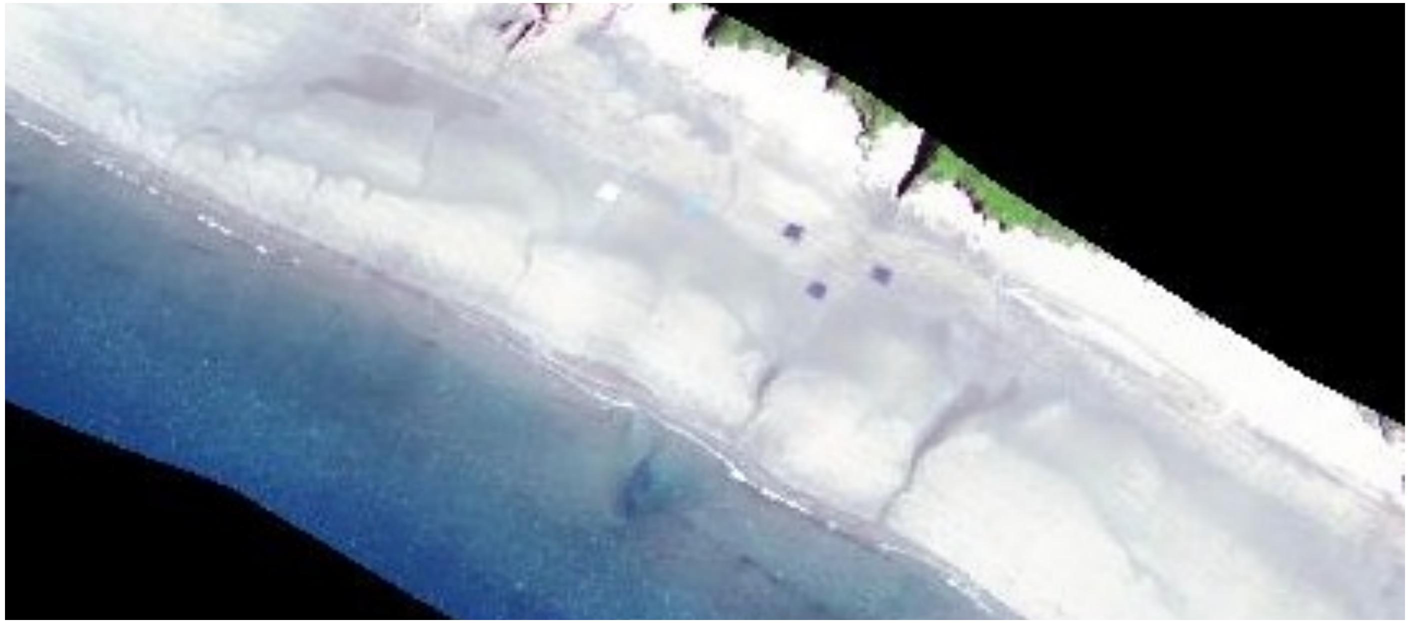
PML | Plymouth Marine Laboratory

Research excellence supporting a sustainable ocean

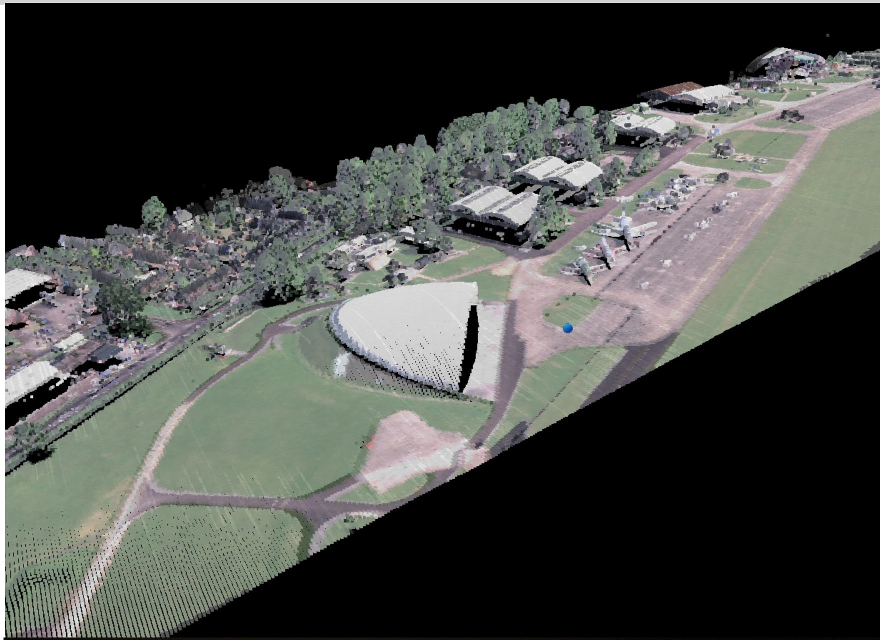
Introduction to Earth Observation Data for AI

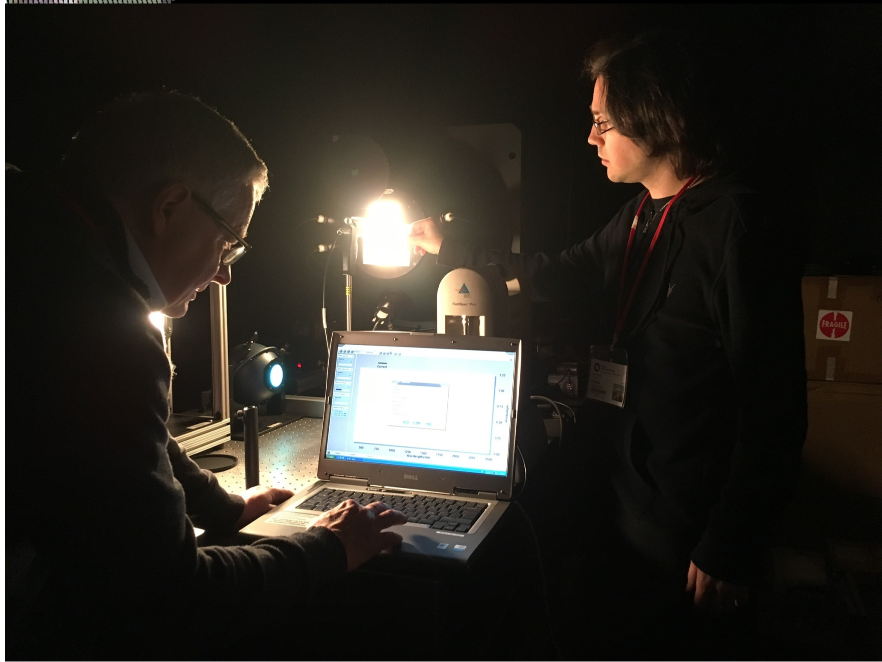
Detection of plastic debris using drones and satellites



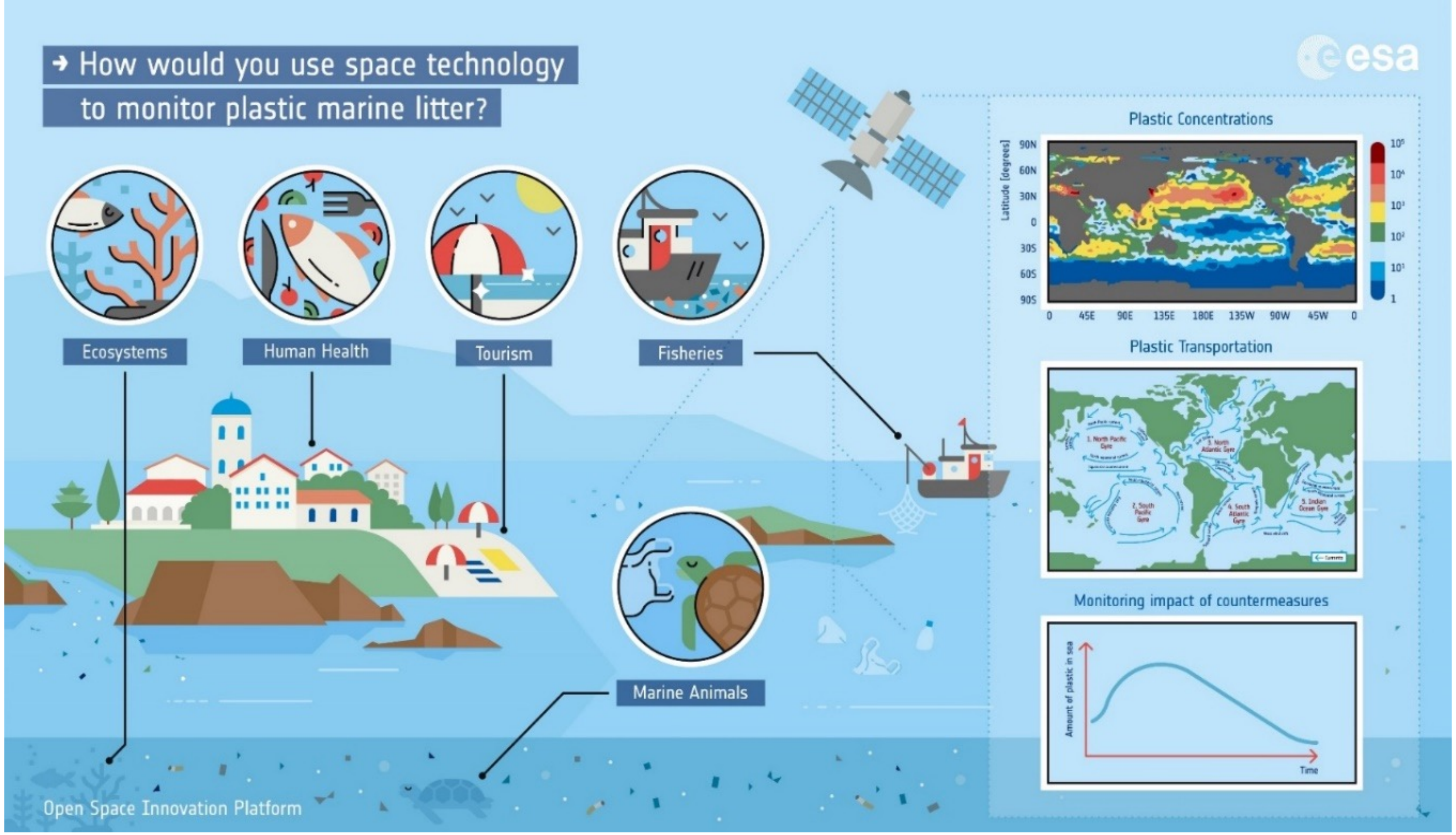
Aser Mata

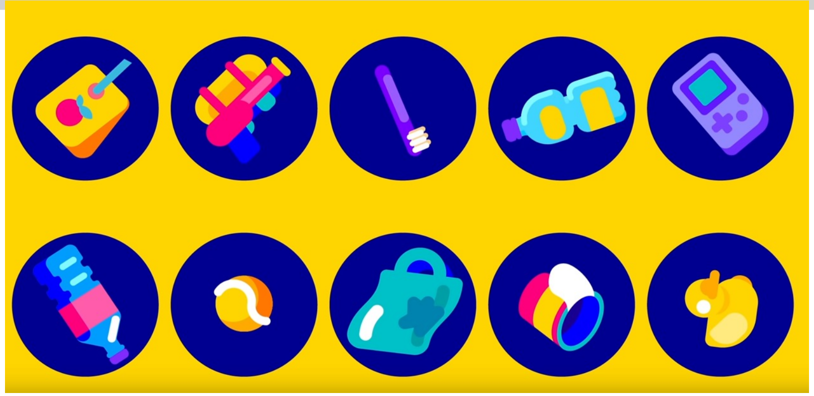
-Physicist, joined PML in 2015
-Airborne data processing and calibration
-Drone pilot with CAA accreditation





