STREAM: SATELLITE-BASED ANALYSIS TOOL FOR RAPID EVALUATION OF AQUATIC ENVIRONMENTS

NIMA PAHLEVAN, NAVID GOLPAYEGANI, ASEN RADOV, AKASH ASHAPURE,
WILLIAM WAINWRIGHT, RYAN O'SHEA, ARUN SARANATHAN, BRANDON SMITH,
SAKIB KABIR

SSAI, FRESHWATER SENSING TEAM
NASA GODDARD SPACE FLIGHT CENTER / CODE 619

LANCE UWG MEETING
29 NOVEMBER 2023

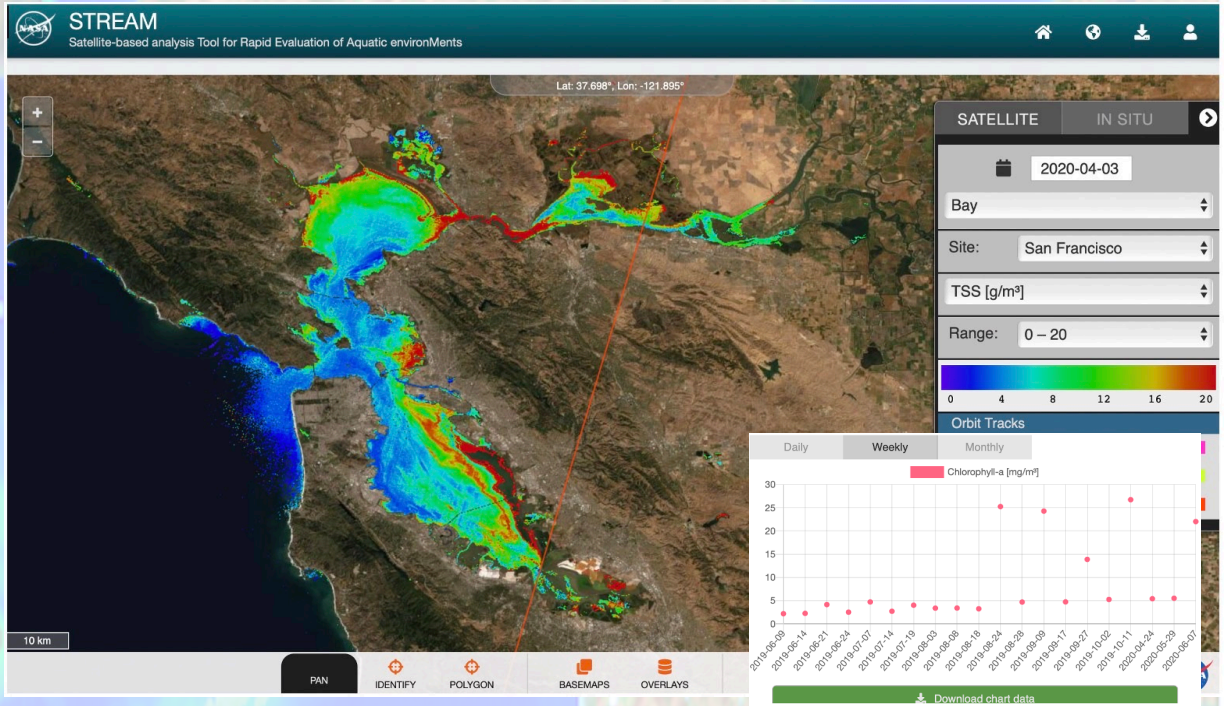
Landsat-8/OLI
Lake Erie; Sister Island, USA

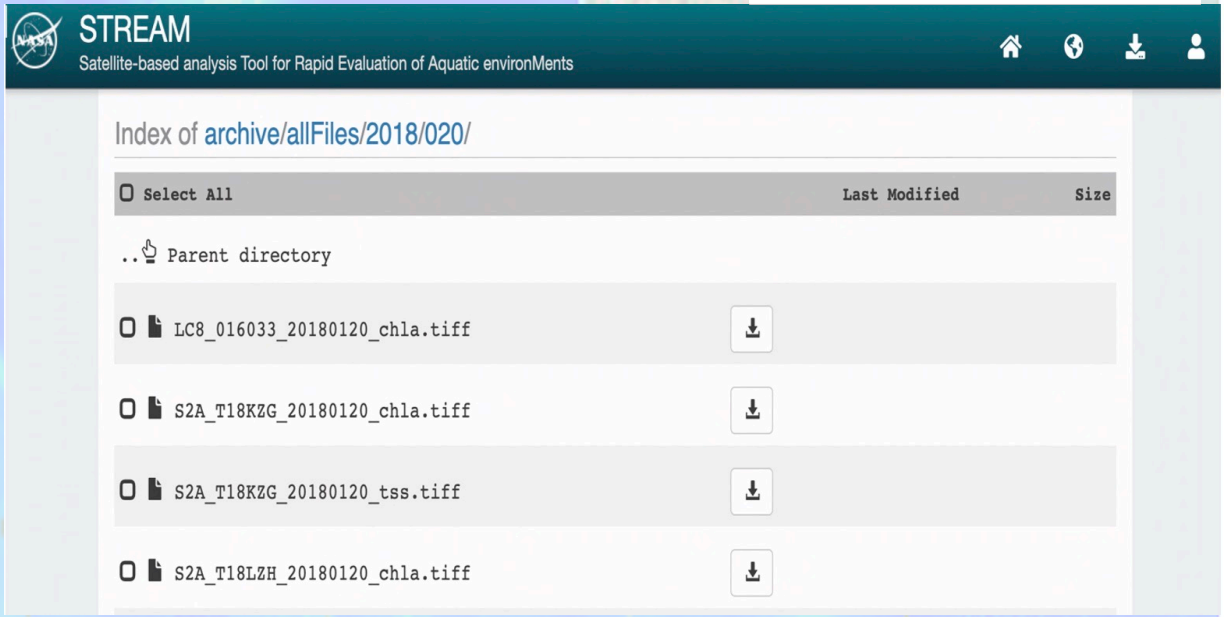
STREAM: Its Inception and Evolution

- **NASA's water quality workshop in 2017**
- **Supported by NASA HQ Applied Sciences**
- **Improve water-quality monitoring**
  - Near-real time
  - Visualization and analysis (SDG 6)
  - Built on FIRMS
- **Aquatic ecosystems > 150 m wide**
  - Complement other similar systems
- **Engage and interact with end-users and UN Environment Program (UNEP)**

