Landsat Based Spatial and Temporal Analysis of Chlorophyll Concentration in the Chesapeake and Delaware Bay Watersheds 1984-2021

Chesapeake Bay Program STAC Workshop
April 22, 2022

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Why Landsat?

Cons:

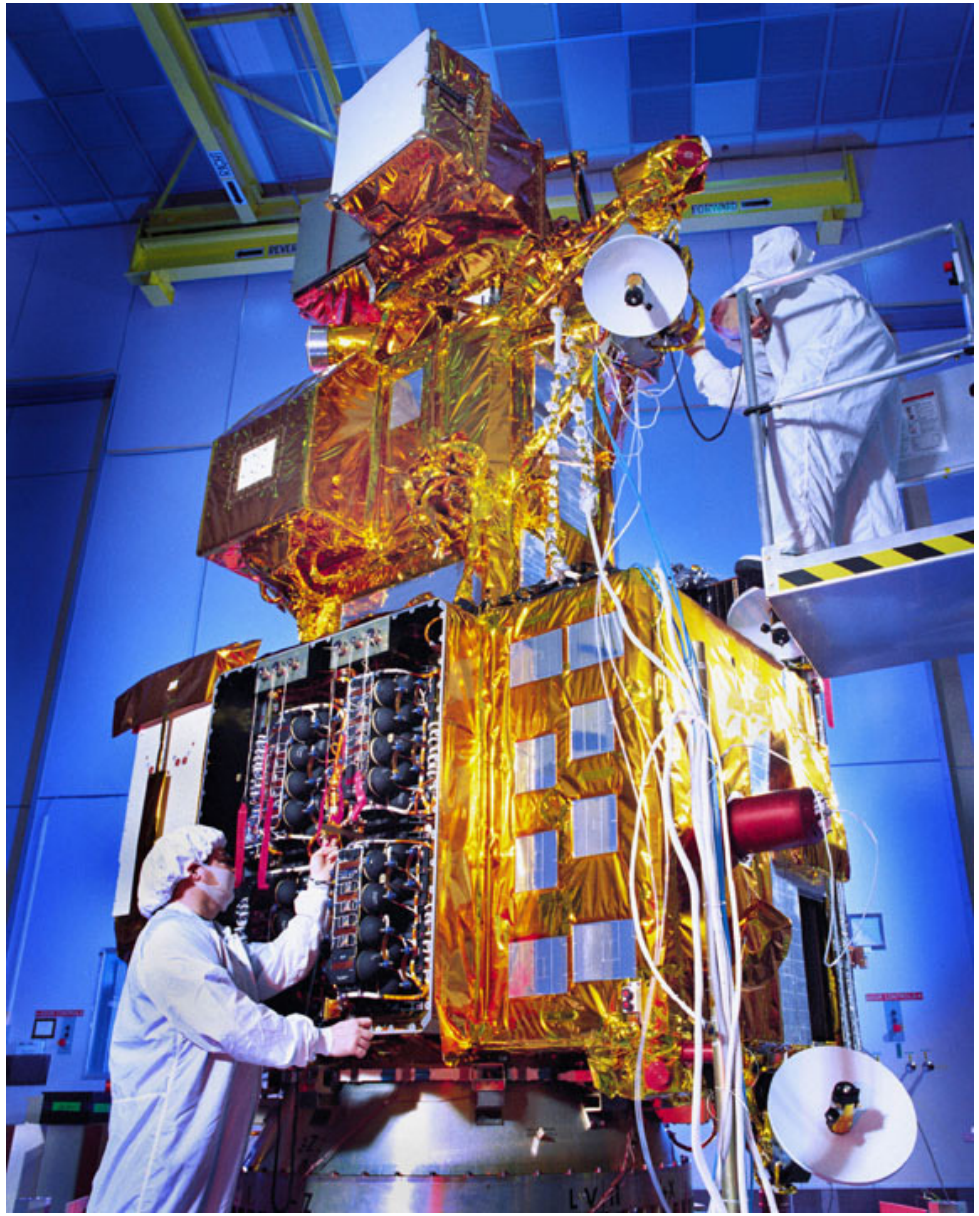
- Relatively poor spectral resolution
  - Outclassed by Sentinel-2 & OLCI
  - Less accurate models

Pros:

- Historical Observations
  - Acquisitions from 1984
  - Potential to fill gaps in historical HAB record

- Available in-situ data across time
  - Used to train ML models

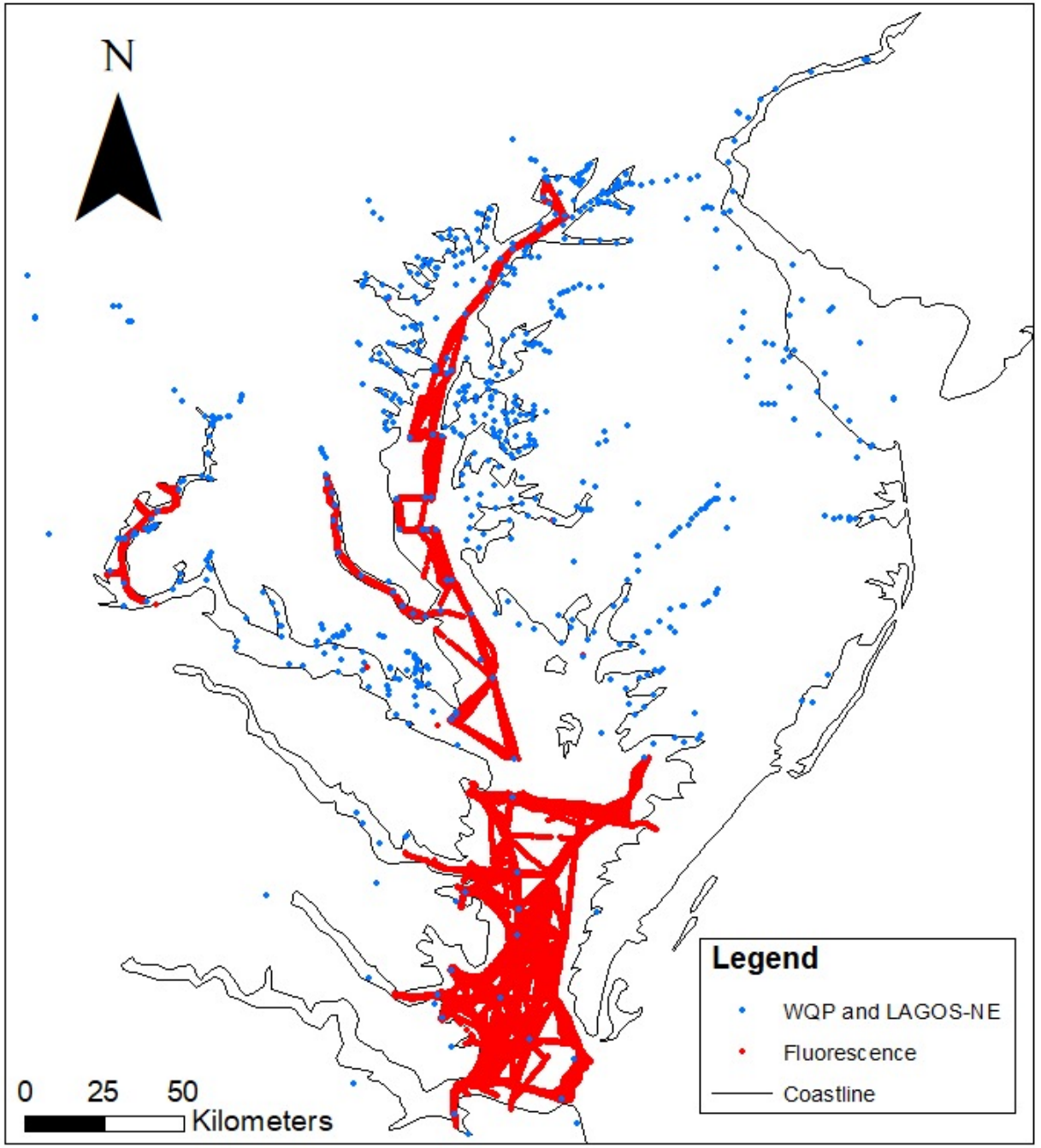
- Relatively high spatial resolution
  - Spatially acute time-series analyses



Training Data

- Red: Chlorophyll fluorescence survey data
  - Acquired from Chesapeake Bay Program - baywide fluorescence database
  - 1984-2012
  - ~100,000 “matchups” (coincident, unobstructed Landsat acquisition)

- Blue: Water Quality Portal and LAGOS-NE data
  - 1984-2018
  - ~5,000 matchups



Landsat Reflectance Input

Model training/testing predictors:

1. All 30m Landsat bands
   - Level-2 Collection-2 Analysis Ready Data
   - Blue, Green, Red, Near Infrared (NIR), Short Wave Infrared (SWIR) 1 & 2
2. Algorithms from previous literature
3. Month and day of acquisition

Algorithms from Literature
(Ho et al., 2017)

#	Algorithm	Algorithm reference(s)
1	Red to blue ratio	Lathrop, 1992
2	Red to near-infrared ratio	Yacobi et al., 1995
3	Green to blue ratio	Gitelson et al., 1993
4	(Blue minus red) over green	Mayo et al., 1995
5	Phycocyanin detection, validated using Lake Erie data[c]	Vincent et al., 2004
6	Near-infrared (NIR), validated using Lake Tai data	Duan et al., 2009
7	NIR with simple atmospheric correction (SAC)	Wang and Shi, 2007
7b	Further refinement of NIR with SAC (#7), as discussed in Section 3.1	Gordon, 1978 Haydn et al., 1982
8	NIR minus red	Tucker, 1979
9	NIR over red, with SAC	Stumpf and Tyler, 1988
10	NIR over red, with baseline atmospheric correction (BAC)[d]	ESA, 2015
11	Curvature method around red band	Wynne et al., 2008

