PML | Plymouth Marine Laboratory

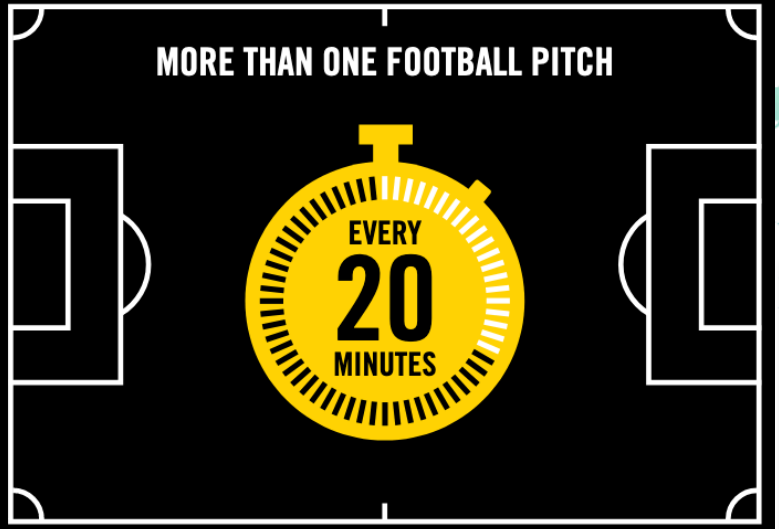
Listen to the ocean

Detecting floating macroplastics using high resolution optical satellite data.

Lauren Biermann, Dan Clewley, Ben O'Driscoll, Aser Mata, Liz Atwood, Victor Martinez Vicente, Tim vanEmmerik, Davida Streett, Yangrong Ling, Ellen Ramirez, Juan Valesco, Mary Crowley and Nikolai Maximenko.

esa

ACROSS JUST SIX COUNTRIES*
COCA-COLA, NESTLÉ, PEPSICO AND UNILEVER
CREATE ENOUGH PLASTIC POLLUTION**
TO COVER 83 FOOTBALL PITCHES EVERY DAY***

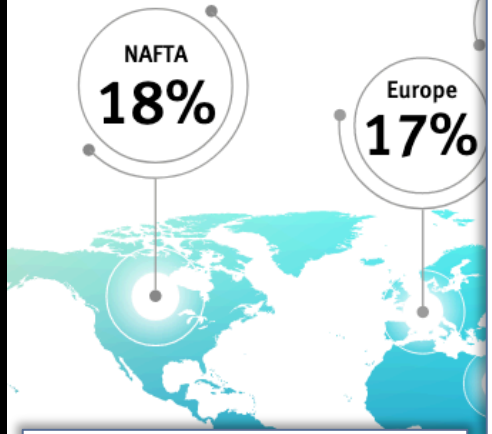


Open burning of their plastic pollution creates the same amount of CO^2 equivalent emissions as 2 million cars in the UK.

Emissions from open burning of Coca-Cola's plastic are as much as three-quarters of their global transport and distribution emissions.

75%

*China, India, the Philippines, Brazil, Mexico, Nigeria. **Plastic dumped or burnt ***To a depth of 10cm



The statistics are staggering:

- An estimated 8.3 billion metric tonnes of plastic have been produced since the 1950s.[10 11] That's one tonne for each of us born within the same timeframe.[12]
- Approximately 80 per cent has ended up in landfill, the oceans, loose in the environment, or being openly burnt. Less than a tenth has been recycled.[13]
- Globally, some 9–10 million tonnes of mismanaged post-consumer plastic waste ends up in the oceans every year.[14]
- About half the amount of plastic waste we produce globally is packaging material that is discarded after just one use.[15]

REUSE VS RECYCLING

Most of the companies focus on recycling, rather than reduction, as the way to address the problem. This is a mistake. Collection and recycling are an important part of the transition, but the right long-term approach is to replace single-use plastic with refillable and reusable alternatives. These are preferable for three key reasons:

1 Reusable and refillable packaging preserves more of the value and natural resources embedded in each bottle and box. By contrast, recycled single-use plastic is typically downcycled into synthetic fabrics, which then become waste again. Furthermore, downcycling maintains a continued need for virgin plastic, with the associated environmental costs.

2 From a technical and economic perspective, it is questionable whether it is possible actually to recycle such a large and ever-increasing volume of plastic. Only 14 per cent of plastic packaging is collected for recycling annually, and even in developed countries, recycling capacity often falls far short of total plastic use.

3 The challenges associated with recycling such a large amount of plastic are instead likely to lead to an increased emphasis on incineration. This generates potentially harmful emissions, including greenhouse gases. It is not a cost-effective or safe solution in developing countries, where capacity to manage and regulate incinerators is low, and the potential for major pollution is therefore greatly increased.

https://learn.tearfund.org/~/media/files/tilz/circular_economy/2020-tearfund-the-burning-question-en.pdf?la=en

Here's the basic problem: All used plastic can be turned into new things, but picking it up, sorting it out and melting it down is expensive. Plastic also degrades each time it is reused, meaning it can't be reused more than once or twice.

On the other hand, new plastic is cheap. It's made from oil and gas, and it's almost always less expensive and of better quality to just start fresh.

All of these problems have existed for decades, no matter what new recycling technology or expensive machinery has been developed. In all that time, less than 10 percent of plastic has ever been recycled. But the public has known little about these difficulties.

It could be because that's not what they were told.

Starting in the 1990s, the public saw an increasing number of commercials and messaging about recycling plastic.

"The bottle may look empty, yet it's anything but trash," says one ad from 1990 showing a plastic bottle bouncing out of a garbage truck. "It's full of potential. ... We've pioneered the country's largest, most comprehensive plastic recycling program to help plastic fill valuable uses and roles."