STREAM functionalities

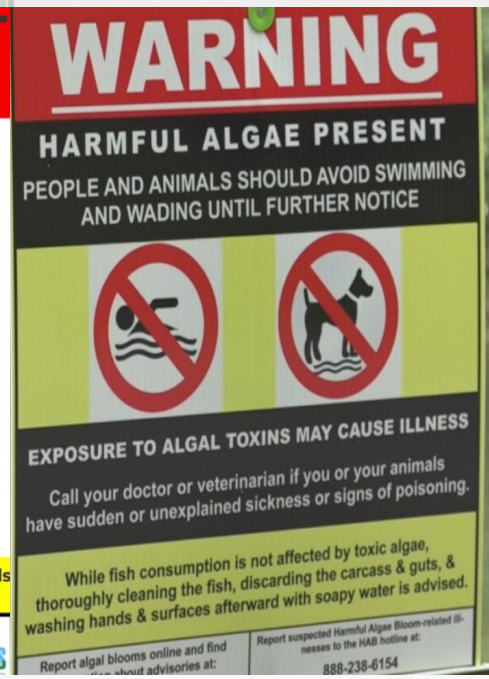
- Missions: Landsat-8/-9 and Sentinel-2 (~20 m)
- NRT image processing (latency of 3-6 hours)
- Products: Chlorophyll-a (Chl*a*), Total Suspended Solids (TSS), Secchi Disk depth (Z_{sd})
- Downloadable maps (Geotiff)
- Visualization
- Time-series analysis (daily/weekly/monthly)
  - Per-pixel queries
  - Lake-wide (area-based) queries
- Notification system
- Early Adopters
  - **Peru** and **Uruguay** via EarthData
  - SDG 6.3.2 reporting

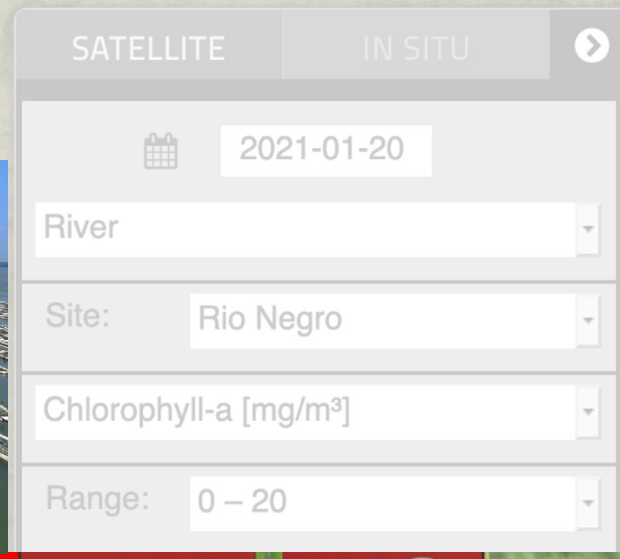




Science and application areas

- Water utilities
  - Optimize operations
  - Minimize disinfection byproducts
- Aquaculture/fisheries ($1.5B industry in 2017)
  - Site identification (“sitting”)
  - Aquaculture operations
  - Restoration activities/projects
- Ecosystem monitoring (=< 30 m resolution is required)
  - Water quality
  - Harmful algal blooms (HABs)
- Sustainable Development Goal 6.3.2 (reporting)
  - Proportion of waterbodies with good ambient water
- Science
  - Carbon cycle and ecosystem
  - HAB-related studies
  - Forecasting & modeling





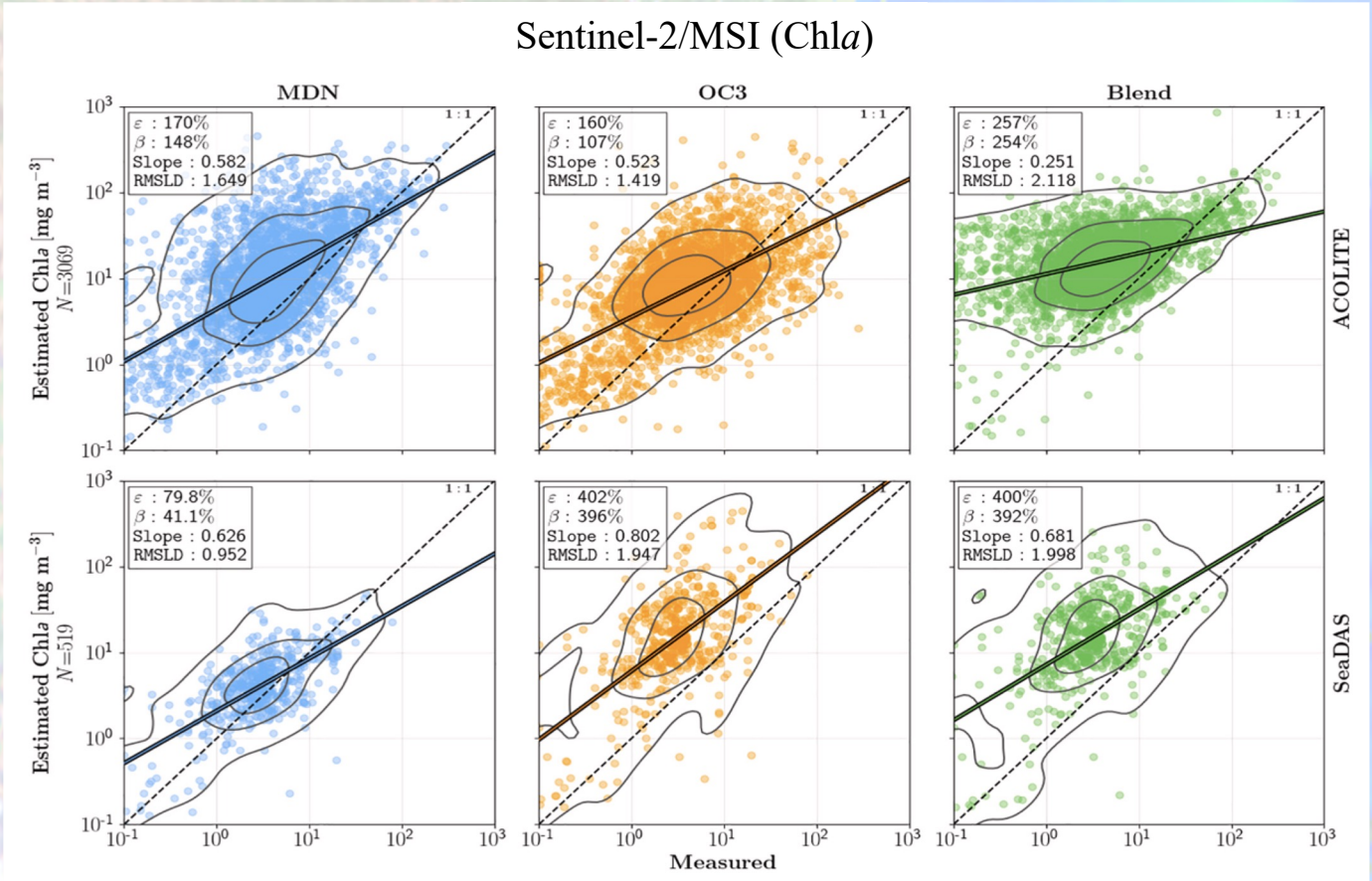
STREAM was released to Early Adopters in 2021

