

Marine debris induced by the Great East Japan Earthquake and Tsunami: A multi-sensor remote sensing assessment

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NOCCG Seminar, December 4, 2024

The Great East Japan Earthquake and Tsunami – March 11, 2011



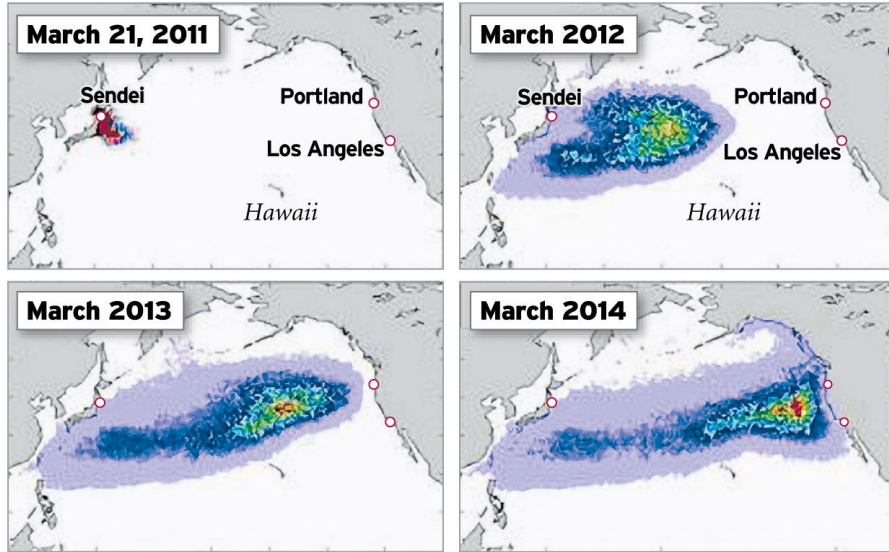
- Earthquake magnitude: 9.0-9.1 M_w
- massive tsunami up to 40.5m
- Cause >18,000 deaths
- destroyed 300,000 buildings
- damaged > 1,000,000 buildings
- > 1.5 million metric tons of debris into the Ocean



(MOE, 2012; Suppasri et al., 2013)

Huge amounts of debris washed in the ocean

Modeled pathways

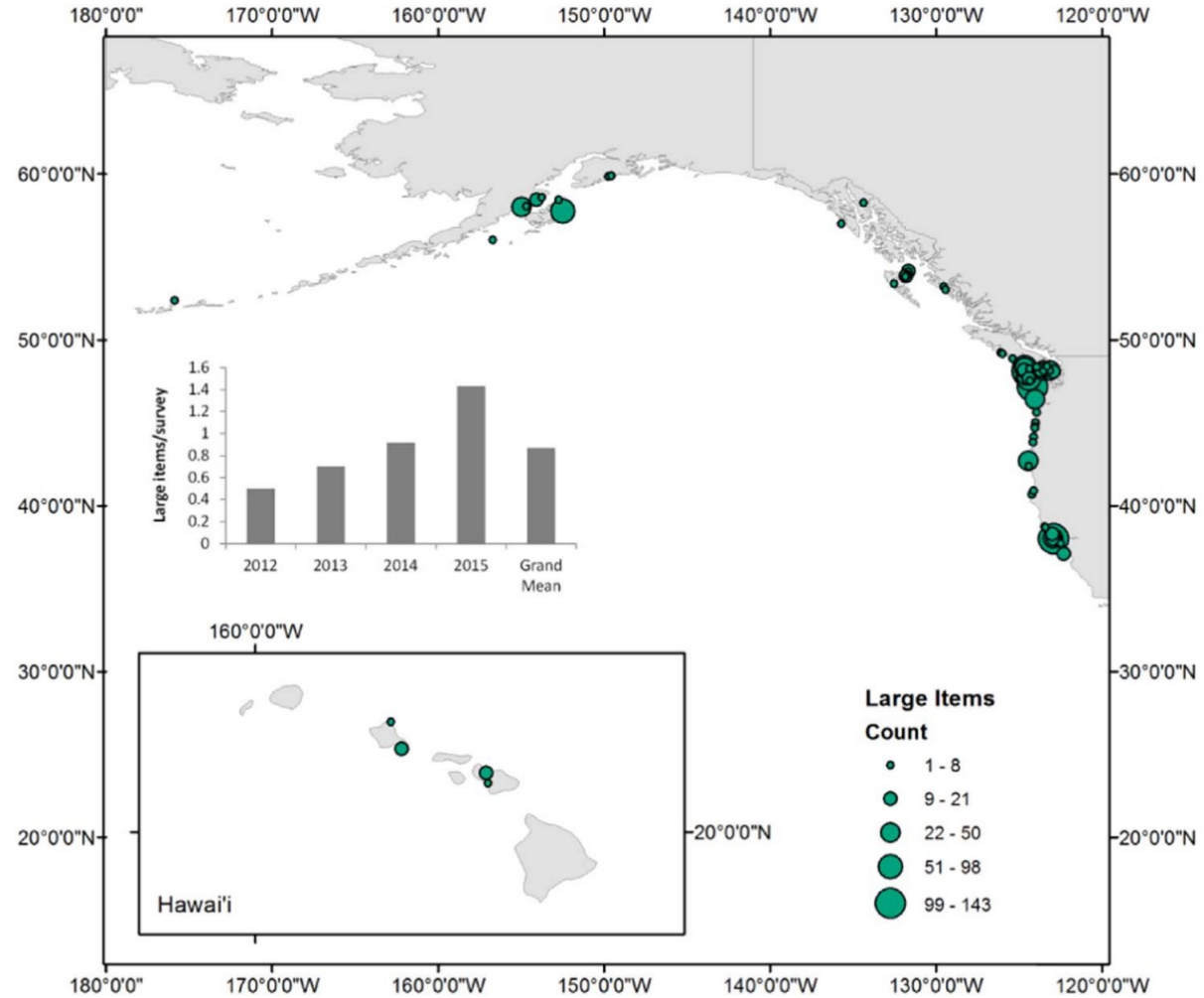


Source: Nikolai Maximenko, International Pacific Research Center

THE OREGONIAN



Observed debris



Murry et al. (2018, MPB)

Web of Science literature

Keyword Search	# of papers
Tsunami Japan 2011	> 3000
+ Debris	140
+ Remote Sensing	9 conference abstracts, 4 papers
	High-res satellites, SAR, aerial imagery
	All limited in spatial and temporal coverage

Thirteen years passed, several questions still remain

- Where are the debris?
- What are they?
- How much?

Why are they so difficult to answer?

Field and/or airborne observations – too few to provide a large picture

Satellite remote sensing – lack of spatial resolution or temporal coverage

lack of algorithm/methodology

Why can we revisit these questions now?

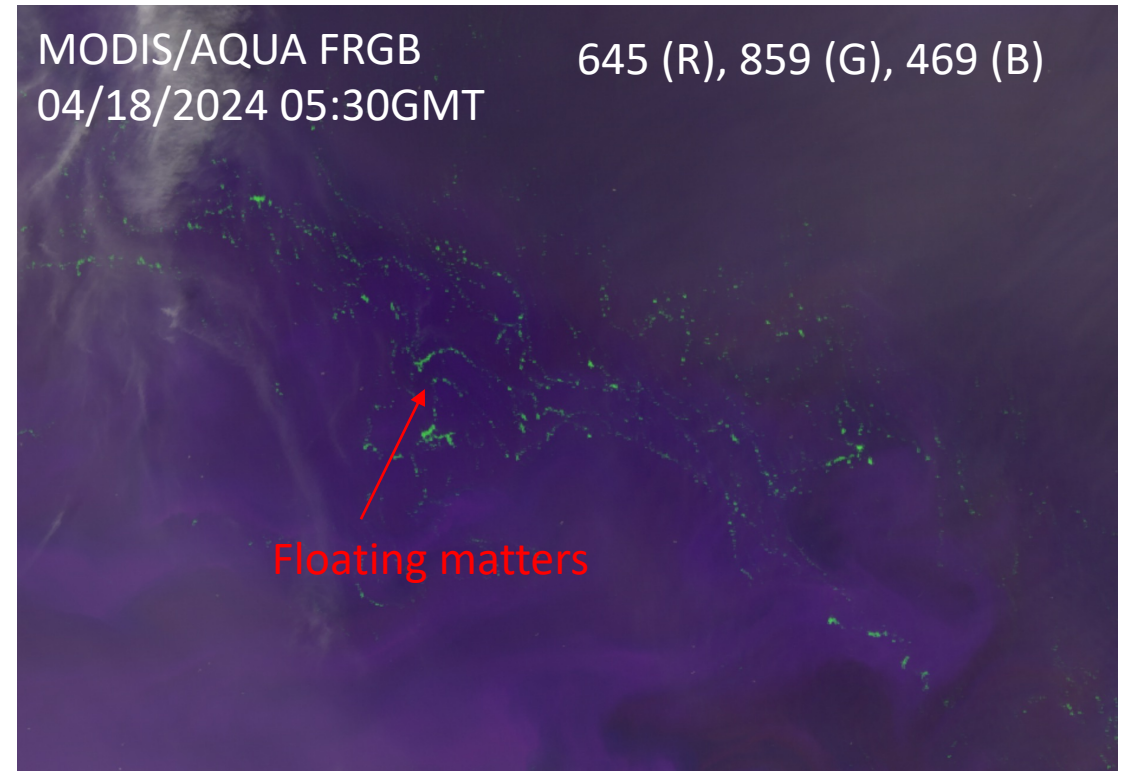
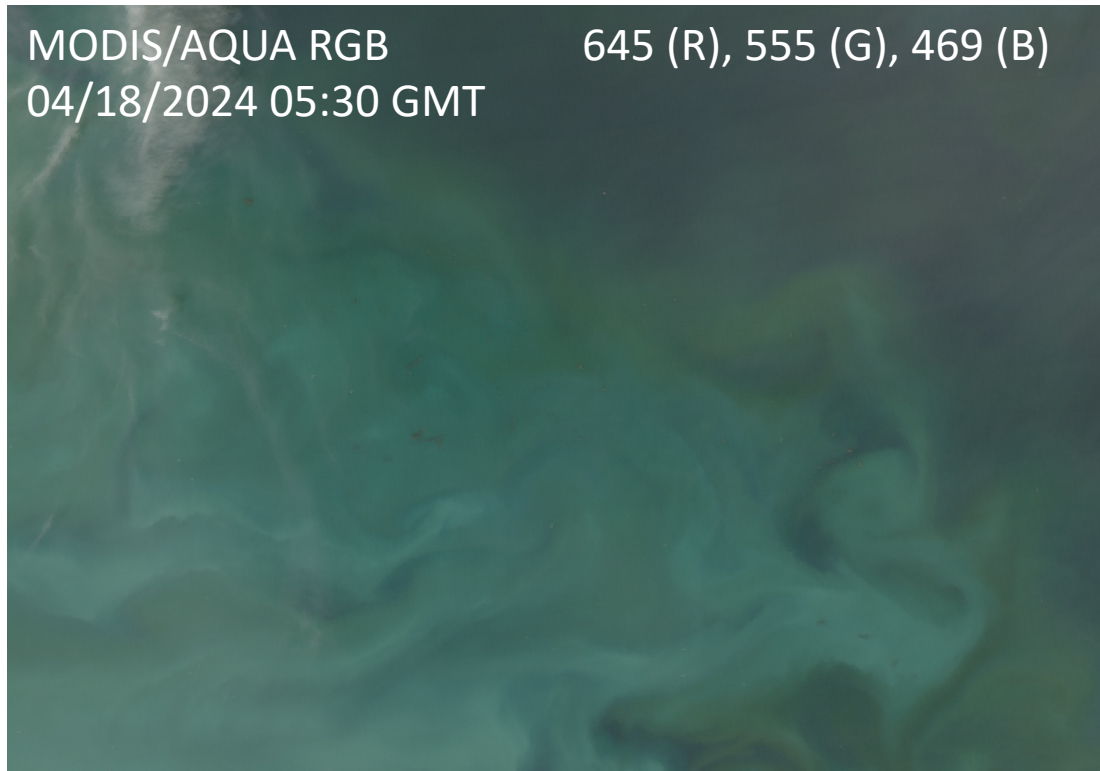
Progresses in satellite remote sensing technology (e.g., high-res constellation) – but it cannot be applied backward to 2011

Progresses in algorithm/methodology – detection of presence, discrimination of type, and quantification