Plastic Pollution

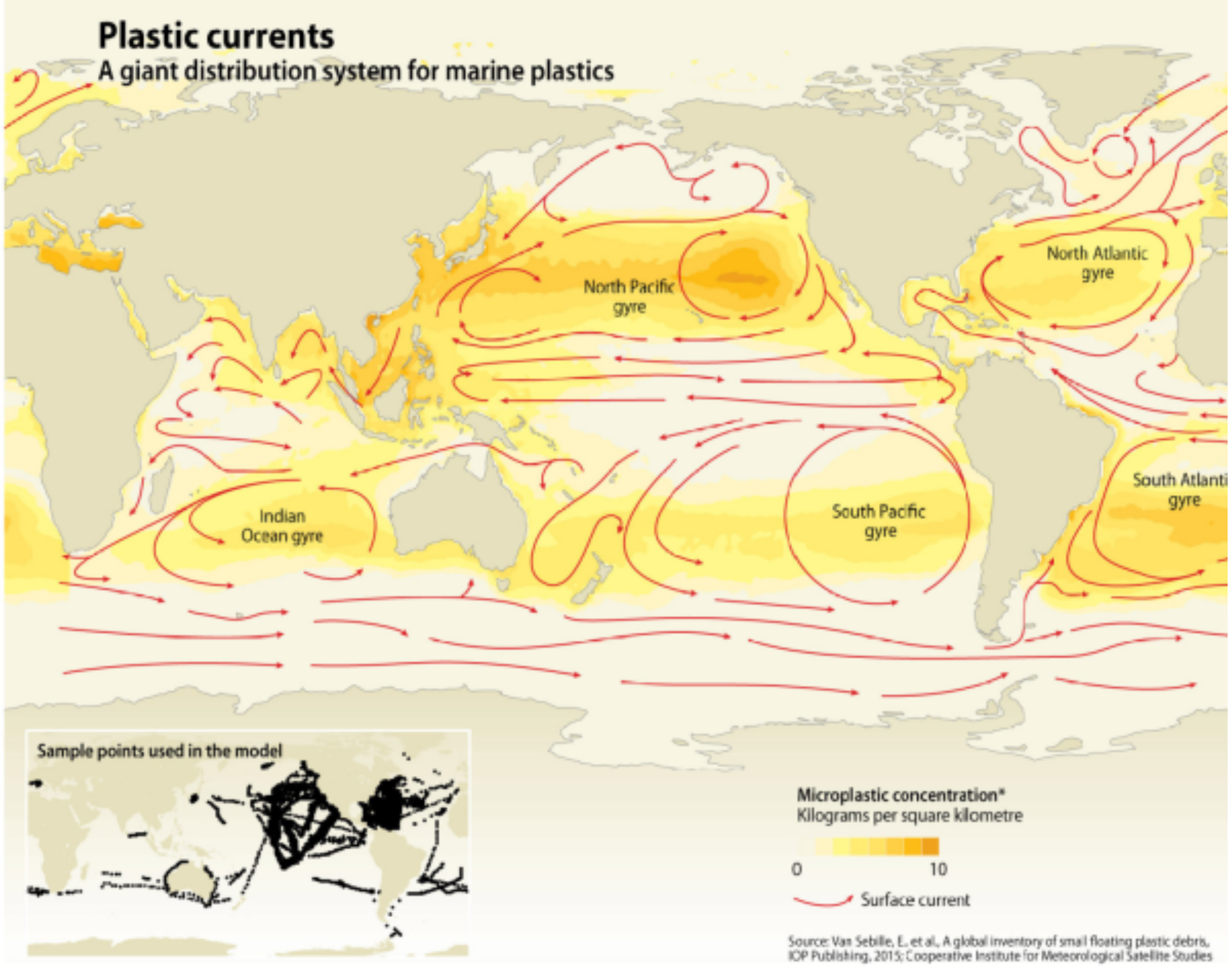




Source: Kuzgesagt

-**Economic cost:** $8bn per year
-**Social impacts:** damage to marine fauna, ethical implications, psychological impact…
-**Human health:** Extent of the impact is yet not fully understood. Plastics enter food chain as well as dangerous substances that are usually used as plastic coatings

A Complex And Global Problem



-Your individual actions make a substantial difference but it needs global solutions
-Challenging problem with socio-economic implications (similar to the climate crisis)
-Sustained observations are required to determine the marine plastic debris mass balance, sinks and sources
-Effective policy for planning remedial action is based in scientific observations
-It needs more observations at global scale
-Remote Sensing systems can contribute to tackle this problem

Washed Up Photo Series – Alejandro Durán

Types of plastic debris

Microplastics as those particle sizes can enter the food chain
Macroplastics is any plastic fragments larger than 5mm.

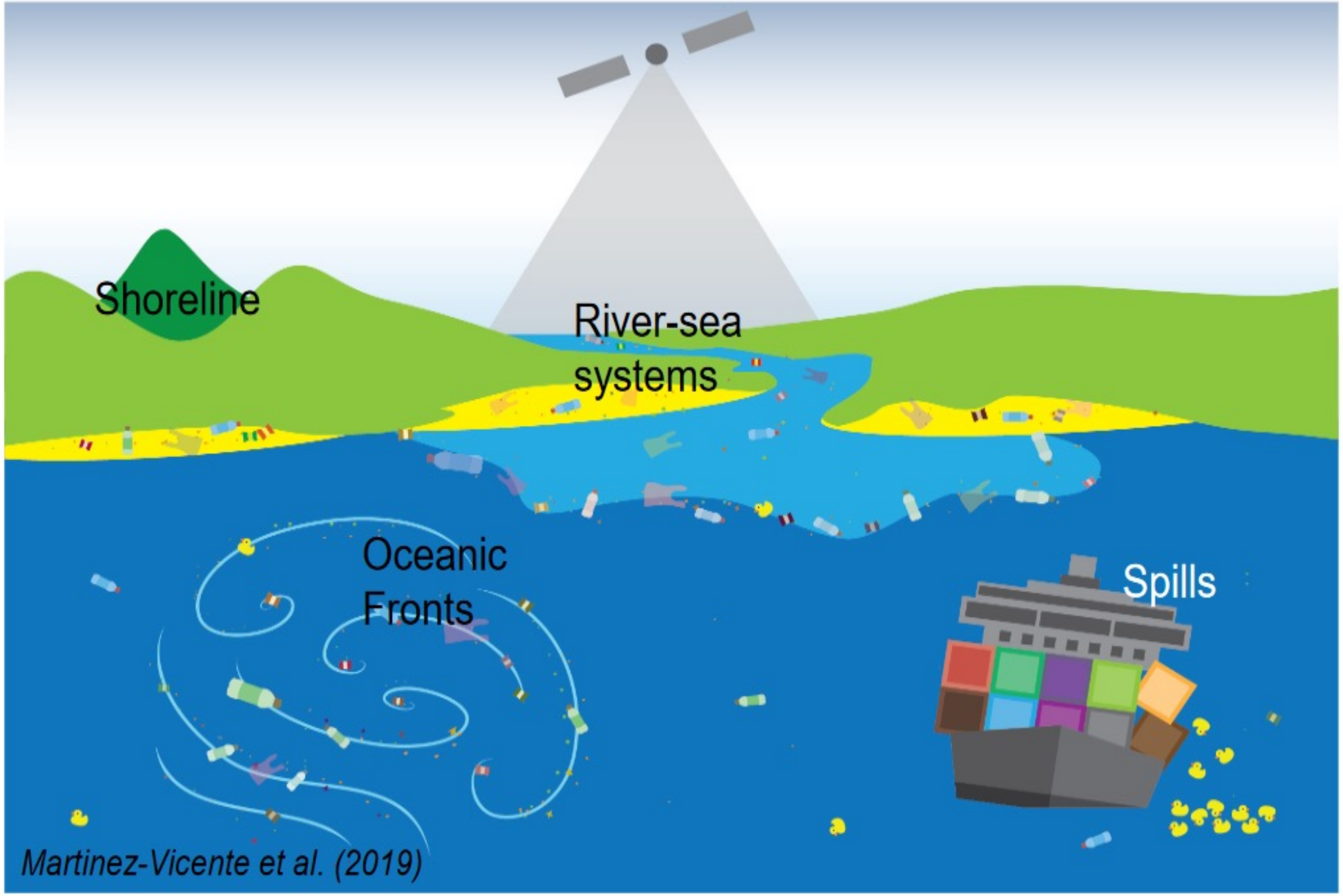
Fragmentation

High surface area, high particle numbers.

Low numbers, large mass, volume

Challenges of using remote sensing

-Is it possible?
-Many different types of plastics polymers, shapes and colours
-Is any platform better suited (satellite/ airborne/ drone) ?
-Feasibility: coverage, repeatability and pixel size
-Challenging environments: turbid waters on rivers, changing currents, bad pixels, atmospheric correction
-Many different backgrounds: water, sand, vegetation, rocks…
-Sensor spectral resolution and signal to noise ration



OPTIMAL (2019)

PI: Victor Martinez-Vicente

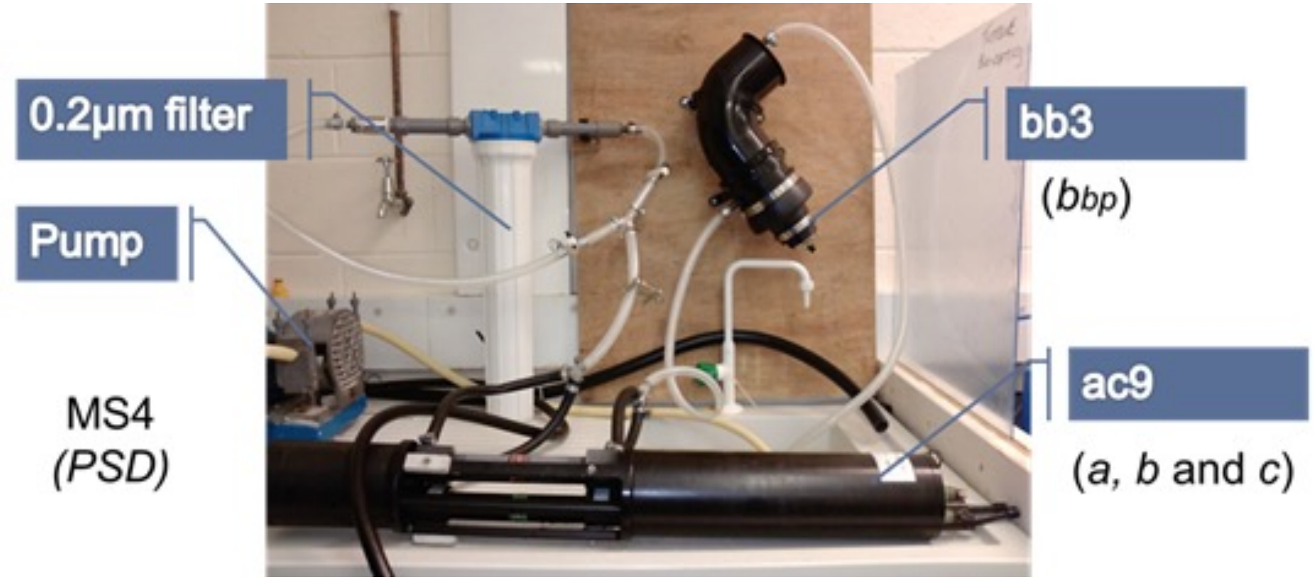
OPTIcal methods for MArine Litter detection