1. **Capacity development (Uruguay & Peru)**
2. **Methodology evaluation & validation**

Remote Sensing Applications: Society and Environment
Available online 10 December 2022, 100891
In Press, Journal Pre-proof

Monitoring Uruguay's freshwaters from space: An assessment of different satellite image processing schemes for chlorophyll-a estimation

J.M. Barreneche [a], B. Guigou [a], F. Gallego [a, b], A. Barbieri [a, c], B. Smith [d, e], M. Fernández [a], V. Fernández [a, c], N. Pahlevan [d, e]



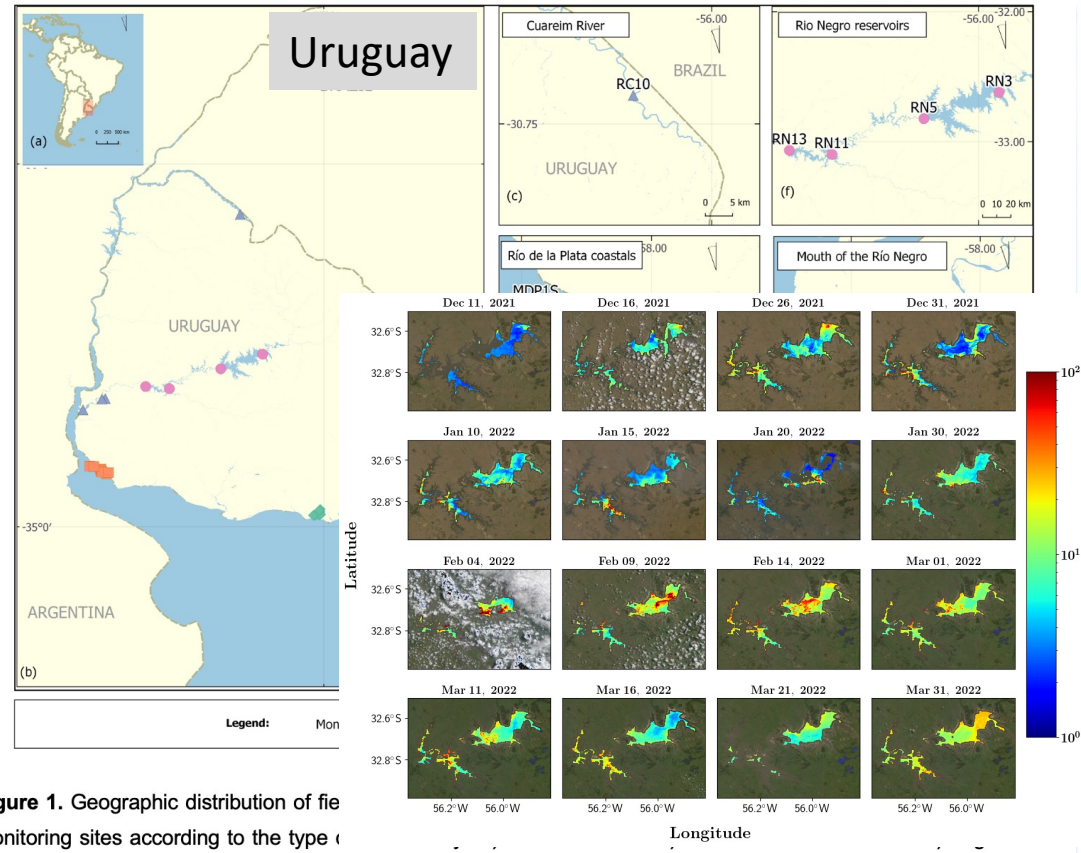
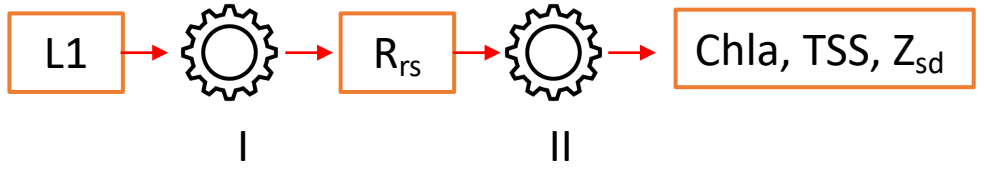


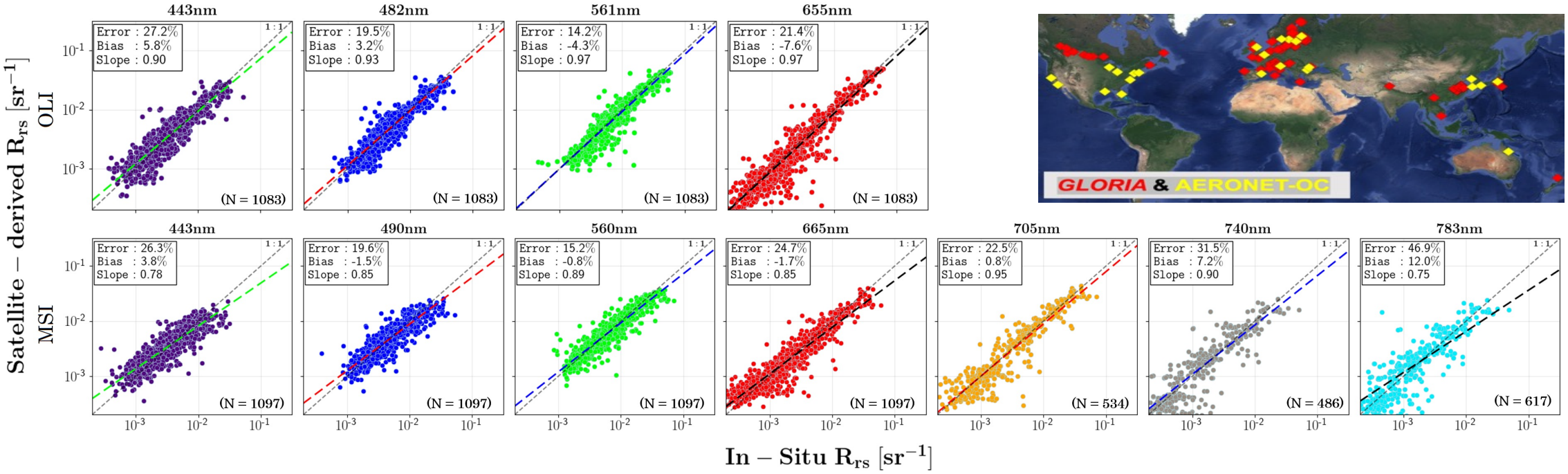
Figure 1. Geographic distribution of fie
monitoring sites according to the type
Sauce. F) Rio Negro reservoirs. G) Mouth of the Río Negro. H) José Ignacio and Garzón Lagoons.

