Converging towards an optical marine litter satellite mission

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Beyond MARLISE

vito remote sensing

Remote Sensing of Marine Litter Workshop 2023

16 - 17 October 2023 | ESA-ESTEC | Netherlands

MARLISE

Marine Litter satellite mission conceptual design study

as presented at:

living planet symposium BONN 23–27 May 2022

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Define use cases:

a) With high impact

Stakeholders

a) Feasible
b) Complementary to existing capabilities

Scientific Community

Windrows = submeso scale accumulations

- aggregations of floating litter, seafoam, seaweeds, plankton
- a few m to several km long, and up to 100 m wide

Use Cases

- policy support
- understanding mass balance
- cleanup

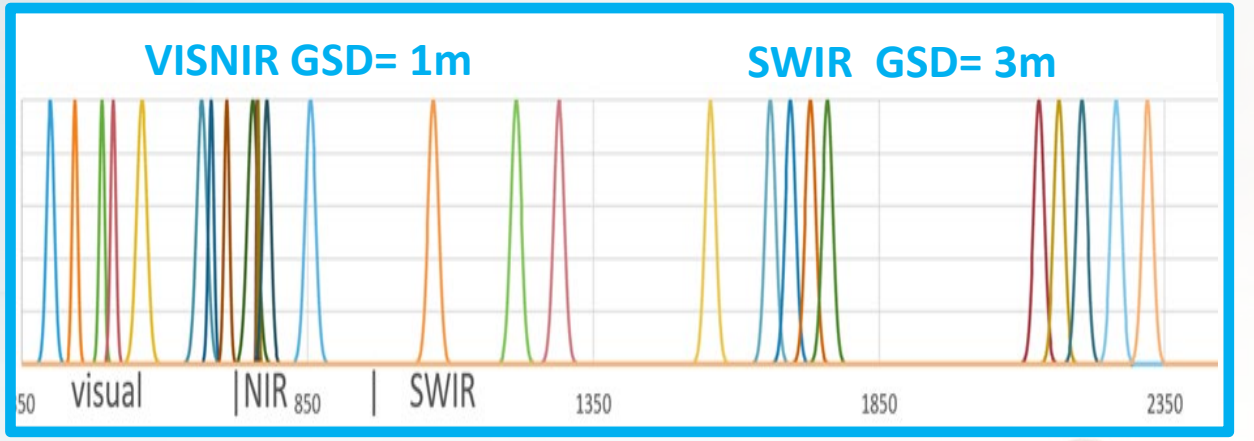
Beaches :

- most visible marine litter
- high fraction is plastics

Landfills :

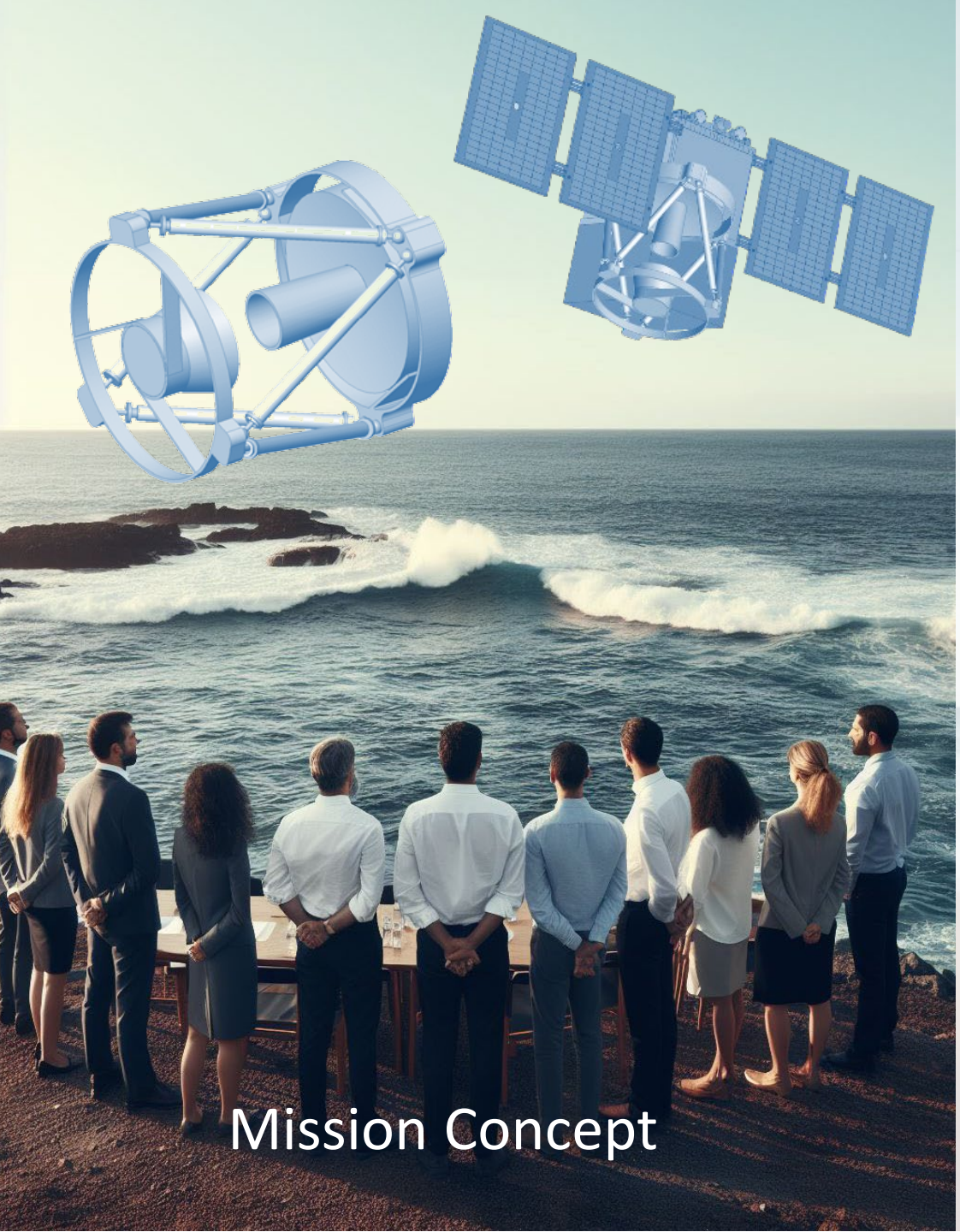
- high concentration of litter (plastics and other)
- direct + indirect (marine) pollution risks

