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

Lin Qi[1,2] (lin.qi@noaa.gov) and Menghua Wang[1]
Chuanmin Hu[3], Junnan Jiao[3], Young-Je Park[4], and many others

[1]NOAA STAR
[2] Global Science and Technology, Inc.
[3]University of South Florida
[4]TelePIX Co. Ltd, Korea

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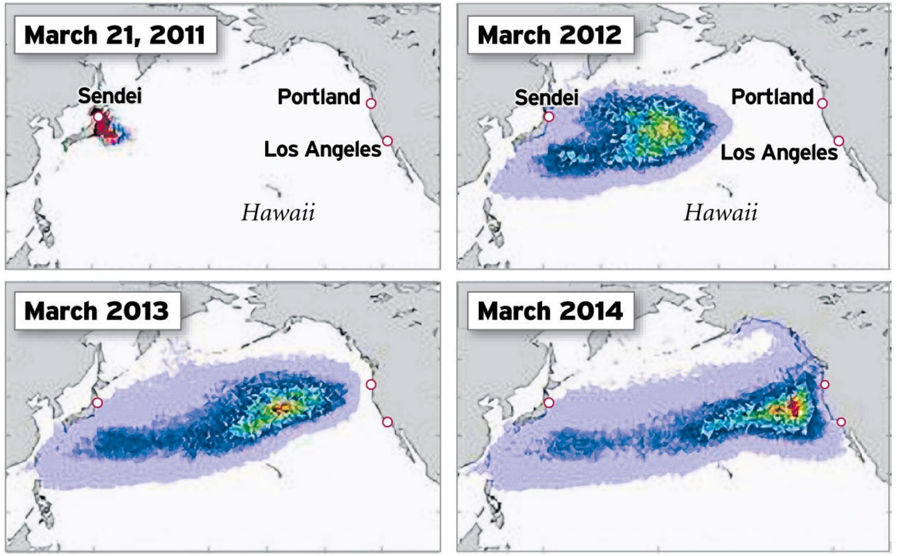
The Great East Japan Earthquake and Tsunami – March 11, 2021

- 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

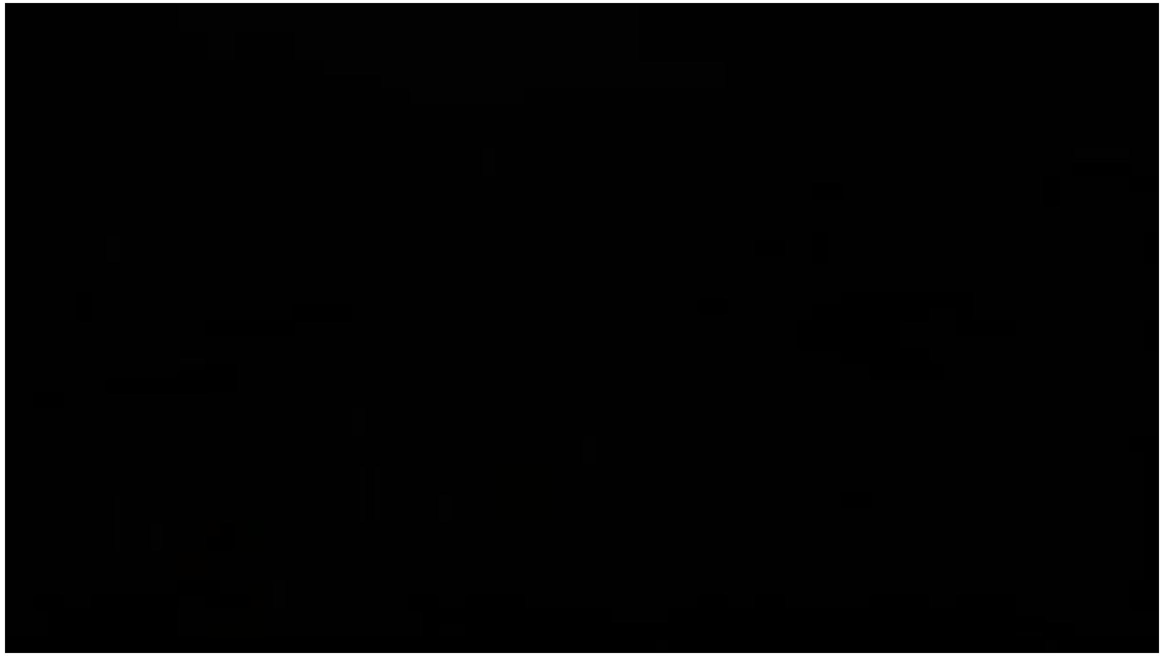
(MOE, 2012; Suppasri et al., 2013)

Huge amounts of debris washed in the ocean

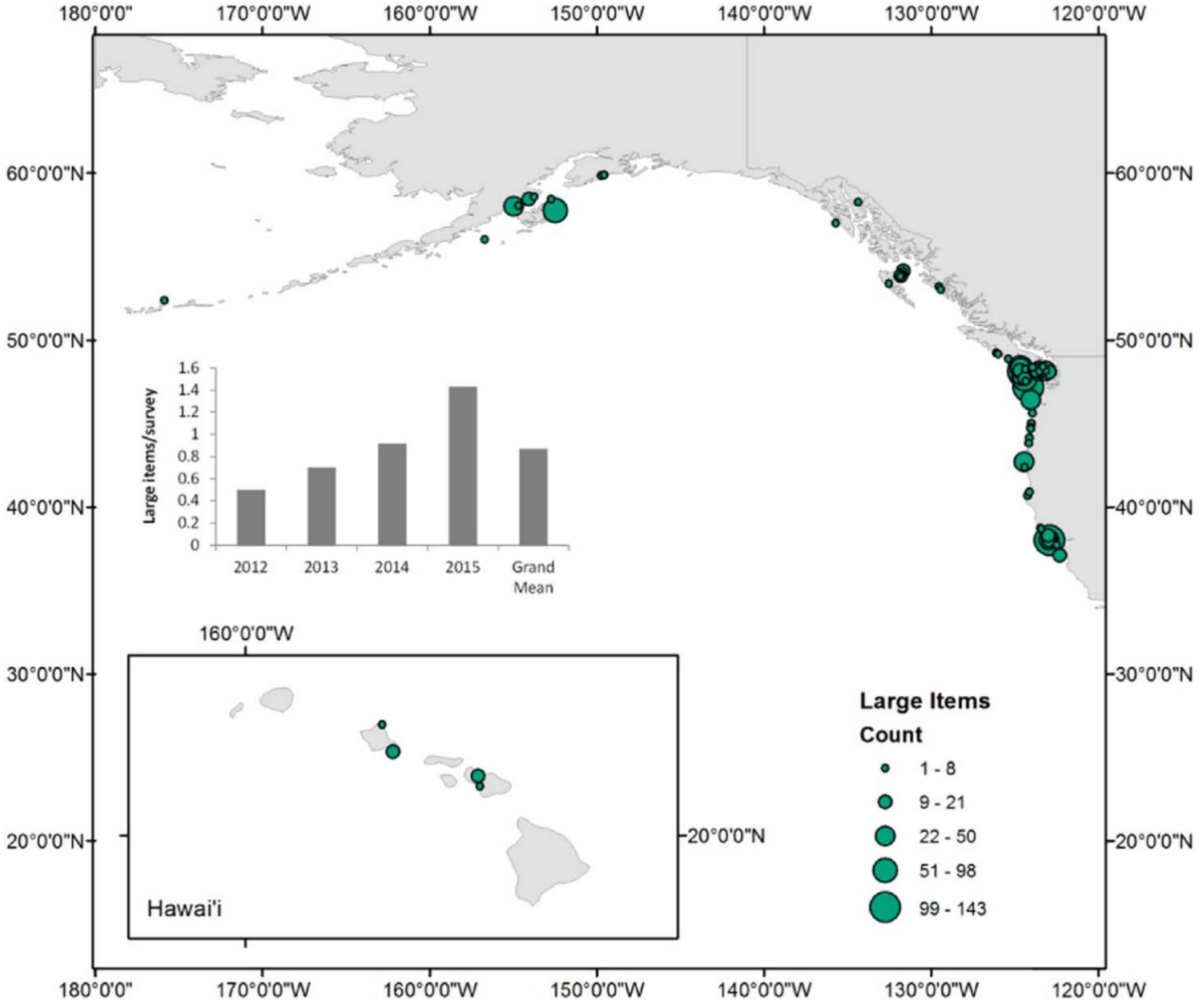
Modeled pathways



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?

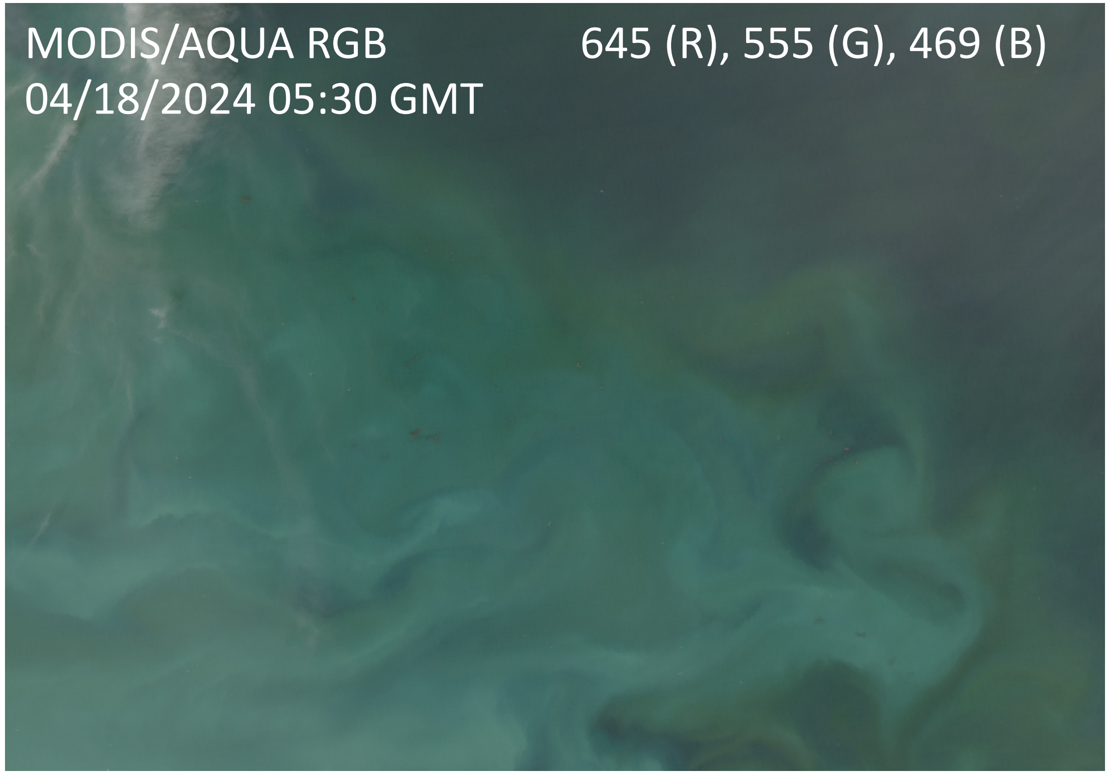
Progresses in satellite remote sensing technology (e.g., high-res constellation) – but it cannot be applied backward to 2011