STREAM processing workflow upgrades

Aquaverse

- In-house ML/AI-based models (Aquaverse)
  - I. Atmospheric correction
    - Formulation, testing, implementation, and extensive validation
  - II. In-water retrievals
    - Formulation, testing, implementation, and extensive validation





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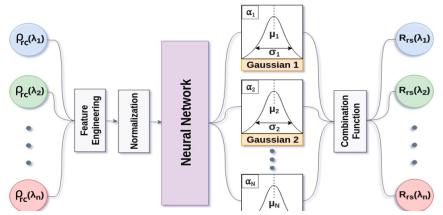
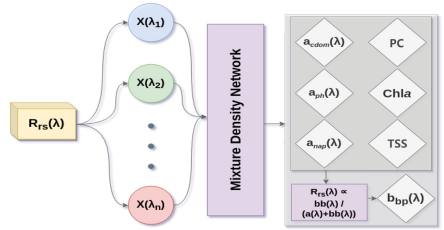
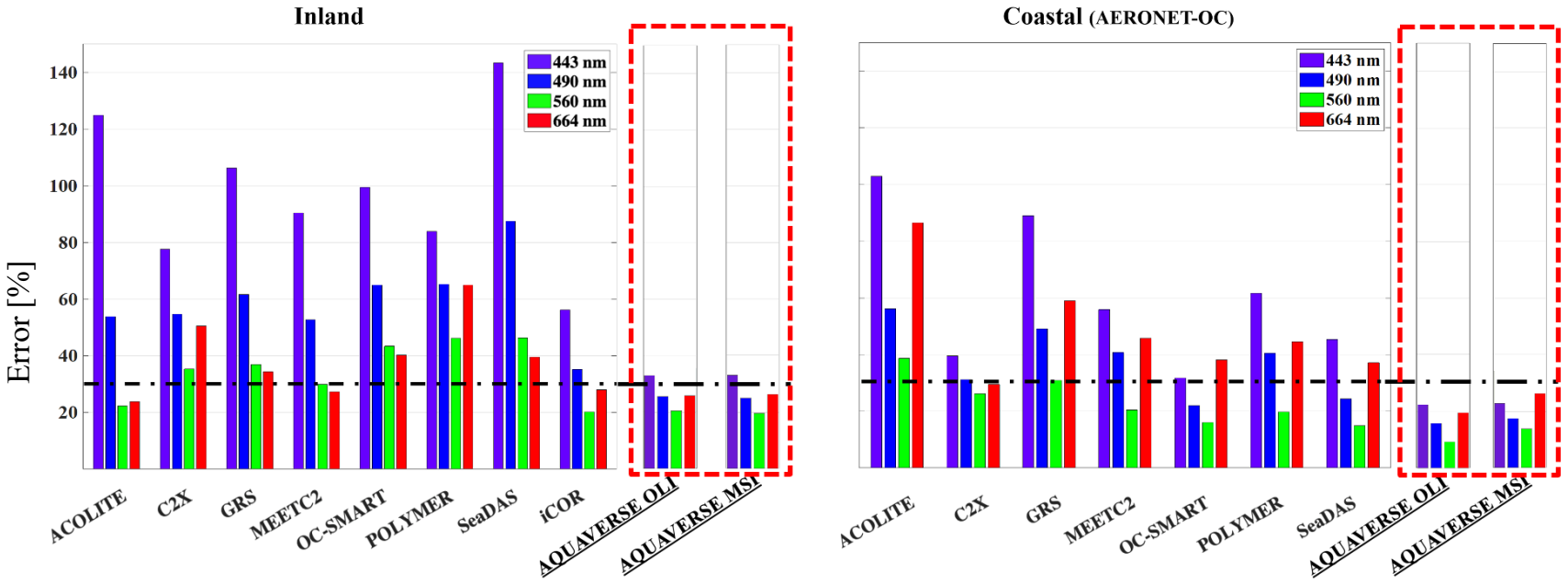
I