Will show these latter progresses first, and then the Japan tsunami case

1. Detection of presence

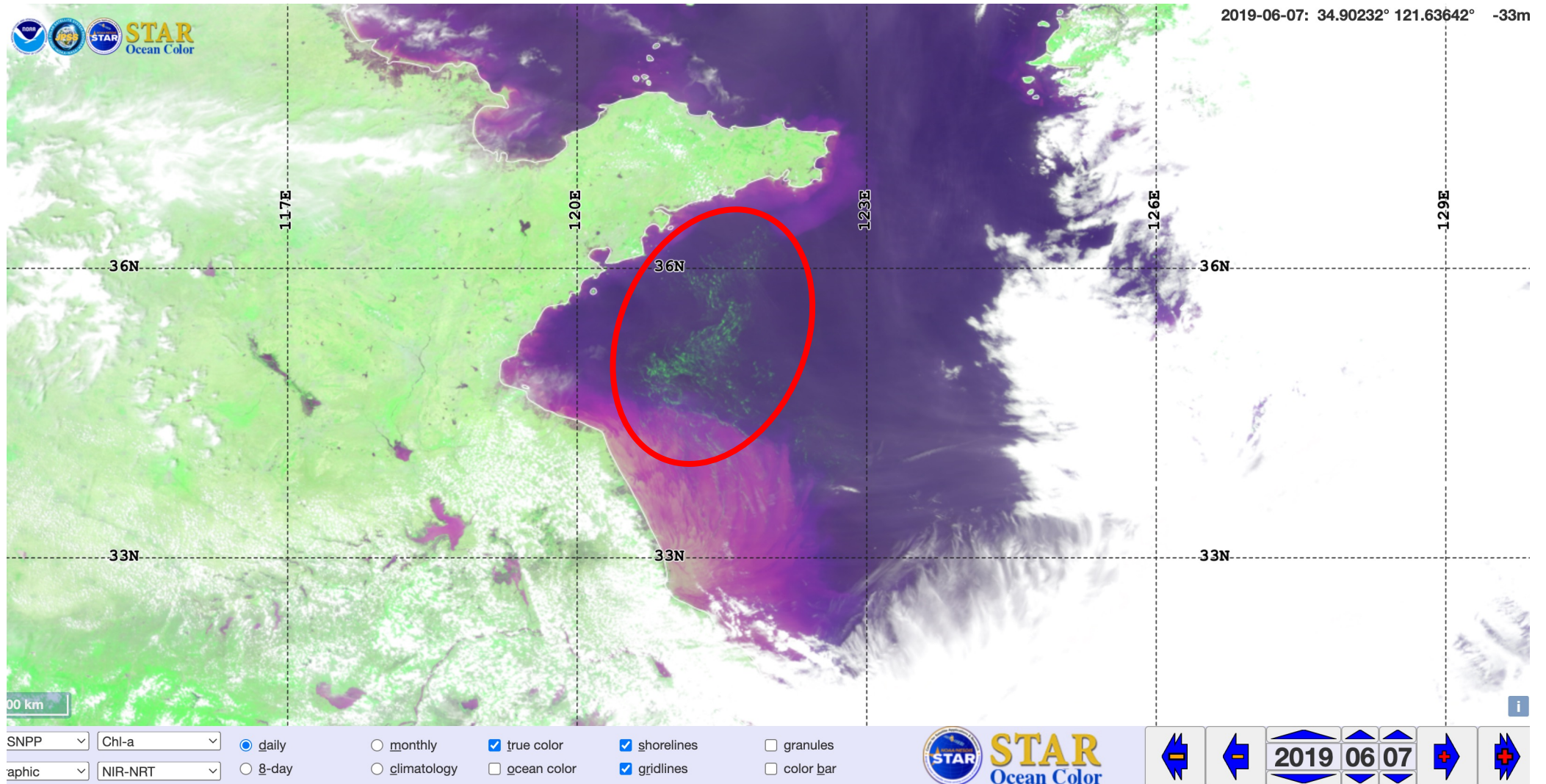
Visualization method and tools



FRGB is better than RGB for visual inspection.
There are other indexes for the same purpose.

1. Detection of presence

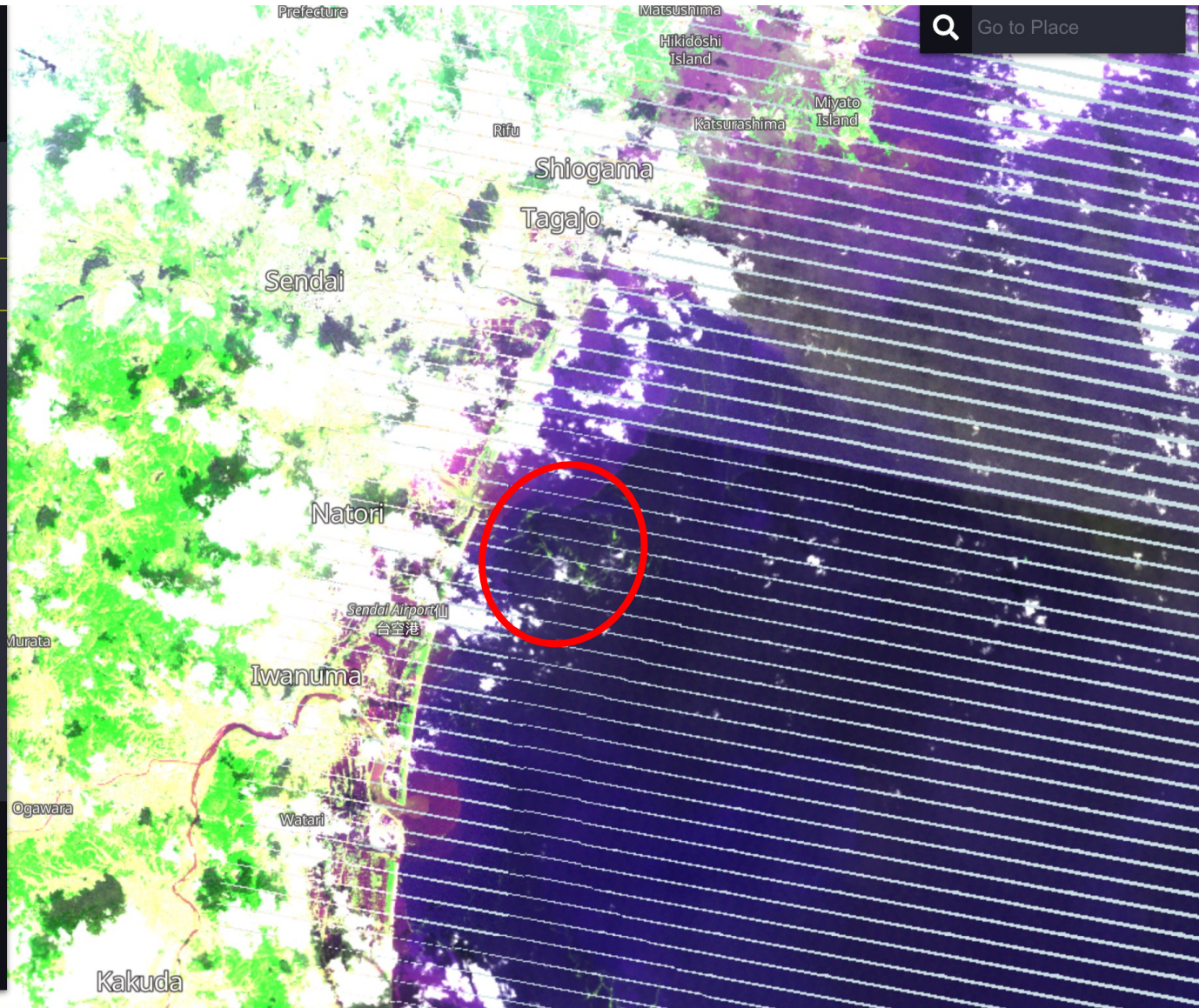
Near real-time online tool (NOAA OCVIEW)



1. Detection of presence

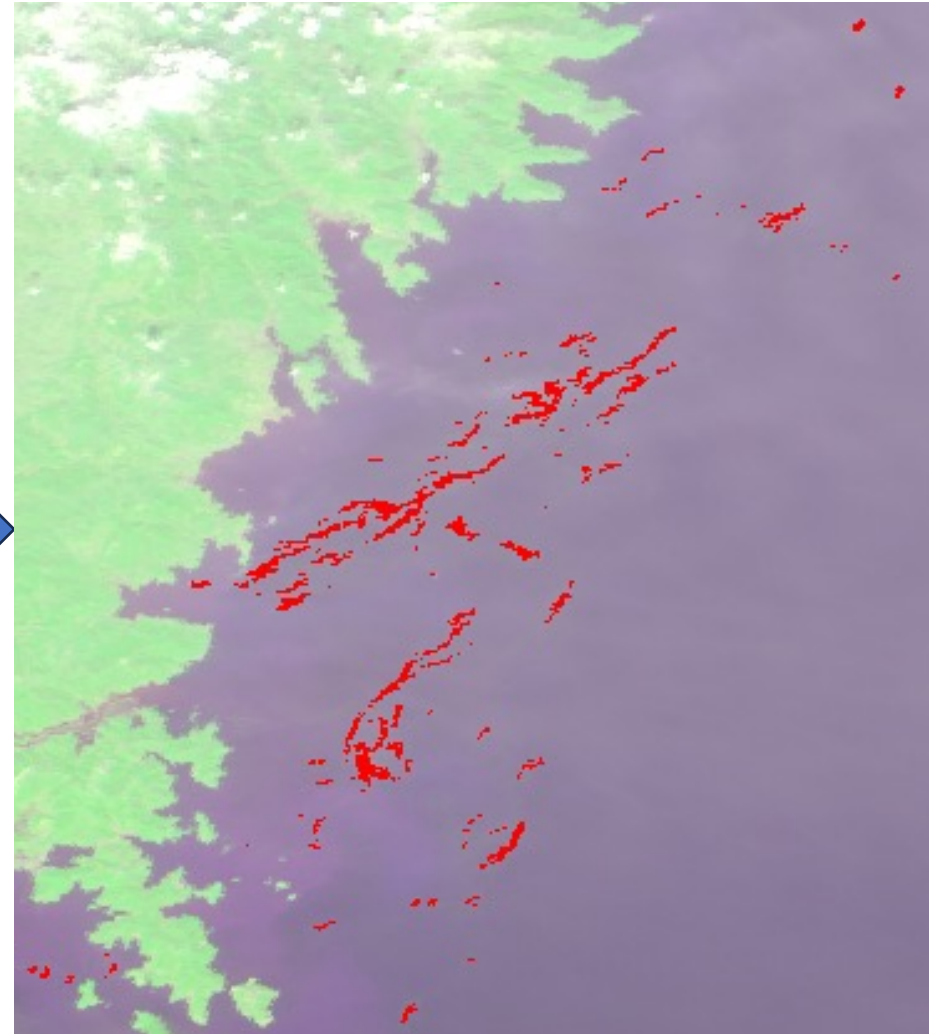
Near real-time online tool (ESA EO browser)

The screenshot shows the ESA EO Browser interface. At the top, it displays 'EO Browser' with a language dropdown set to 'ENGLISH' and a user greeting 'Hello, Lin Qi'. Below this are navigation buttons for 'Discover', 'Visualize', 'Compare', and 'Pins'. The current dataset is 'Landsat 7 ETM+ L2', with a 'Show L1' button. The date is set to '2011-03-12'. A toolbar contains icons for various actions. The main configuration area has tabs for 'Composite', 'Index', and 'Custom script'. Under 'Composite', 'Reflectance' is selected, and 'Brightness temperature' is also visible. A note says 'Drag bands onto RGB fields.' Below this are six colored circles representing bands: B01 (blue), B02 (green), B03 (orange), B04 (red), B05 (purple), and B07 (dark red). At the bottom, the current RGB configuration is shown as 'R: B03 G: B04 B: B01'. The footer includes 'Powered by Planet Insights Platform v3.61.3' and a banner for 'Explore Copernicus Data Space Ecosystem' with 'Free access to Copernicus Sentinel data'.