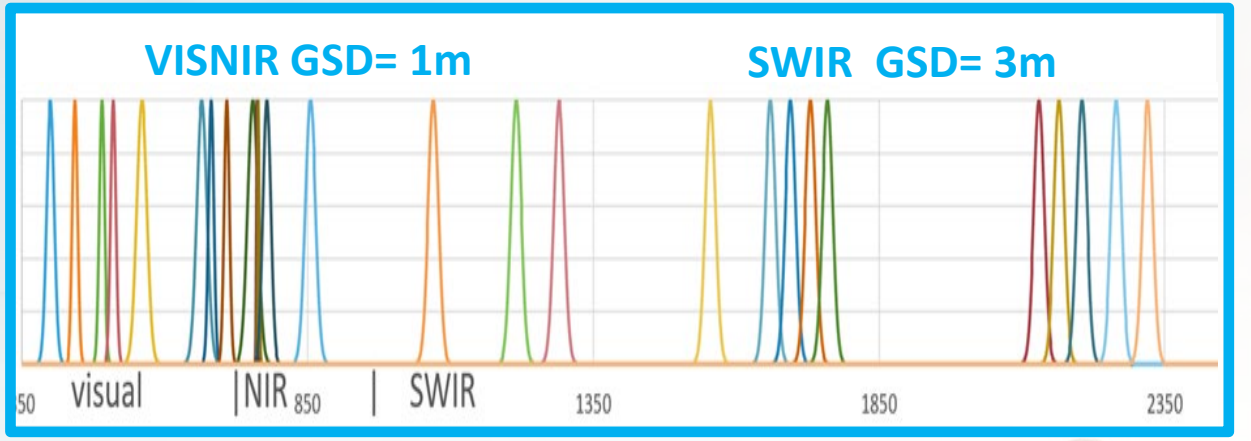
Use Cases



Requirements

characteristics		consolidated	unit
Spatial resolution	GSD	**1-3m**	m
Coverage	Swath	**10**	km
Spectral	range	**400-2400**	nm
Spectral	bands	**20-26 bands identified**	
Spectral resolution	FWHM	**2.5-20**	nm
Radiometric resolution	average SNR	**High (200)**	
Temporal		**monthly/seasonal**	





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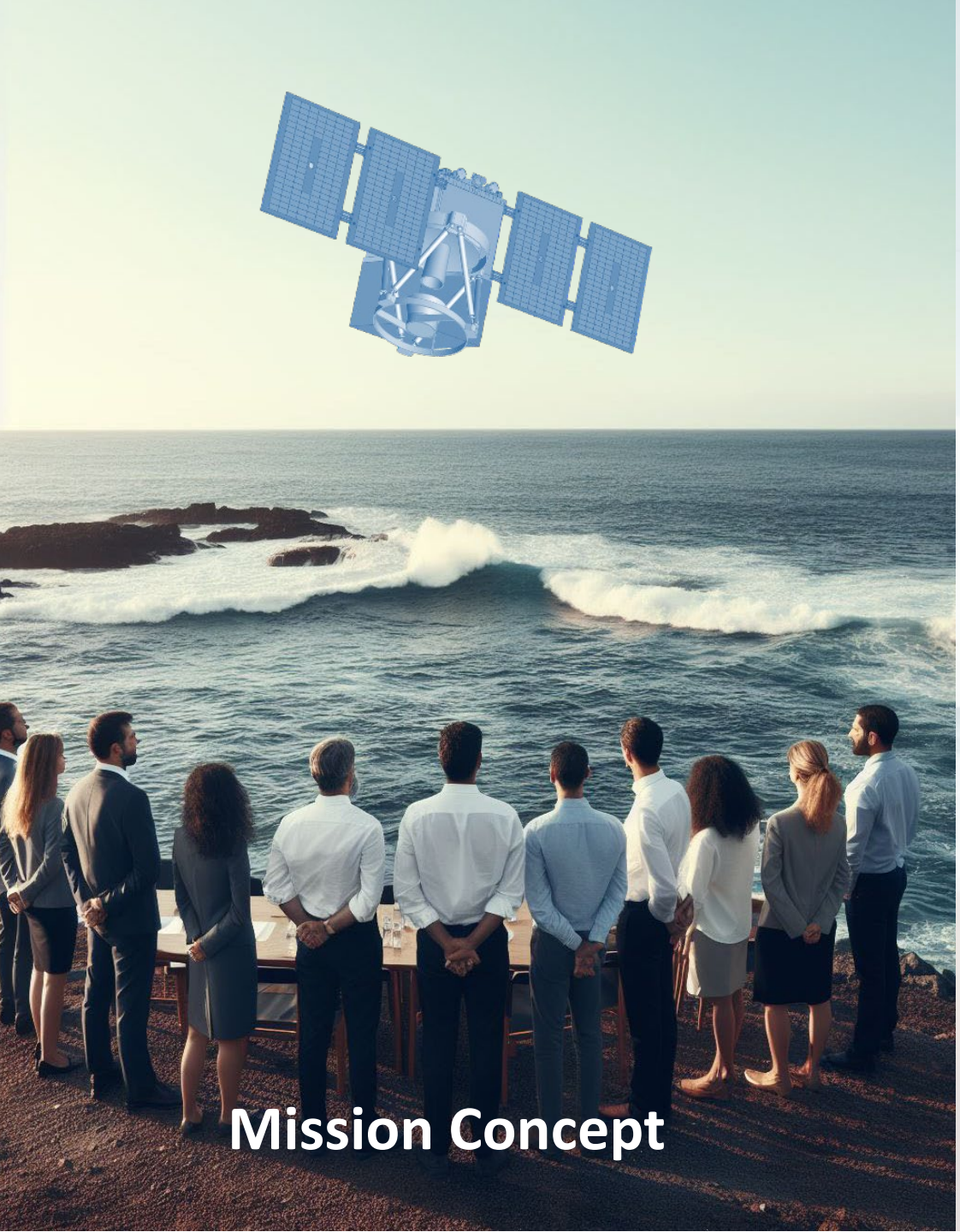
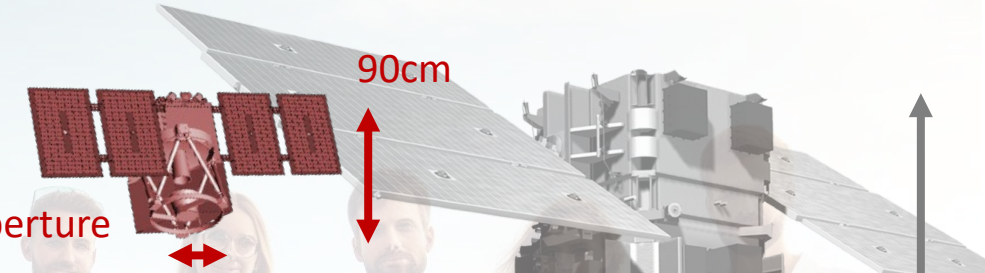
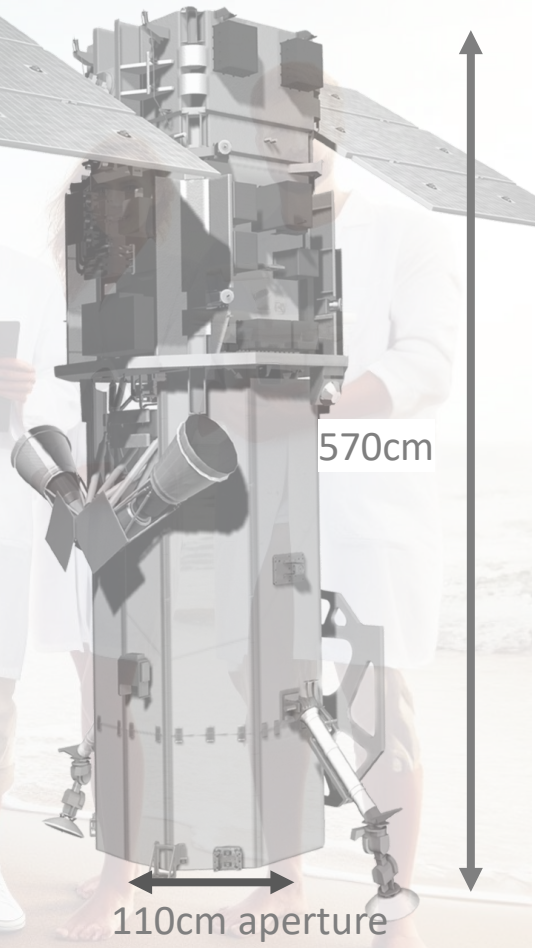