It may have sounded like an environmentalist's message, but the ads were paid for by the plastics industry, made up of companies like Exxon, Chevron, Dow, DuPont and their lobbying and trade organizations in Washington.

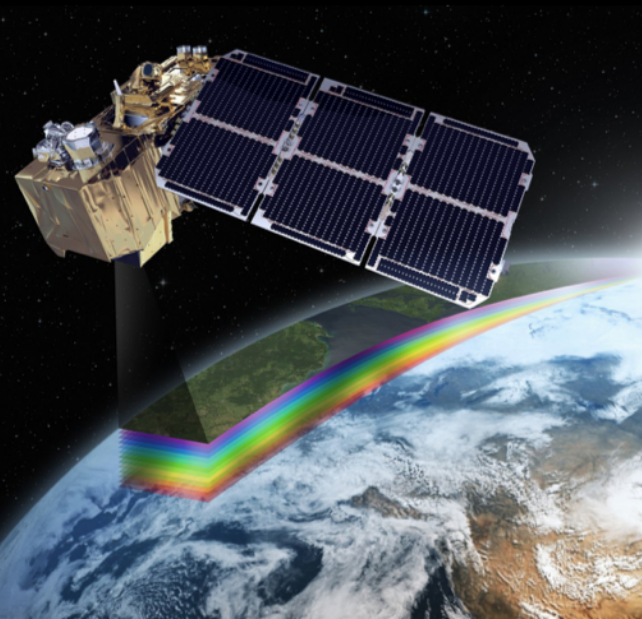
Industry companies spent tens of millions of dollars on these ads and ran them for years, promoting the benefits of a product that, for the most part, was buried, was burned or, in some cases, wound up in the ocean.

Documents show industry officials knew this reality about recycling plastic as far back as the 1970s.

Satellites to Detect Floating Macroplastics

Satellite data are not yet widely used for the detection of macroplastics in the marine environment.

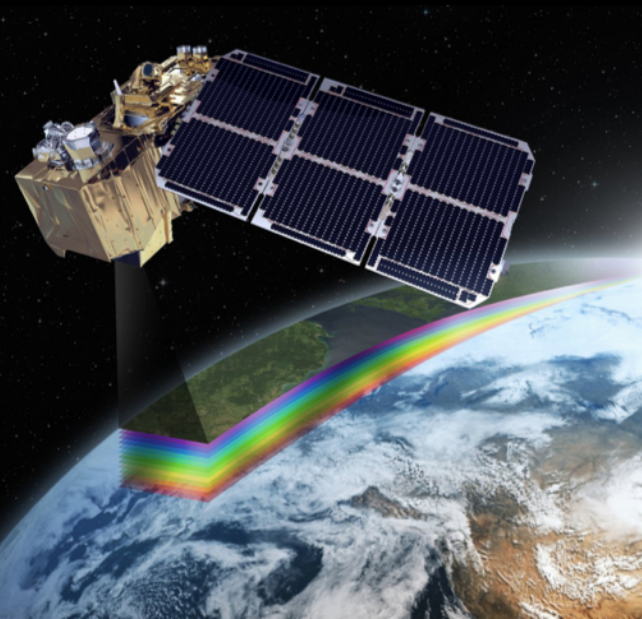
- S-2A & B launched in 2015 and 2017.
- Developed for terrestrial services, but coverage includes coastal waters.
- Image every 2 to 5 days at 10 m.
- Limitations for detecting plastics incl. cloudiness & wavecaps; reliant on **submesoscale features**.



Satellites to Detect Floating Macroplastics

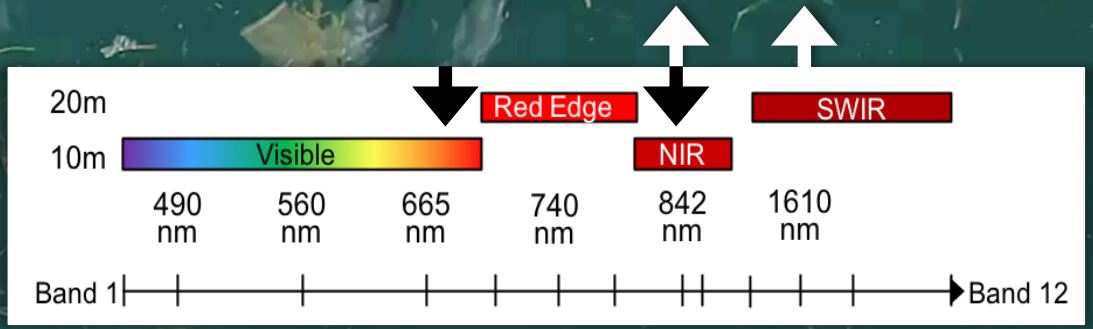
Satellite data are not yet widely used for the detection of macroplastics in the marine environment.

- S-2A & B launched in 2015 and 2017.
- Developed for terrestrial services, but coverage includes coastal waters.
- Image every 2 to 5 days at 10 m.
- Limitations for detecting plastics incl. cloudiness & wavecaps; reliant on **submesoscale features**.



Normalised Difference Vegetation Index (NDVI)

Floating Debris Index (FDI)



Video from
@HFiskJohnson

Processing and FDI sub-pixel detection

Atmospheric Correction:

- ACOLITE processor (RBINS) for Sentinel-2 conserves NIR to SWIR wavelengths – Dark Spectrum Fitting.

Floating Debris Index:

- Based on a floating algae index Hu (2009), red edge (RE) bands were incorporated to develop the **Floating Debris Index (FDI)**
- Leverages difference between NIR, and baseline reflectance NIR.