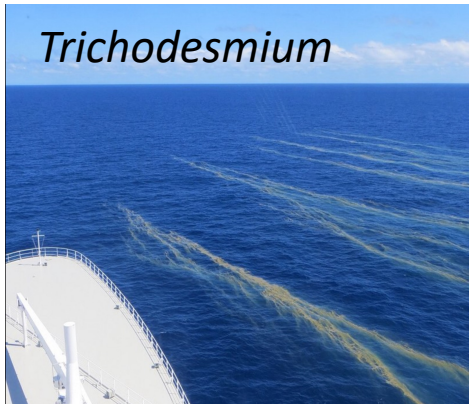
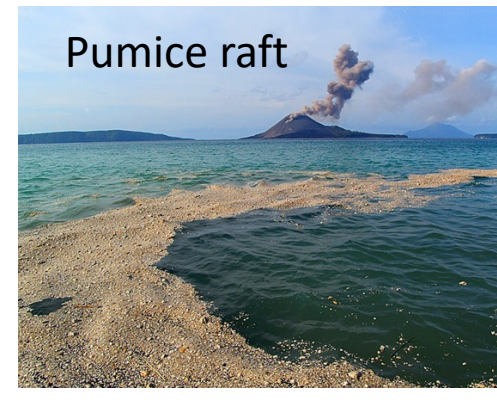
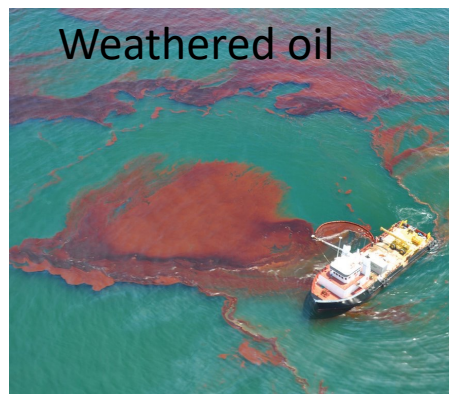
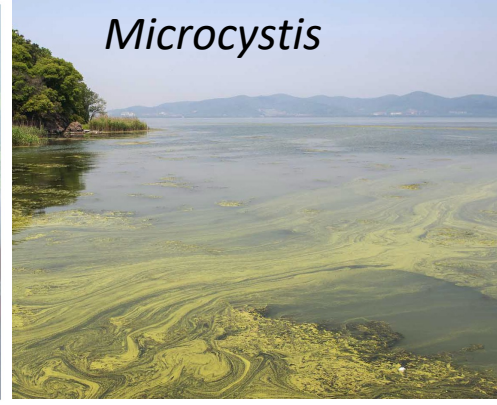
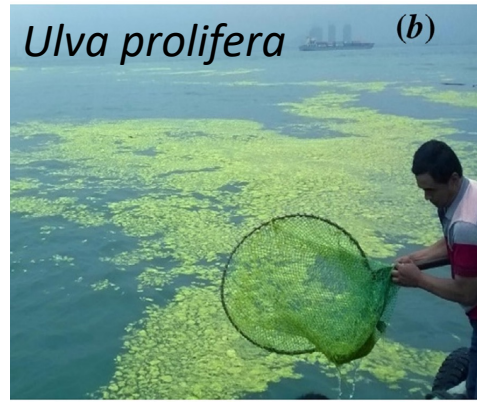
1. Detection of presence

AI automation (deep-learning)

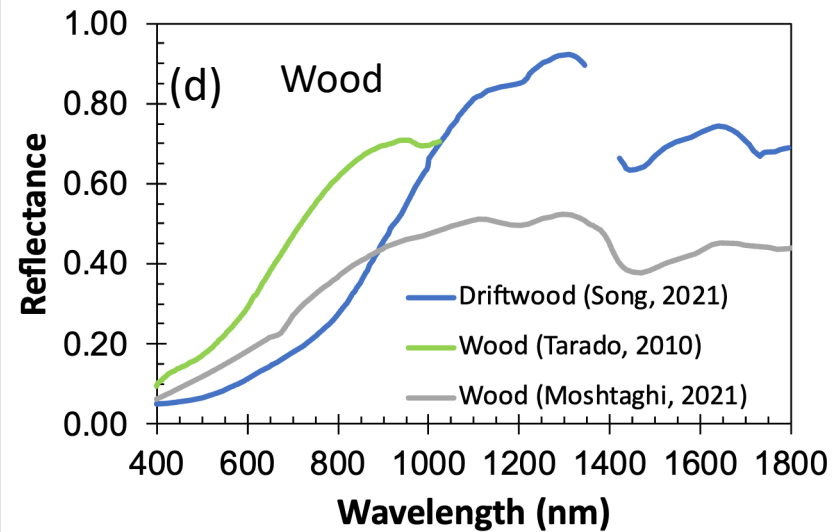
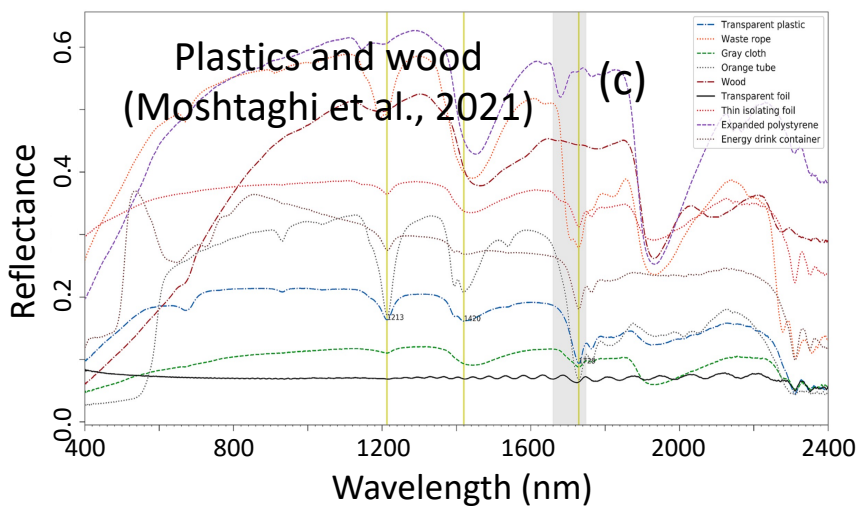
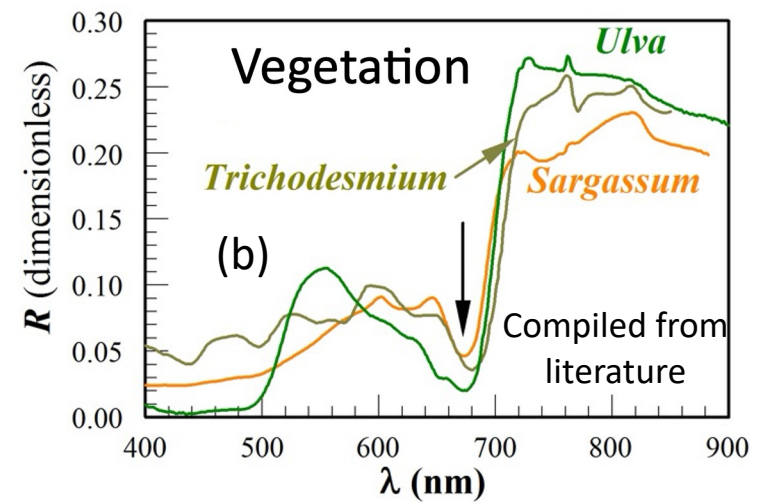
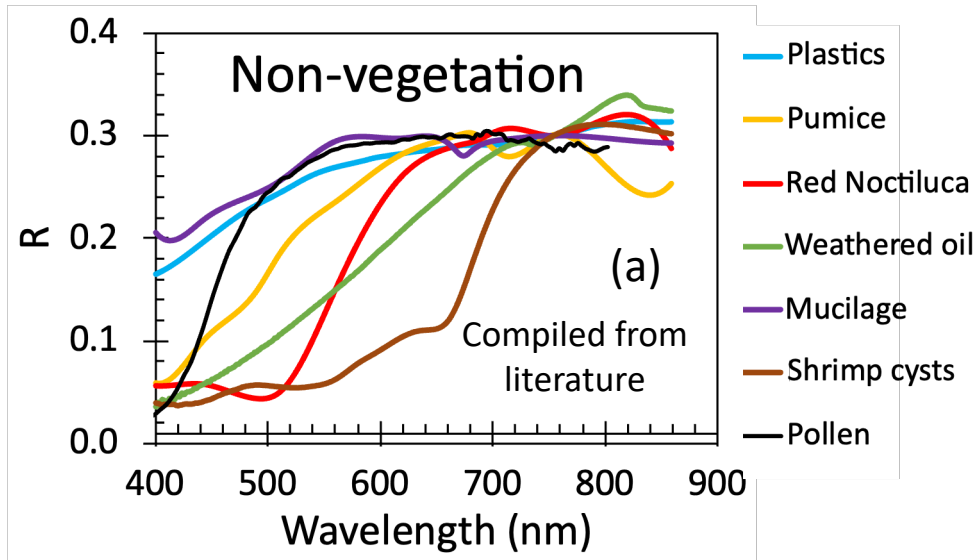


2. Discrimination of type

The many types of floating matters



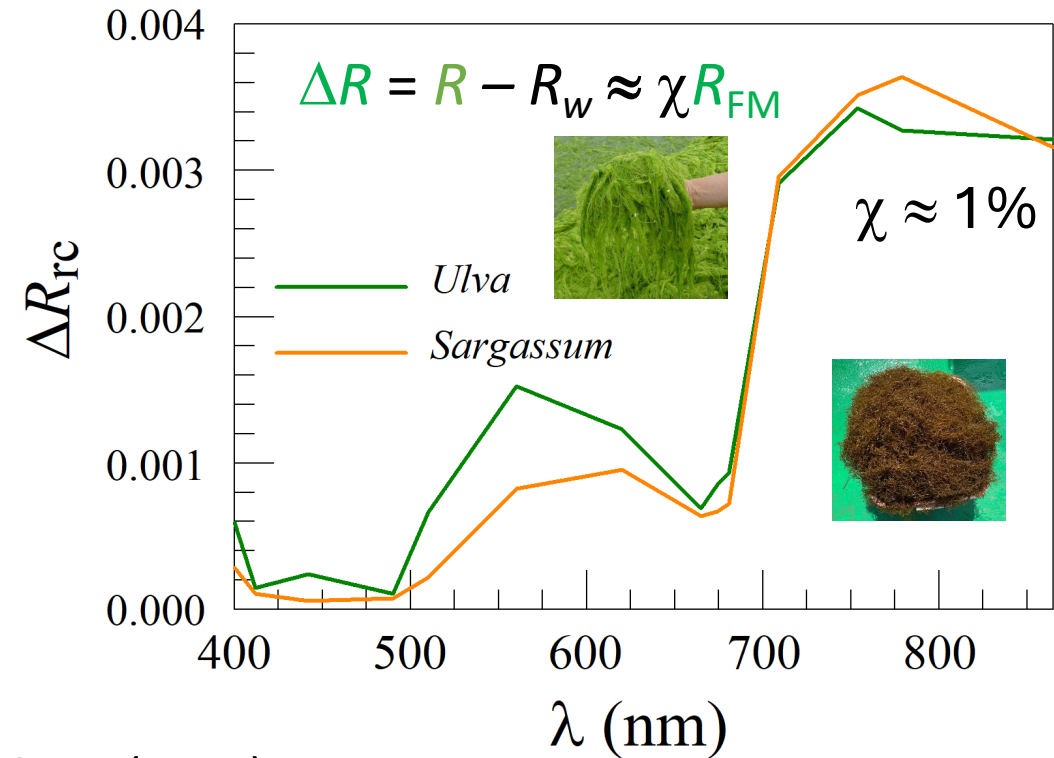
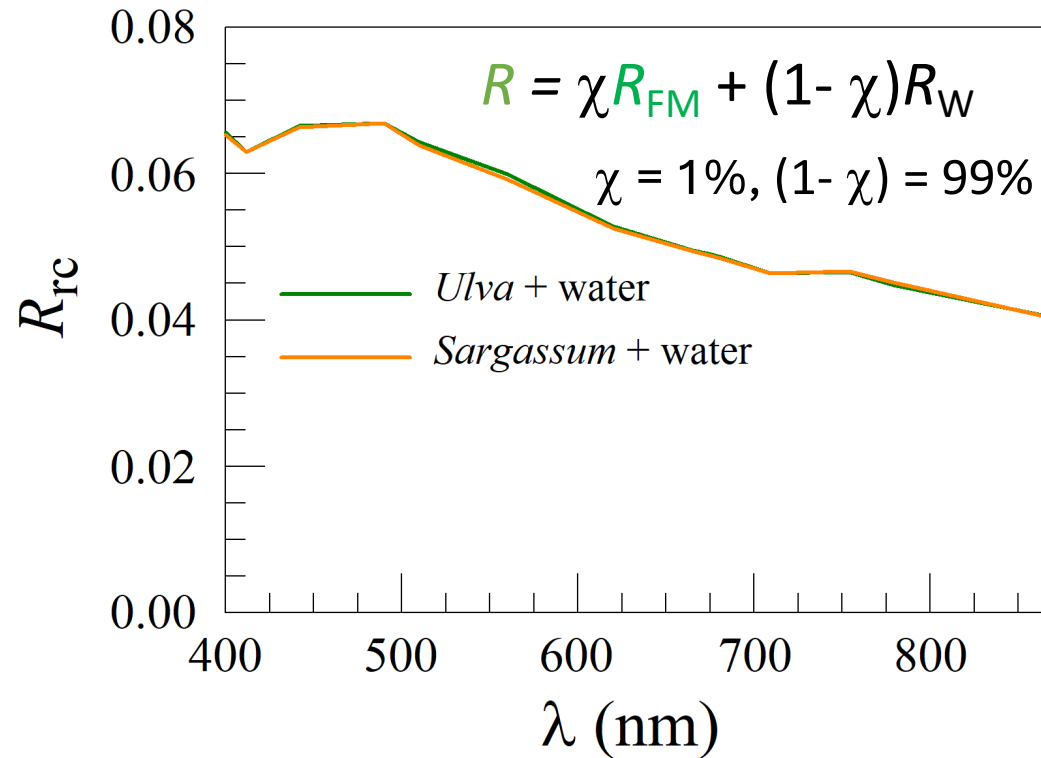
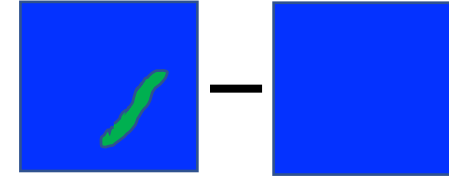
2. Discrimination of type Spectral endmember library