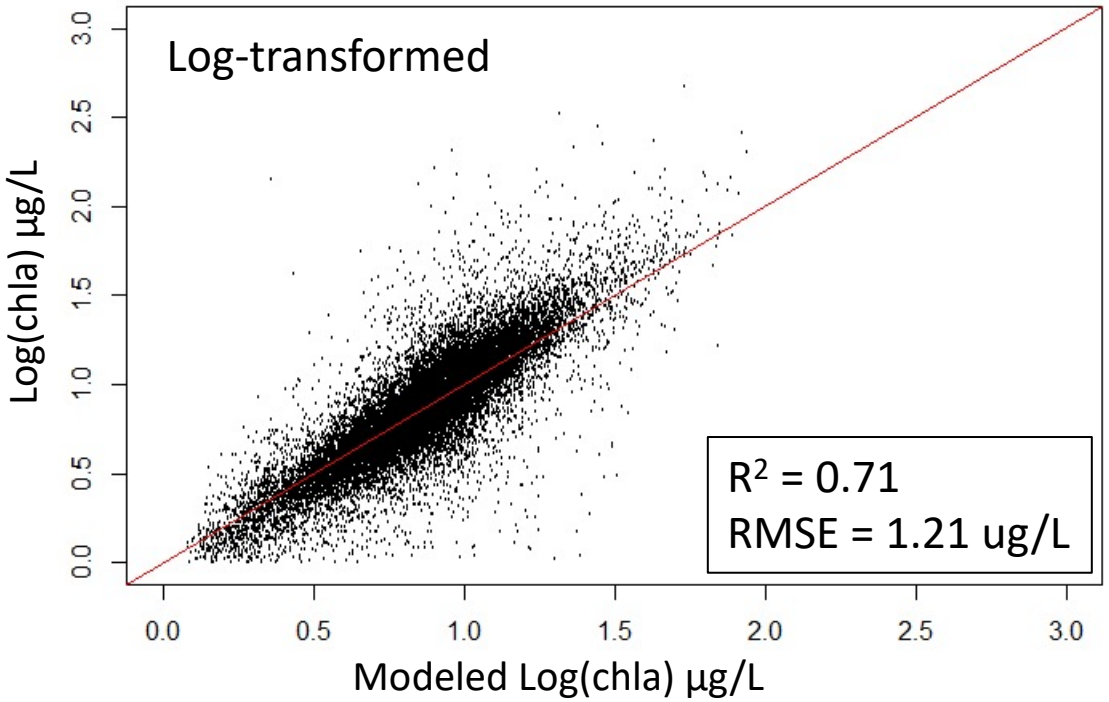
Selected Model Inputs

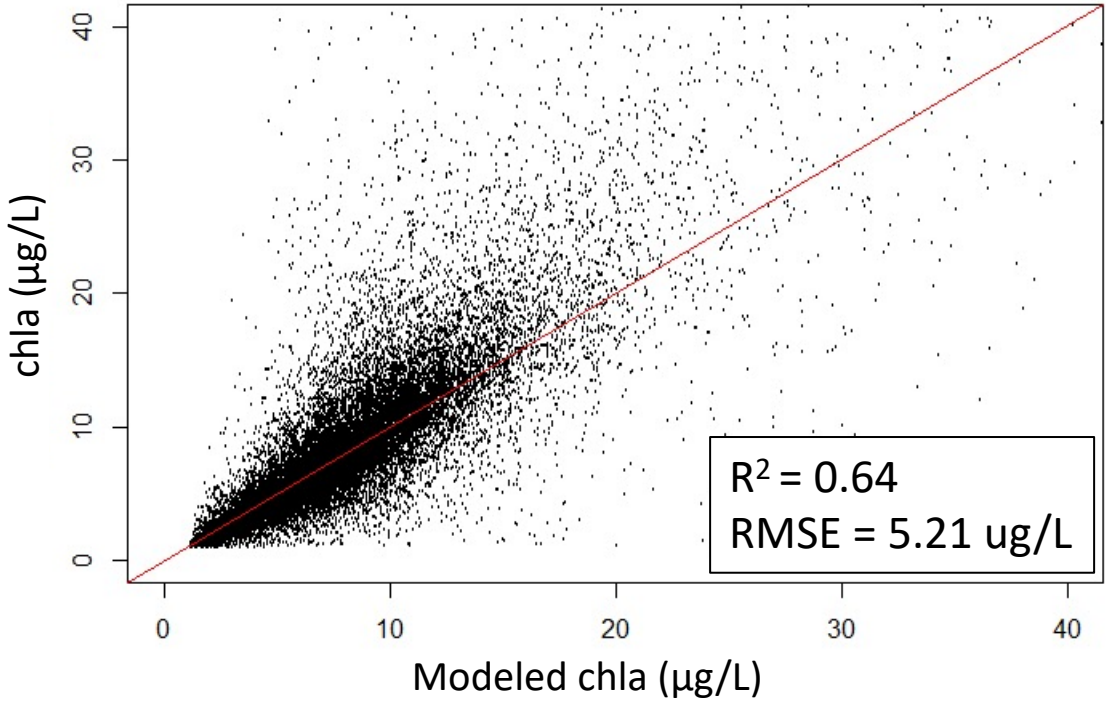
Input Variables (by order of importance):

1. Cos(day of year)
2. (NIR)-(1.03*SWIR1)
3. Blue
4. Green/Blue
5. (NIR-SWIR1)/(Red-SWIR1)
6. Sin(month)
7. Phycocyanin: (47.7 - (9.21*red/blue)+29.7*(nir/blue)-118*(nir/red)-6.81*(swir1/red) + 41.9*(swir2/red)-14.7*(swir2/nir))
8. SWIR2

Modeling Approach

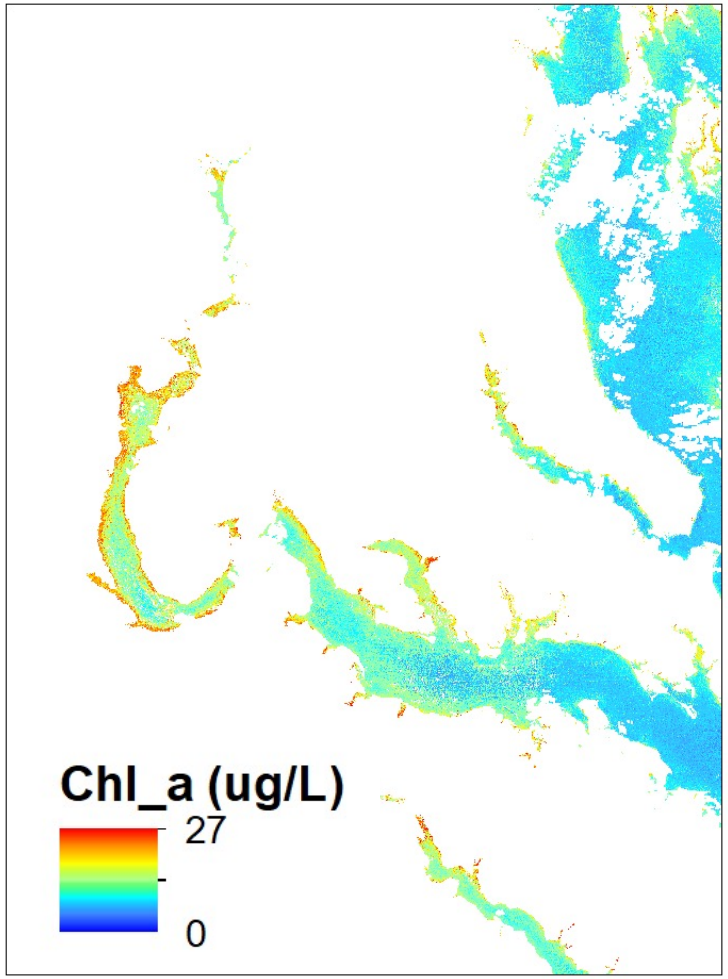
- R tidymodels framework
- Random Forest
- Log transformation of chlorophyll fluorescence
- Cross validation (5 folds)
- Hyperparameter tuning