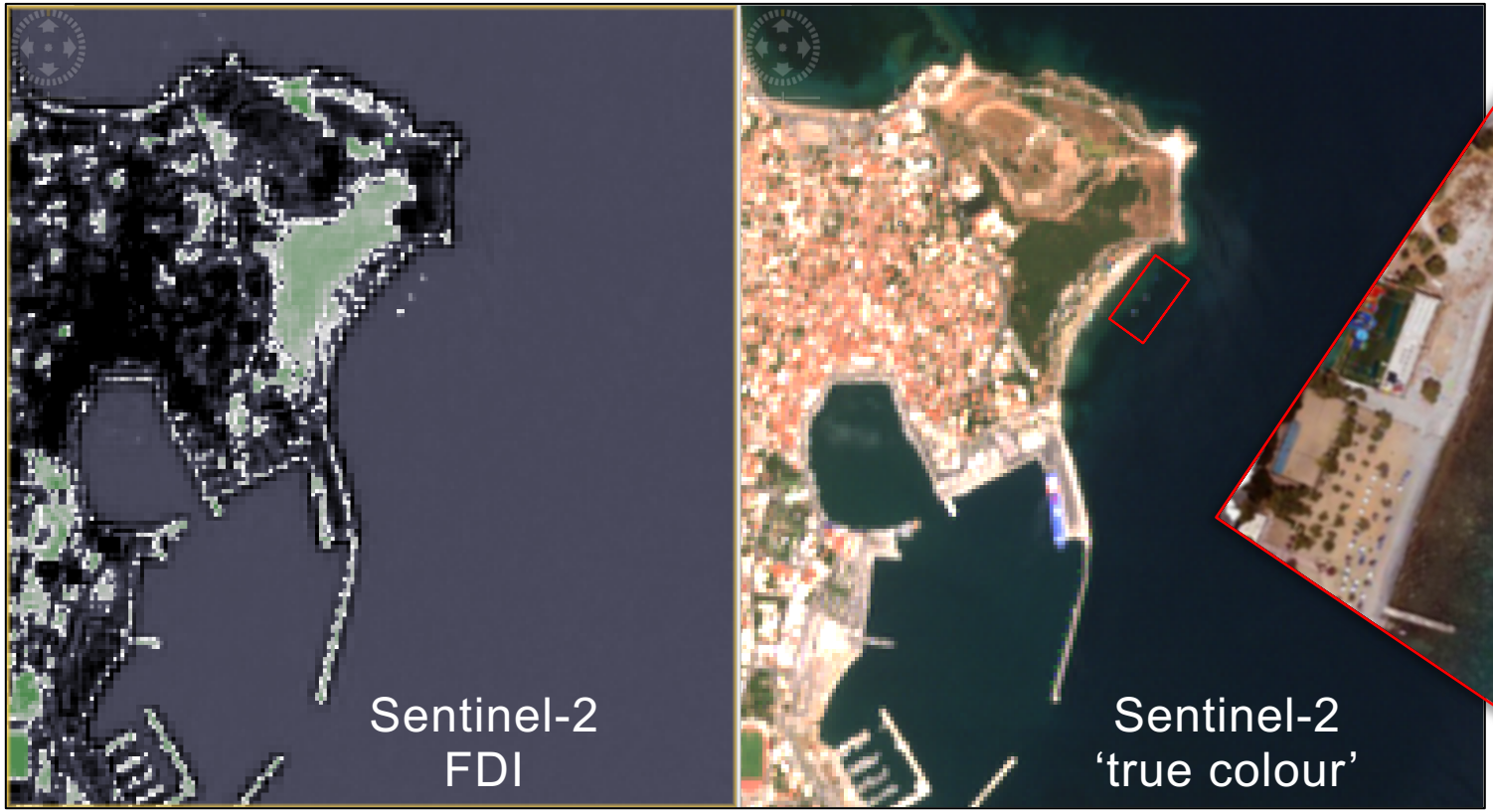
$$FDI = R_{rs,NIR} - R'_{rs,NIR}$$

$$R'_{rs,NIR} = R_{rs,RE2} + (R_{rs,SWIR1} - R_{rs,RE2}) \times \frac{(\lambda_{NIR} - \lambda_{RED})}{(\lambda_{SWIR1} - \lambda_{RED})} \times 10$$

