NOAA-CESSRST

CENTER FOR EARTH SYSTEM SCIENCES &
REMOTE SENSING TECHNOLOGIES
(CESSRST-II)

A National Oceanic and Atmospheric Administration (NOAA) Educational Partnership Program with Minority Serving Institutions (EPP/MSI) Cooperative Science Center (CSC) since 2016 (**#NA22SEC4810016**)

Assessing the impact of extreme weather events on marsh organic matter in Long Island Sound using remote sensing platforms

CoastWatch Seminar
October 10, 2024

Charlotte Rhoads, Jonathan Sherman, Maria Tzortziou, Veronica Lance

The City College of New York · CUNY The City University of New York · UPR Recinto Universitario de Mayagüez · Hampton University The Standard of Excellence · UMBC · UTEP · SDSU San Diego State University

Introduction

- **MSI/EPP NOAA-CESSRST-II Cohort 2**
- **Degree Program & Institution:** MSc Candidate in Earth and Atmospheric Science at City College of New York
    - Tzortziou Bio-Optics Laboratory
- **Research focus:**
    - Optical signatures of Color Dissolved Organic Matter (CDOM) in Long Island Sound
        - *Is it possible to discriminate autochthonous CDOM from allochthonous CDOM from changes in spectral signatures?*
- **Academic background:**
    - Undergrad: Environmental Studies (concentrated in Physics and Sociology) with Mathematics and Hispanic Studies minors at Vassar College

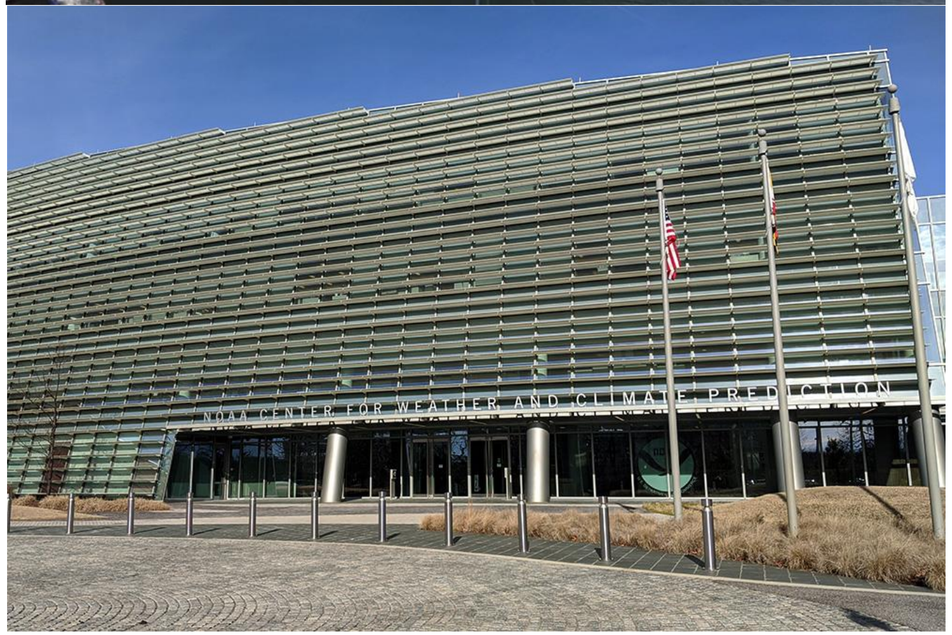


Collection of remote sensing reflectance (R_{rs}) in the field with a handheld radiometer during a Sentinel 2A overpass.

NERTO Experience

- **Format & Location:** Northeast Fisheries Science Center – Milford, CT and National Environmental Satellite, Data and Information Service - College Park, MD
- **Duration:** May 2023 -August 2023
- **NERTO/NOAA Mentors:** Veronica Lance, Jonathan Sherman, Gary Wilkfors, Lisa Guy
- **CESSRST-II Faculty Mentor:** Maria Tzortziou
- **Activities:**
  - NMFS/ NOAA Milford: *What is the optical signature of organic matter produced by Dinoflagellates in LIS ?*
  - NESDIS/ CoastWatch: *How does extreme precipitation impact the organic matter dynamics in nearshore environments in LIS?*

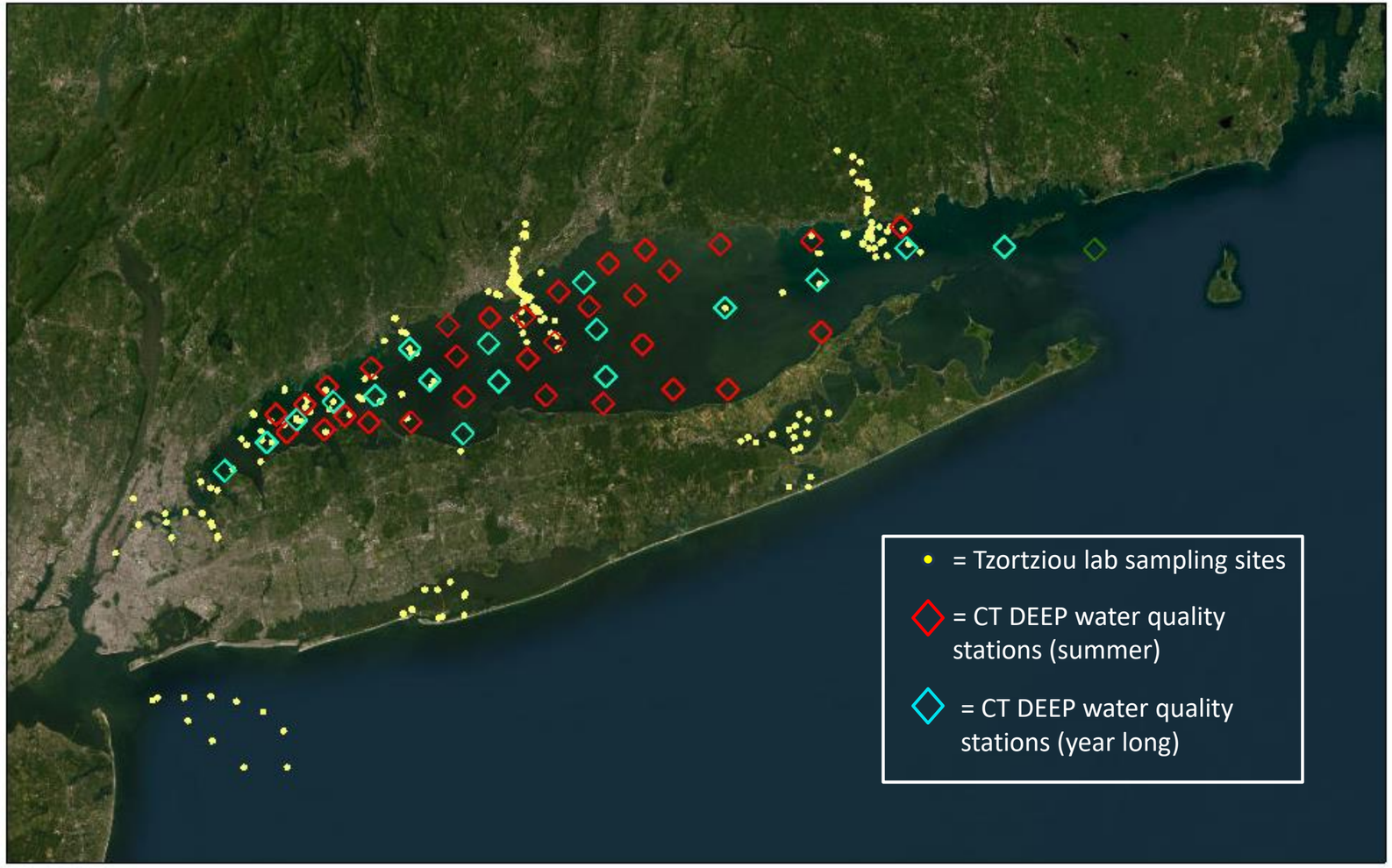




Images from Google.

Study area

- Long Island Sound (LIS), home to 9 million people, faces **persistent water quality challenges,** especially near New York City.
- Despite improvements in wastewater treatment, nearly **half of LIS's nitrogen comes from sewer sources** (Menendez & Tzortziou, 2024).
- LIS is a **net heterotrophic system** and contributes dissolved organic carbon (DOC) to the Mid-Atlantic Bight (Menendez & Tzortziou, 2024).
- Climate change, with increased storm frequency, will require constant **assessment of water quality** (Menendez & Tzortziou, 2024).



West vs. East LIS

- The **western Sound is more stagnant** and narrower, while the **eastern Sound has dynamic water** exchange with the Mid-Atlantic Bight (Cao & Tzortziou, 2024).

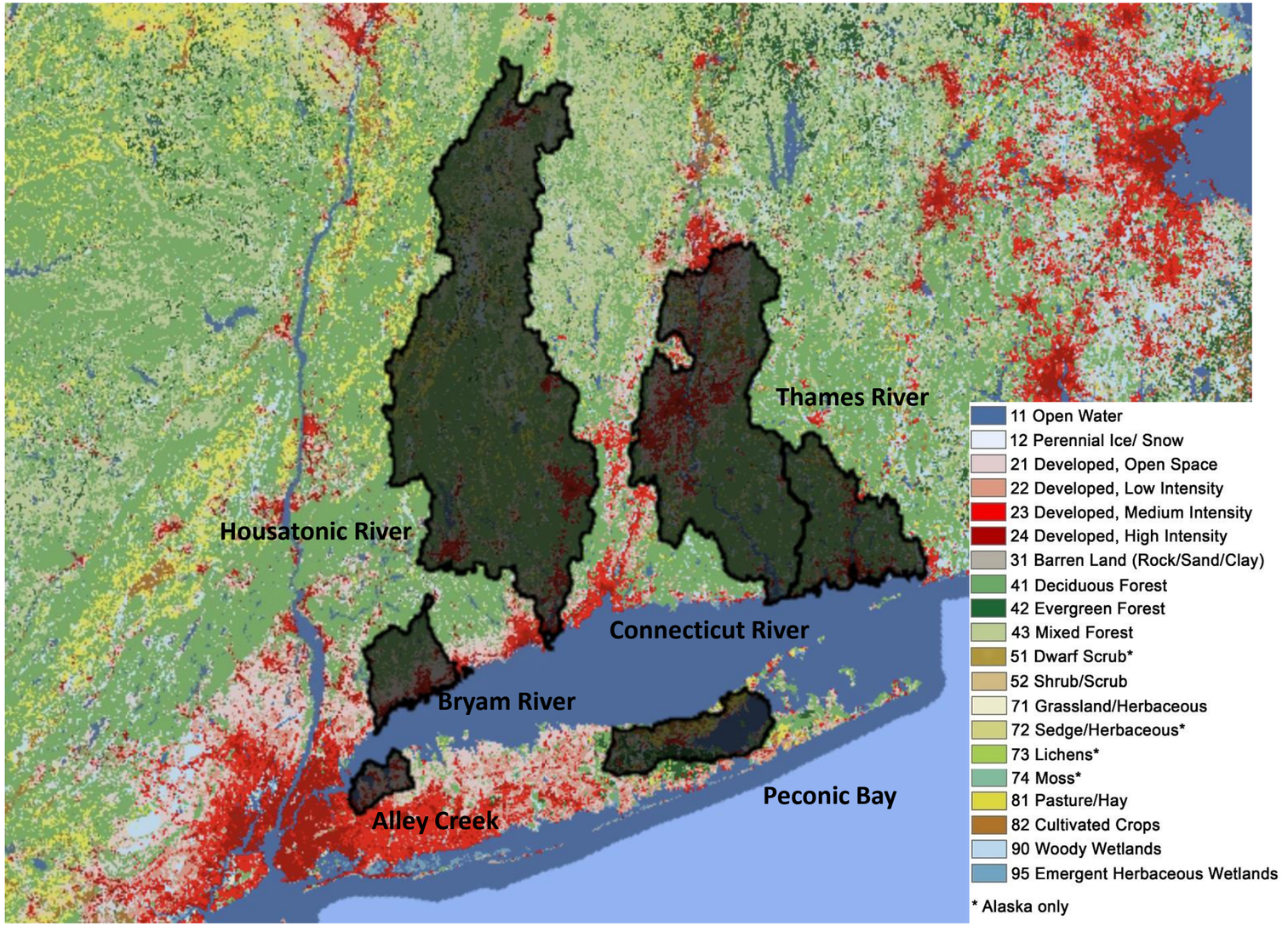
- The **nutrient-rich and polluted freshwater** from the Hudson and East Rivers flows into the **western LIS** (Cao & Tzortziou, 2024)

- The **western LIS consistently has poor water quality** due to high nutrient levels from human sources, leading to low water clarity, eutrophic conditions, and hypoxia (Menendez & Tzortziou, 2024).

North vs. South LIS

- Most of the **fresh water flowing into LIS originates from the north shore** (Cao & Tzortziou, 2024).

- **South shore has less major river systems**.



Background



Image from NASA (September 13, 2013).

Research Question: How do extreme precipitation events impact the dynamics of dissolved organic matter (DOM) at the exchange point between mainstem LIS and LIS marshes and estuaries? Do these weather events disrupt or enhance respective watershed dynamics as it pertains to water quality?

Objective: To leverage satellite data and the optical properties of organic matter and assess the effects of extreme weather on coastal water quality in nearshore environments.

Approach:

•**High-Resolution Satellite Imagery**: Utilize Sentinel-2A/B Multispectral Instrument (MSI) at 60 m resolution and Landsat-8/9 (OLI) at 30 m resolution.

•**Regionally Optimized Algorithm**: Apply a CDOM algorithm specific to LIS, developed by Alana Menendez and Maria Tzortziou (Menendez and Tzortizou, *in review*).

Water quality and optical signatures of carbon

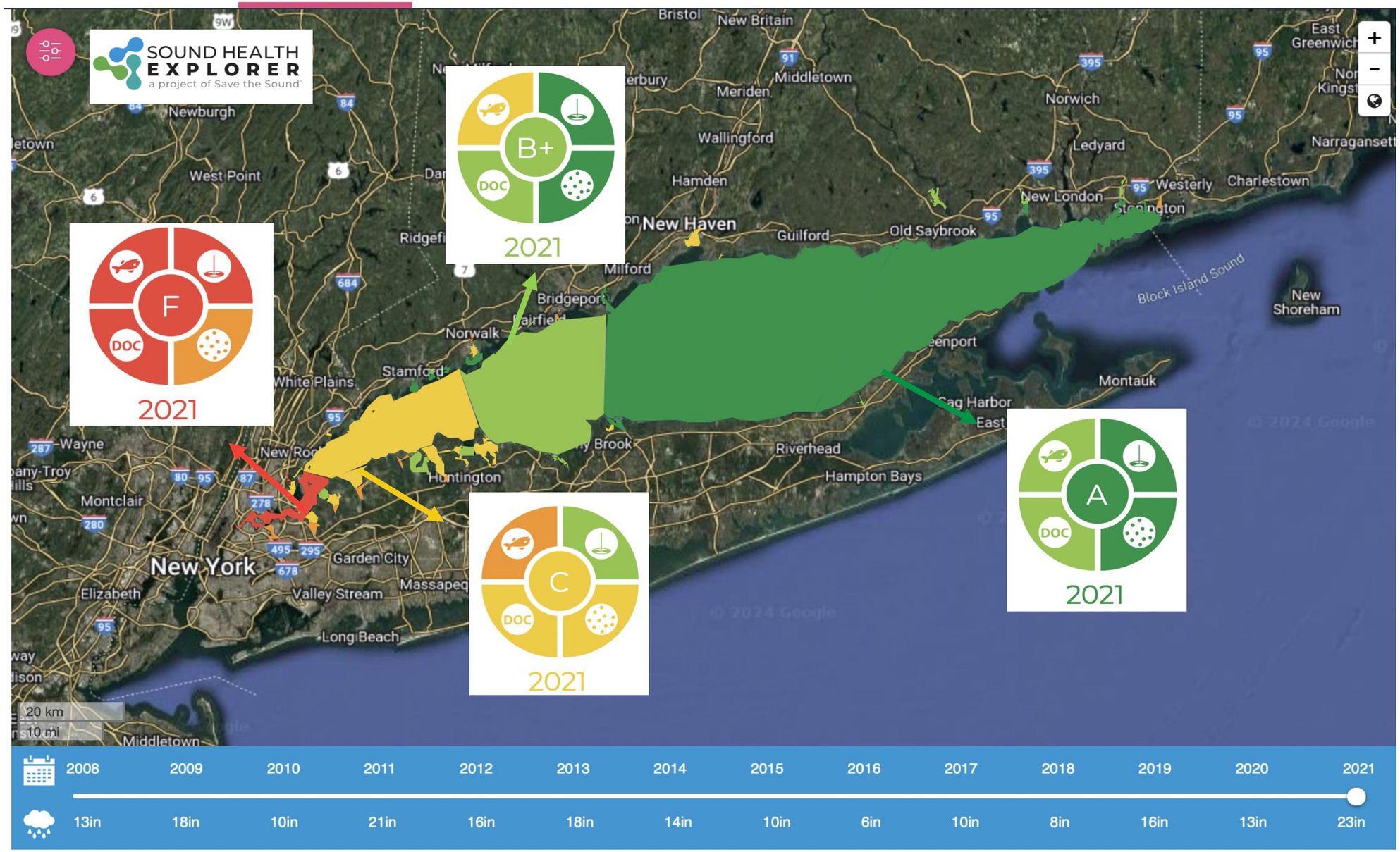
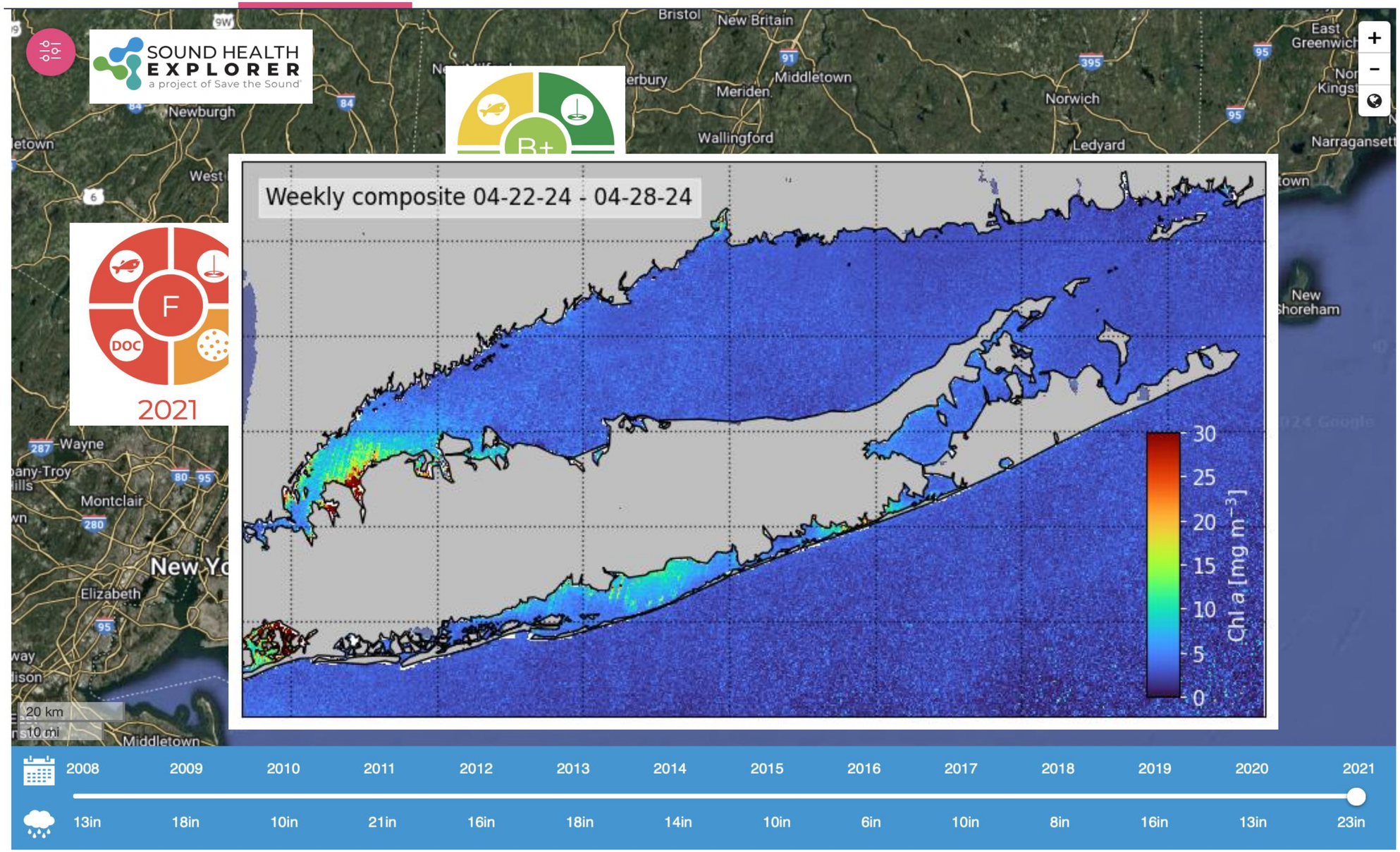
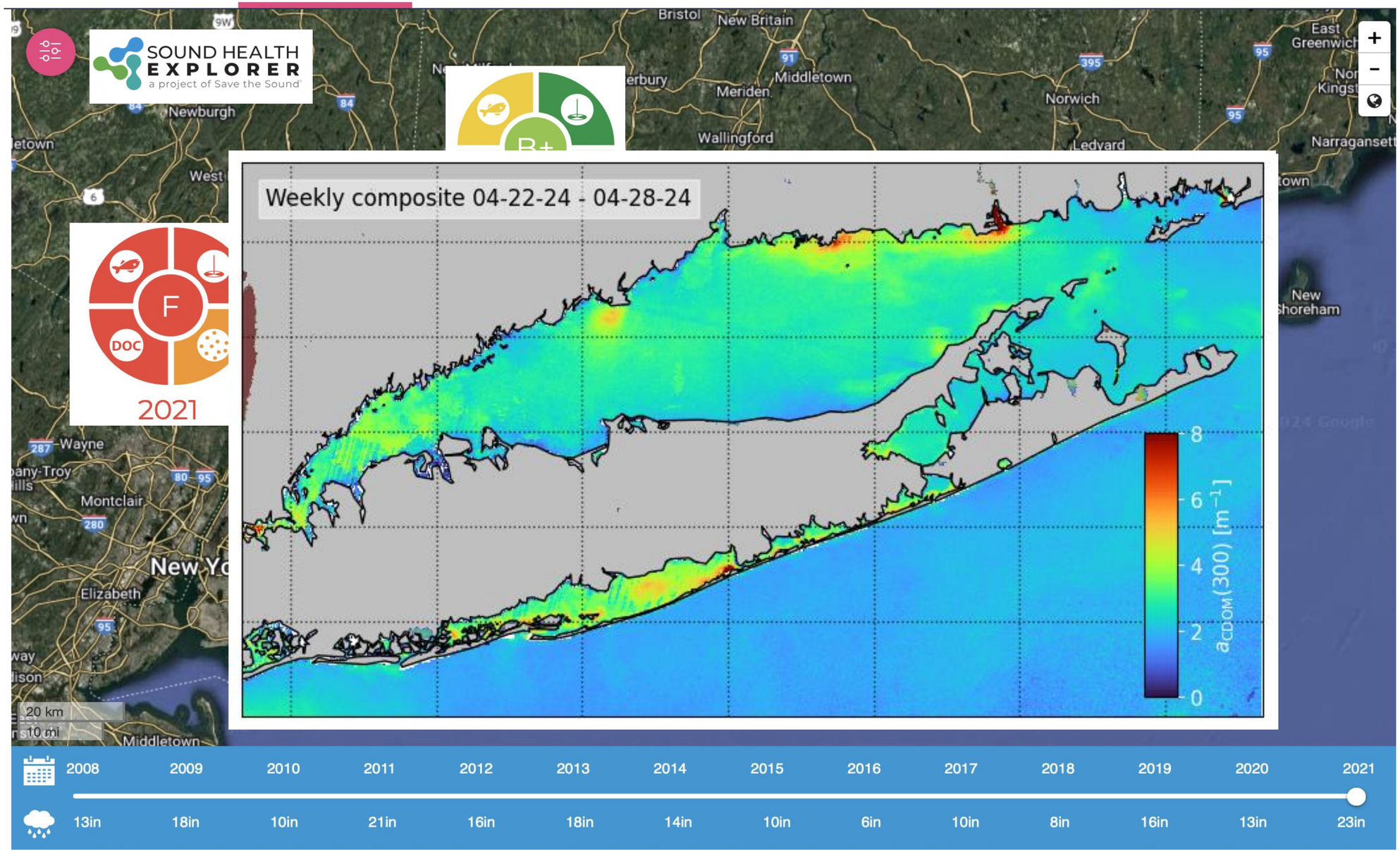


Image from Sound Health Explorer.



