On the logic of remote detection of marine plastics

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Outline

I. What are we talking about?

II. What's the logic?

III. What's possible?

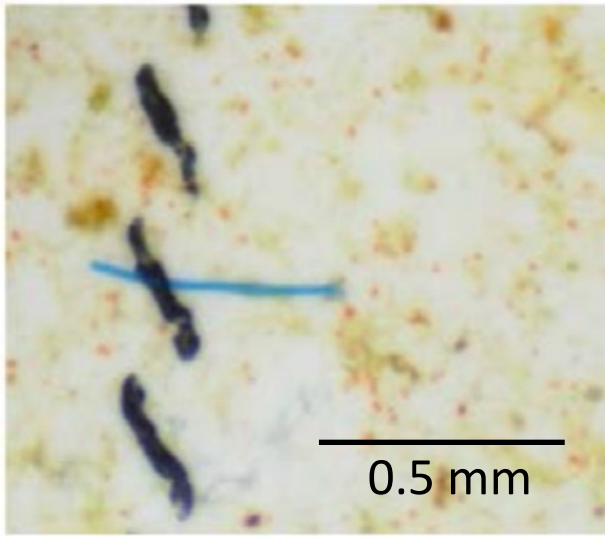
I. What are we talking about?

Subject => Marine plastics (a sub-category of marine debris or marine litter):

Marine litter: Solid materials released to the marine environment from natural disasters (e.g., hurricanes, Tsunami) or human activities: Microplastic particles, plastic bags, plastic bottles, fishing gear, tree branches/leaves, driftwood, ……

Microplastic particles

Microfibers (> 91%), mostly < 1 mm



Barrrows et al. (2018)

Larger particles (< 5 mm)

Garaba & Dierssen (2018)

Macroplastics

& other debris

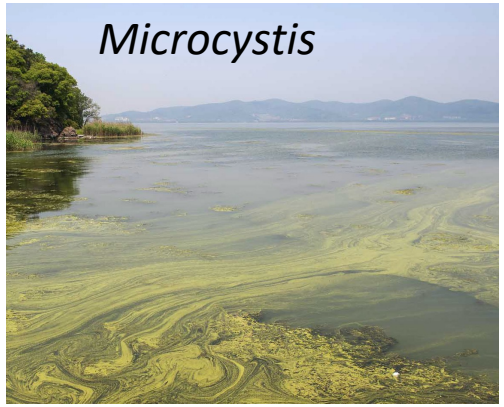
Web source

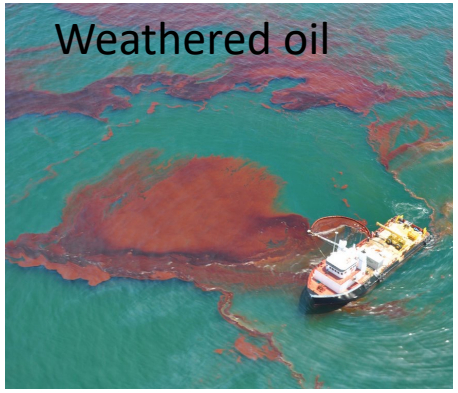
Mixture

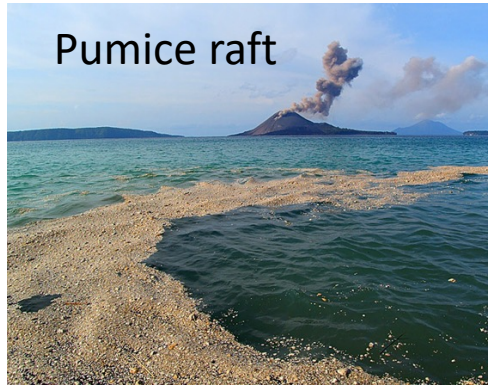
of everything

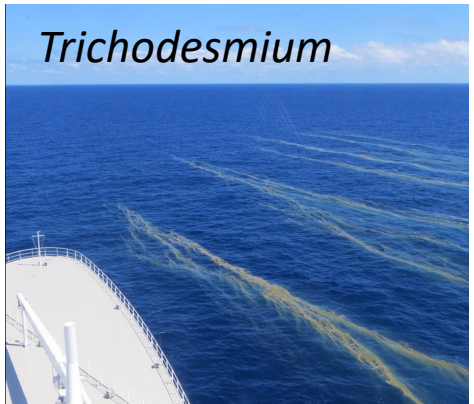
Web source

I. What are we talking about?
The many types of floating matter









I. What are we talking about?
The many types of image features

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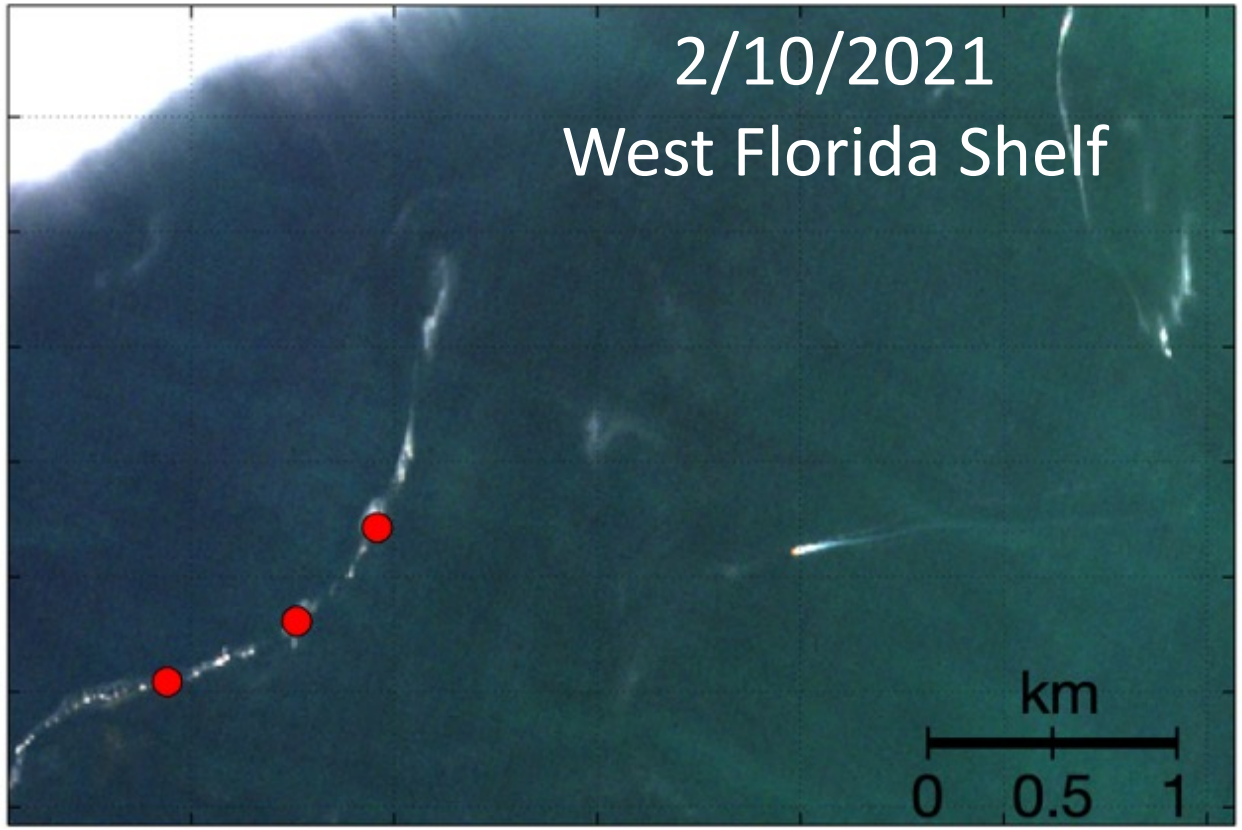
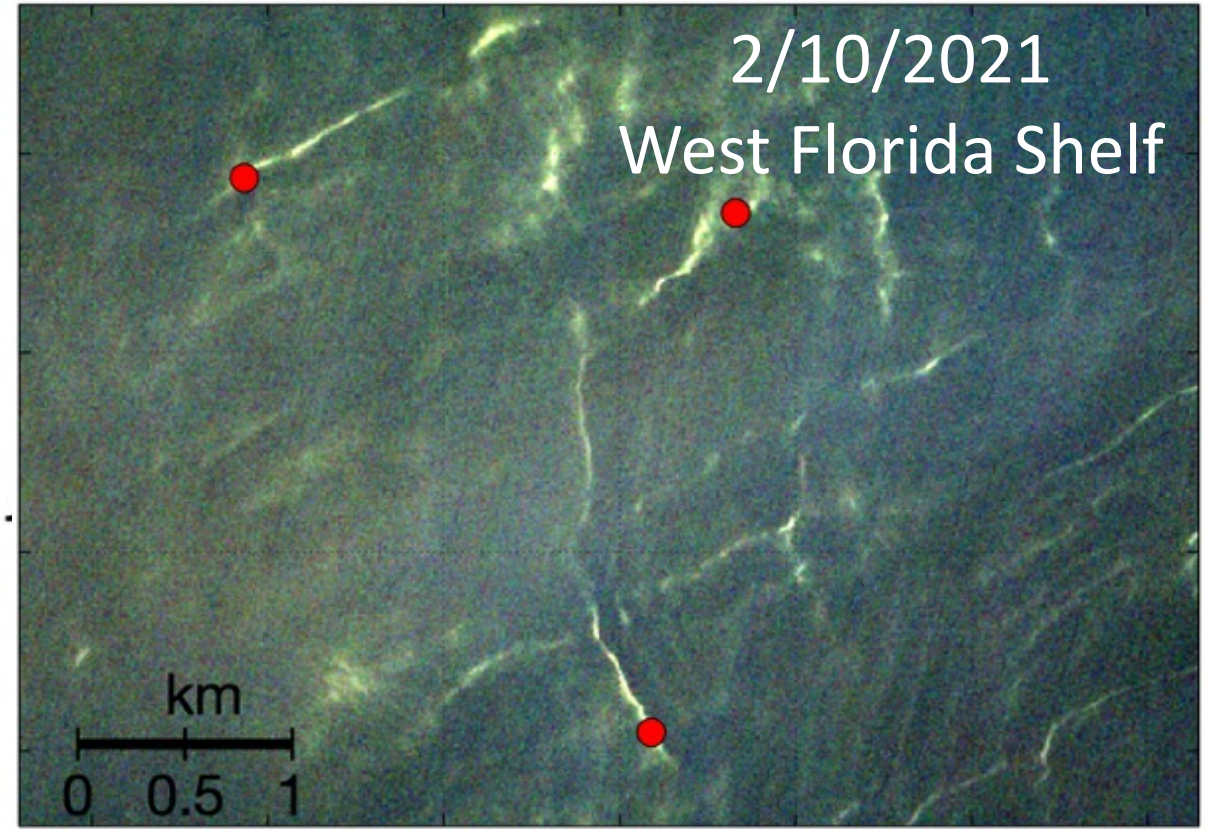




II. What's the logic?

Plastics (A) => image features and/or spectral shapes (Z)