2. Discrimination of type

Problem: too small to show these characteristics

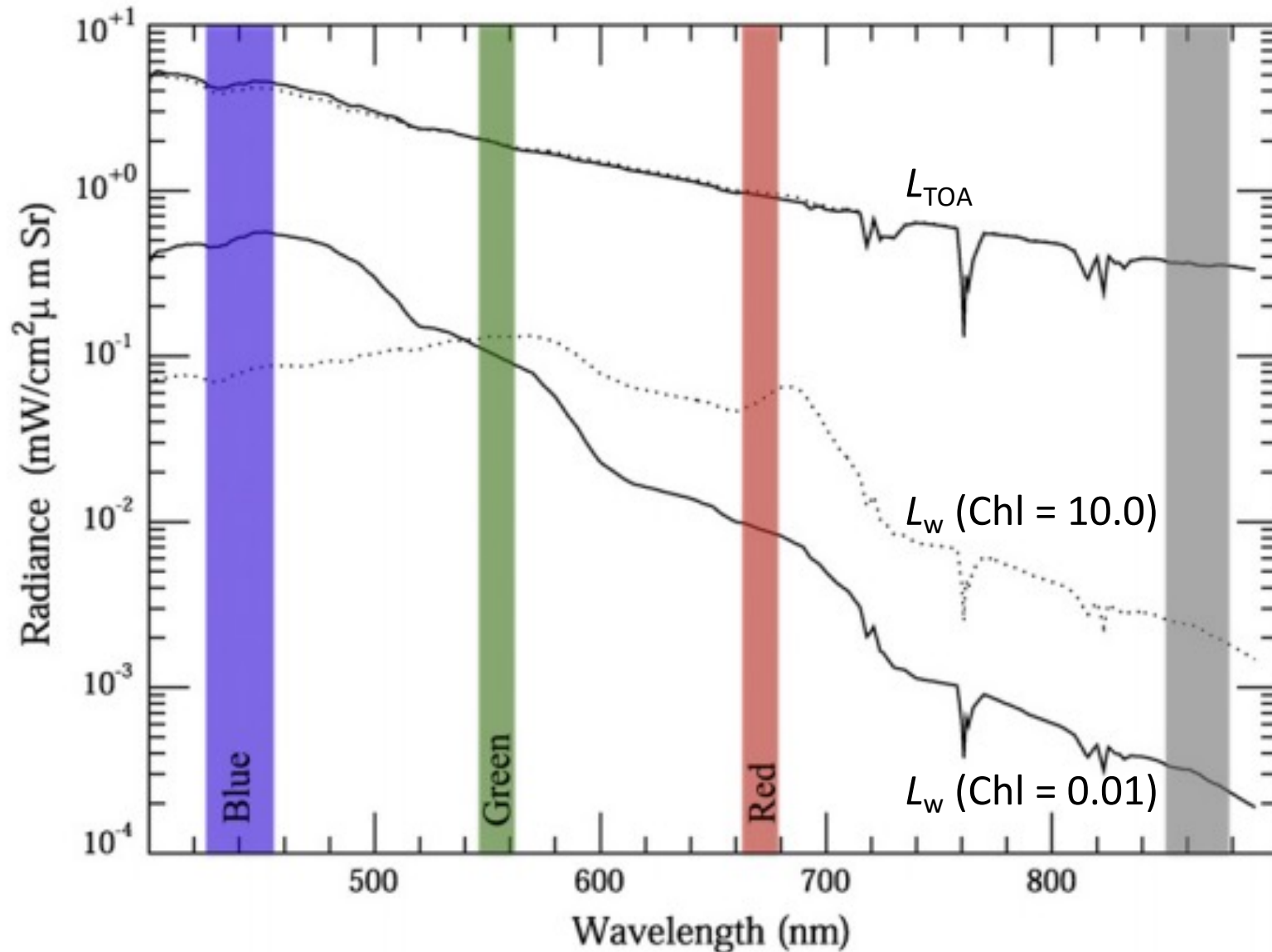
Solution: subtraction of nearby water



Qi & Hu (2021)

2. Discrimination of type

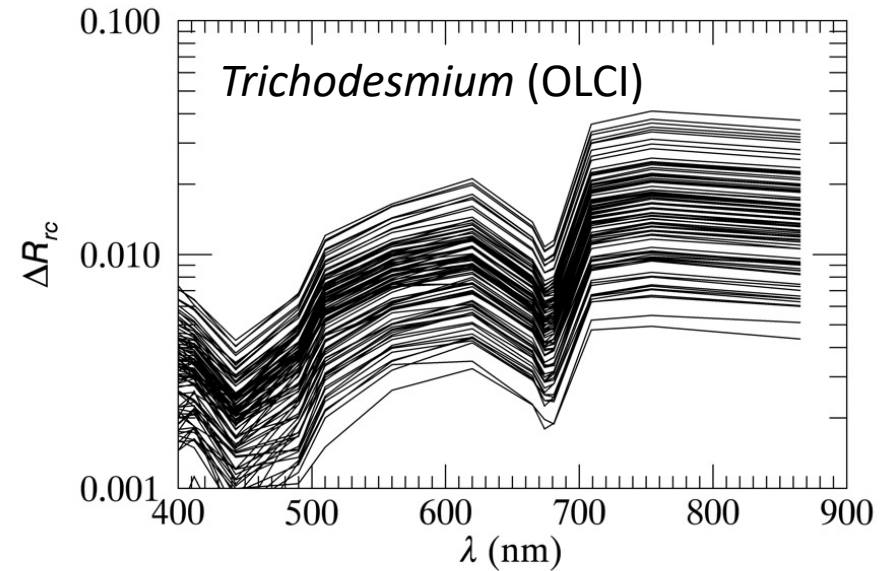
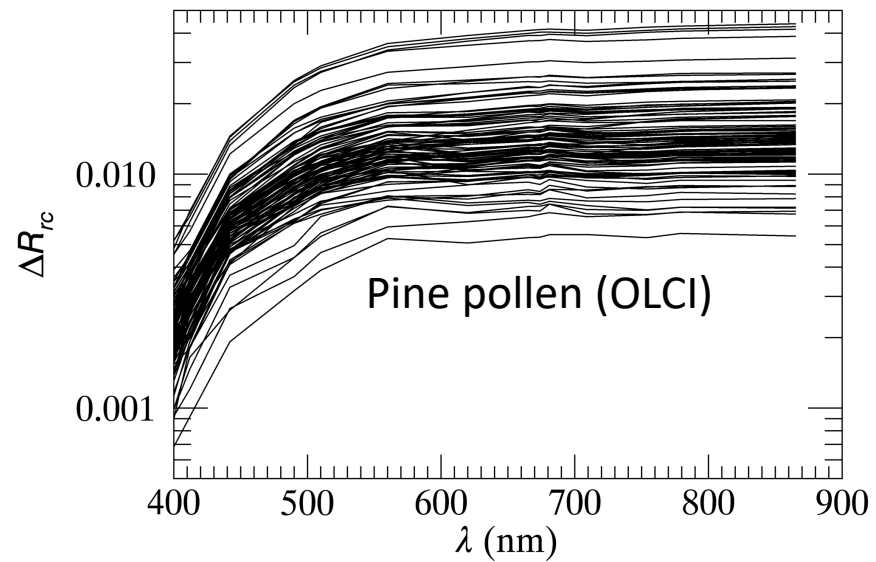
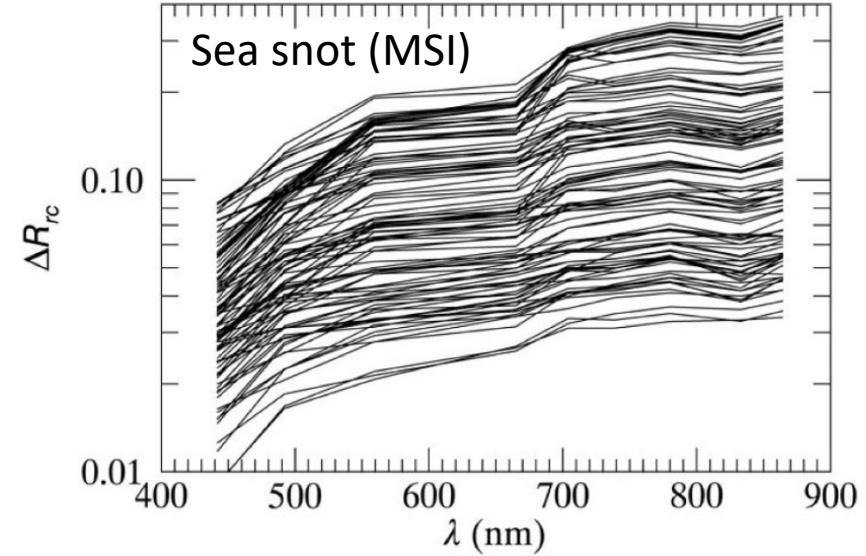
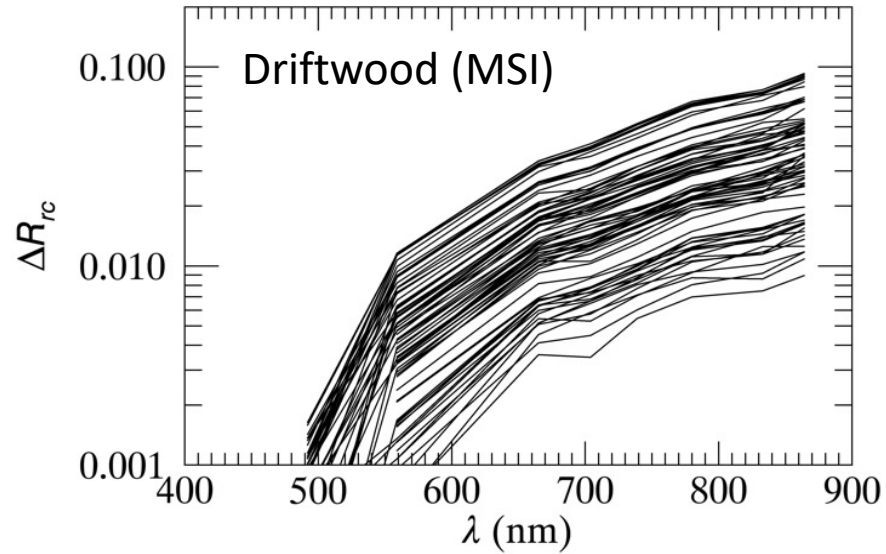
Analogy to atmospheric correction of ocean color (Gordon, 1983)