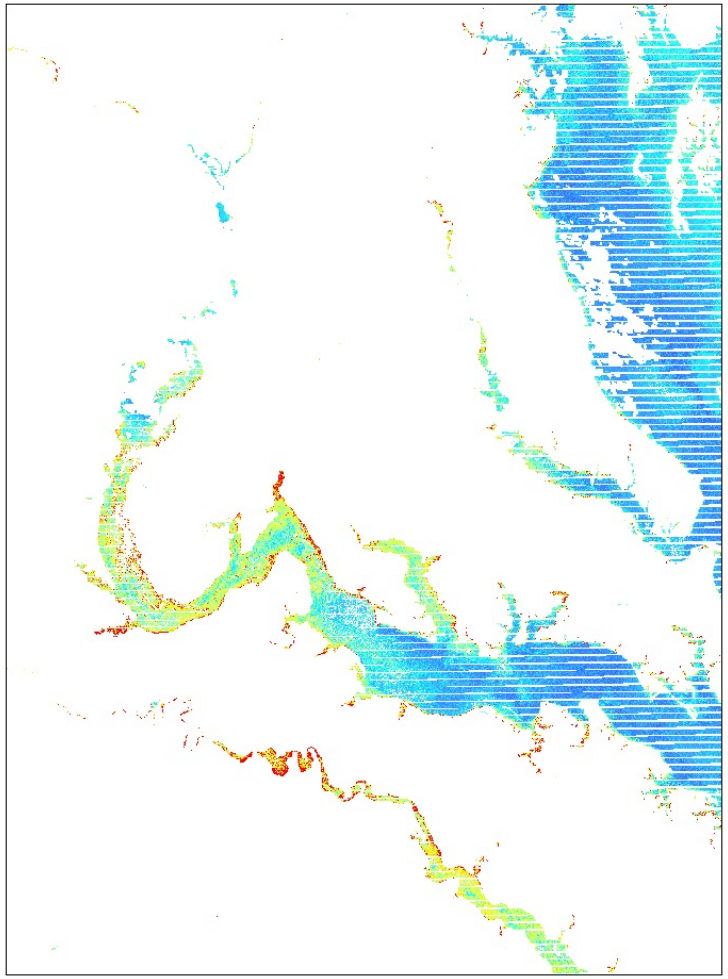


Potomac River – CyanoHAB – Summer 2004

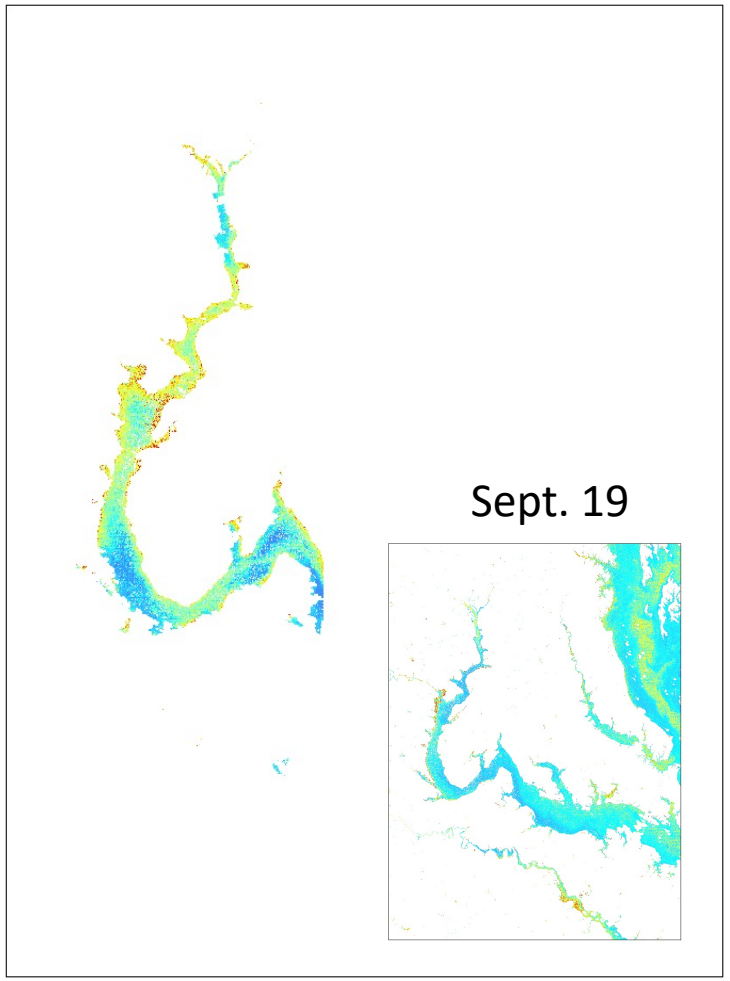
July 1



July 9

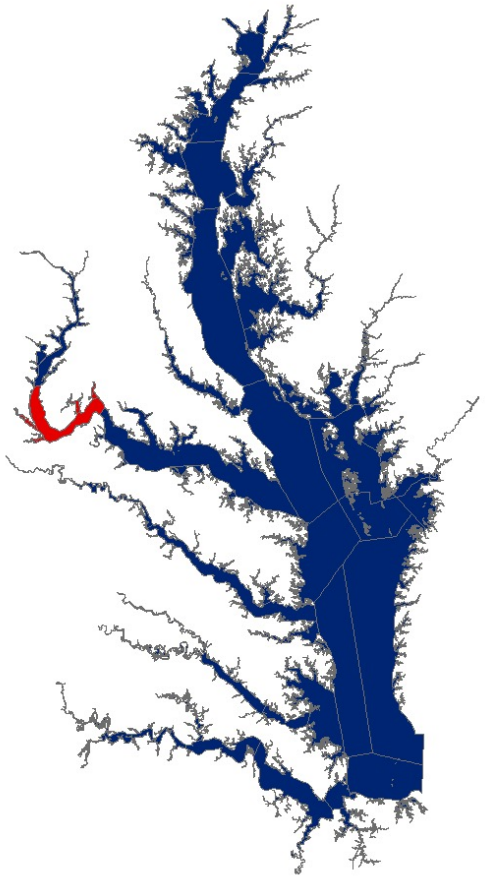