However, in logic, A => Z does not lead to Z => A

This is because we also have B => Z, C => Z, D => Z, ……

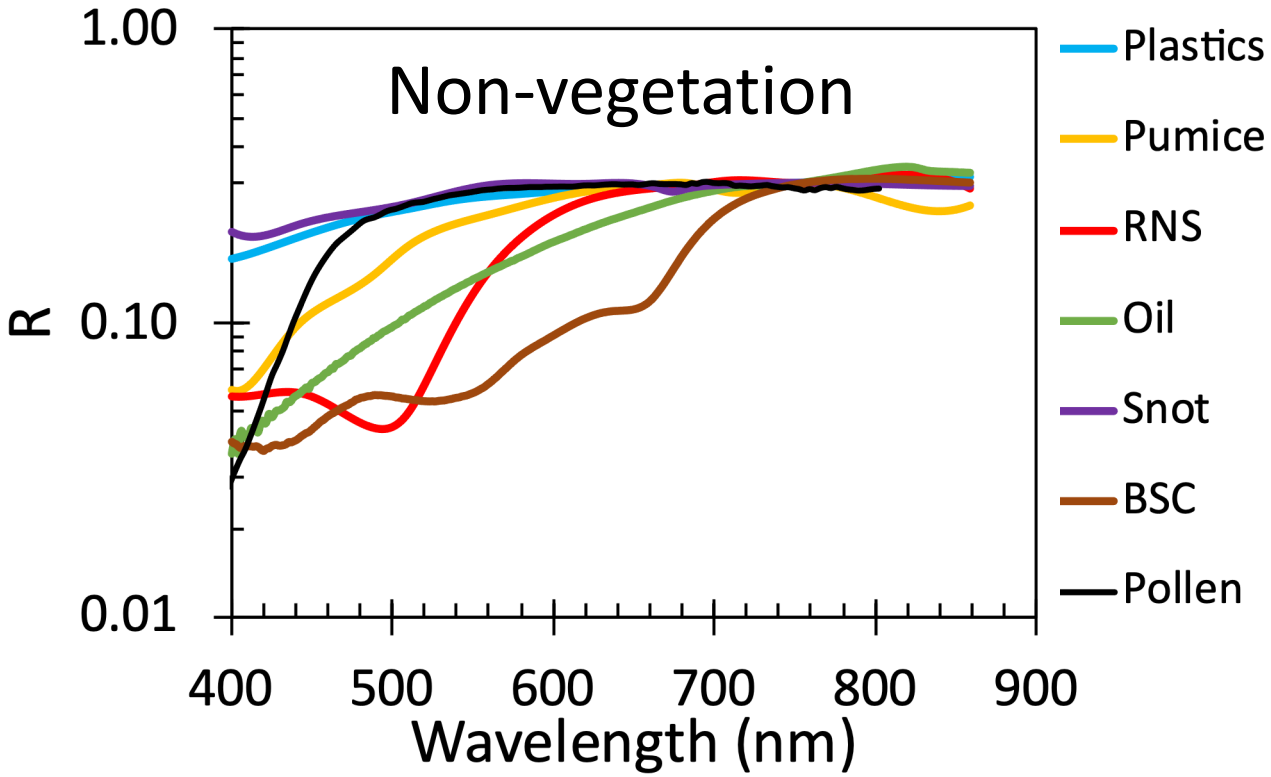
So, unless (B, C, D, ….) can all be ruled out, we cannot say Z => A

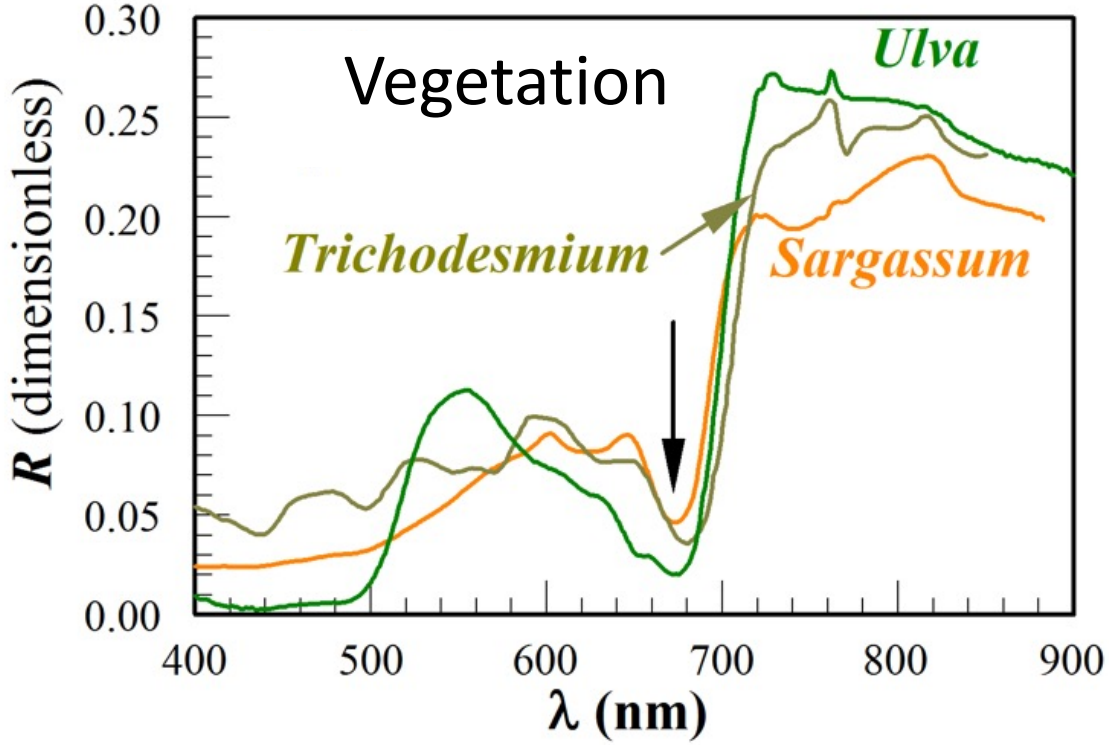
Here, (B, C, D, ….) also include image or processing artifacts.

III. What's possible?

Once we have Z, how do we rule out (B, C, D, ….)?

1. Direct field validation (very rare)
2. Local knowledge (important and very useful)
3. **Spectral similarity** **(sounds easy but very tricky)**

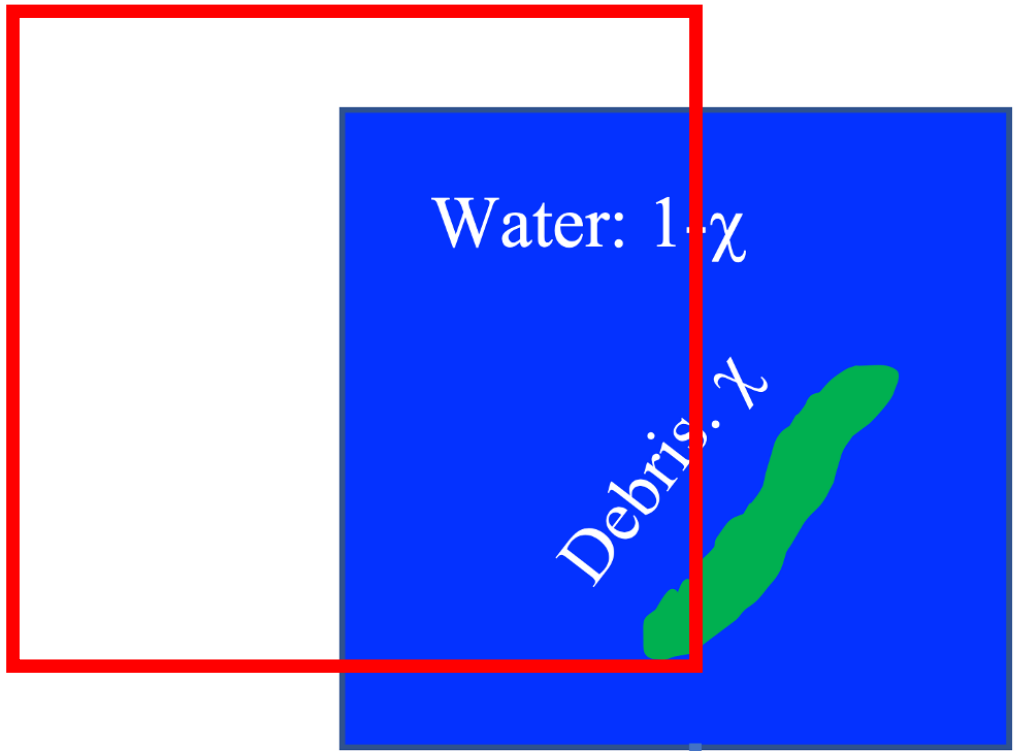




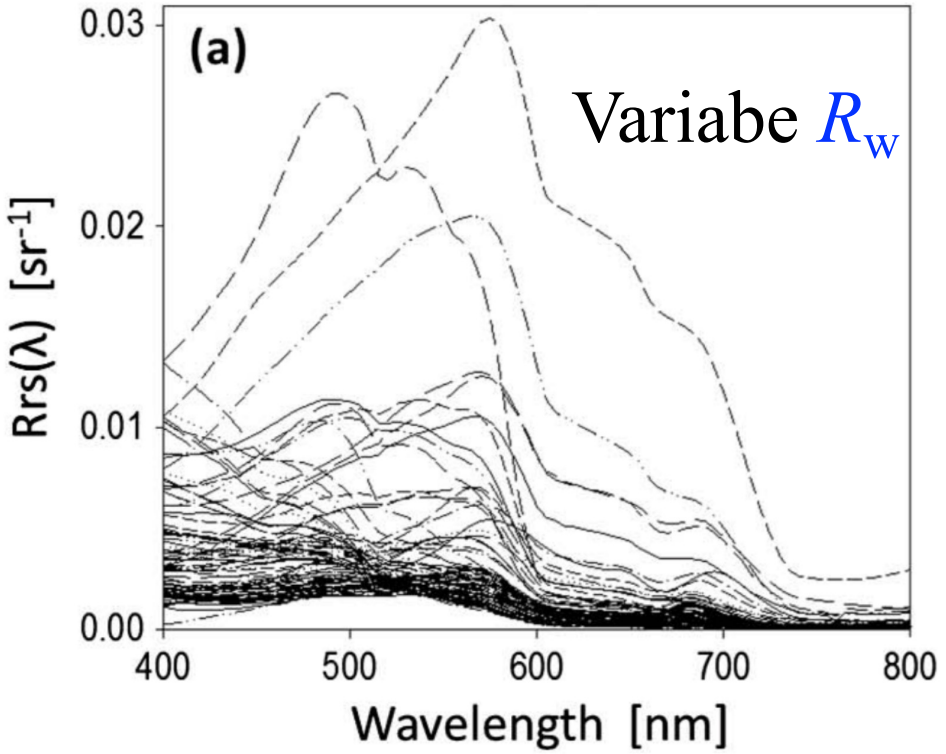
III. What's possible?

Spectral similarity – why is it so tricky?