2. Discrimination of type

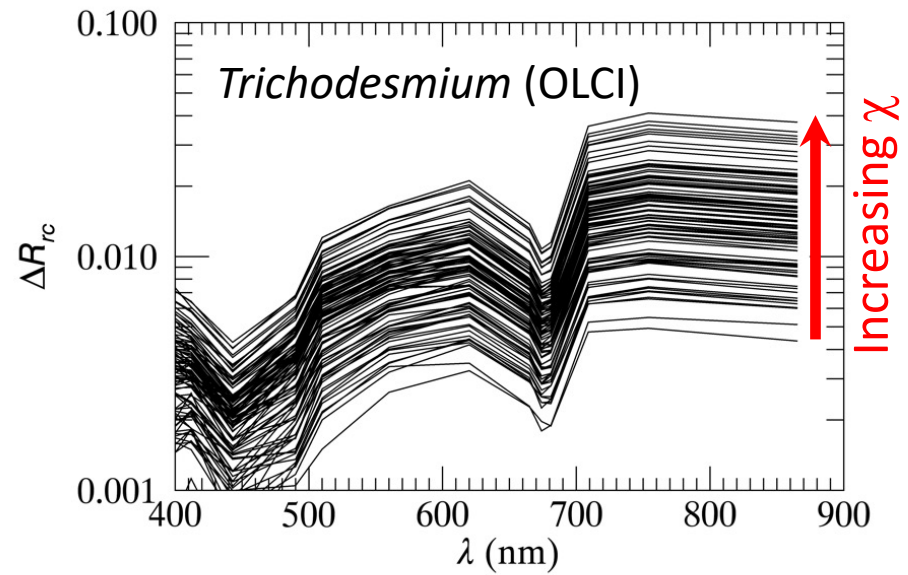
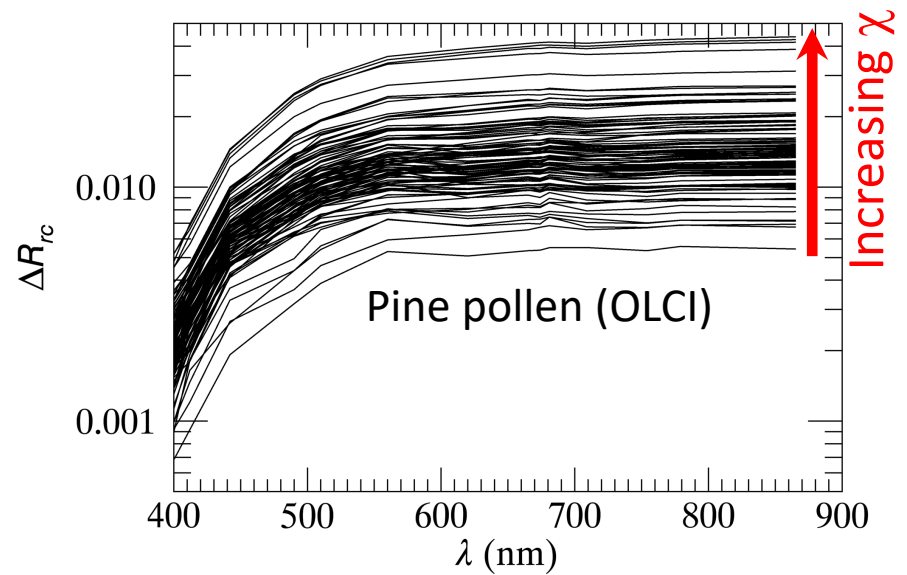
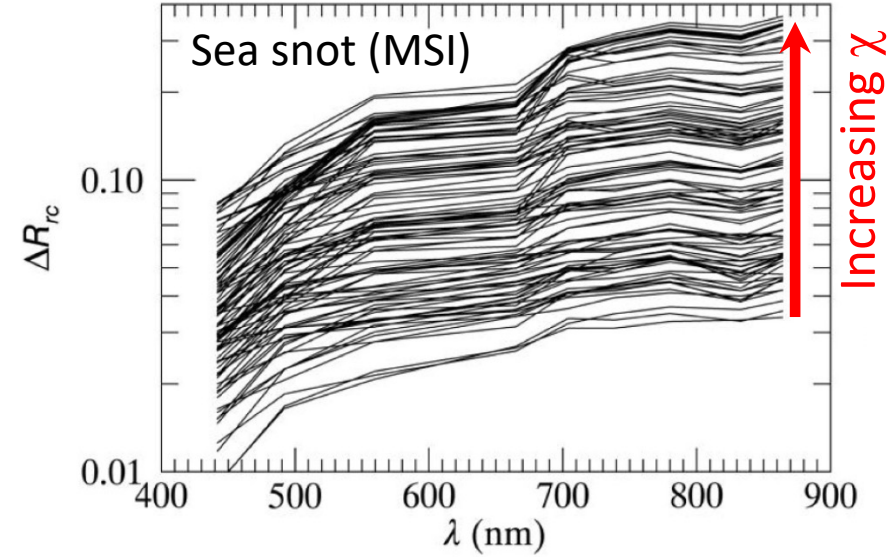
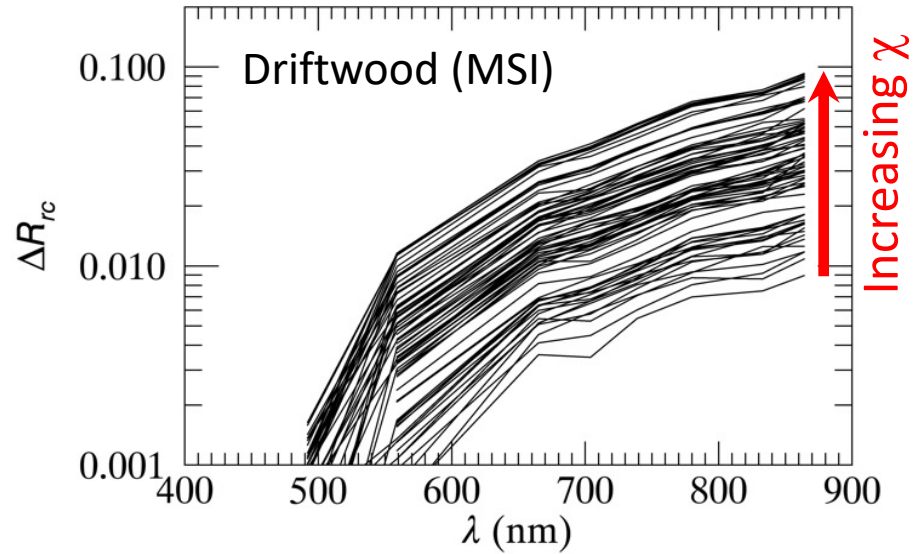
Compare spectral shape with endmember spectra

$$\Delta R = R - R_w \approx \chi R_{FM}$$



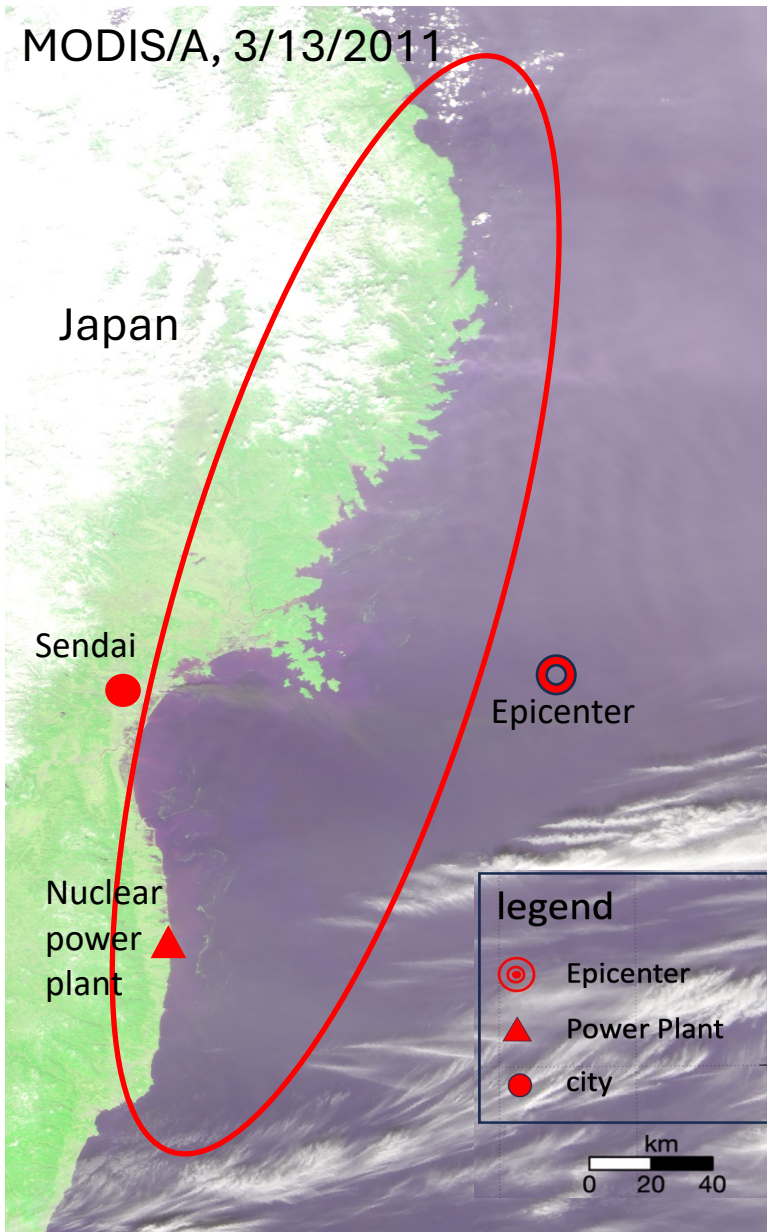
3. How much?