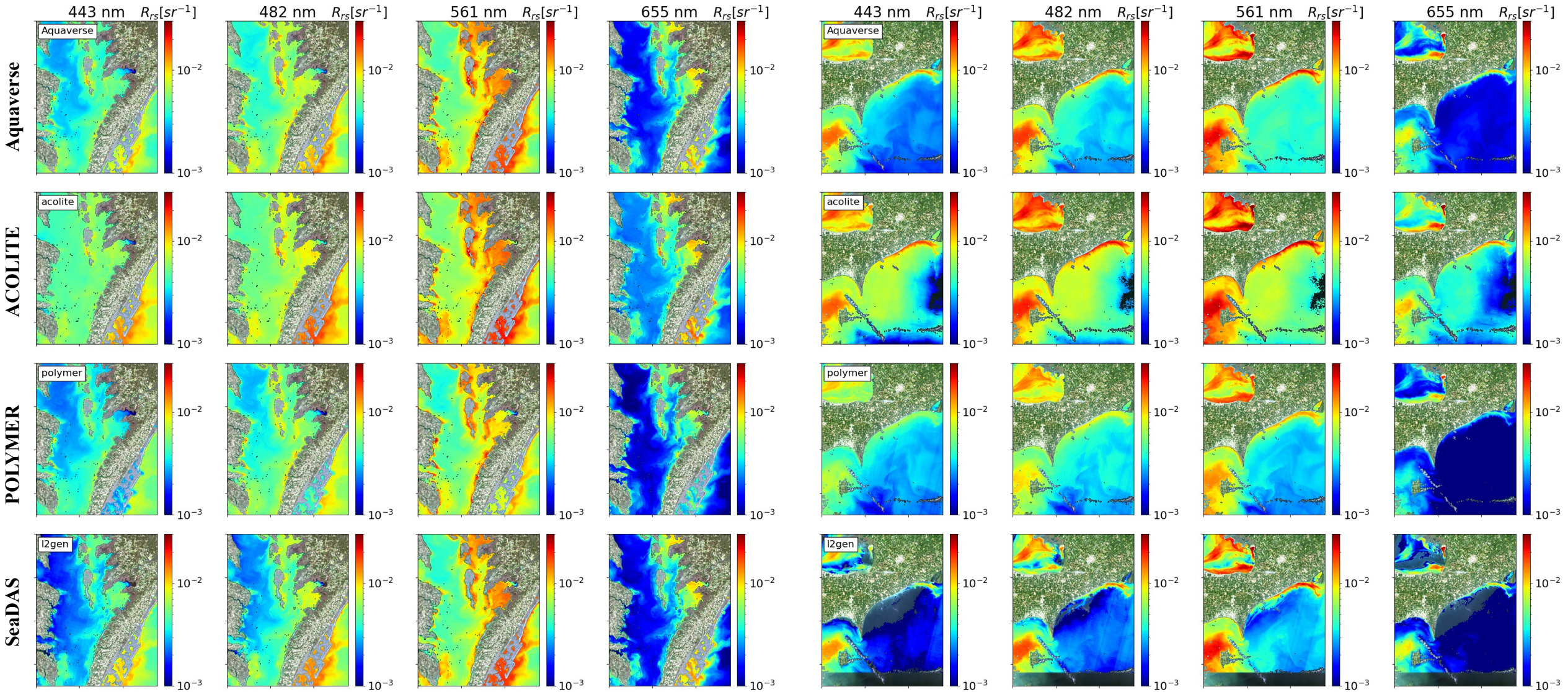


II





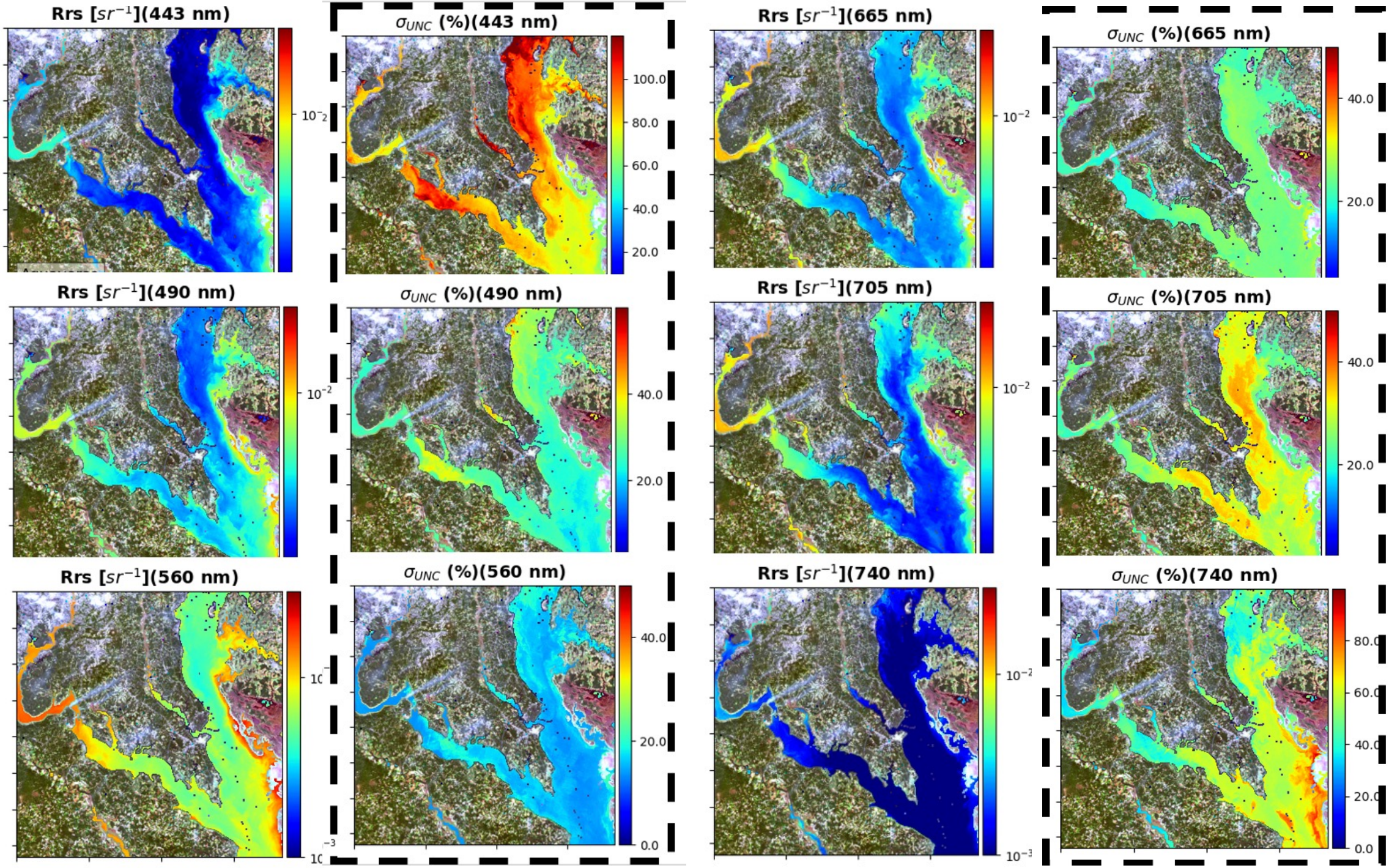
Pahlevan et al. 2021; ***ACIX-Aqua: Atmospheric correction intercomparison exercise***



Landsat-8 examples

How about uncertainties?

Sentinel-2 (Sep 27, 2021)

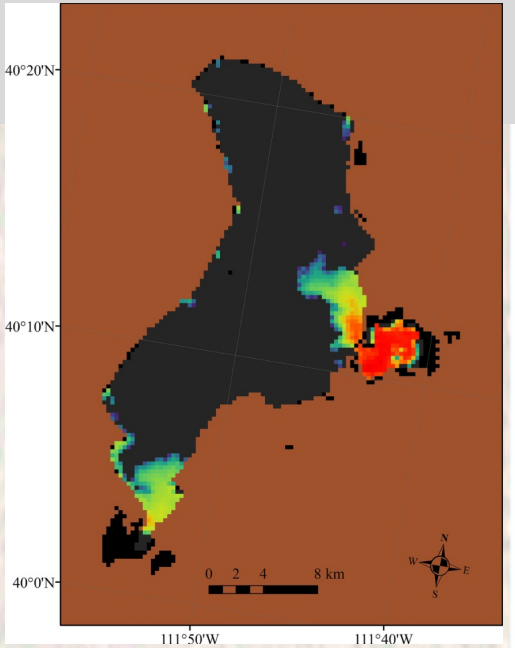


STREAM complements and fills the gaps

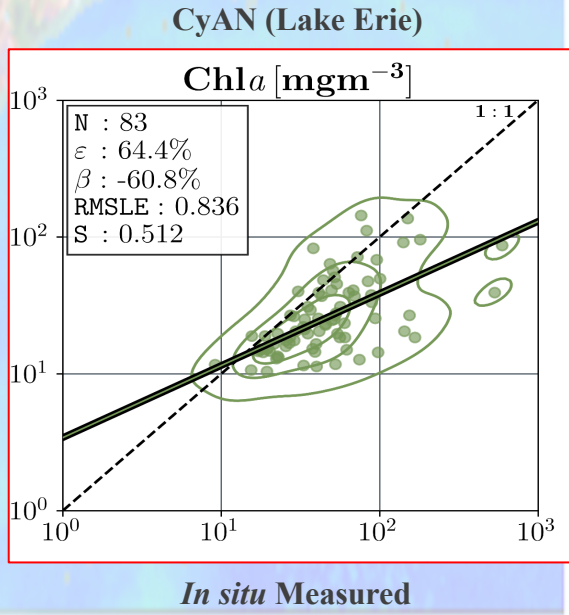
- Cyanobacteria Assessment Network (CyAN)
  - Based on Sentinel-3/OLCI's 300-m resolution
  - Detects areas with chlorophyll-a > 10 mg m^{-3} (presence vs. absence)
  - Enhanced end-users' trust in satellite products (since 2019)