3 reasons: Mixed pixels; mixed band resolutions; band registration errors



$$R_T = \chi R_D + (1 - \chi)\, R_W$$

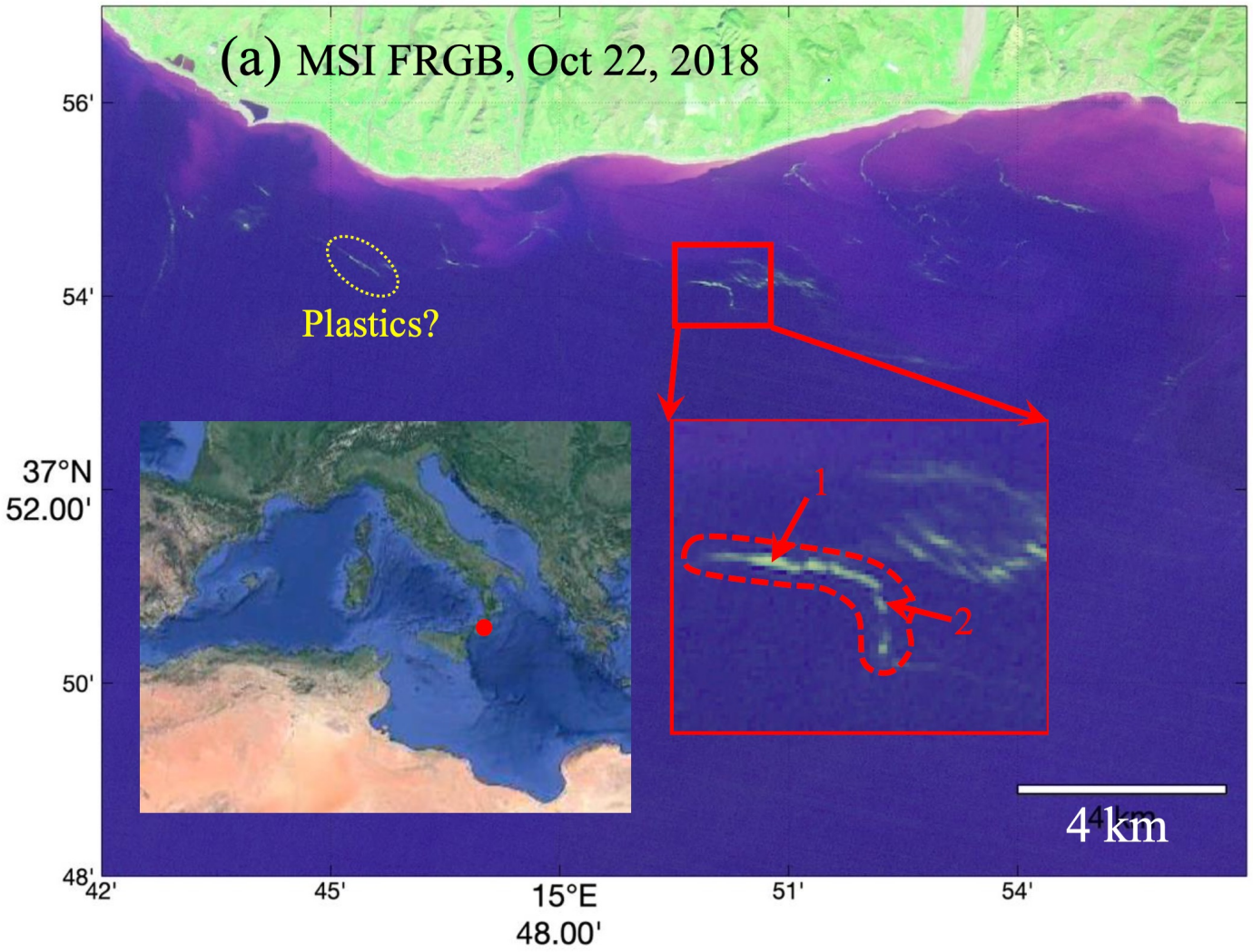


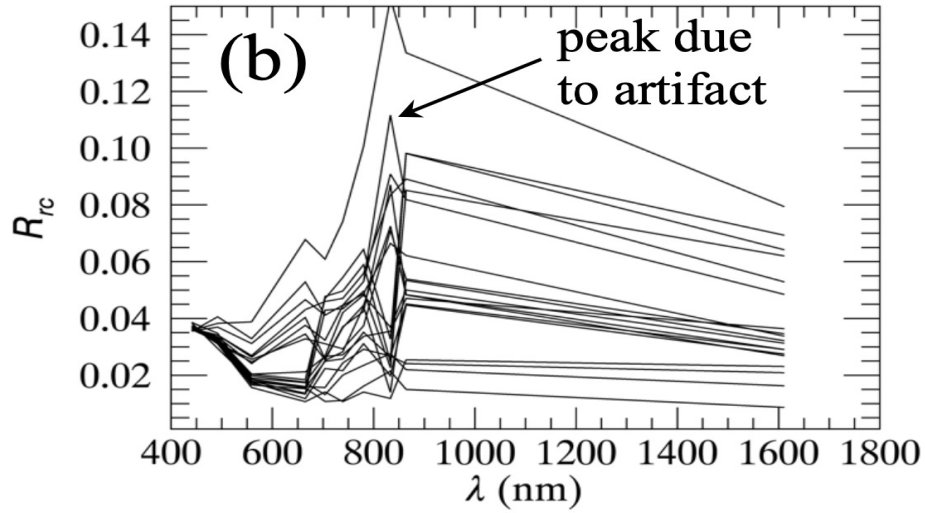
Lee et al. (2014)

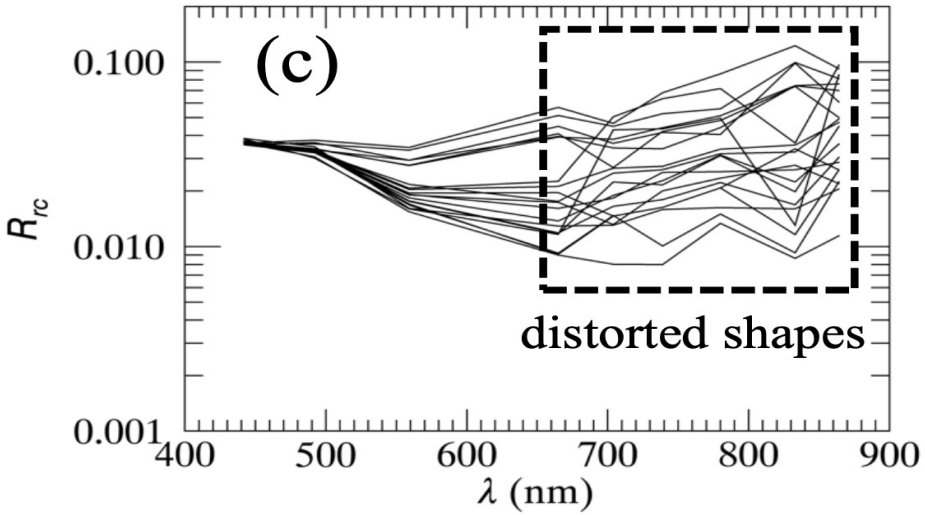
III. What's possible?

Spectral similarity – why is it so tricky?

MSI demonsration: image features off Italy







III. What's possible?

Spectral similarity – solutions

1. Mixed pixels

Original: $$R_T = \chi R_{\mathrm{D}} + (1 - \chi)\, R_{\mathrm{W}} \qquad (1)$$

Solution: $$\Delta R = R_T - R_w = \chi(R_{\mathrm{D}} - R_{\mathrm{W}}) \qquad (2)$$

$$\approx \chi\, R_{\mathrm{D}}$$

2. Mixed band resolutions

3. Band-to-band registration errors

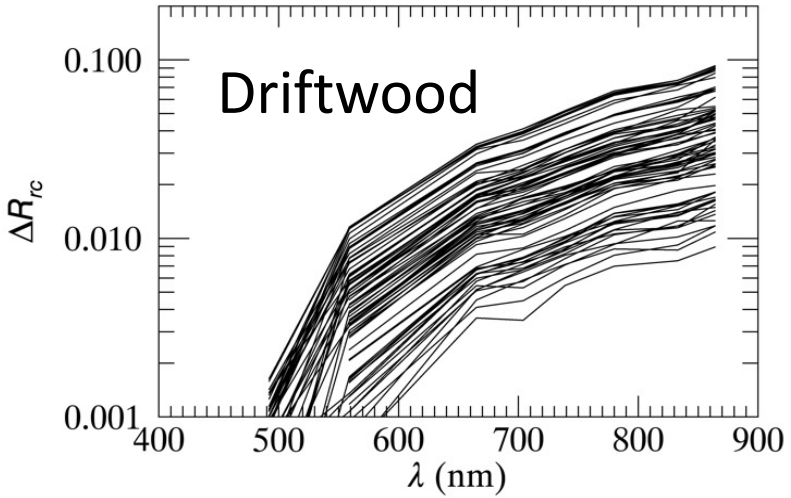
} 5 x 5 pixel averaging

III. What's possible?

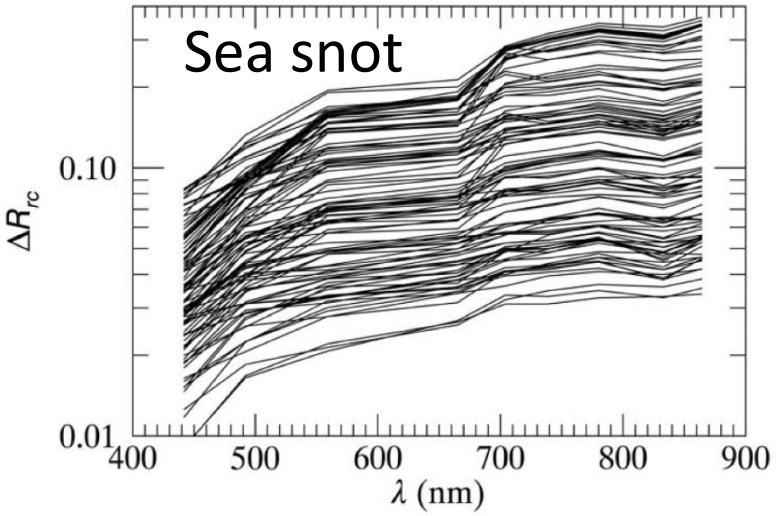
Spectral similarity – solutions

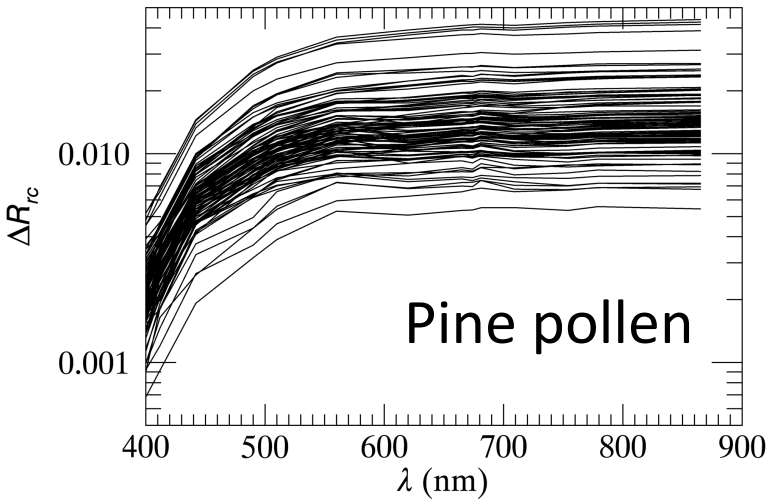
MSI demonsration: image features off Italy

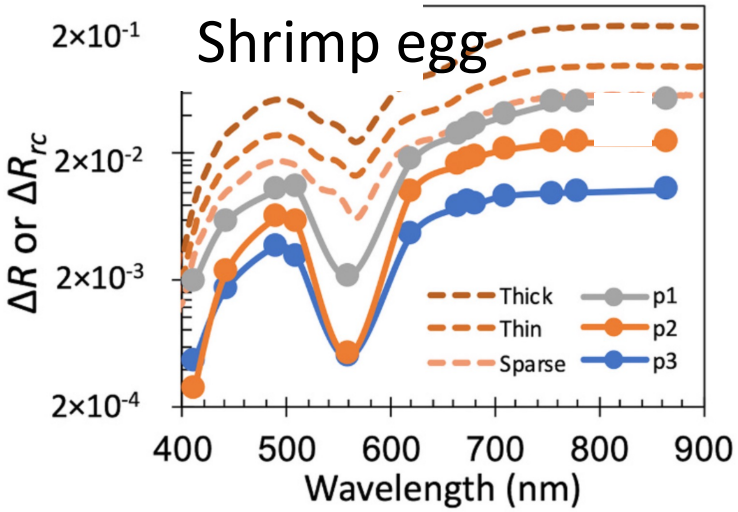
ΔR retains spectral shape
5x5 removes cross-band mismatch



Same method applied elsewhere:

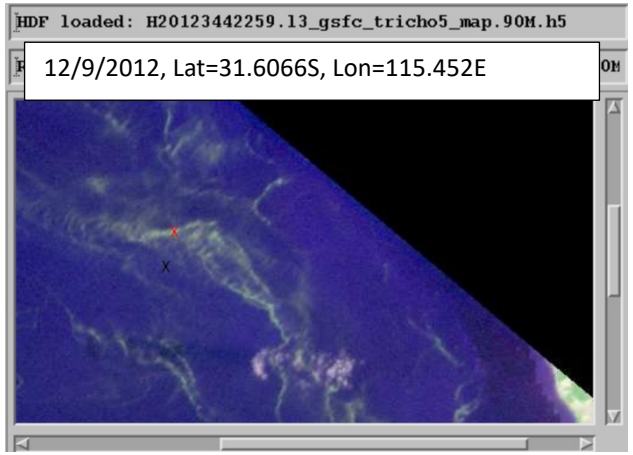


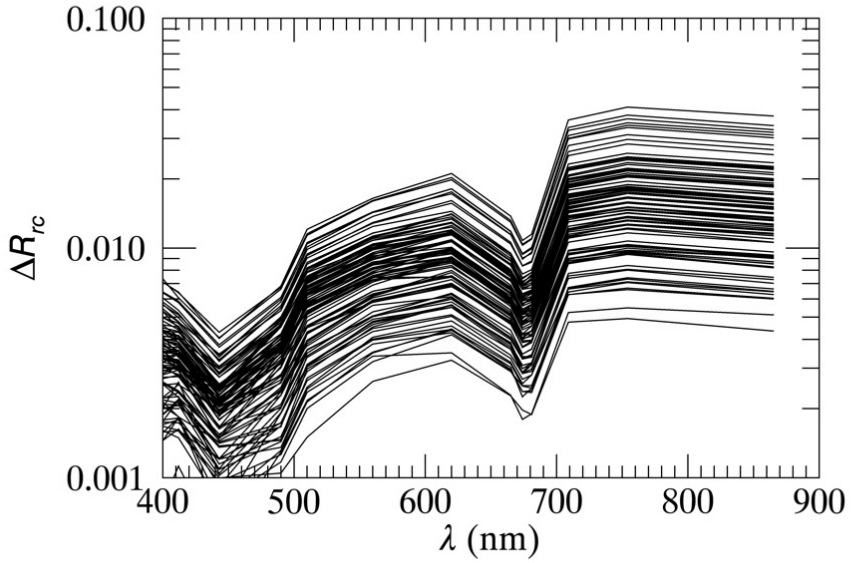




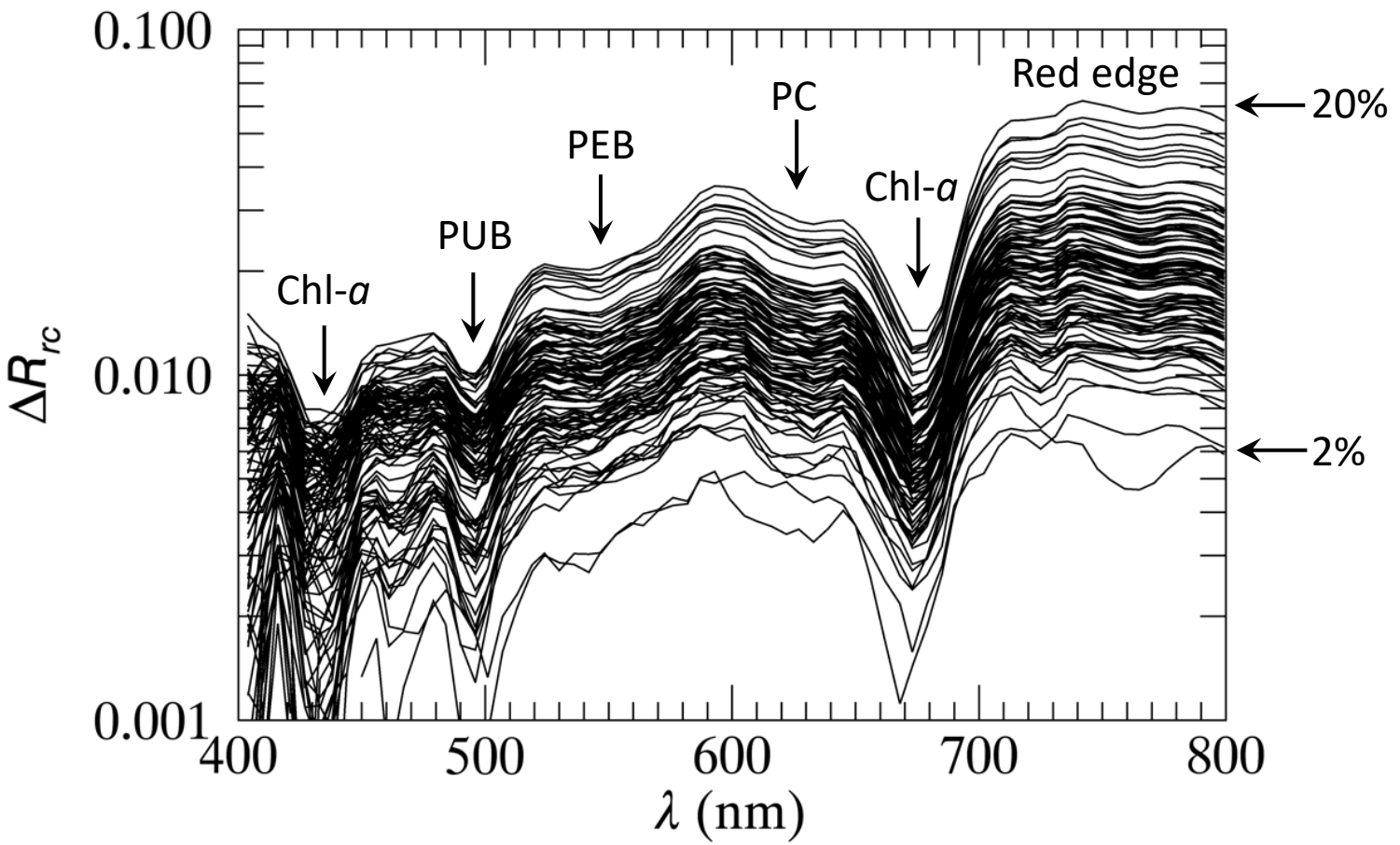
III. What's possible?

Spectral similarity – solutions





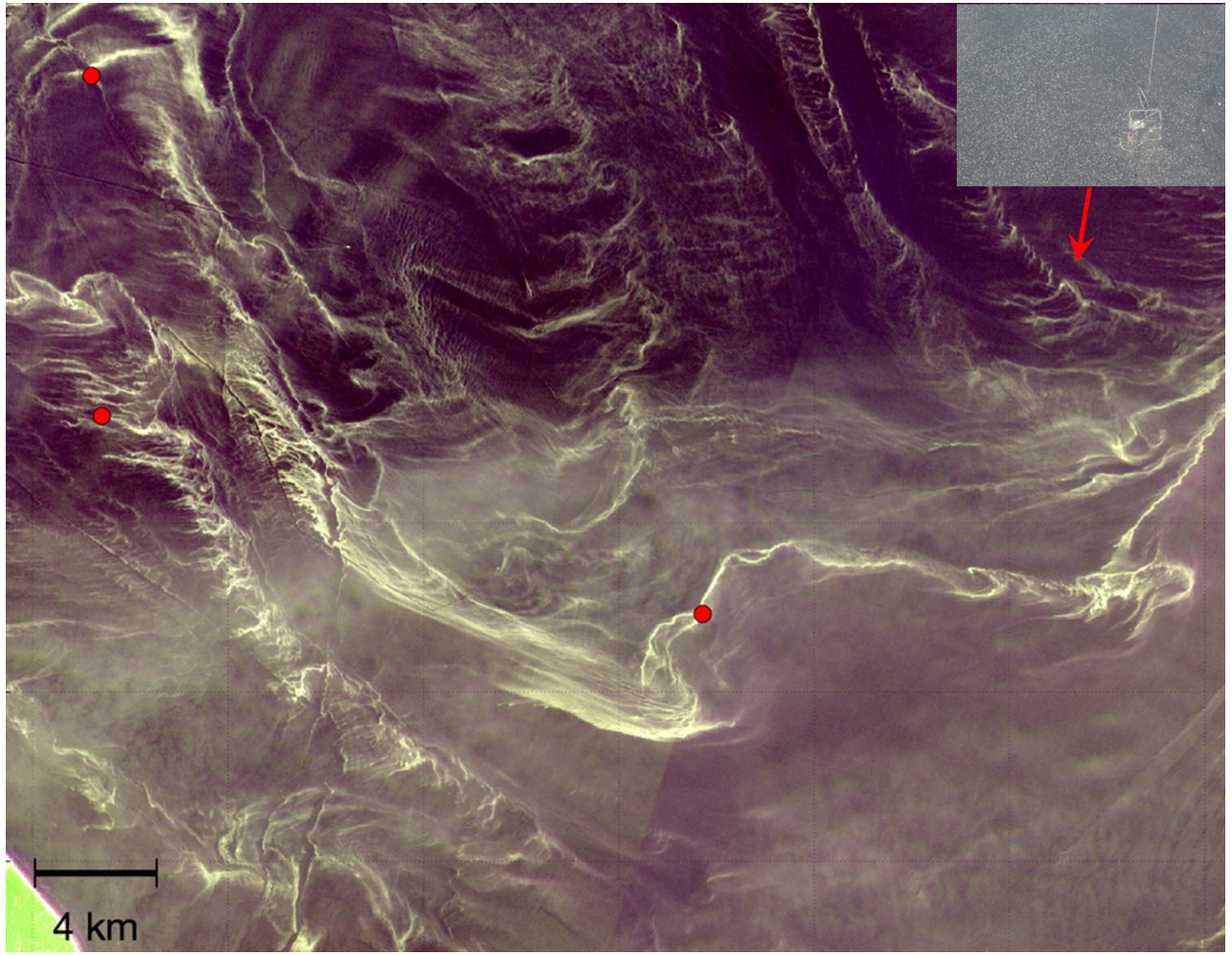
Trichodesmium



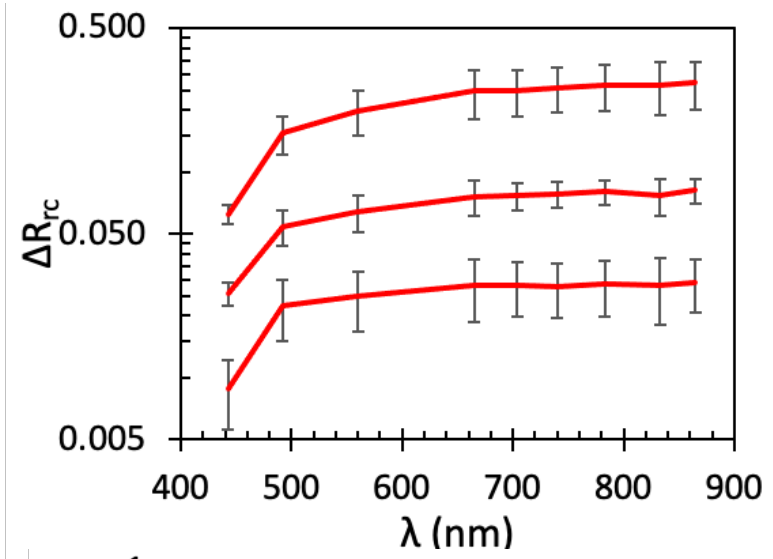
Qi et al. (2023, GRL)

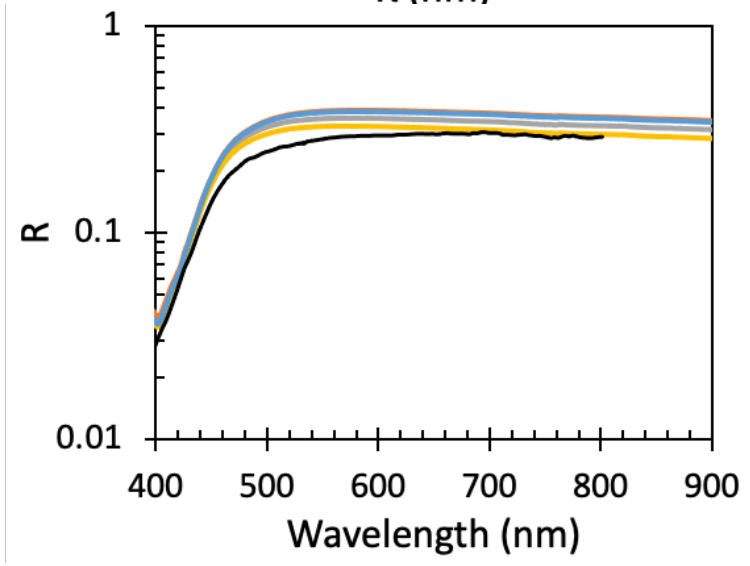
III. What's possible?

