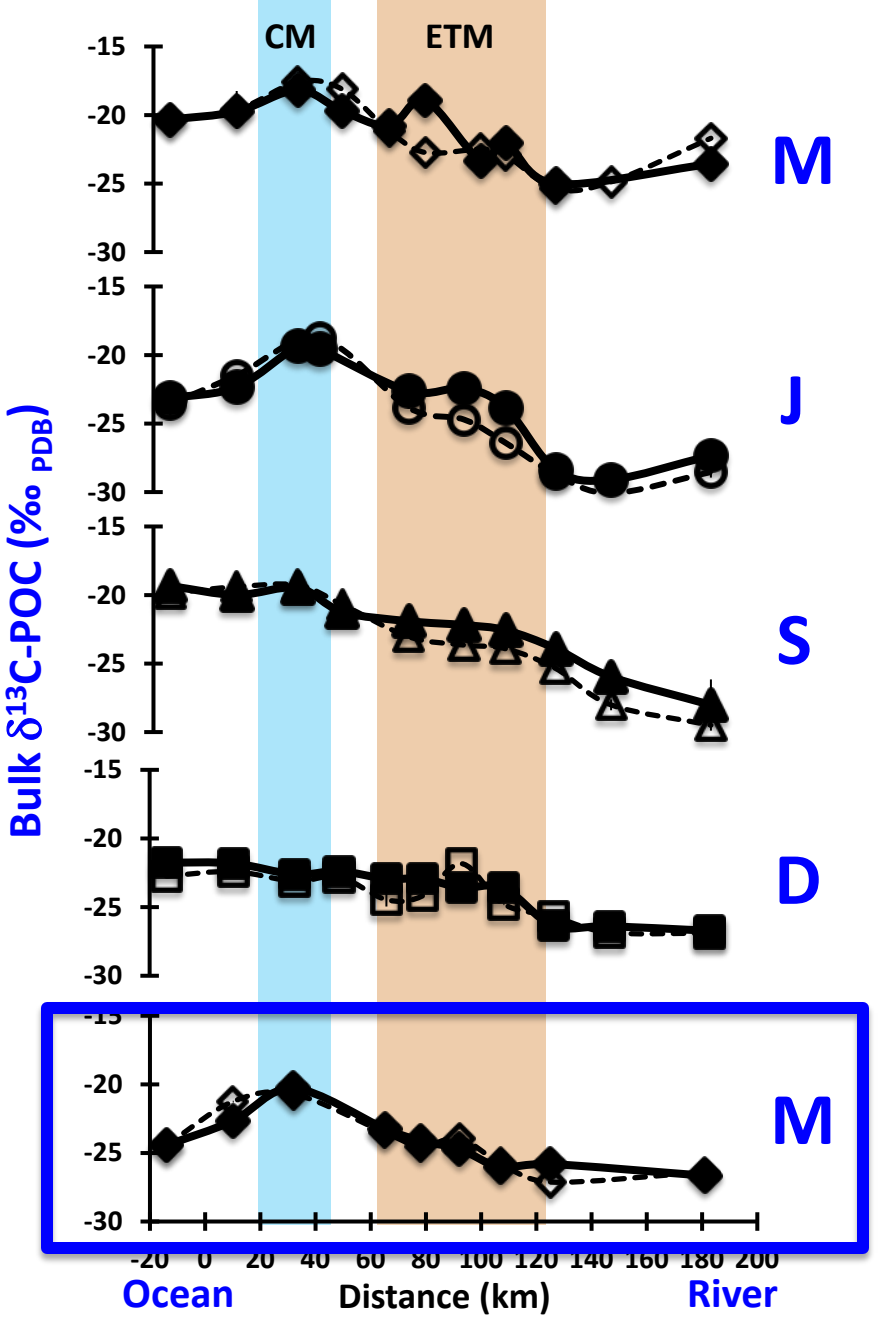
anna.hermes@noaa.gov



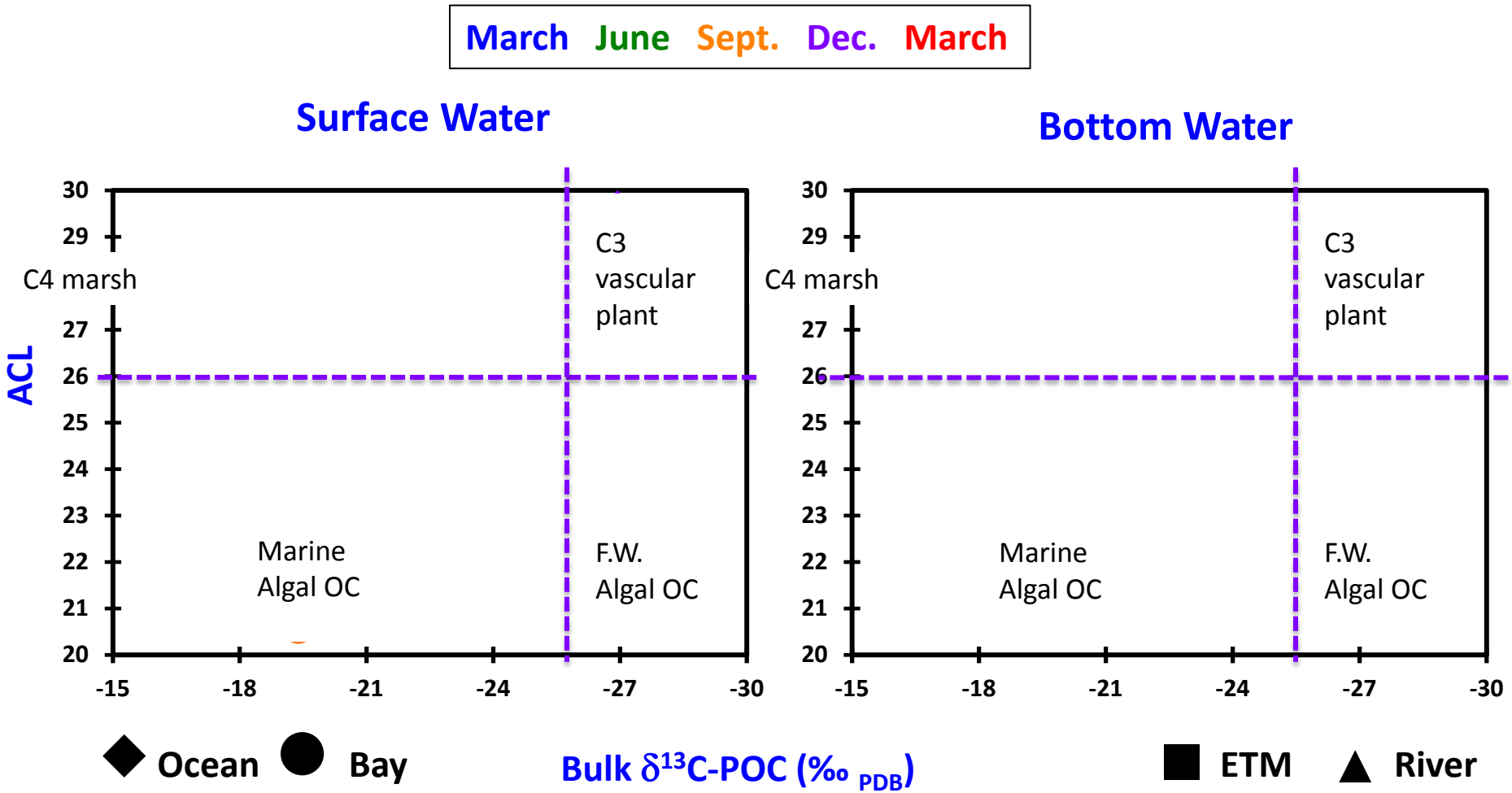
The bulk stable carbon isotopic composition of POC reflects the average of POC sources.