- It only covers < 6% of the U.S. inland waterbodies & ~50% of U.S. estuaries.
- It has not been rigorously/statistically validated with global *in situ* data
- Its detection limit is restricted to impacted areas.
- Limited to CONUS.

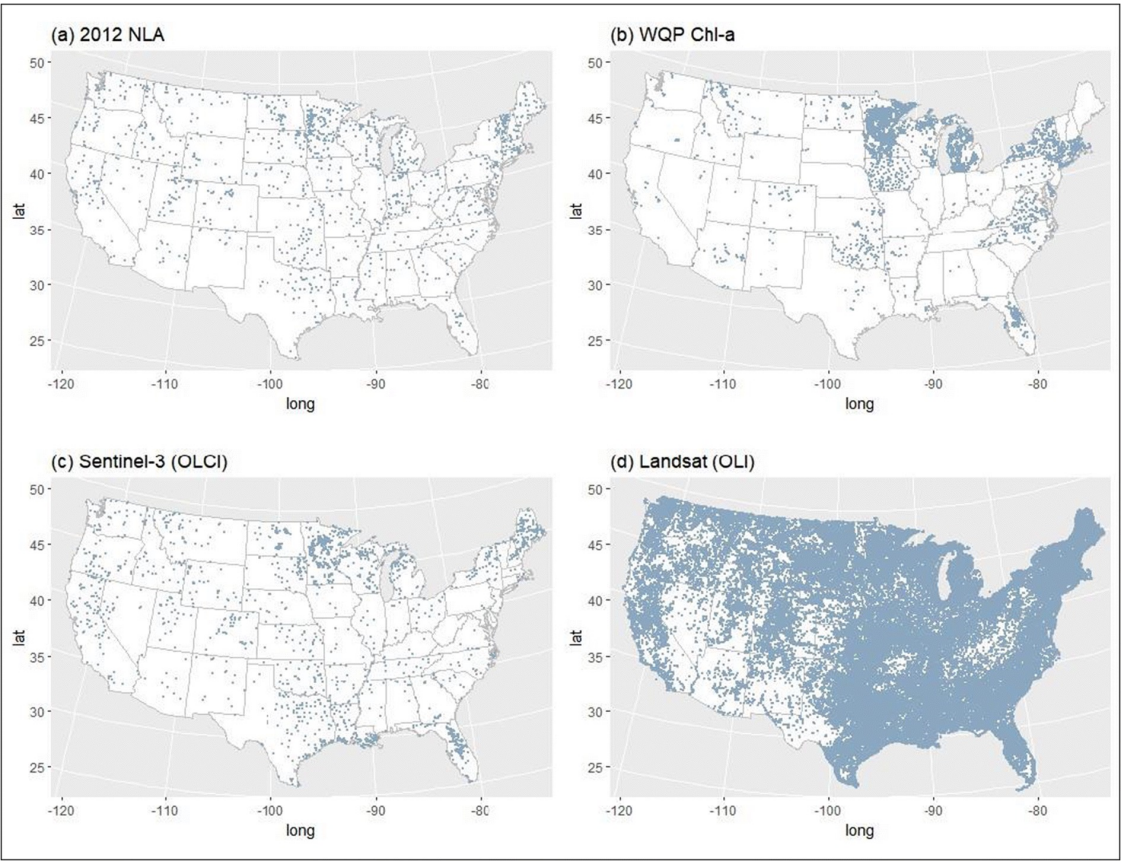
- There are a few other similar services, but none are rigorously validated.
  - Freshwater Explorer, Copernicus Global Land Service (not global)

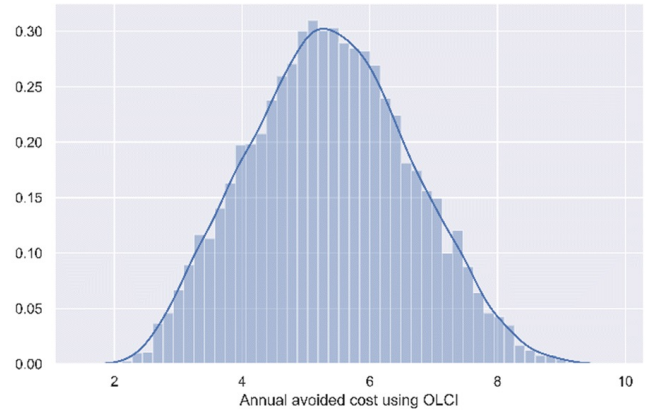


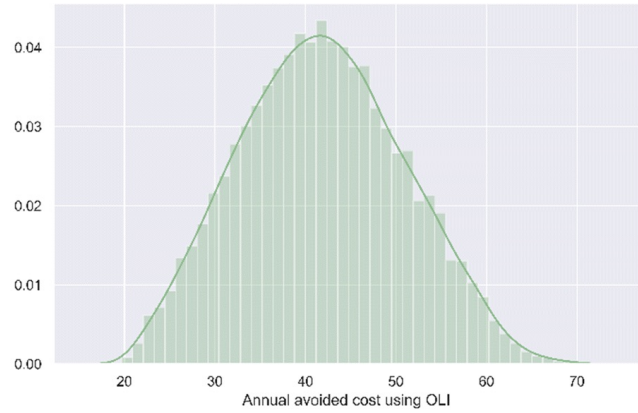
6/21/217, Utah Lake
Socioeconomic benefits of $370k