Smallsat with Worldview-3 capability

realistic in a reasonable time and budget





	MARLISE	Worldview-3	unit
detector	**Frame**	Pushbroom	
SNR boost	**pitch slowdown + digital TDI**	TDI	
GSD PAN	**omitted**	0.3	m
GSD VNIR	**0.96**	1.24	m
GSD SWIR	**3**	3.7	m
swath	**10.8**	13.1	km
mass	**250**	2800	kg
altitude	**500**	617	km

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What's new ?

Support

living planet symposium BONN 23–27 May 2022

Obstacles

Knowledge gaps

New insights

Refinements to be made

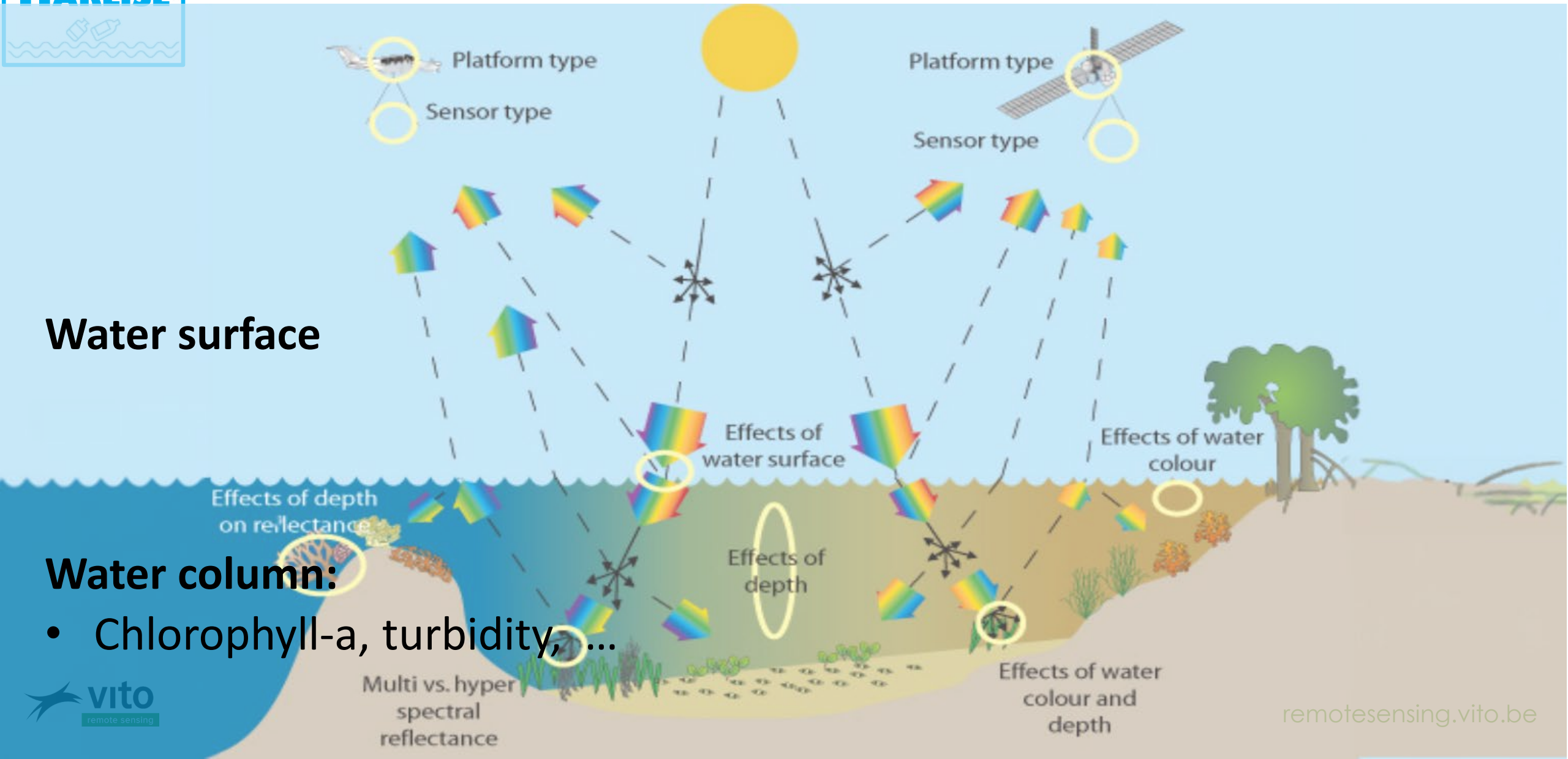
nature reviews earth & environment