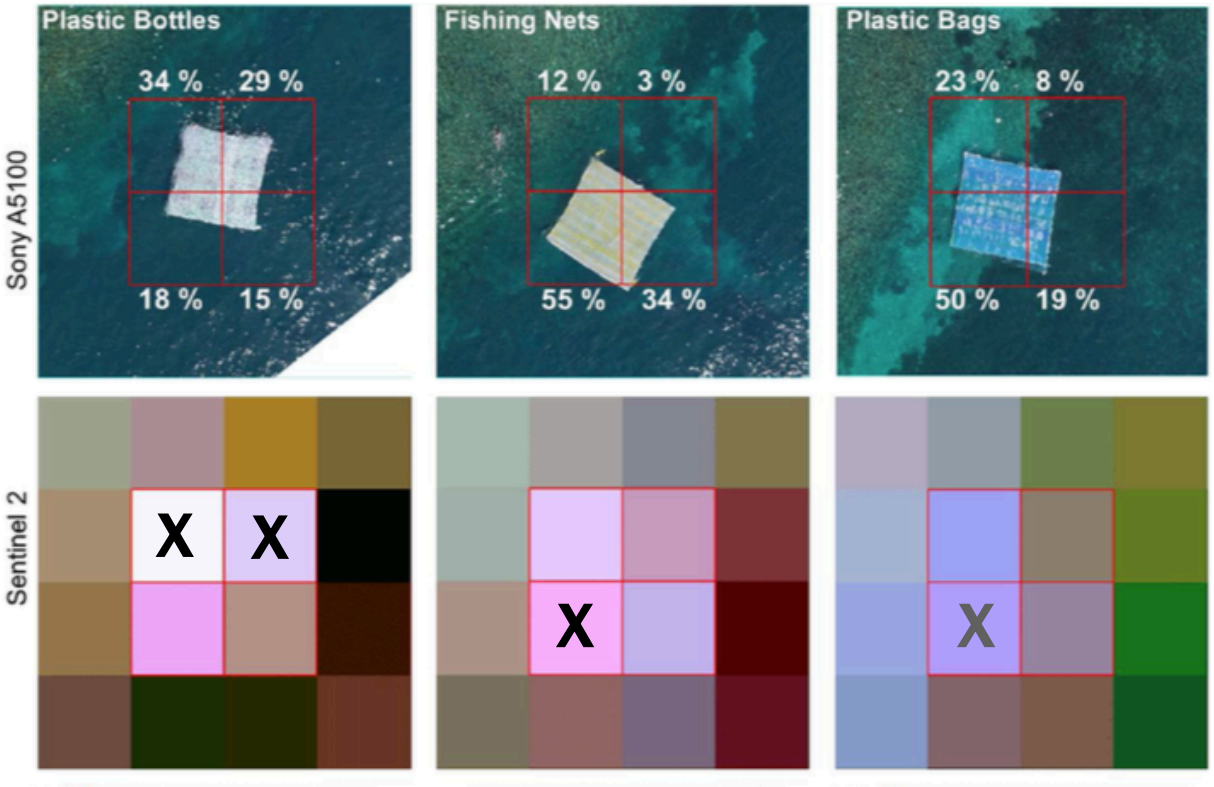
Sub-pixel detection

Three 10m x 10m Plastic Targets

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



10 m x 10 m Plastic Targets



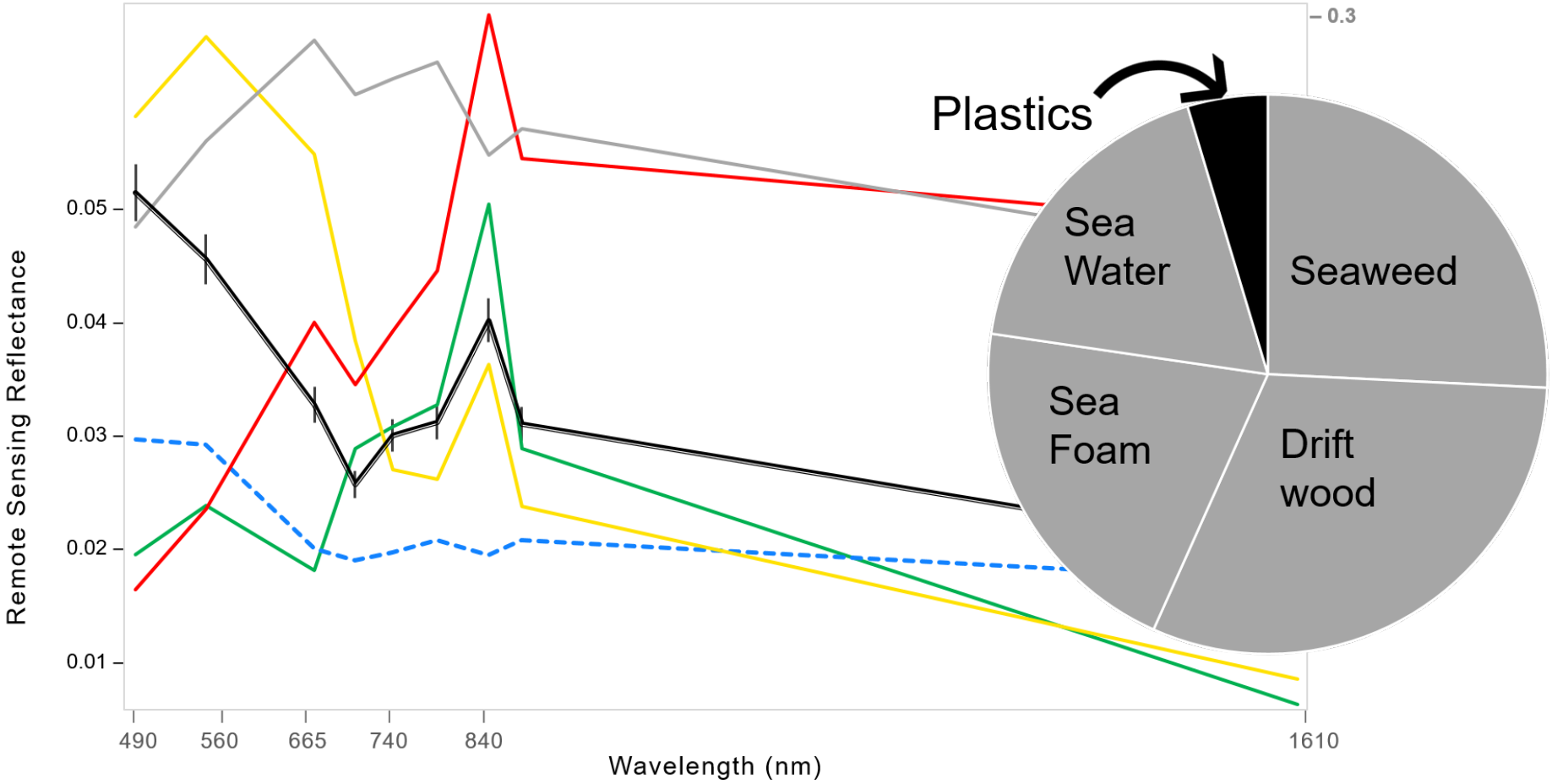
MARINE REMOTE SENSING GROUP
DEPARTMENT OF MARINE SCIENCES
UNIVERSITY OF THE AEGEAN

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.