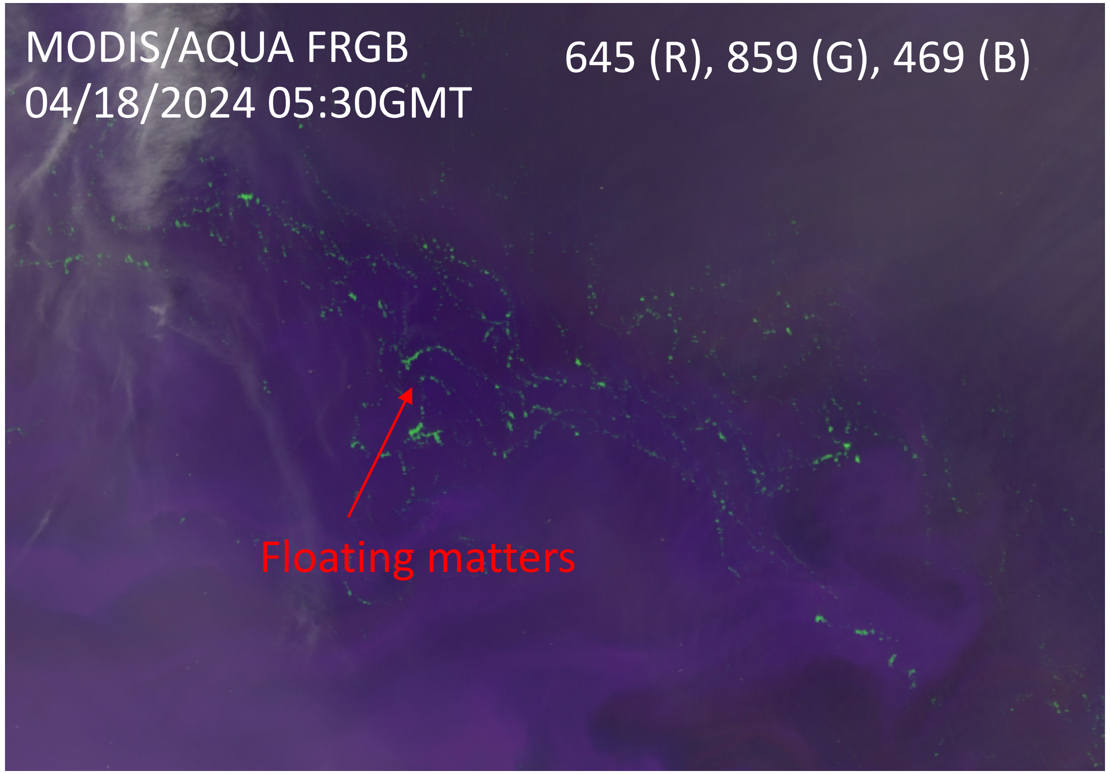
Progresses in algorithm/methodology – detection of presence, discrimination of type, and quantification

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

1. Detection of presence

Visualization method and tools

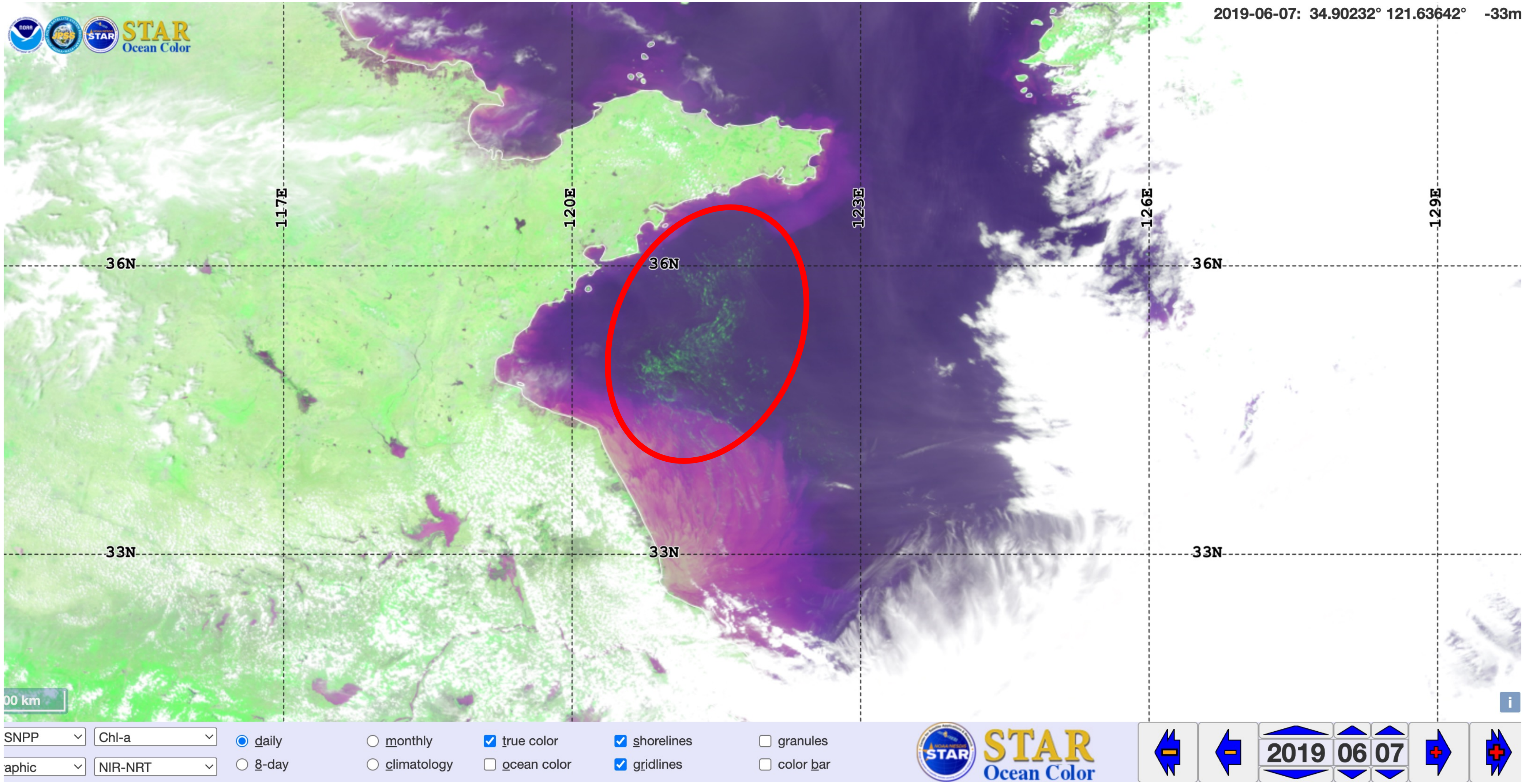




FRGB is better than RGB for visual inspection.
There are other indexes for the same purpose.

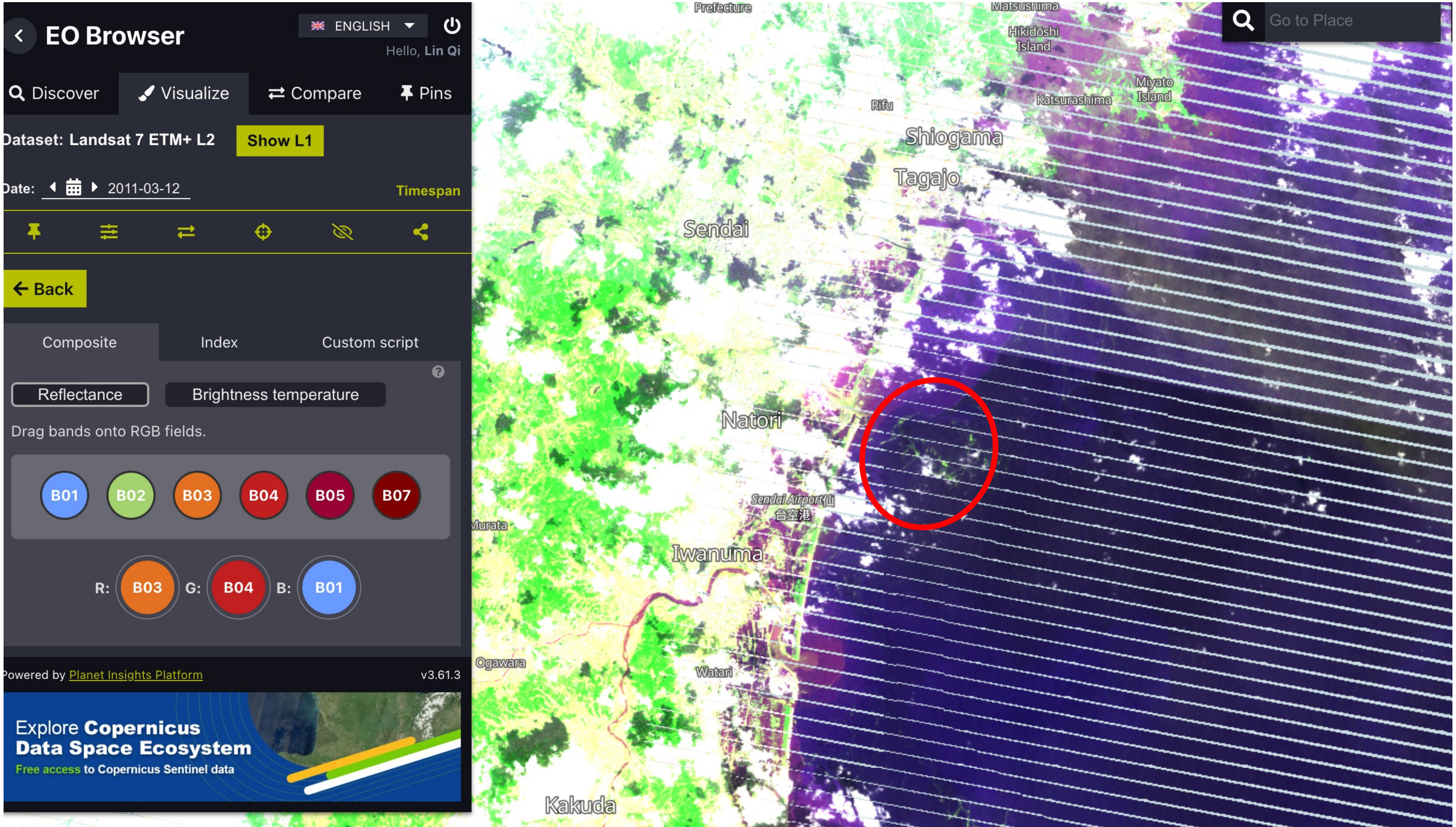
1. Detection of presence

Near real-time online tool (NOAA OCVIEW)