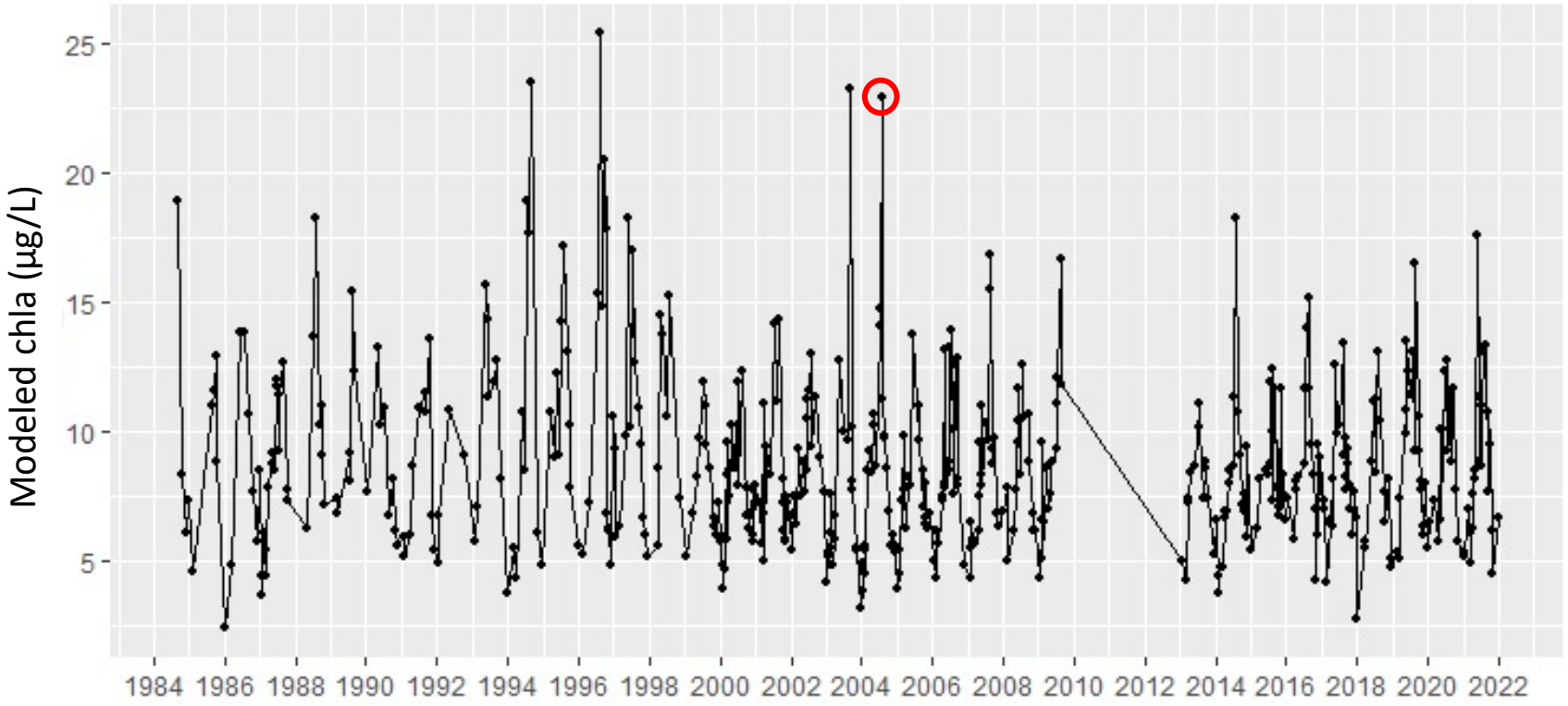
August 18



Sept. 19

Potomac Chlorophyll Time-Series





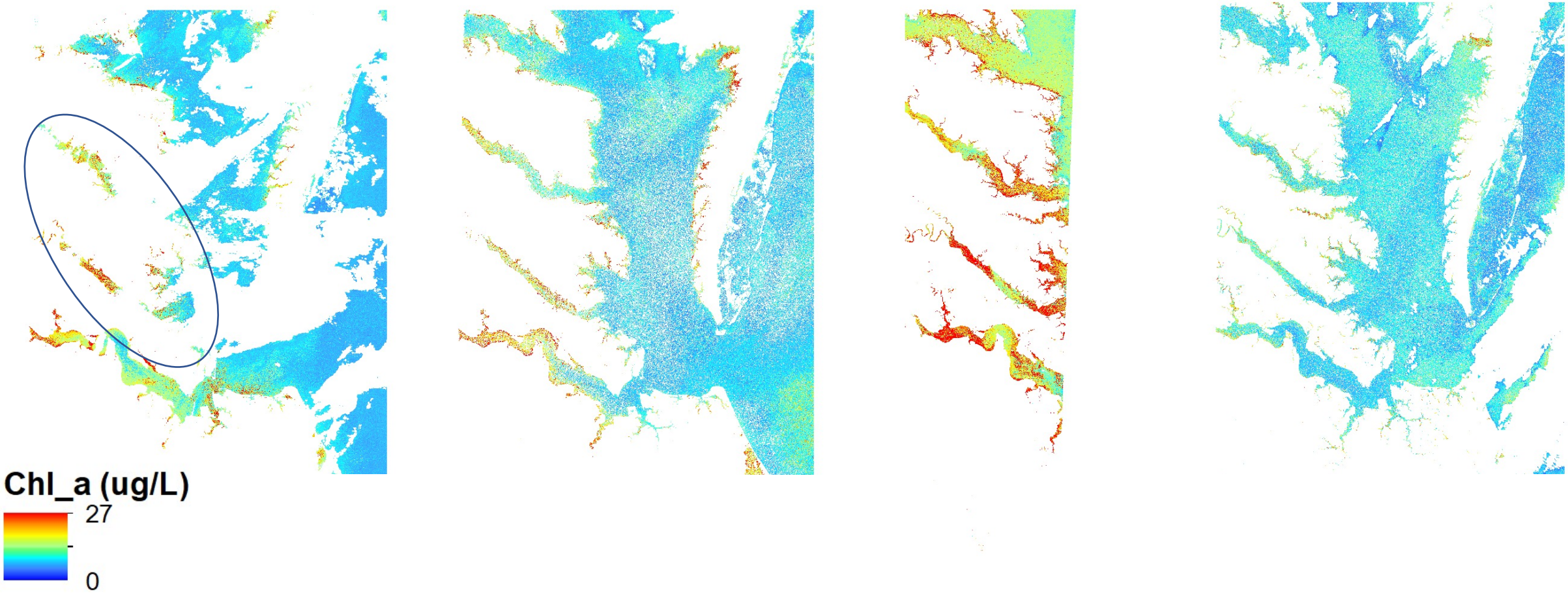
York & Rappahannock Rivers – Polykrikoides - Mid-summer to early fall 1992