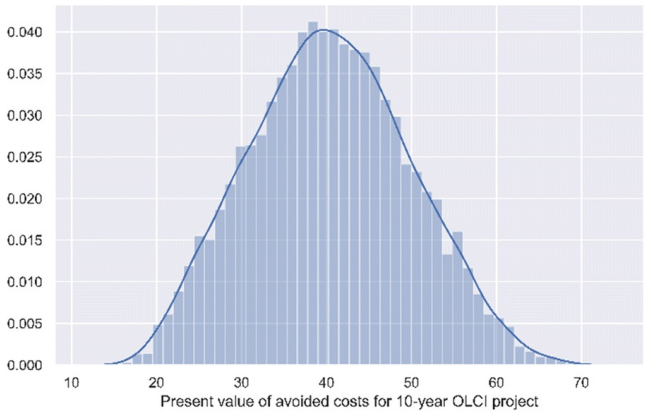


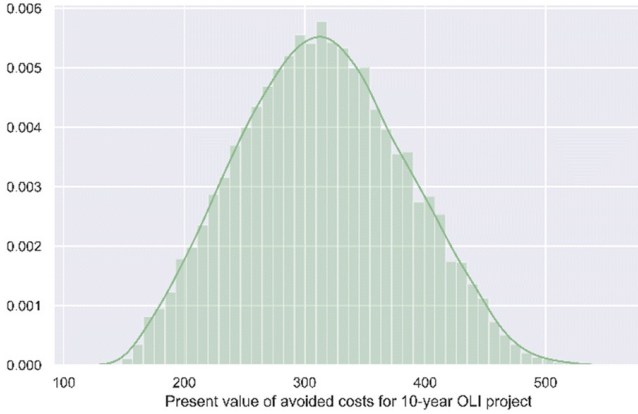
STREAM complements and fills the gaps











Papenfus, M., B. Schaeffer, A.I. Pollard, and K. Loftin, *Exploring the potential value of satellite remote sensing to monitor chlorophyll-a for US lakes and reservoirs.* Environmental Monitoring and Assessment, 2020. **192**(12): p. 808.

Takeaways

- STREAM is based on *6+ years of R&D* and support from various R&A programs + EO4SDG.
- It offers three critical water quality products: *Chla, TSS, and transparency.*
- It offers the only *globally validated (20-meter)* products accompanied by pixel-wise uncertainties.
- This is supported by 15+ peer-reviewed articles describing and validating our workflow *since 2020*.

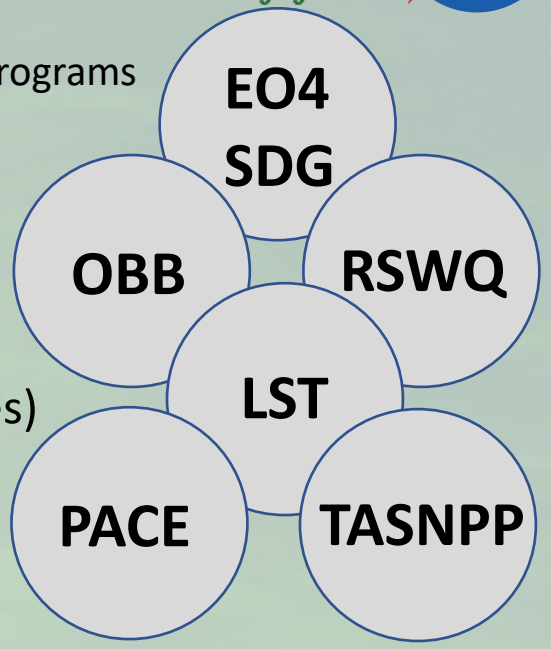
- More validation is underway.
- Reprocessing (Peru and Uruguay) began in mid-October 2023.
- Web interface is being revamped
  - Optimize the load time per user by pre-processing the map tile generation
  - Write a purpose-built, faster API that end users can also script

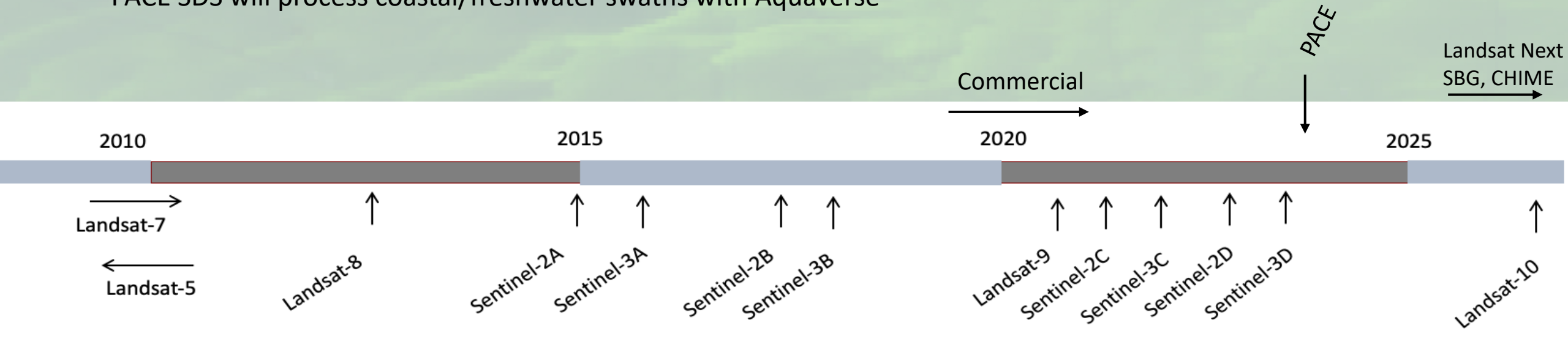
- **Stakeholders**
  - NOAA, USDA, Water Utilities, Public Health, States, Army Corps

Next steps

- Backend/frontend development
  - Product validation
- Gradual public release by **World Water Day** (3/22/2024)
- Strong support from HQ (Jared, Laura, Woody)
- Utilize near-future opportunities to communicate STREAM (Landsat project, user conferences)
- LANCE enhancement request to be submitted
- HLS can archive historic products
- Extension to other missions – SDG monitoring requires baseline setting
  - PACE SDS will process coastal/freshwater swaths with Aquaverse