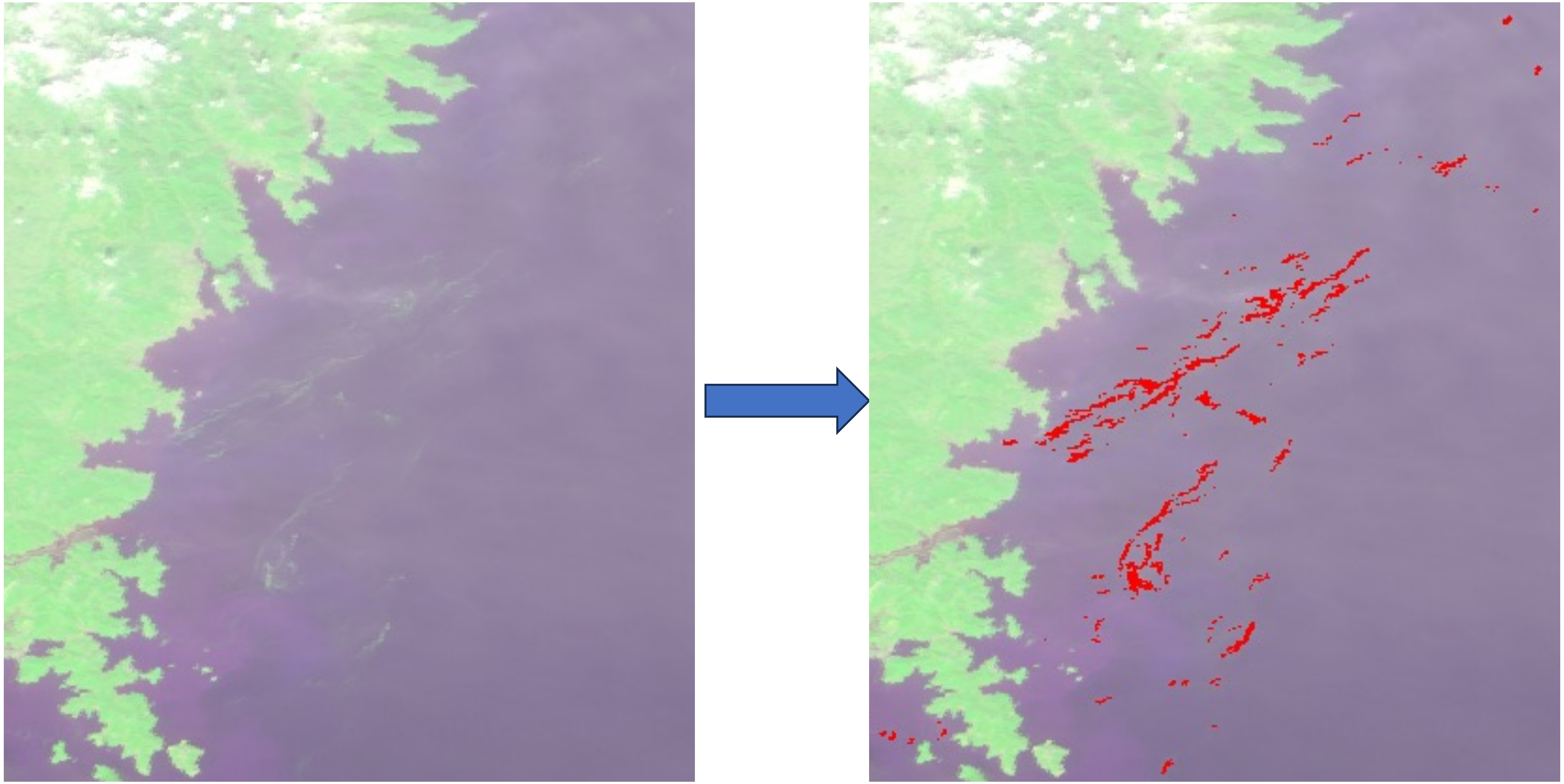
1. Detection of presence

Near real-time online tool (ESA EO browser)



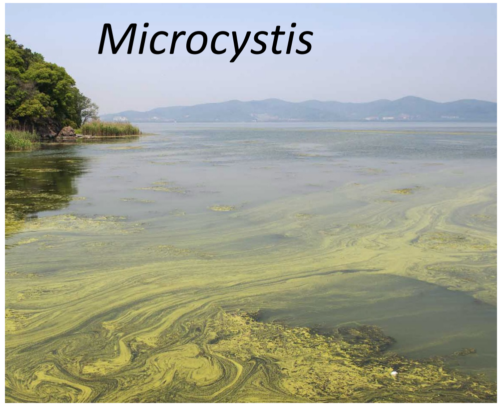
1. Detection of presence

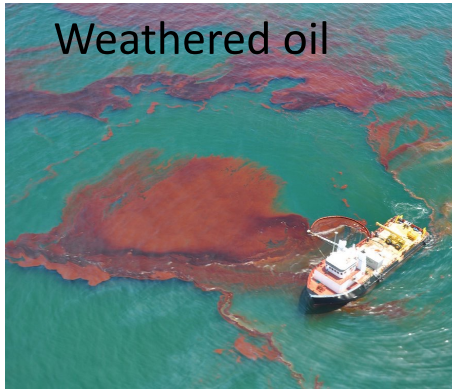
AI automation (deep-learning)