•Identify and characterise applications potentially accessible to remote sensing.
•Evaluate existing and planned sensor capabilities for detecting/quantifying marine litter.
•Define the activities necessary to utilise current and foreseen sensors to detect marine litter, if existing; or define the characteristics of new sensors

Laboratory Experiments + Field Campaign

OPTIMAL laboratory experiments

Polystyrene beads:
0.2 µm, 1µm, **2µm**, 10µm, **20 µm**
Real Refractive index = 1.15



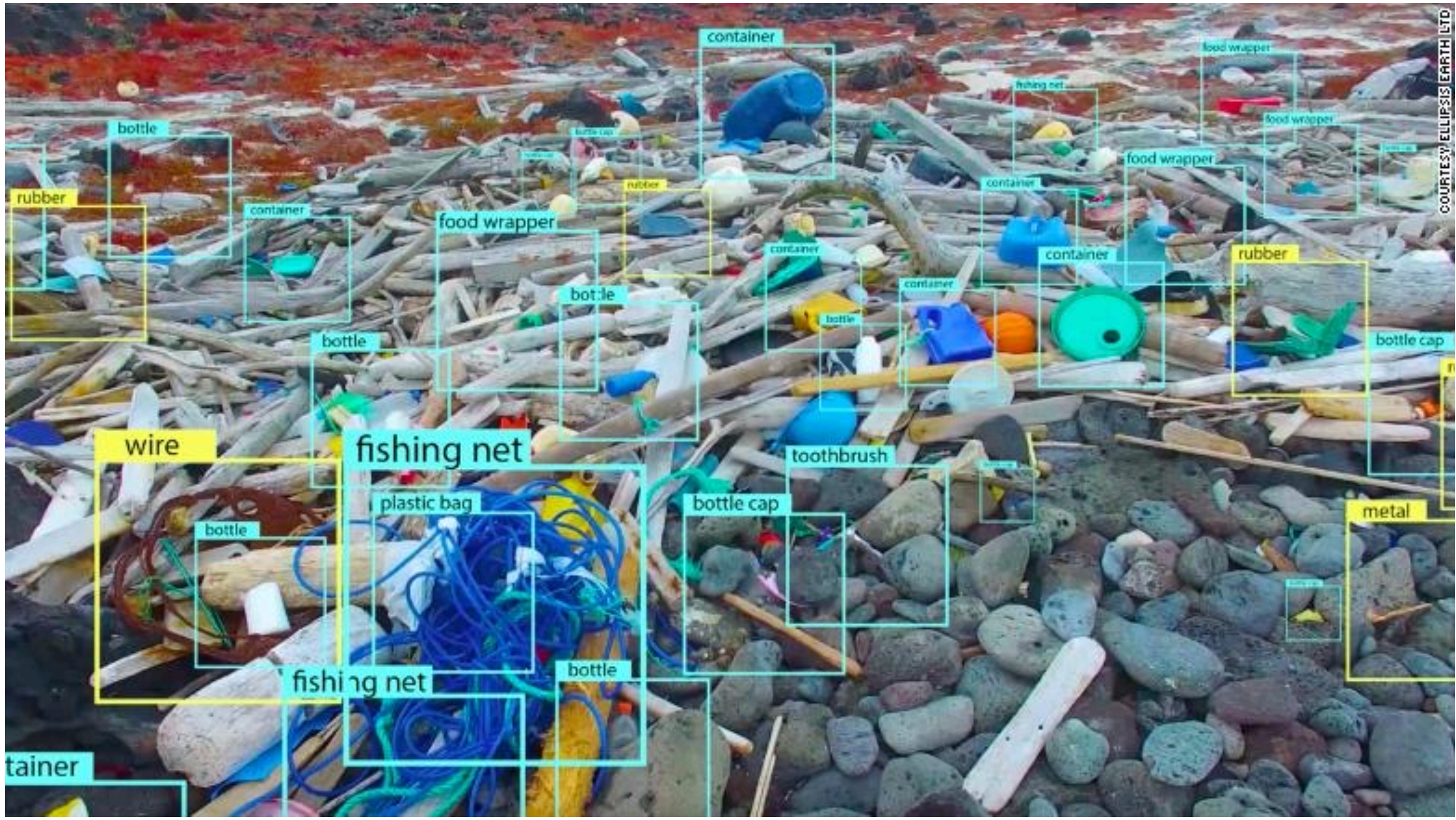
Conclusion: Microplastics could have an effect in the visible spectra only at extremely high MP abundances and low chlorophyll concentrations.

1) Features outside visible region or indirect methods
2) Detect macroplastics

Using drones for classifying plastic litter

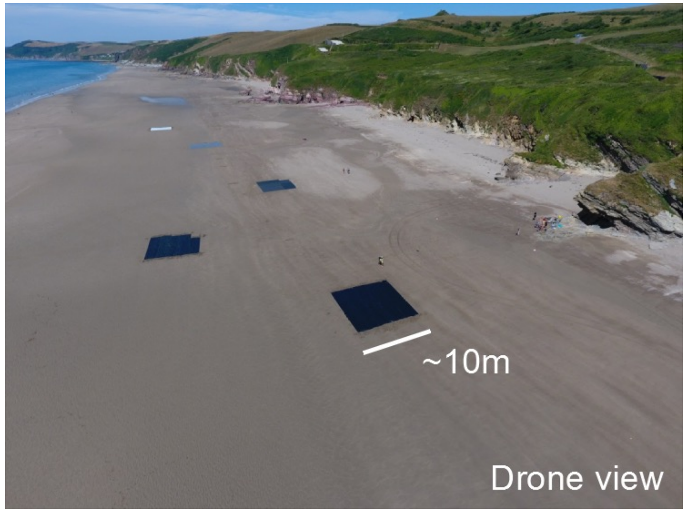
-Using regular photos (RGB) macroplastics can be classified and counted using AI
-Surveys can be therefore automated using drones and saving time
-It is a method currently used and being further developed

BUT
-Needs to fly at very low altitudes (5m) for the pixel resolution to resolve small pieces
-and therefore cover very small areas
-Algorithms need to be trained and training dataset must be tagged (very costly)
-Does not allow for subpixel detection



Source: The Plastic Tide

OPTIMAL field campaign: assessing SWIR plastic features



Plastic Targets Deployment

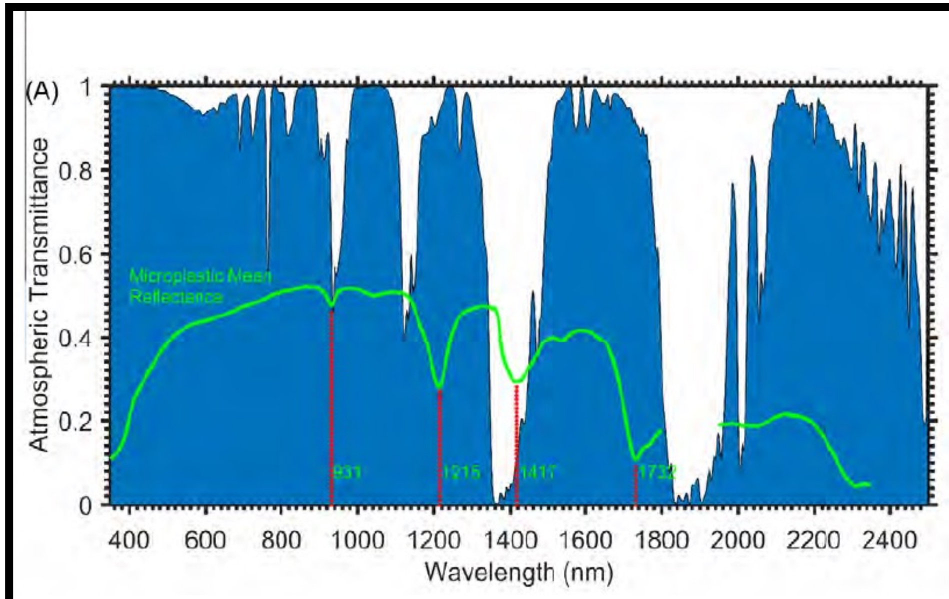
Sentinel 2B Overpass

Hyperspectral Handheld Instruments

Airborne Hyperspectral Fenix (VNIR+SWIR)

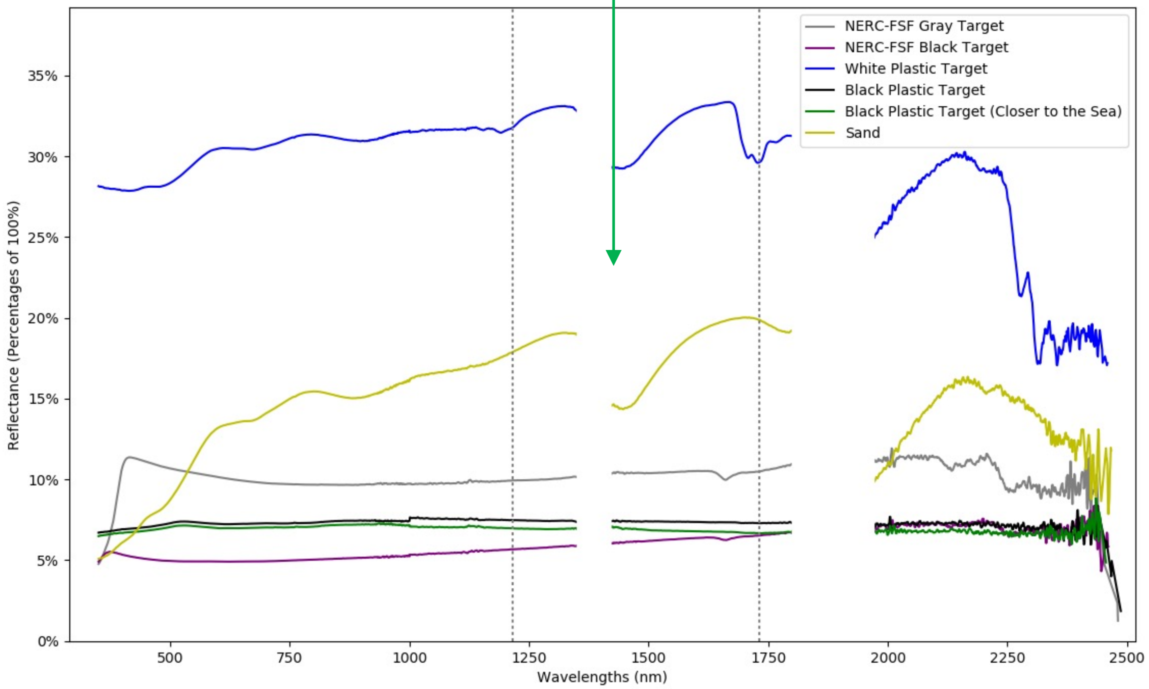
OPTIMAL field campaign

As noted in the scientific literature, many types of plastics share spectral features on the **SWIR**, the most pronounced around 1732nm



Garaba and Dierssen submitted RSE

In situ data showed indeed absorption features on those bands



Plastic spectral features on the **SWIR** can be exploited for its remote detection

Hydrocarbon Indices

We analysed the airborne data to explore if different indices of hydrocarbon detection (Hydrocarbon indices) that exploit those features can be used for remote detection of plastics in the shoreline