Polymer processed OLCI image, courtesy of Tong Lin.

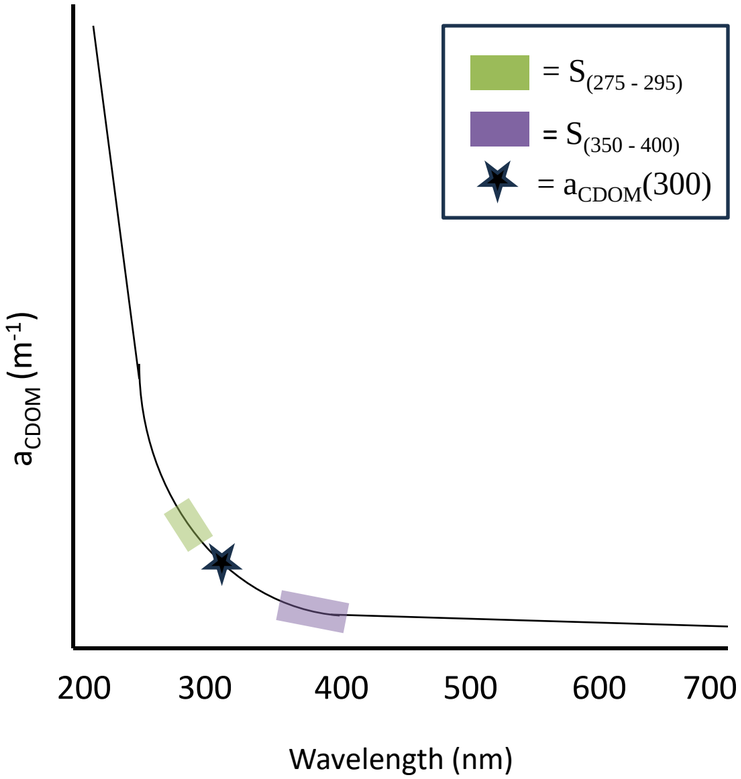


Polymer processed OLCI image, courtesy of Tong Lin.

CDOM (Colored Dissolved Organic Matter): Colored constituents of DOM that absorb UV to visible light. Optical proxy for monitoring DOM dynamics in nearshore ecosystems.

These optical properties help discern changes in CDOM from varying sources and processes, enhancing understanding of carbon cycling and water quality in nearshore environments:

- **$a_{CDOM}(300)$:** Light absorption by CDOM at 300 nm.
- **$S_{275–295}$:** Slope of aCDOM between 275 nm and 295 nm.
- **$S_{350–400}$:** Slope of aCDOM between 350 nm and 400 nm.
- **S_R (Slope Ratio):** Ratio of $S_{275–295}$ to $S_{350–400}$.
- **Dissolved Organic Carbon (DOC)**: Concentration of carbon within the DOM pool. DOC in coastal estuaries can be retrieved from $S_{275–295}$ and $a_{CDOM}(300)$ (Cao and Tzortziou, 2024).



- Spectral slope (S): the rate of exponential decrease in absorption is frequently utilized by researchers to characterize quality of DOM (eq. 1)
  - Limitation: results vary over which wavelength interval is calculated

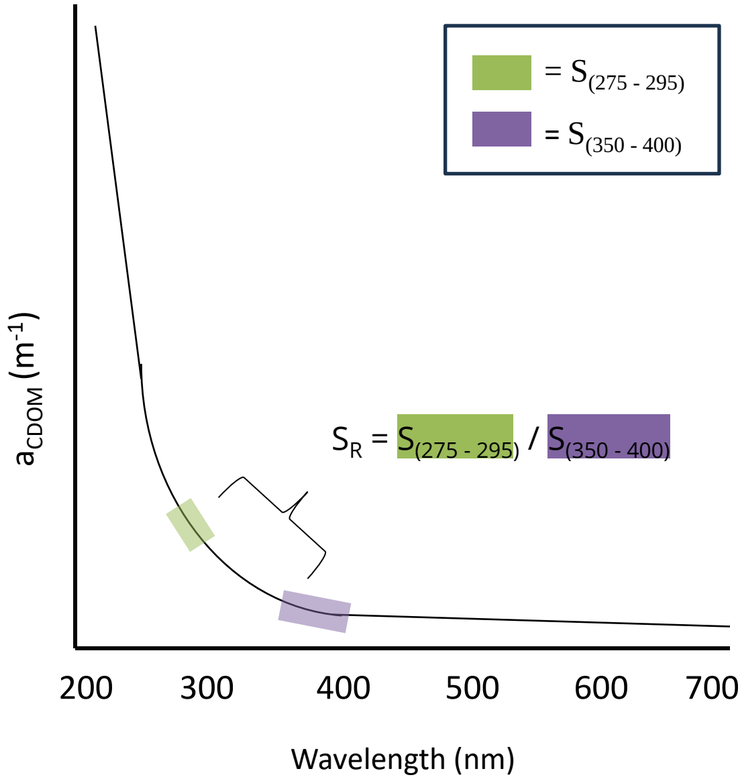
$$S = -\log(a_{CDOM}(\lambda)/ a_{CDOM}(\lambda_0)) / (\lambda-\lambda_0) \quad \text{(eq. 1)}$$

- Slope ratio (S_R) takes the ratio of the wavelength region of 275 nm to 295 nm to the region of 350 nm to 400 nm providing a dimensionless value (eq. 2).

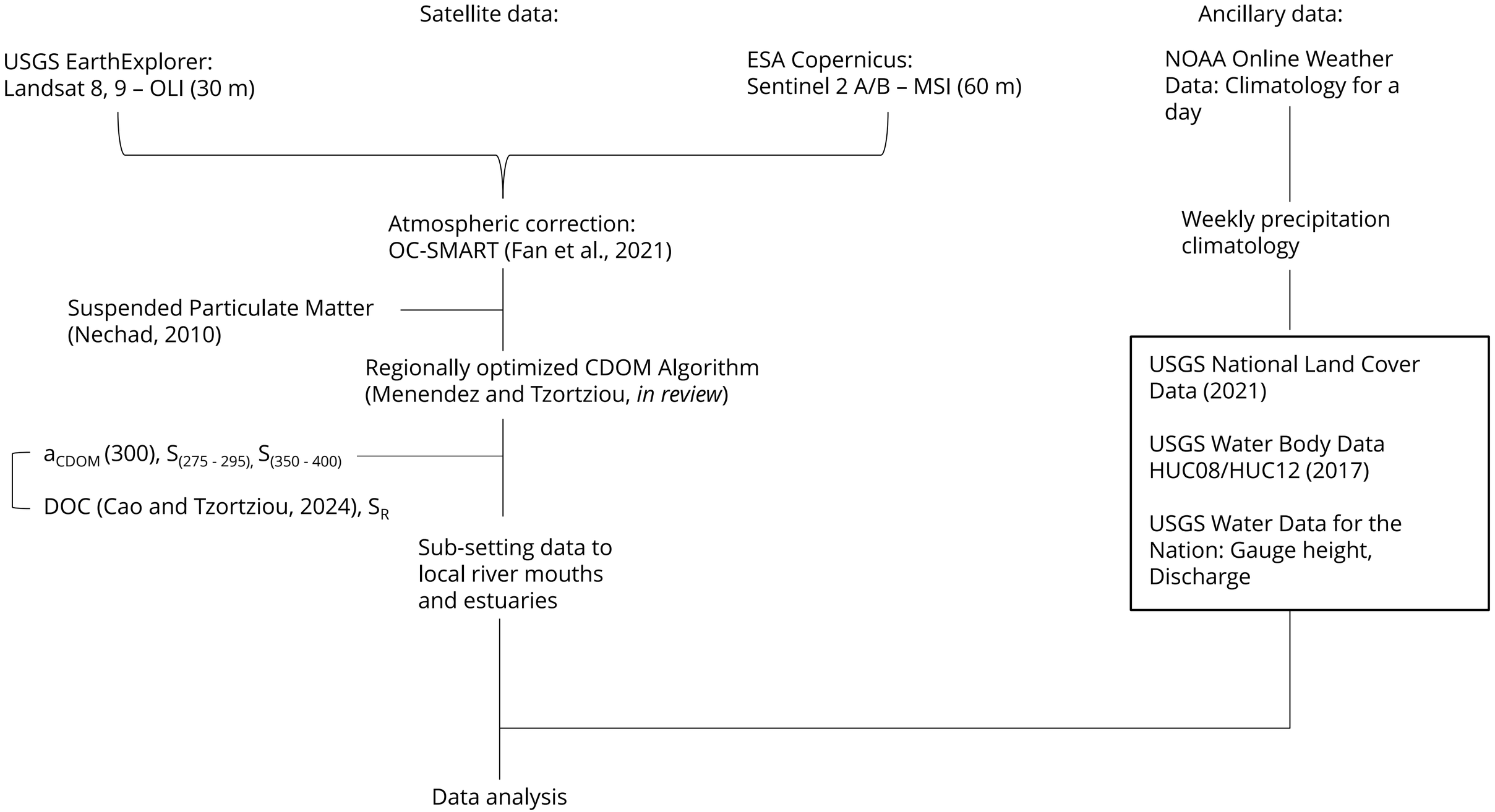
$$S_R = S_{(275 - 295)} / S_{(350 - 400)} \quad \text{(eq. 2)}$$

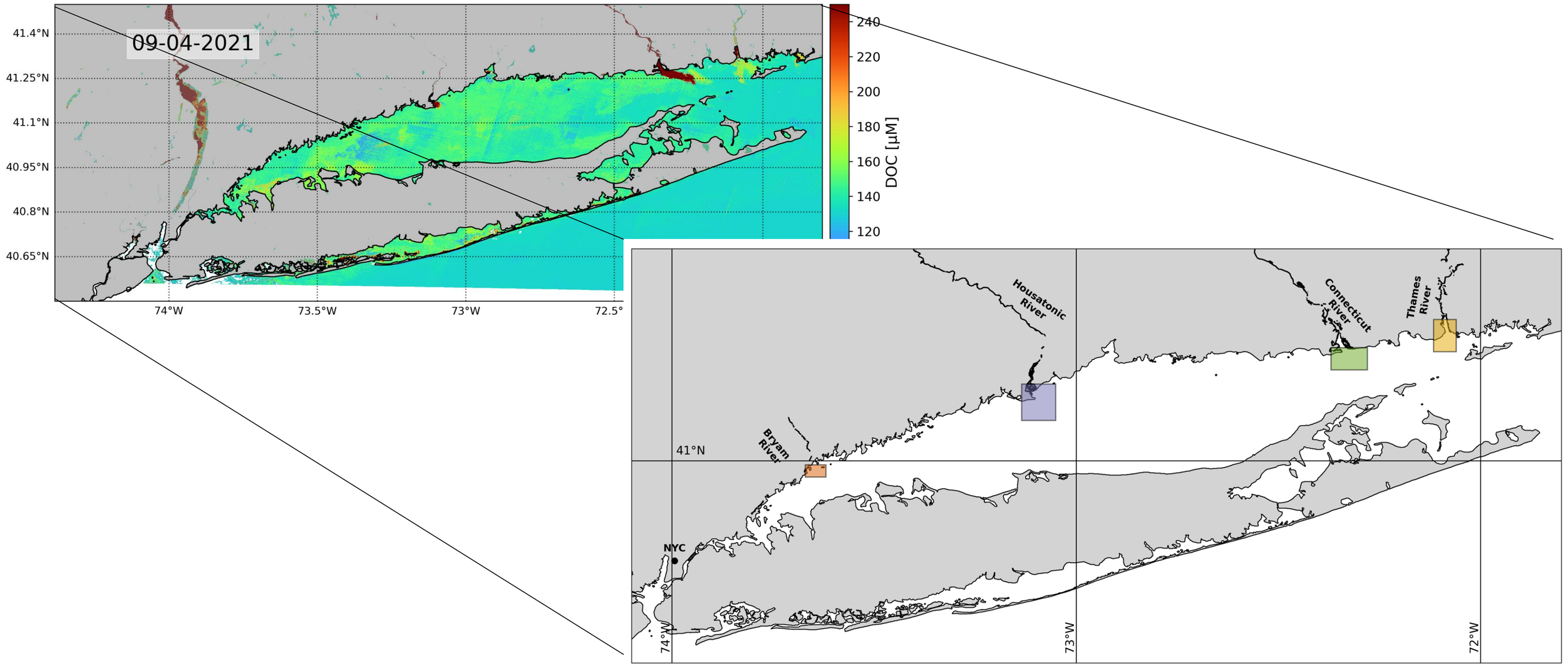
High S_R
- Marine origin
- High salinity
- Low concentrations CDOM
- HMW CDOM
- Photobleaching

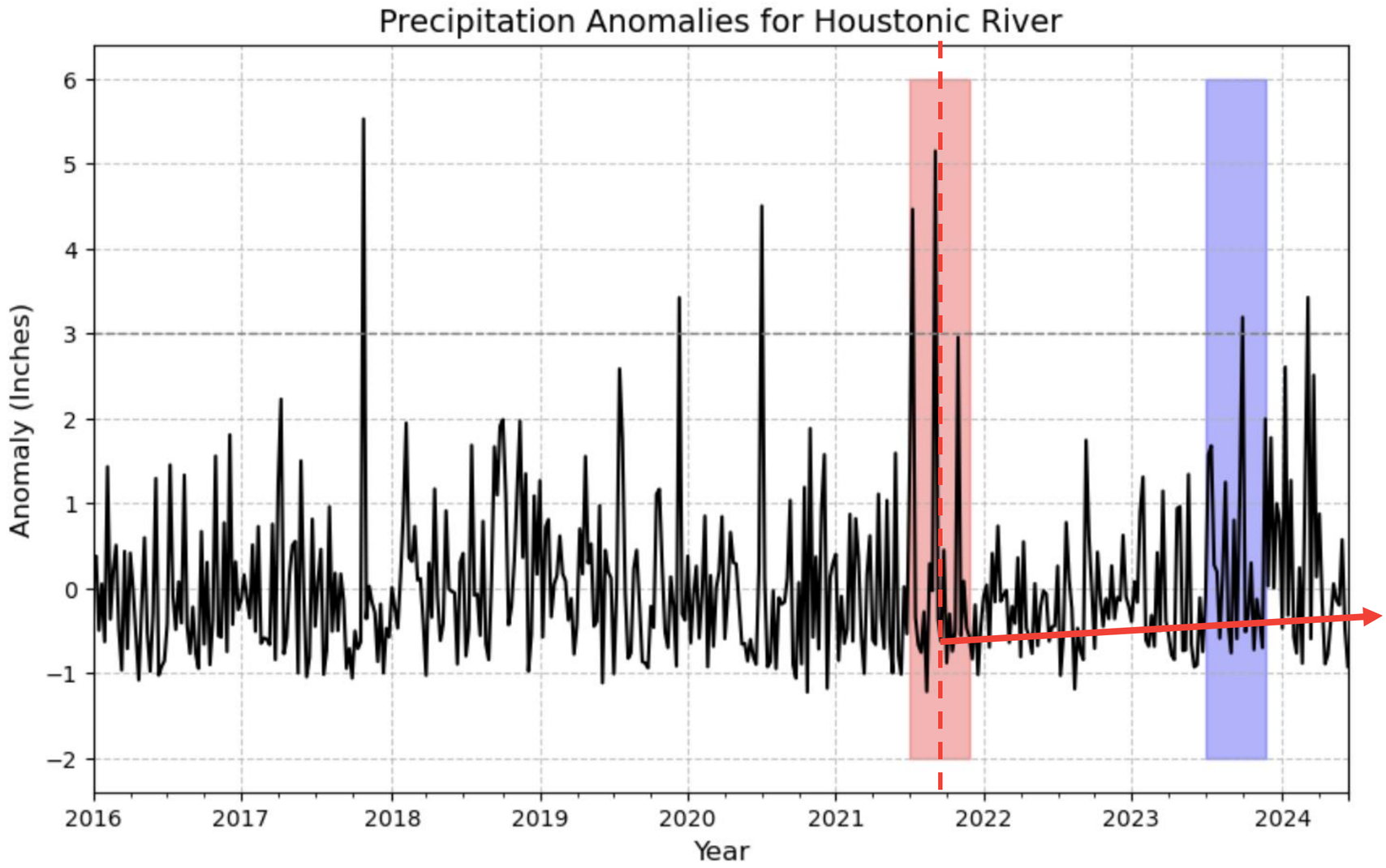
Low S_R
- Terrestrial origin
- Low salinity
- High concentrations of CDOM
- LMW CDOM
- Microbial degradation

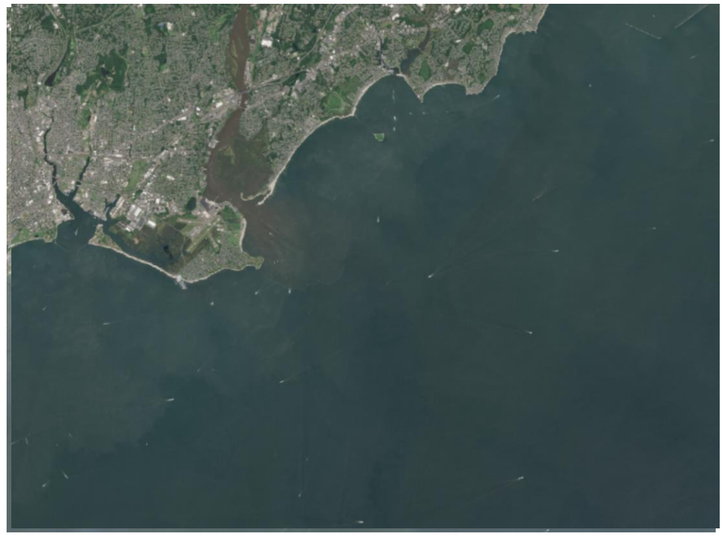


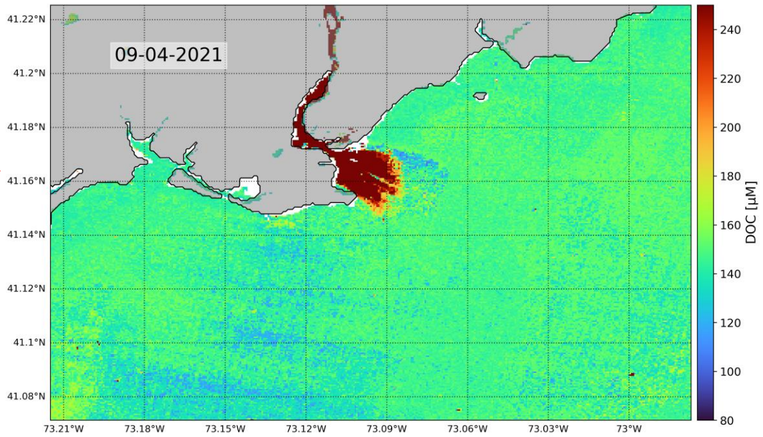
Methodology

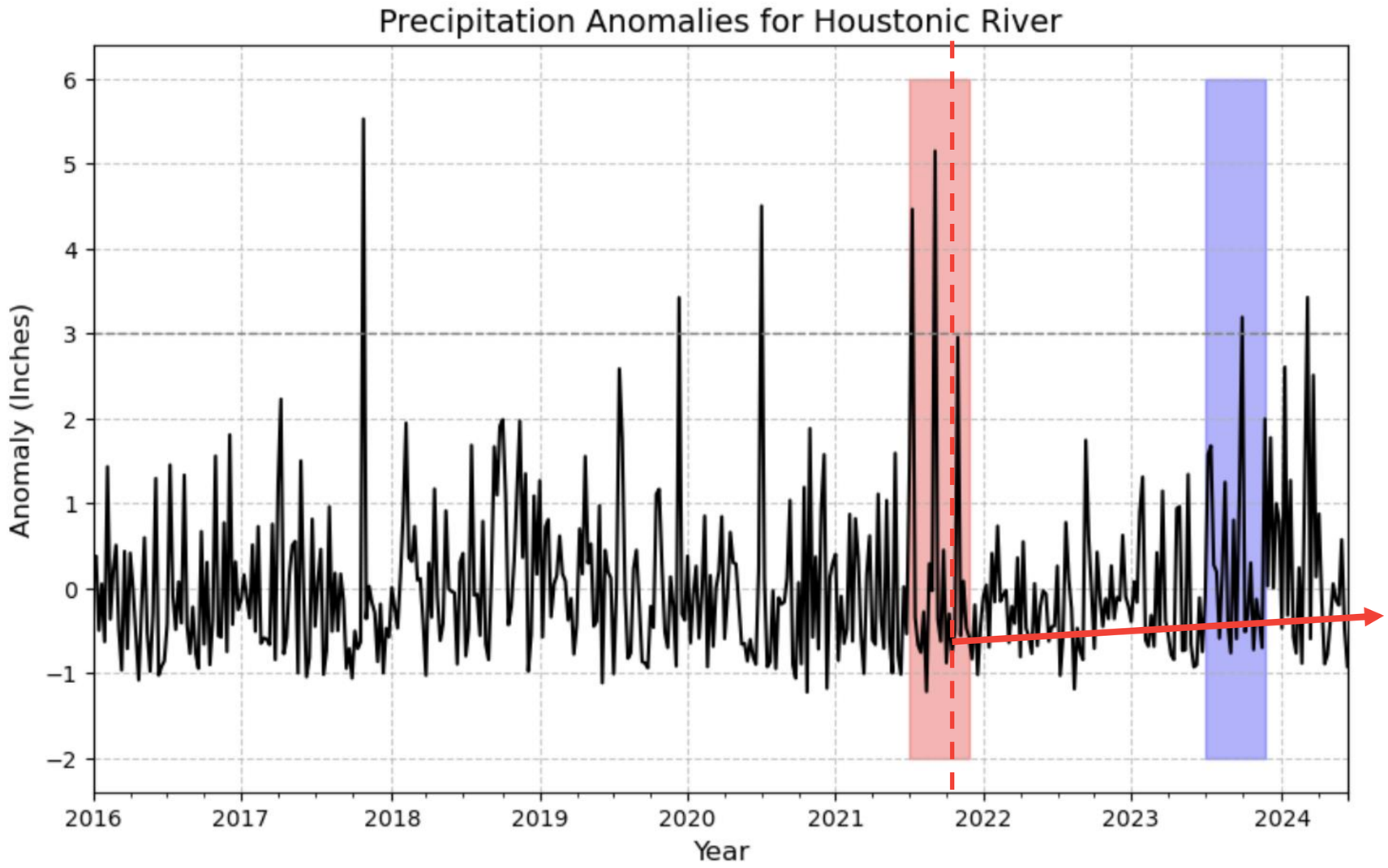

Satellite data:
Ancillary data:
USGS EarthExplorer:
Landsat 8, 9 – OLI (30 m)
ESA Copernicus:
Sentinel 2 A/B – MSI (60 m)
NOAA Online Weather Data: Climatology for a day
Atmospheric correction:
OC-SMART (Fan et al., 2021)
Weekly precipitation climatology
Suspended Particulate Matter
(Nechad, 2010)
Regionally optimized CDOM Algorithm
(Menendez and Tzortziou, in review)
USGS National Land Cover Data (2021)
USGS Water Body Data HUC08/HUC12 (2017)
USGS Water Data for the Nation: Gauge height, Discharge
a_CDOM (300), S_(275 - 295), S_(350 - 400)
DOC (Cao and Tzortziou, 2024), S_R
Sub-setting data to local river mouths and estuaries
Data analysis

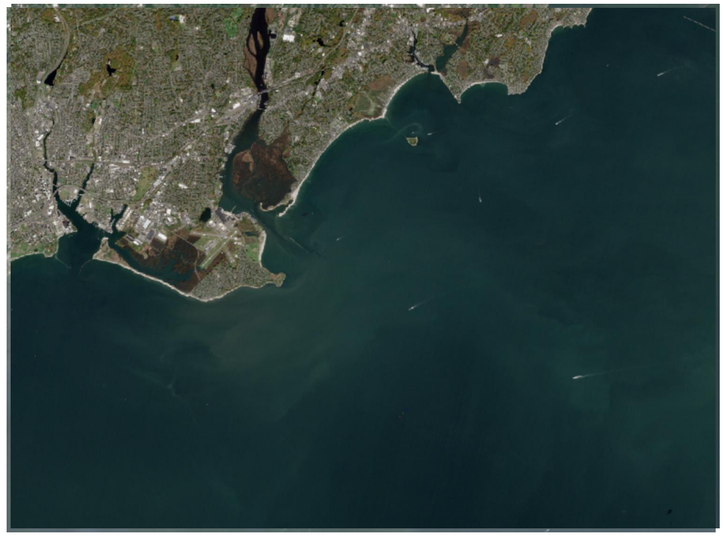

09-04-2021
41.4°N
41.25°N
41.1°N
40.95°N
40.8°N
40.65°N
74°W
73.5°W
73°W
72.5°
240
220
200
180
160
140
120
DOC [µM]
Housatonic River
Connecticut River
Thames River
Bryam River
41°N
NYC
74°W
73°W
72°W