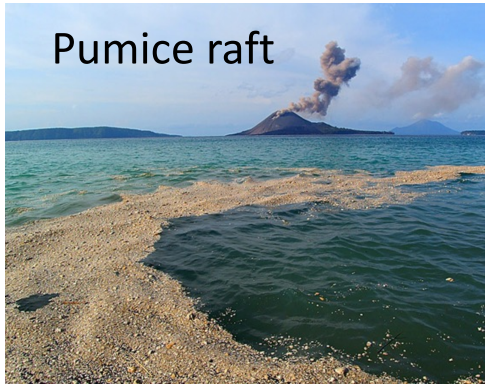


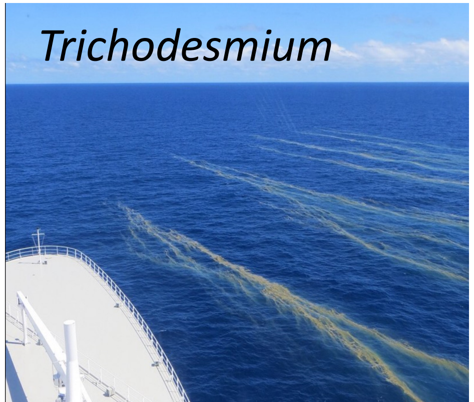
2. Discrimination of type

The many types of floating matters



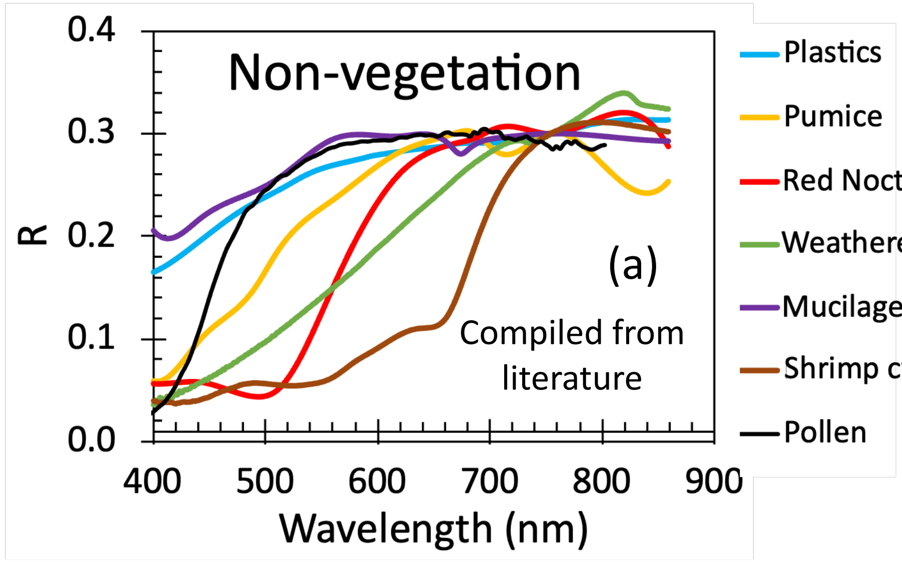


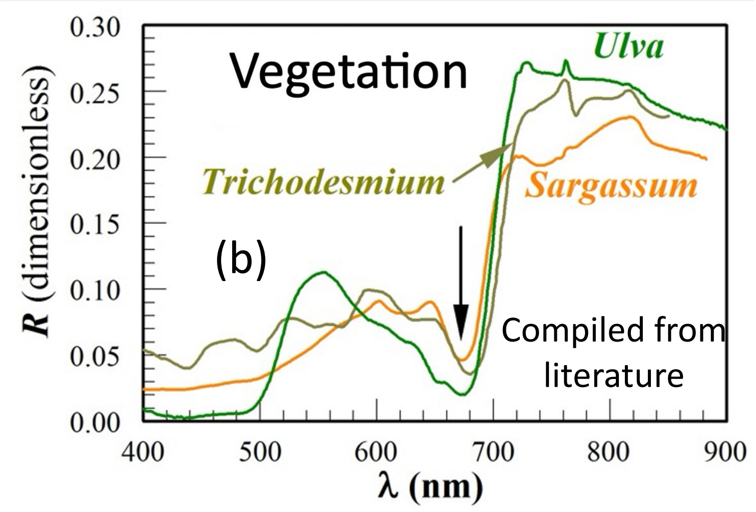


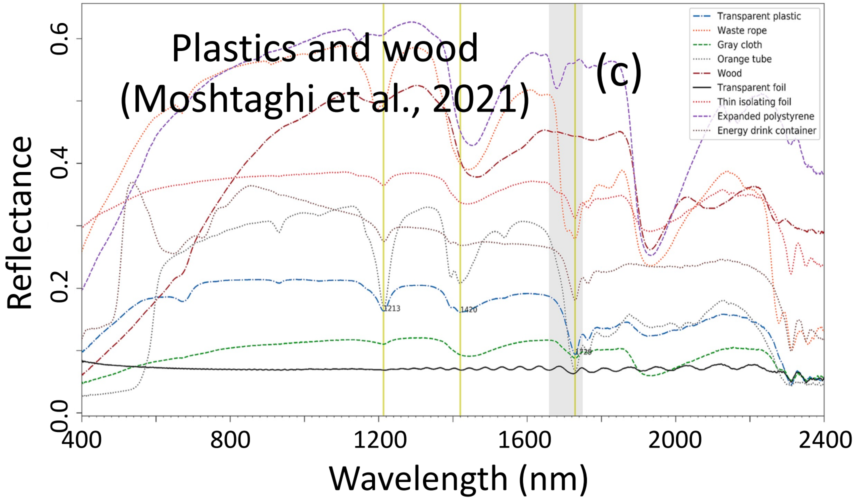


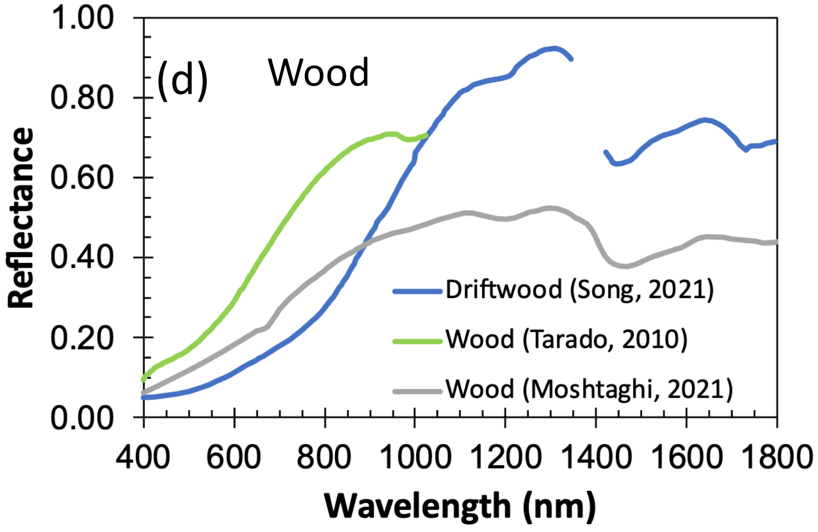
2. Discrimination of type

Spectral endmember library





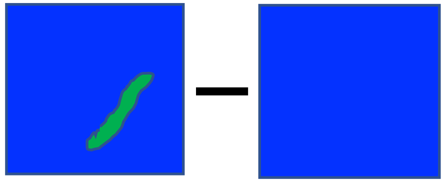


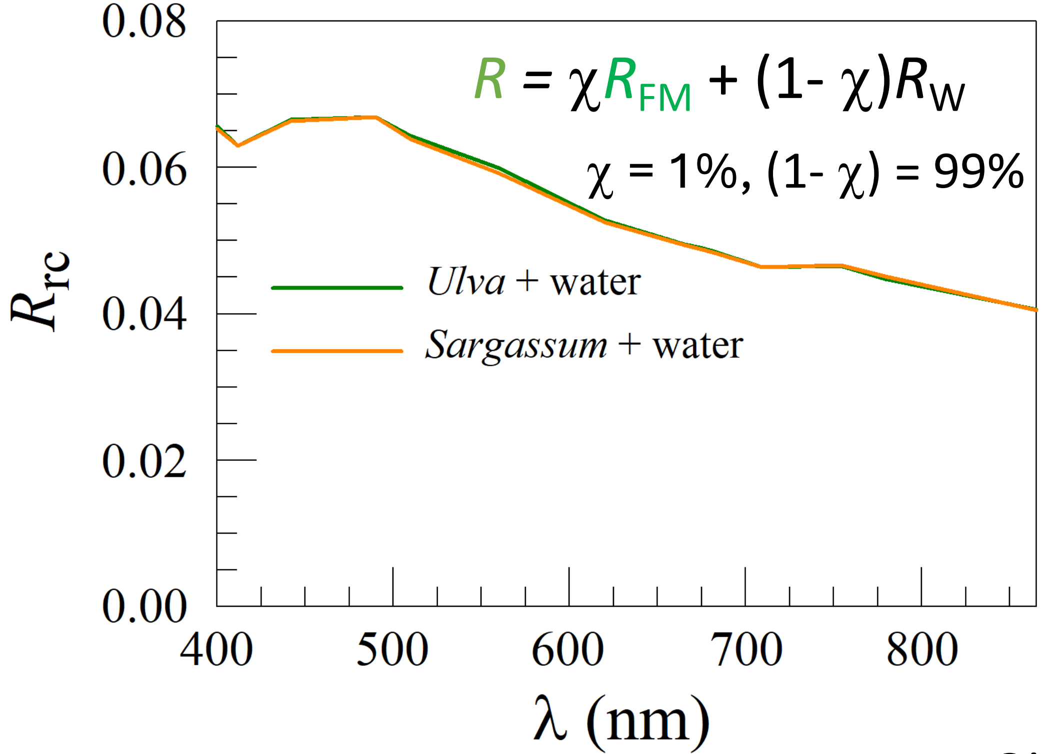


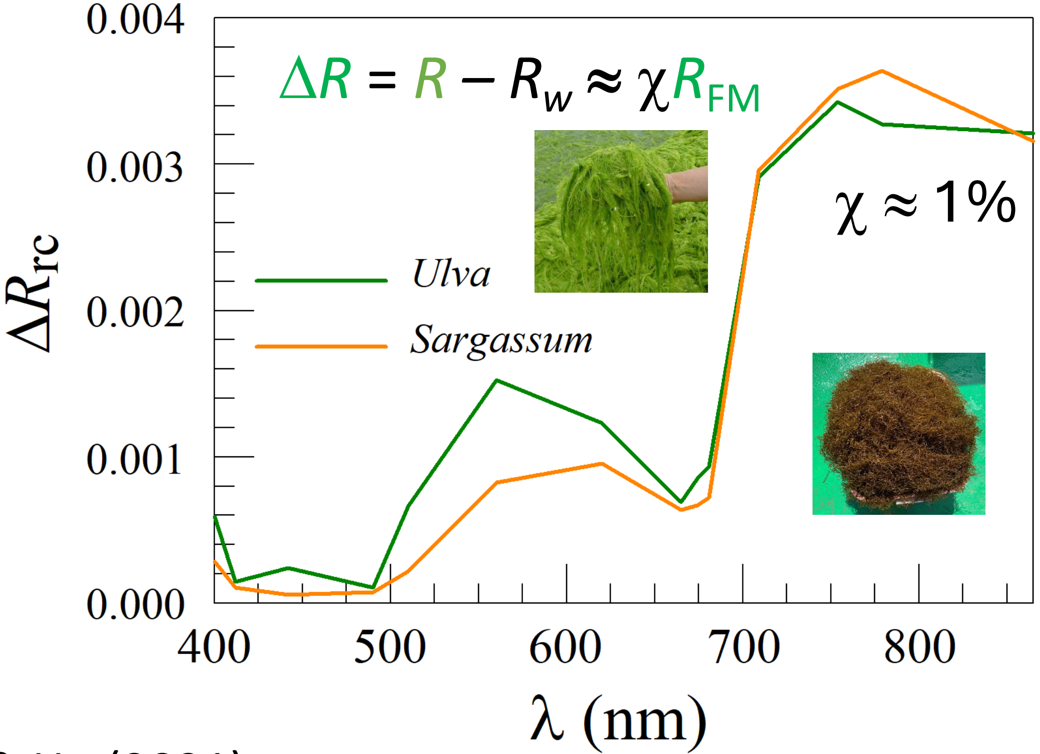
2. Discrimination of type

Problem: too small to show these characteristics

Solution: subtraction of nearby water



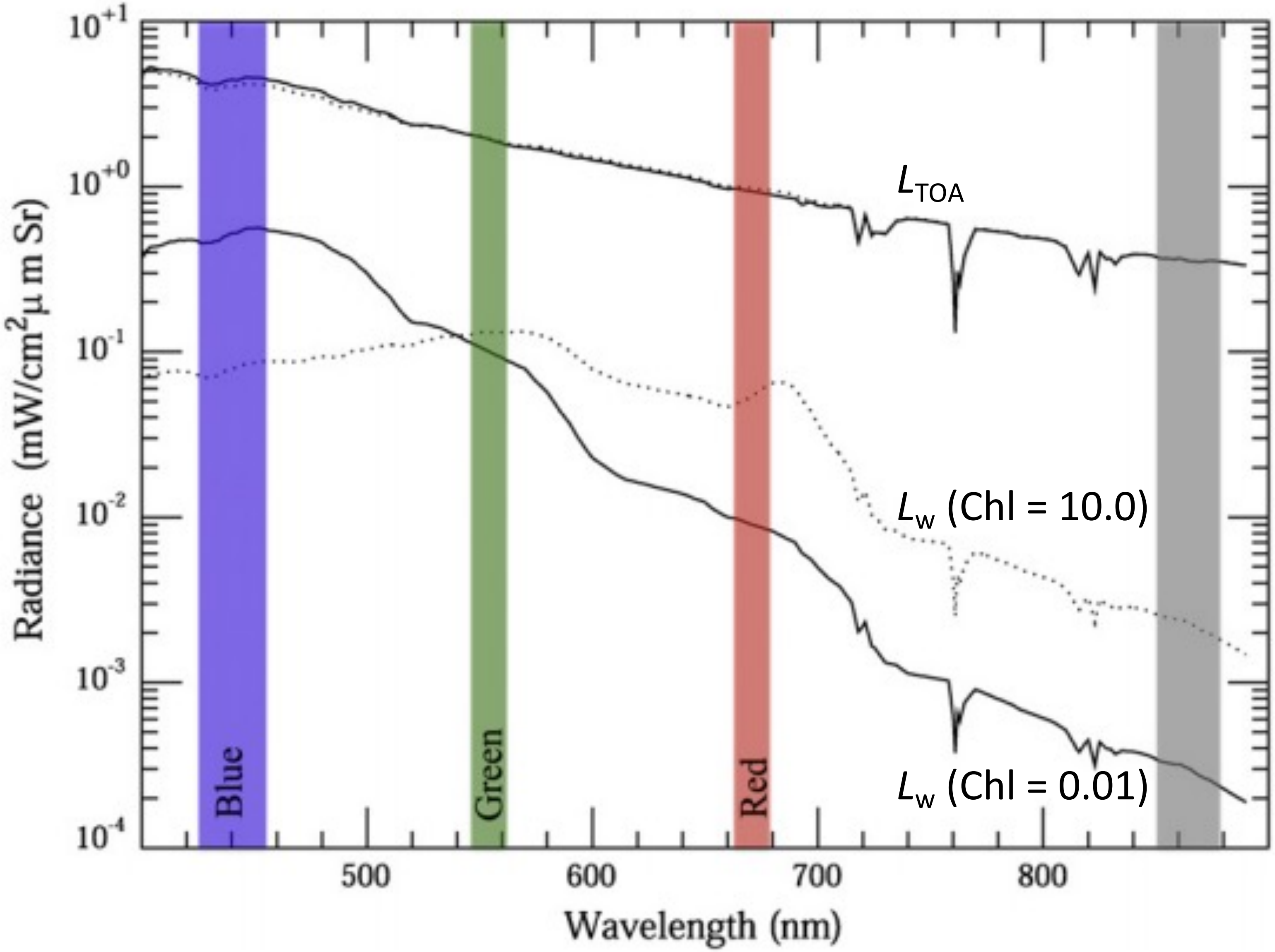




Qi & Hu (2021)