Hydrocarbon Index:

$$HI = \frac{2}{3}(R_{1741} - R_{1705}) + R_{1705} - R_{1729}$$

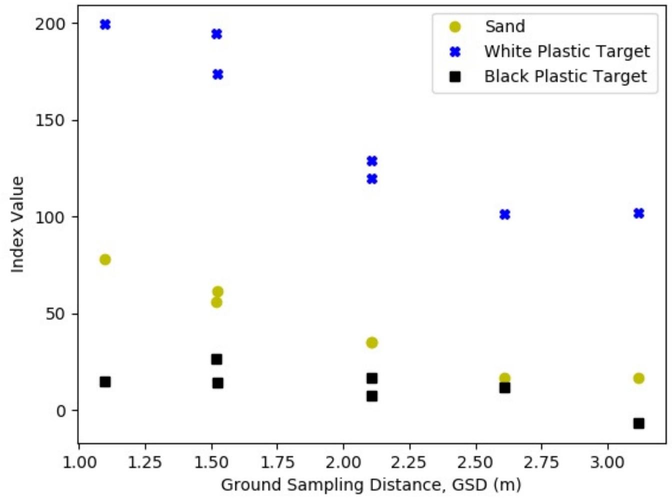
Index based on radiance (Kuhn et al.2004)

Where R denotes Radiance at the wavelengths of 1705, 1729 and 1741nm
HI needs therefore hyperspectral data

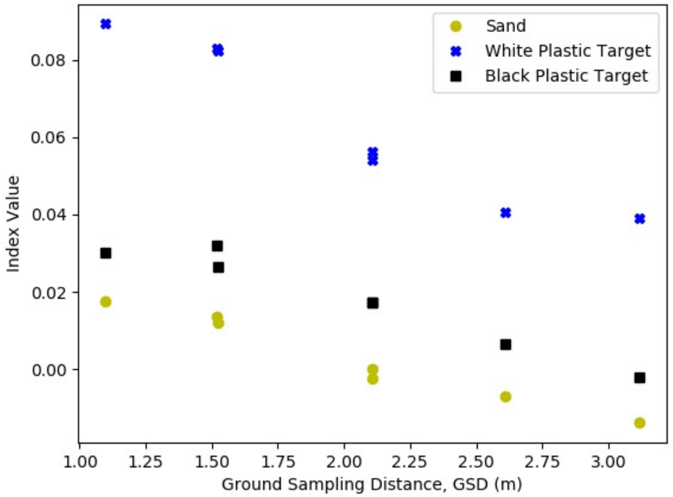
And assessed a new Normalised Difference Hydrocarbon Index:

$$NDHI = \frac{Reflectance(1610nm) - Reflectance(1732nm)}{Reflectance(1610nm) + Reflectance(1732nm)}$$

HI vs GSD

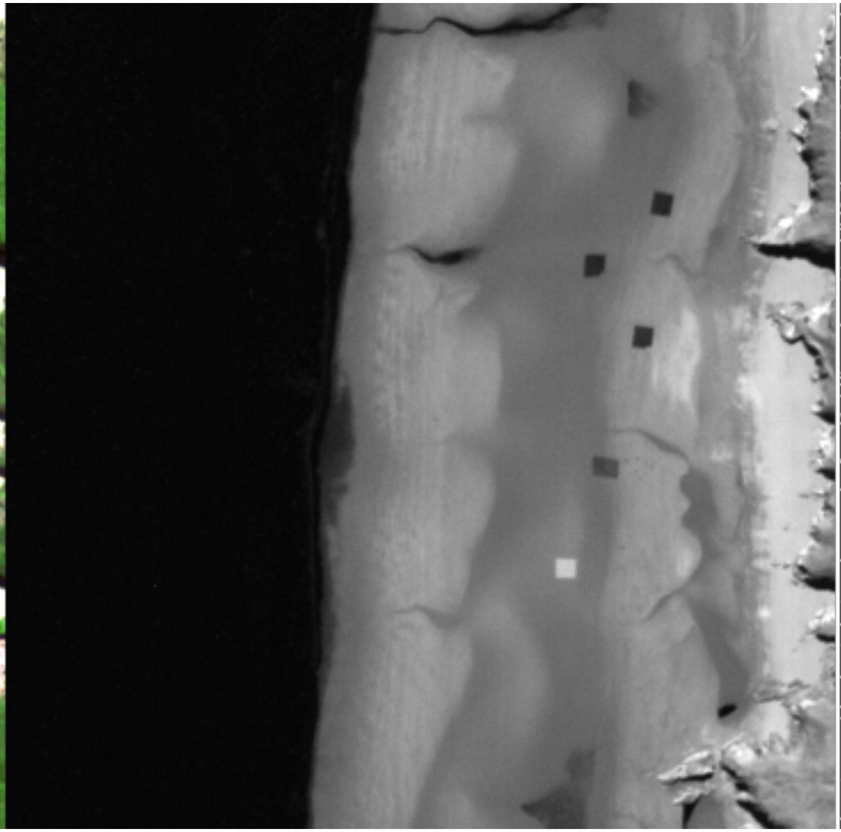


NDHI vs GSD

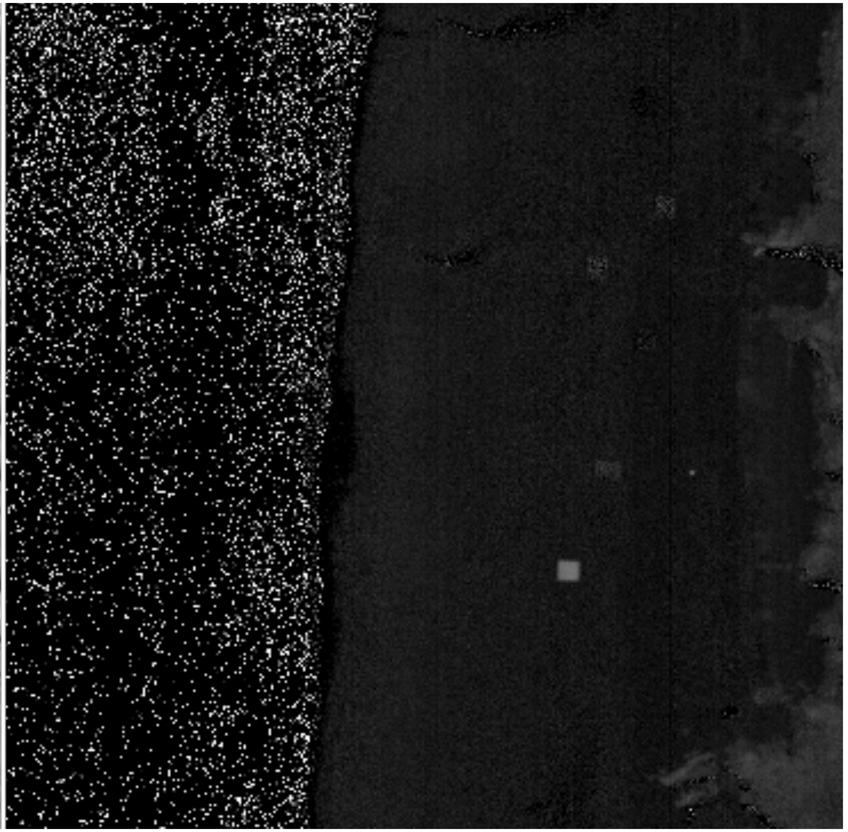


OPTIMAL field campaign: Airborne Data Analysis

True colour image



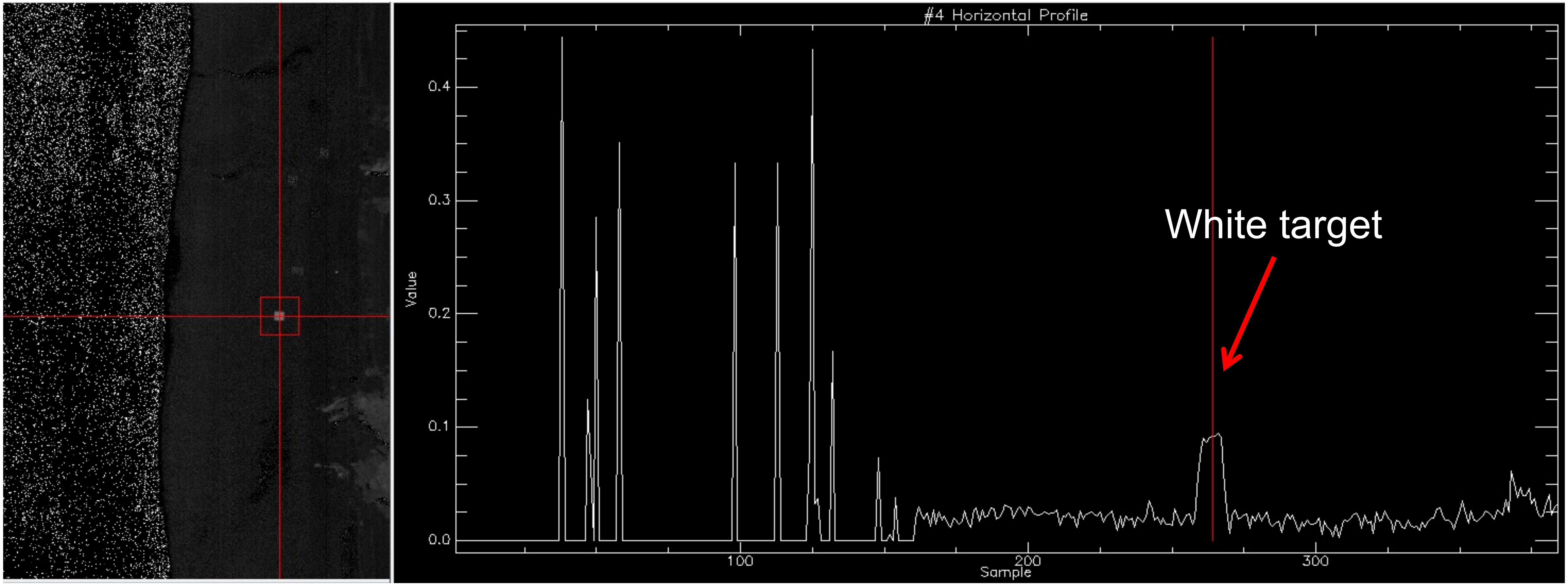
Hydrocarbon Index (HI)
(Kuhn et al.2004)



NDHI
(PML; Mata et al, in prep)

Index specific for land detection, able to separate plastic from sand.

