→ ATLANTIC FROM SPACE WORKSHOP

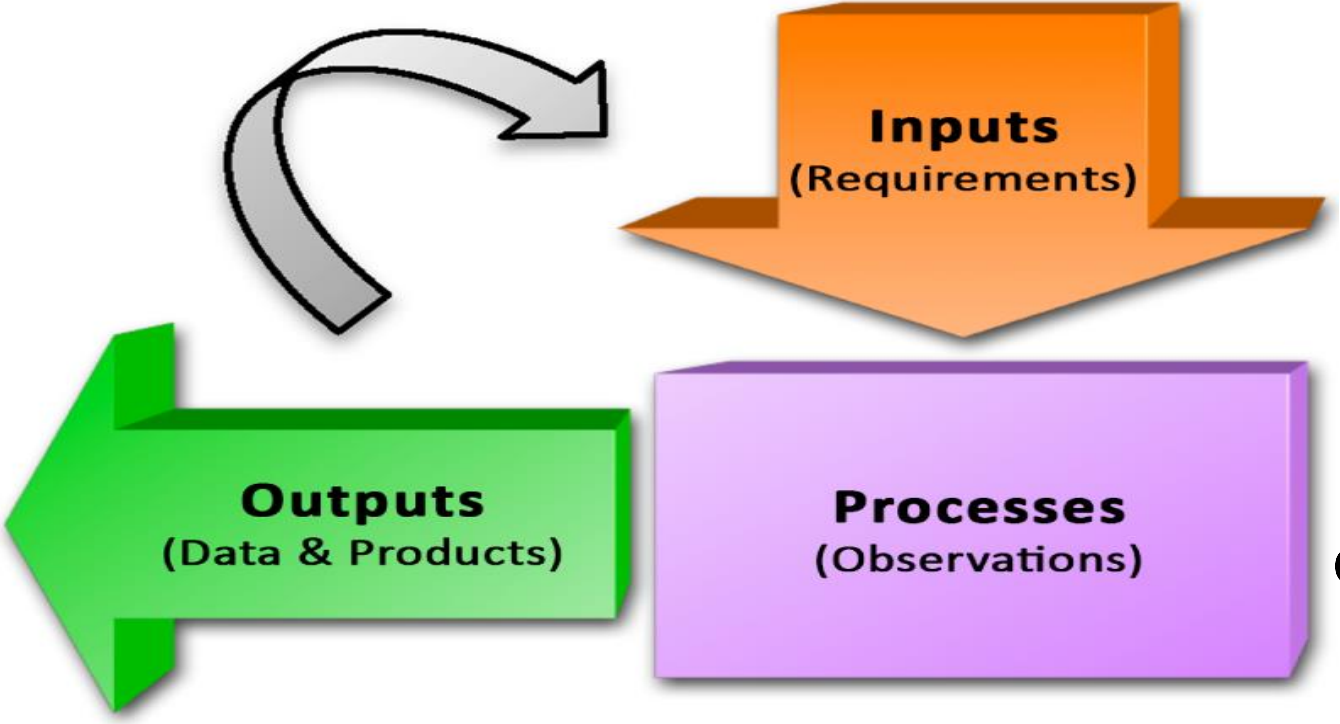
23–25 January 2019
National Oceanography Centre
Southampton, UK

Optical methods for marine litter detection (OPTIMAL): from user requirements to roadmap design for marine plastic detection system

Victor Martinez-Vicente[1], Aser Mata[1], Lauren Biermann[1], James Clark[1], Pennie Lindeque[1] and Paolo Corradi[2]

[1]Plymouth Marine Laboratory (PML, UK)
[2]European Space Agency (ESA, NL)

OPTIMAL: from user requirements to roadmap



USERS
- -Models
- -Impact
- -Monitoring
- -Policy

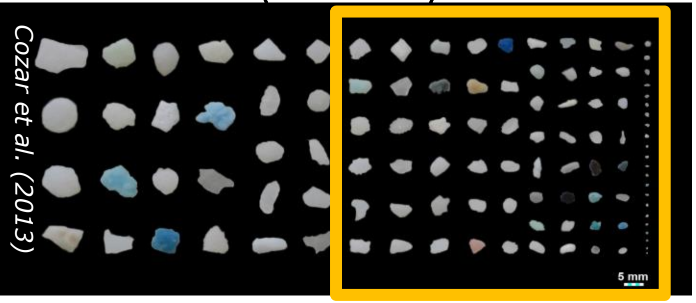
QUESTIONS
- -Accumulation?
- -Sources?
- -Movement?