Spectral similarity – applications: pollen in the Baltic Sea



Hu et al. (2023, GRL)

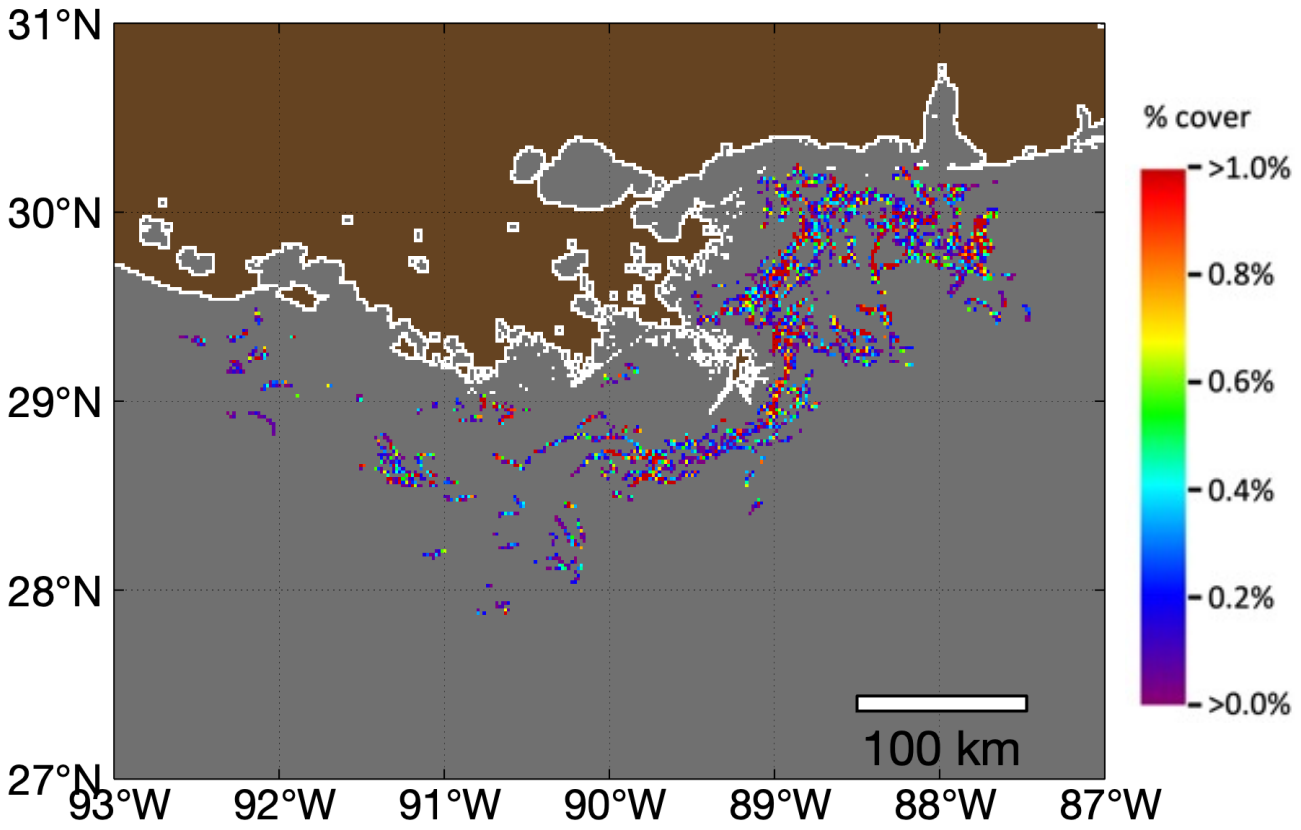


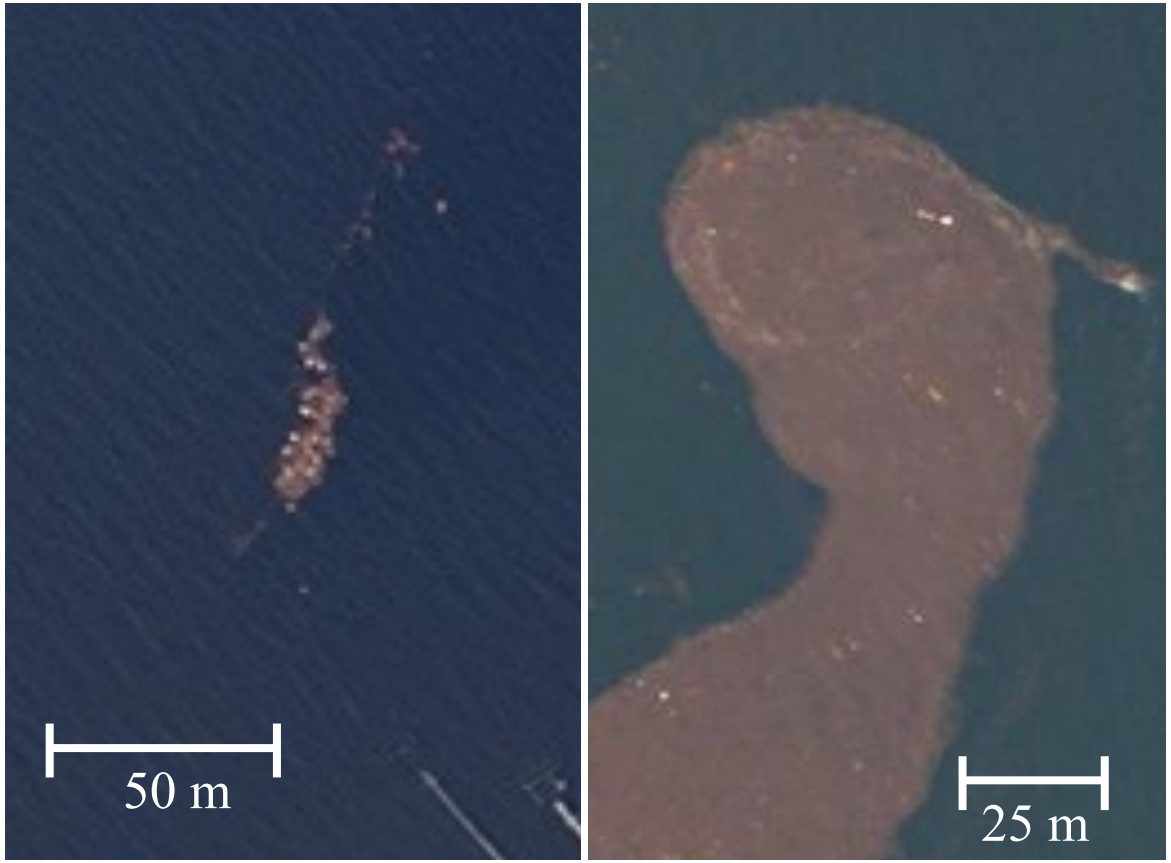


III. What's possible?

Spectral similarity – applications: debris after Hurricane Katrina

Mississippi River delta: mostly driftwood and dead plants, possibly small amount of plastics

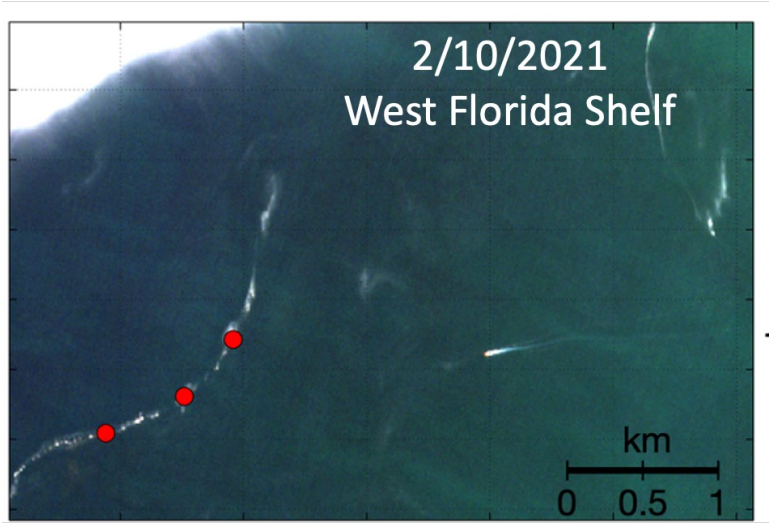


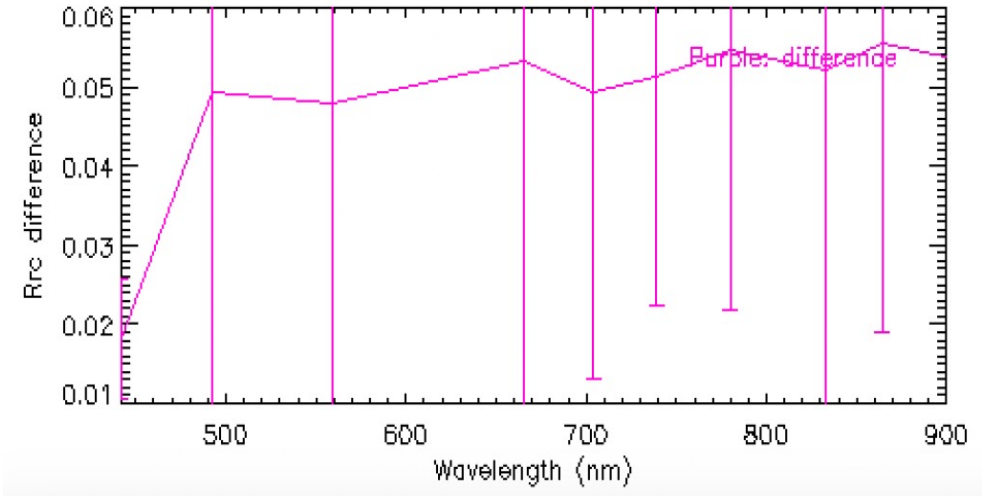


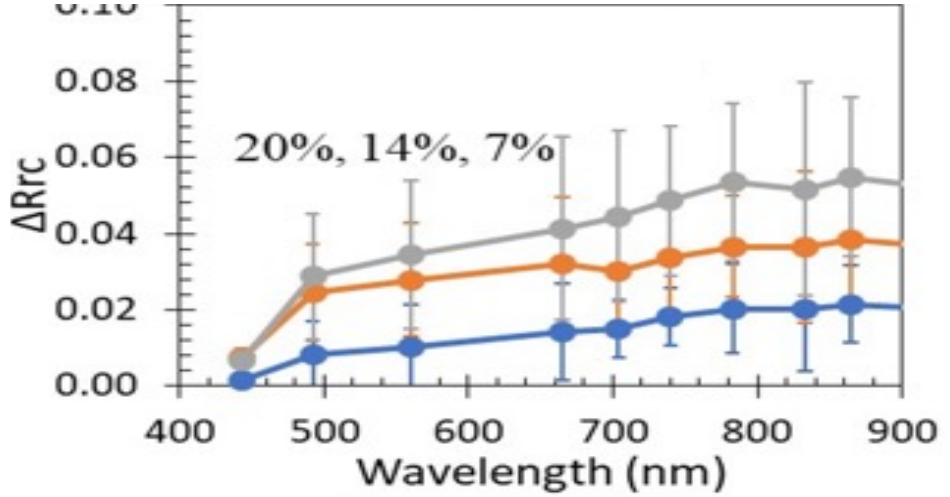
Hu et al. (2023, EST)