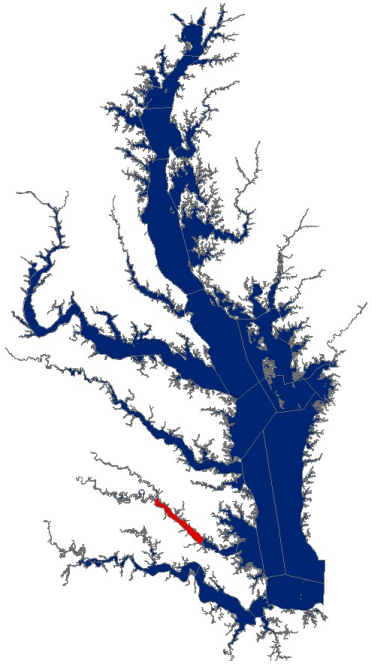
June 23

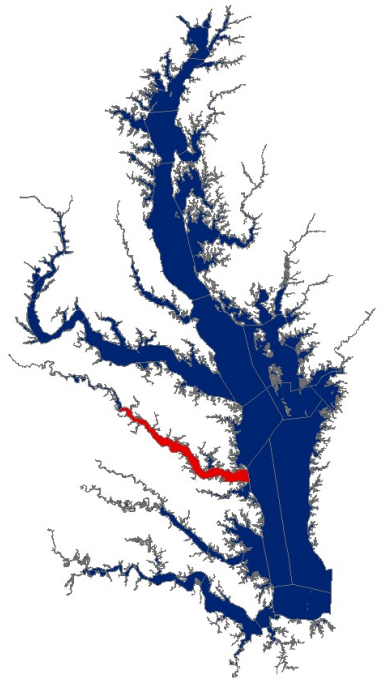
August 10

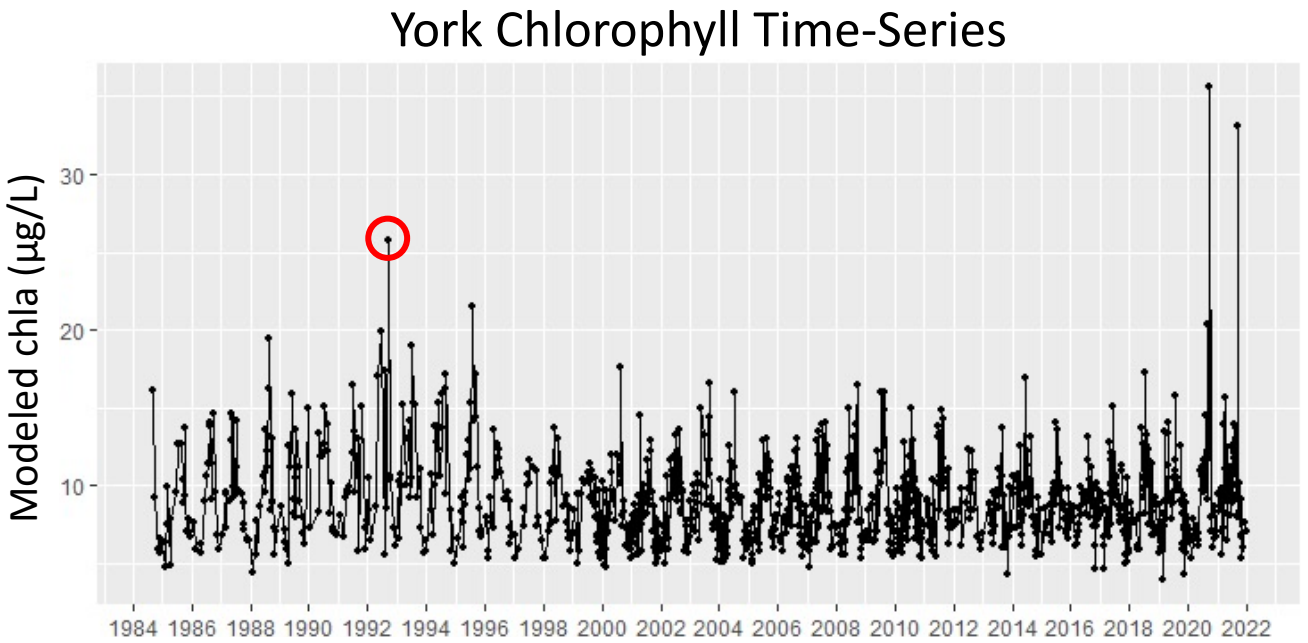
Sept. 18

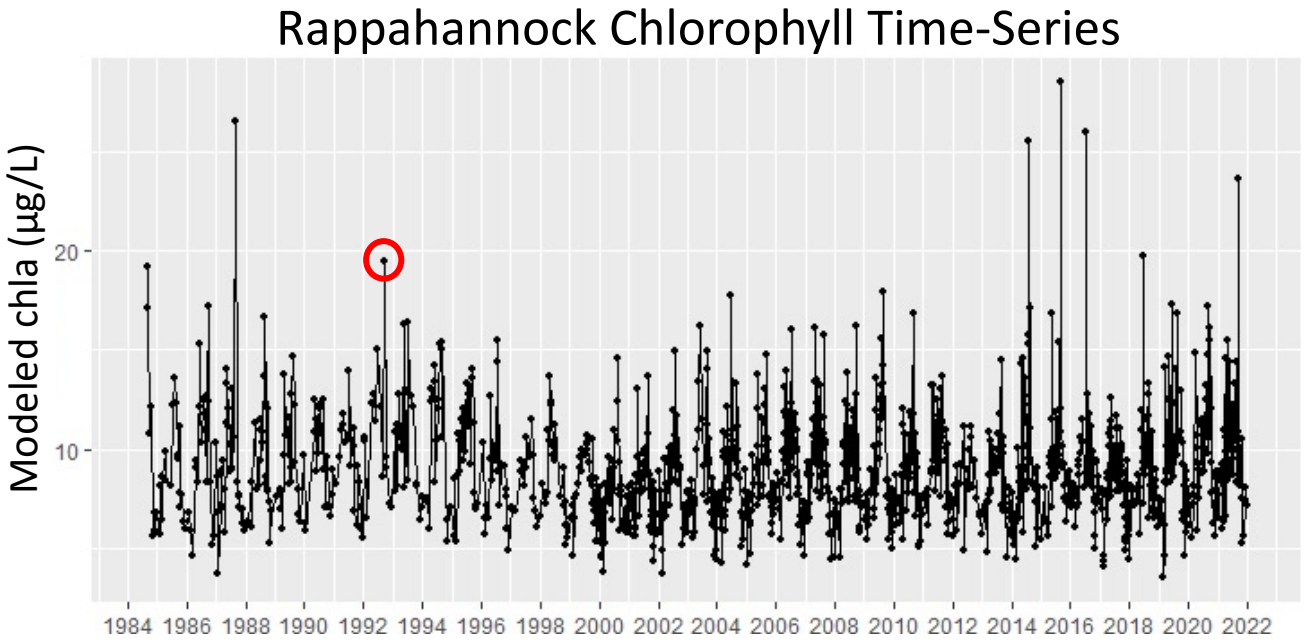
October 13





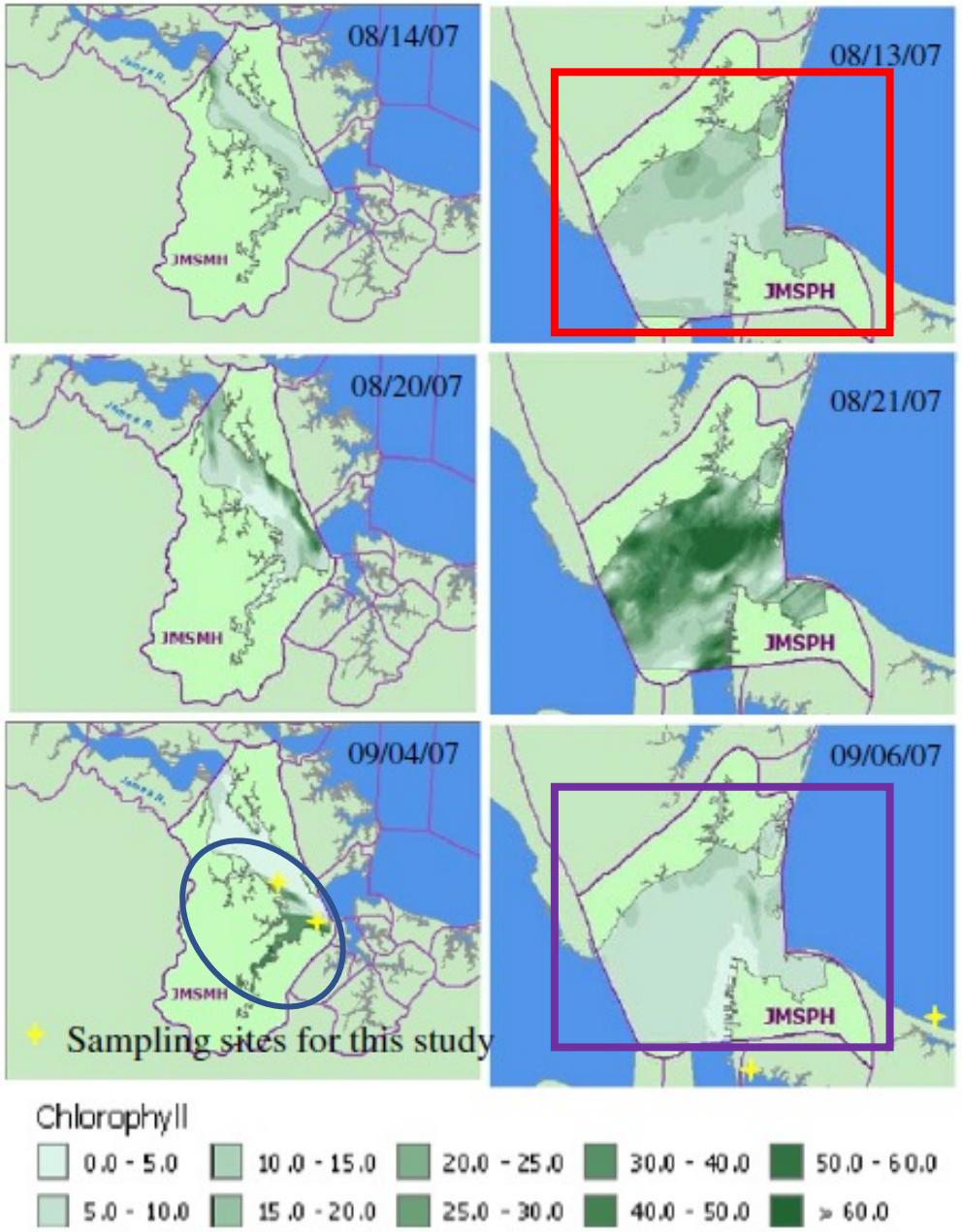



York Chlorophyll Time-Series
Modeled chla (µg/L)
30
20
10
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

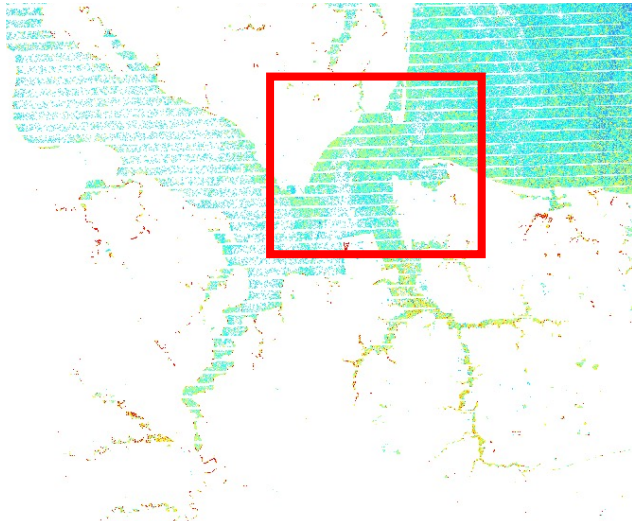

Rappahannock Chlorophyll Time-Series
Modeled chla (µg/L)
20
10
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

James River – Polykrikoides – August-September 2007

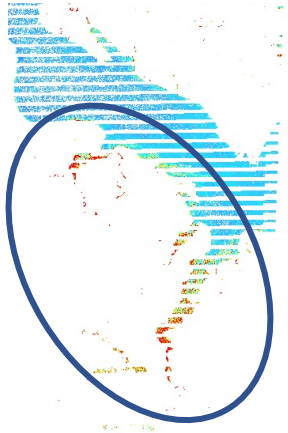
DATAFLOW comparison
(Mulholland et al., 2009)