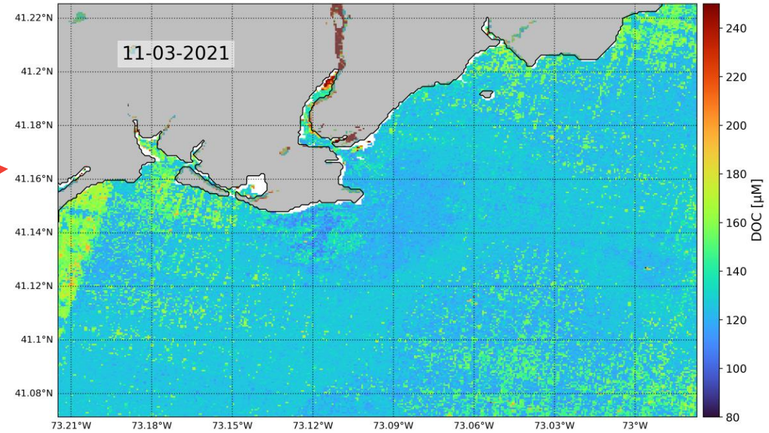

Precipitation Anomalies for Houstonic River
Anomaly (Inches)
6
5
4
3
2
1
0
−1
−2
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year

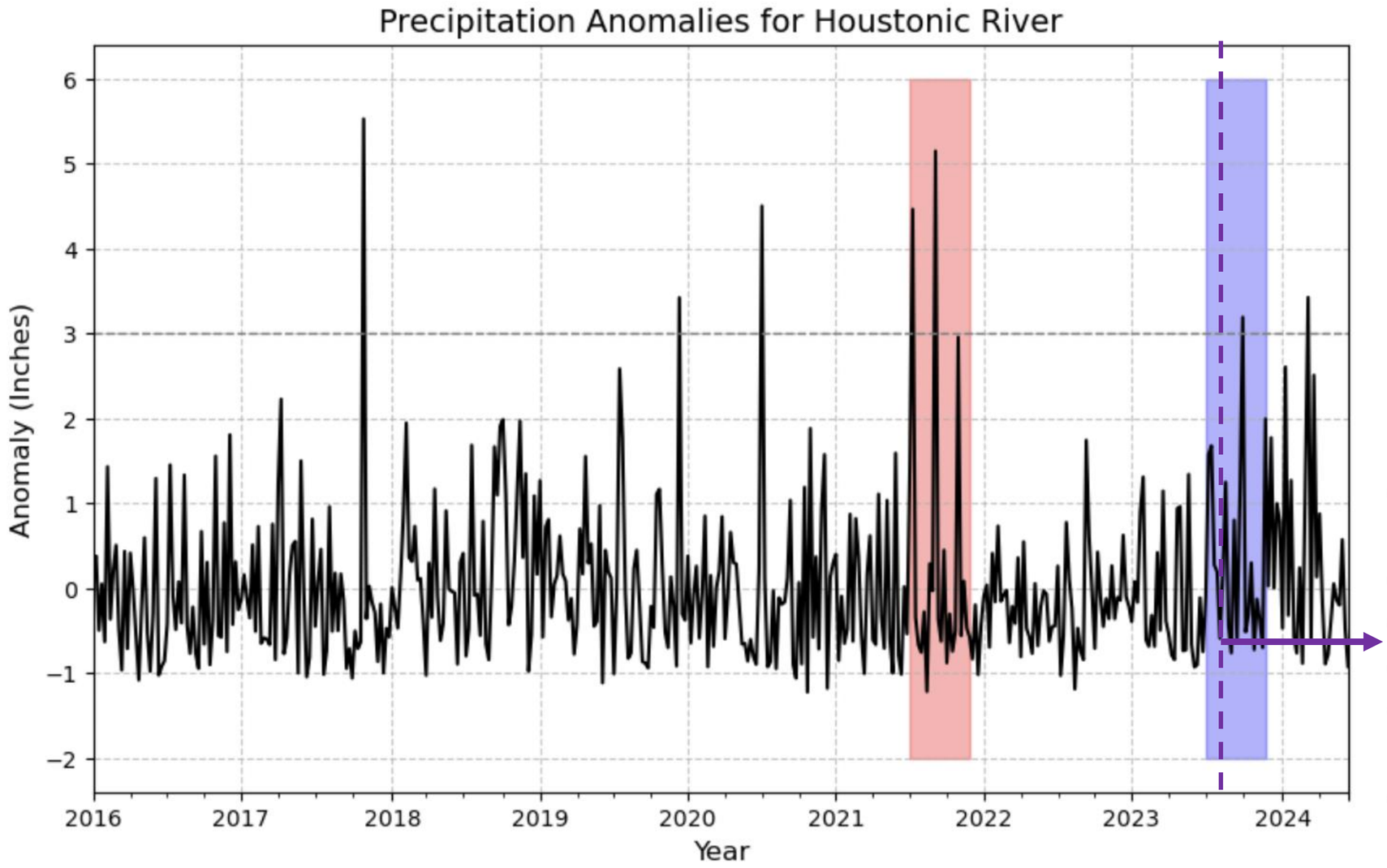



09-04-2021
41.22°N
41.2°N
41.18°N
41.16°N
41.14°N
41.12°N
41.1°N
41.08°N
73.21°W
73.18°W
73.15°W
73.12°W
73.09°W
73.06°W
73.03°W
73°W
DOC [µM]
240
220
200
180
160
140
120
100
80

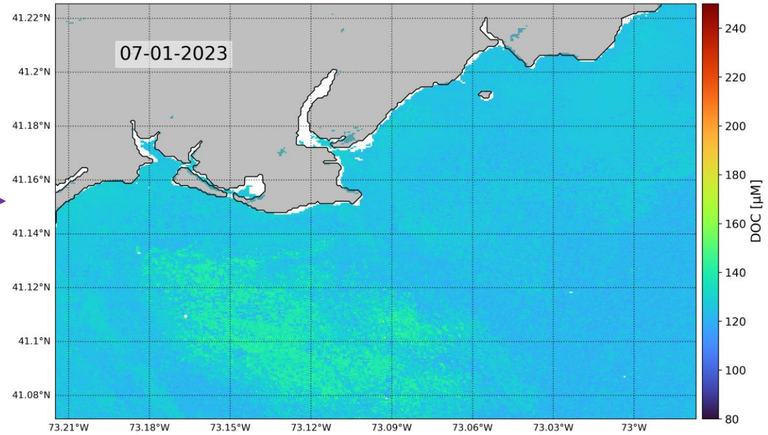

Precipitation Anomalies for Houstonic River
Anomaly (Inches)
6
5
4
3
2
1
0
−1
−2
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year

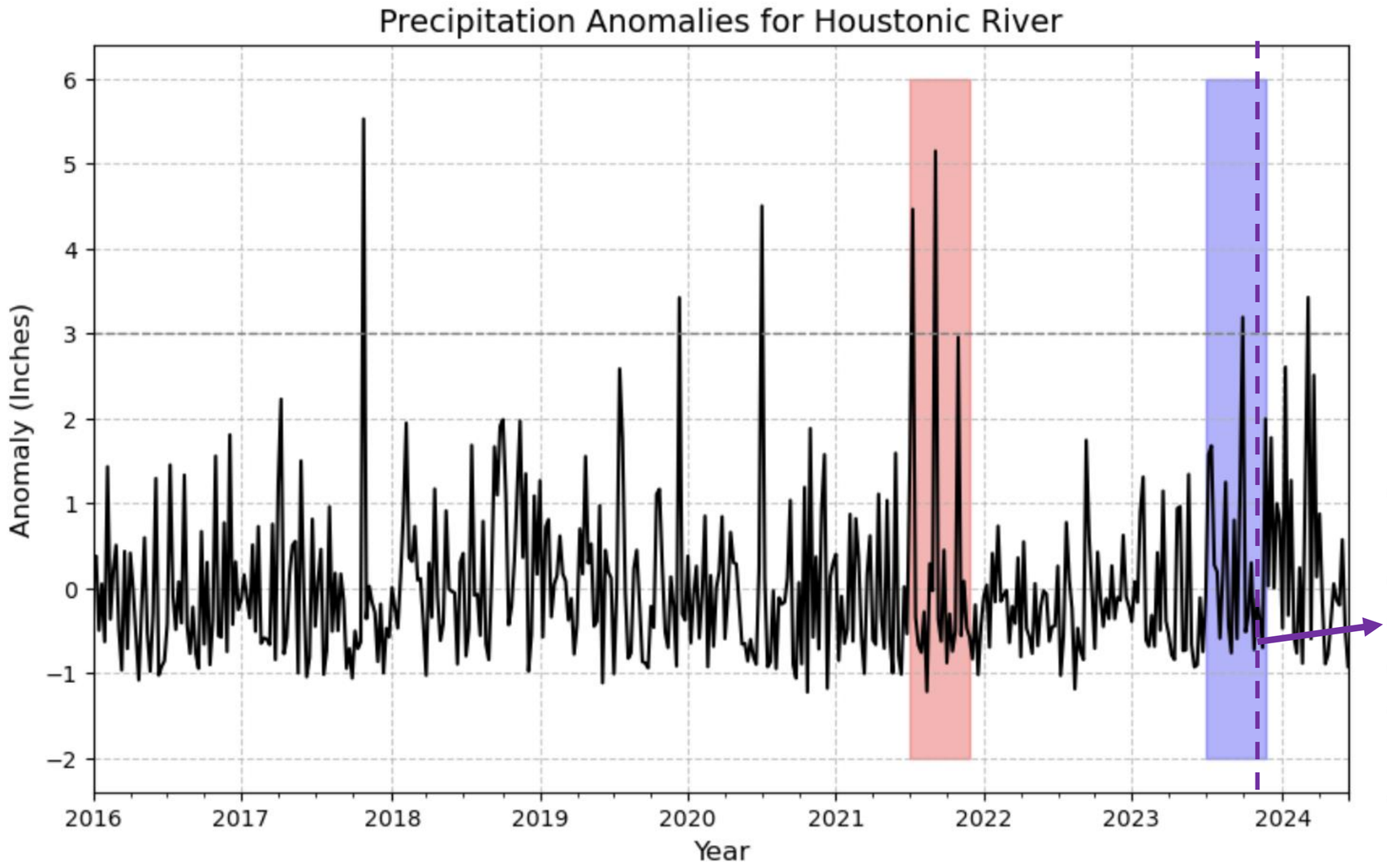


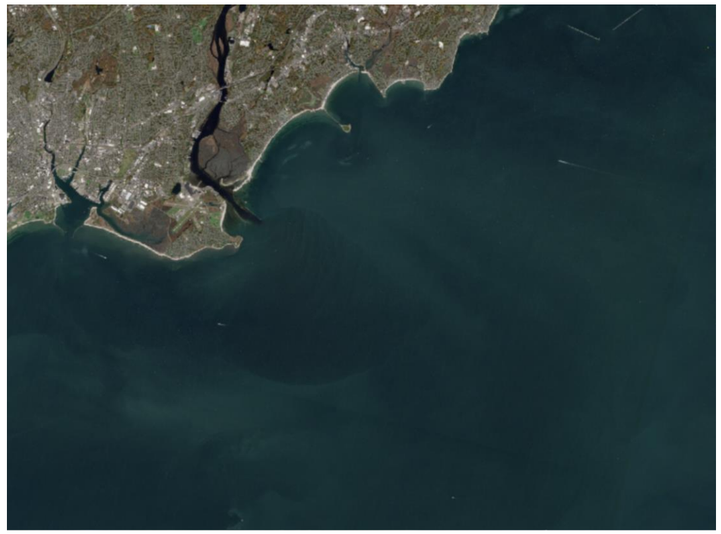

11-03-2021
41.22°N
41.2°N
41.18°N
41.16°N
41.14°N
41.12°N
41.1°N
41.08°N
73.21°W
73.18°W
73.15°W
73.12°W
73.09°W
73.06°W
73.03°W
73°W
240
220
200
180
160
140
120
100
80
DOC [µM]

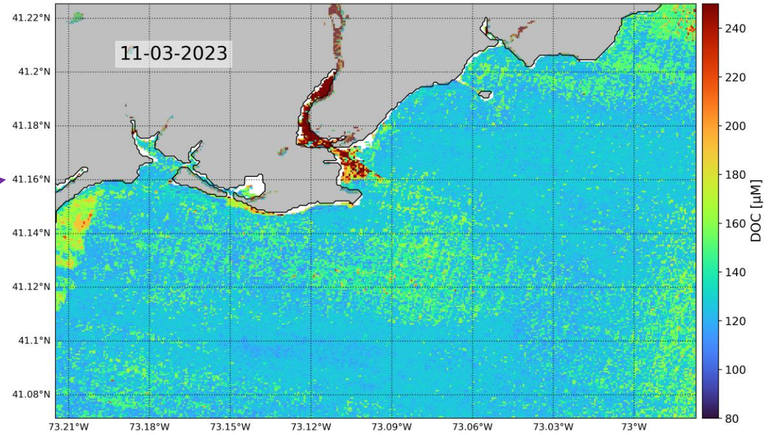

Precipitation Anomalies for Houstonic River
Anomaly (Inches)
6
5
4
3
2
1
0
−1
−2
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year



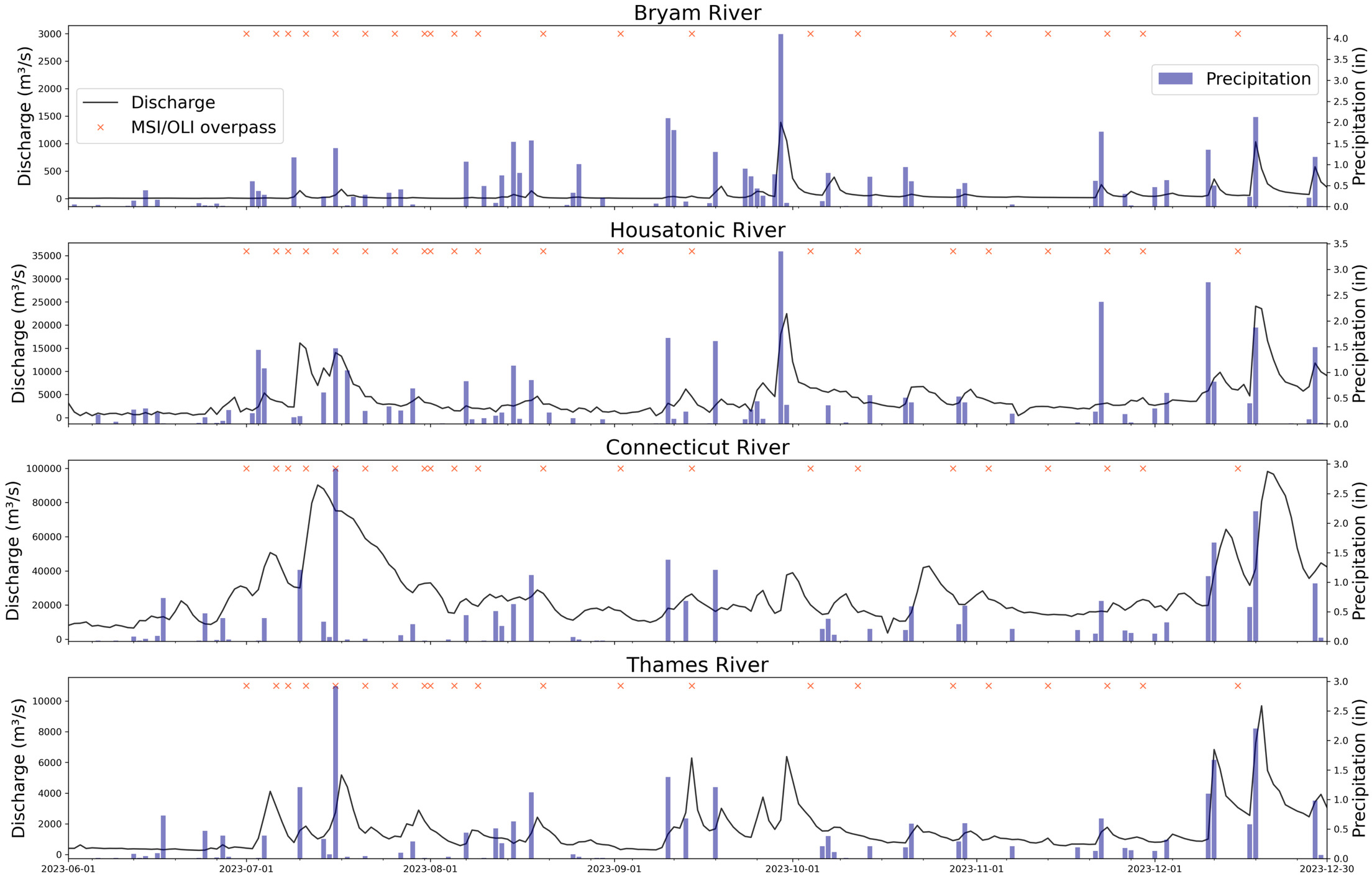

07-01-2023
41.22°N
41.2°N
41.18°N
41.16°N
41.14°N
41.12°N
41.1°N
41.08°N
73.21°W
73.18°W
73.15°W
73.12°W
73.09°W
73.06°W
73.03°W
73°W
DOC [µM]
240
220
200
180
160
140
120
100
80

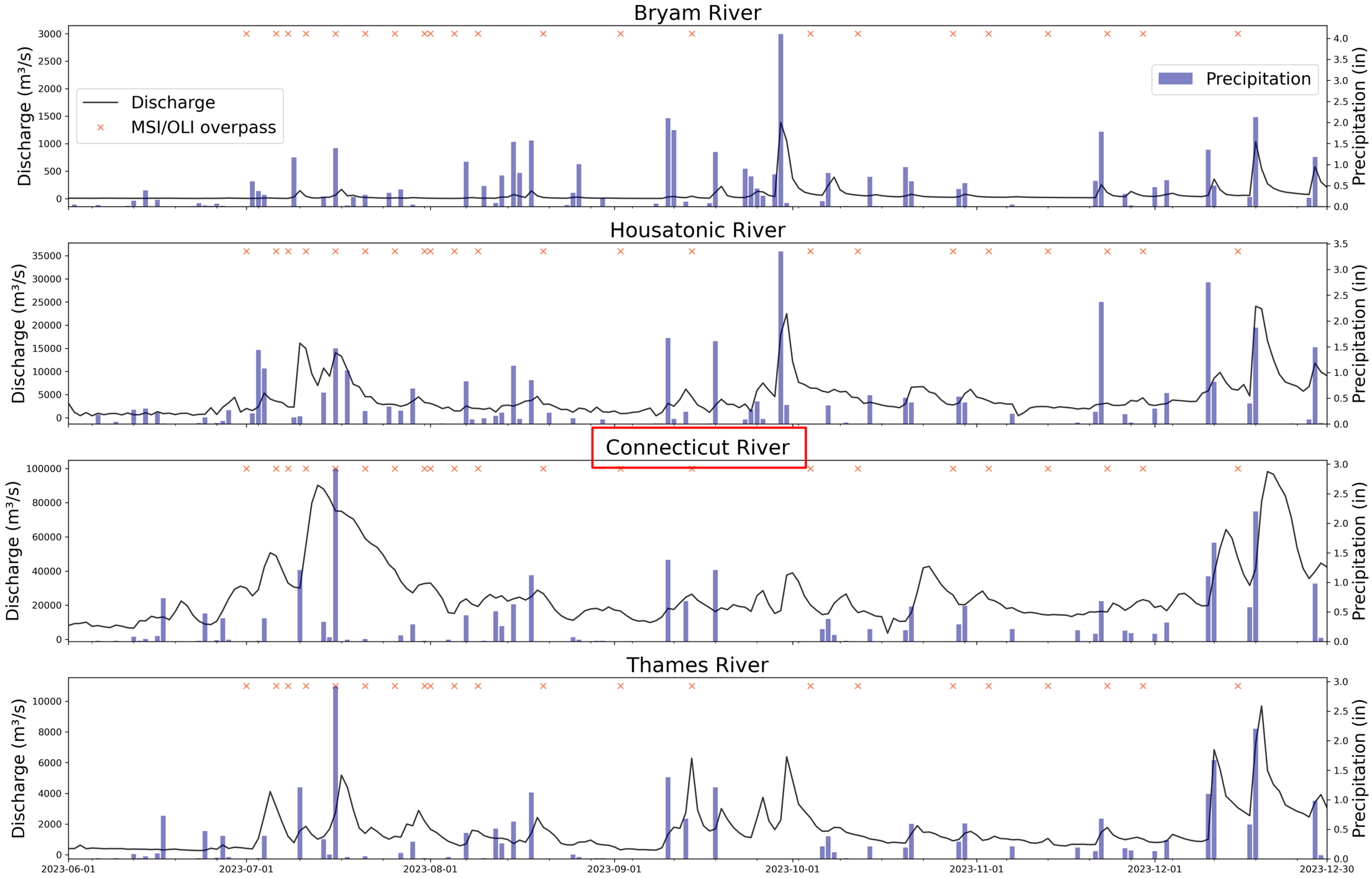

Precipitation Anomalies for Houstonic River
Anomaly (Inches)
6
5
4
3
2
1
0
−1
−2
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year