The need for a dedicated marine plastic litter satellite mission

Victor Martinez-Vicente

Monitoring marine plastic pollution requires repeated, long-term, global and harmonised observations of plastic presence, quantity and type, which satellites can provide. To convince space agencies to take action, coordinated activities are urgently needed to agree on target environments and to integrate in situ and satellite-derived measurements.

Water monitoring



Water surface

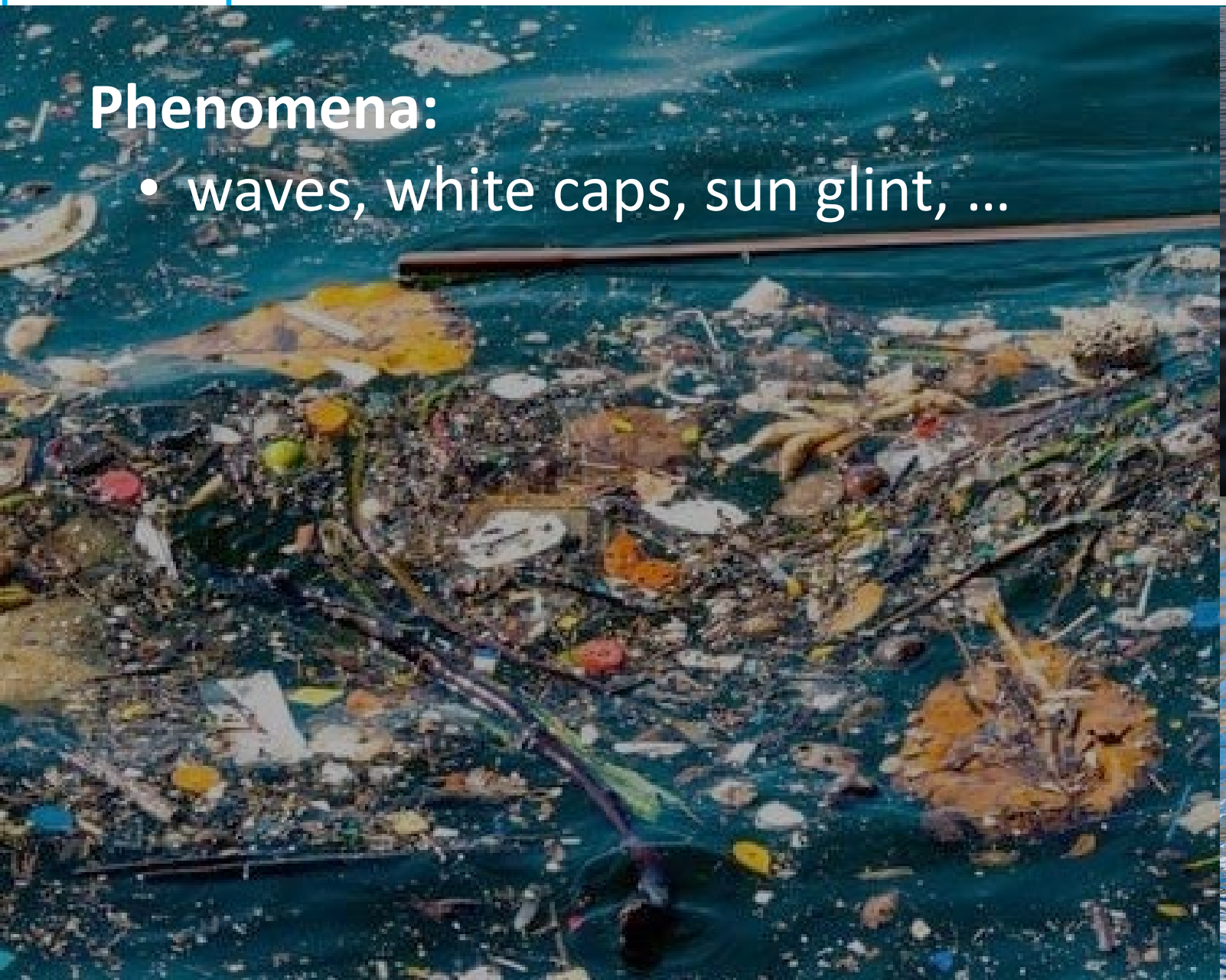
Water column:

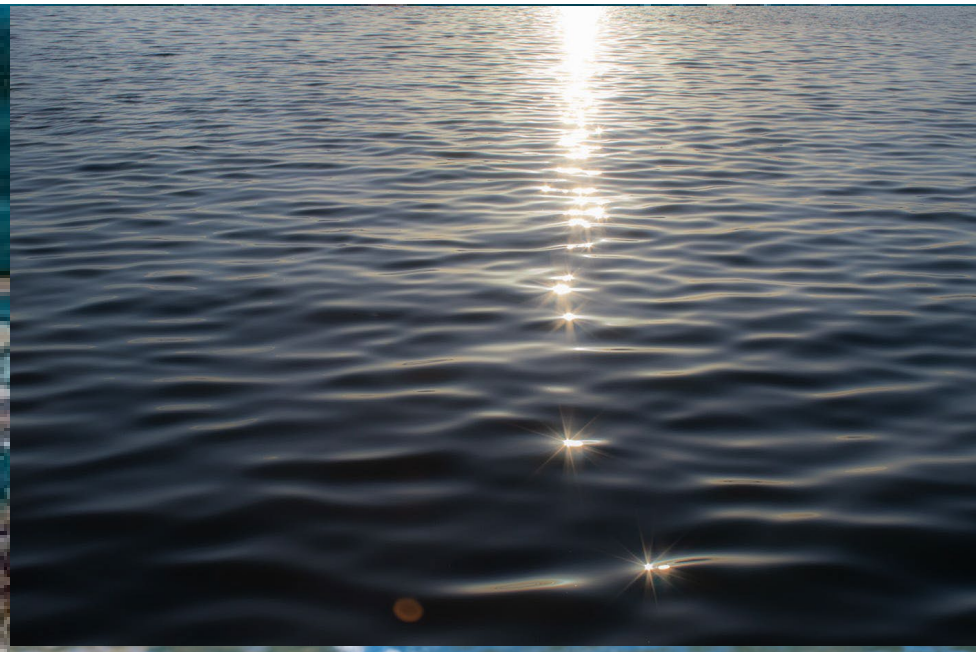
- Chlorophyll-a, turbidity, …

Water surface monitoring

Phenomena:

- waves, white caps, sun glint, …





Water surface monitoring

Phenomena:

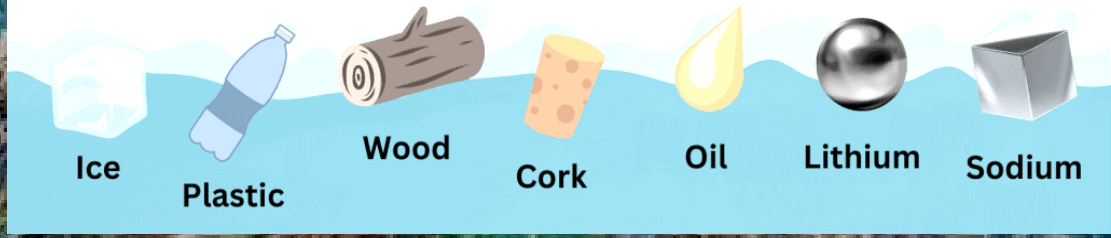
- waves, white caps, sun glint, …

Floating material:

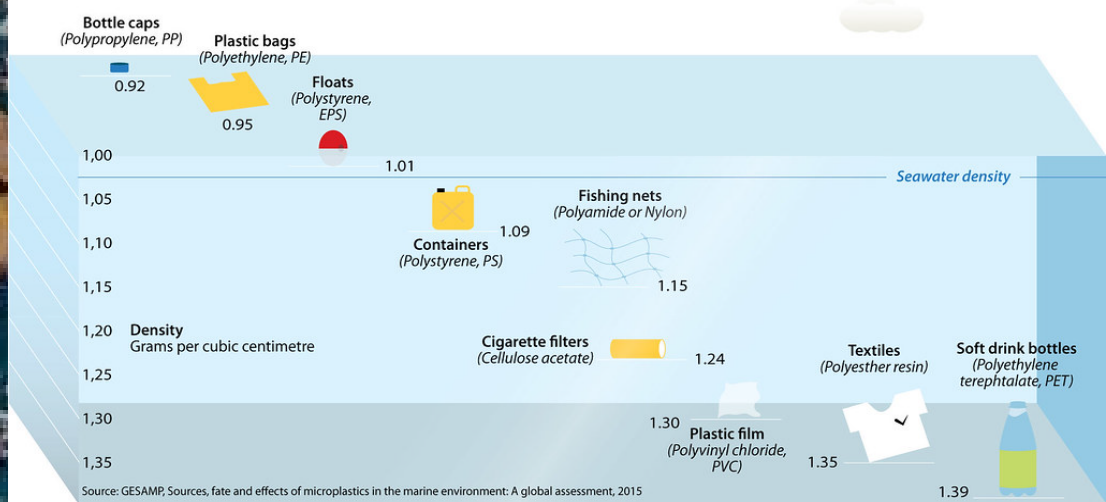
- vessels
- natural materials (algae, water plants, …)
- litter (wood, plastic, …)

it's a mess !

many other materials float



not all plastics float



Marine Plastic anomaly detection?