OBSERVATIONS
- -EO
- -Optical

Framework for Ocean Observing (GOOS)

Main question: how much plastic is there? Where?

Microplastic
(D≤5mm)



Macro and megaplastic
(D≥2.5cm)

Macroplastic
(2.5cm≤D≤1m)

User consultation workshop and questionnaire (ESTEC, 2017)

Open Ocean
Modellers / impacts

Shoreline
Monitoring/ policy makers

Floating on water
Monitoring/ policy makers

-Experiments –Modelling -In situ -Earth Observation

OLCI-Sentinel-3

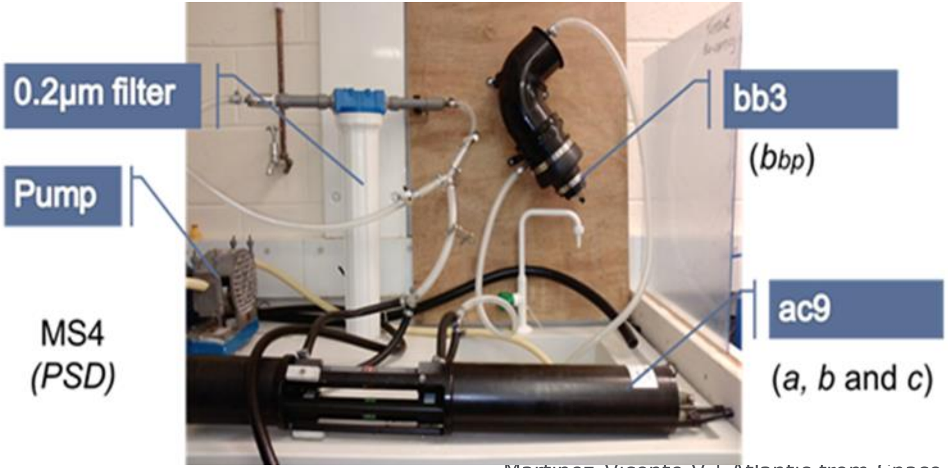
Development plan

MSI-Sentinel-2

Approach for "small" microplastics

$$r_{rs}(\lambda) = [0.09 + 0.13 \times \frac{b_{bp}(\lambda)}{(a(\lambda)+b_b(\lambda))}] \times \frac{b_b(\lambda)}{(a(\lambda)+b_b(\lambda))}$$ (Gordon, 1988)

$$b_{bpMP}(\lambda) = \sigma_{bbp,MP} N_{MP}$$ ← from literature



Microplastic accumulation in the ocean: Method

Polystyrene beads: **0.2 µm**, 1µm, **2µm**, 10µm, **20 µm**

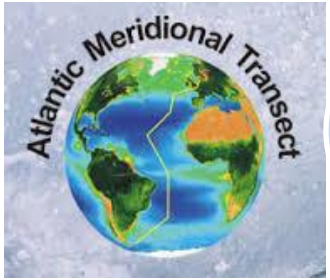
Beads → Sizes, Composition

Experiment →
- Absorption (a)
- Backscattering (b_{bp})

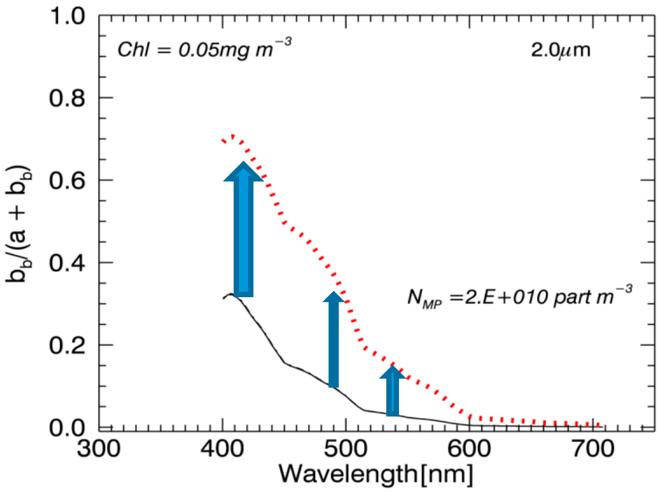
Expected Concentration → Simulation of reflectance (R_{rs})