III. What's the logic?

Other possibilities are ruled out – these may be called "suspect debris."
It may be a little bit stretch to call them "suspect plastics"



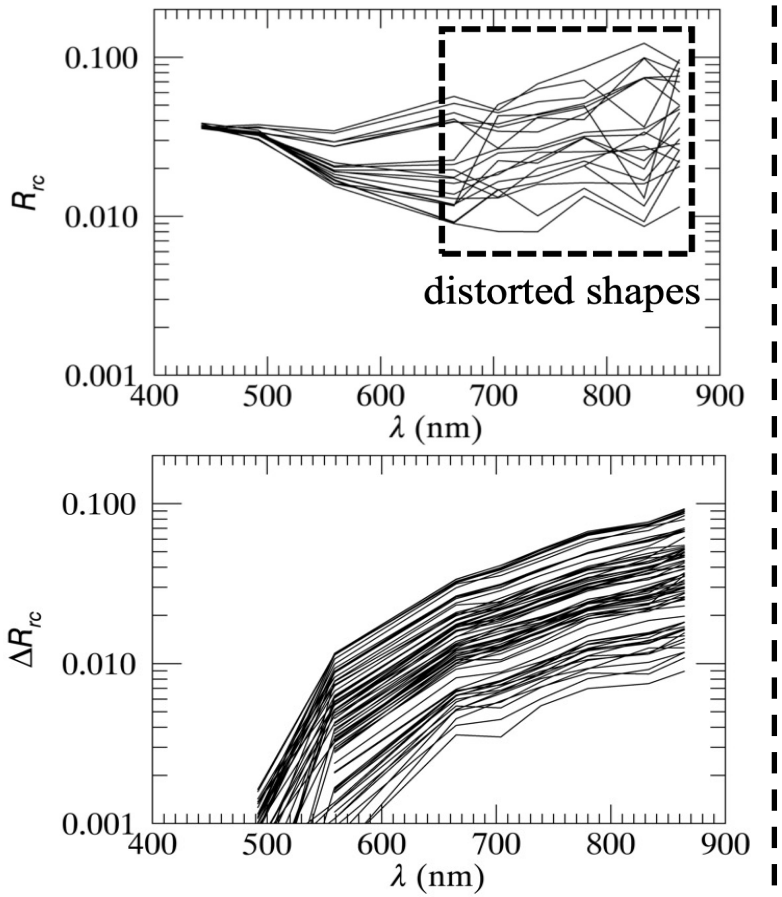




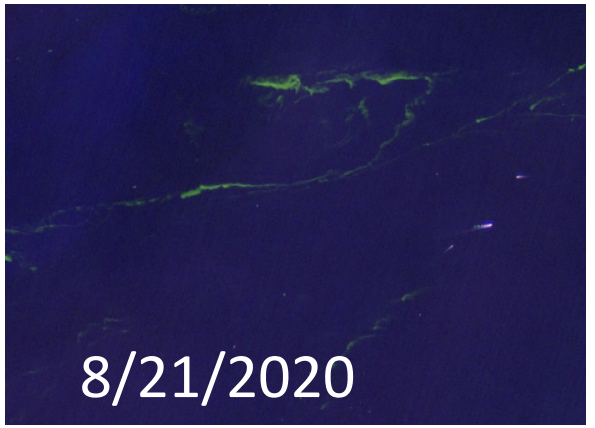
III. What's the logic?

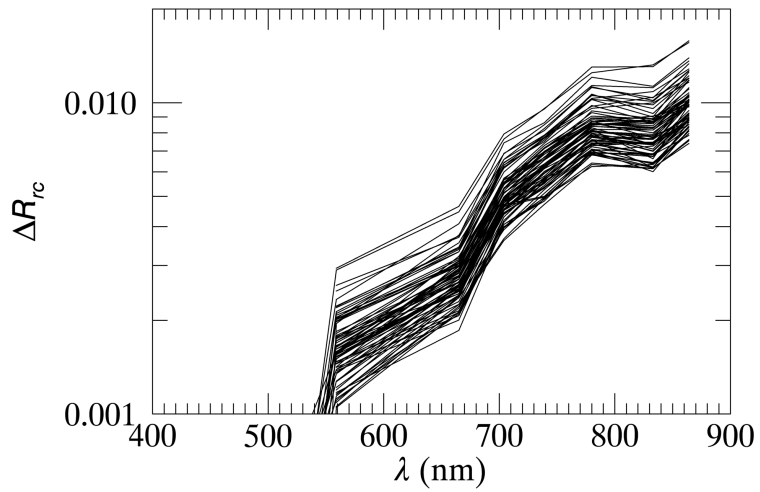
The derived spectra must resemble at least one of the known endmembers

Among all possibilities, it's not "either A or plastics"

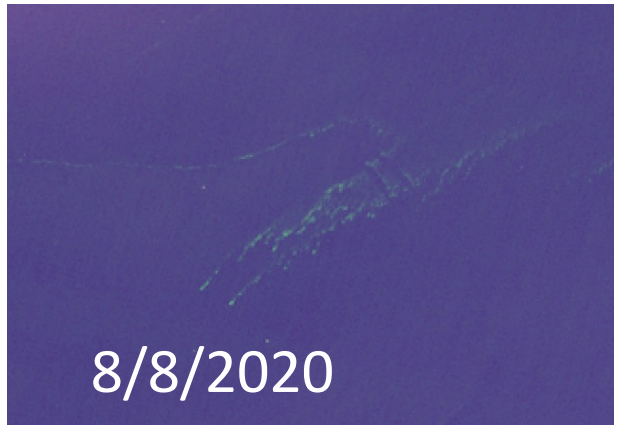


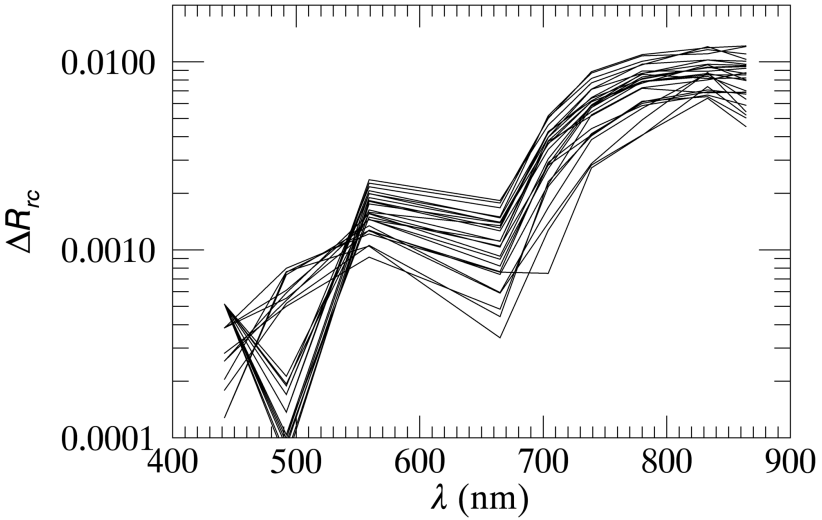
N Adriatic Sea, mucilage





N Adriatic Sea, vegetation





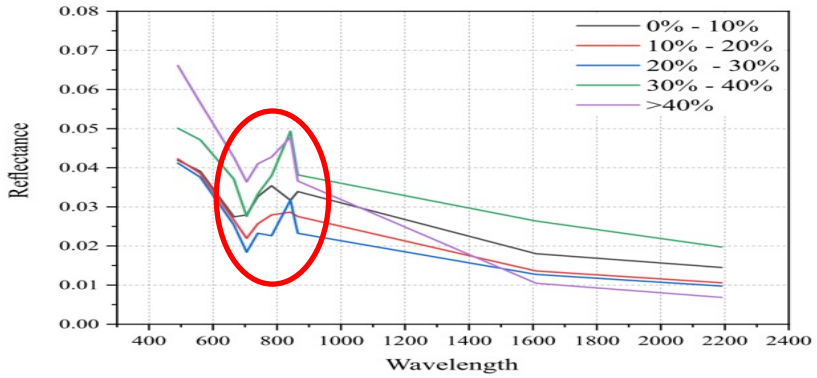
Summary – what' the logic?

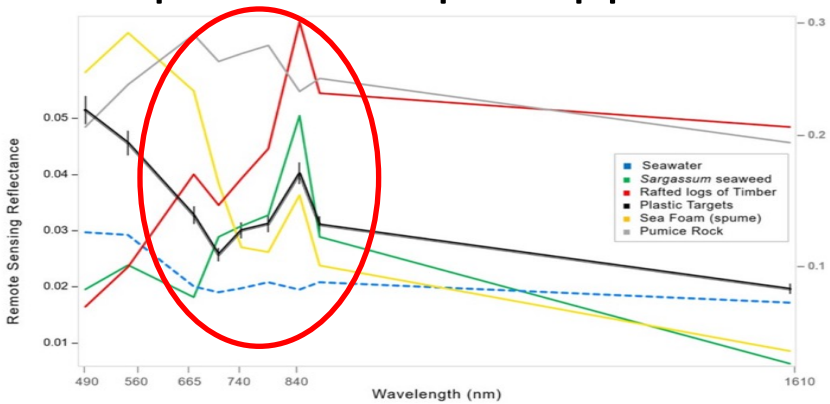
- **Not every bright pixel is debris, and not every debris pixel is plastics**
- Detecting "something" is relatively easy
- Unless other possibilities can be ruled out, we should not call that "something" plastics (a.k.a. **Ocaam's Razor principle**)
- We should not call that "something" "suspect plastics" either, unless such a possibility overwhelms others (e.g., data artifacts, foams, etc)
- Most often, we do not have an "either or" case (e.g., in an environment rich in vegetation, ruling out vegetation does not infer plastics)
- What's possible? Narrow down floating matter type by applying spectral differencing and spectral mixing
- Such logic is also applicable to other techniques (e.g., SAR)
- The real challenge: plastics and some other debris can be similar