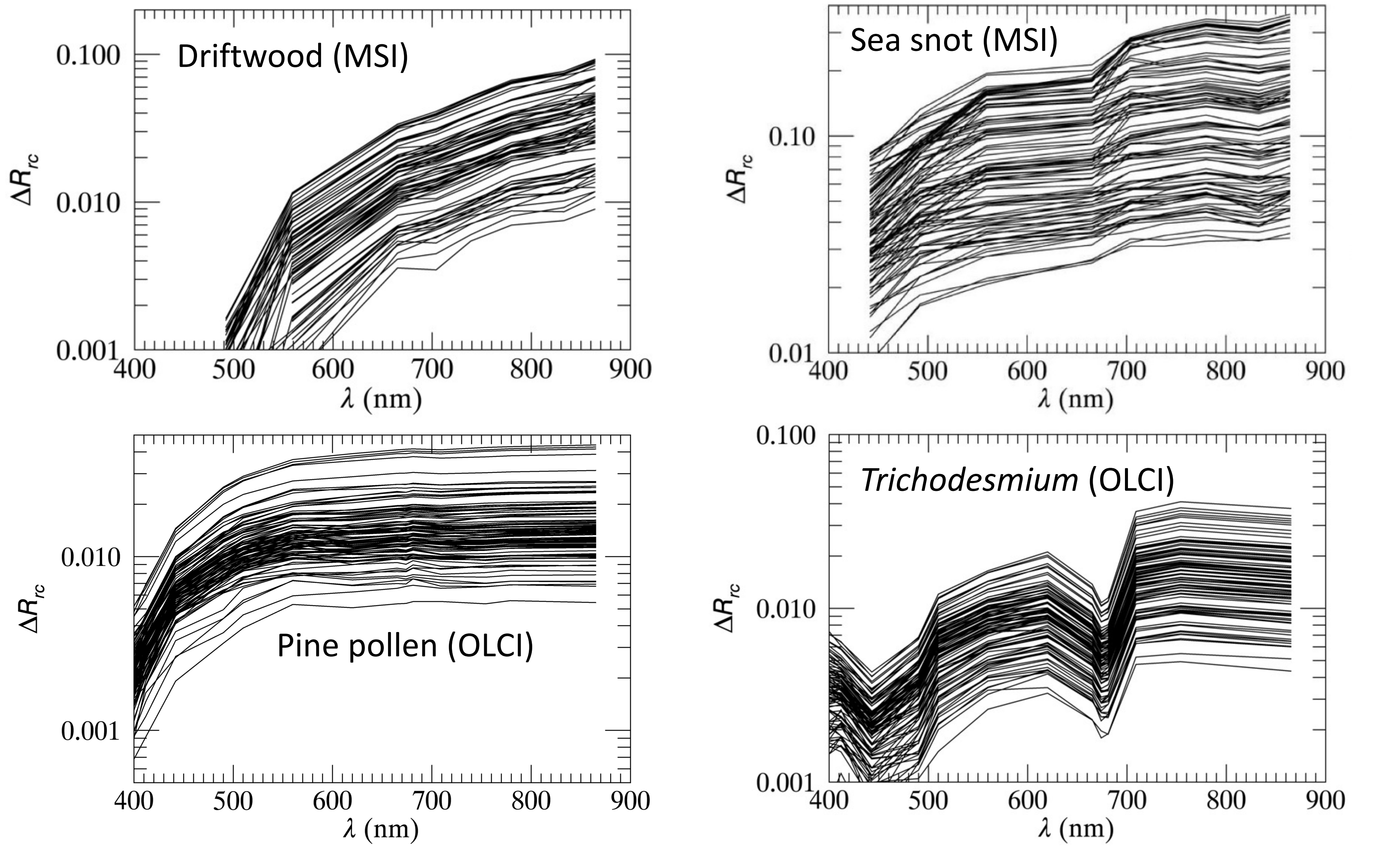
2. Discrimination of type

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



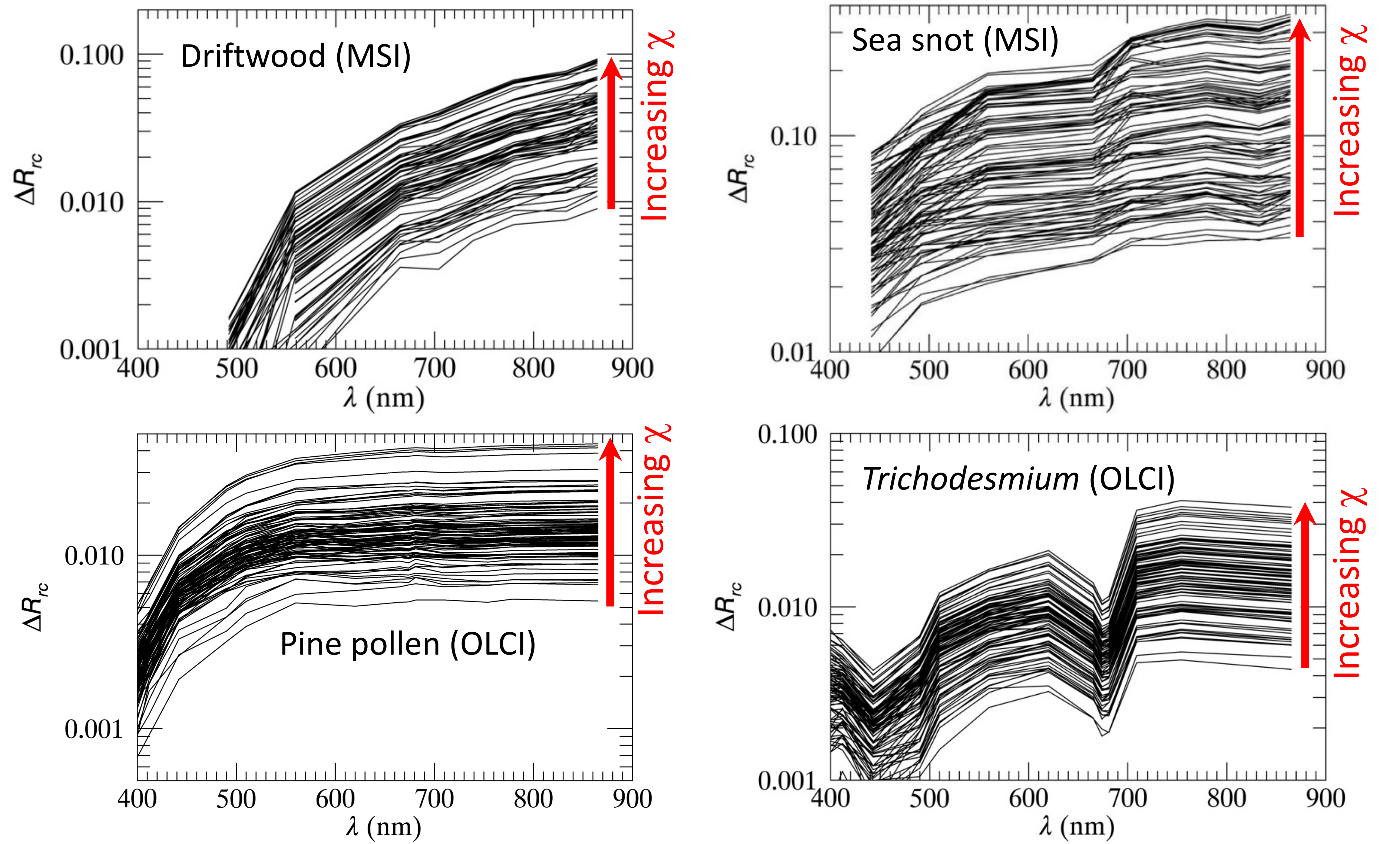
2. Discrimination of type

Compare spectral shape with endmember spectra $\Delta R = R - R_w \approx \chi R_{FM}$



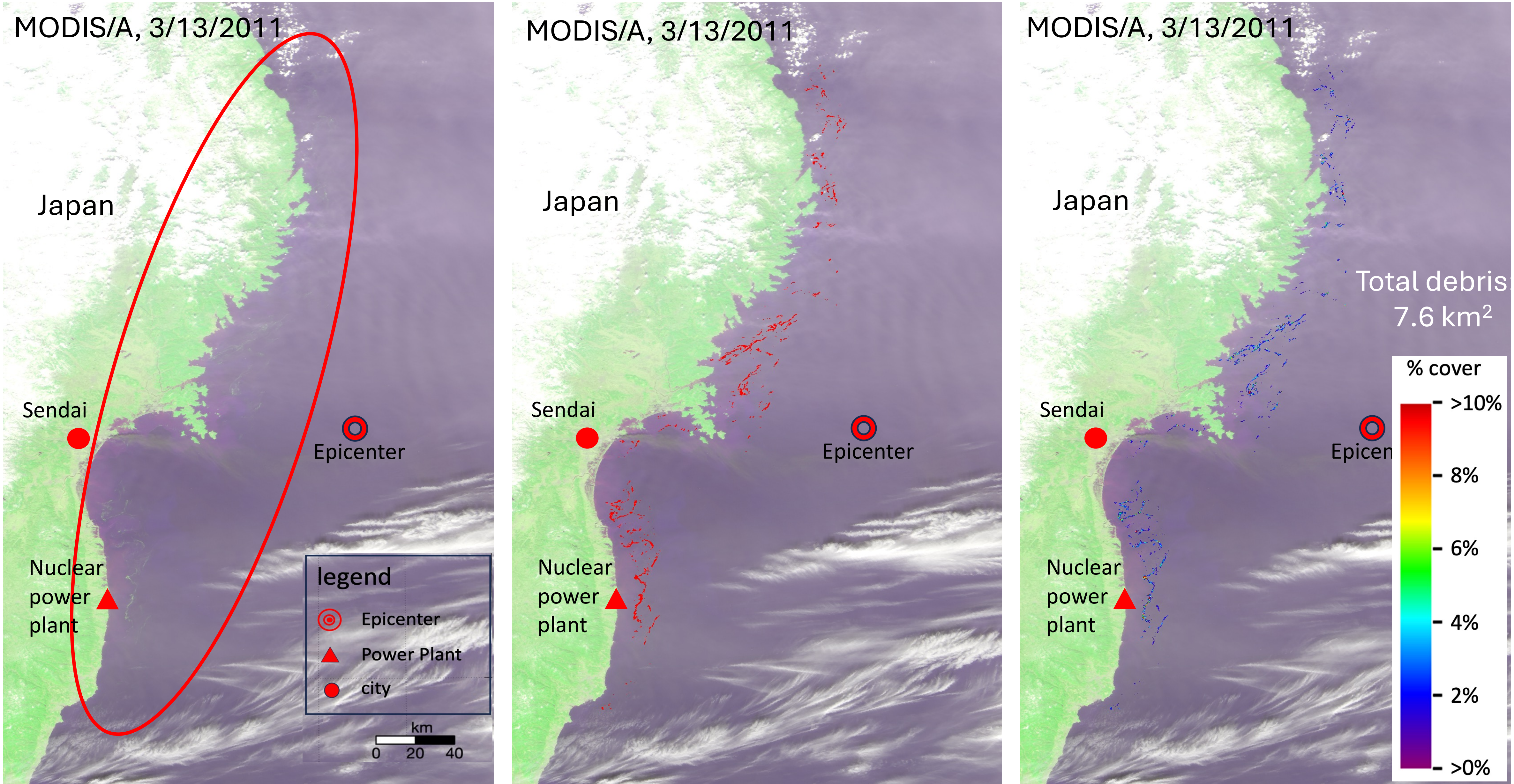
3. How much?