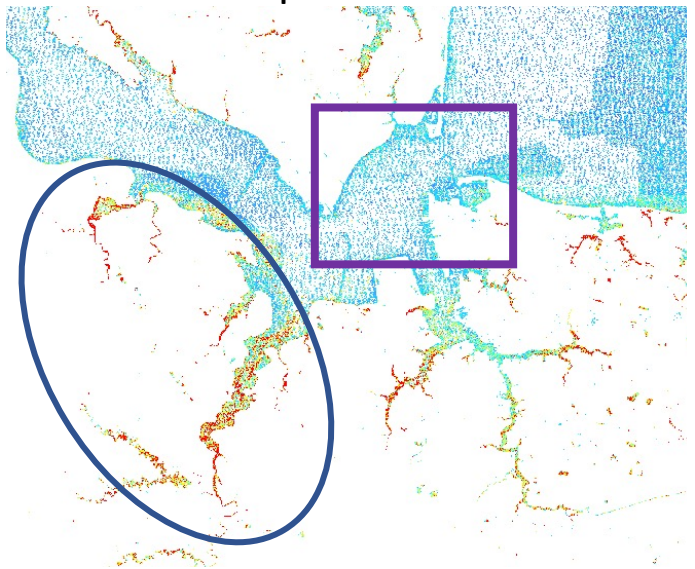
August 12

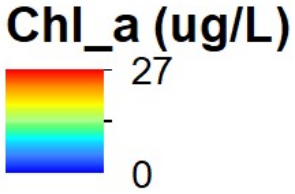


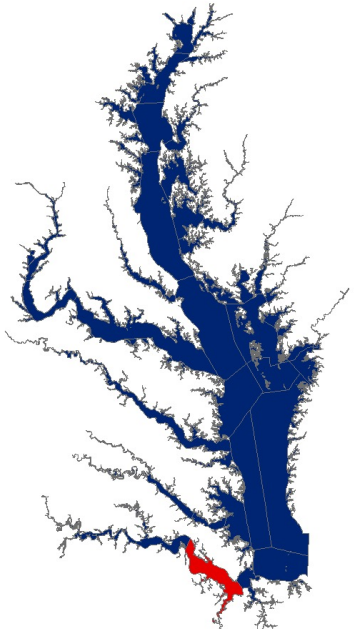
September 4

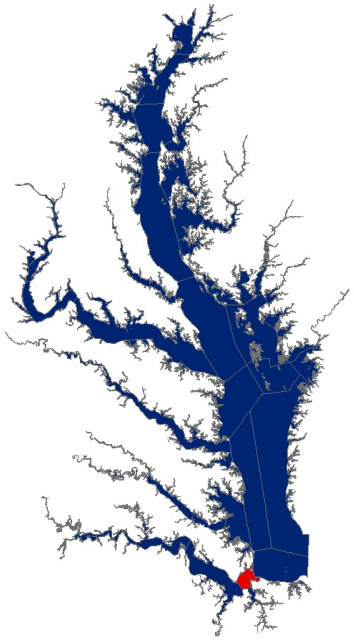


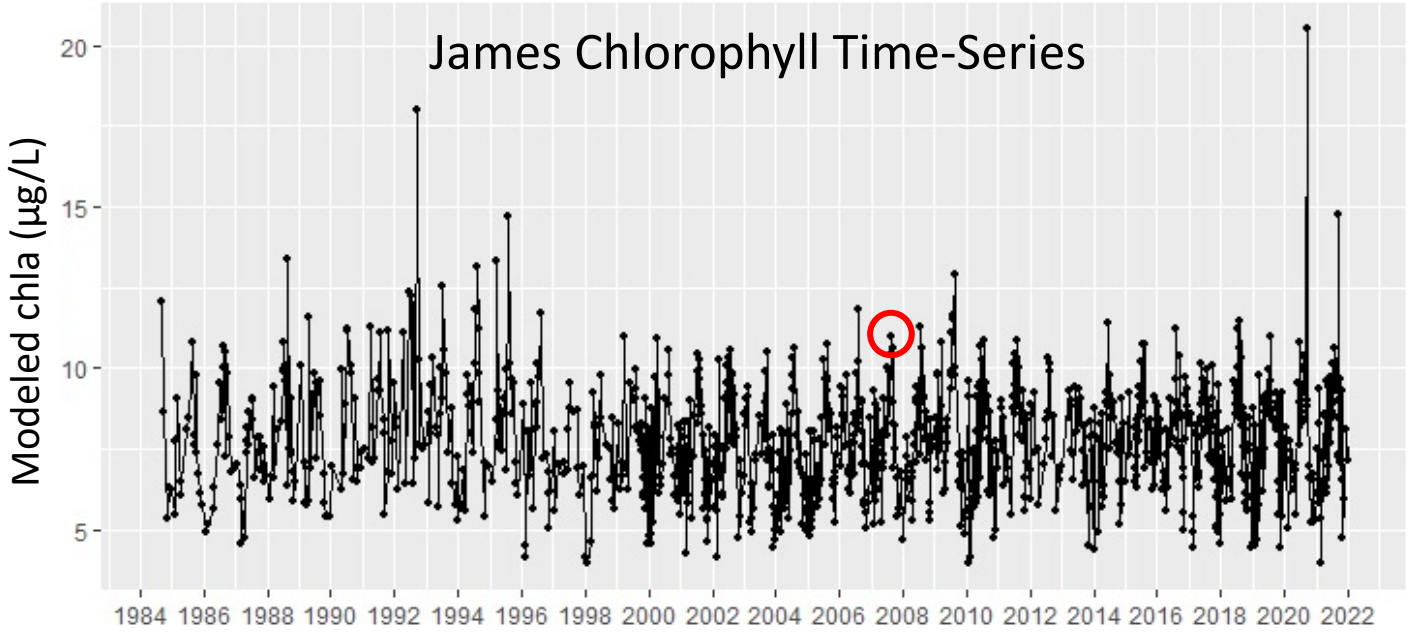
September 5

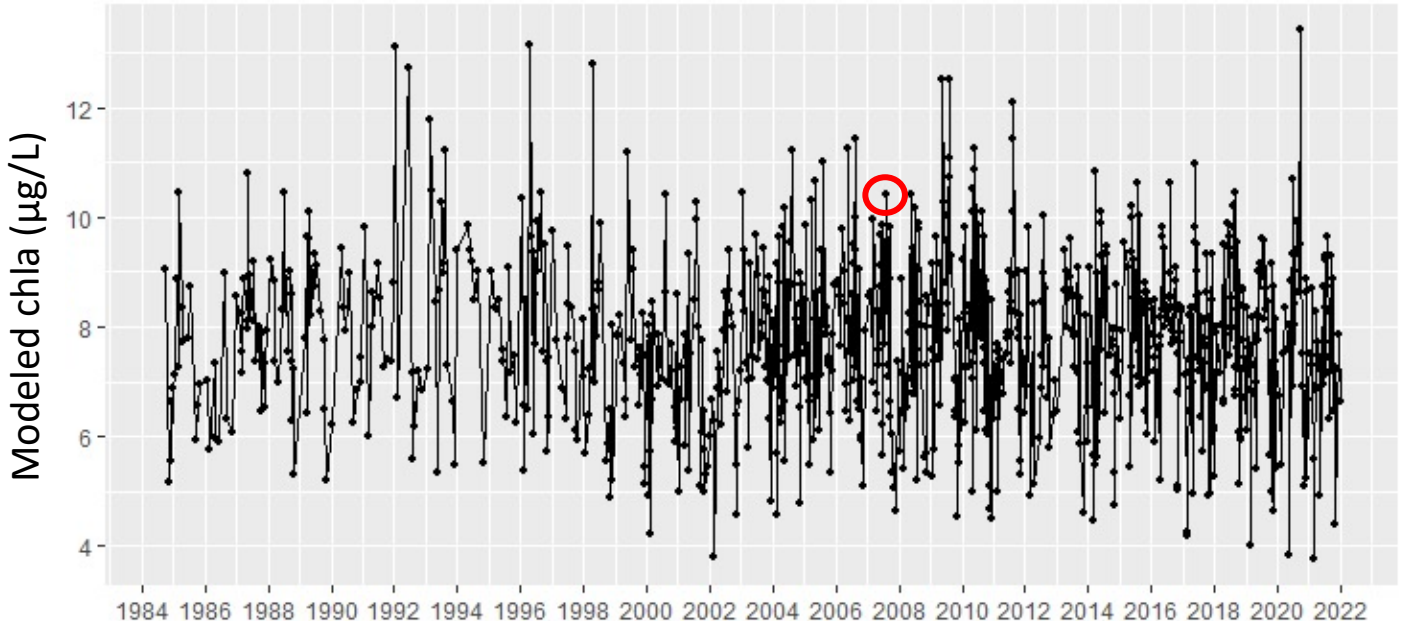









James Chlorophyll Time-Series
Modeled chla (µg/L)
20
15
10
5
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022


Modeled chla (µg/L)
12
10
8
6
4
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Bush River – M. aeruginosa – July 2003

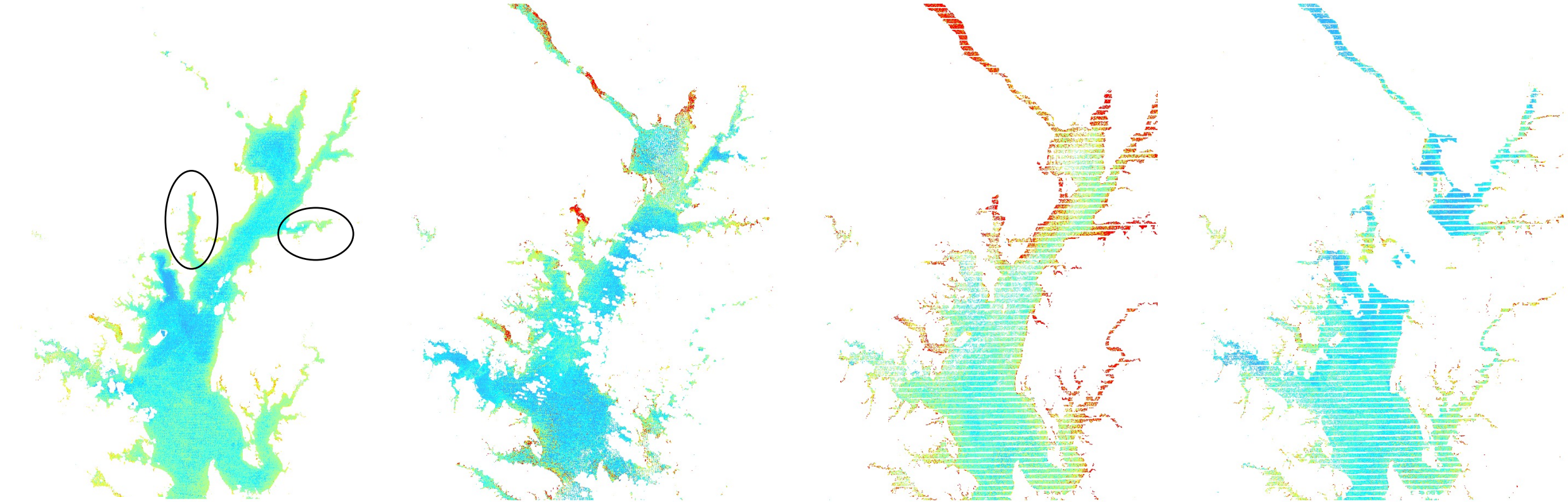
Sassafras River – CyanoHAB – Summer 2003