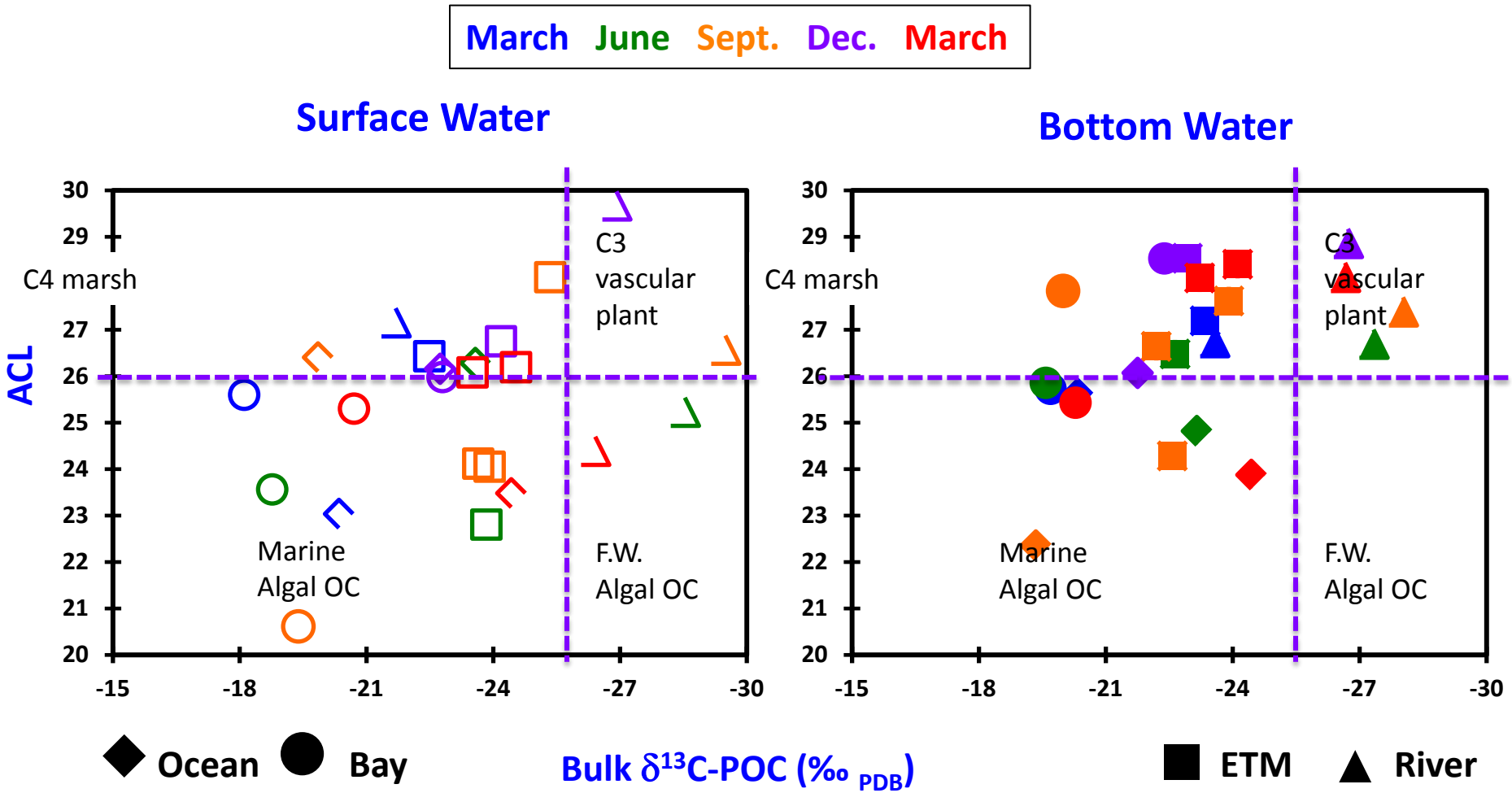
M - 2011





The bulk stable carbon isotopic composition of POC differentiates seasonal **algal** blooms in the lower estuary and **C3 vascular plant** OM in the upper estuary.