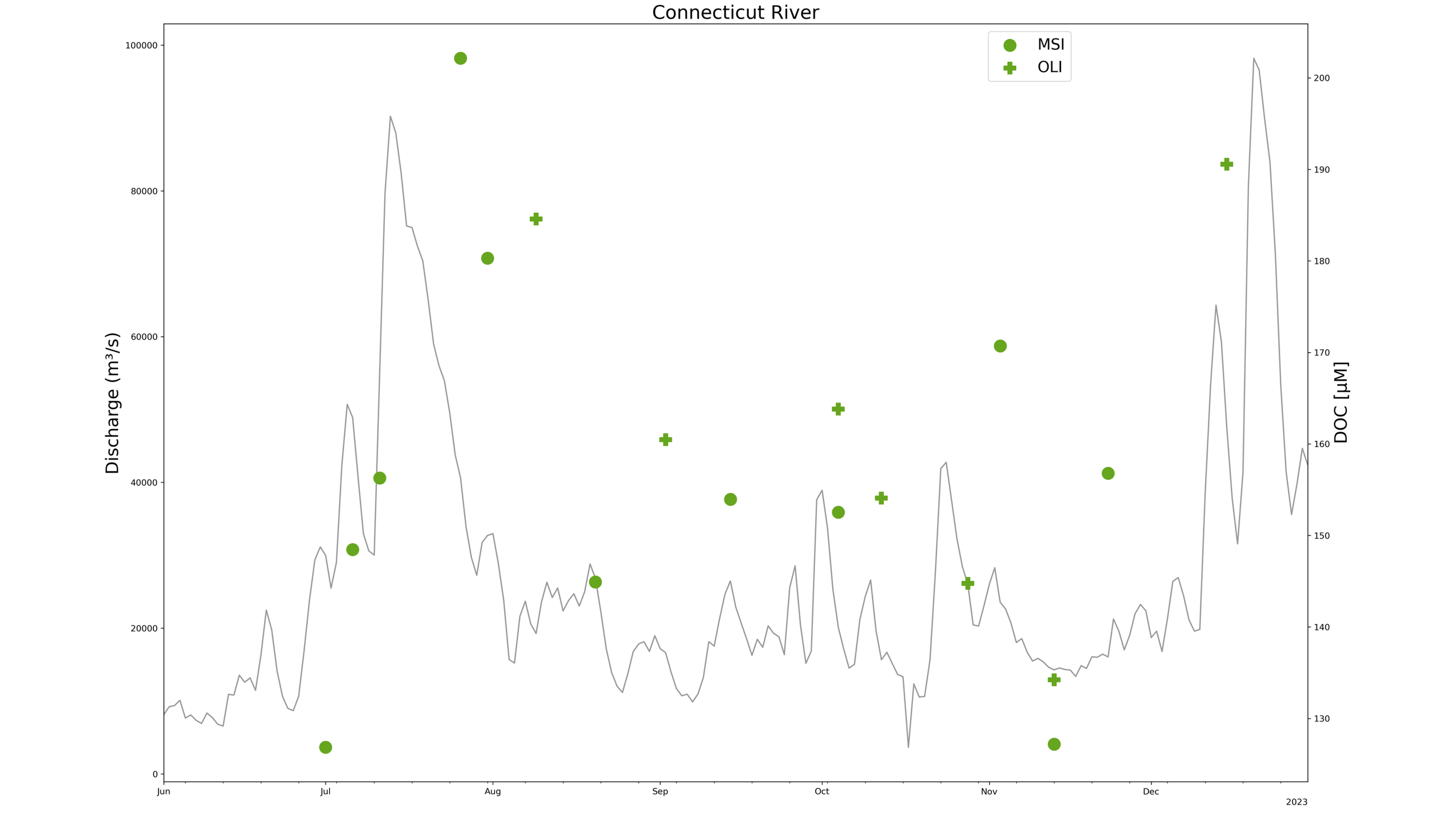


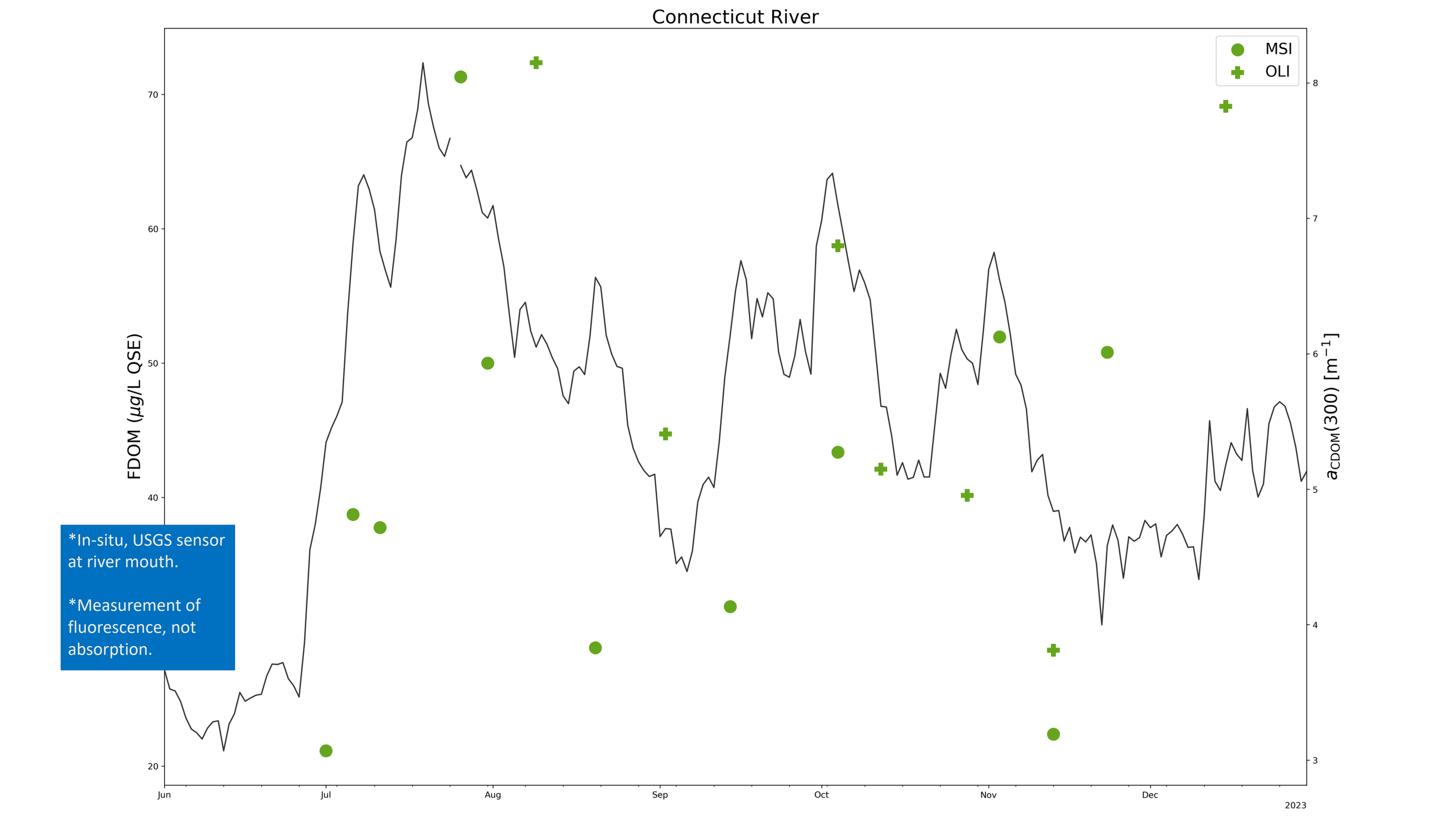

11-03-2023
41.22°N
41.2°N
41.18°N
41.16°N
41.14°N
41.12°N
41.1°N
41.08°N
73.21°W
73.18°W
73.15°W
73.12°W
73.09°W
73.06°W
73.03°W
73°W
DOC [µM]
240
220
200
180
160
140
120
100
80

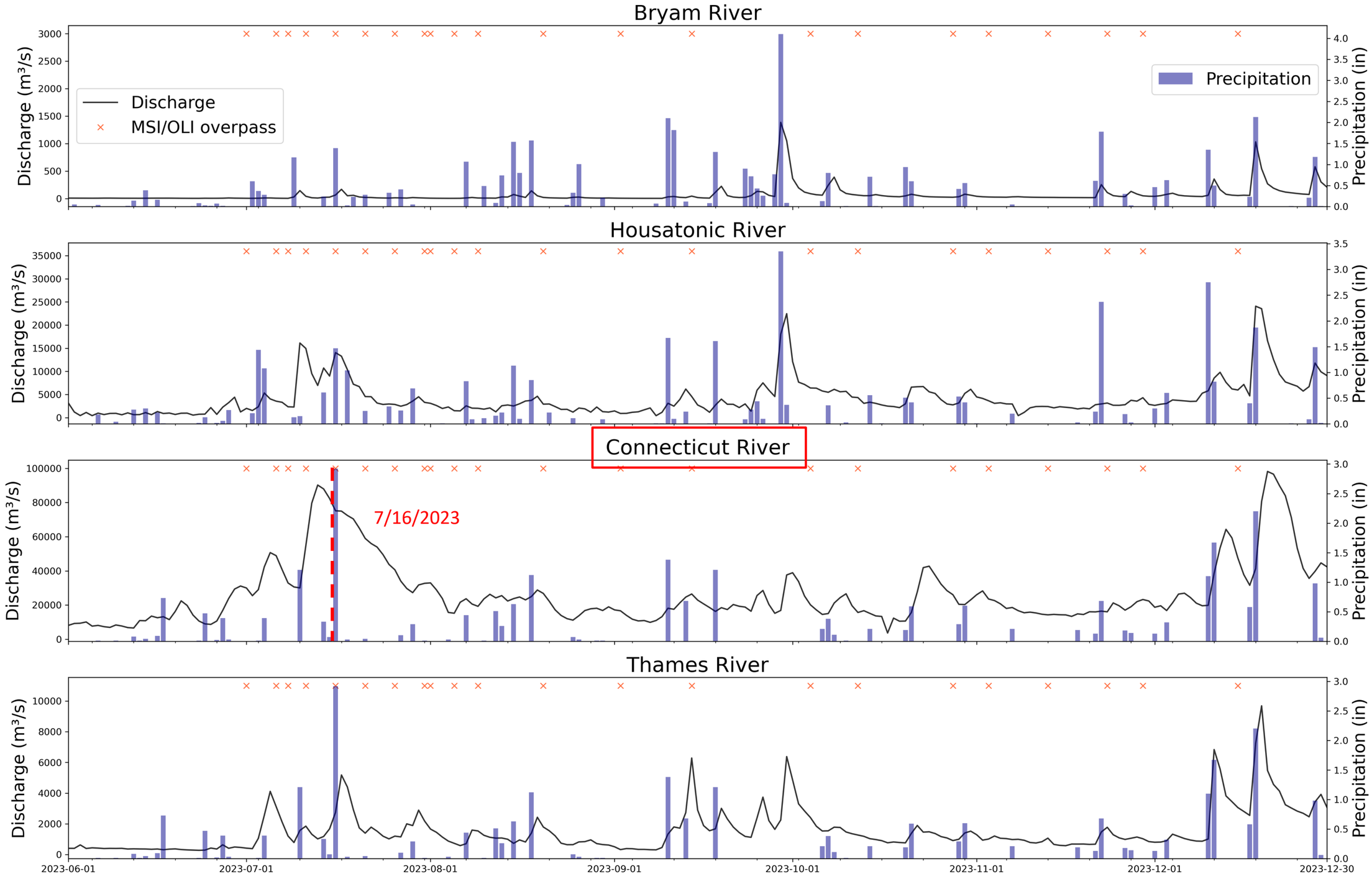
2023 Results

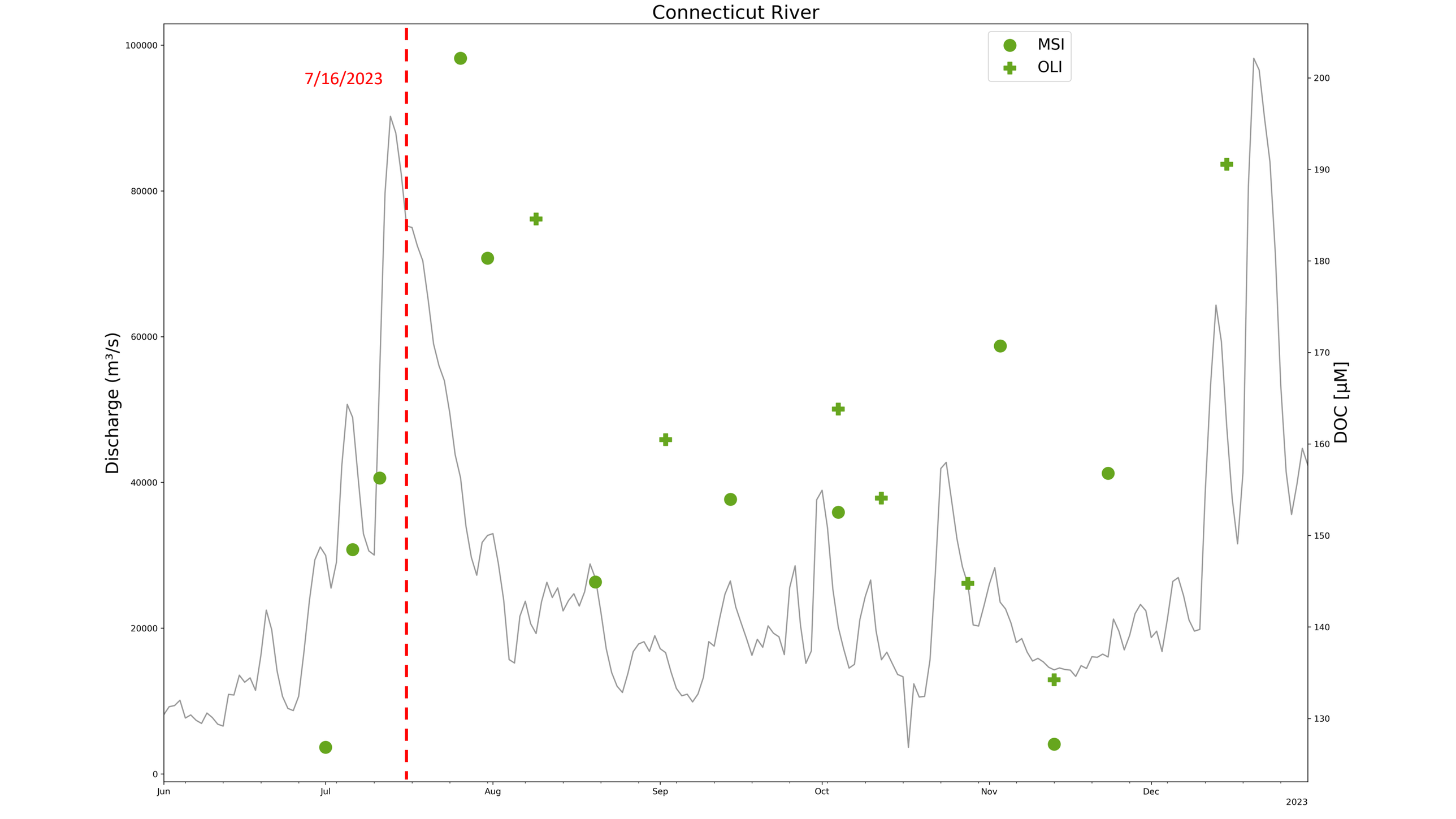

Bryam River
Discharge (m³/s)
Precipitation (in)
Discharge
MSI/OLI overpass
Precipitation
Housatonic River
Discharge (m³/s)
Precipitation (in)
Connecticut River
Discharge (m³/s)
Precipitation (in)
Thames River
Discharge (m³/s)
Precipitation (in)
2023-06-01
2023-07-01
2023-08-01
2023-09-01
2023-10-01
2023-11-01
2023-12-01
2023-12-30

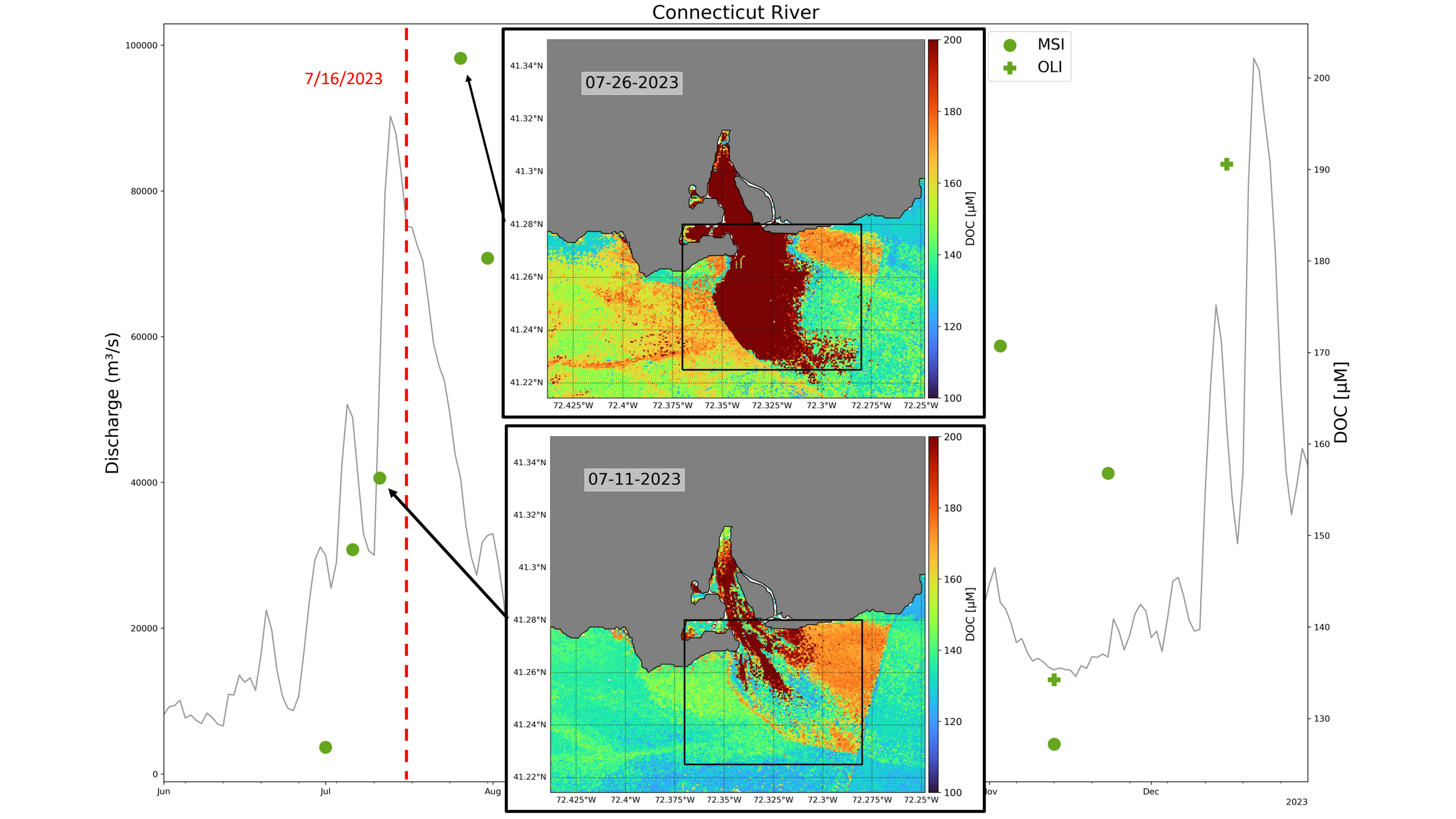

Bryam River
Discharge (m³/s)
Precipitation (in)
Discharge
MSI/OLI overpass
Precipitation
Housatonic River
Discharge (m³/s)
Precipitation (in)
Connecticut River
Discharge (m³/s)
Precipitation (in)
Thames River
Discharge (m³/s)
Precipitation (in)
2023-06-01
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2023-11-01
2023-12-01
2023-12-30

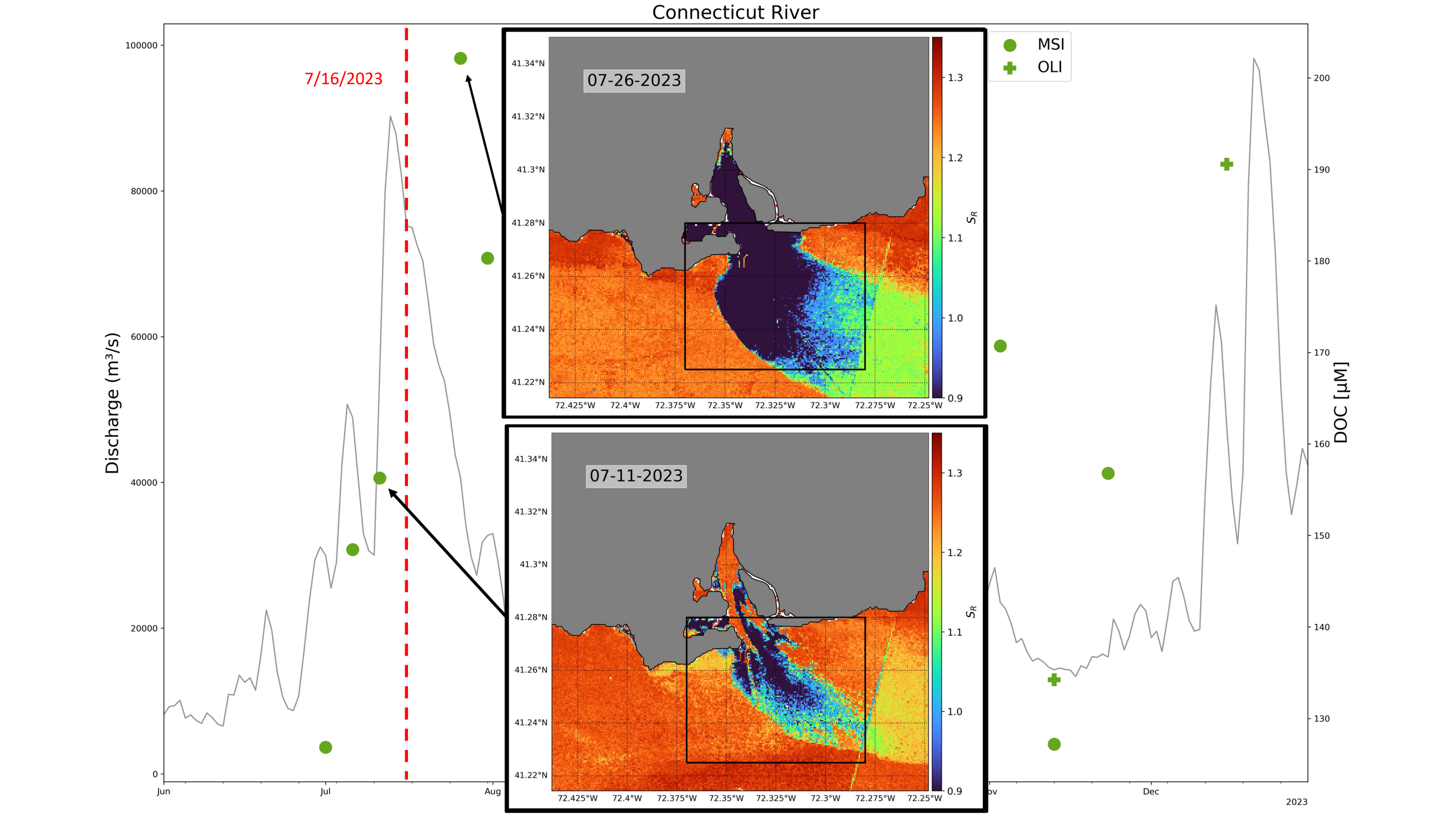

Connecticut River
MSI
OLI
Discharge (m³/s)
DOC [µM]
0
20000
40000
60000
80000
100000
130
140
150
160
170
180
190
200
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023

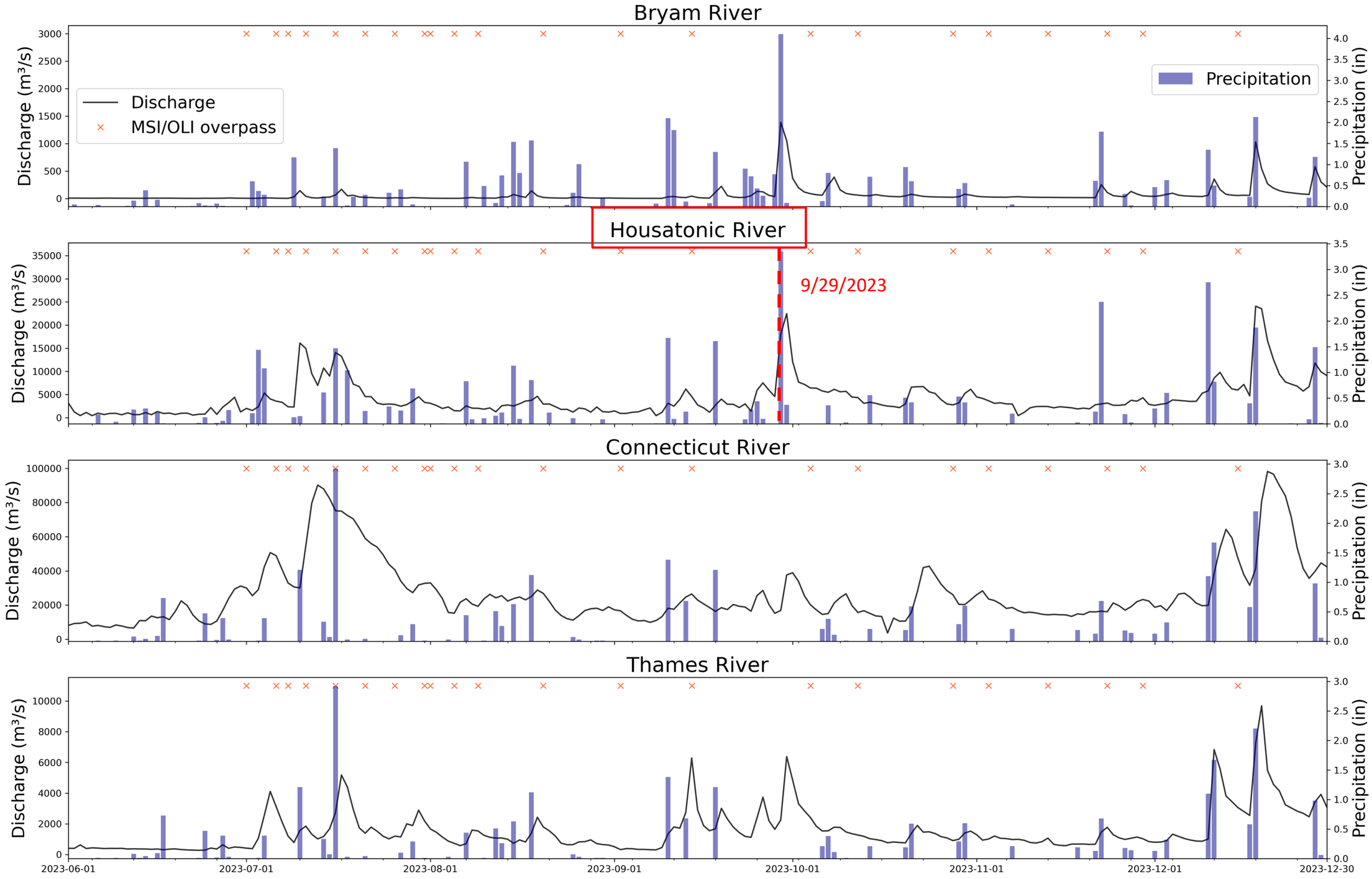

Connecticut River
MSI
OLI
FDOM (μg/L QSE)
$a_{CDOM}(300)$ [m^{-1}]
70
60
50
40
20
8
7
6
5
4
3
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023
*In-situ, USGS sensor at river mouth.
*Measurement of fluorescence, not absorption.