Testing impact of microplastics on simulated R_{rs}

→ **Validation**



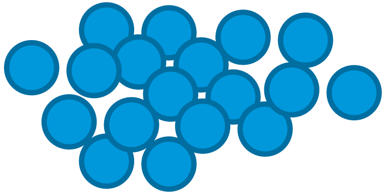
Microplastic accumulation in the ocean: Results



1. Very high microplastic concentrations are needed to produce deviations in reflectance

2. At lower concentrations of Chlorophyll, the potential for microplastics to modify reflectance is greater → there is more potential for detection.

How much plastic is that?



Polystyrene density = 1.04 g cm^{-3}

$2x10^{10}$ part m^{-3} 2 μm beads~$10x10^{-14}$ gm^{-3}

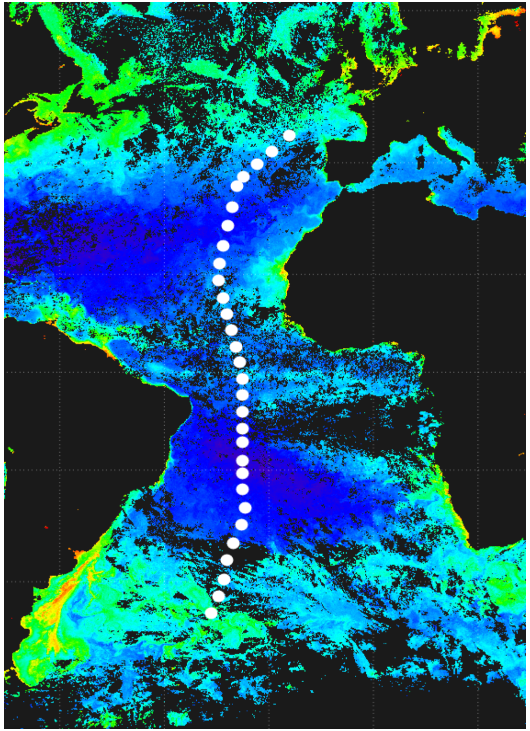
Average weight = 1.5 g

(*Hocking, 1991,Science: Paper versus Polystyrene: a complex choice*)

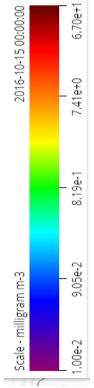
Is small plastic detectable using current Ocean Colour?

1. In-situ measured plastic (D≥63 µm) concentrations in the Atlantic Area have provided preliminary confirmation of laboratory results

2. In-situ measurements of plastic abundances (D<63 µm) are needed



Weekly Chl-a composite (OC-CCI v3.1, 4km, 2016-10-15; https://www.oceancolour.org)