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



Now the 2011 Japan tsunami case

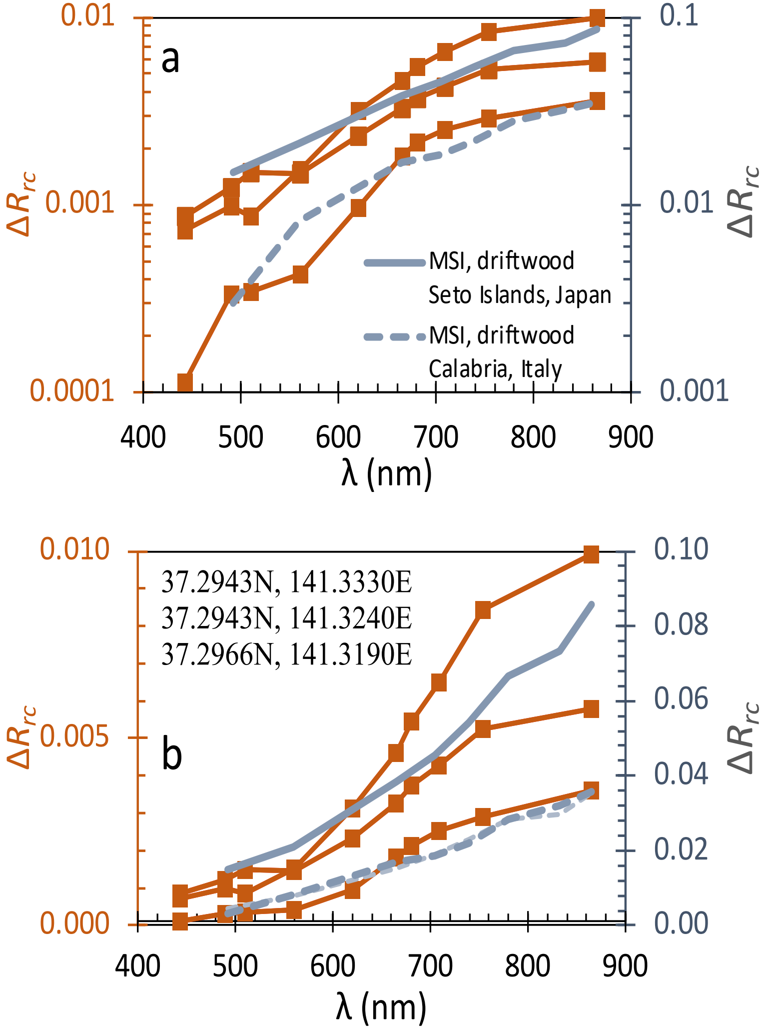
Visualization | Presence/absence detection | Quantification



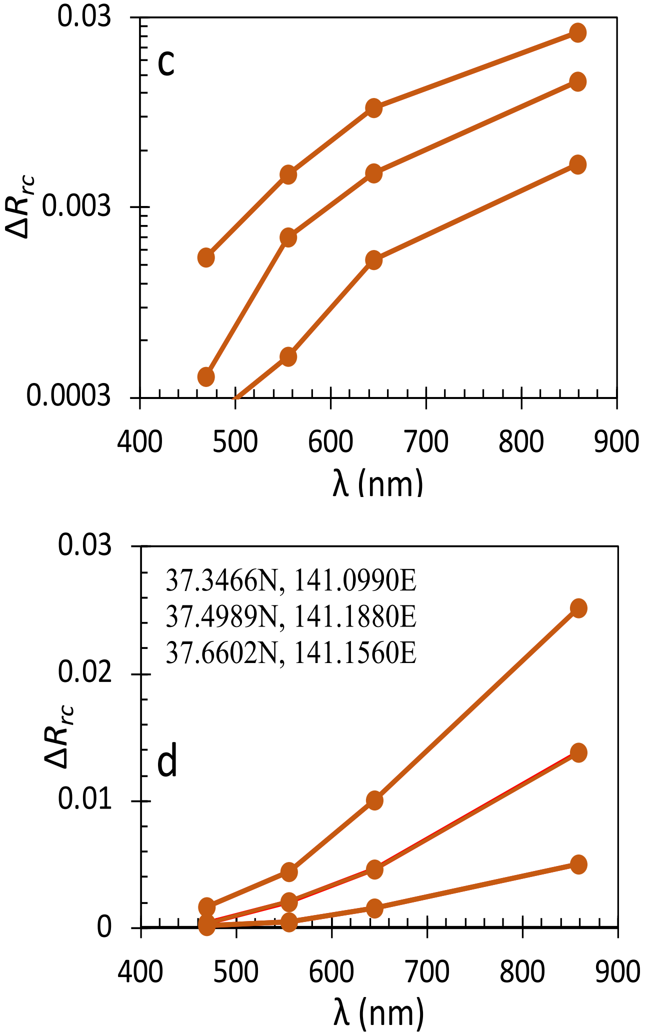
What are they? Spectral analysis

Japan tsunami case

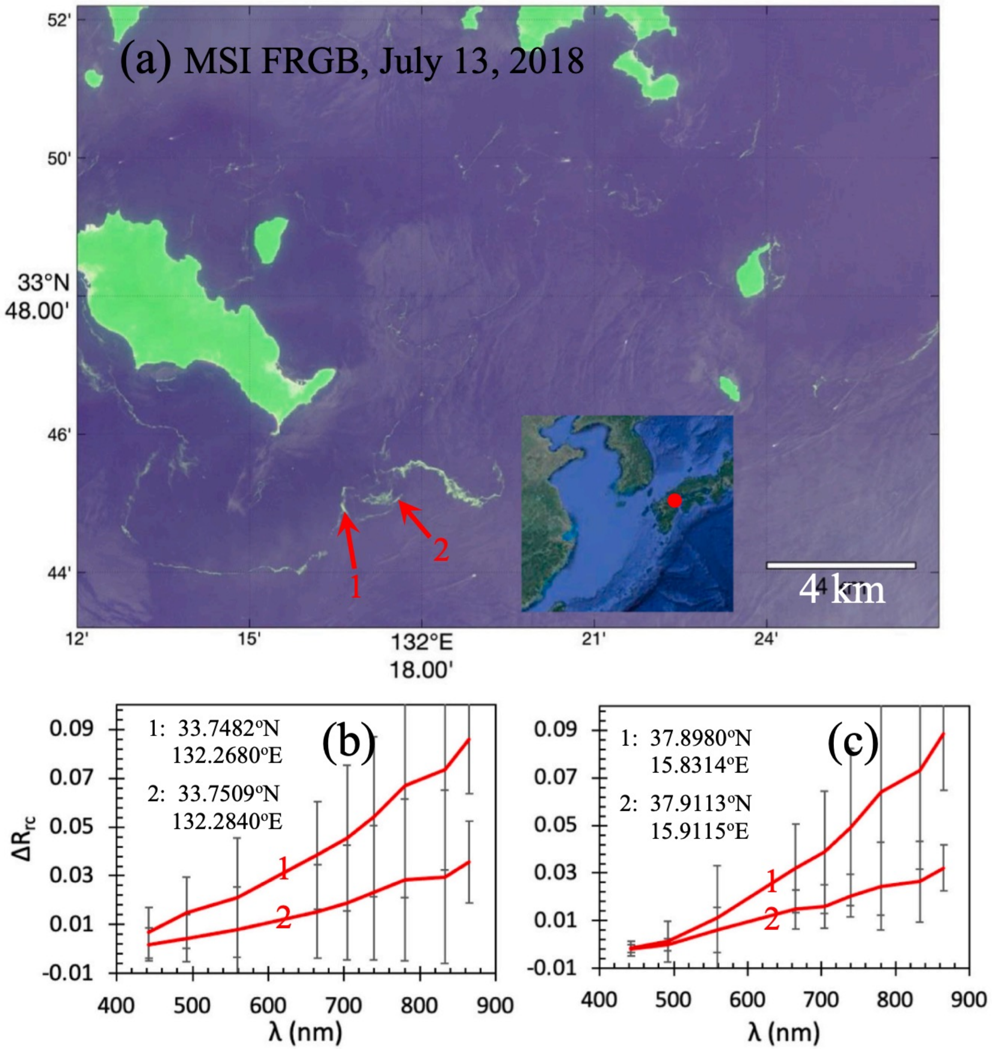
MERIS



MODIS



Flooding case, Japan



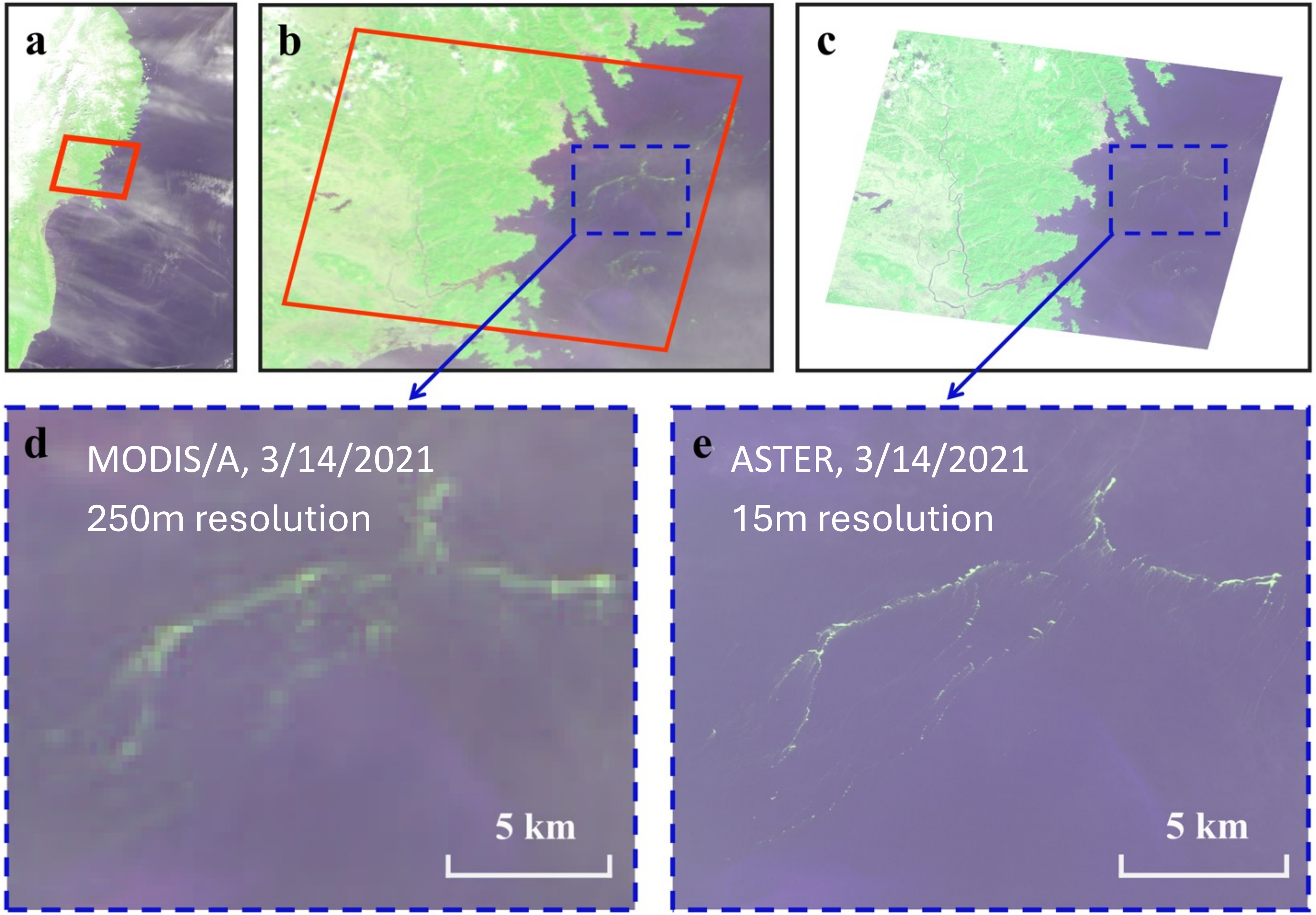
How can we trust these results?