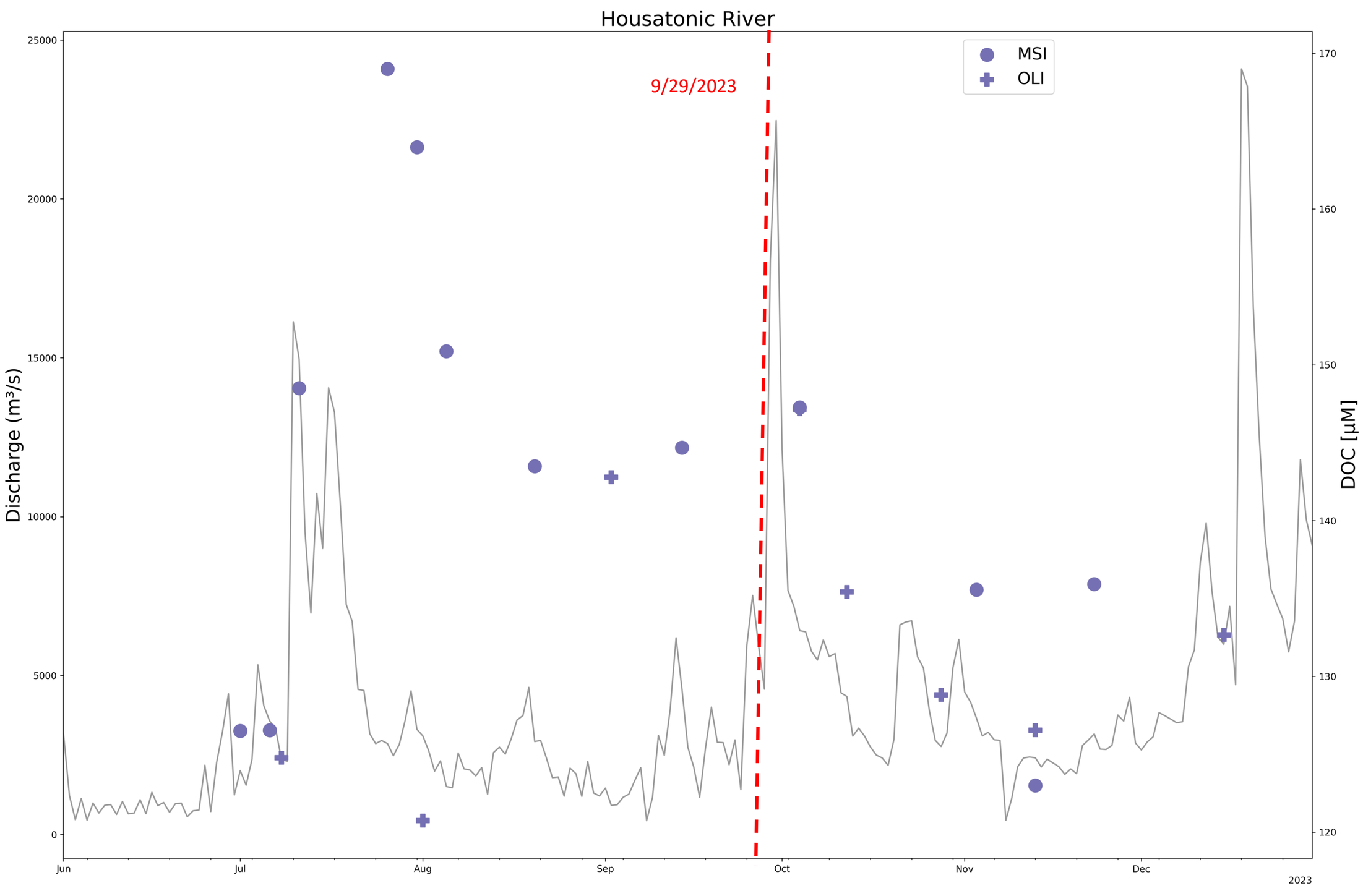

Bryam River
Discharge (m³/s)
Precipitation (in)
Discharge
MSI/OLI overpass
Precipitation
Housatonic River
Connecticut River
7/16/2023
Thames River
2023-06-01
2023-07-01
2023-08-01
2023-09-01
2023-10-01
2023-11-01
2023-12-01
2023-12-30

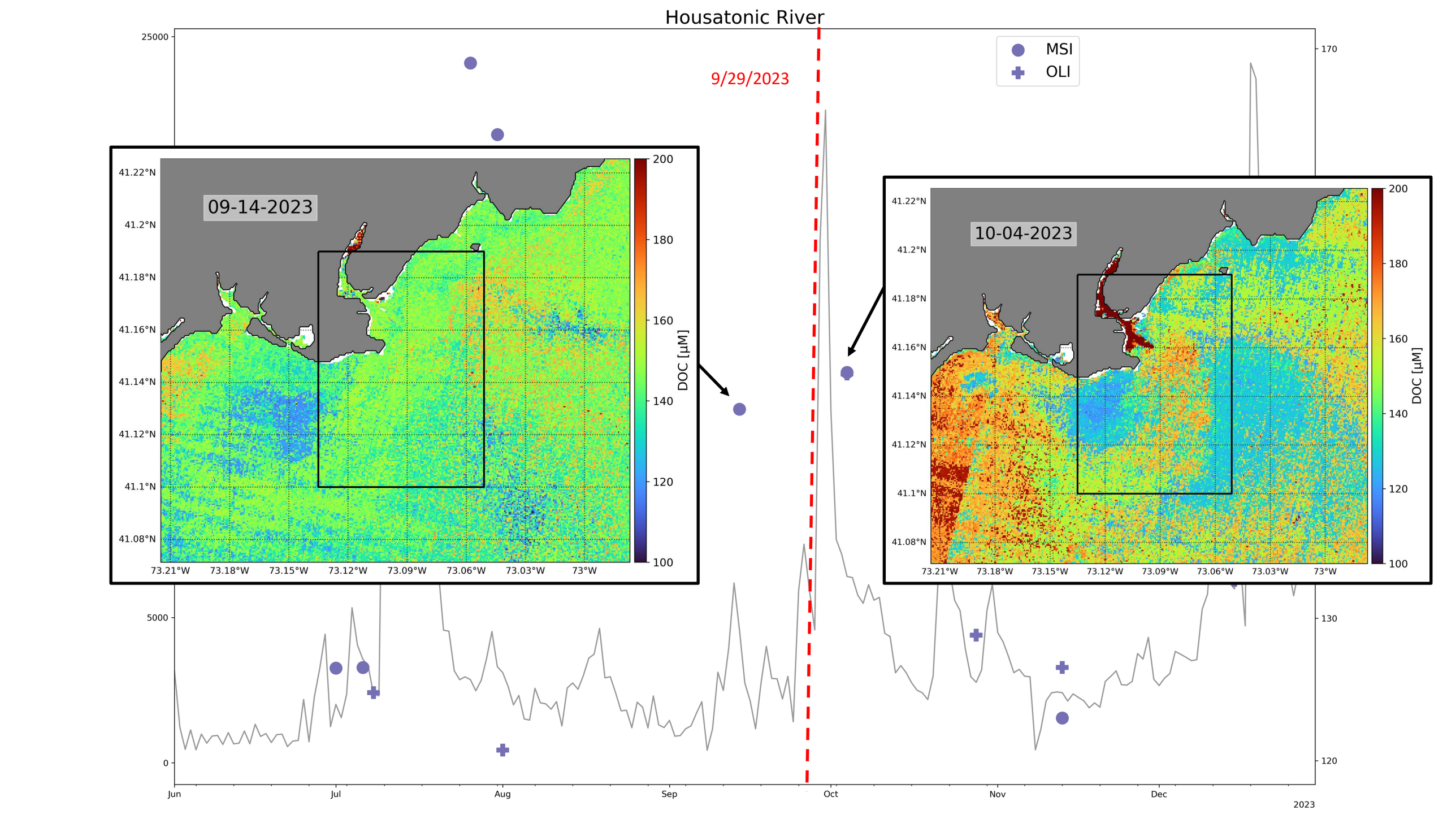

Connecticut River
7/16/2023
MSI
OLI
Discharge (m³/s)
DOC [µM]
0
20000
40000
60000
80000
100000
130
140
150
160
170
180
190
200
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023

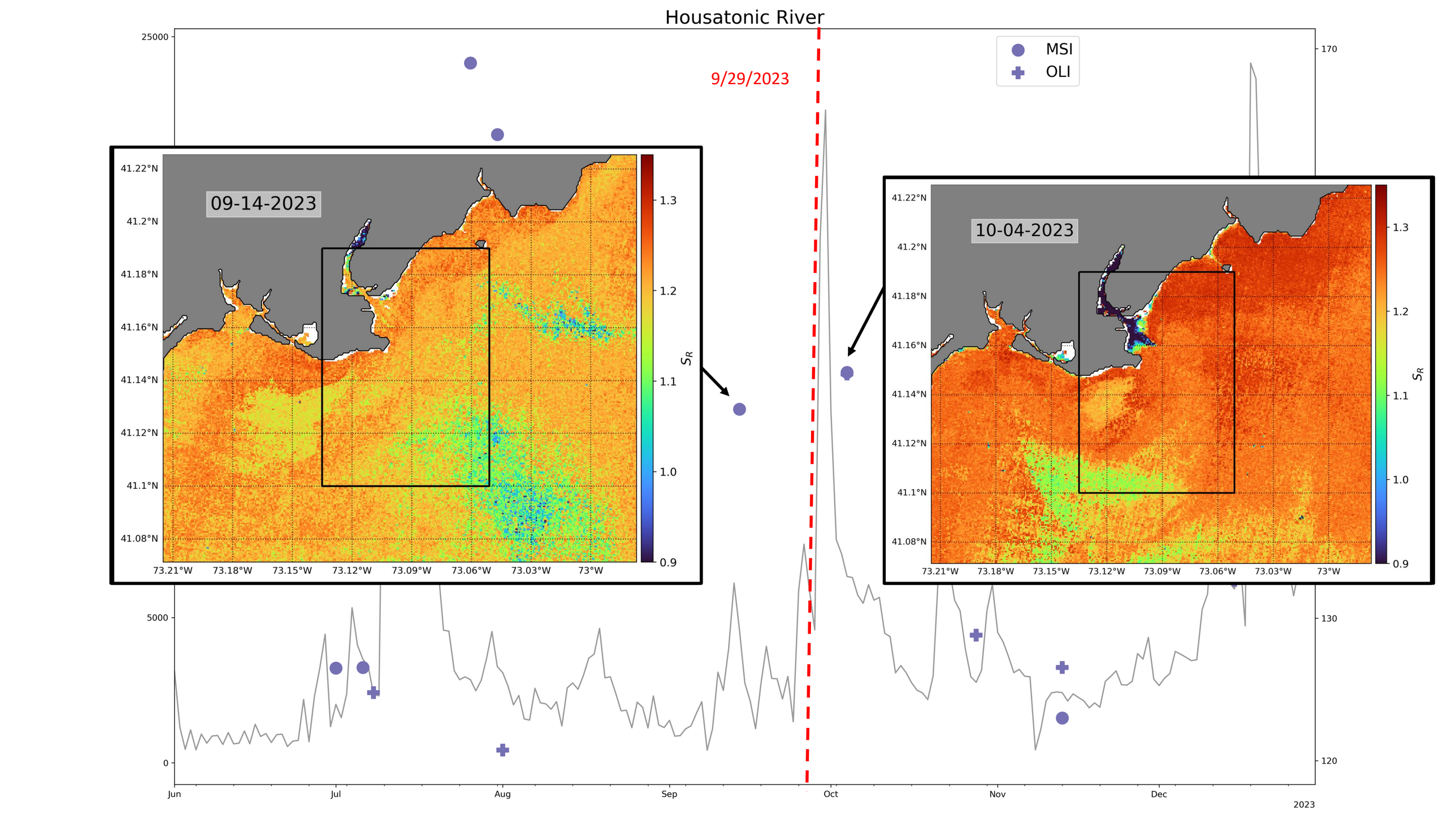

Connecticut River
7/16/2023
07-26-2023
07-11-2023
MSI
OLI
Discharge (m³/s)
DOC [µM]
100000
80000
60000
40000
20000
0
200
190
180
170
160
150
140
130
Jun
Jul
Aug
Dec
2023
41.34°N
41.32°N
41.3°N
41.28°N
41.26°N
41.24°N
41.22°N
72.425°W
72.4°W
72.375°W
72.35°W
72.325°W
72.3°W
72.275°W
72.25°W
200
180
160
140
120
100
DOC [µM]

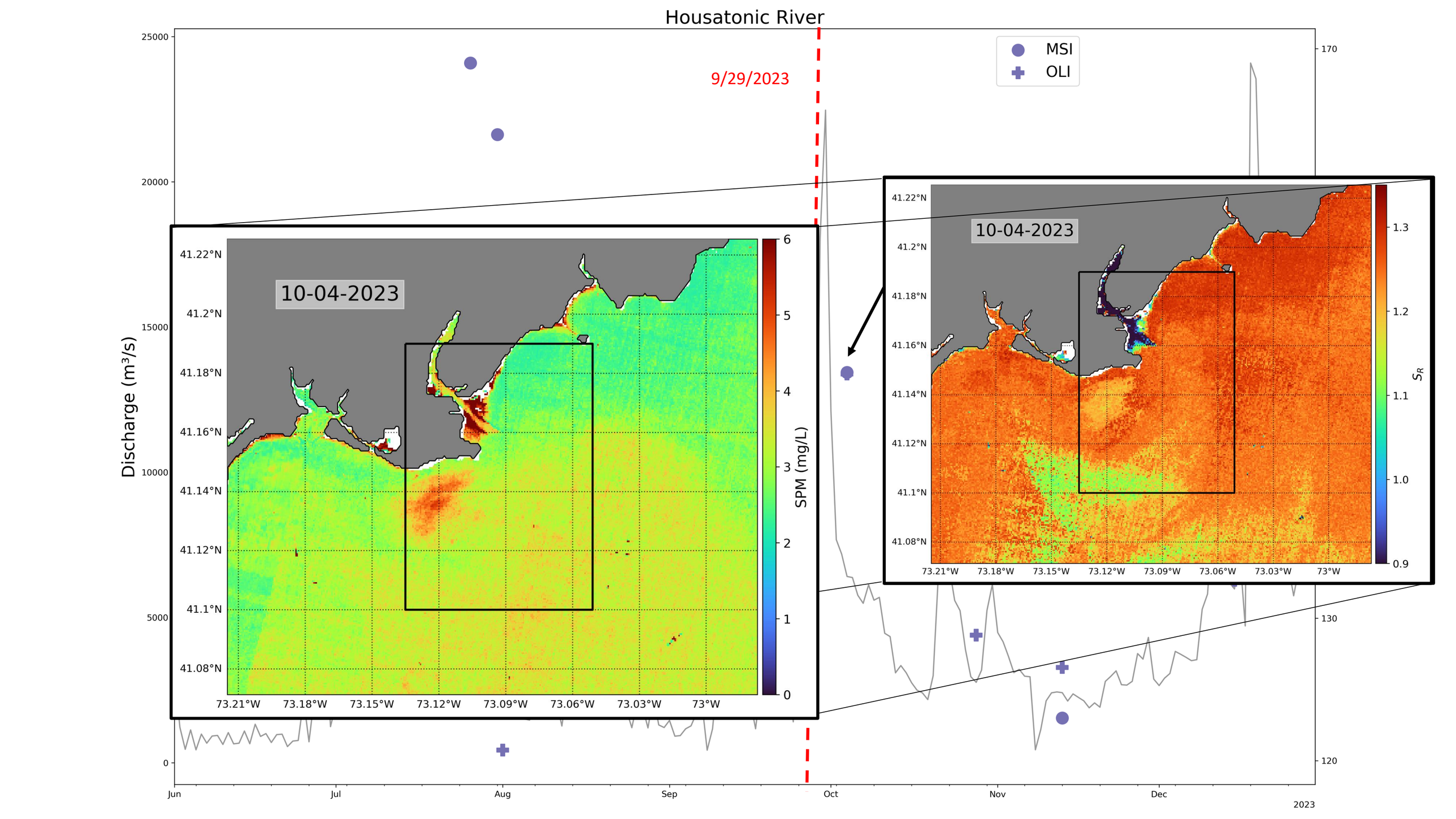

Connecticut River
7/16/2023
07-26-2023
07-11-2023
MSI
OLI
Discharge (m³/s)
DOC [µM]
S_R
41.34°N
41.32°N
41.3°N
41.28°N
41.26°N
41.24°N
41.22°N
72.425°W
72.4°W
72.375°W
72.35°W
72.325°W
72.3°W
72.275°W
72.25°W
0.9
1.0
1.1
1.2
1.3
0
20000
40000
60000
80000
100000
130
140
150
160
170
180
190
200
Jun
Jul
Aug
Dec
2023

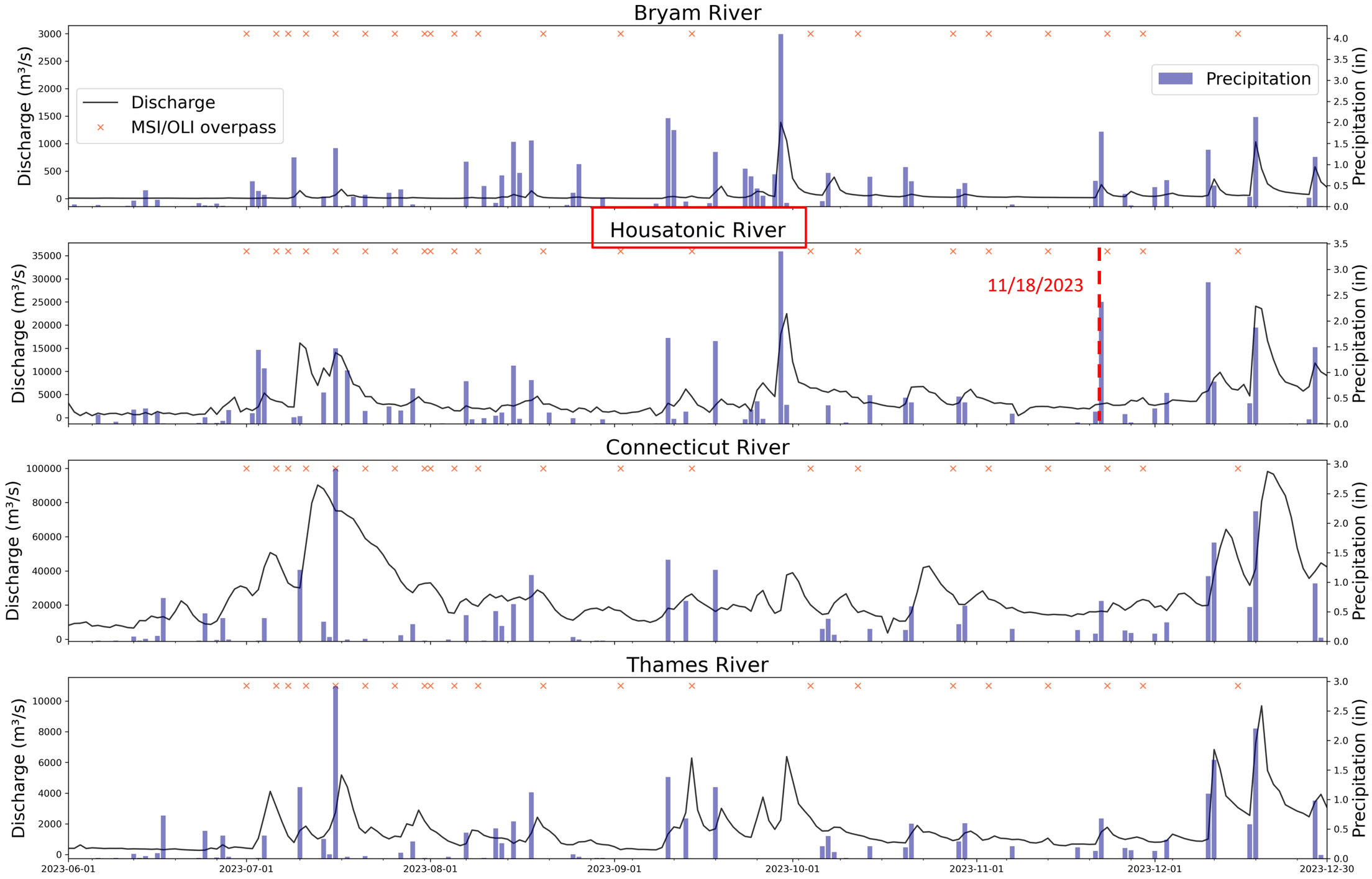

Bryam River
Housatonic River
Connecticut River
Thames River
Discharge
MSI/OLI overpass
Precipitation
Discharge (m³/s)
Precipitation (in)
9/29/2023
2023-06-01
2023-07-01
2023-08-01
2023-09-01
2023-10-01
2023-11-01
2023-12-01
2023-12-30

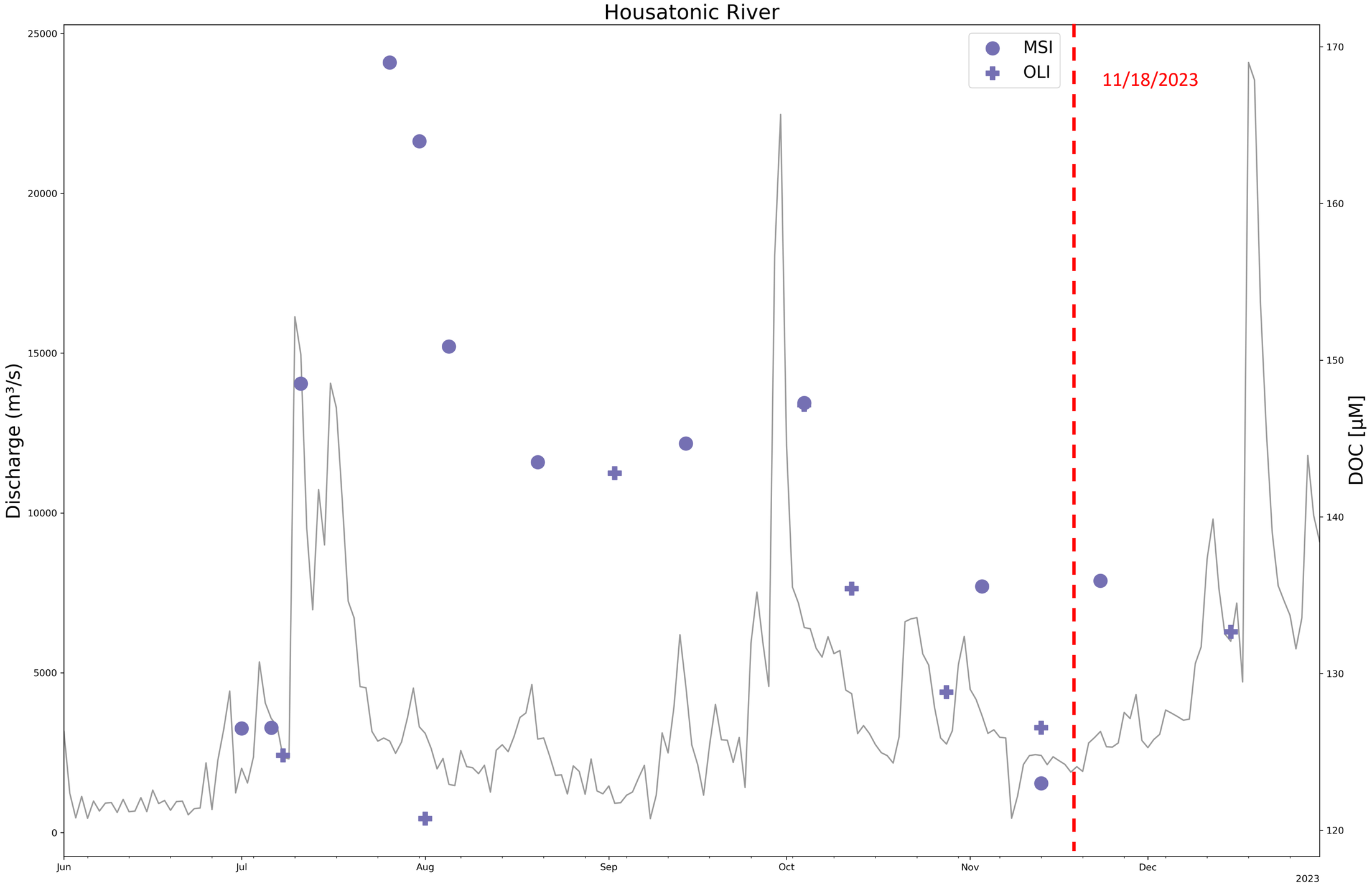

Housatonic River
9/29/2023
MSI
OLI
Discharge (m³/s)
DOC [µM]
25000
20000
15000
10000
5000
0
170
160
150
140
130
120
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023