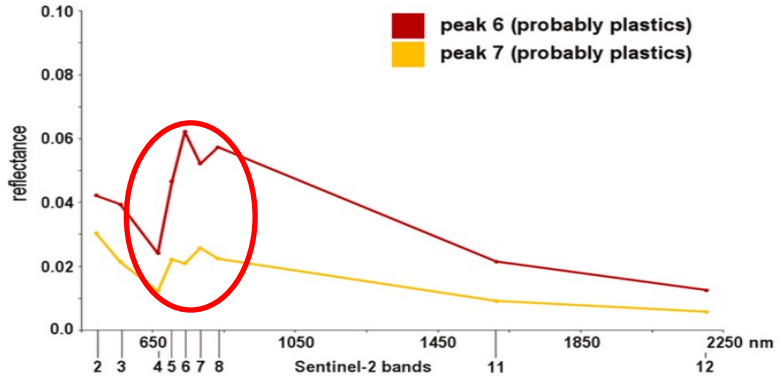
Backup slides

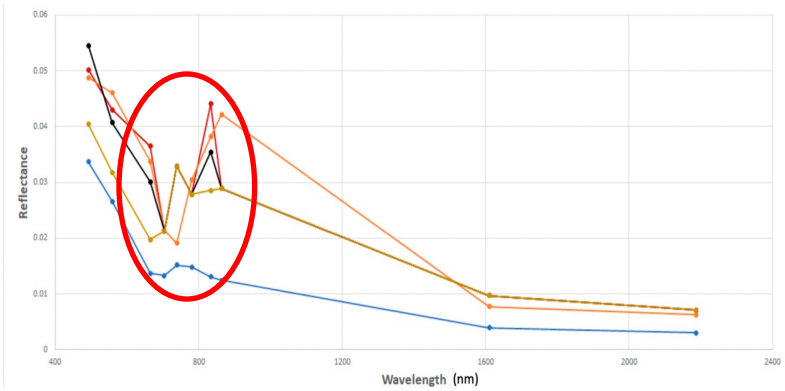
Spectral distortion examples

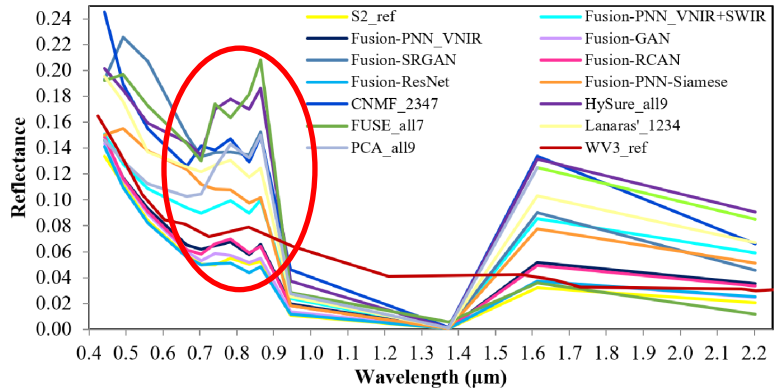
Spectral endmembers based on MSI pixels – spectral shapes appear distorted

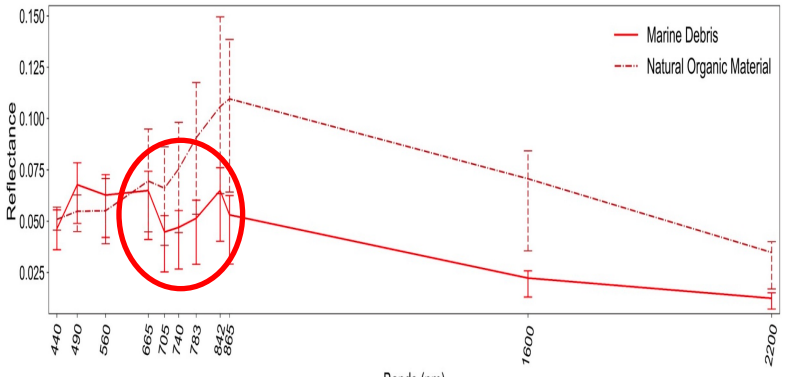






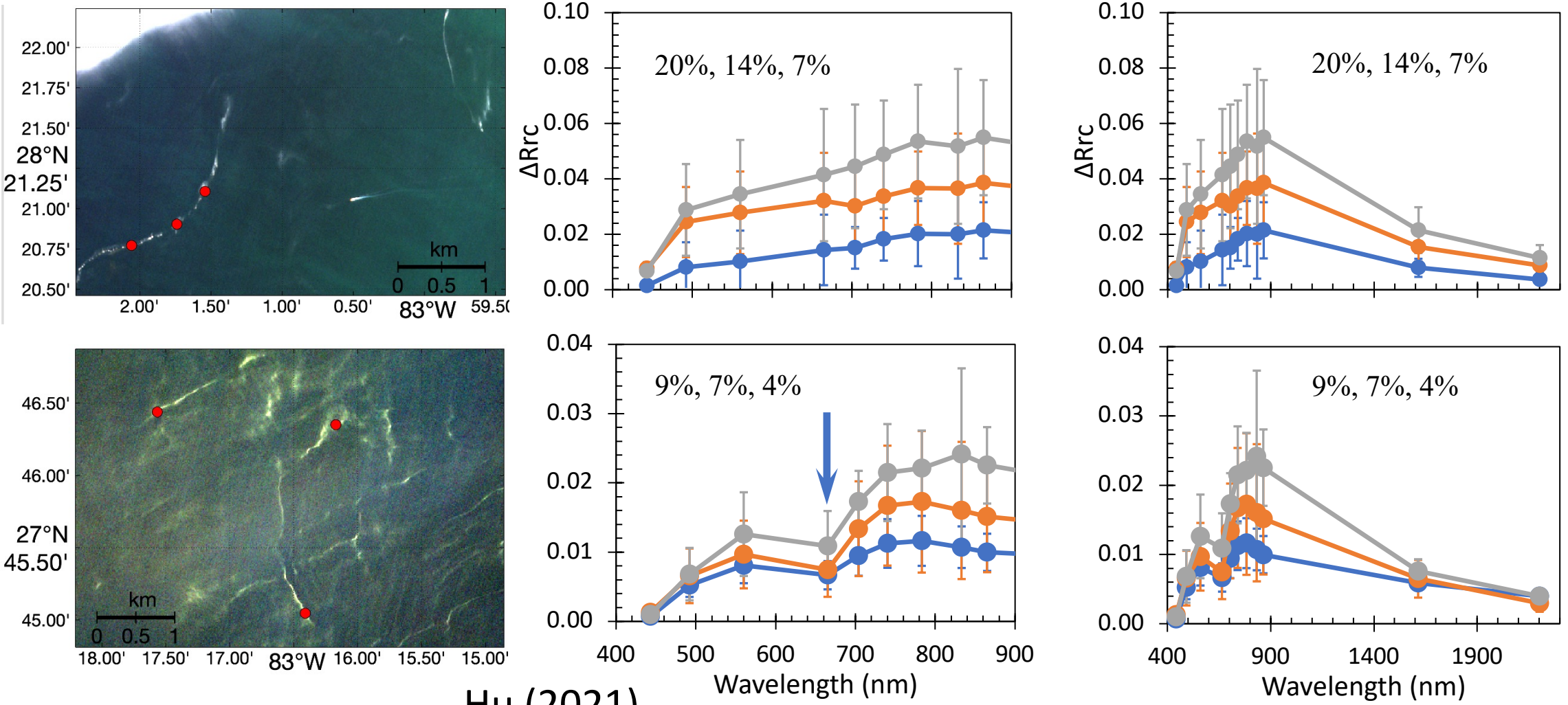






Can SWIR bands help?

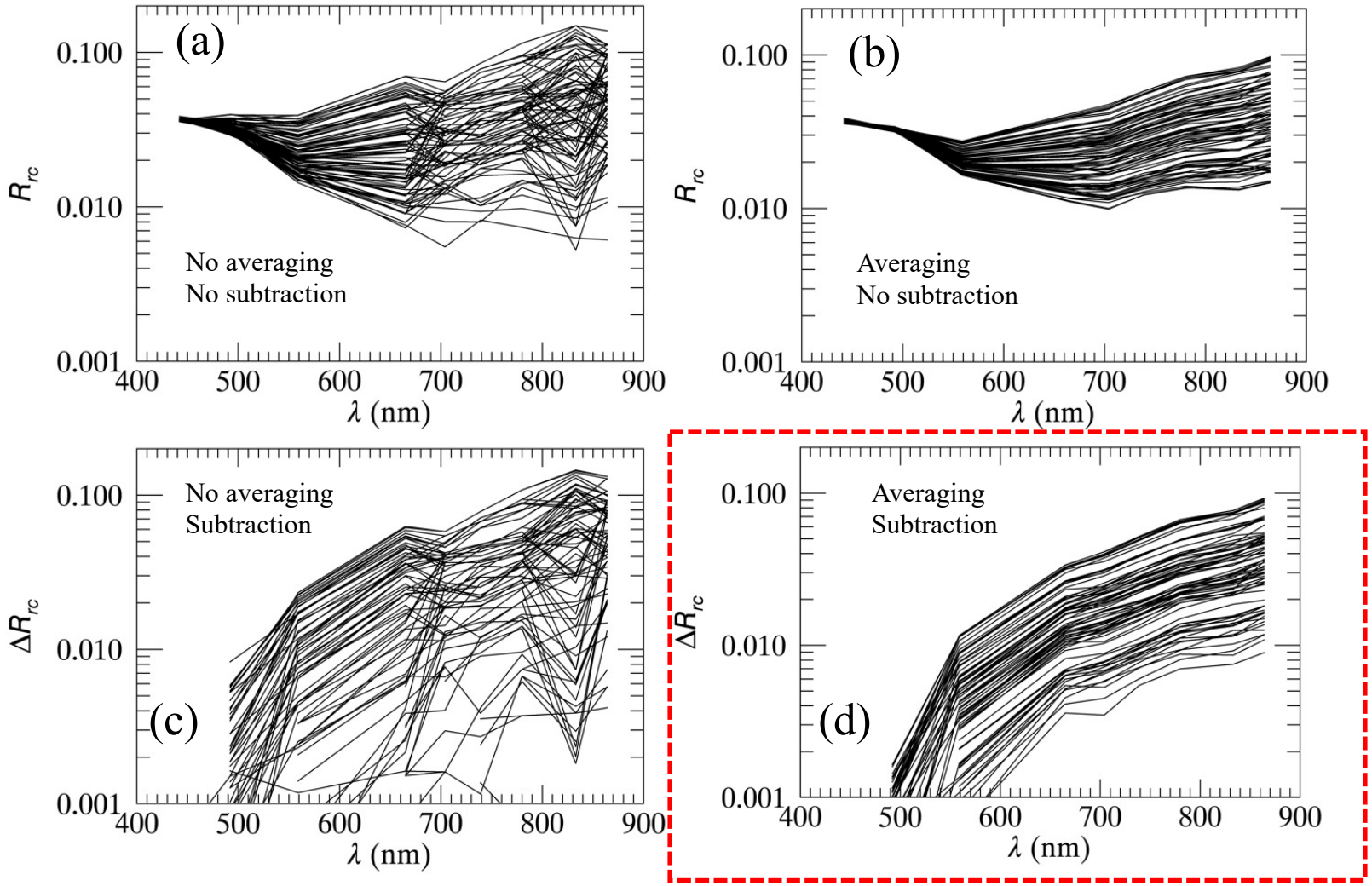
SWIR bands do not add much information



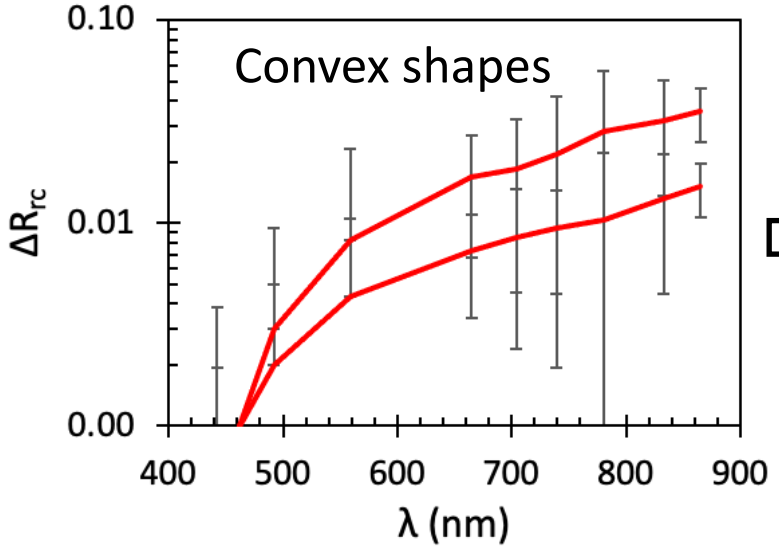
Hu (2021)