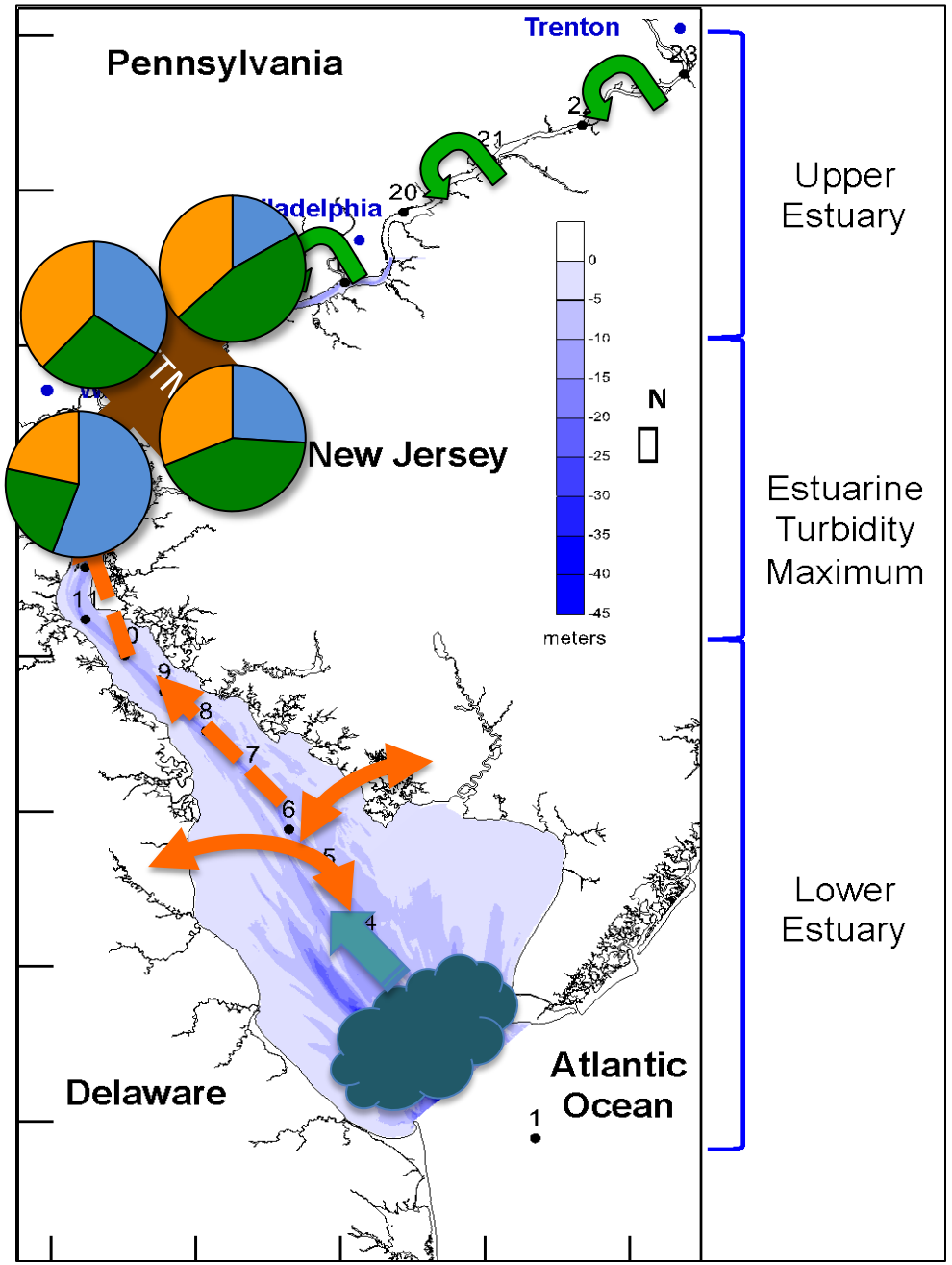

March June Sept. Dec. March
Surface Water
Bottom Water
ACL
C4 marsh
C3 vascular plant
Marine Algal OC
F.W. Algal OC
30
29
27
26
25
24
23
22
21
20
-15
-18
-21
-24
-27
-30
Ocean
Bay
ETM
River
Bulk δ13C-POC (‰ PDB)