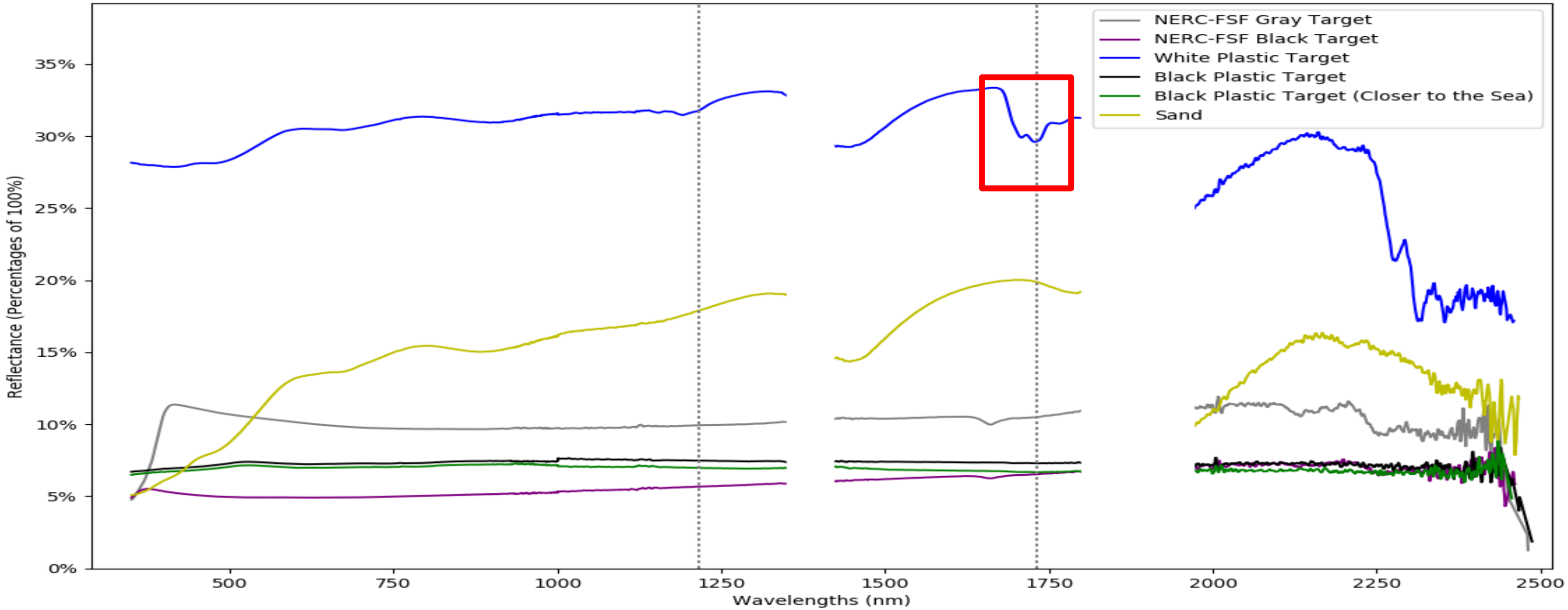


(Martinez-Vicente et al., in prep)

Megaplastic accumulation on the shore: Method

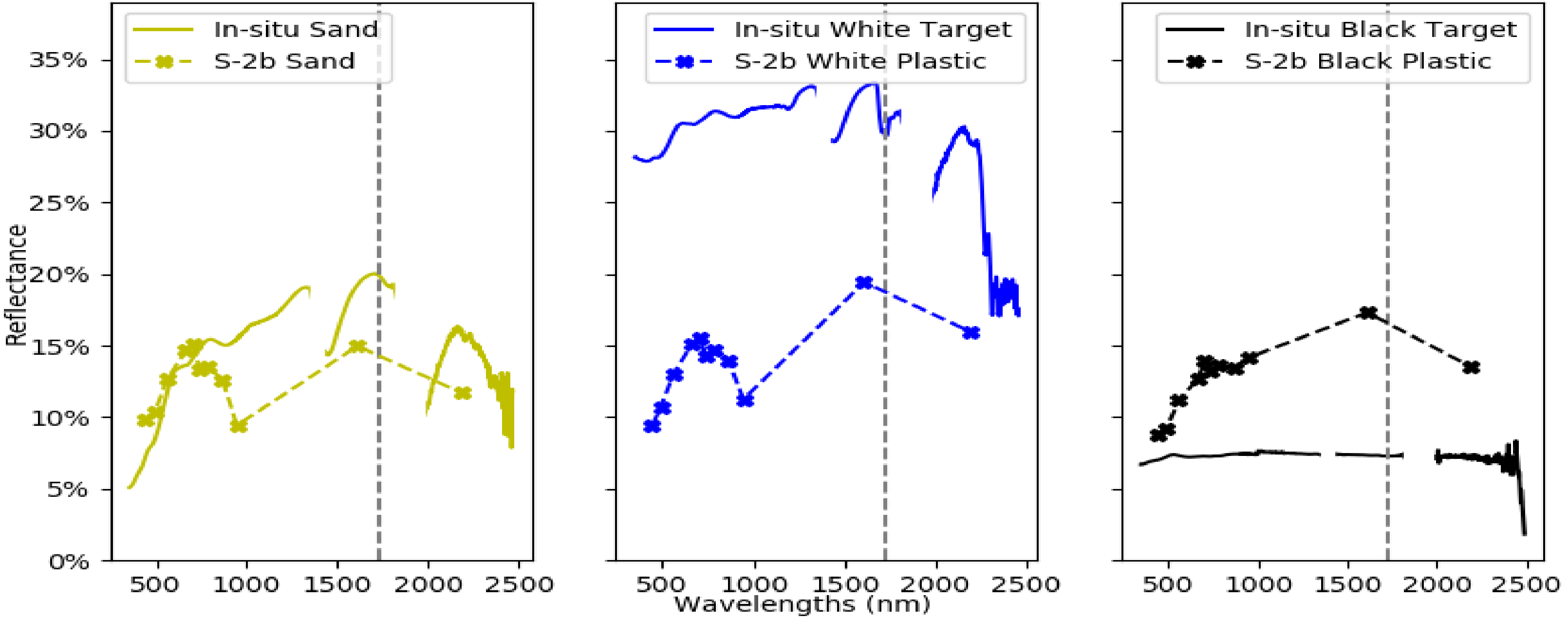
- In situ Hyperspectral radiometry
- Sentinel-2B matchup
- Aircraft Hyperspectral radiometry