floating plastic has much **higher SWIR** reflectance than water

→ easy to detect

But detected anomalies can be: any surface phenomena

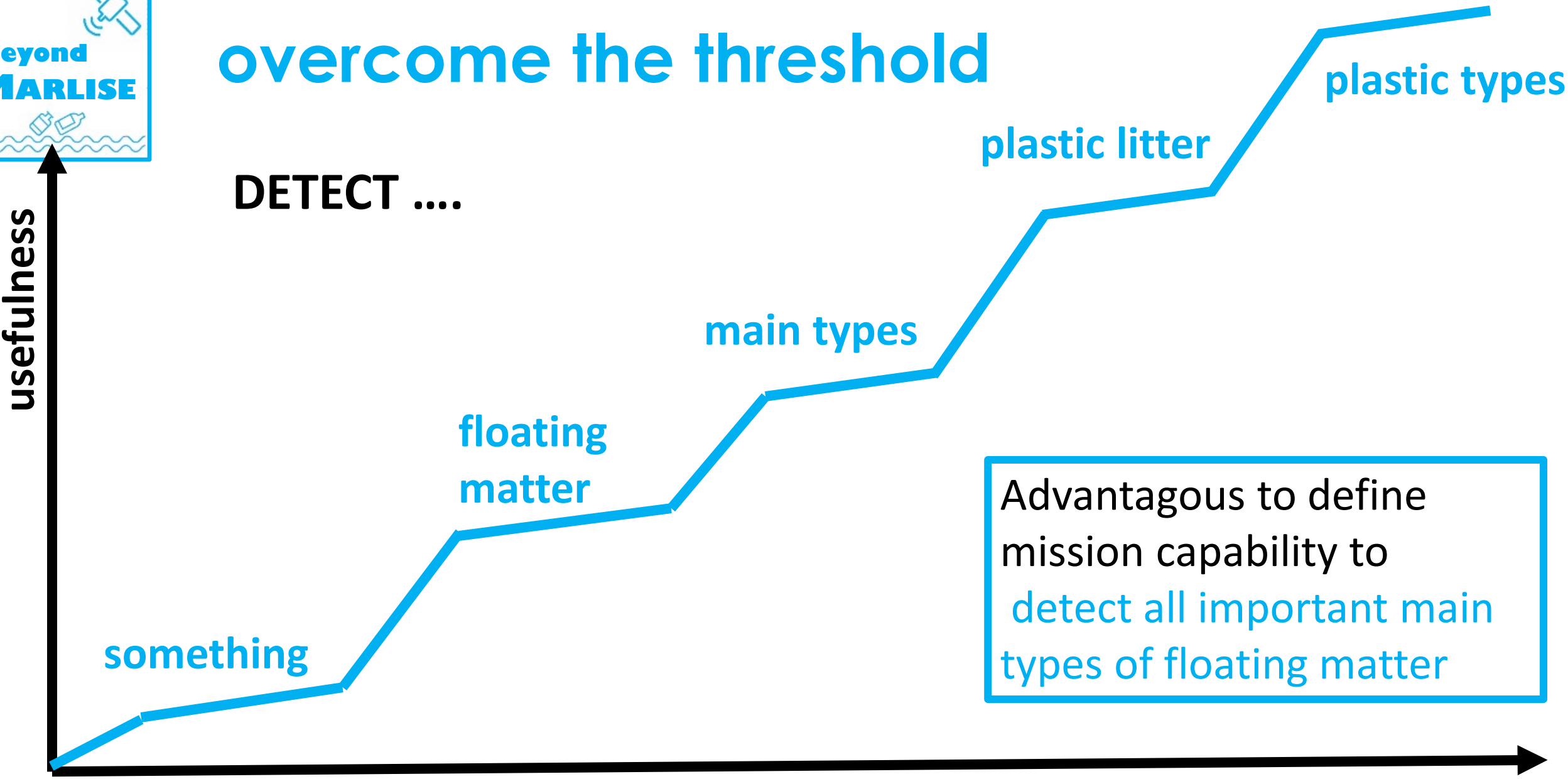
any kind of floating material

→ not very useful

→ only as early warning “this area deserves a closer look”

Beyond MARLISE

overcome the threshold



Advantagous to define mission capability to detect all important main types of floating matter

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Floating matter mission

Surface anomalies:

- Vessels, infrastructure etc…
- Glint, foam and white caps?
- Adjacency?

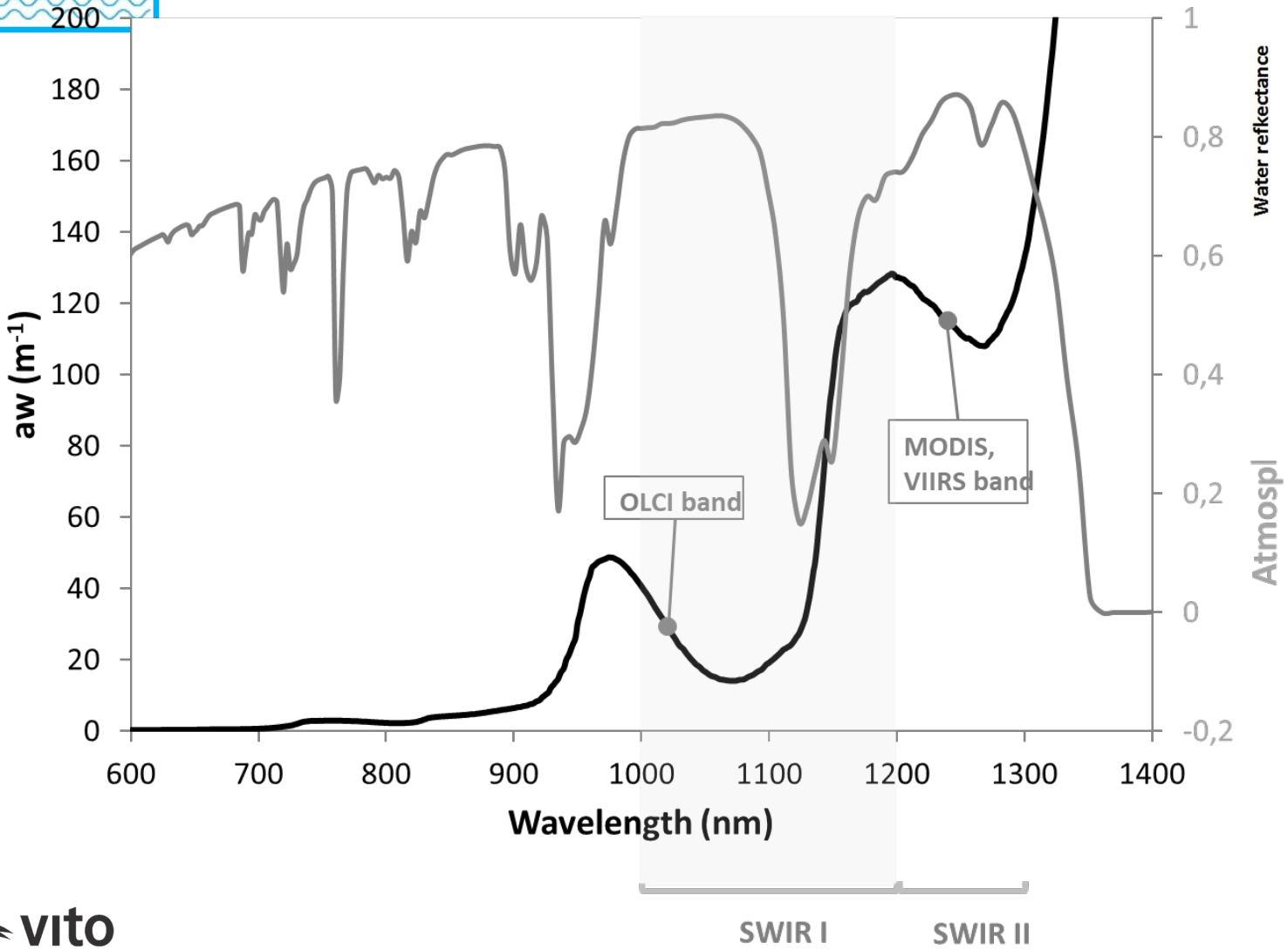
Additional stakeholders/use cases:

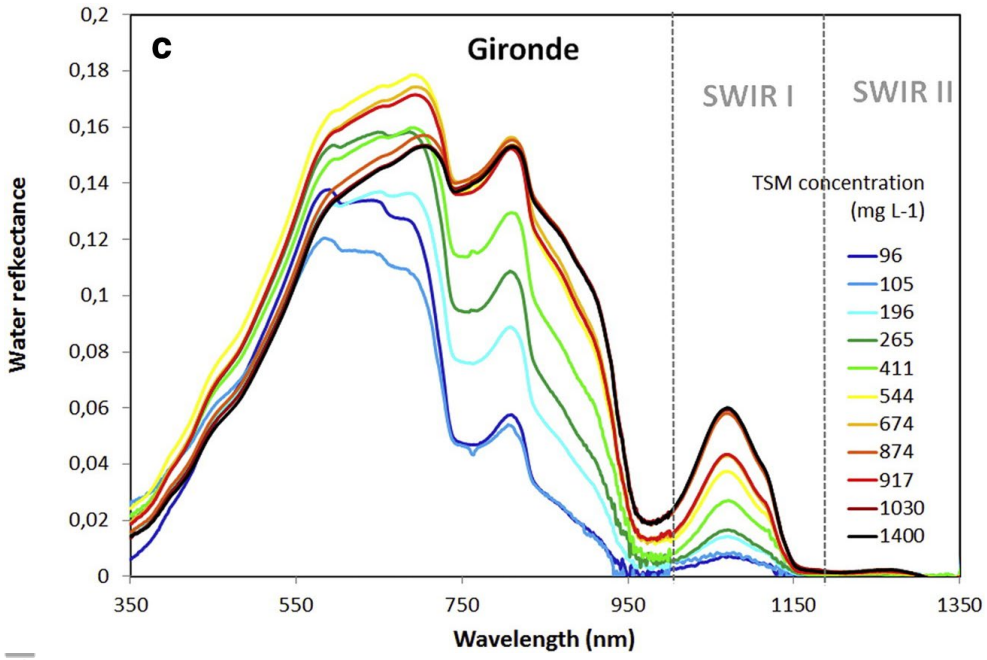
- **Tourism** (visual pollution, toxic, bad smell, access to beaches..)
- **Fisheries, Industry** (clogging of infrastructure)
- **Environment** (water clarity, negative impact on growth salt marshes, fish kill..)
- **Carbon storage** (seagrass as carbon sink…)
- **Economical opportunities (**e.g. bioethanol production from water hyacinth)

Main applications:

- On **land**: Direct detection of plastic litter on beaches
- At **sea**: detection and identification of floating matter
  - Plastics, Oil slicks, Seaweed, Seagrass, Water hyacinths, …