Spectral Signatures – Plastics & Natural Materials

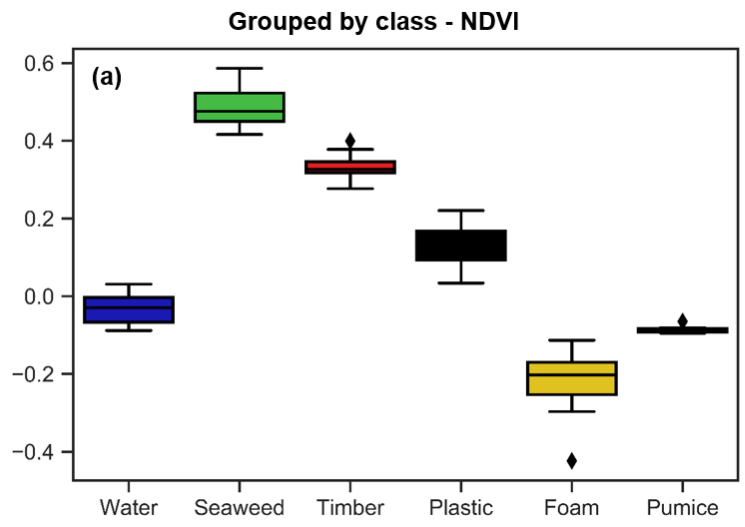


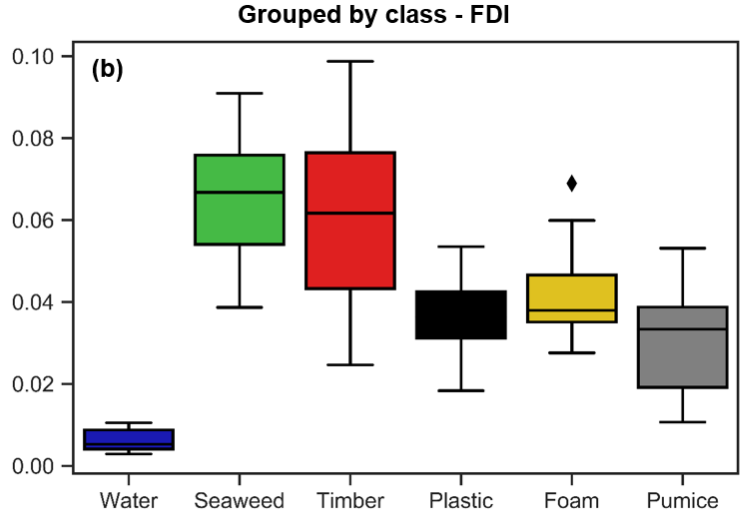
Validated Plastics in the Marine Environment

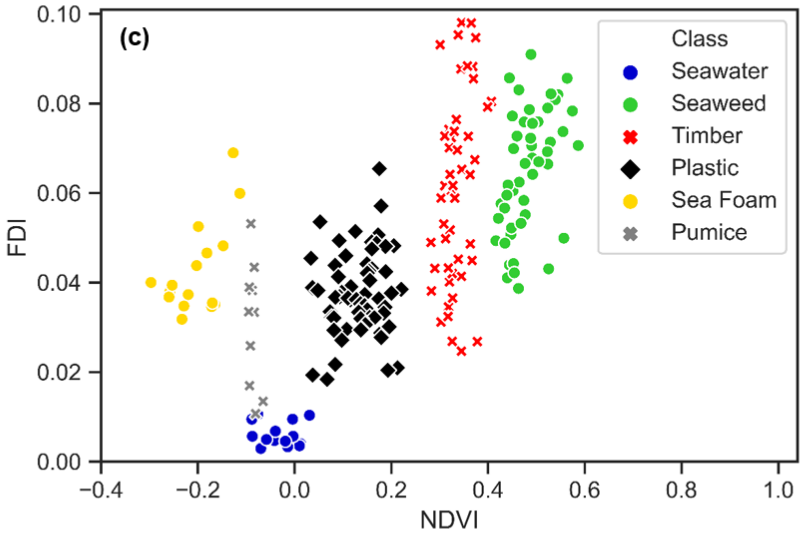
- KwaZulu Natal experienced severe flooding in April 2019.
- Plastics choked Durban harbour and the beaches.
- We detected well over 50 pixels of ‘validated’ ocean plastics.

Photos by Grant Blakeway (left) and Sifiso Mngoma (above)

Identifying floating materials in the marine environment.







Shown in 2-variable feature space of NDVI and FDI, clustering of materials is evident.