Pixel unmixing: $\Delta R(\lambda) \approx \chi R_{\text{FM}}(\lambda)$

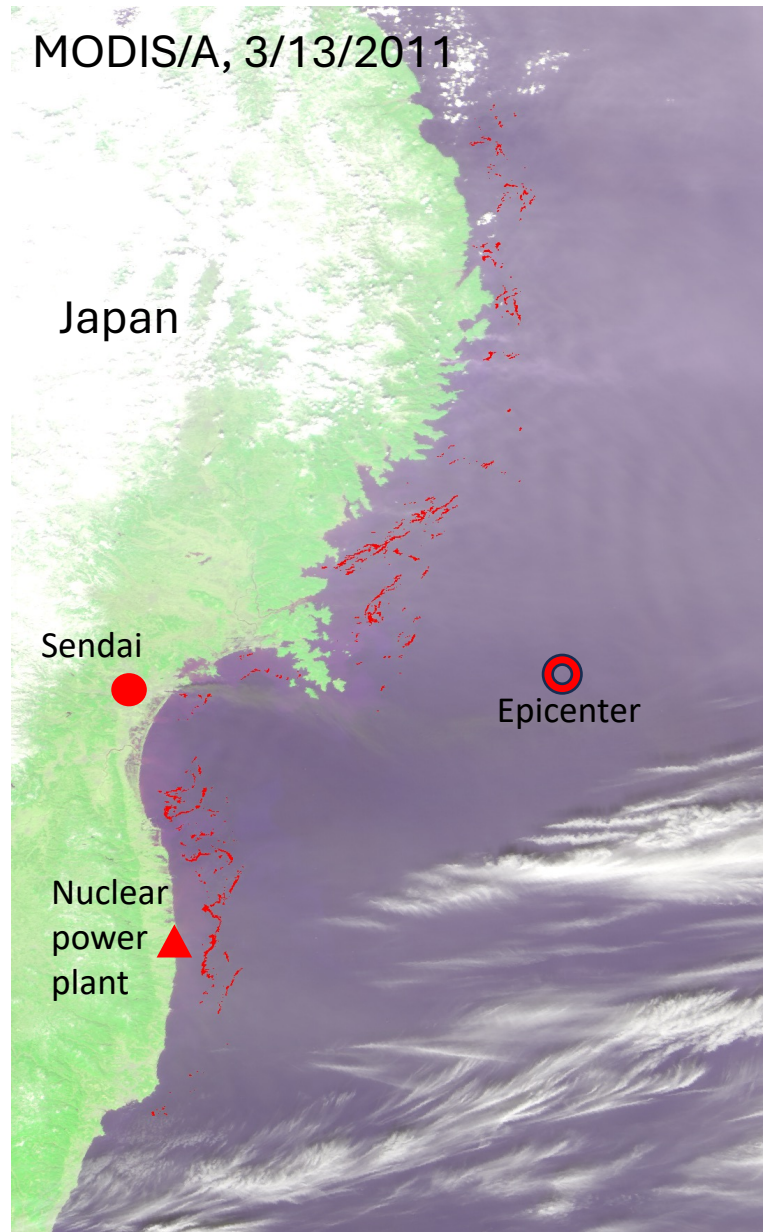


Now the 2011 Japan tsunami case

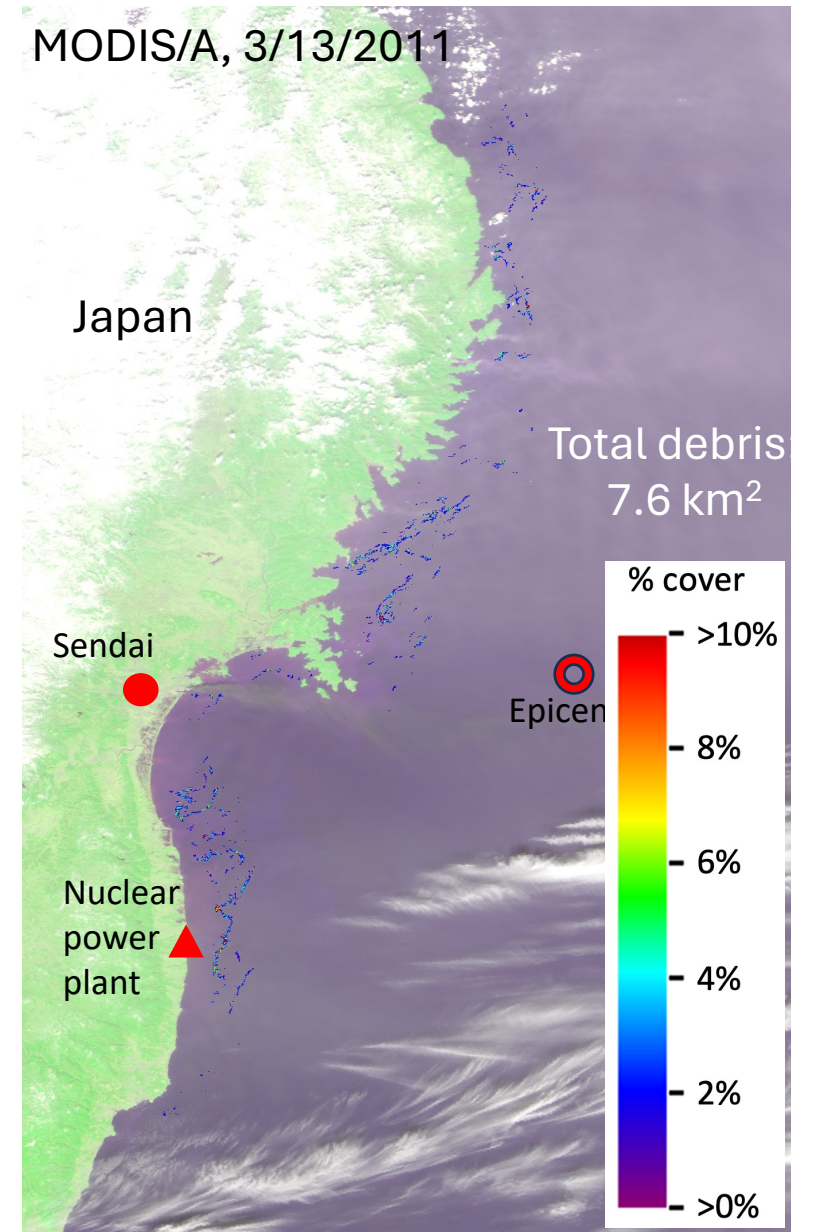
Visualization



Presence/absence detection



Quantification

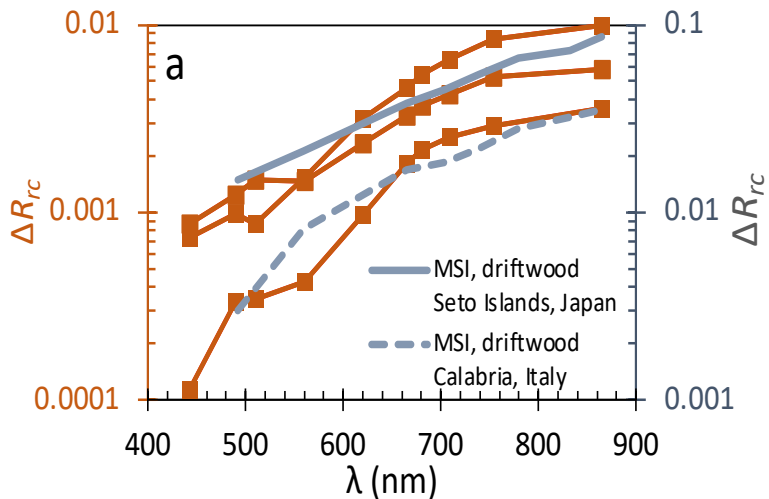


What are they? Spectral analysis

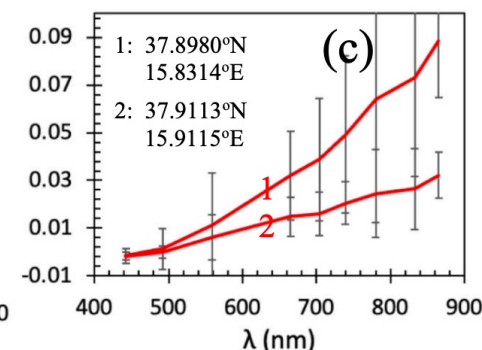
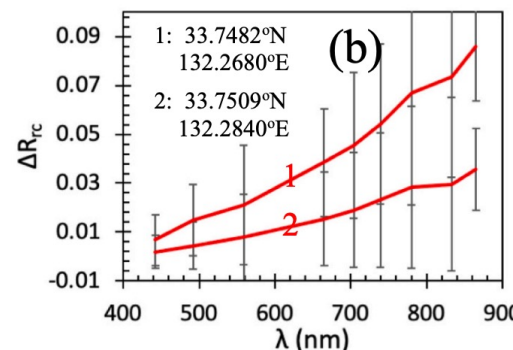
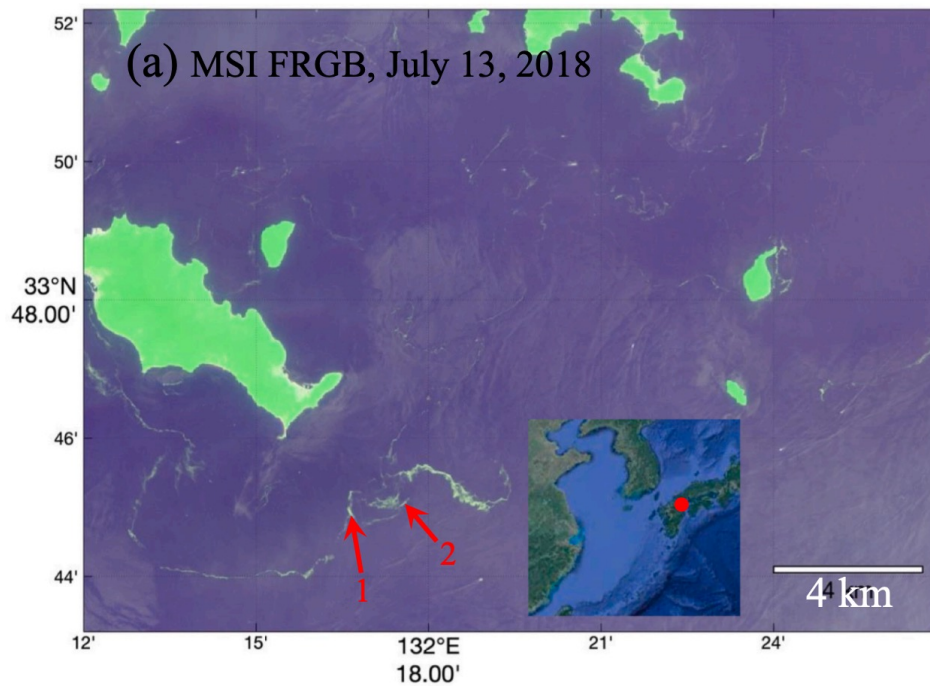
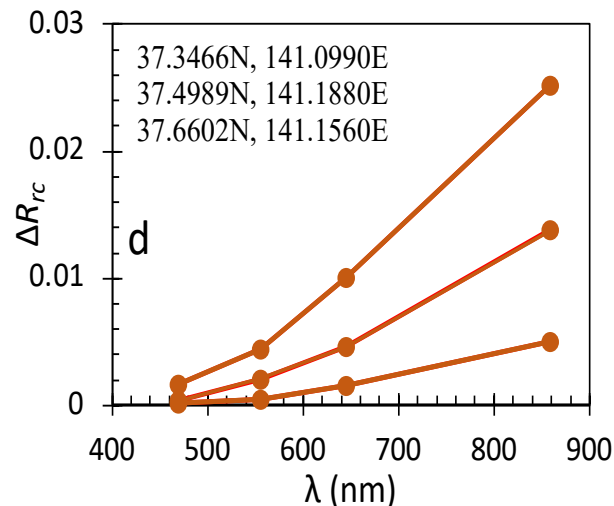
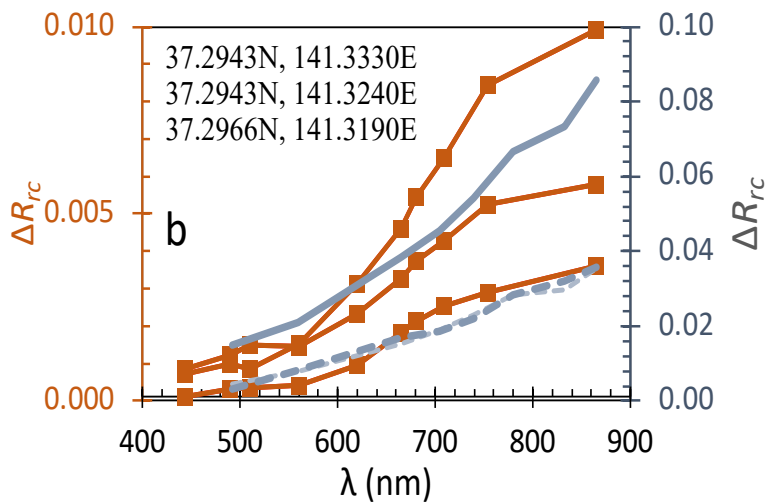
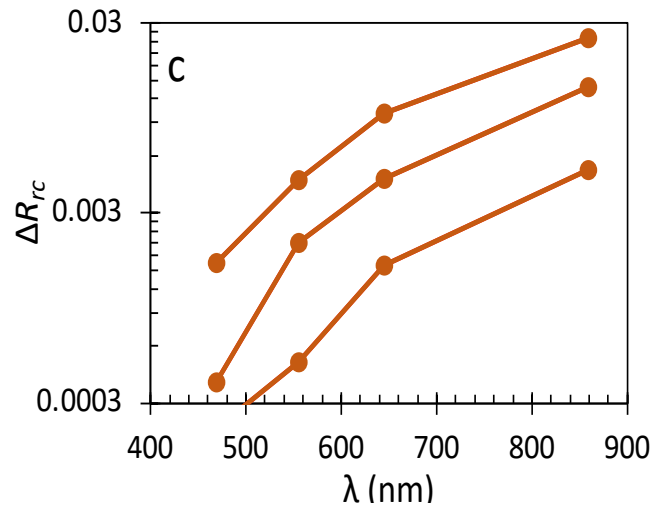
Japan tsunami case

Flooding case, Japan

MERIS



MODIS



How can we trust these results?

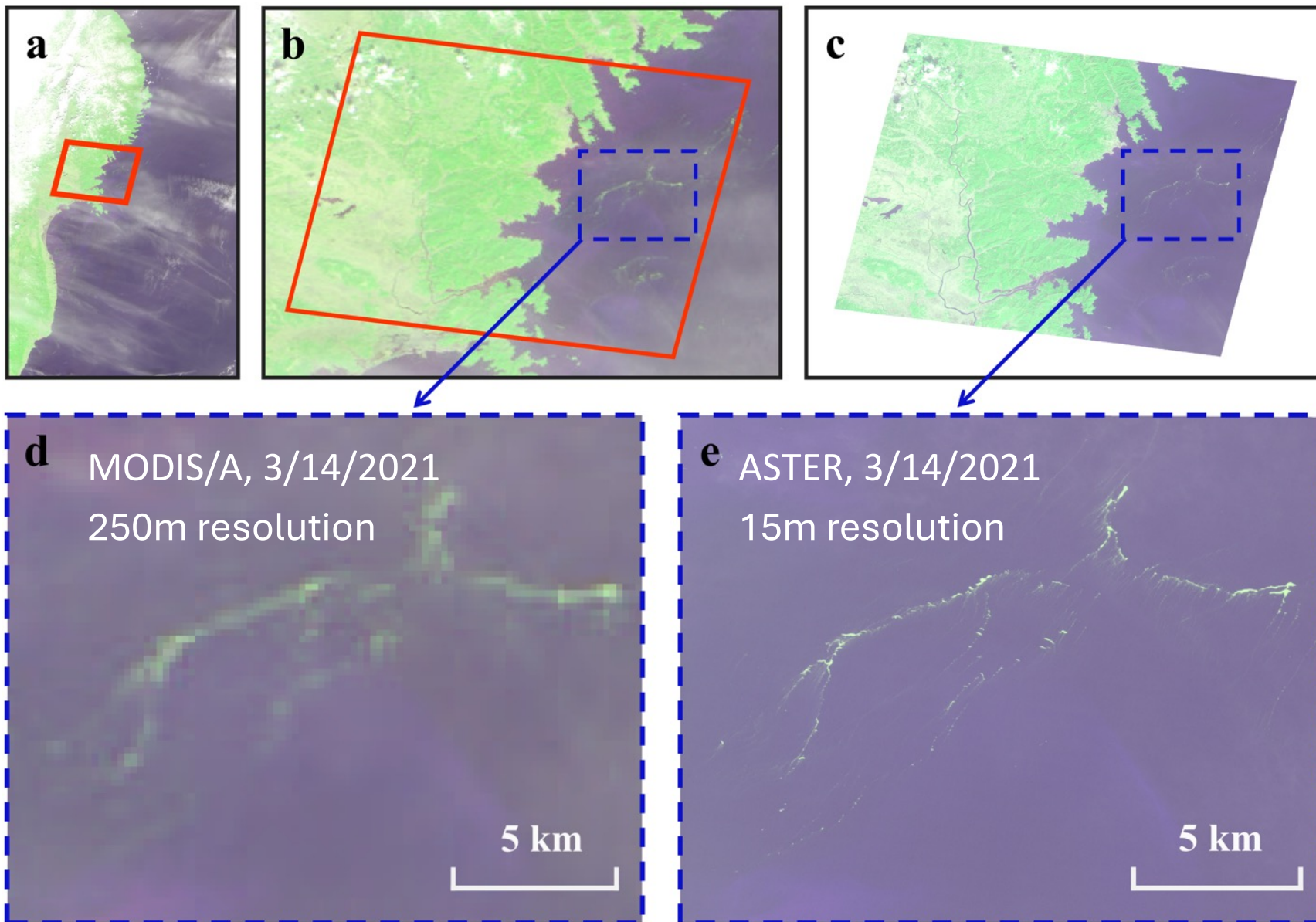
Debris type: confirmation from limited aerial photos