Megaplastic accumulation on the shore: Results
In situ radiometric data



1. Confirm existence of absorption valley around 1732nm.
2. Not present on all materials tested

Megaplastic accumulation on the shore: Results
In-situ data vs S-2B comparison



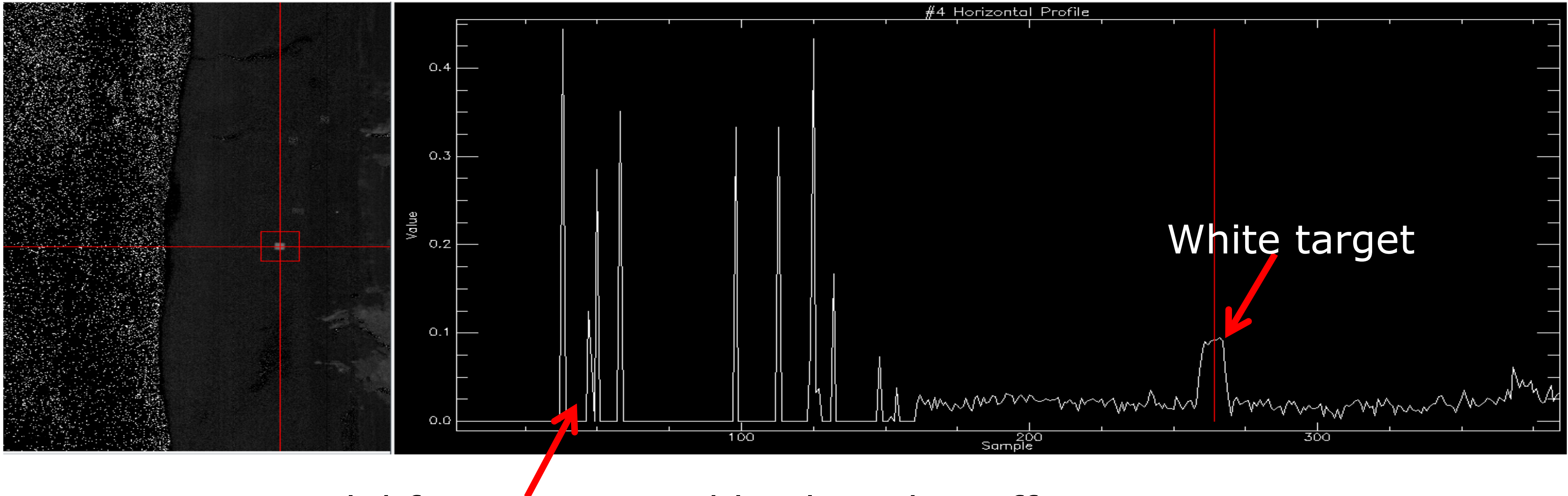
Dotted lines are features previously identified (Garaba et al., 2018 a,b)