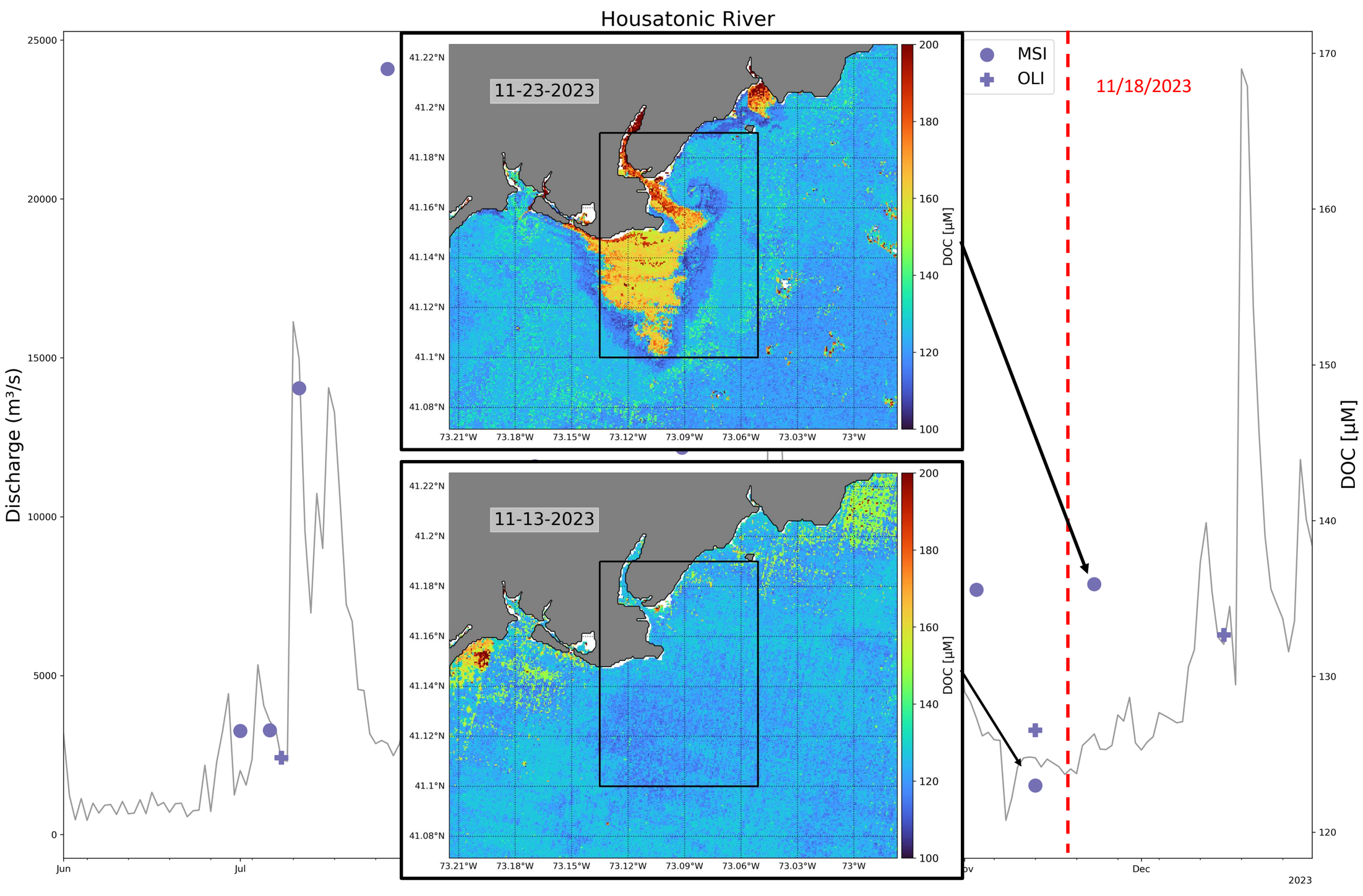

Housatonic River
MSI
OLI
9/29/2023
09-14-2023
10-04-2023
DOC [µM]
25000
5000
0
170
130
120
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023
41.22°N
41.2°N
41.18°N
41.16°N
41.14°N
41.12°N
41.1°N
41.08°N
73.21°W
73.18°W
73.15°W
73.12°W
73.09°W
73.06°W
73.03°W
73°W
200
180
160
140
120
100

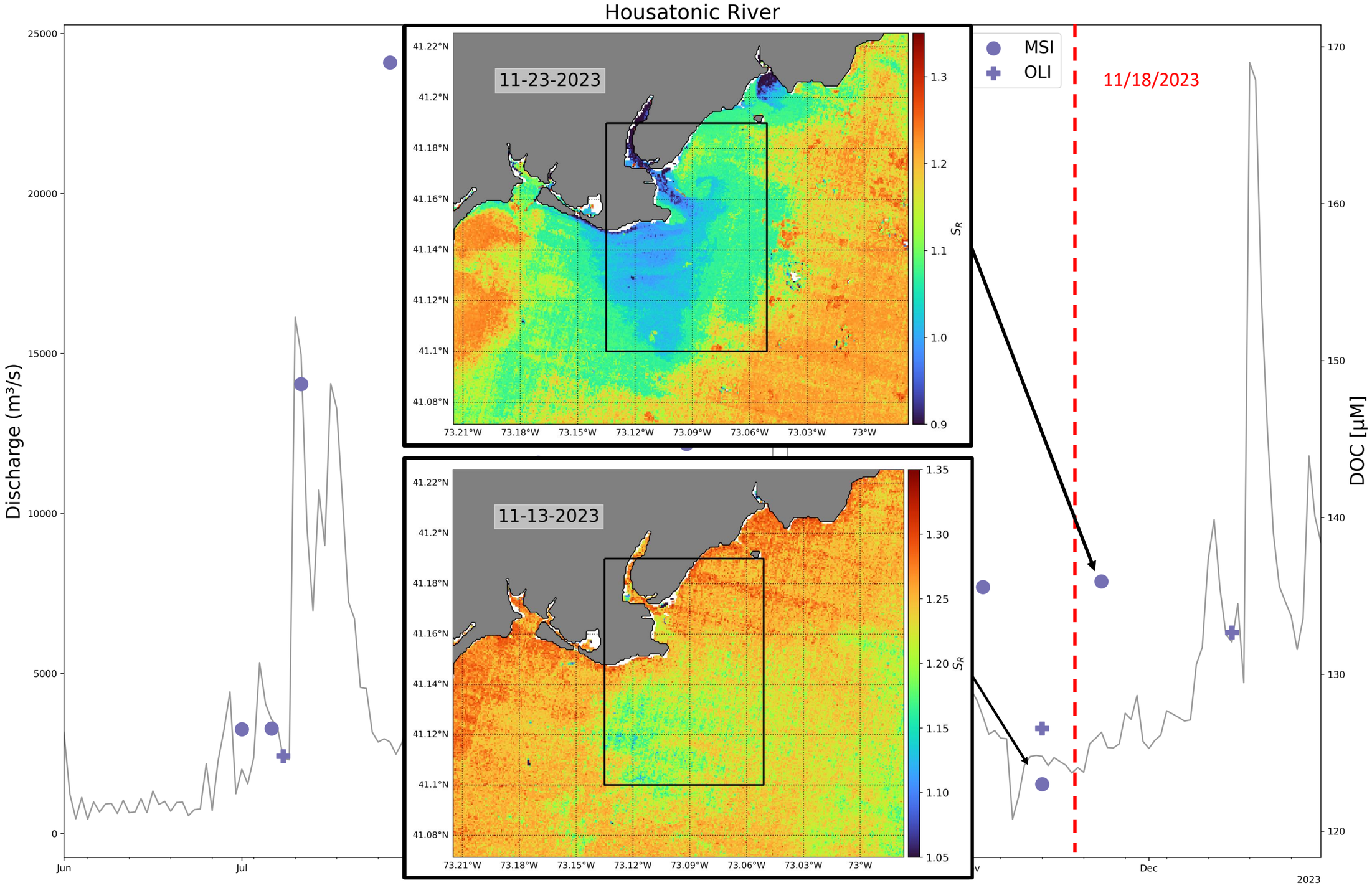

Housatonic River
9/29/2023
MSI
OLI
09-14-2023
10-04-2023
S_R
25000
5000
0
170
130
120
41.22°N
41.2°N
41.18°N
41.16°N
41.14°N
41.12°N
41.1°N
41.08°N
73.21°W
73.18°W
73.15°W
73.12°W
73.09°W
73.06°W
73.03°W
73°W
1.3
1.2
1.1
1.0
0.9
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023

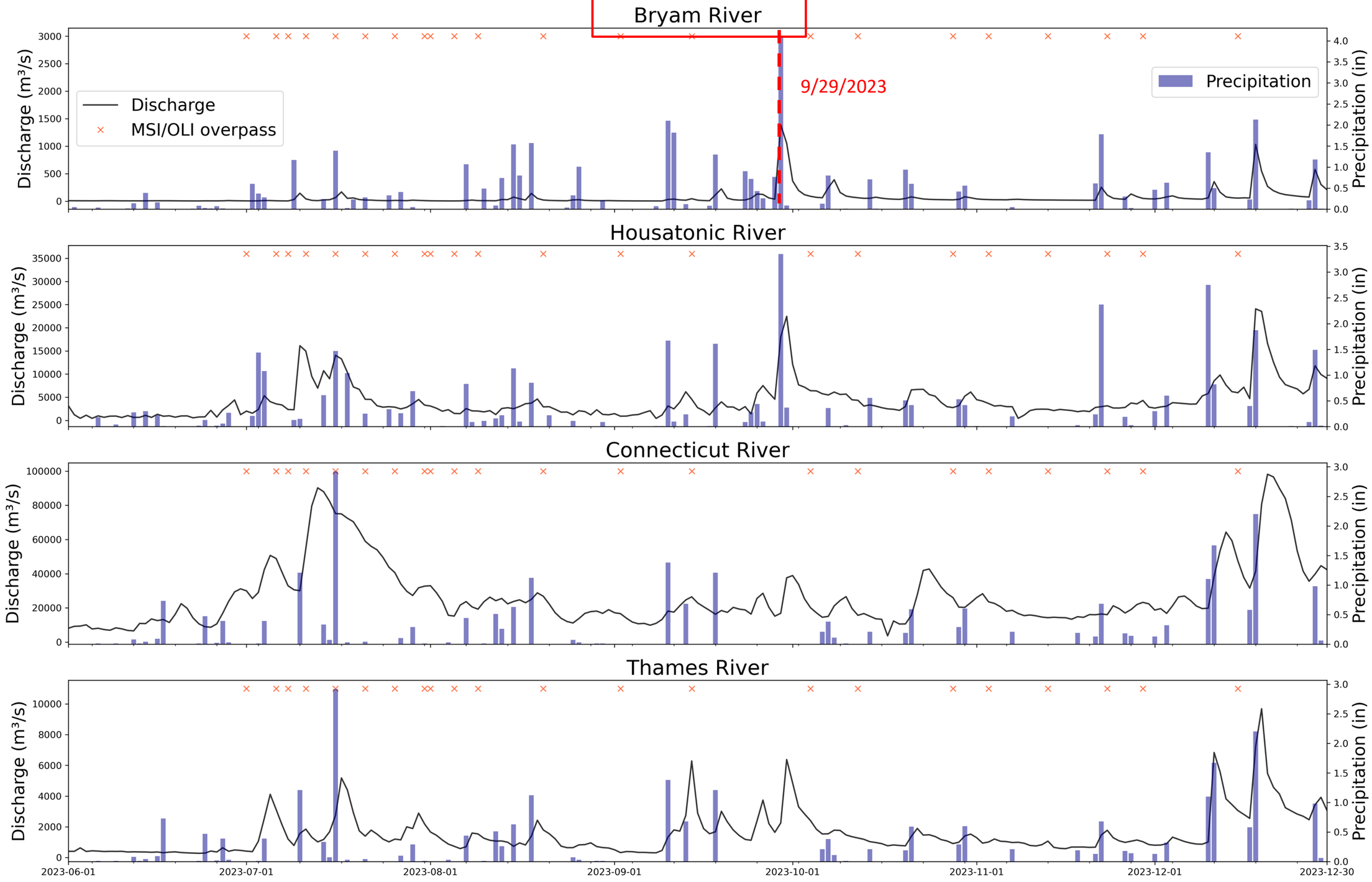

Housatonic River
9/29/2023
MSI
OLI
Discharge (m³/s)
25000
20000
15000
10000
5000
0
170
130
120
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023
10-04-2023
41.22°N
41.2°N
41.18°N
41.16°N
41.14°N
41.12°N
41.1°N
41.08°N
73.21°W
73.18°W
73.15°W
73.12°W
73.09°W
73.06°W
73.03°W
73°W
SPM (mg/L)
6
5
4
3
2
1
0
S_R
1.3
1.2
1.1
1.0
0.9

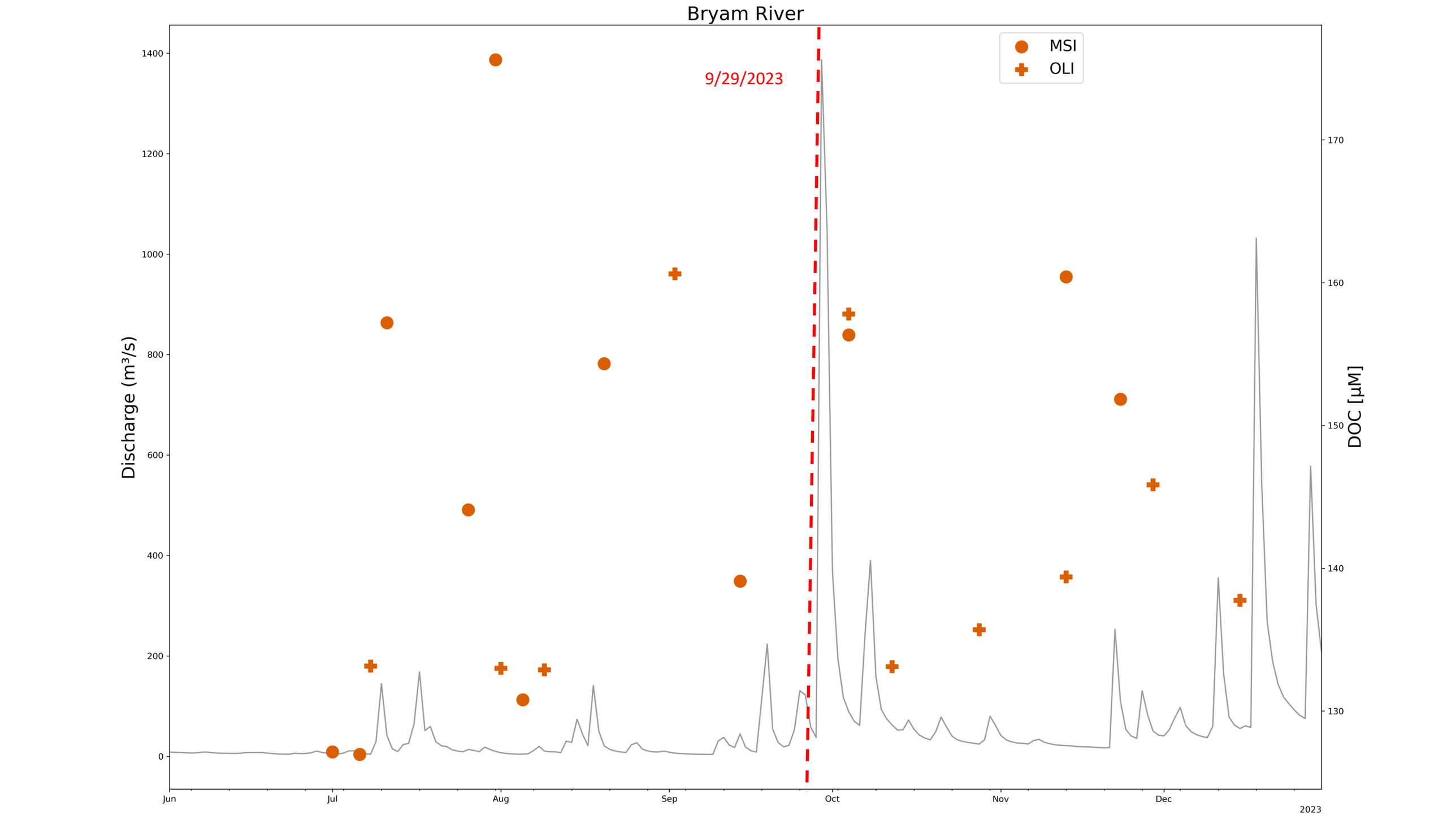

Bryam River
Discharge
MSI/OLI overpass
Precipitation
Discharge (m³/s)
Precipitation (in)
Housatonic River
11/18/2023
Connecticut River
Thames River
2023-06-01
2023-07-01
2023-08-01
2023-09-01
2023-10-01
2023-11-01
2023-12-01
2023-12-30

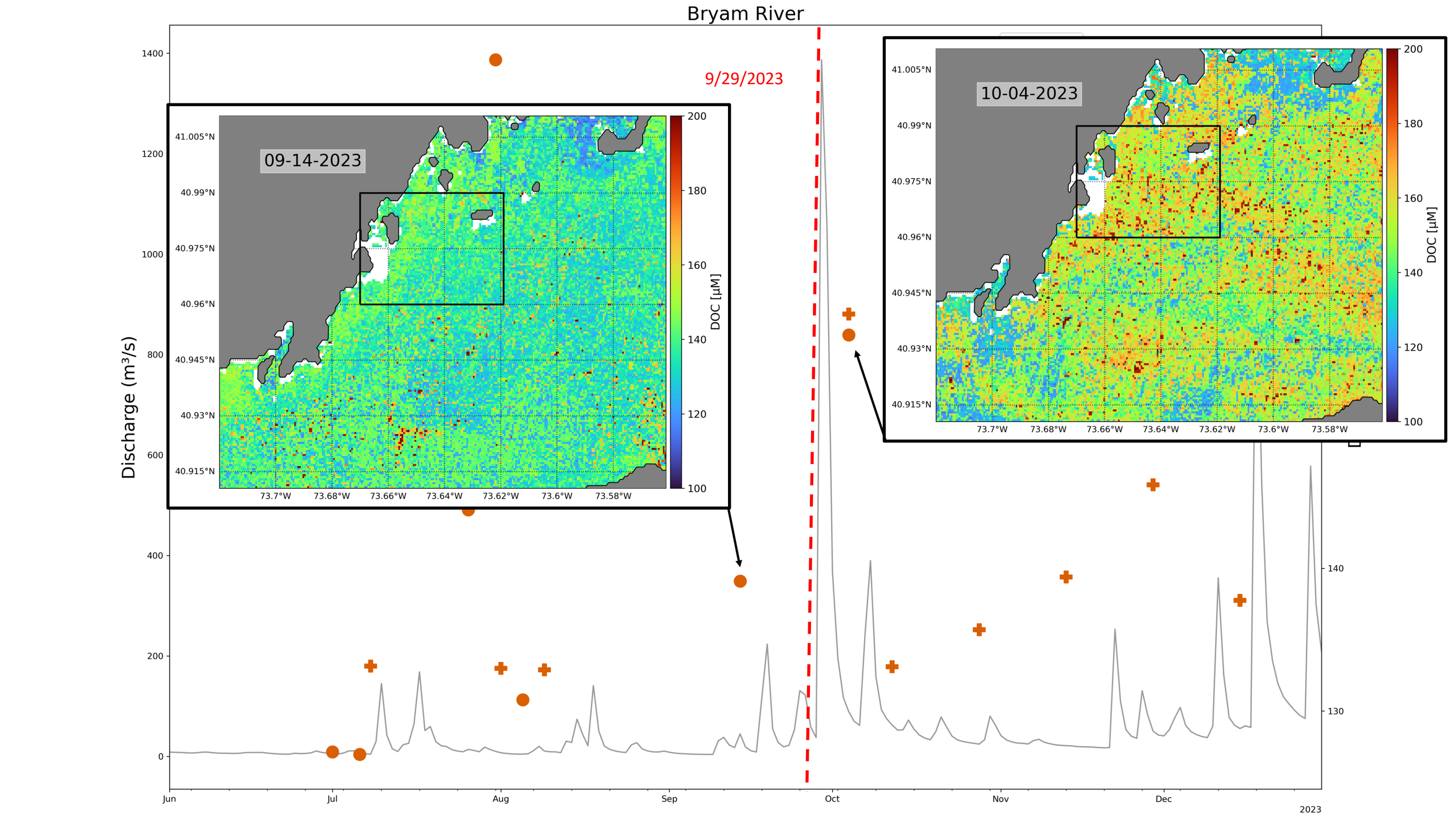

Housatonic River
MSI
OLI
11/18/2023
Discharge (m³/s)
DOC [µM]
25000
20000
15000
10000
5000
0
170
160
150
140
130
120
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023

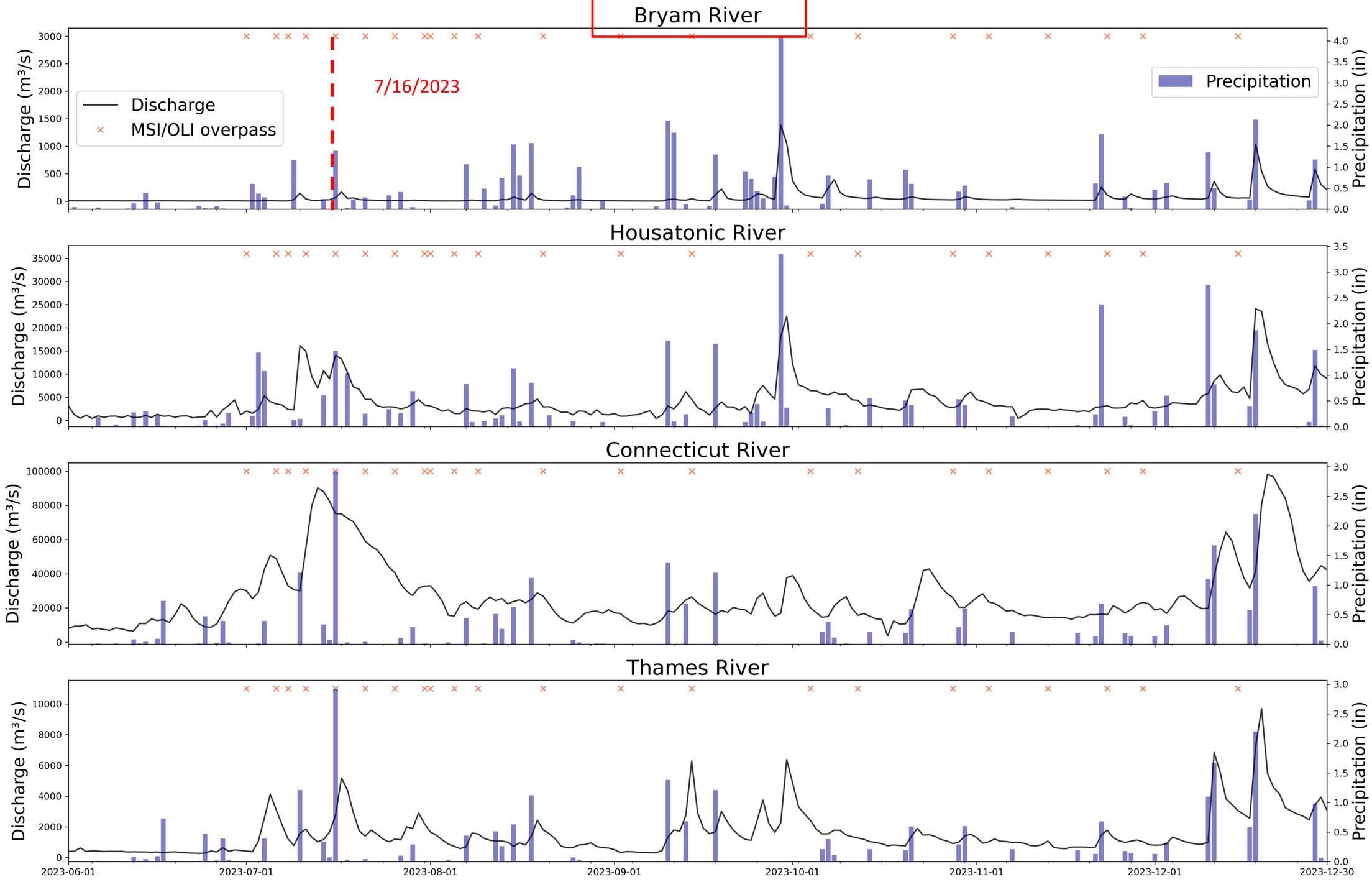

Housatonic River
Discharge (m³/s)
DOC [µM]
MSI
OLI
11/18/2023
11-23-2023
11-13-2023
DOC [µM]
Jun
Jul
Dec
2023