Supporting Programs





Backup

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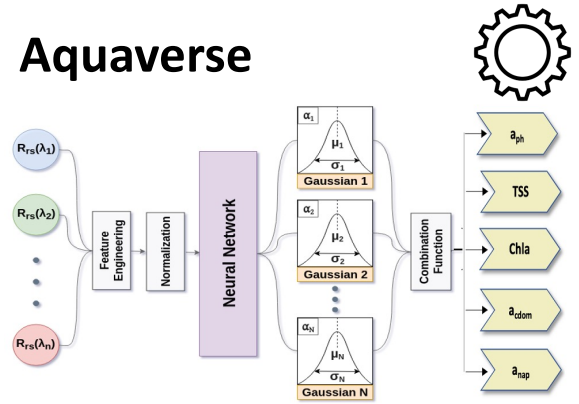
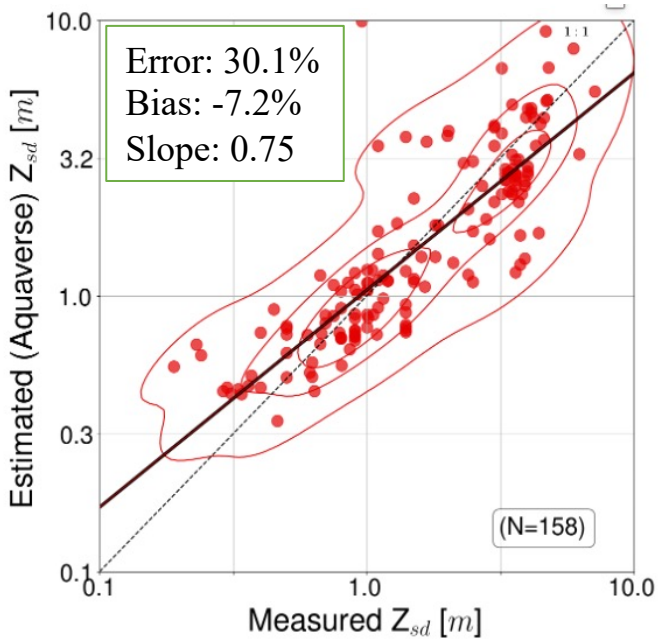
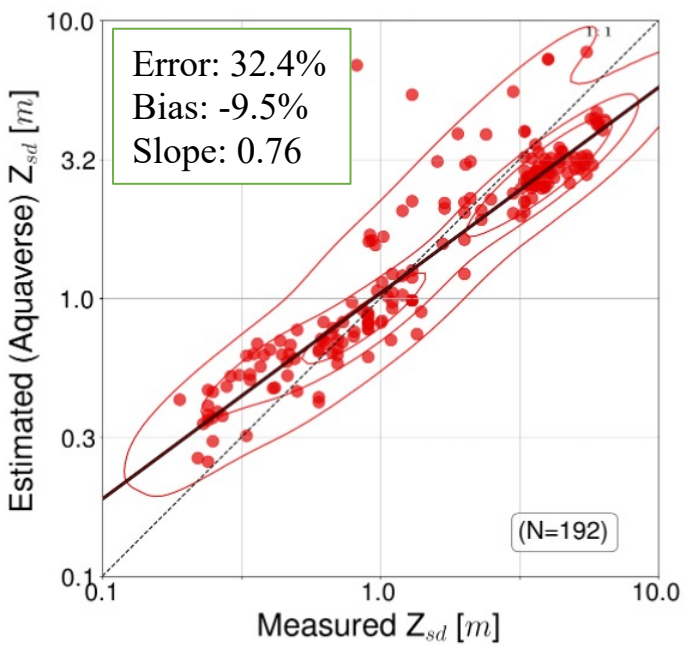


Consistent cross-mission Secchi (transparency) products

Landsat/OLI

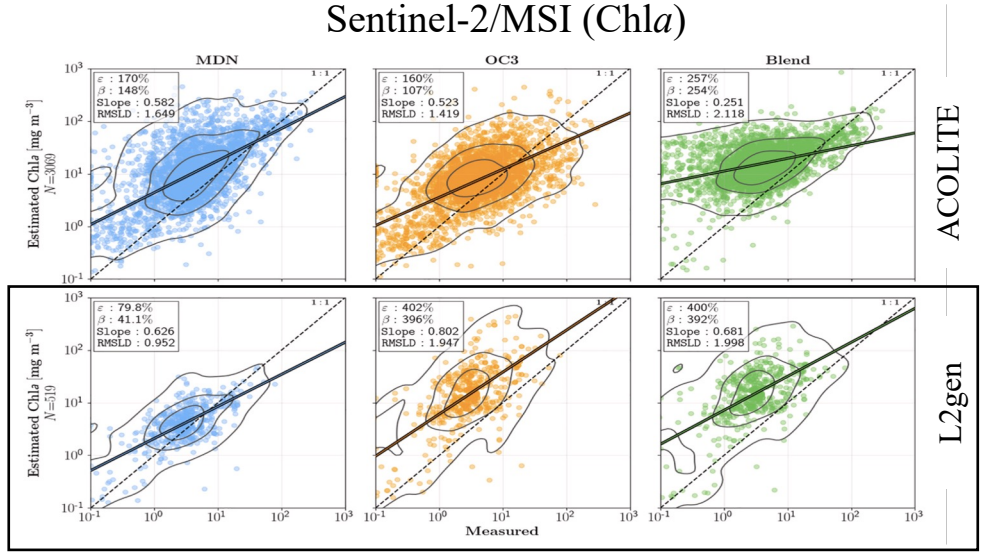


Sentinel-2/MSI



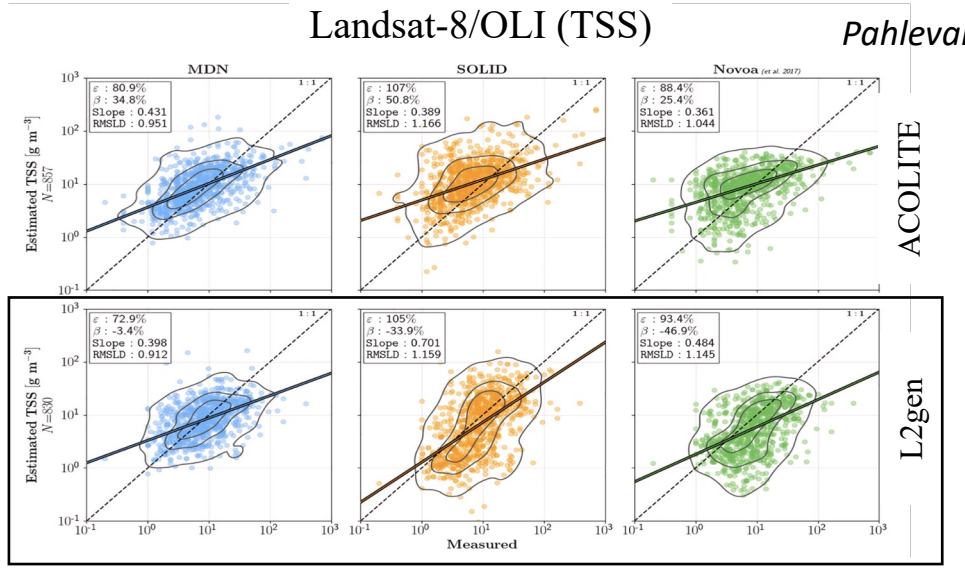
State-of-the-art product quality (prior to 2021)

Sentinel-2/MSI (Chl*a*)



Landsat-8/OLI (TSS)

Pahlevan et al. 2022



Sentinel-3/OLCI

Unpublished