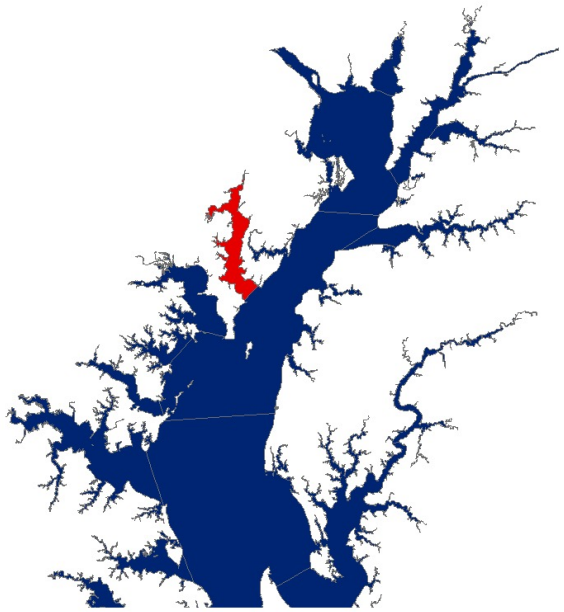
June 29

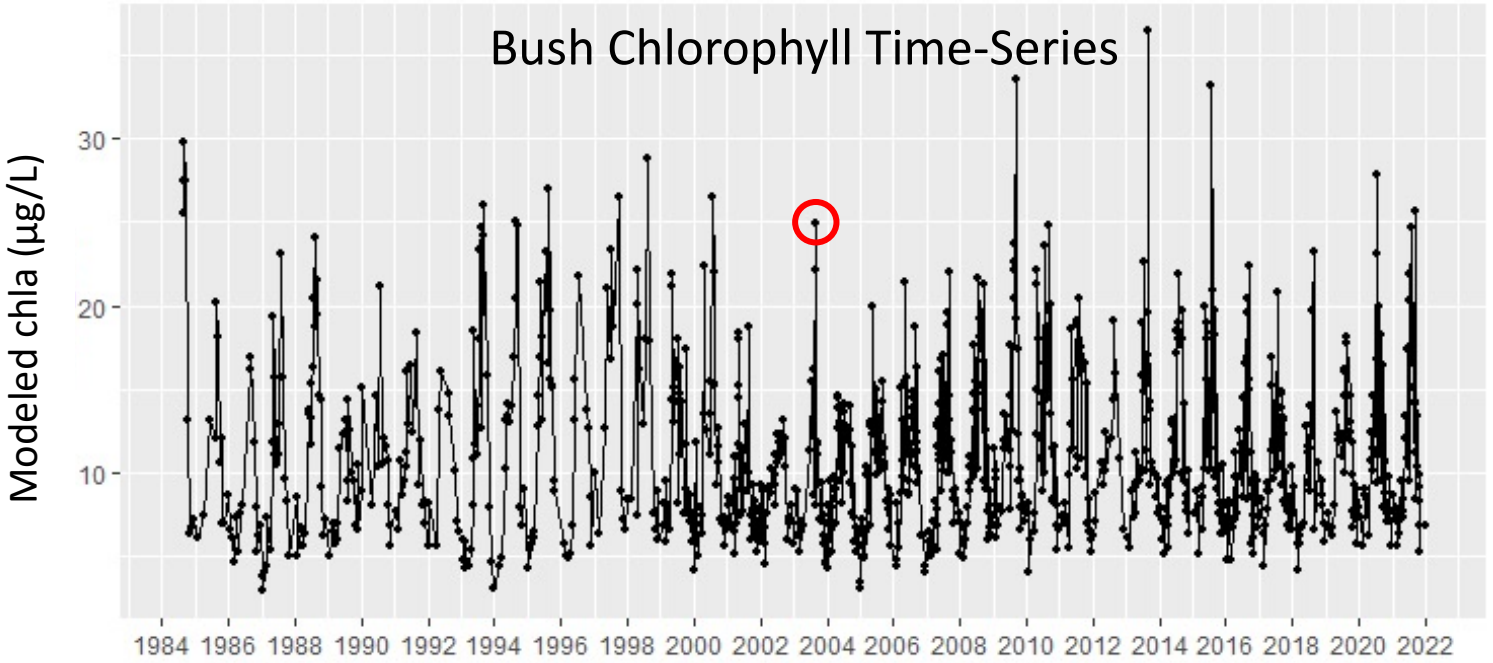
July 15

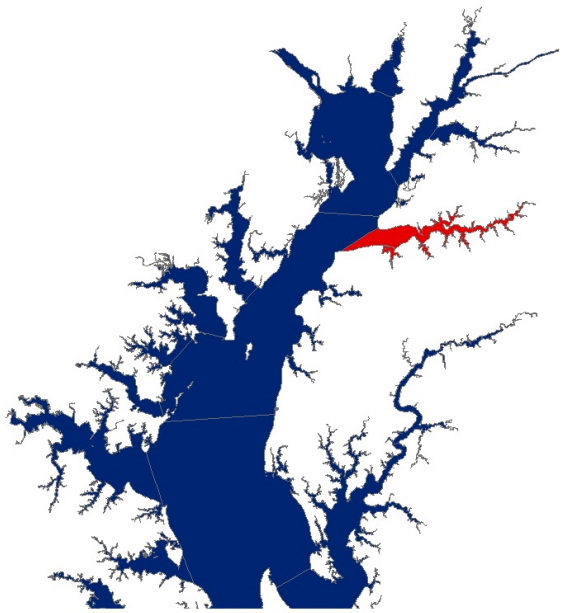
August 24

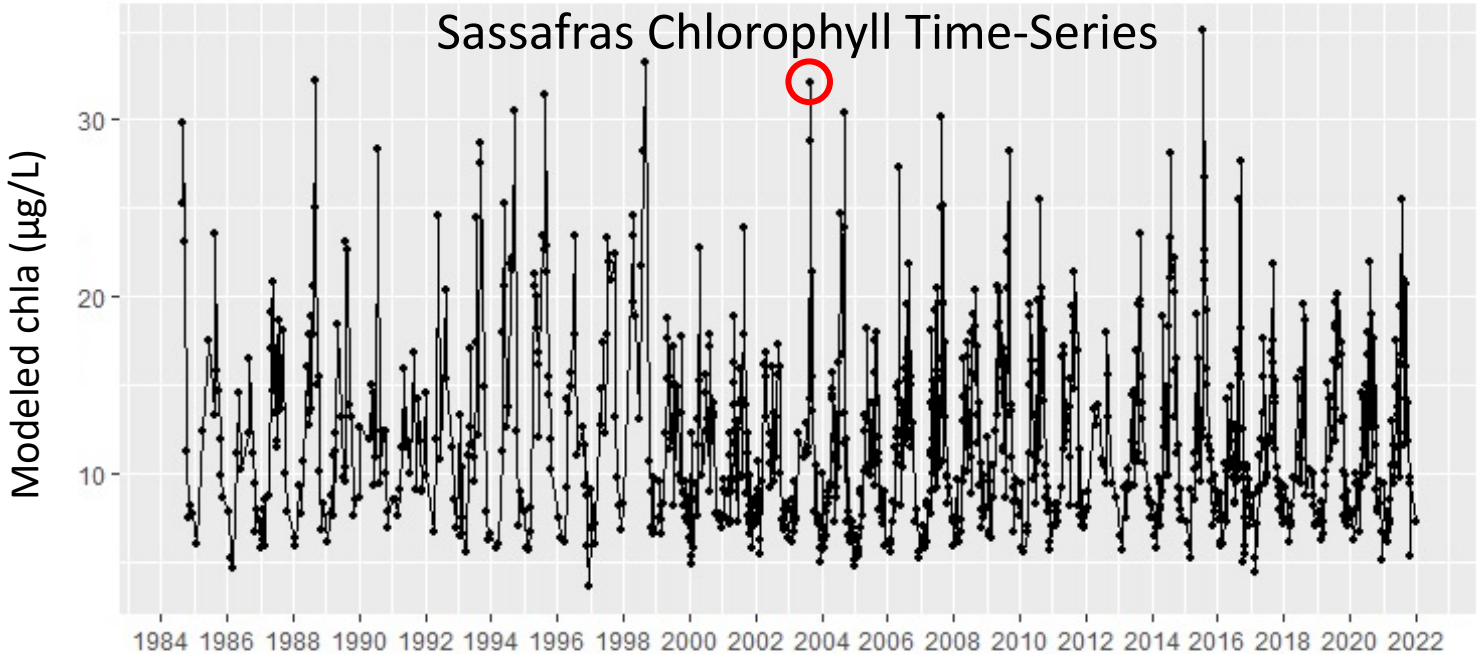
September 25





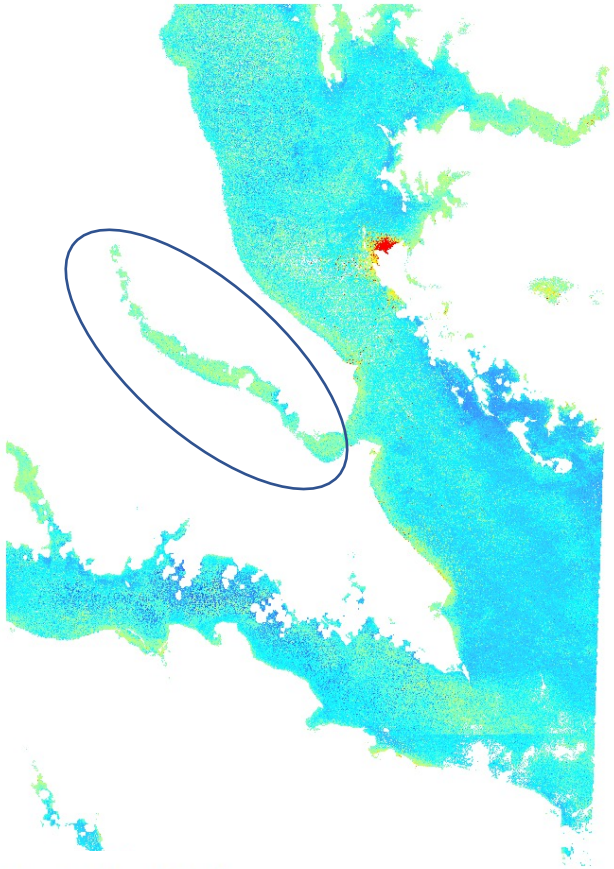

Bush Chlorophyll Time-Series
Modeled chla (µg/L)
30
20
10
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022



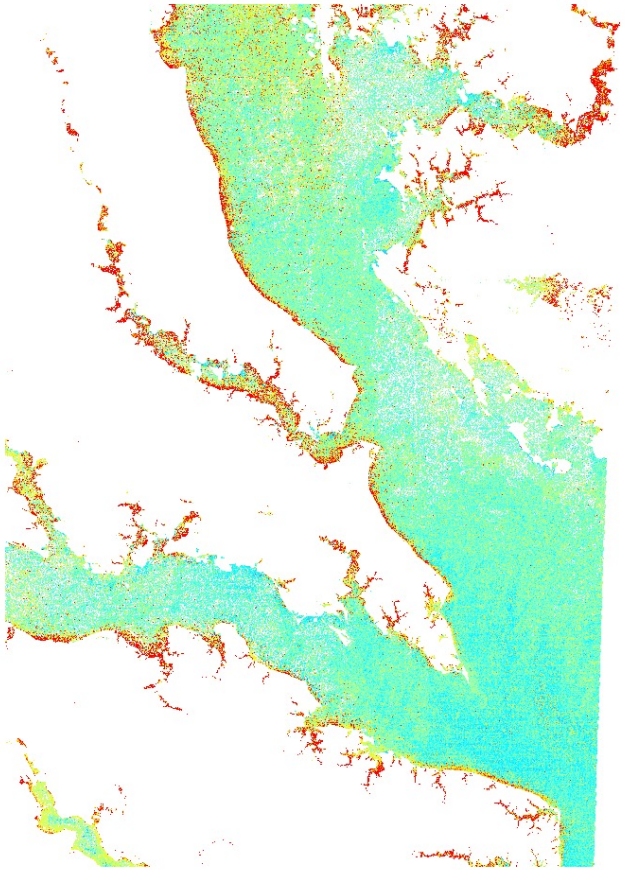

Sassafras Chlorophyll Time-Series
Modeled chla (µg/L)
30
20
10
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Patuxent River – P. minimum – August 1989