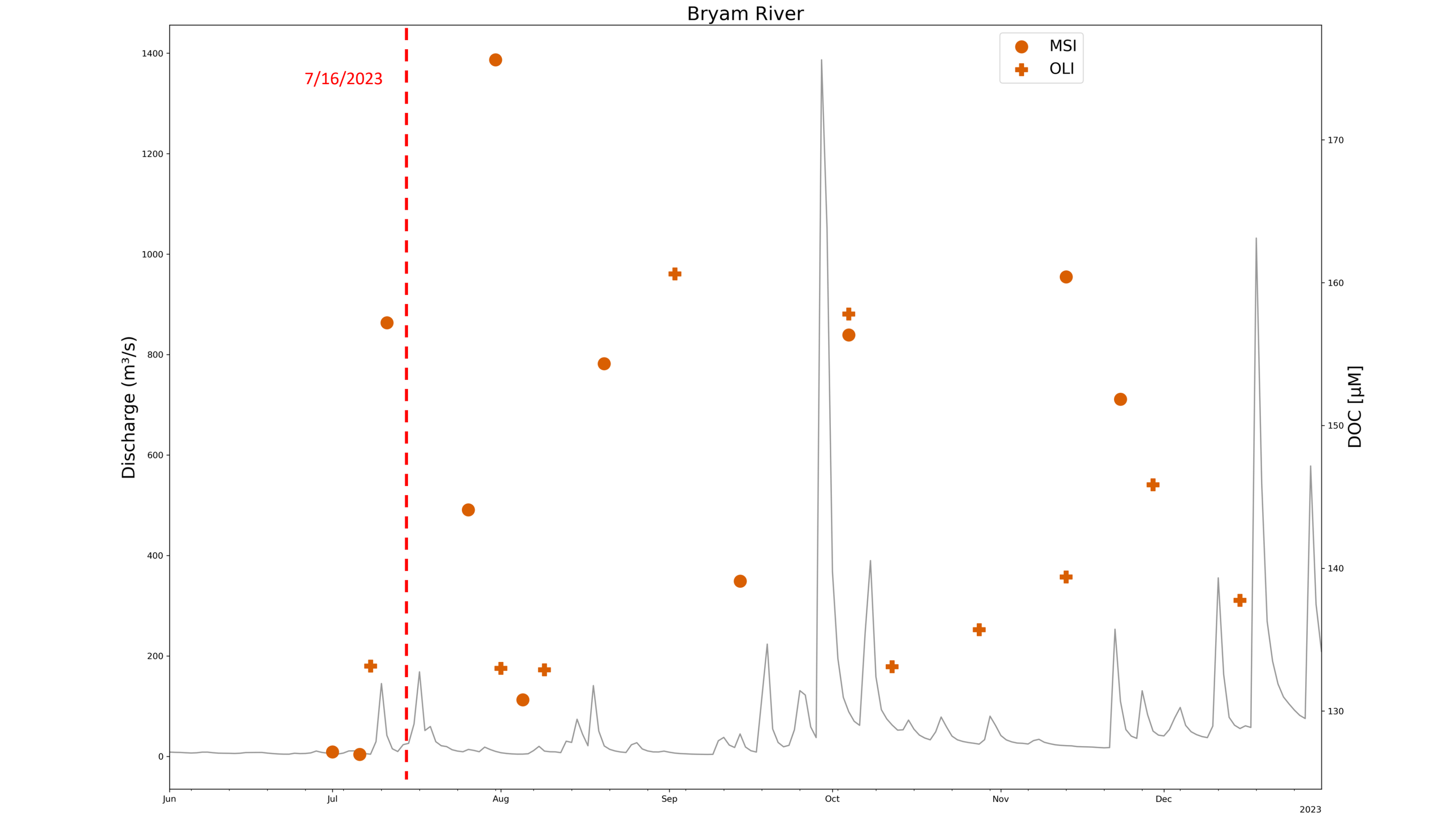

Housatonic River
Discharge (m³/s)
DOC [µM]
MSI
OLI
11/18/2023
11-23-2023
11-13-2023
S_R
41.22°N
41.2°N
41.18°N
41.16°N
41.14°N
41.12°N
41.1°N
41.08°N
73.21°W
73.18°W
73.15°W
73.12°W
73.09°W
73.06°W
73.03°W
73°W
Jun
Jul
Dec
2023

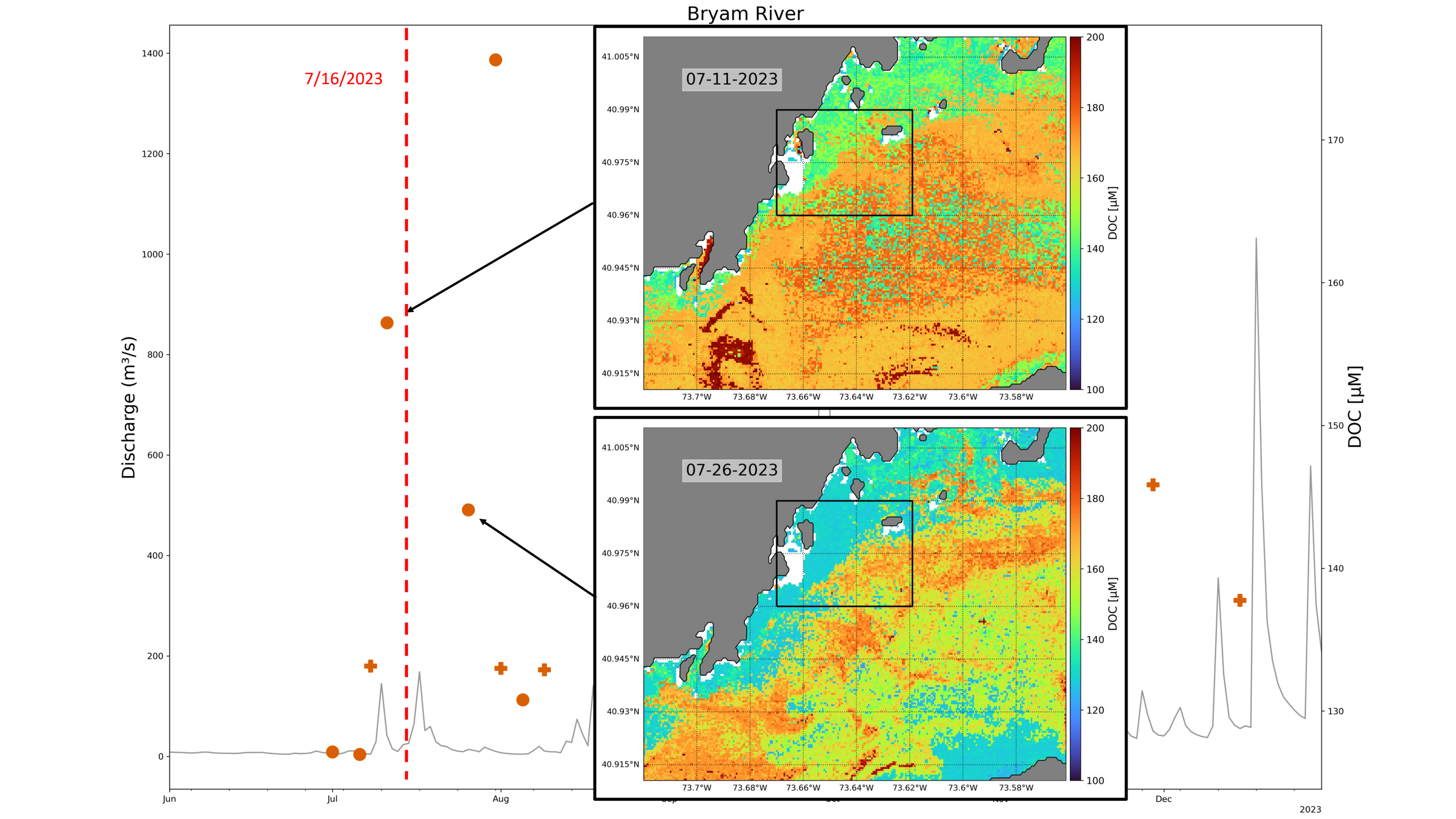

Bryam River
9/29/2023
Discharge
MSI/OLI overpass
Precipitation
Discharge (m³/s)
Precipitation (in)
Housatonic River
Connecticut River
Thames River
2023-06-01
2023-07-01
2023-08-01
2023-09-01
2023-10-01
2023-11-01
2023-12-01
2023-12-30

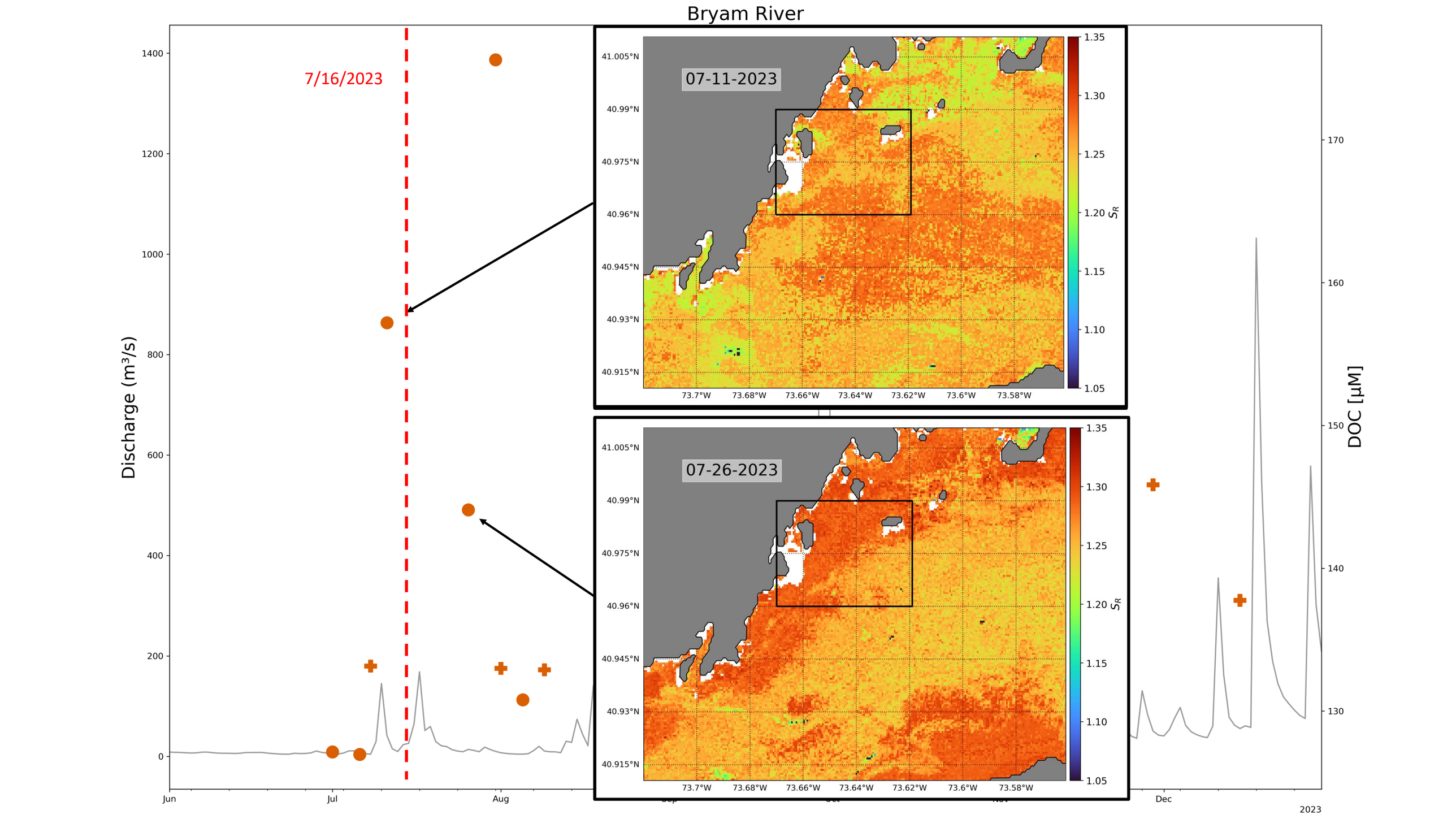

Bryam River
MSI
OLI
9/29/2023
Discharge (m³/s)
DOC [µM]
0
200
400
600
800
1000
1200
1400
130
140
150
160
170
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023

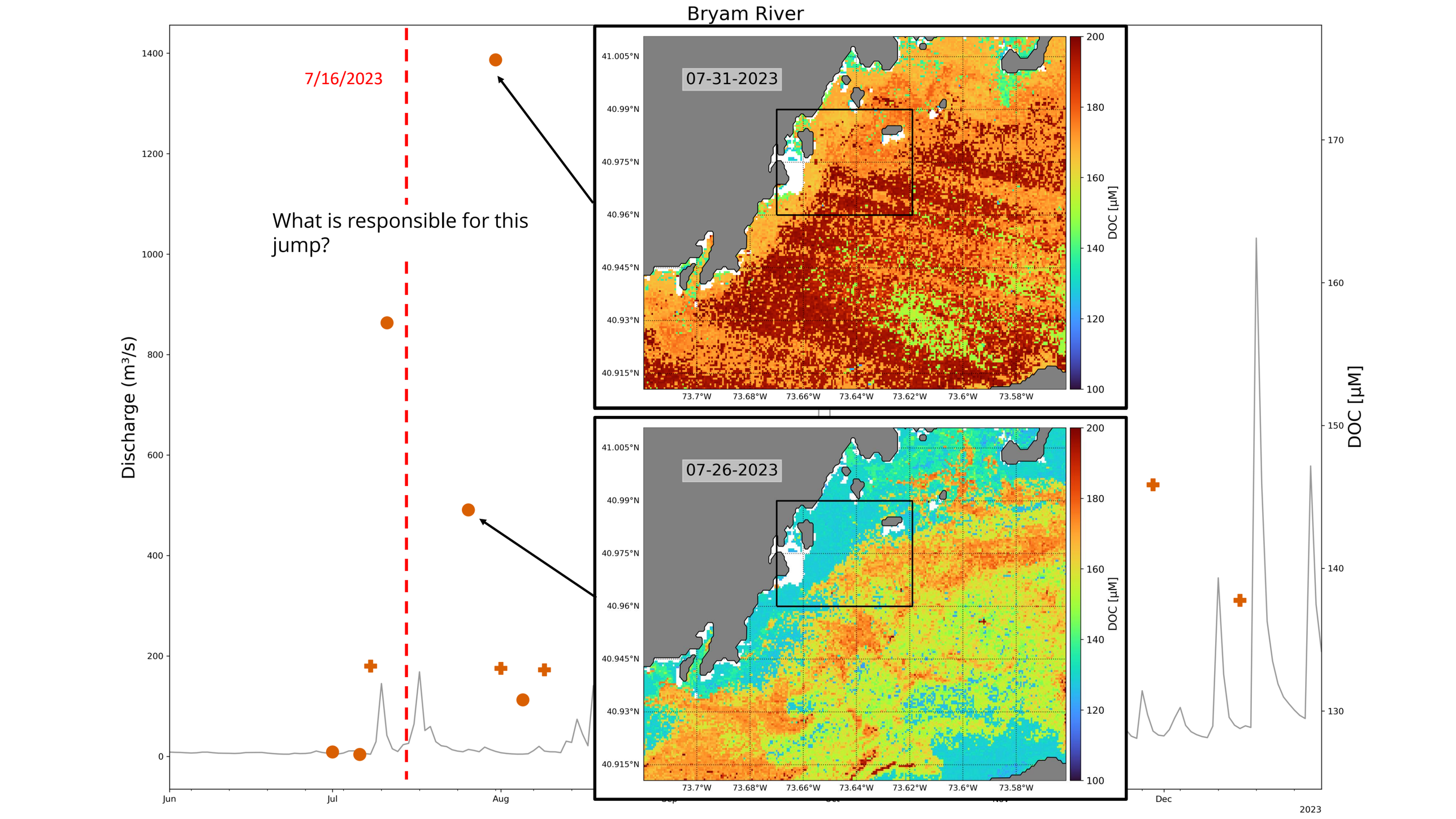

Bryam River
9/29/2023
09-14-2023
10-04-2023
Discharge (m³/s)
DOC [µM]
41.005°N
40.99°N
40.975°N
40.96°N
40.945°N
40.93°N
40.915°N
73.7°W
73.68°W
73.66°W
73.64°W
73.62°W
73.6°W
73.58°W
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023

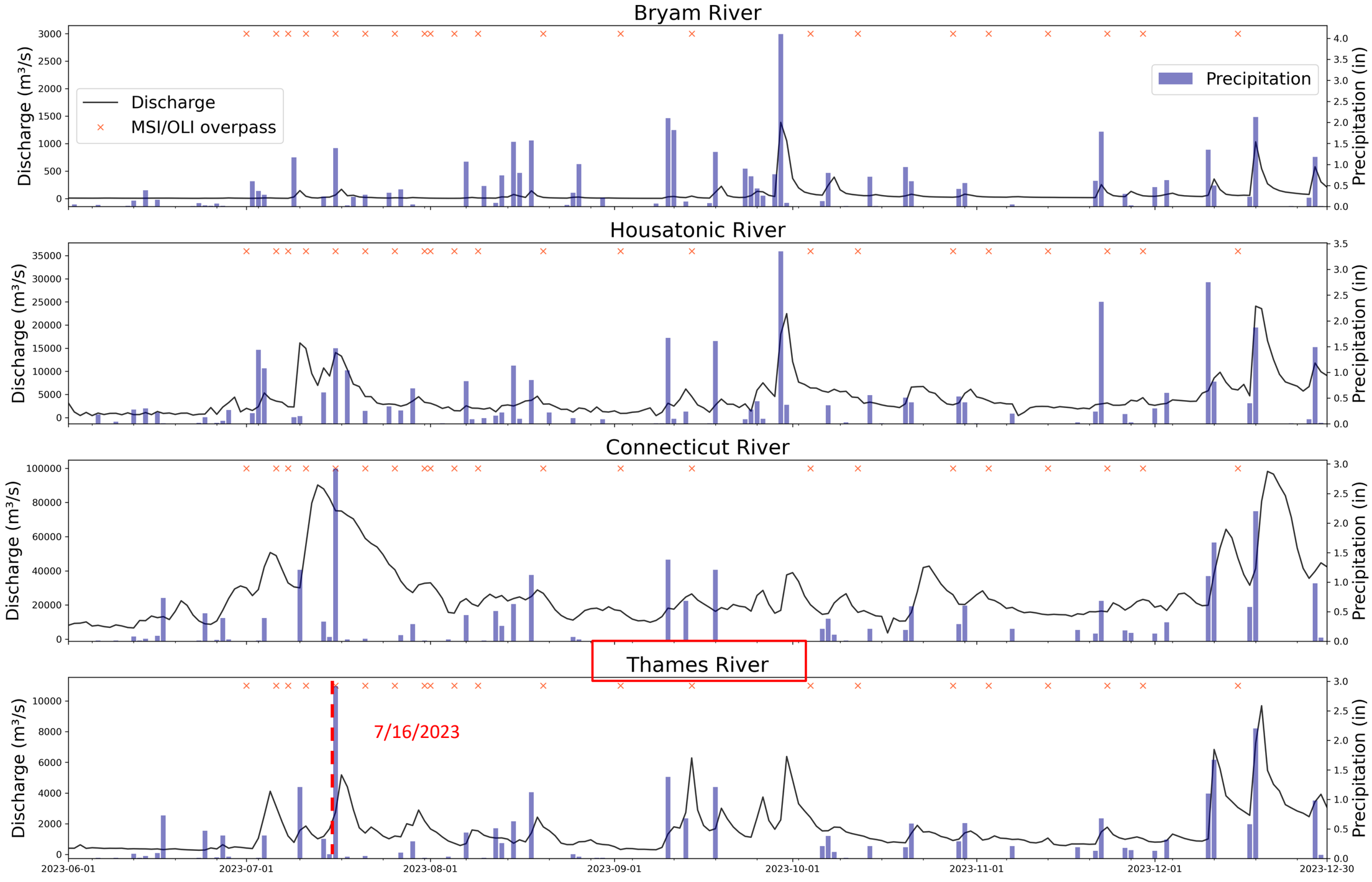

Bryam River
7/16/2023
Discharge
MSI/OLI overpass
Precipitation
Discharge (m³/s)
Precipitation (in)
Housatonic River
Connecticut River
Thames River
2023-06-01
2023-07-01
2023-08-01
2023-09-01
2023-10-01
2023-11-01
2023-12-01
2023-12-30

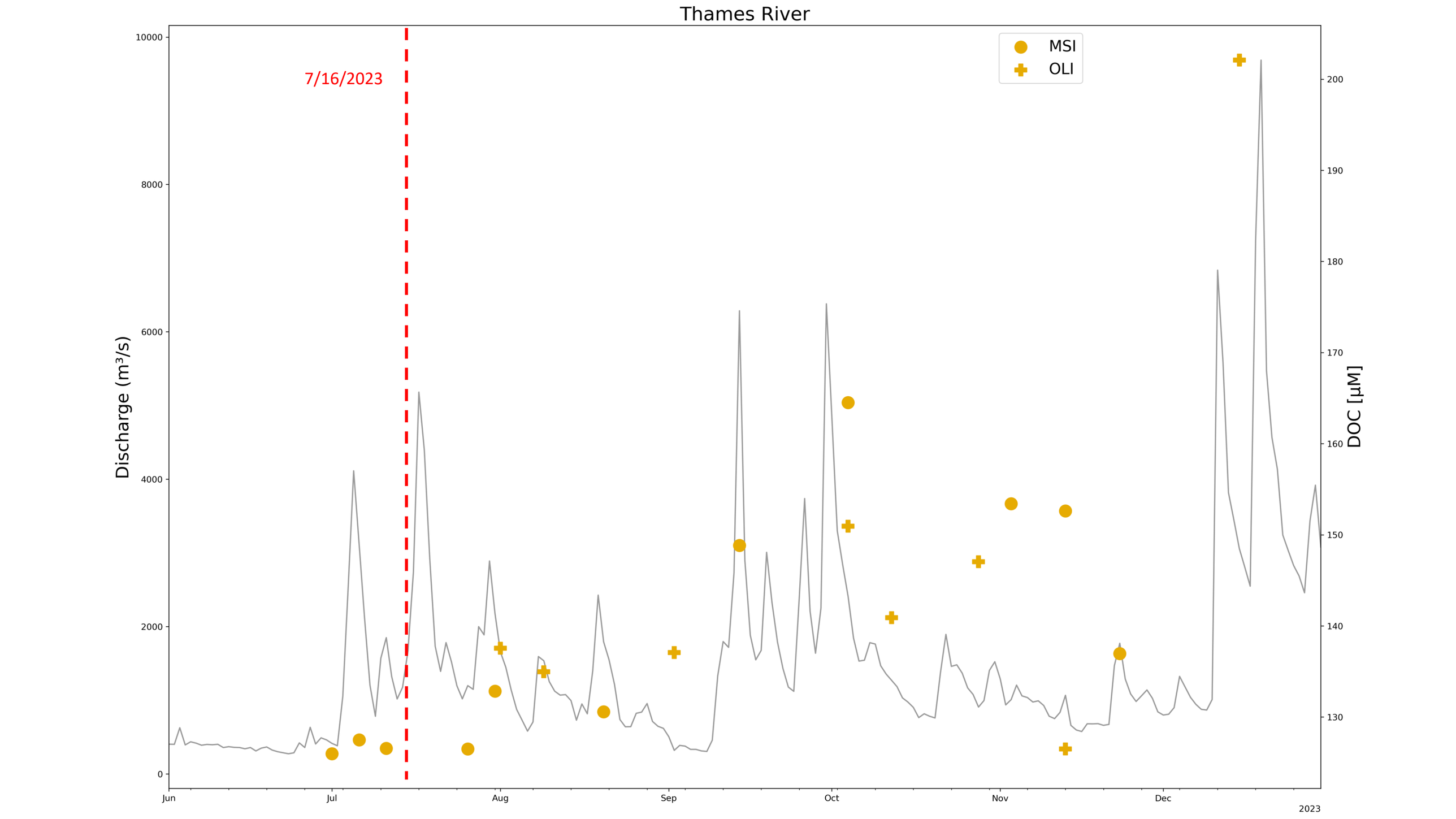

Bryam River
MSI
OLI
7/16/2023
Discharge (m³/s)
DOC [µM]
0
200
400
600
800
1000
1200
1400
130
140
150
160
170
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023