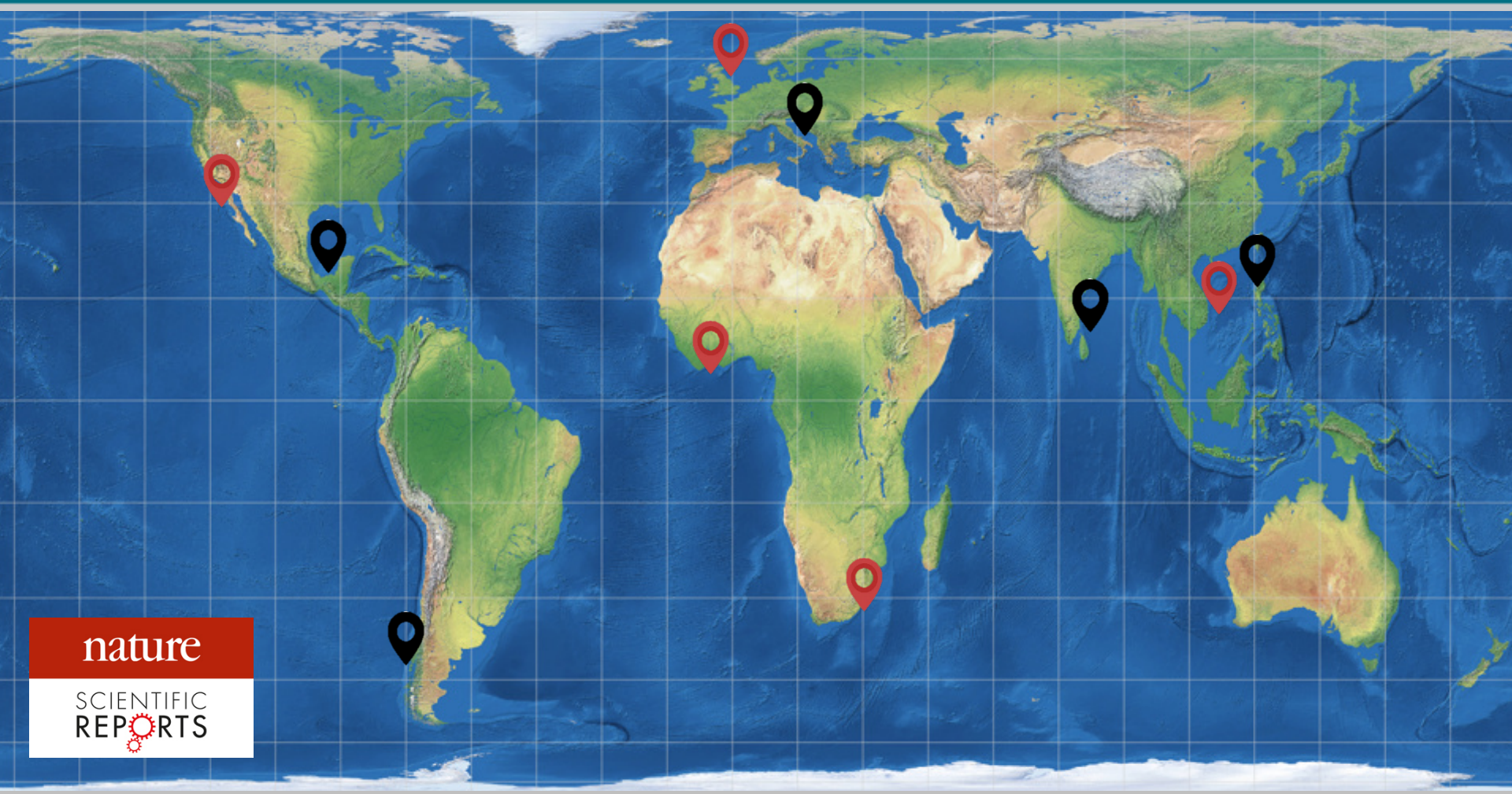
Naïve Bayes Classification of Plastics

- Using all these validated datasets of plastics and natural materials for training, we tested if it was possible to automate classification of detected materials using a Naïve Bayes (Bayesian) ML approach.
- Requires only a small number of samples to train and assumes that predictors / features are independent.
- For FDI, NDVI and several MSI remote sensing bands, it computes the probability of a detected pixel belonging to each of the classes, and assigns it to the one with highest probability.

Naïve Bayes Classification of Plastics

- Using all these validated datasets of plastics and natural materials for training, we tested if it was possible to automate classification of detected materials using a Naïve Bayes (Bayesian) ML approach.
- Requires only a small number of samples to train and assumes that predictors / features are independent.
- For FDI, NDVI and several MSI remote sensing bands, it computes the probability of a detected pixel belonging to each of the classes, and assigns it to the one with highest probability.