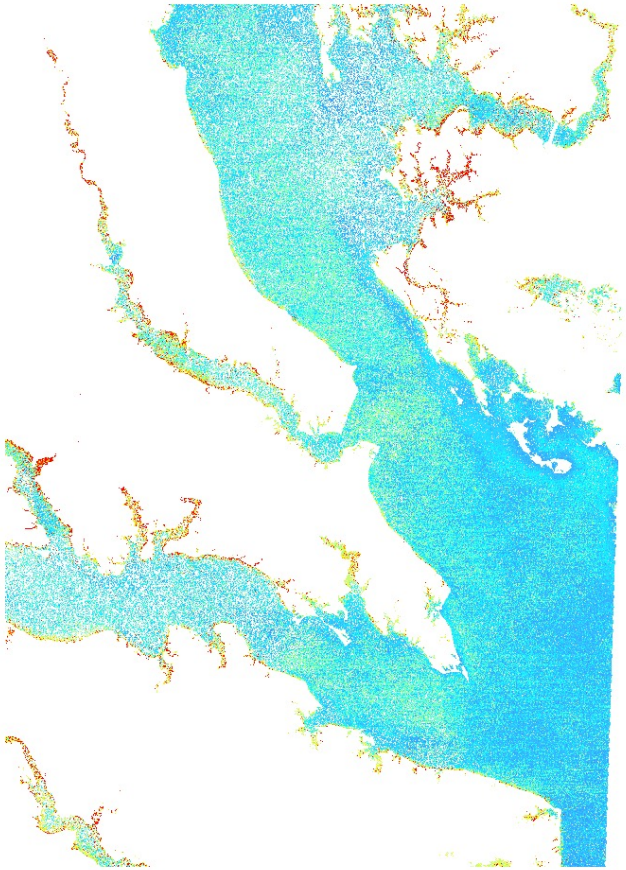
July 24

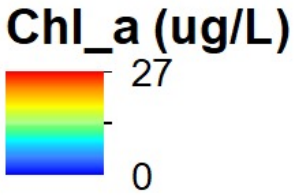


August 9

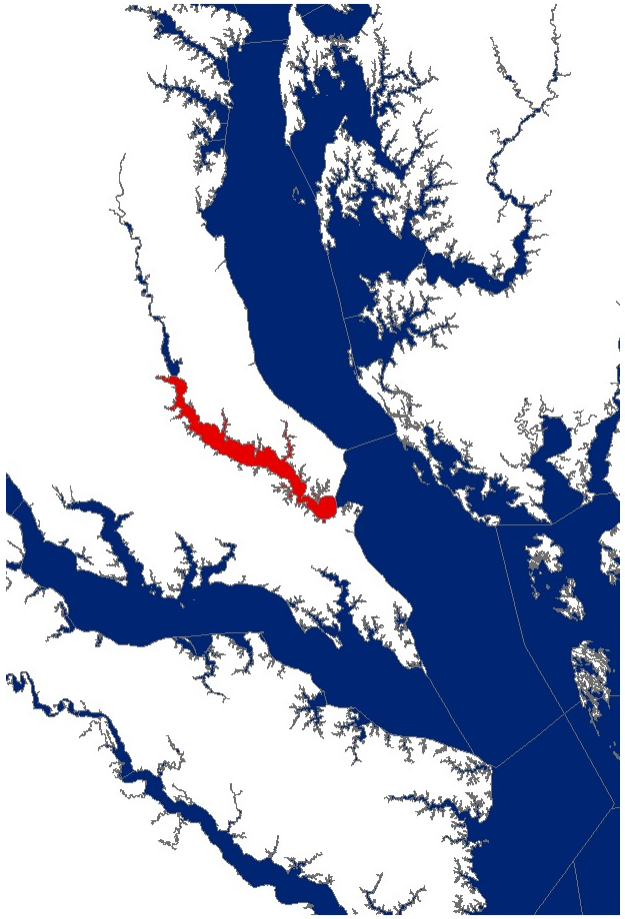


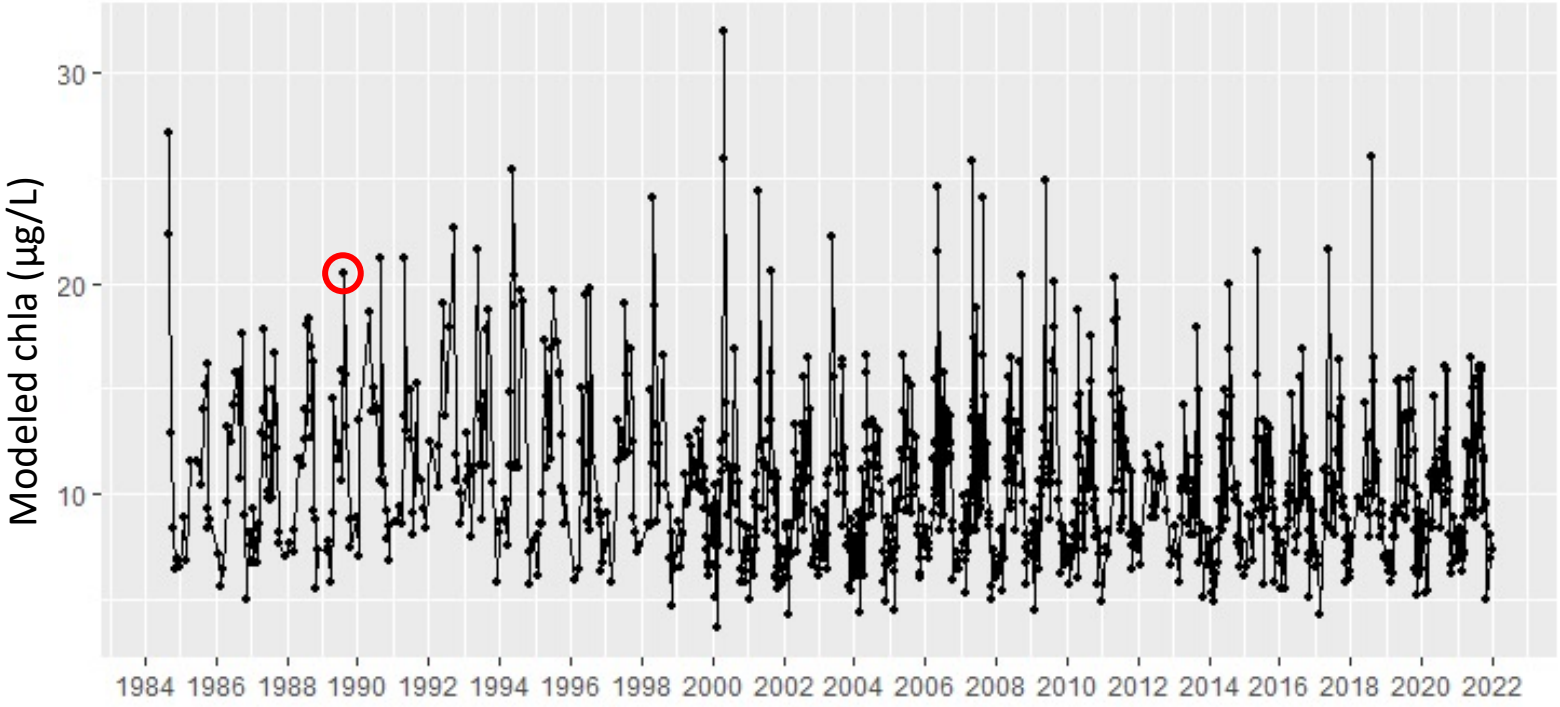
September 10



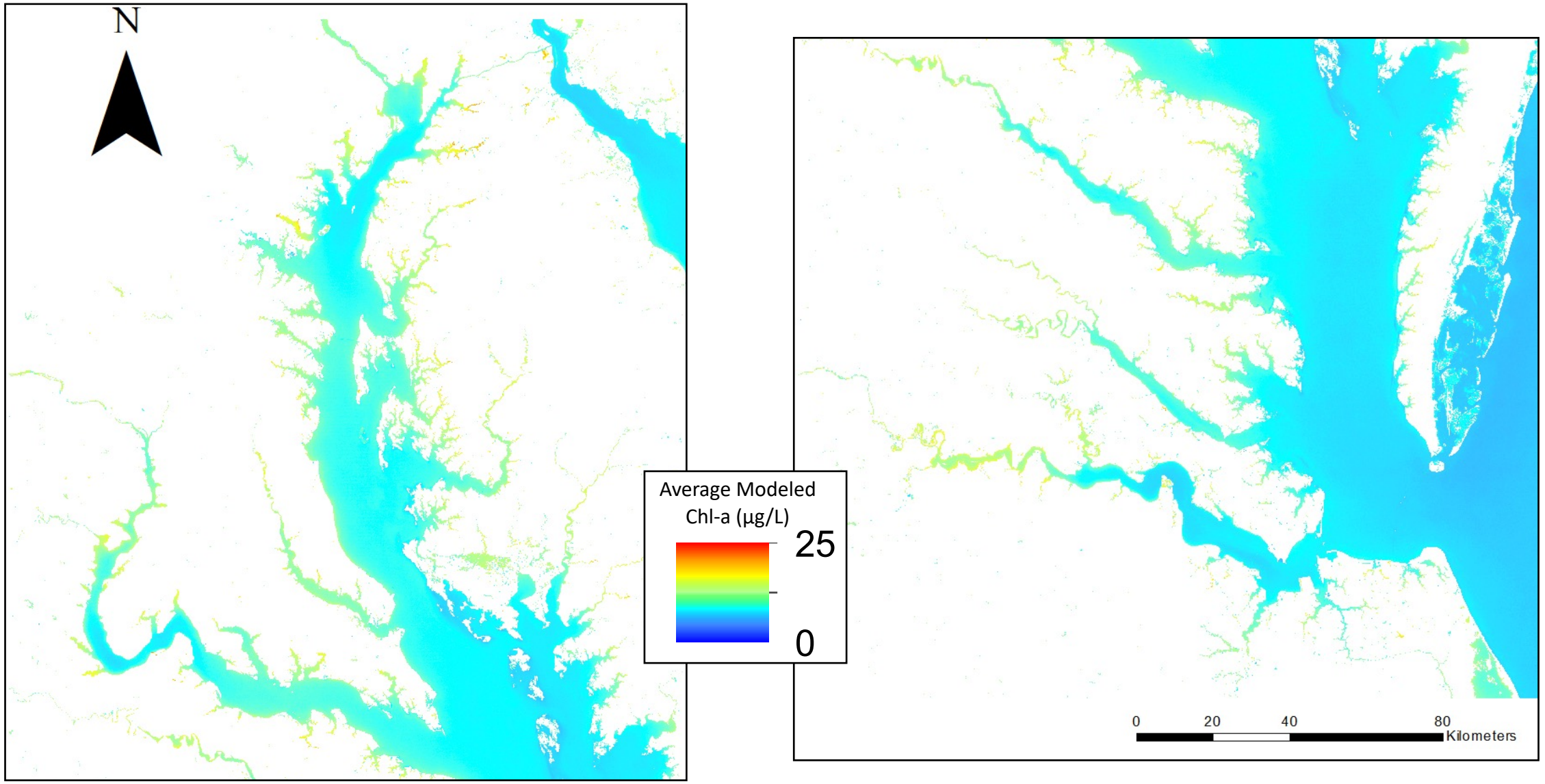


Patuxent Chlorophyll Time-Series





Average Modeled Chlorophyll 1984-2021



Thank You!

- Collaborators
  - Matthew Cashman
  - John Hammond
  - Mark Nardi

- Cooperative Funding
  - USGS NWQP for HABs
  - DNREC

USGS
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