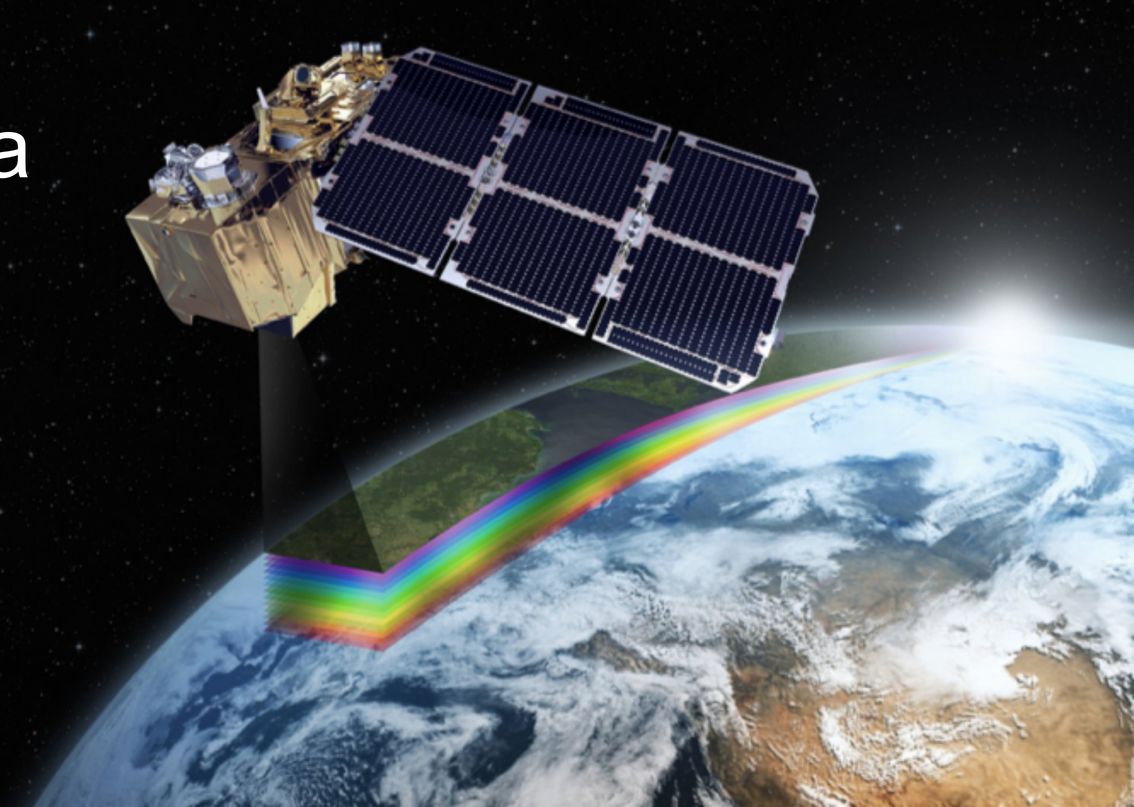
NDHI Horizontal transect



- HI needs hyperspectral data at 1732nm, NDHI is a relation between 1732 and 1610nm.
- Exploiting those spectral features will allow for subpixel detection

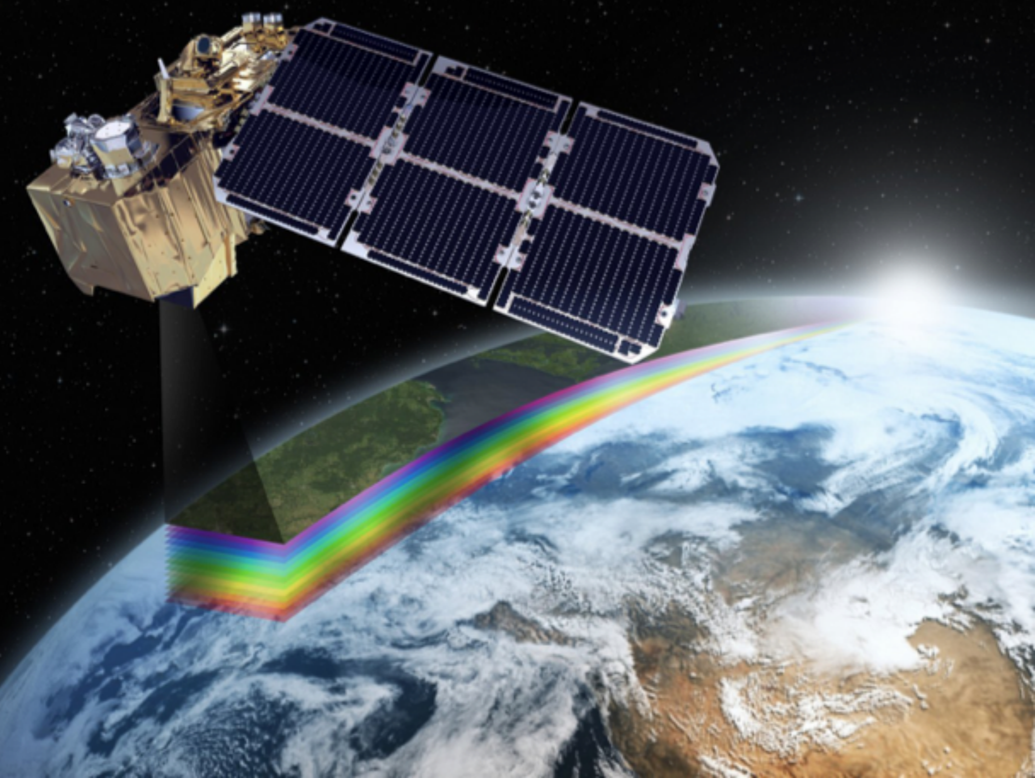
Can satellites detect macroplastics?

- Satellite data are not yet widely used for the detection of macroplastics in the marine environment.
- Limiting factors include:
  - Lack of *in situ* validation data
  - Environmental factors
  - Satellite sensor limitations:
    - Spectral range
    - **Pixel size**



Sentinel-2 to detect plastic debris

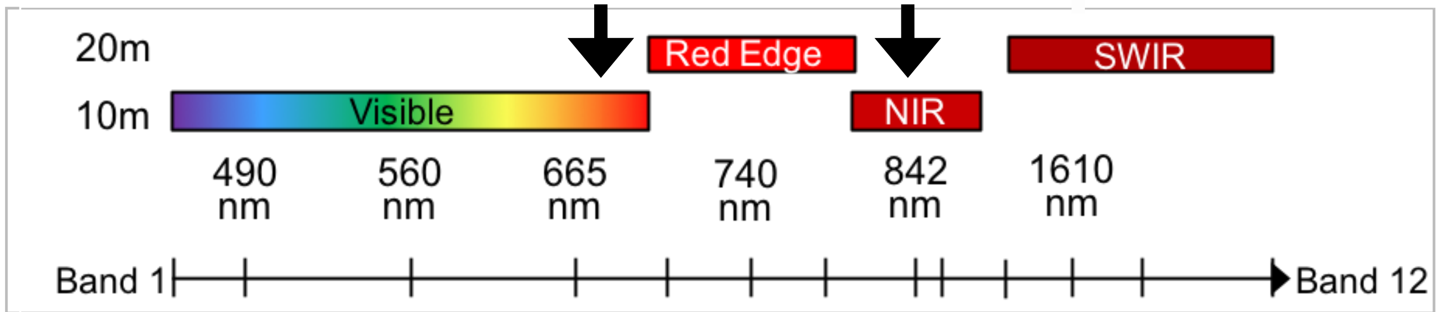
- Sentinel-2A & B satellites were launched in 2015 & 2017.
- Terrestrial services but coverage includes coastal waters.
- Image every 2 to 5 days at 10m, 20m or 60m spatial resolution (depending on the band)
- Submesoscale features are known to aggregate floating materials.



Sentinel-2 bands

MSI band	Descriptor	Wavelength	Resolution
Band 1	Coastal Aerosol	443 nm	60 m
Band 2	Blue	490 nm	10 m
Band 3	Green	560 nm	10 m
Band 4	Red	665 nm	10 m
Band 5	Red Edge 1	704 nm	20 m
Band 6	Red Edge 2	740 nm	20 m
Band 7	Red Edge 3	780 nm	20 m
Band 8	Near Infrared	842 nm	10 m
Band 8a	Narrow NIR	865 nm	20 m
Band 9	Water Vapour	940 nm	60 m
Band 10	SWIR Cirrus	1375 nm	60 m
Band 11	SWIR 1	1610 nm	20 m
Band 12	SWIR 2	2190 nm	20 m

Sentinel-2 does not have any band around 1732nm or other plastic absorption features



Detect plastic accumulations using Sentinel 2B

At a global level, plastic litter is estimated to constitute 83–87% of all marine litter
Plastic patches can be detected as floating debris segregated from vegetation and seaweed

Lauren Bierman

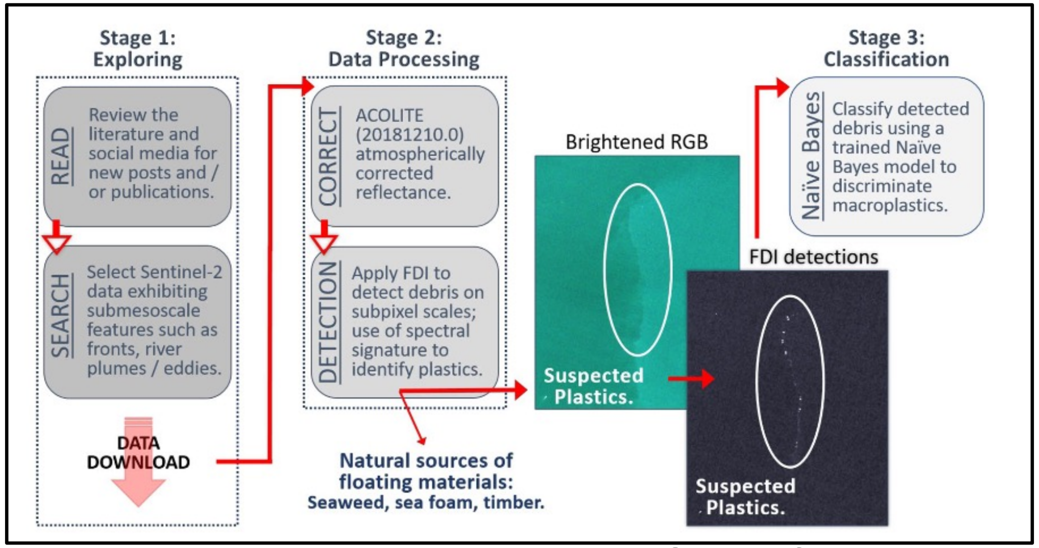
Sub-pixel Debris Detection:

- Based on a floating algae index developed by Hu (2009), red edge (RE) bands were incorporated to develop the **Floating Debris Index**:

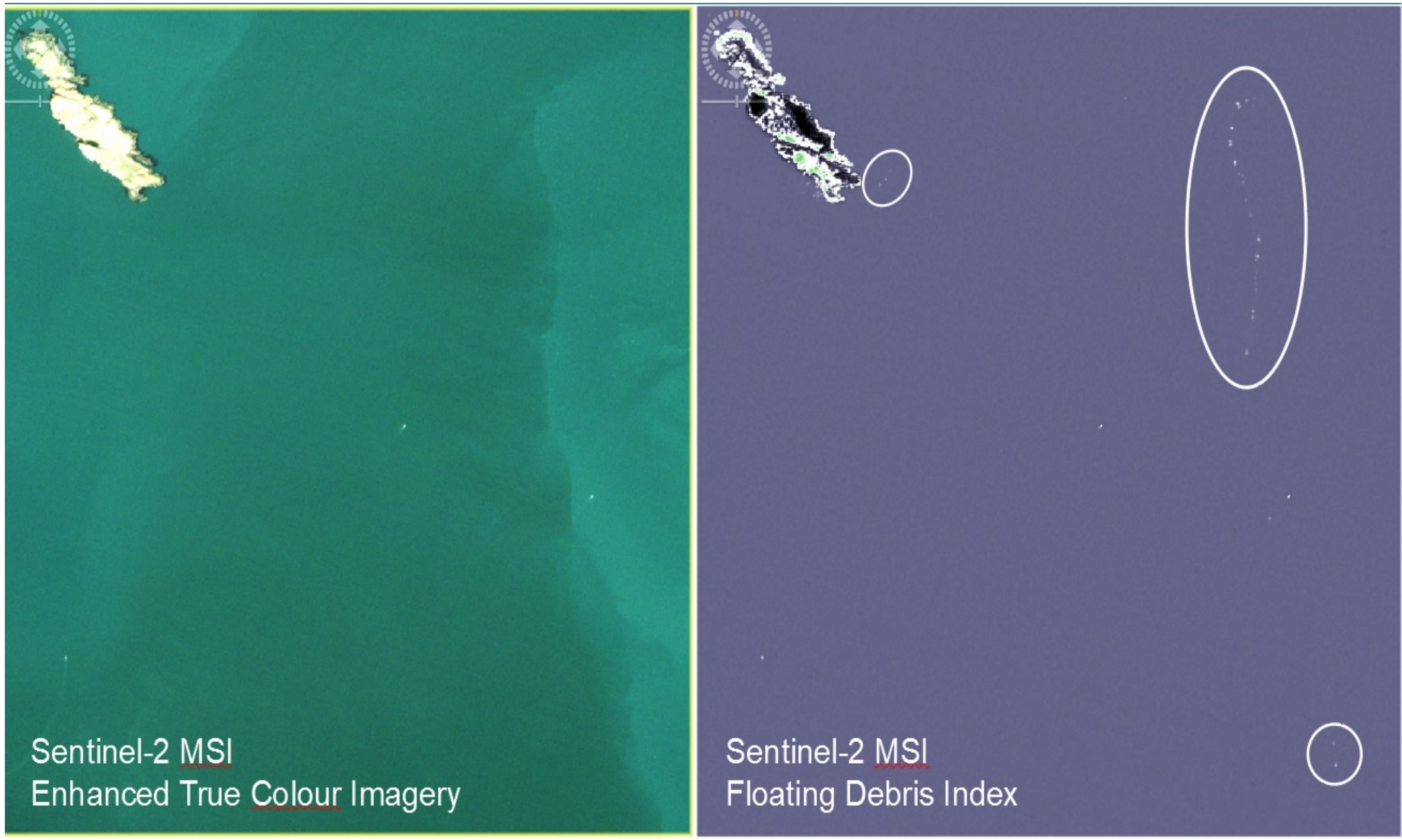
$$FDI = Rrs_{,NIR} - R_{rs,RE} - (R_{rs,SWIR} - R_{rs,RE})\frac{(\lambda_{NIR} - \lambda_{RE})}{(\lambda_{SWIR} - \lambda_{RE})}$$

Simultaneously, we applied a Normalised Difference Vegetation Index (NDVI) to segregate floating vegetation from other materials:

$$NDVI = \frac{(R_{rs,NIR} - R_{rs,RED})}{(R_{rs,NIR} + R_{rs,RED})} \quad (2)$$

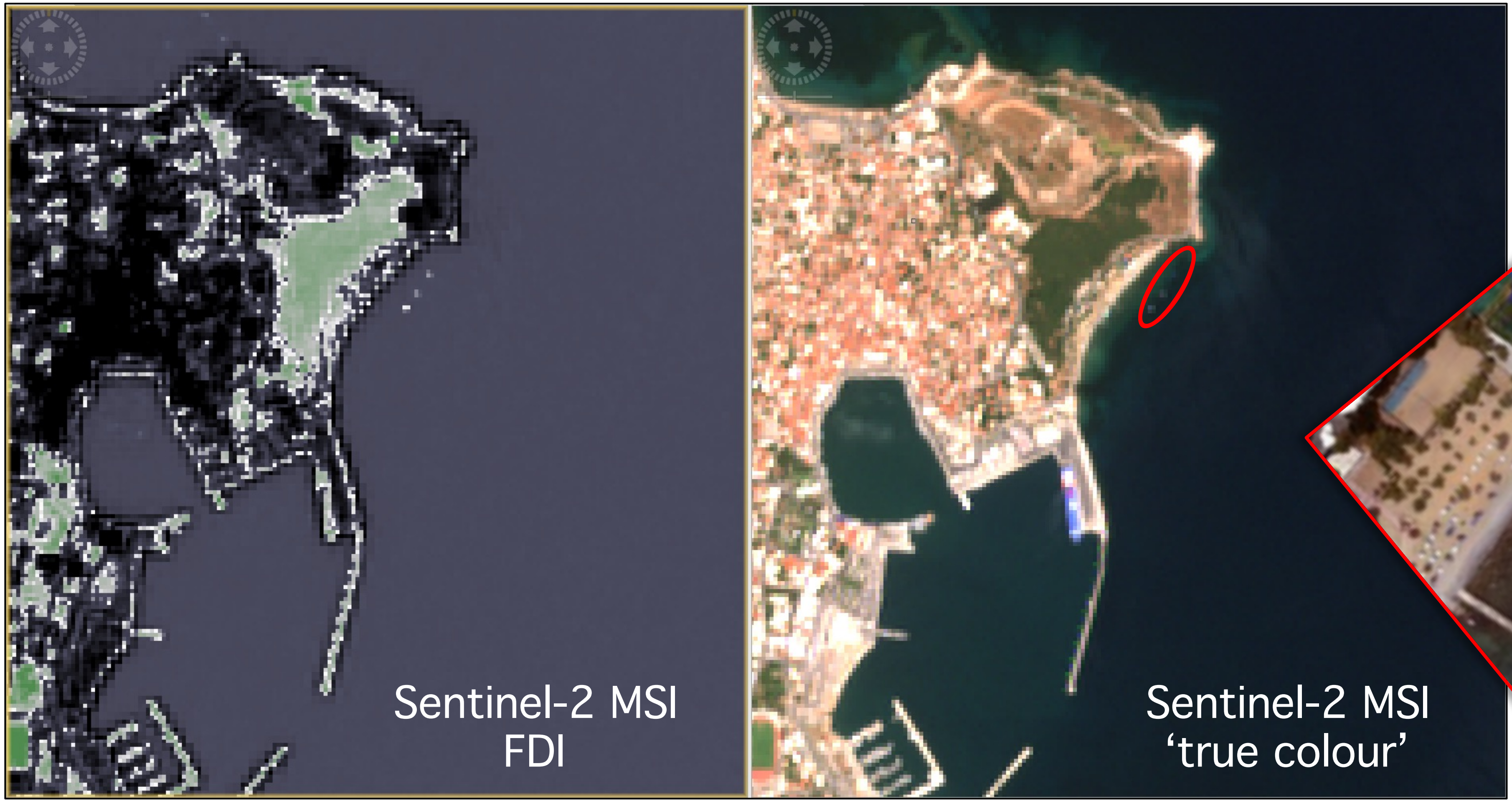


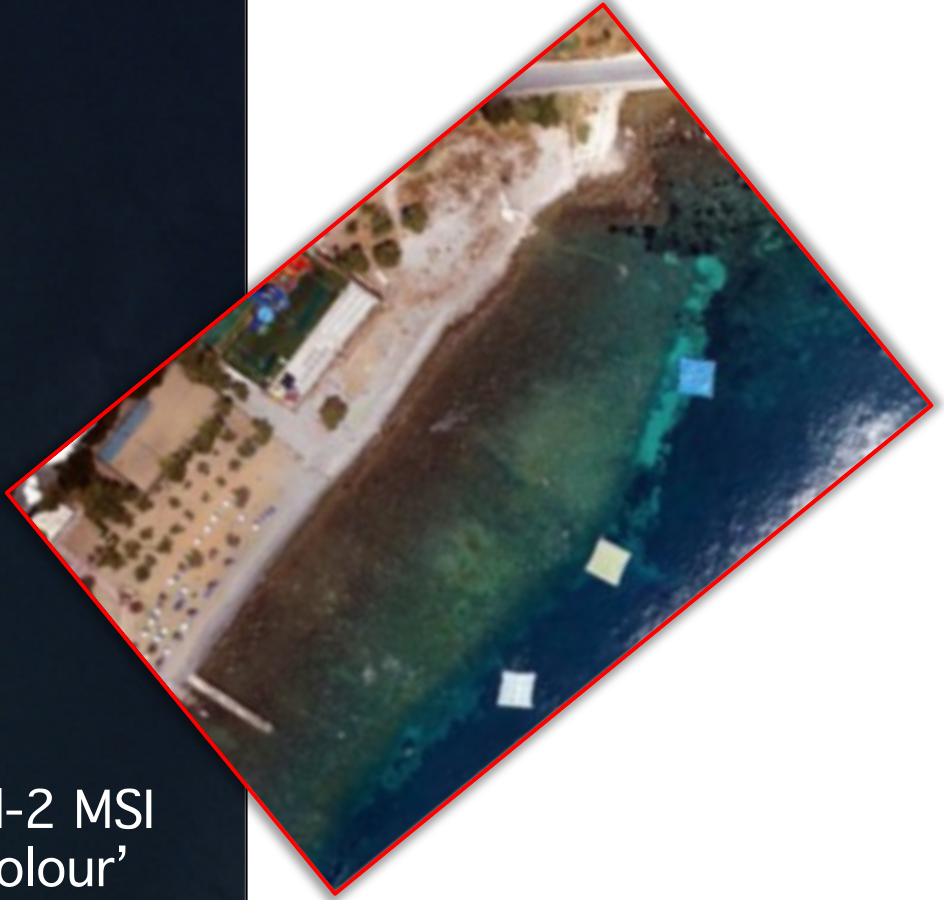
Bierman et al 2020, Scientific Reports



Validation of Subpixel Detection

MARINE REMOTE SENSING GROUP
DEPARTMENT OF MARINE SCIENCES
UNIVERSITY OF THE AEGEAN





10 m x 10 m Plastic Targets

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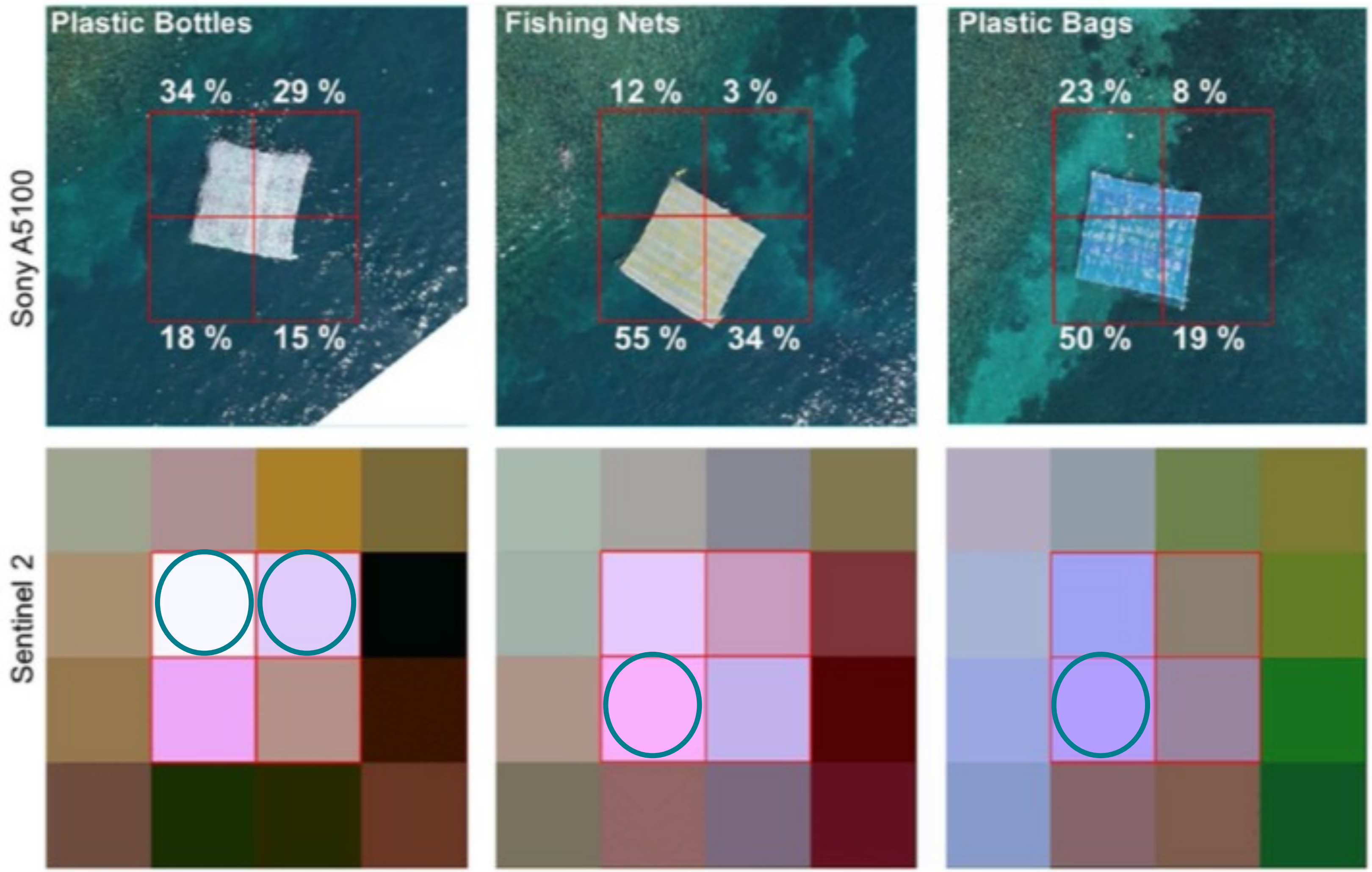
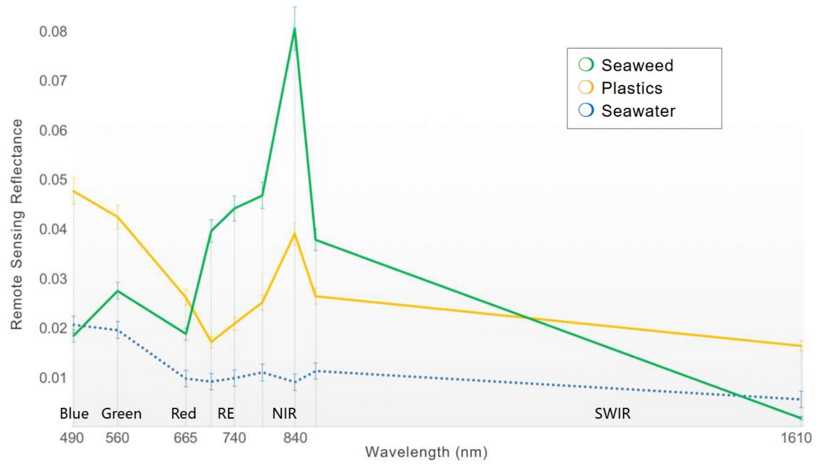


Topouzelis K, Papakonstantinou A, Garaba, S.P. (2019).
Detection of floating plastics from satellite and unmanned aerial systems (PlasticLitterProject 2018).
International Journal of Applied Earth Observation and Geoinformation



ESA Open Space Innovation Platform

25 Projects funded

New technologies (MWR, thermal..), AI for modelling and tracking, EO simulations…

HyperDrone

PI: Aser Mata

PML | Plymouth Marine Laboratory + SCOTTISH ASSOCIATION for MARINE SCIENCE

+ Support from Field Spectroscopy Facility NATURAL ENVIRONMENT RESEARCH COUNCIL

Development Of Spectroradiometric Proxies Of Shoreline Marine Plastic Debris For Satellite Validation Using Remotely Piloted Aircrafts

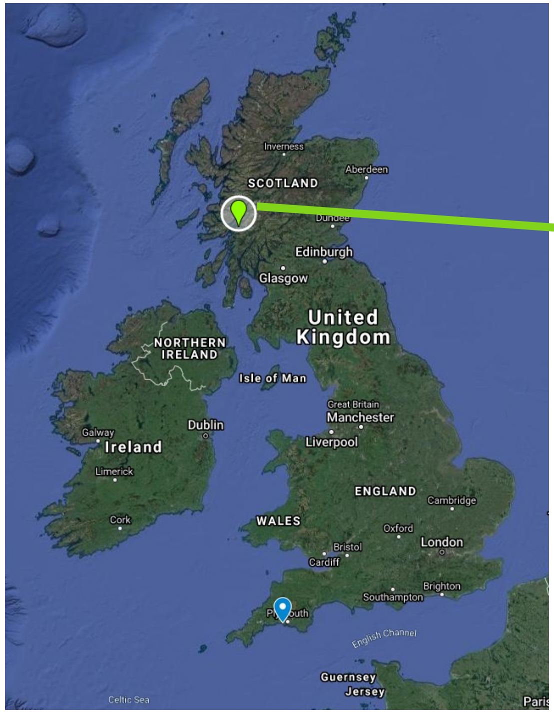
esa European Space Agency

Project funded via the ESA Open Space Innovation Platform (OSIP) Remote Sensing of Marine Litter Campaign

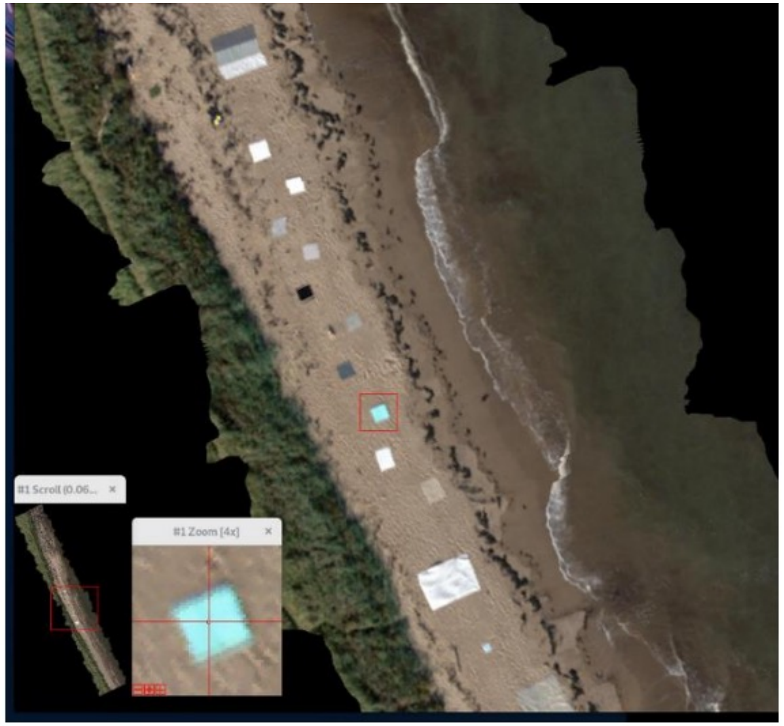
Tyninghame Beach (Scotland, UK)

HyperDrone

Reflectance data with uncertainty budgets from plastic targets on rocky and sandy shores will be collected using hyperspectral instruments on drones flying at different altitudes. Building on top of findings from the OPTIMAL project, HyperDrone seeks to provide proxies for plastic detection and precise spaceborne mission requirements.



Oban Airport, Scotland



HyperDrone objectives

O1: Build a **standardised dataset** of plastic spectra for remote sensing. Dataset to be made freely available

O2: Development of **proxies** for plastic debris detection on the shoreline

O3: Assessment of Ground Sampling Distance (GSD), Signal-to-Noise Ratio (SNR) and subpixel detection for future **Spaceborne Mission Requirements**

Hyperspectral sensors

Field Spectroscopy Facility
Natural Environment Research Council

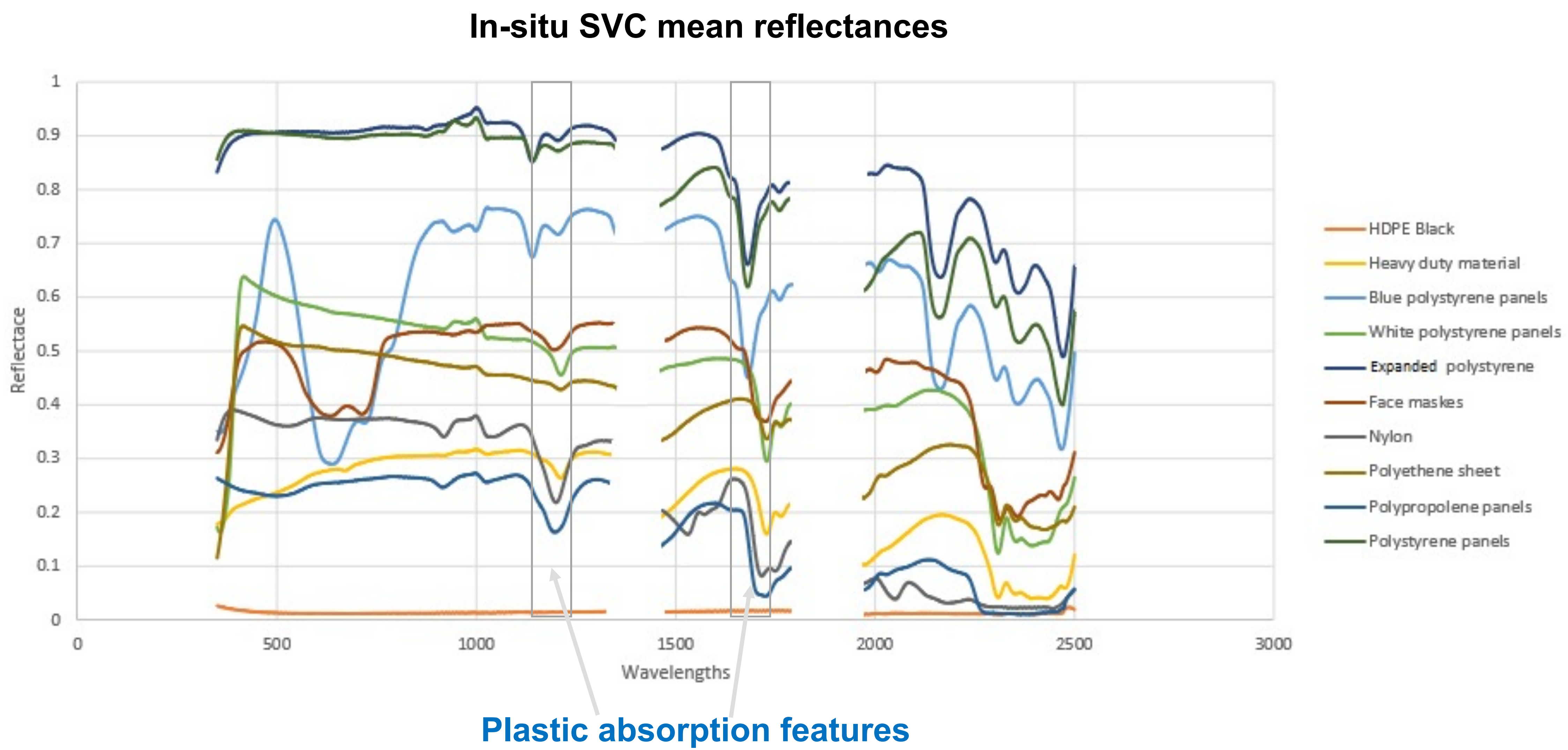
Headwall co-aligned VNIR+SWIR hyperspectral imager
400 -1000nm + 900 – 2500 nm