PML | Plymouth Marine Laboratory

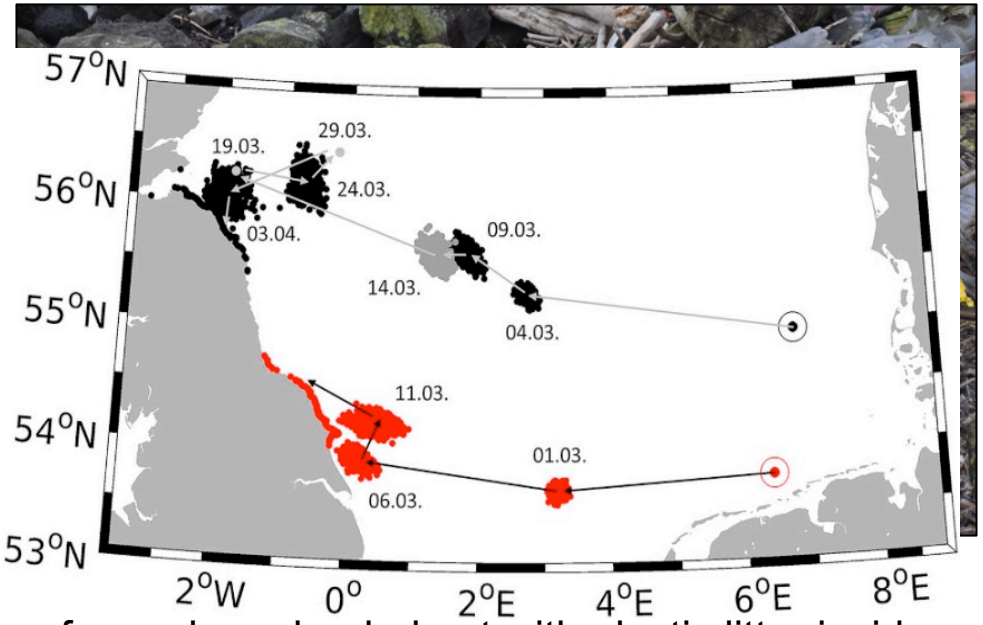


nature

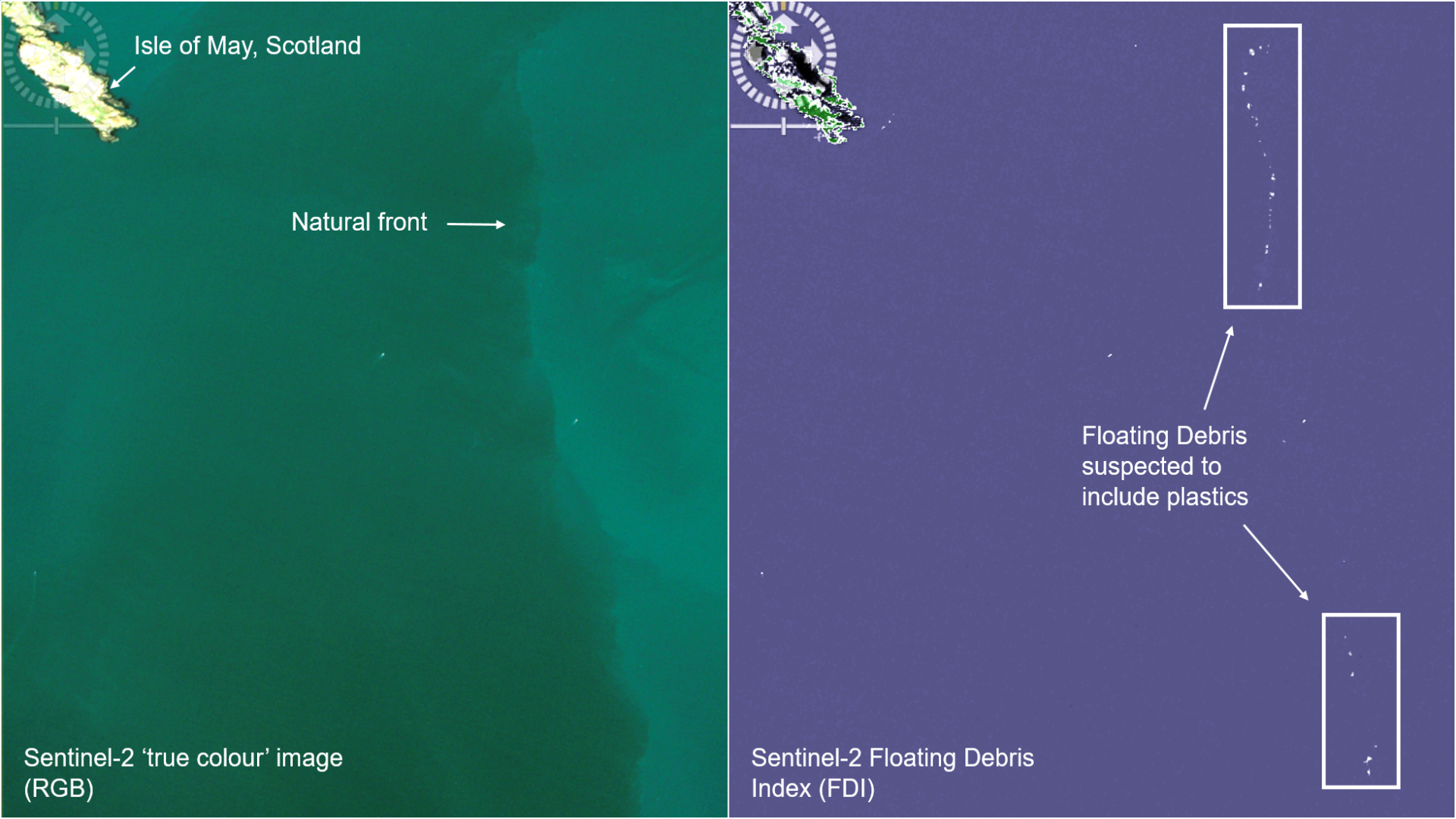
SCIENTIFIC REPORTS

Study Site 1: East Coast of Scotland, UK

- Marine Conservation Society UK: across Scottish beaches, litter (mainly plastics & polystyrene) increased by 14% since 2017.
- Extreme westward surface drift in the North Sea: Public reports of stranded drifters & Lagrangian tracking (Stanev et al., 2019)

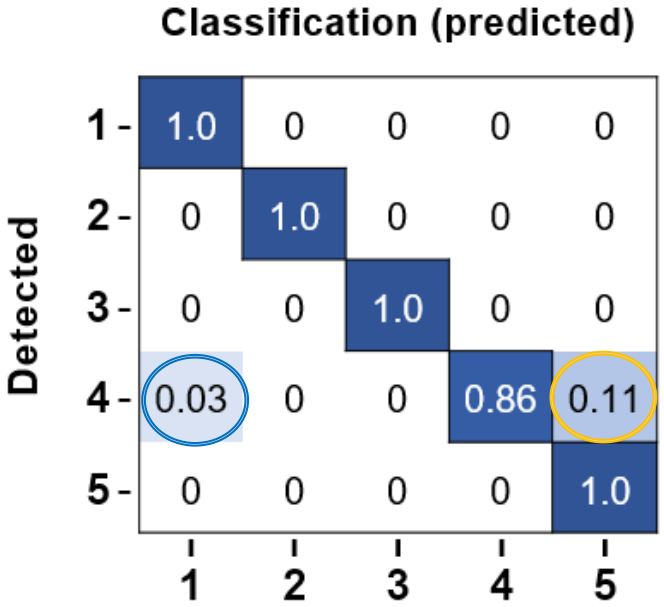


of a seal pup hauled out with plastic litter inside the Firth of Forth, Scotland - @MattIDCarter


Isle of May, Scotland
Natural front
Floating Debris suspected to include plastics
Sentinel-2 'true colour' image (RGB)
Sentinel-2 Floating Debris Index (FDI)

Results:

Across all sites, suspected plastics (manually selected) were classified as plastics by the Naïve Bayes model with an accuracy of **86%** :



1= seawater
2= seaweed
3= driftwood
4= plastics
5= sea foam

Canada	100%	Polystyrenes
Ghana	87%	
Scotland	83%	
Vietnam	77%	High Turbidity

What we've demonstrated:

- Plastic has a relatively distinct spectral signature & the FDI helps to detect floating objects on subpixel scales.
- Possible to discriminate between floating objects using Naïve Bayes (Bayesian) ML classification approach.
- Tricky! More work needed on **atmospheric correction** (AC), adjacency effects, and the impacts of **high turbidity** including in **river waters**.
- We need more variable data from a range of marine environments for improved ML training algorithms and to serve as validation data.