Debris type: confirmation from limited aerial photos

Mostly wood, but mixed with plastics

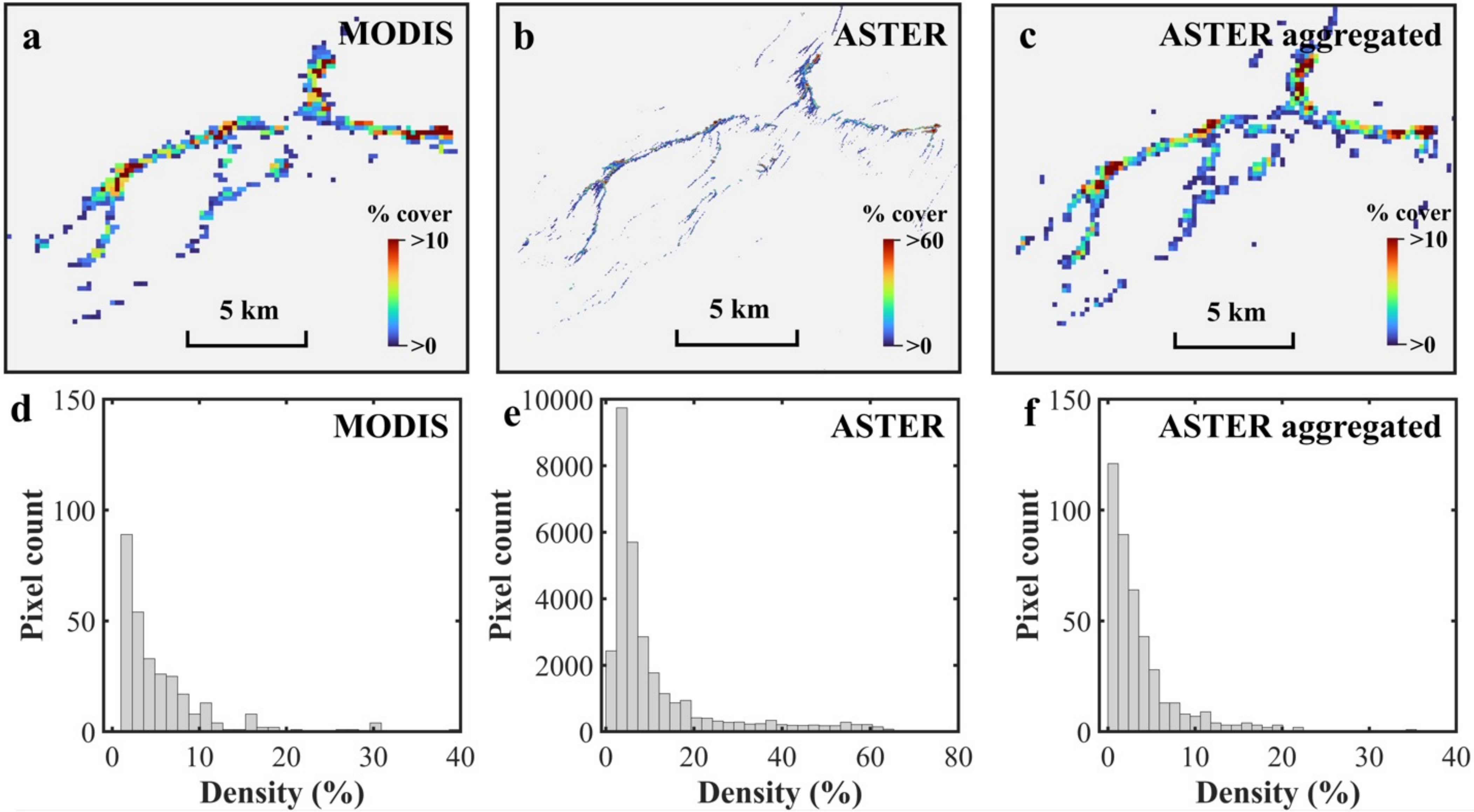
How can we trust these results?

Debris amount: compare with high-res images

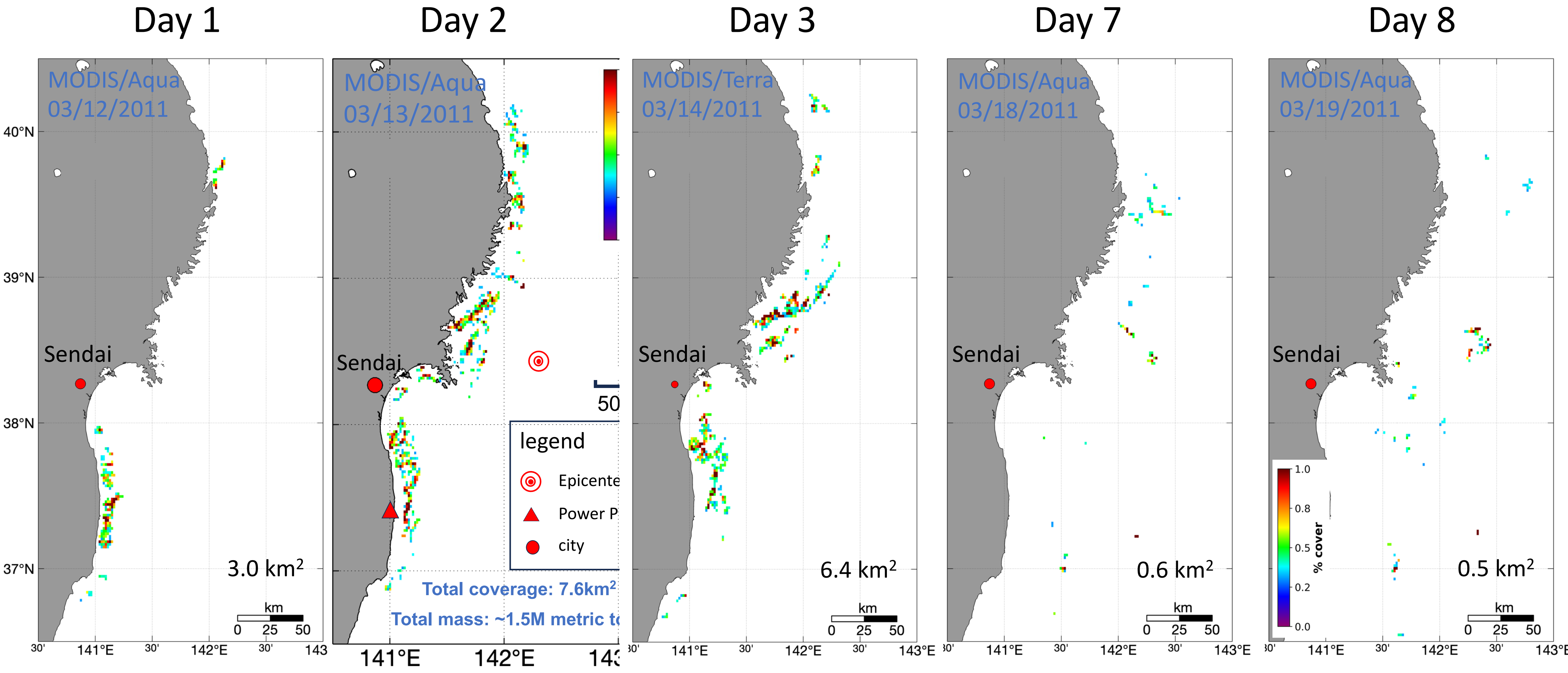


How can we trust these results?

Debris amount: compare with high-res images



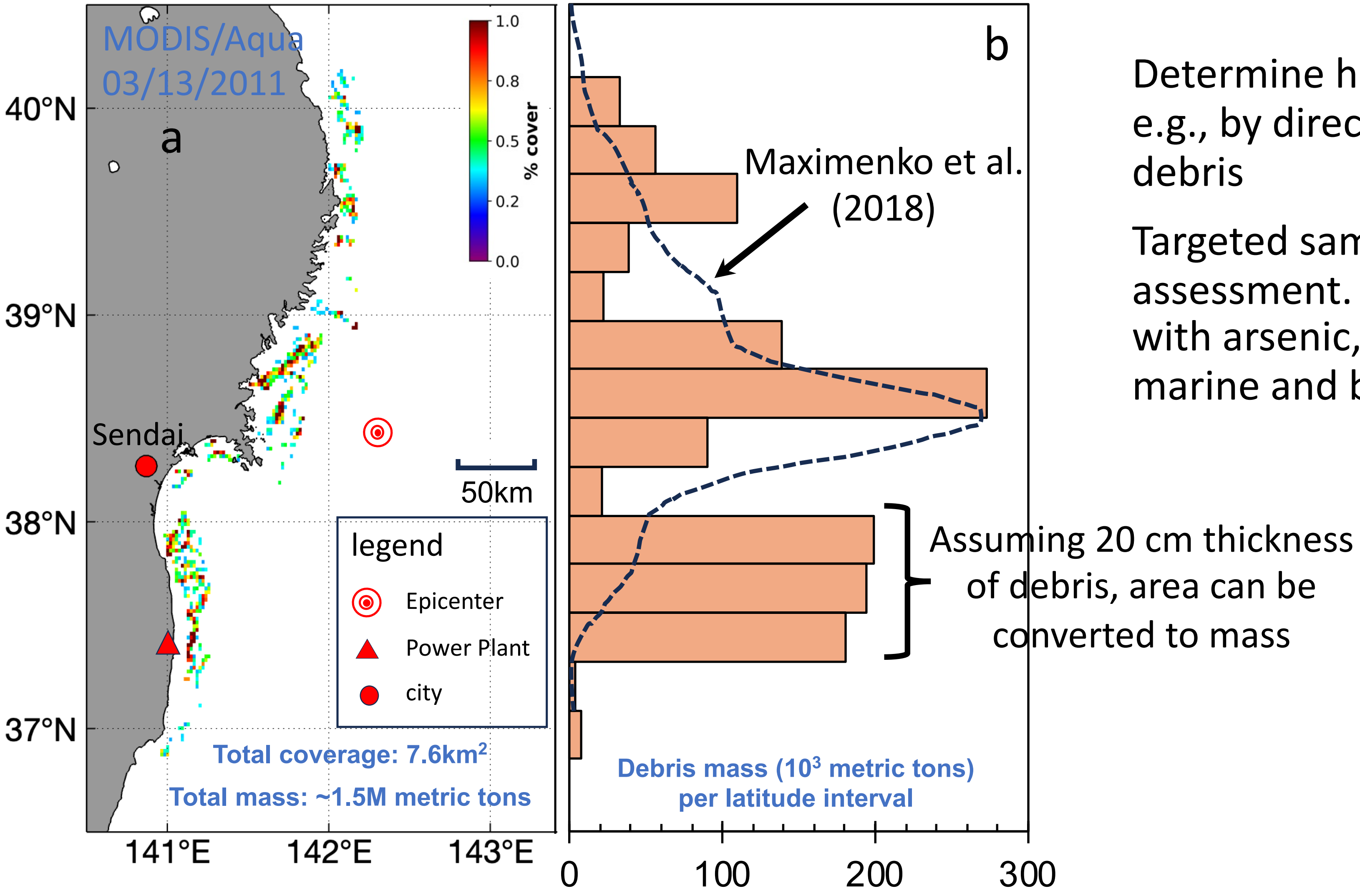
Distribution patterns



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

Now what?