Spectra Vista Corporation (SVC) Handheld hyperspectral spectrometer
350 – 2500 nm

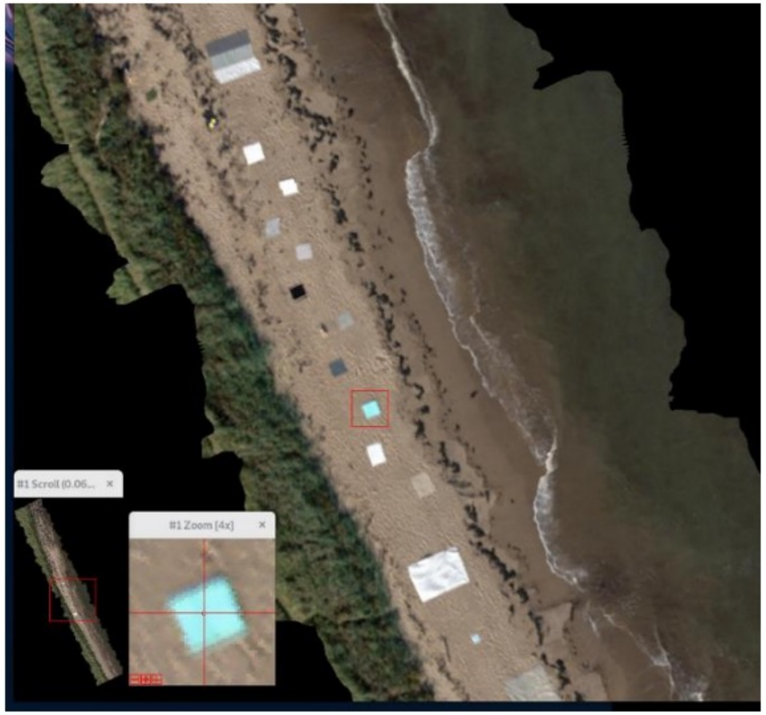
SCOTTISH ASSOCIATION for MARINE SCIENCE

Hyperspectral BaySpec OCI-F SWIR Hyperspectral sensor
900 – 1700 nm

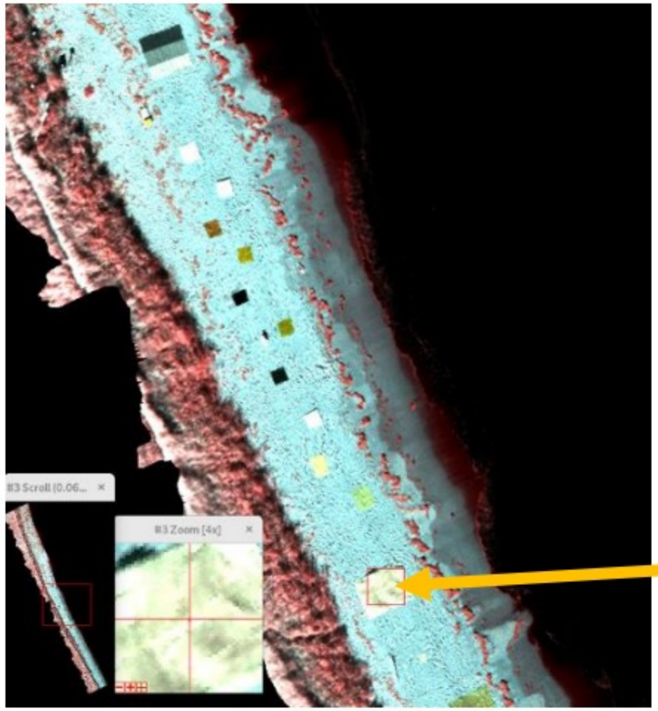
The project: tests and modelling



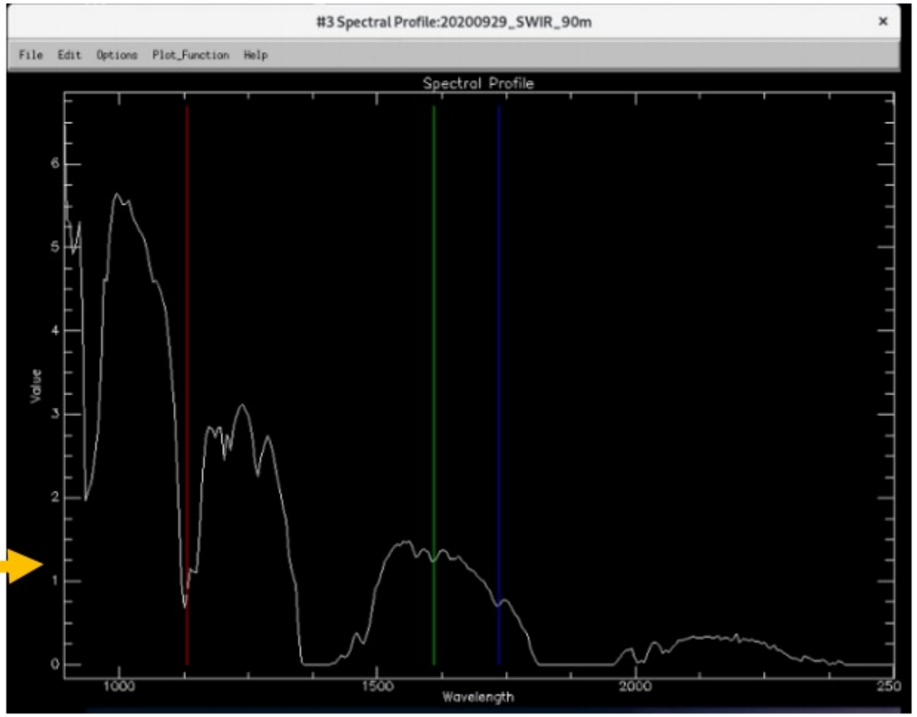
The project: tests and modelling



VNIR



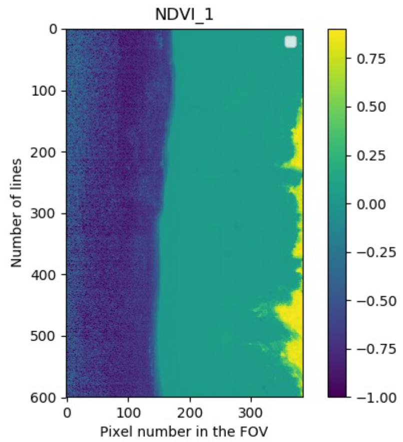
SWIR

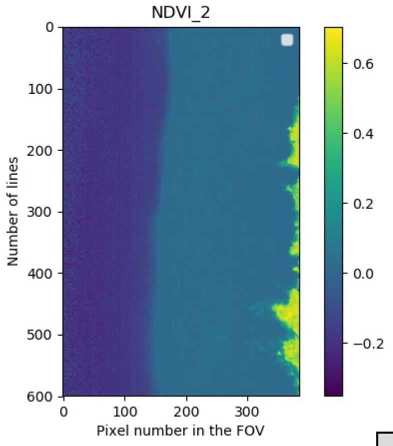


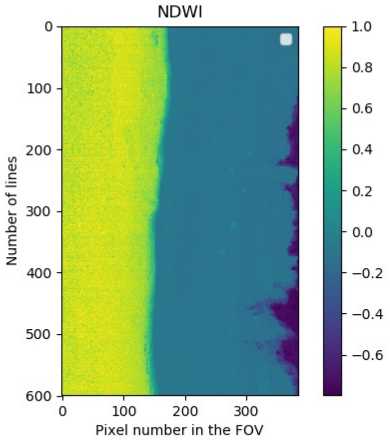
At sensor radiance from plastic target in the SWIR

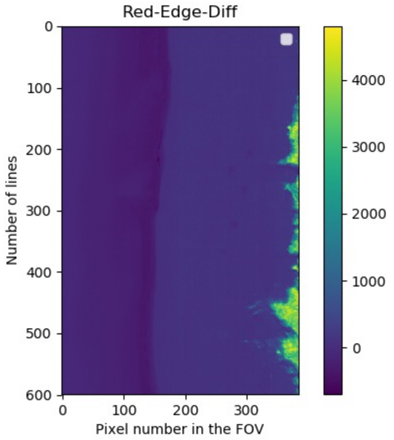
Combining different spectral indices

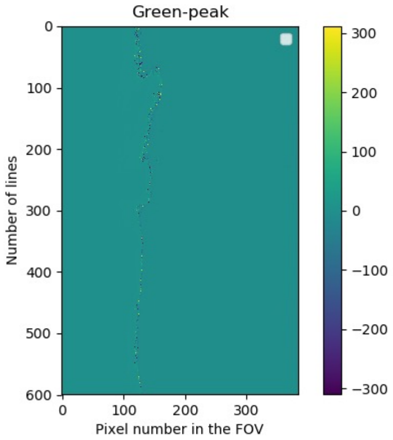
APPROXIMATE TRUE COLOUR

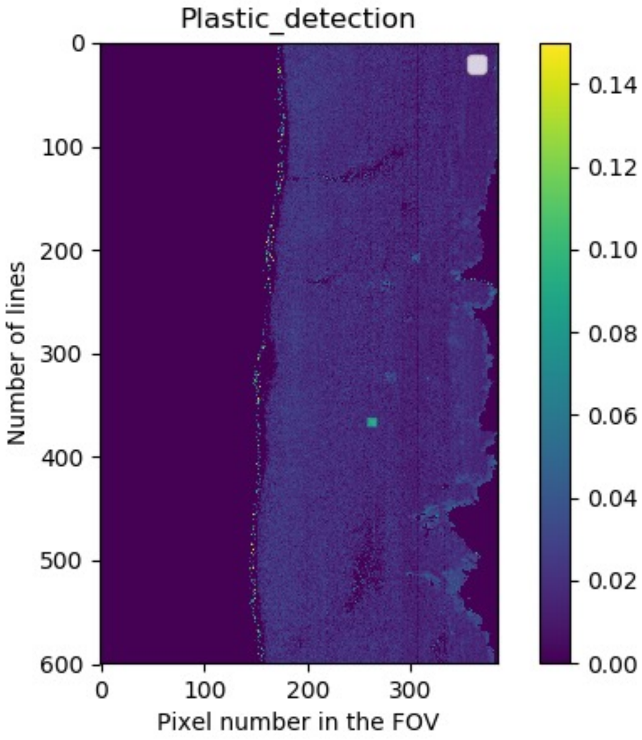


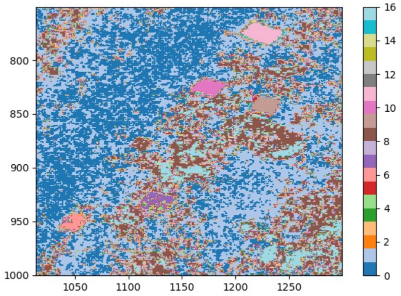


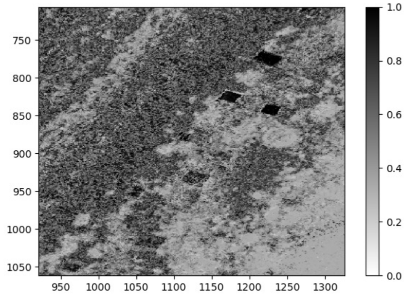












Conclusions:

-Plastic pollution is a complex problem
-Solutions and policies will need continuous monitoring and assessment
-Models need in situ data with standardised quality
-Remote sensing solutions will come from a range of different platforms (drones, airborne, satellites)
-Assumptions for atmospheric correction models will need to be re-evaluated

Thank you