What we've demonstrated:

- Plastic has a relatively distinct spectral signature & the FDI helps to detect floating objects on subpixel scales.
- Possible to discriminate between floating objects using Naïve Bayes (Bayesian) ML classification approach.
- Tricky! More work needed on **atmospheric correction** (AC), adjacency effects, and the impacts of **high turbidity** including in **river waters**.
- We need more variable data from a range of marine environments for improved ML training algorithms and to serve as validation data.

WAGENINGEN
UNIVERSITY & RESEARCH

esa

Plastic Plants: Saigon River

- Hyacinth is a pest / invasive species.
- Transports >70% of river plastics.
- Patches detectable by Sentinel-2.
- ML classification library for rivers.

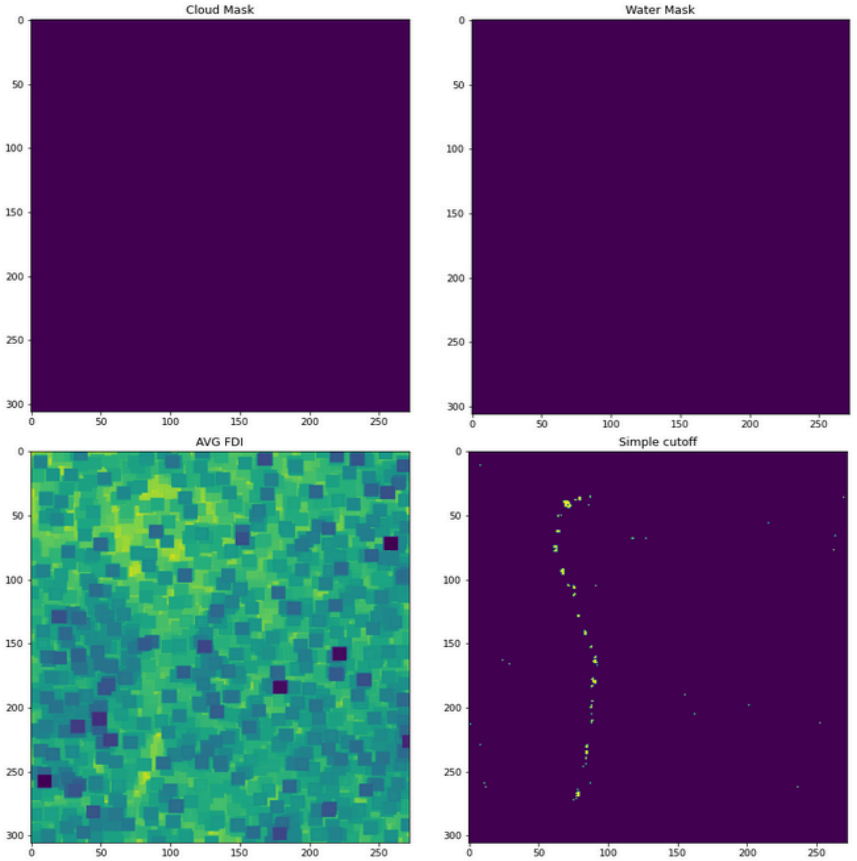
AIR-SOS: tidal & turbid coastal waters

esa

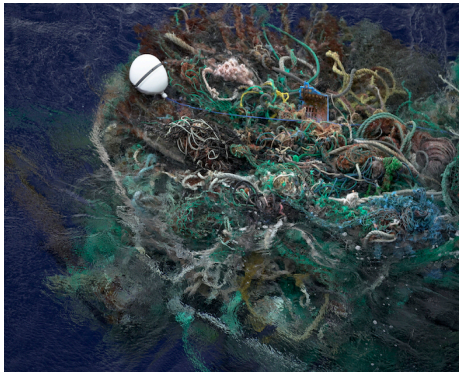
- Seaplane flying Go-Pro, MAIA, Micasense RE.
- Elbe river mouth.
- Library of all floating materials plus water types.
- Commercial flights – future?

Patchwise Normalisation for Feature Extraction and Detection – PaNFED

- Data-driven alternative to Atmospheric Correction.
- Still in early stages, testing by Ben O'Driscoll now being funded by NEODAAS.
- Automated processing chain for S2 floating debris detection, application of PaNFED, ML classification.



GIANT Ocean: Ghost nets in the GPGP



PML | Plymouth Marine Laboratory

Thank you

Listen to the ocean

NEODAAS

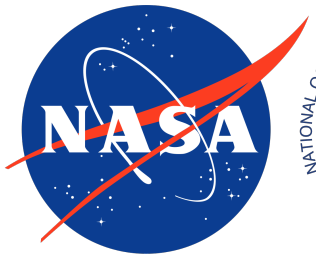
NERC Earth Observation Data Acquisition and Analysis Service

National Centre for Earth Observation

NATURAL ENVIRONMENT RESEARCH COUNCIL

MARINE REMOTE SENSING GROUP

DEPARTMENT OF MARINE SCIENCES
UNIVERSITY OF THE AEGEAN



Marine Atmospheric Correction (AC):

- Removes atmospheric components from ‘true’ ocean surface reflectance values.
- Marine ACs often rely on the black pixel assumption of near-zero water-leaving radiances in the NIR.
- This will also remove any spectral signals from floating debris…
- Trialing with Sen2Cor and POLYMER.
- ACOLITE processor (RBINS) for Sentinel-2 conserves NIR to SWIR wavelengths – Dark Spectrum Fitting AC approach.