- Good comparison between radiometry in situ and satellite for sand at all wavelengths.
- Plastic targets spectra are contaminated by surrounding sand

Megaplastic accumulation on the shore: Results
Airborne hyperspectral & Normalised Difference HI

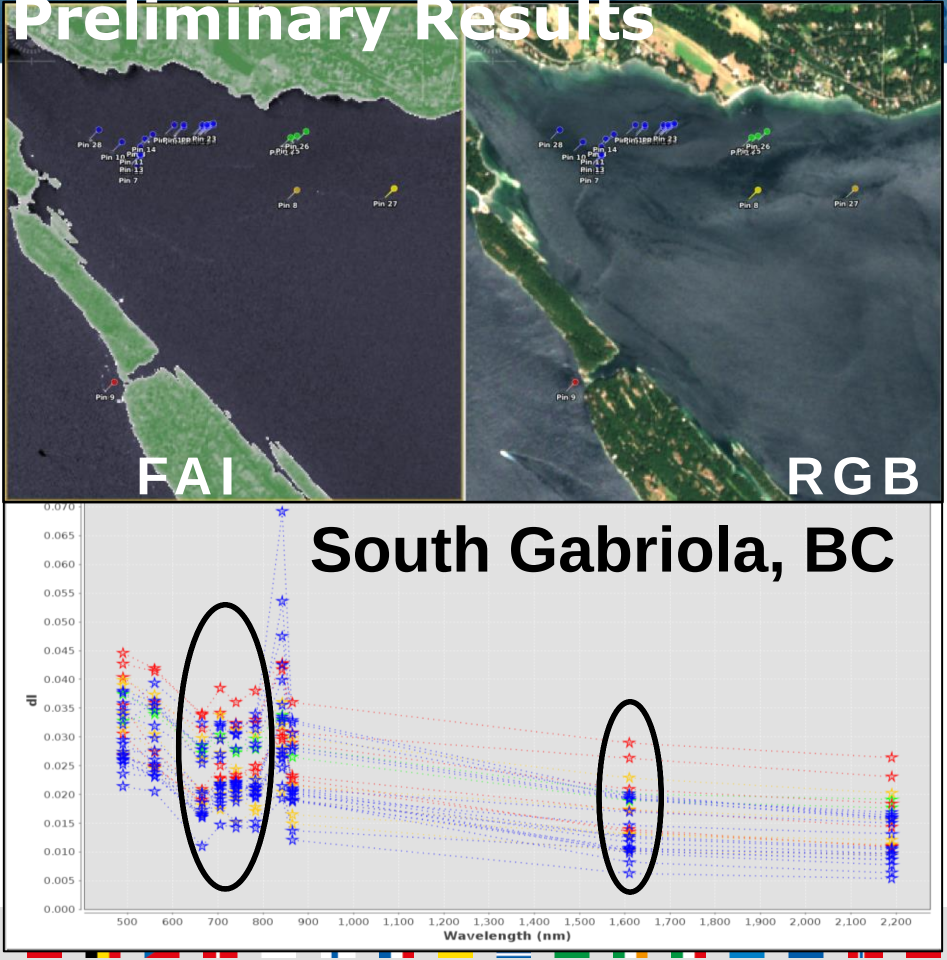
1. Index specific for land detection, able to separate plastic from sand.
2. No hyperspectral data required, but band centred around 1732 nm.