Solutions to remove spectral distortions

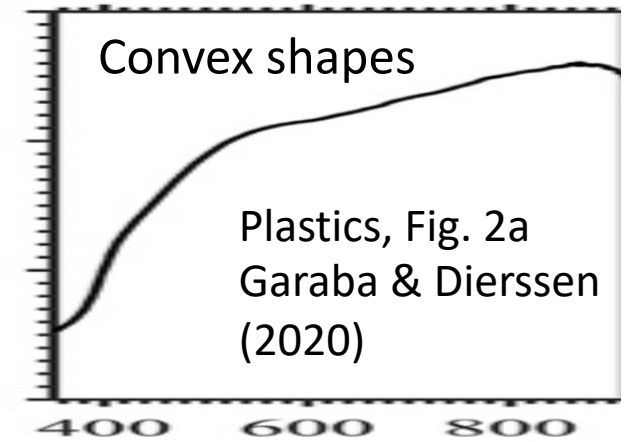
Floating matter features off Italy (Sannigrahi et al., 2022)

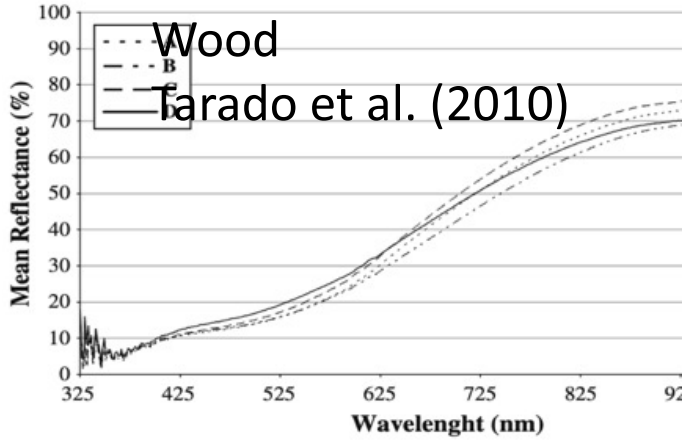


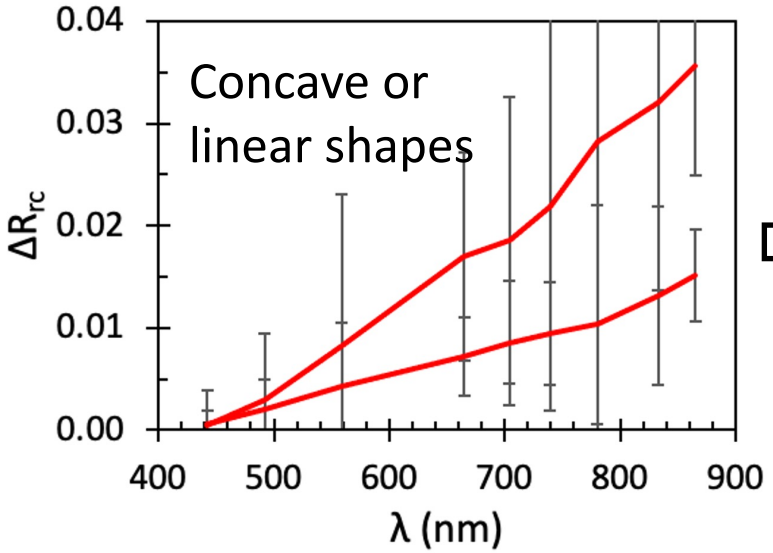
Driftwood spectra



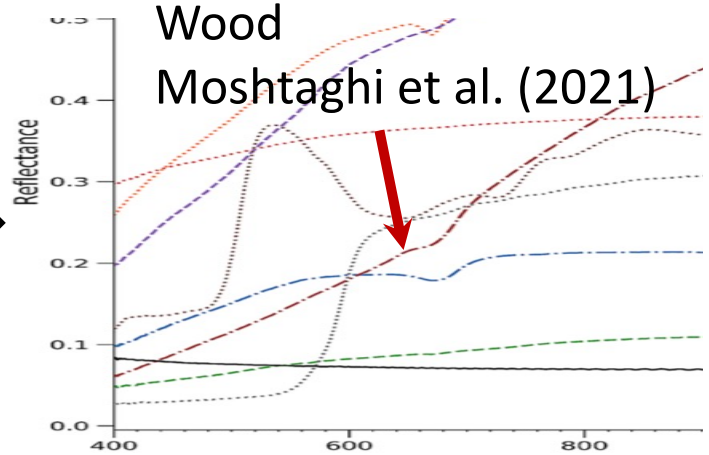
Plastics?

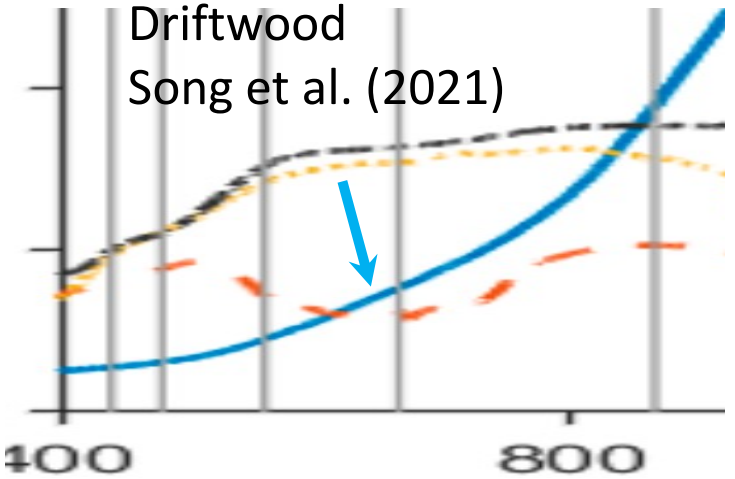






Wood?

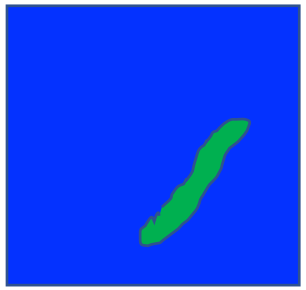




The beauty of spectral differencing

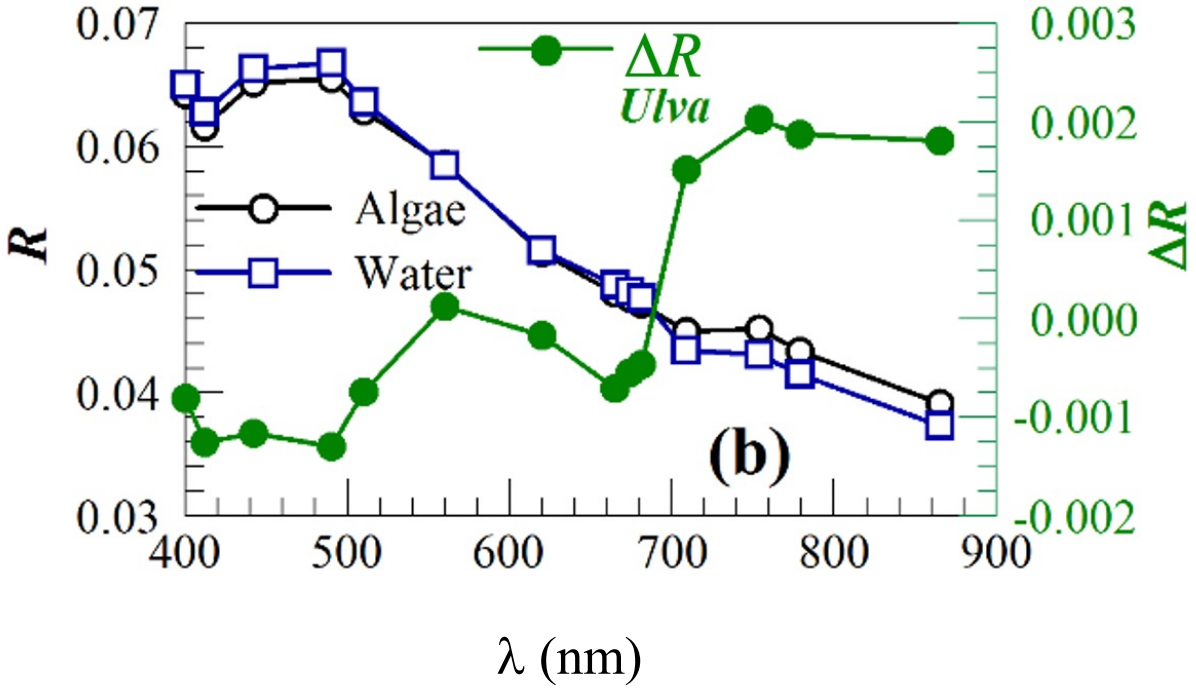
1. Spectral differencing (Gower et al., 2006)

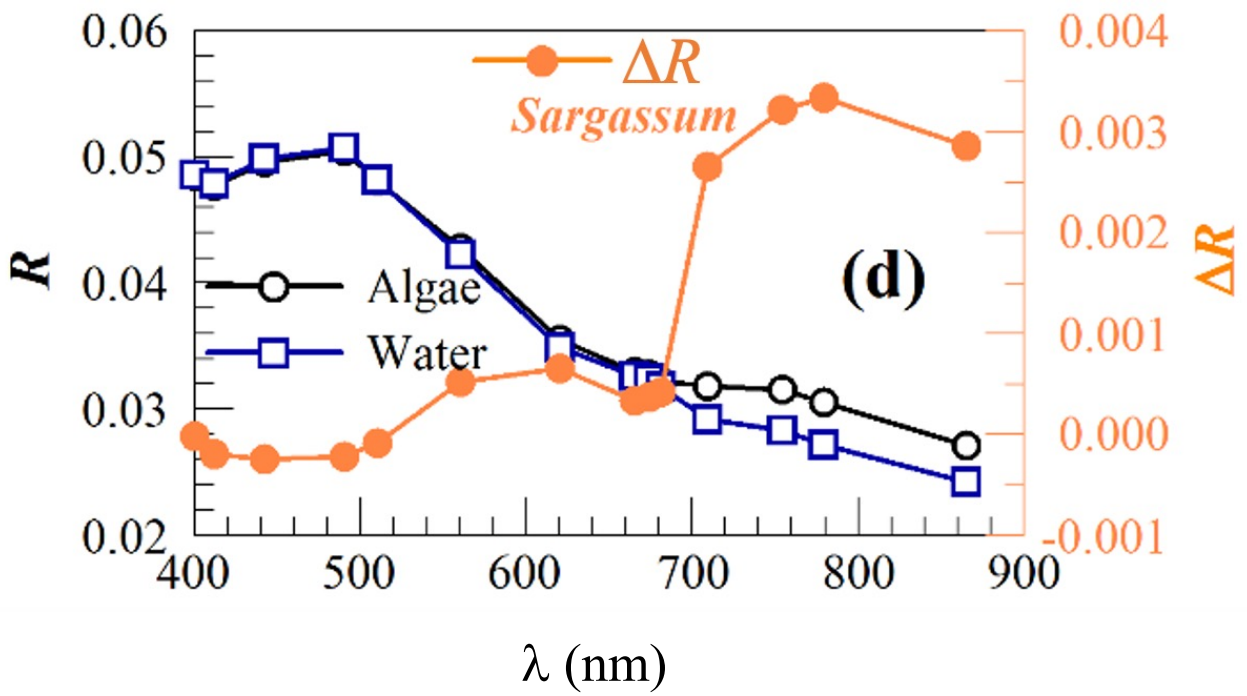
Target pixel



$$R_{target} = \chi R_{FM} + (1- \chi) R_W$$

$$\Delta R = R_{target} - R_w = \chi(R_{FM} - R_W)$$





OLCI spectra, Qi and Hu (2021)