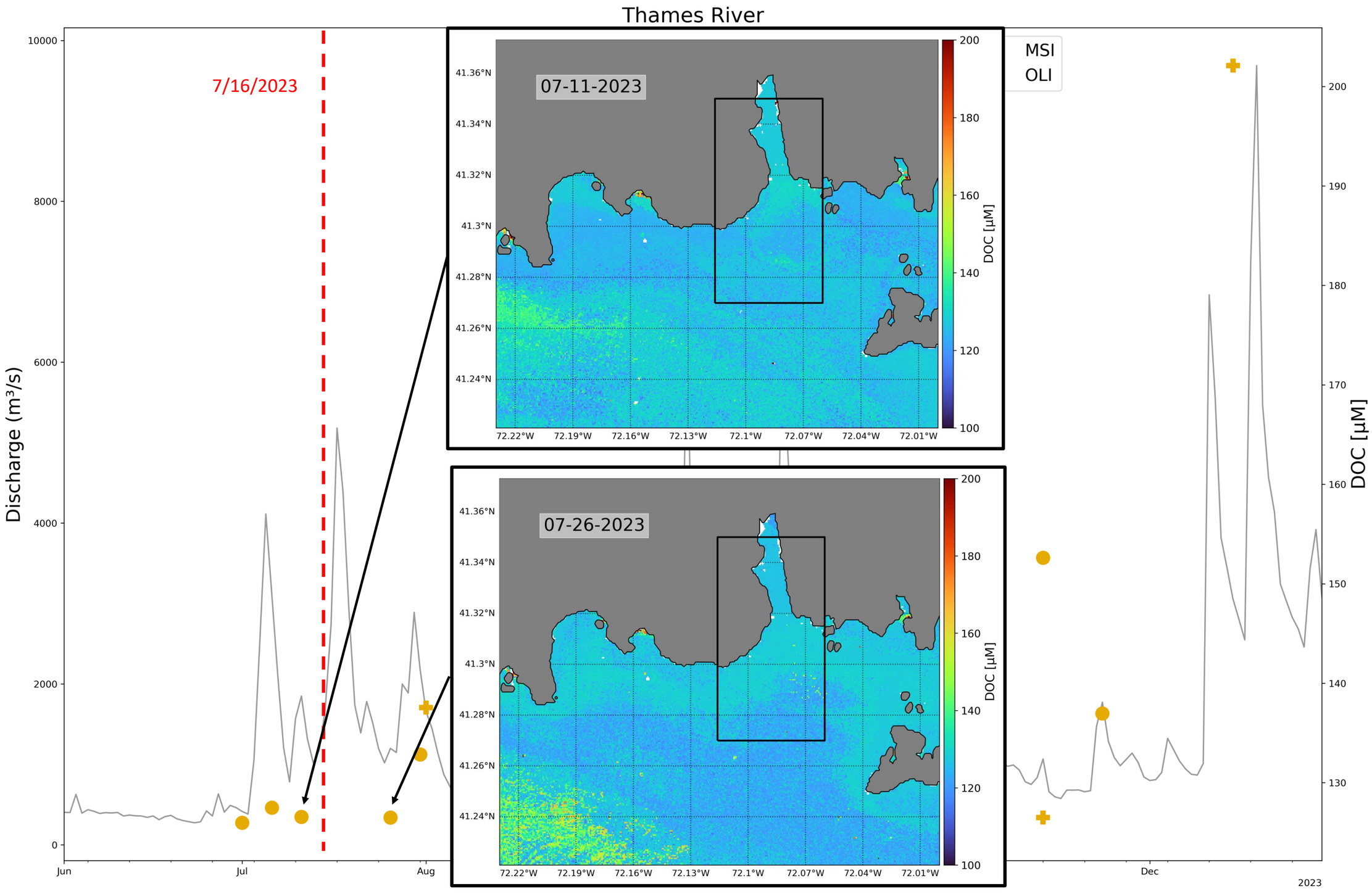

Bryam River
7/16/2023
07-11-2023
07-26-2023
Discharge (m³/s)
DOC [µM]
Jun
Jul
Aug
Dec
2023
41.005°N
40.99°N
40.975°N
40.96°N
40.945°N
40.93°N
40.915°N
73.7°W
73.68°W
73.66°W
73.64°W
73.62°W
73.6°W
73.58°W

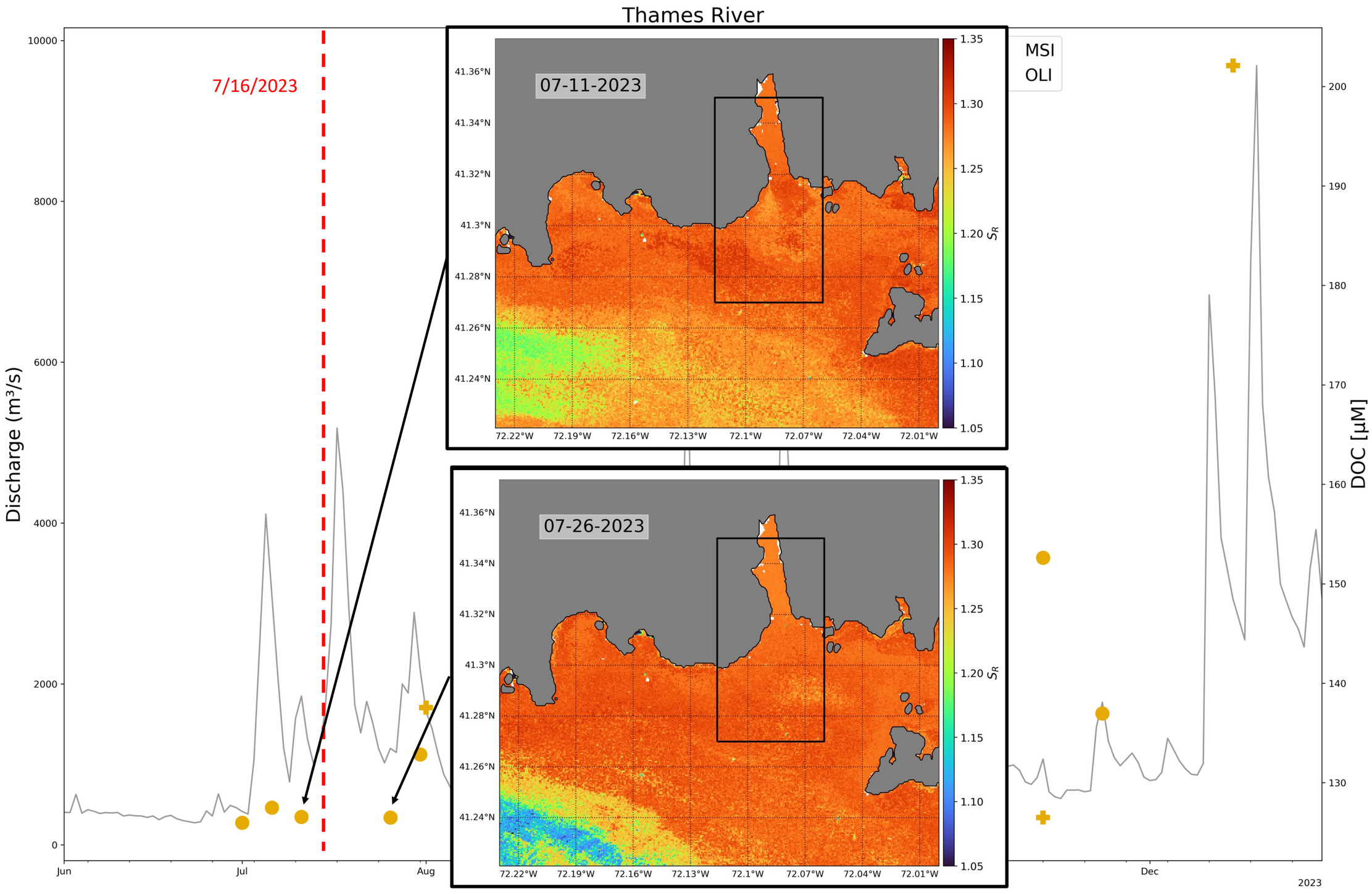

Bryam River
7/16/2023
07-11-2023
07-26-2023
Discharge (m³/s)
DOC [µM]
S_R
41.005°N
40.99°N
40.975°N
40.96°N
40.945°N
40.93°N
40.915°N
73.7°W
73.68°W
73.66°W
73.64°W
73.62°W
73.6°W
73.58°W
1.35
1.30
1.25
1.20
1.15
1.10
1.05
0
200
400
600
800
1000
1200
1400
130
140
150
160
170
Jun
Jul
Aug
Dec
2023

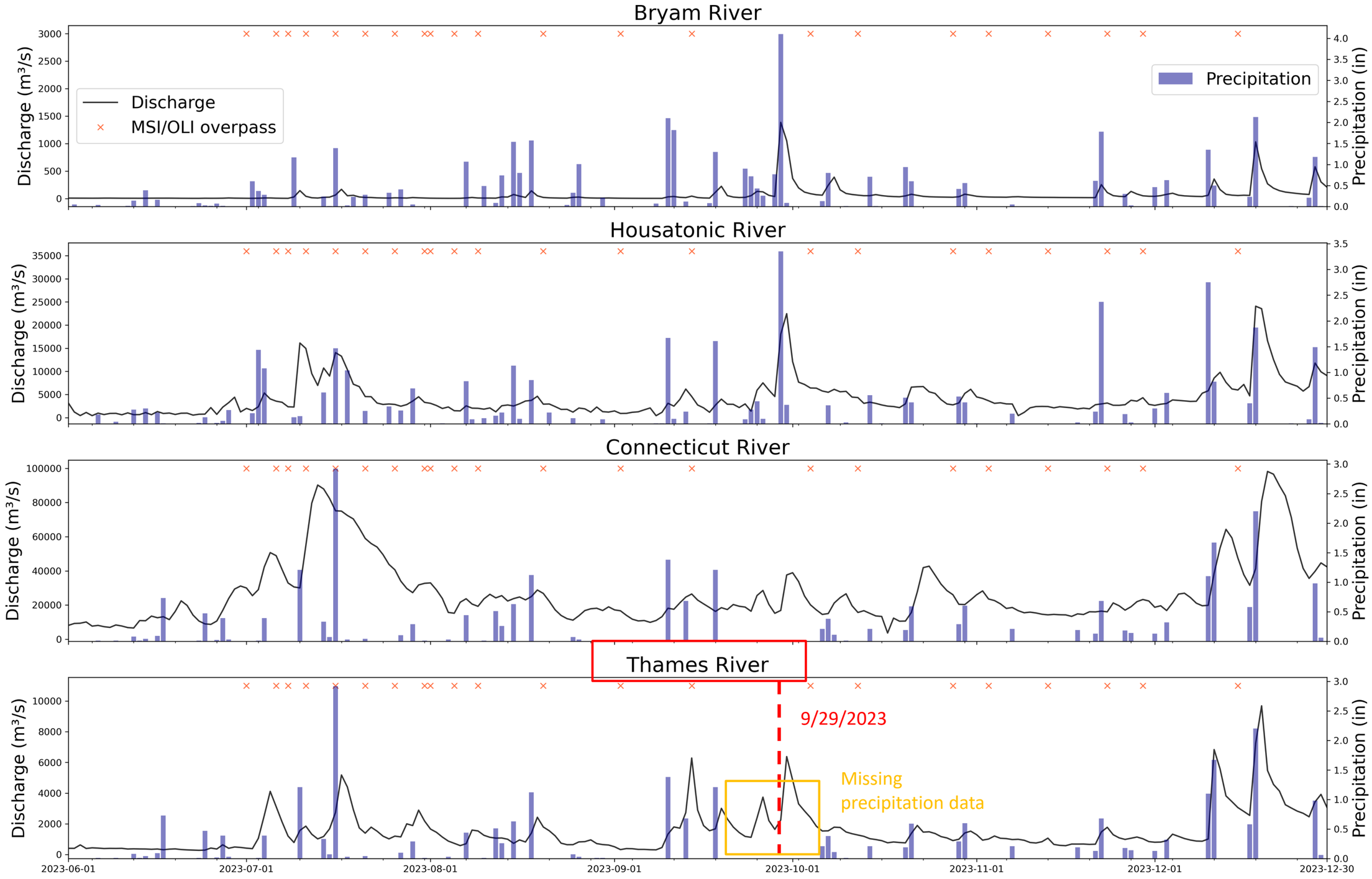

Bryam River
7/16/2023
What is responsible for this jump?
07-31-2023
07-26-2023
Discharge (m³/s)
DOC [µM]
Jun
Jul
Aug
Dec
2023
41.005°N
40.99°N
40.975°N
40.96°N
40.945°N
40.93°N
40.915°N
73.7°W
73.68°W
73.66°W
73.64°W
73.62°W
73.6°W
73.58°W

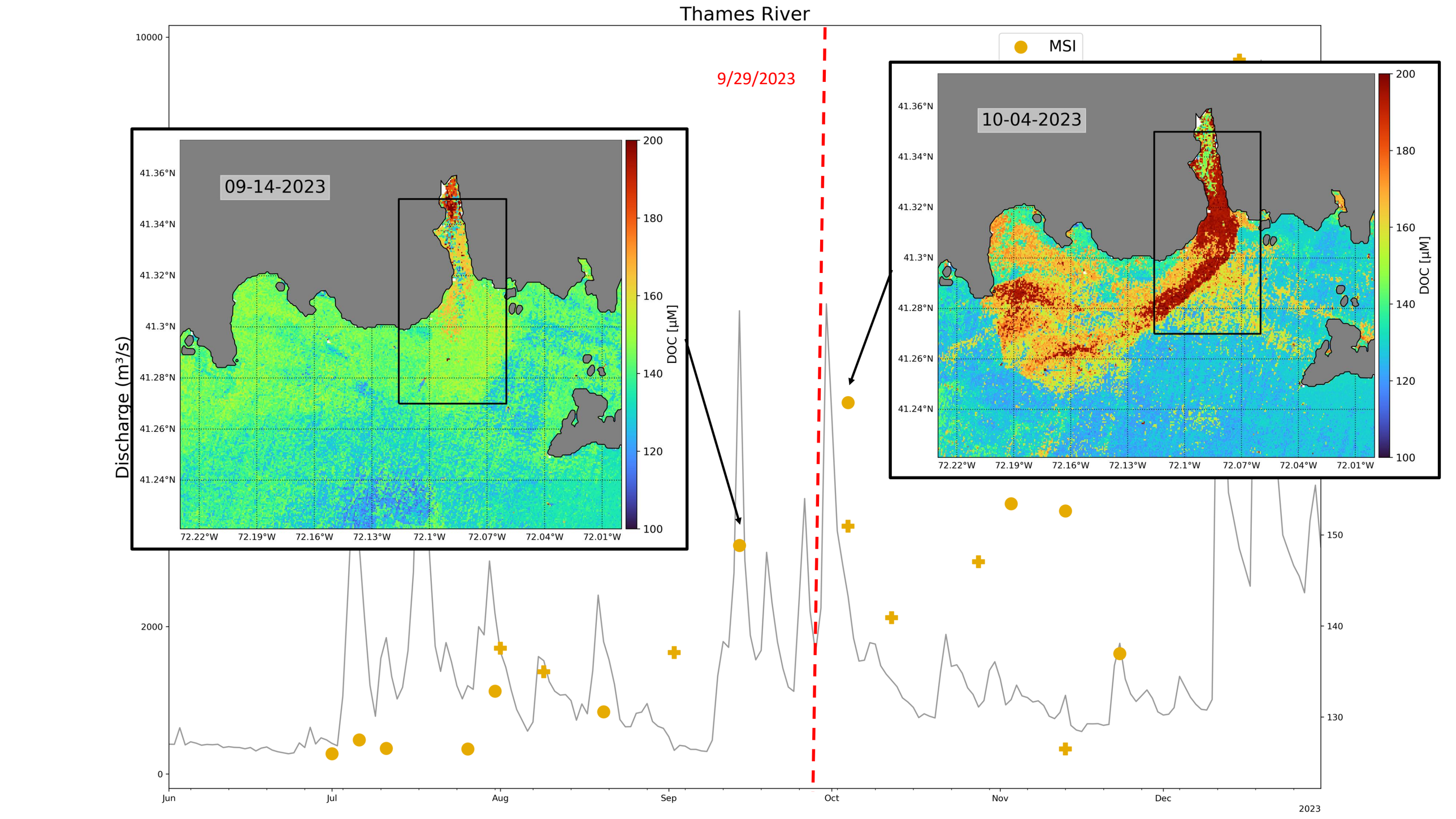

Bryam River
Discharge
MSI/OLI overpass
Precipitation
Discharge (m³/s)
Precipitation (in)
Housatonic River
Connecticut River
Thames River
7/16/2023
2023-06-01
2023-07-01
2023-08-01
2023-09-01
2023-10-01
2023-11-01
2023-12-01
2023-12-30

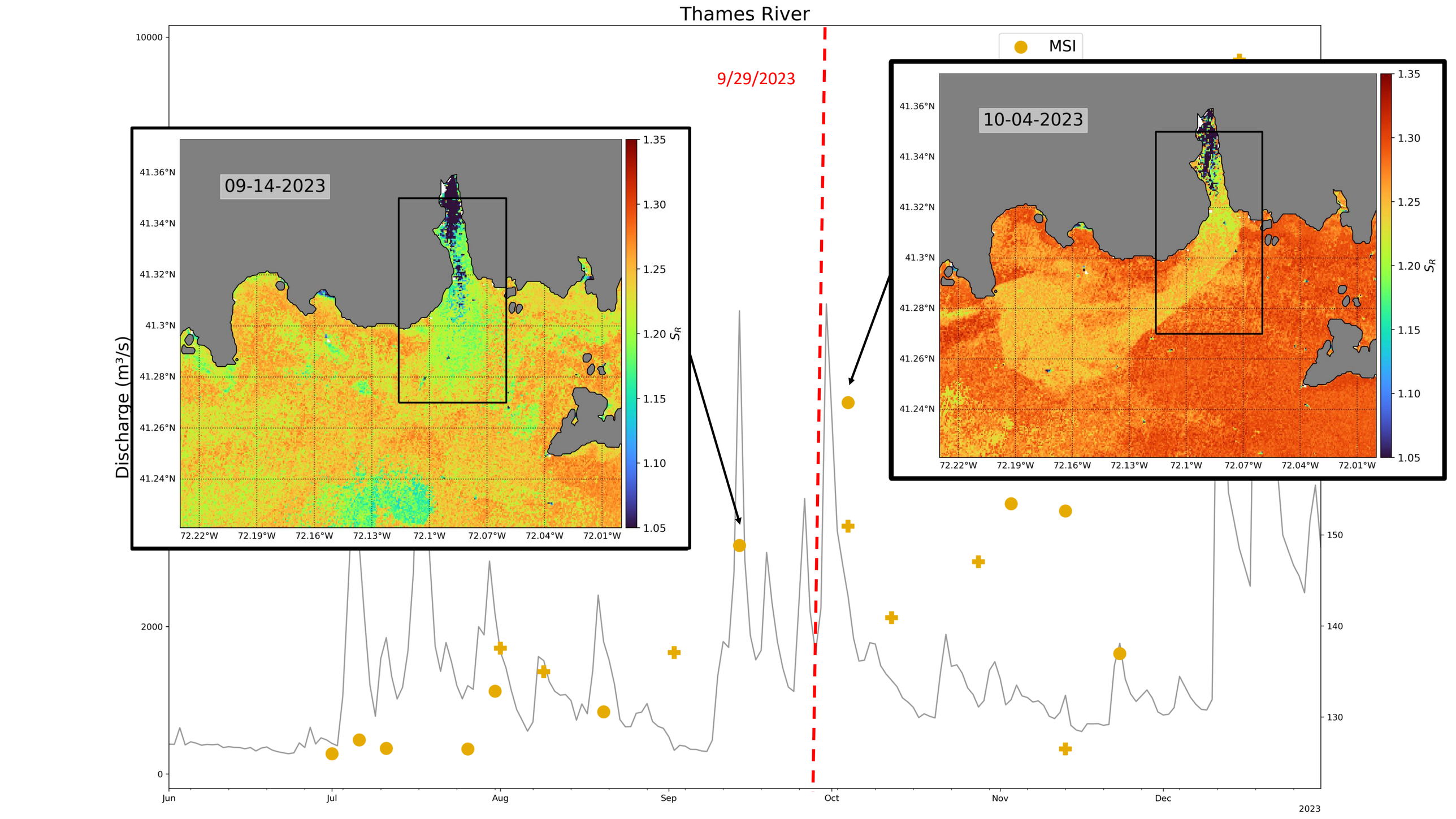

Thames River
7/16/2023
MSI
OLI
Discharge (m³/s)
DOC [µM]
0
2000
4000
6000
8000
10000
130
140
150
160
170
180
190
200
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023


Thames River
7/16/2023
MSI
OLI
07-11-2023
07-26-2023
Discharge (m³/s)
DOC [µM]
10000
8000
6000
4000
2000
0
200
190
180
170
160
150
140
130
Jun
Jul
Aug
Dec
2023
41.36°N
41.34°N
41.32°N
41.3°N
41.28°N
41.26°N
41.24°N
72.22°W
72.19°W
72.16°W
72.13°W
72.1°W
72.07°W
72.04°W
72.01°W
200
180
160
140
120
100


Thames River
7/16/2023
07-11-2023
07-26-2023
MSI
OLI
Discharge (m³/s)
DOC [µM]
S_R
Jun
Jul
Aug
Dec
2023
72.22°W
72.19°W
72.16°W
72.13°W
72.1°W
72.07°W
72.04°W
72.01°W
41.36°N
41.34°N
41.32°N
41.3°N
41.28°N
41.26°N
41.24°N


Bryam River
Housatonic River
Connecticut River
Thames River
Discharge
MSI/OLI overpass
Precipitation
Discharge (m³/s)
Precipitation (in)
9/29/2023
Missing
precipitation data
2023-06-01
2023-07-01
2023-08-01
2023-09-01
2023-10-01
2023-11-01
2023-12-01
2023-12-30


Thames River
MSI
9/29/2023
09-14-2023
10-04-2023
Discharge (m³/s)
DOC [µM]
10000
2000
0
150
140
130
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023
41.36°N
41.34°N
41.32°N
41.3°N
41.28°N
41.26°N
41.24°N
72.22°W
72.19°W
72.16°W
72.13°W
72.1°W
72.07°W
72.04°W
72.01°W
200
180
160
140
120
100


Thames River
MSI
9/29/2023
Discharge (m³/s)
10000
2000
0
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2023
150
140
130
09-14-2023
10-04-2023
41.36°N
41.34°N
41.32°N
41.3°N
41.28°N
41.26°N
41.24°N
72.22°W
72.19°W
72.16°W
72.13°W
72.1°W
72.07°W
72.04°W
72.01°W
1.35
1.30
1.25
1.20
1.15
1.10
1.05
S_R

Conclusions

- Summary:
  - Thames River:
    - Experiences a flushing influence from the Atlantic Ocean.
  - Connecticut River:
    - Exhibits the most significant changes in DOM quantity and quality due to rain events.
    - Optical trends of DOM from satellites follow similar trend as in-situ retrievals.
  - Housatonic River:
    - Highly responsive to rain events, though its plume can be bottlenecked by sandbar at the mouth of the river effecting how DOM is exchanged with mainstem sound.
  - Bryam River:
    - Has a small watershed and located in less dynamic part of LIS, so dynamics are influenced more by general circulation than river discharge.

Conclusions

Main take-aways:

•Transient plumes retrieved by CDOM algorithm (Menendez and Tzortizou, *in review*) align with climatology described by Cao & Tzortziou (2024).

•SR can be used to help more precisely define and track terrestrial DOM/DOC plumes.

•Impacts of precipitation events on nearshore environments can be measured with high spatial resolution satellites.

Future research

Limitations:

- High spatial resolution satellite: The lack of temporal coverage makes it difficult to conduct time series analyses for localized areas and specific events.
- Nature of the question: extreme events, especially precipitation, can be challenging to study via satellite.

Next steps:

- Automate plume identification and plume tracking.
- Further validation of the algorithm → in-situ ground truthing, comparison with OLCI retrievals and other algorithms.
- Similar analysis on more precipitation events.
- NOAA/CoastWatch aligned goals: actionable data for stakeholders and coastal management.

Acknowledgments

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