Mostly wood, but mixed with plastics

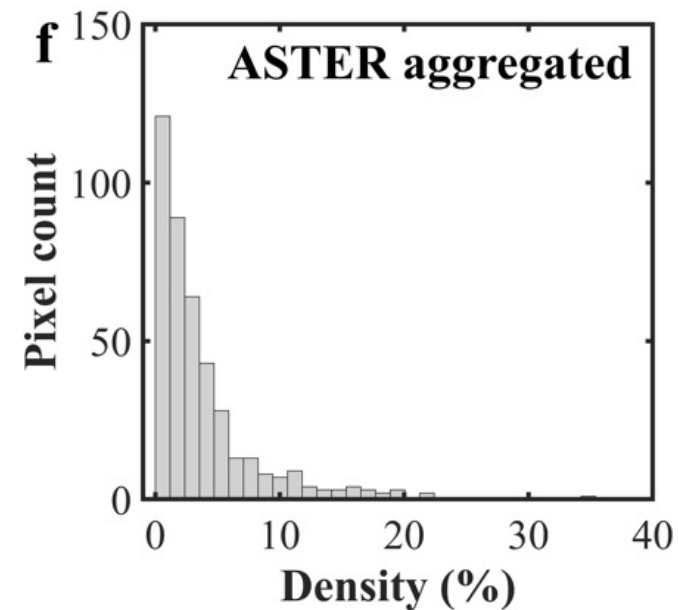
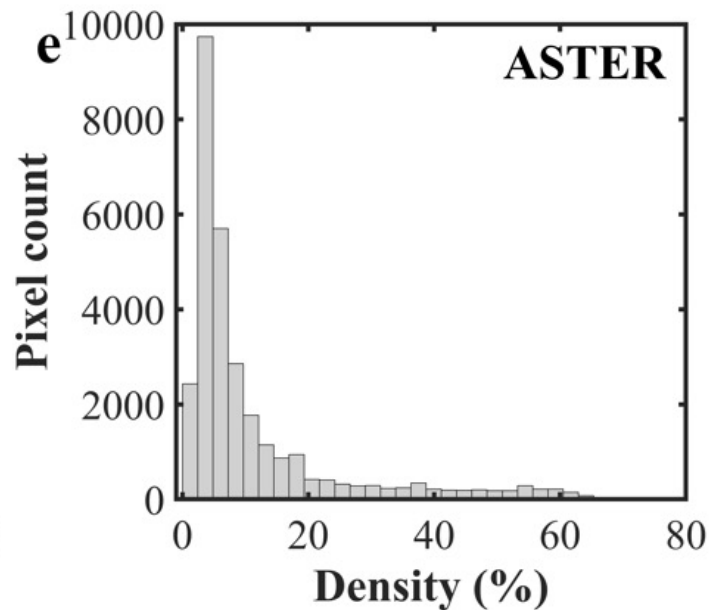
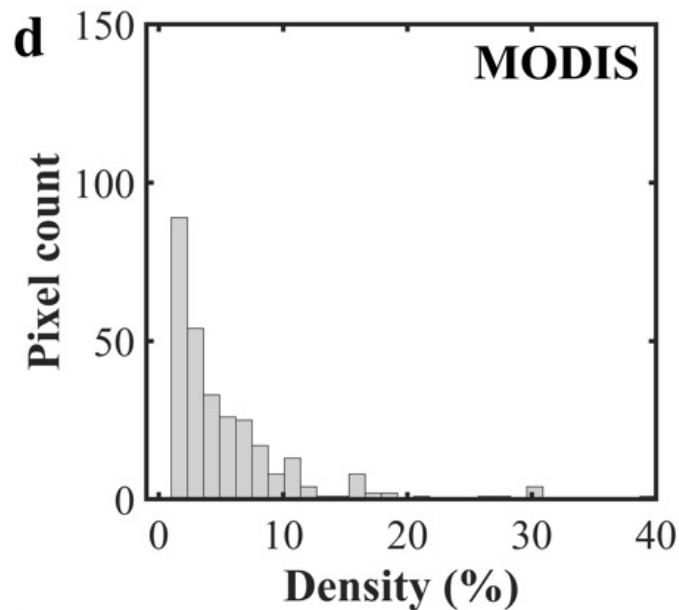
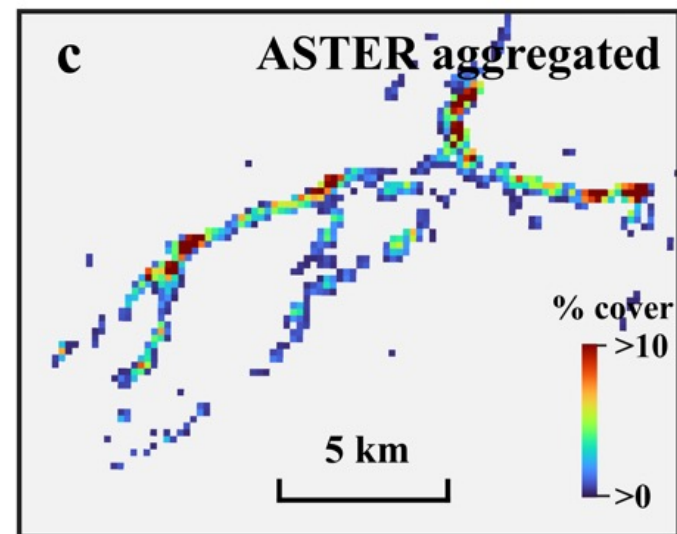
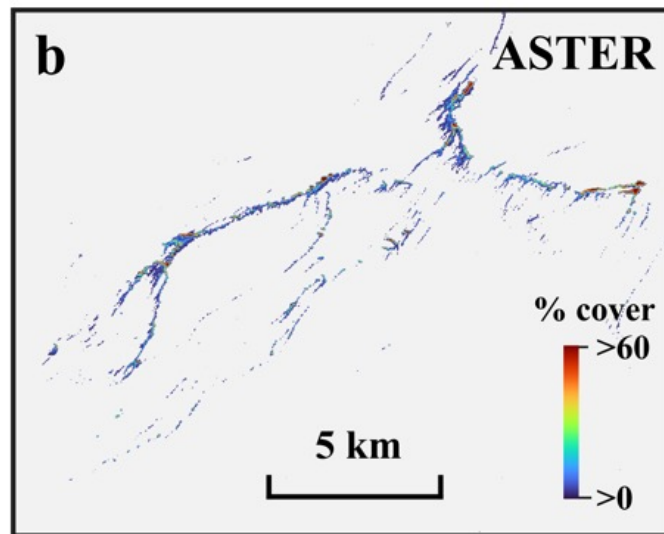
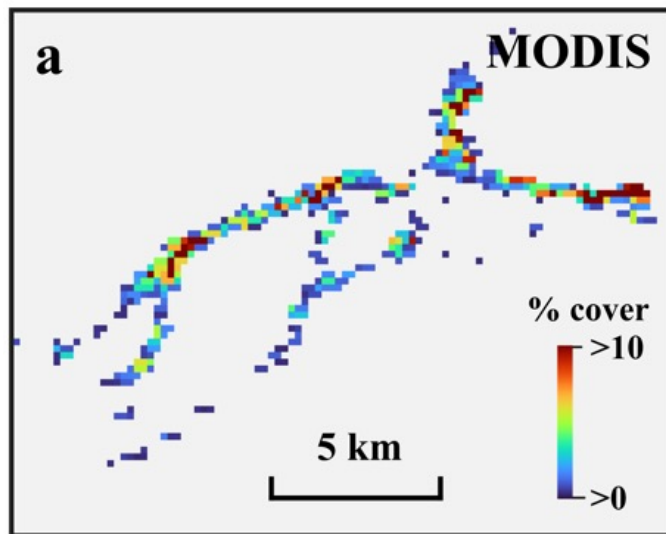
How can we trust these results?

Debris amount: compare with high-res images



How can we trust these results?

Debris amount: compare with high-res images



Distribution patterns

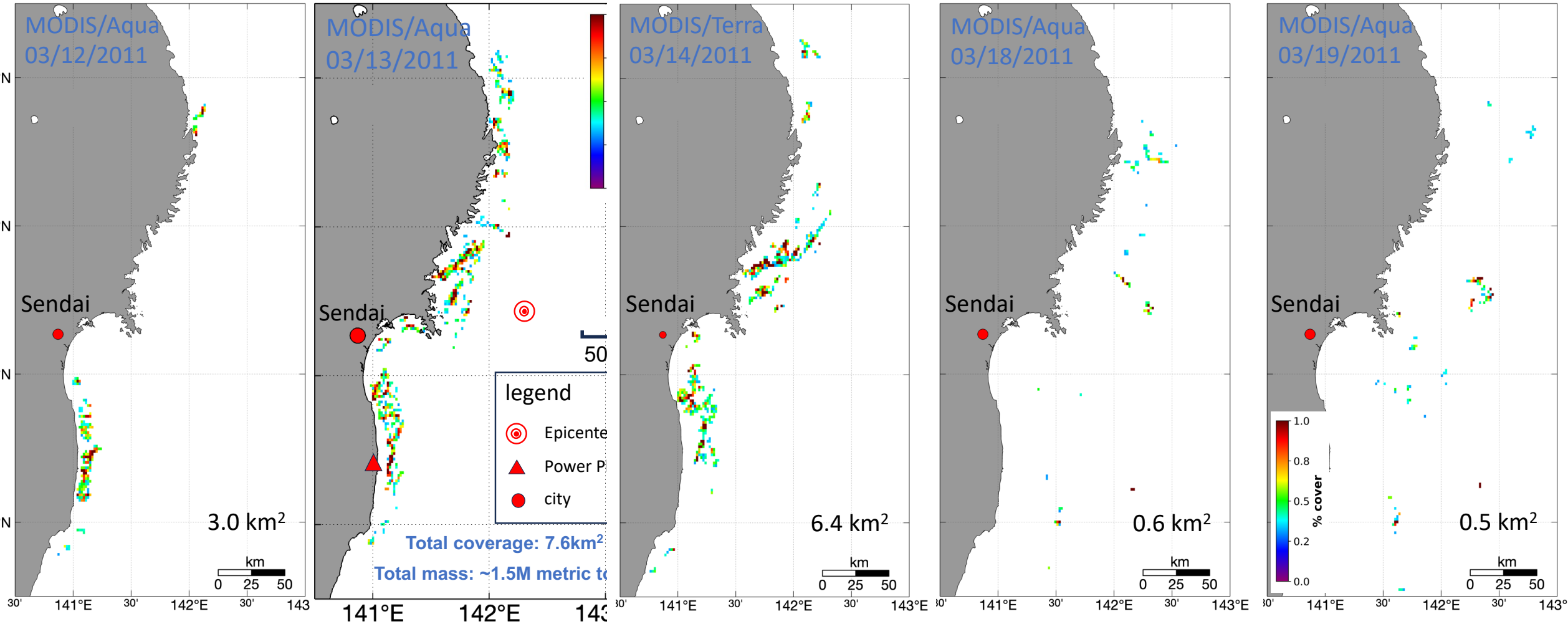
Day 1

Day 2

Day 3

Day 7

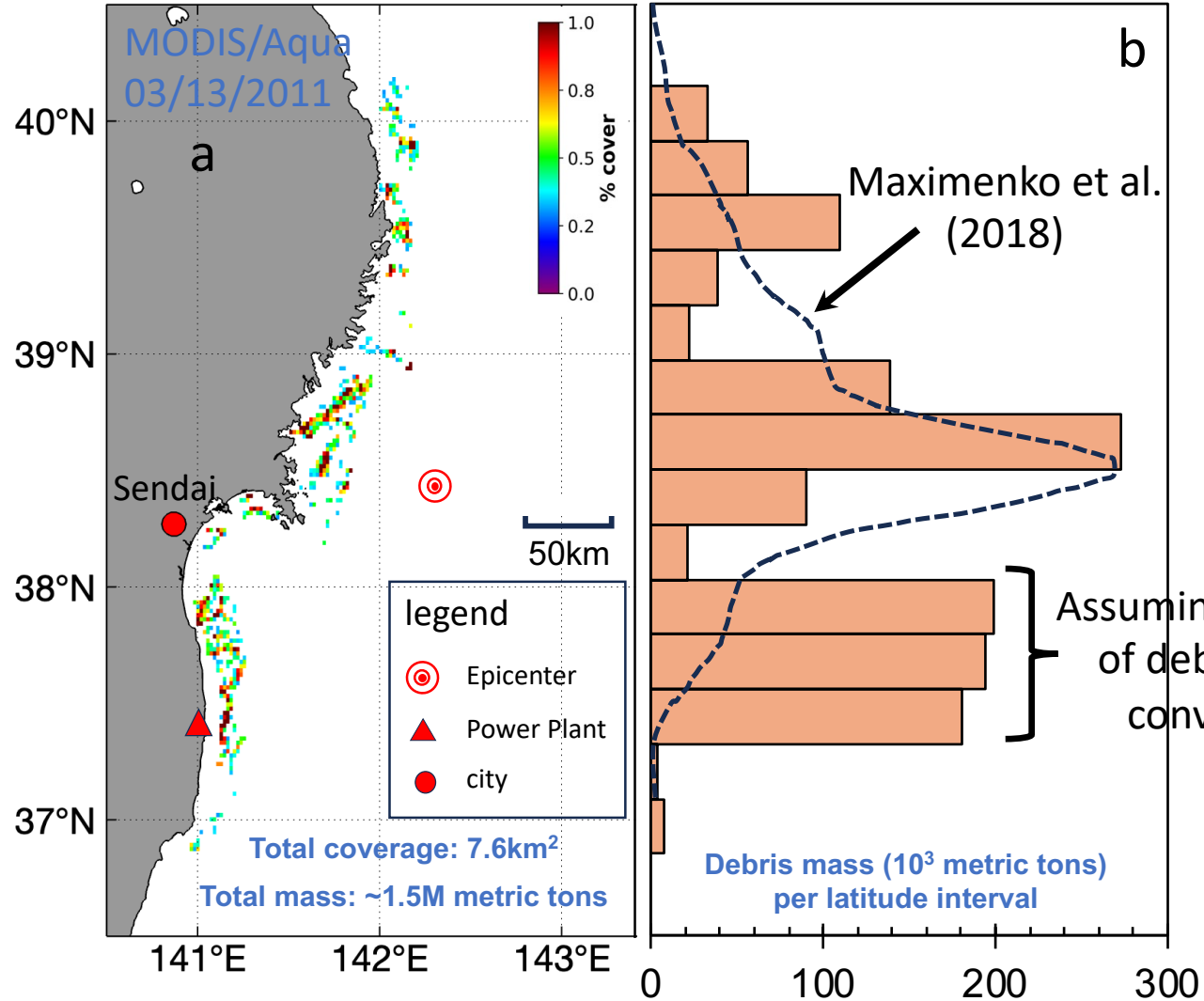
Day 8



MODIS: up to 3/28/1011 (Day 17); Landsat: up to 4/6/2011 (Day 26)

Now what?