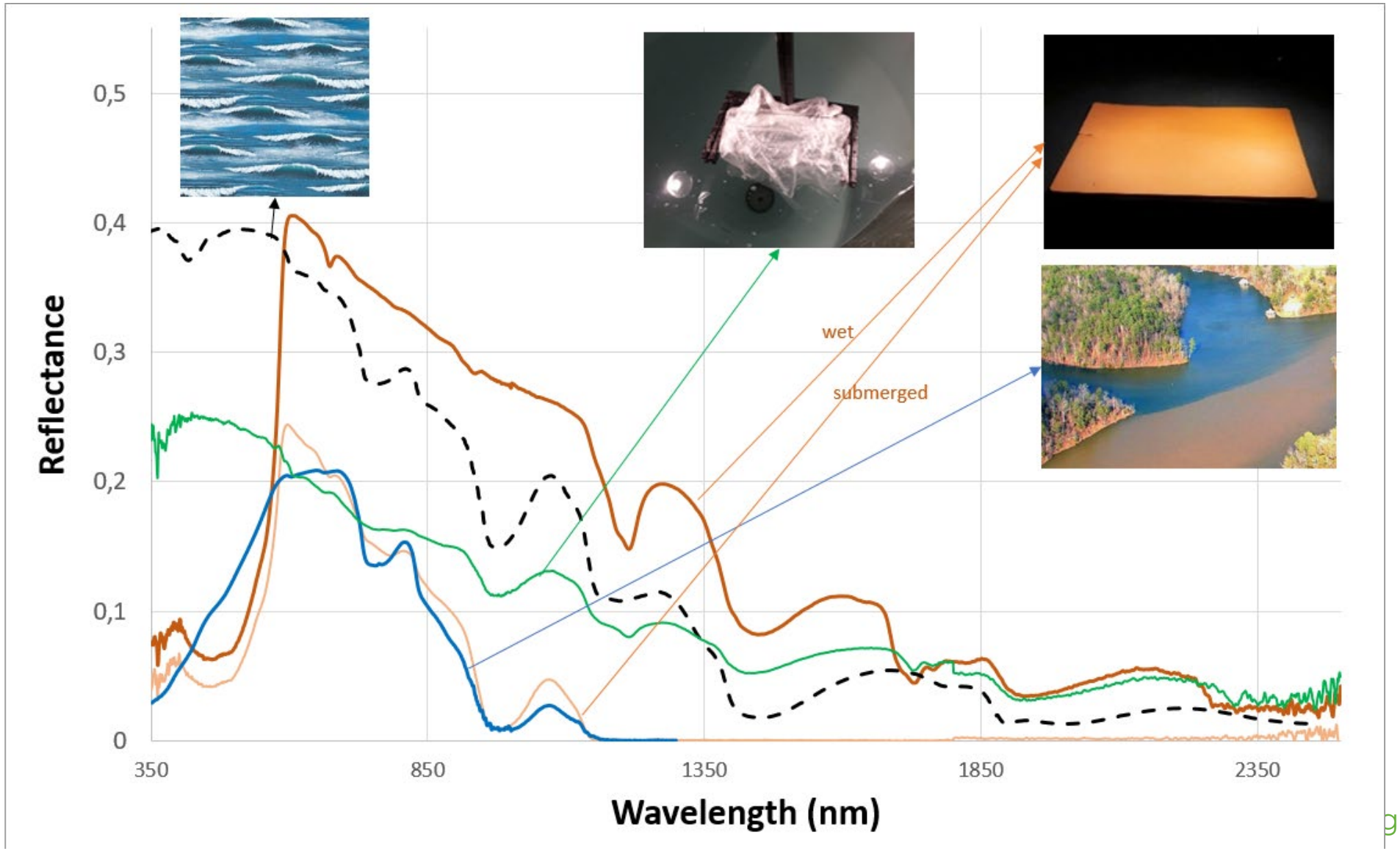
SWIR signal is not zero



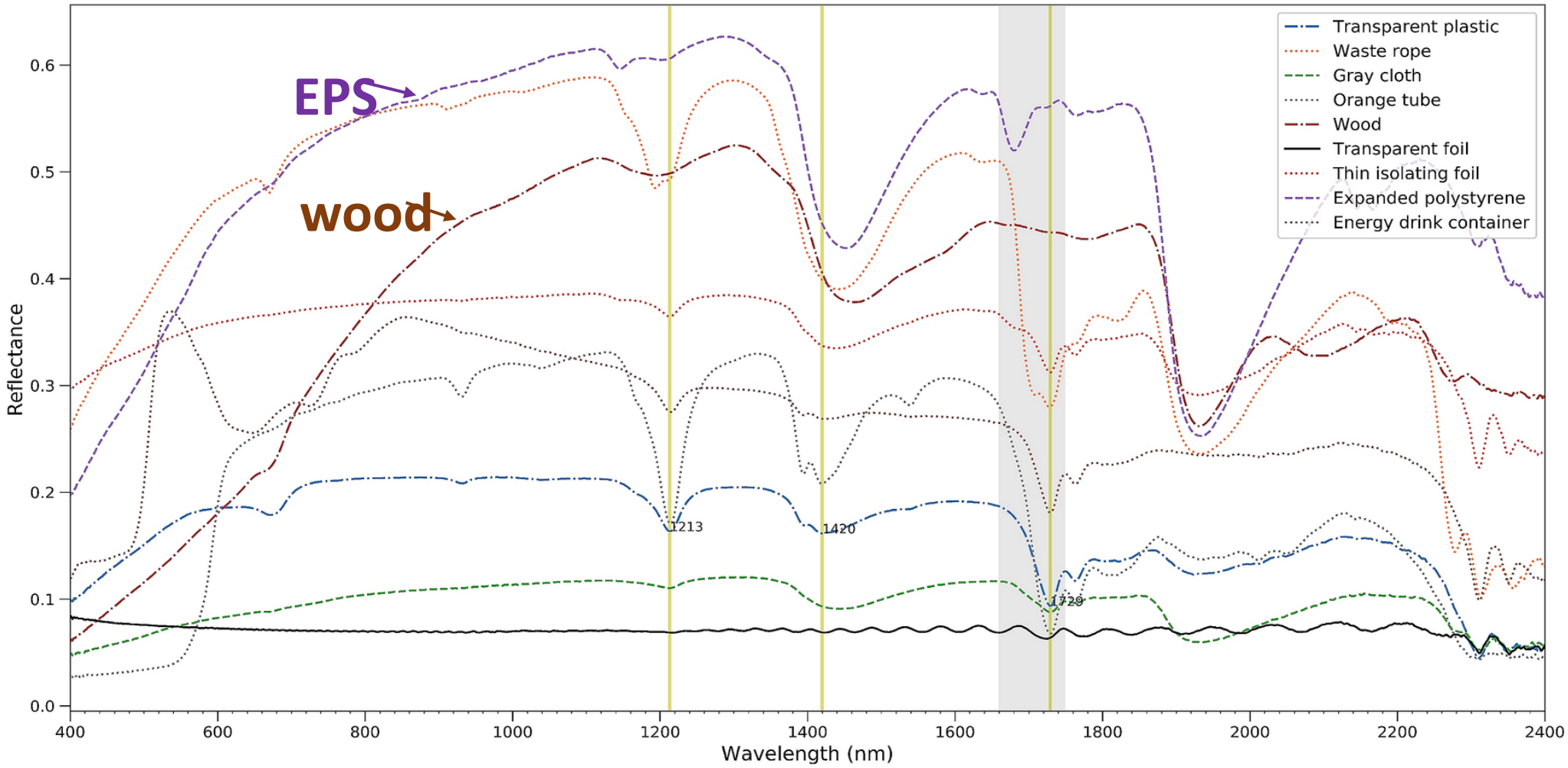


Knaeps et al., 2015

White caps, turbid water



Spectral details



Exact absorption features of plastics? How does this influence retrieval? Best FWHM ?
Weathering? Thin and transparent plastics?

Spectral or Spatial?

many studies use **per pixel spectral information** only

unmixing is used to overcome resolution limitations

but often setup focuses on **100% plastic**

→ **Need experimental data on low fractions**

A. *Hueni and S. Bertschi, Detection of Sub-pixel plastic abundance on water surfaces using airborne imaging spectroscopy, Proc. IGARRS, 2020.*

Study of abundances between 1% - 5% using airborne imaging spectroscopy

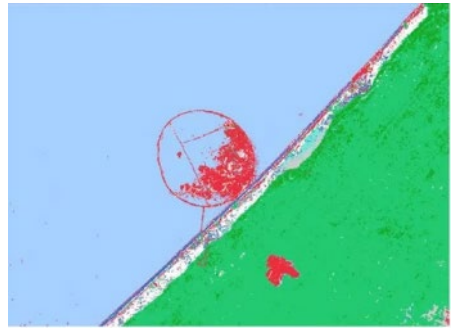
Ground truth

Aim for realistic conditions:

weathered, low fractions, mix of materials, …

Avoid limitations of earlier studies:

- use real **weathered samples**
- **fractional coverage** & mixtures (other debris, plastic types, …)
- realistic locations: beach and windrow (different backgrounds)
- mimic real distribution with **aggregation patterns**
- establish good **ground truth** (as open data)



Combining strengths of state-of-the-art research

Study	Platform	Camera	Fraction	Material	Weathered	result
Hueni 20	Aerial	400-2500nm	5%, 2,5%, 1%	only PET bottles	no	abundances estimated
Freitas 21	Aerial	400-2500nm	100%	3 plastic types	harvested	70–80% precision
Garaba 18	Lab/ aerial	400-2500nm	100%	Variety of samples	marine harvested	absorption features identified
Tasseron 21	Lab	400-1700 nm	100%	5 plastic types + vegetation	virgin plastics	important spectral bands identified
Schmidt 23	Simulations on measured spectra	400-2500nm	100%	6 plastic types	degrees of weathering	differentiate polymer types with detailed SWIR
Zhou 21	Sensitivity analysis	400-900nm	simulated fractions	plastic and other (algae, …)	virgin samples	limit at 0.2% coverage

Conclusion

MARLISE study: a useful ML mission is possible

Go beyond anomaly detection → floating matter mission

Spatial information is important at every scale

Ground truth under realistic conditions

Refine science case → allows to improve mission design

On the way to: **"Converge towards an optical marine litter satellite mission"**

Conclusion

Should not be marine litter be part of the EO strategy of the space agencies?