1. Improve numerical model

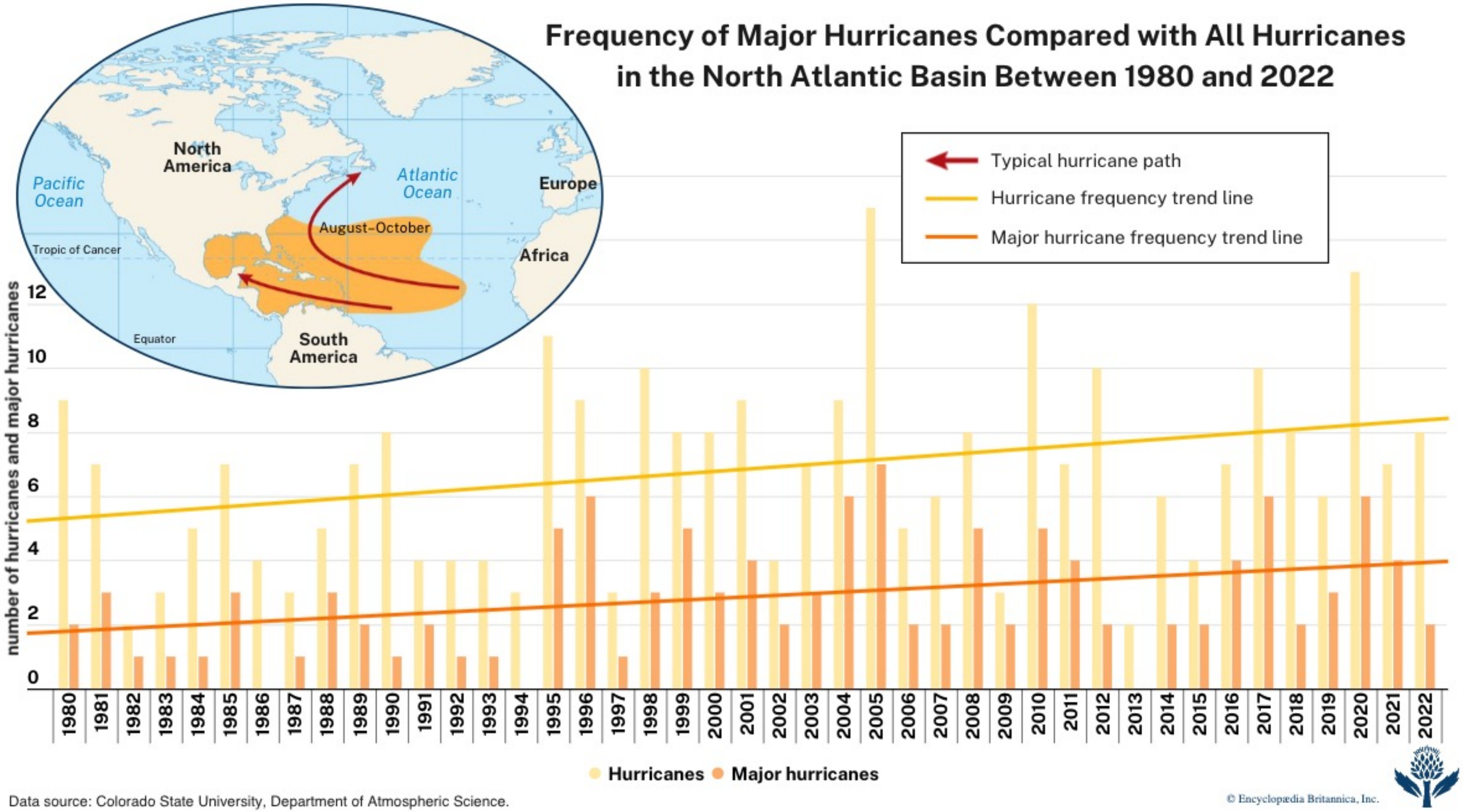


2. Improve disaster response

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

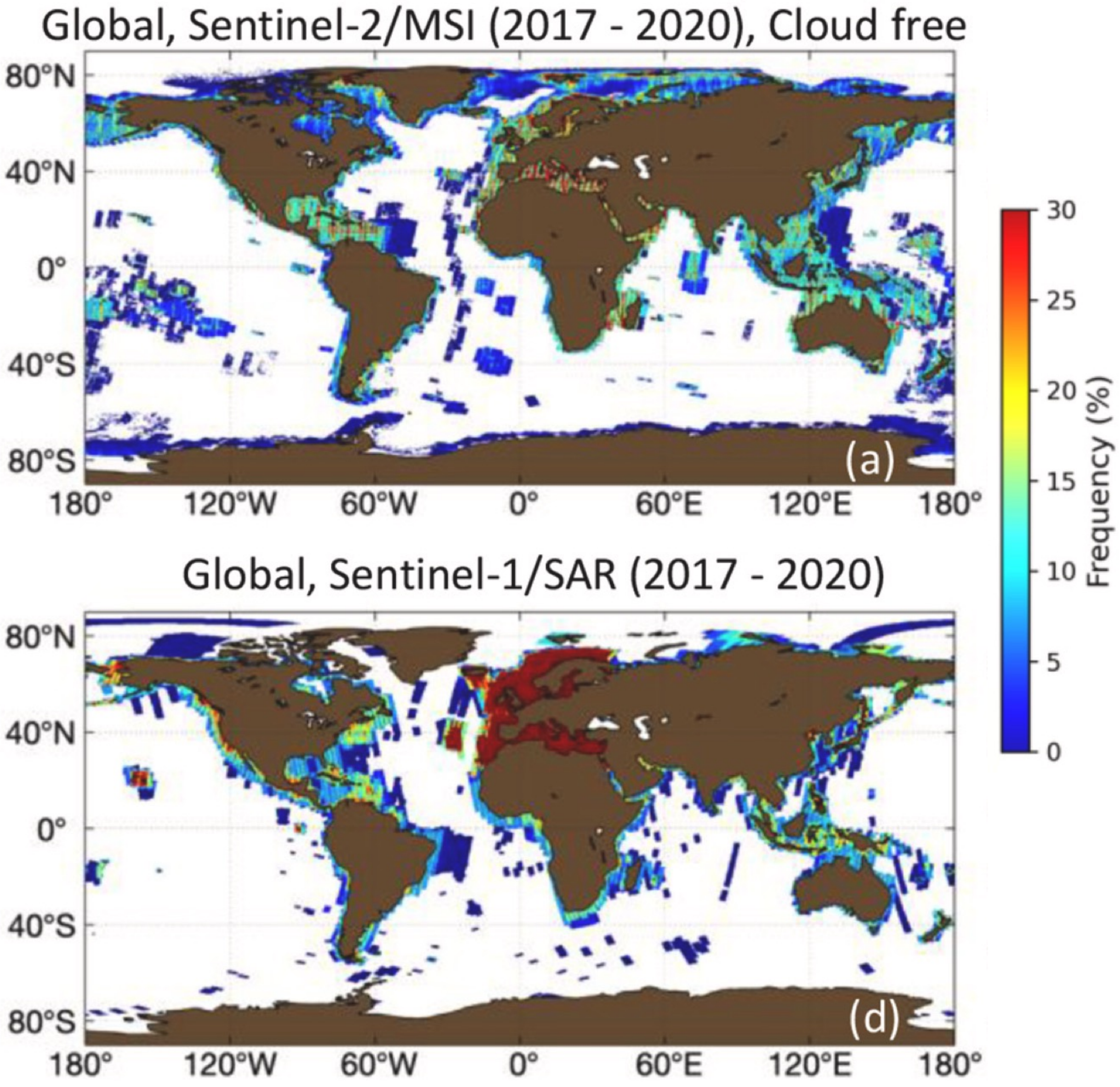
Targeted sampling for post-disaster assessment. Lumber woods are often treated with arsenic, therefore possibly toxic to the marine and benthic environments

What's next
Improve capacity for event response



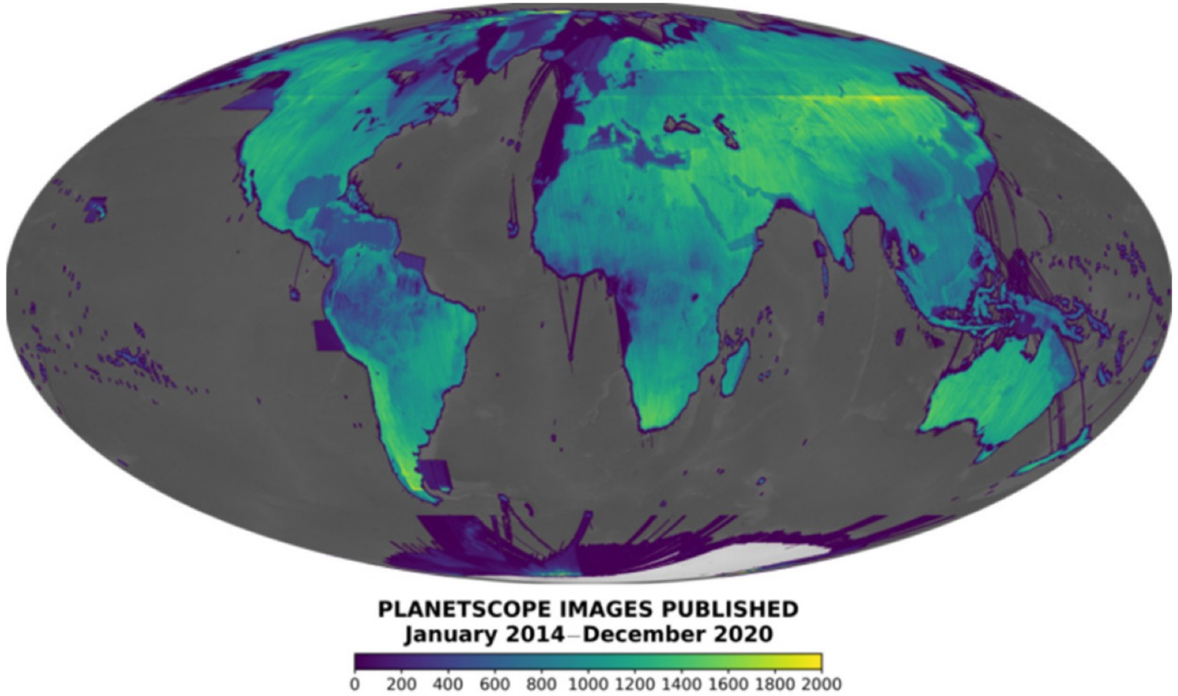
What’s next

Improve coverage with high-res satellites



PlanetScope constellations

(4 m resolution, 1-2 day revisits)



However, challenges still remain

Most challenge comes from the difficulty in separating debris from others

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 km^2, about 1.5M metric tons, maximum water area of 7000 km^2, 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)