1. Improve numerical model



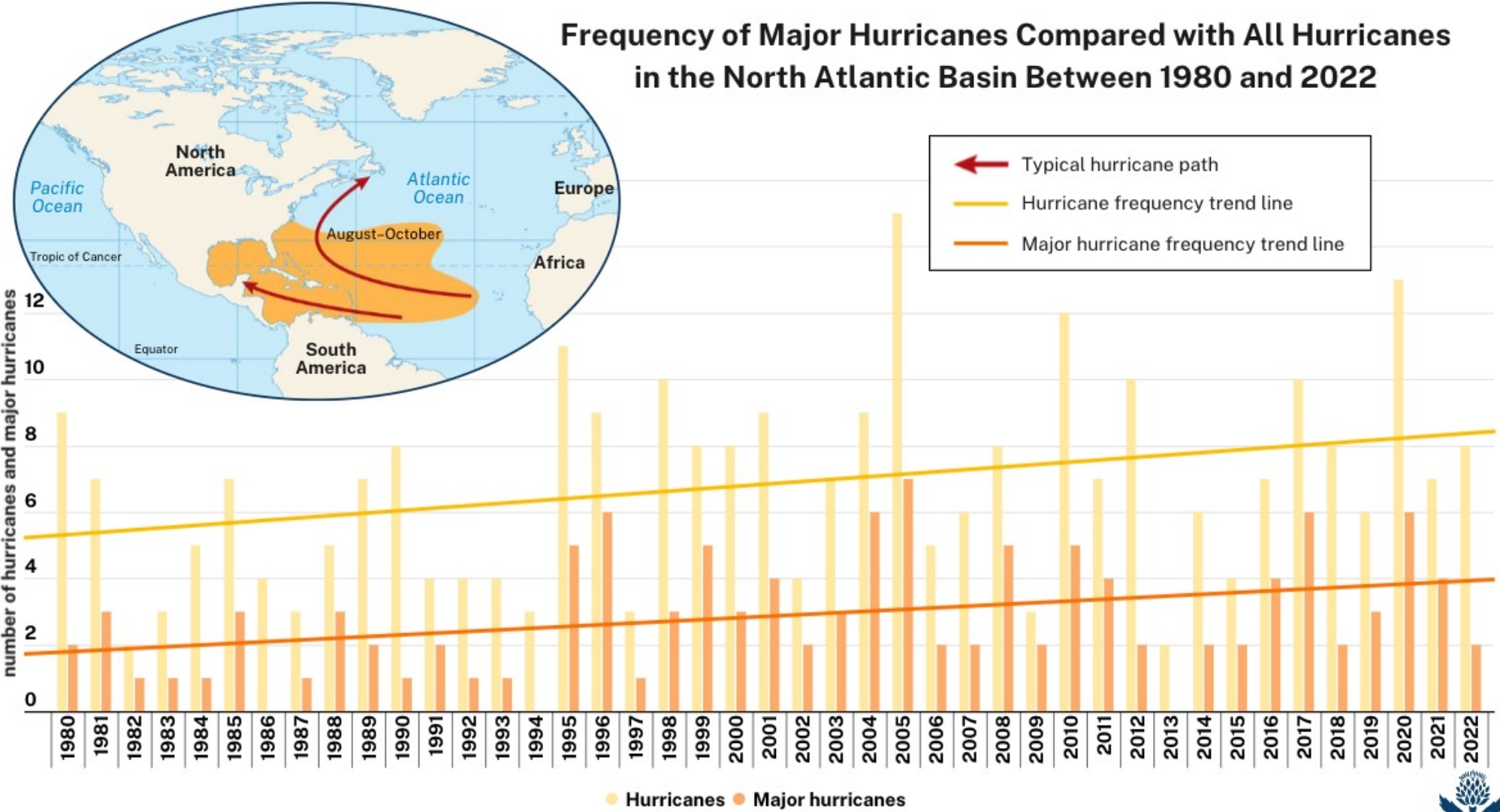
2. Improve disaster response

Determine hotspots to help mitigation efforts, e.g., by directing boat operations to remove debris

Targeted sampling for post-disaster assessment. Lumber woods are often treated with arsenic, therefore possibly toxic to the marine and benthic environments

What's next

Improve capacity for event response



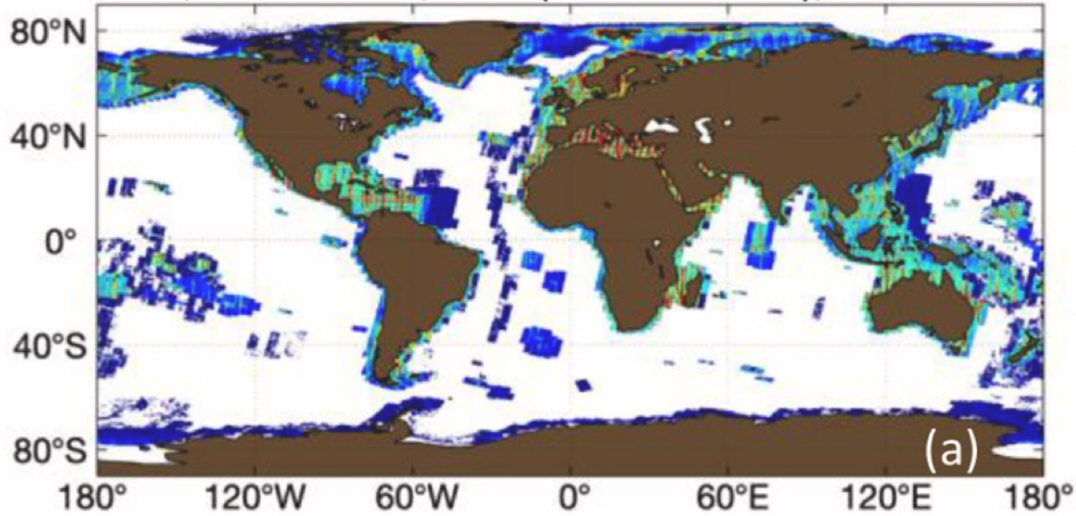
Data source: Colorado State University, Department of Atmospheric Science.



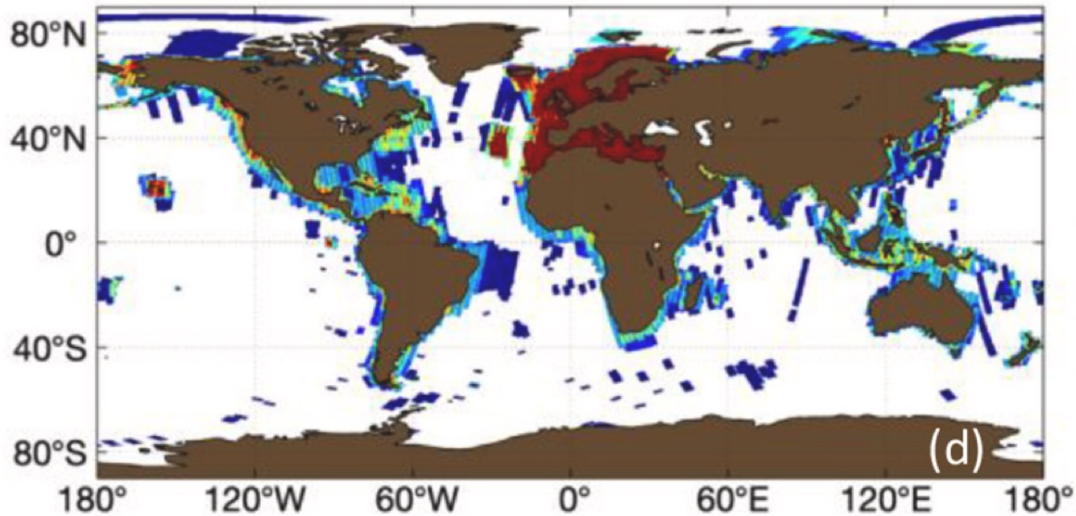
What's next

Improve coverage with high-res satellites

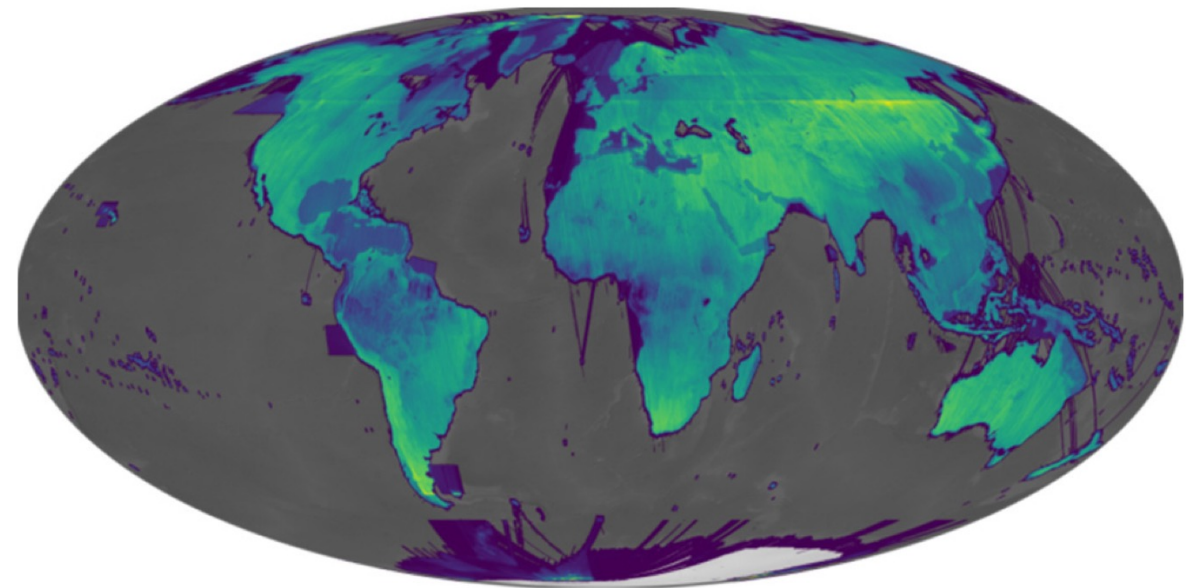
Global, Sentinel-2/MSI (2017 - 2020), Cloud free



Global, Sentinel-1/SAR (2017 - 2020)



PlanetScope constellations
(4 m resolution, 1-2 day revisits)



PLANETSCOPE IMAGES PUBLISHED
January 2014 - December 2020

0 200 400 600 800 1000 1200 1400 1600 1800 2000

However, challenges still remain

Most challenge comes from the difficulty in separating debris from others



10/5/2022, 5 days
after Hurricane Ian
Charlotte Harbor,
Florida, USA

1 km



Summary and Conclusions

- **Significant progresses have been made** in algorithm/methodology development to detect, discriminate, and quantify marine debris and other floating materials.
- **Applying such algorithm/methodology to the 2011 Japan tsunami event** led to new information on the debris distribution, type, and amount (maximum 7.6 km², about 1.5M metric tons, maximum water area of 7000 km², duration of about 4 weeks)
- **Multi-sensor assessment shows the advantage:** MODIS – mapping; MERIS – spectral analysis; ASTER – validation; Landsat – duration.
- **Satellite remote sensing technology** (e.g., high-res constellation, hyperspectral) has advanced rapidly, providing much improved capacity to map marine debris for various purposes.
- **Japan tsunami case published in** Qi et al. (2024, MPB)