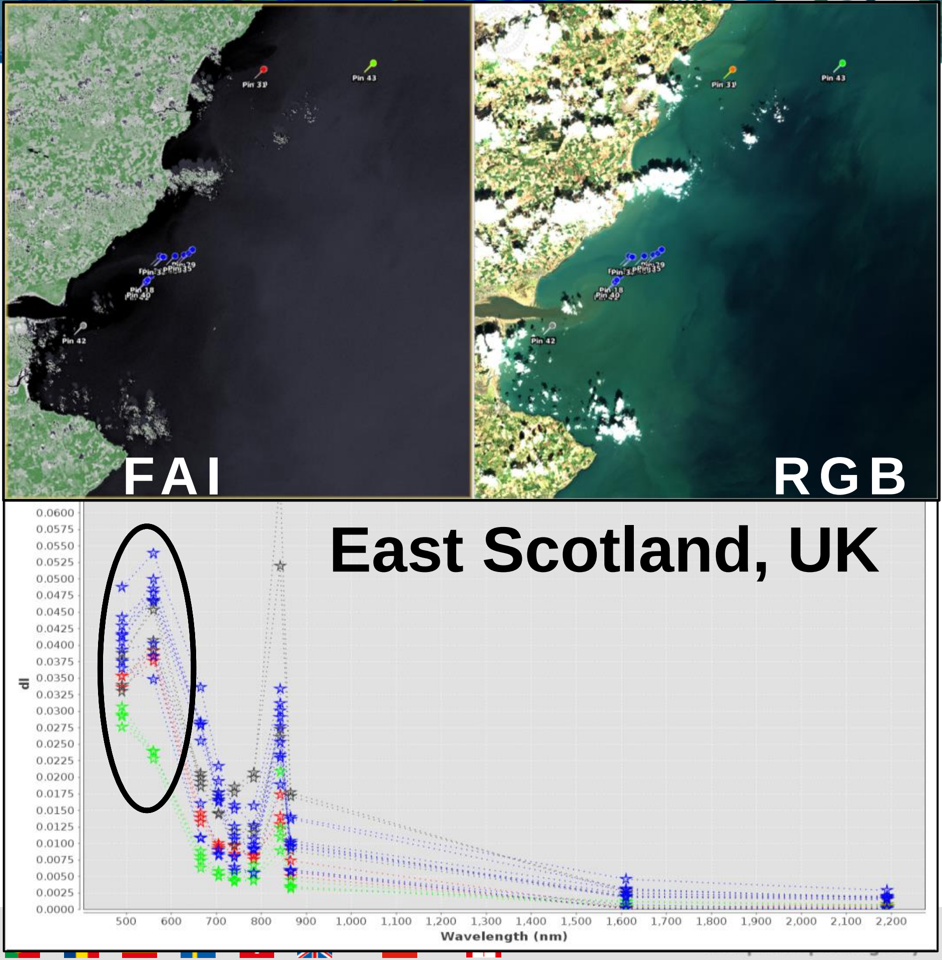
Megaplastic accumulation on the shore: Results Airborne data –



- NDHI is not valid for water. Possible algorithm effects.

Macroplastic accumulation in the ocean: Preliminary Results





Conclusions

1. Initial (idealised situations) results point to potential for detection using purely radiometric methods.

2. Microplastic in the ocean:
   a) Low Chlorophyll concentrations
   b) High accumulation of very small particles

3. Megaplastic on the shore:
   a) Some plastics have a (strong) signal in the SWIR, remotely detectable
   b) However, this is not captured by current sensors- too coarse spatial res.

4. Macroplastic floating on the ocean:
   a) Potential modification of signal in the NIR & visible range

Recommendations

1. To use controlled experiments/ validation campaign in more representative experimental setups to progressively move towards better definition of system requirements (short term)

2. To combine ocean colour with other EO data streams: high (spatial) resolution and indirect for accumulation (i.e. currents, fronts)

3. More in-situ data are needed. They need to be standardised and accessible to the community

4. To develop a wider science plan for EO of marine litter, e.g. through SCOR working group-FLOTSAM (http://scor-flotsam.it/) as part of a wider effort for an international monitoring network for marine litter (Ocean Obs 2019, *Maximenko et al., submitted*)

Acknowledgements

- ESA for funding for OPTIMAL

- SCOR WG153: Floating Litter and its Oceanic TranSport Analysis and Modelling (FLOTSAM, http://scor-flotsam.it/)

- NERC ARF for Flight support
- NERC FSF for in-situ instrument loan

vmv@pml.ac.uk | @VMartinezPML