March June Sept. Dec. March
Surface Water
Bottom Water
ACL
C4 marsh
C3 vascular plant
Marine Algal OC
F.W. Algal OC
30
29
27
26
25
24
23
22
21
20
-15
-18
-21
-24
-27
-30
Ocean
Bay
ETM
River
Bulk δ13C-POC (‰ PDB)

SUMMARY

September 2010-

Late summer, low discharge

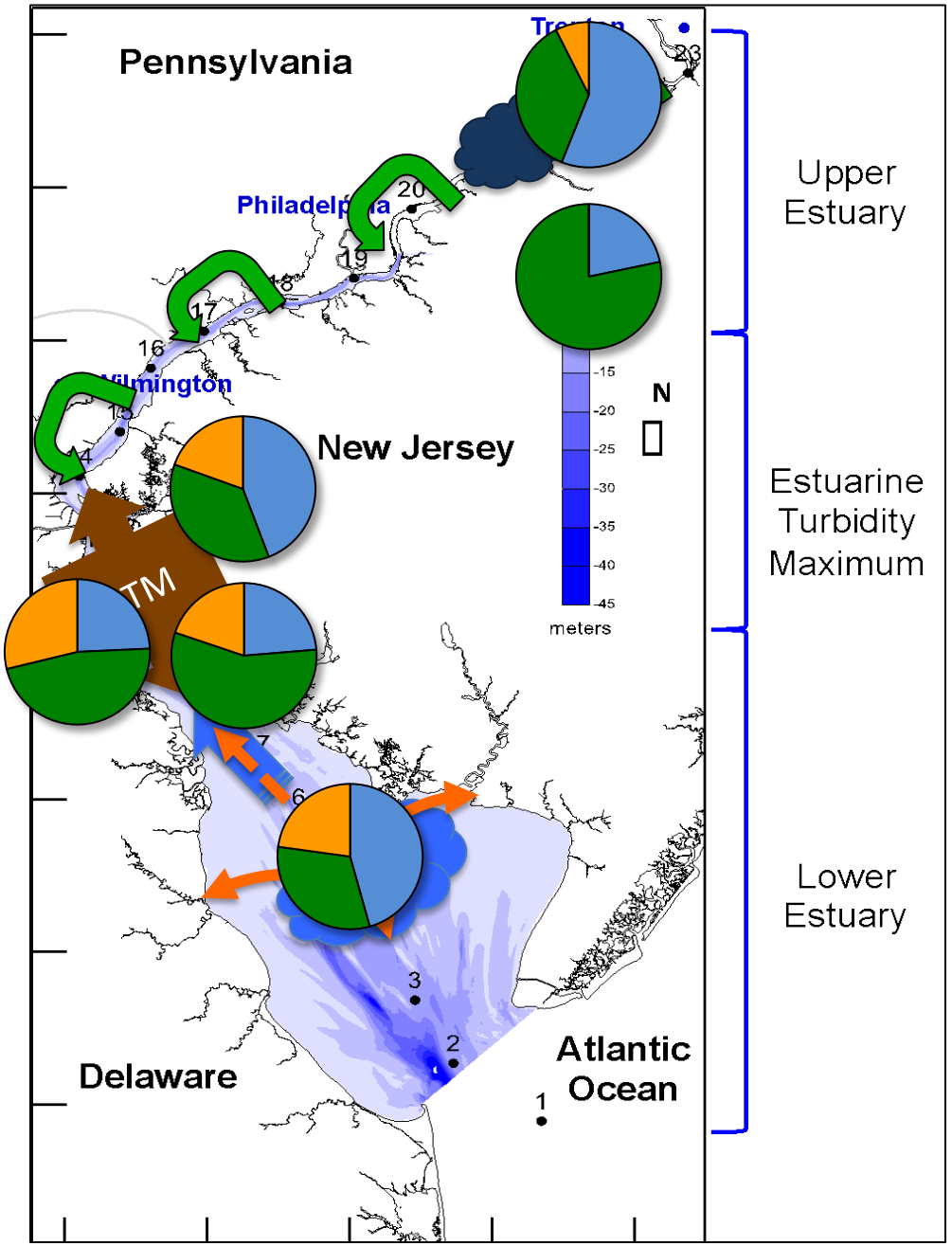


Marsh
Terrestrial
Algal

SUMMARY

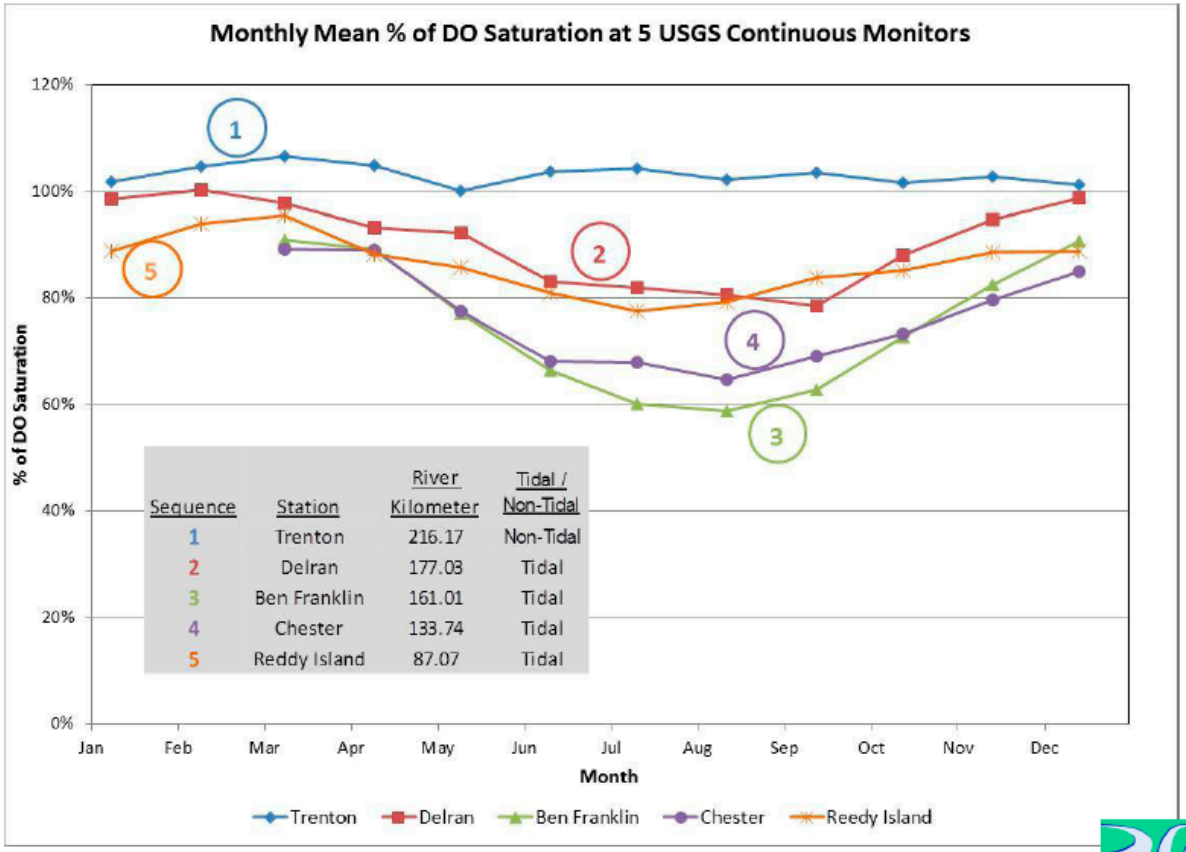
March 2011-

Spring bloom, after freshets



Marsh
Terrestrial
Algal

DO Saturation (2000-2010)



Sequence	Station	River Kilometer	Tidal / Non-Tidal
1	Trenton	216.17	Non-Tidal
2	Delran	177.03	Tidal
3	Ben Franklin	161.01	Tidal
4	Chester	133.74	Tidal
5	Reddy Island	87.07	Tidal

Delaware River Basin Commissi
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UNITED STATES OF AMERIC

GREEN STREETS: STORMWATER PLANTER