Detecting Floating Debris
Towards a method for detecting macroplastics in coastal waters using data collected by earth observation satellites.

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Marine Litter and Floating Macroplastics

- **Macro**plastics = any plastics or plastic fragments larger than 5mm.
- Majority of micro- to macroplastics enter our coastal waters from land-based sources.
Satellites to detect floating 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
Using Sentinel-2 to detect floating debris

• Sentinel-2A & B satellites were launched in 2015 & 2017.
• Developed for terrestrial services, but coverage includes coastal waters.
• Image every 2 to 5 days at 10m spatial resolution.
• Submesoscale features are known to aggregate floating materials.
<table>
<thead>
<tr>
<th>MSI band</th>
<th>Descriptor</th>
<th>Wavelength</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1</td>
<td>Coastal Aerosol</td>
<td>443 nm</td>
<td>60 m</td>
</tr>
<tr>
<td>Band 2</td>
<td>Blue</td>
<td>490 nm</td>
<td>10 m</td>
</tr>
<tr>
<td>Band 3</td>
<td>Green</td>
<td>560 nm</td>
<td>10 m</td>
</tr>
<tr>
<td>Band 4</td>
<td>Red</td>
<td>665 nm</td>
<td>10 m</td>
</tr>
<tr>
<td>Band 5</td>
<td>Red Edge 1</td>
<td>704 nm</td>
<td>20 m</td>
</tr>
<tr>
<td>Band 6</td>
<td>Red Edge 2</td>
<td>740 nm</td>
<td>20 m</td>
</tr>
<tr>
<td>Band 7</td>
<td>Red Edge 3</td>
<td>780 nm</td>
<td>20 m</td>
</tr>
<tr>
<td>Band 8</td>
<td>Near Infrared</td>
<td>842 nm</td>
<td>10 m</td>
</tr>
<tr>
<td>Band 8a</td>
<td>Narrow NIR</td>
<td>865 nm</td>
<td>20 m</td>
</tr>
<tr>
<td>Band 9</td>
<td>Water Vapour</td>
<td>940 nm</td>
<td>60 m</td>
</tr>
<tr>
<td>Band 10</td>
<td>SWIR Cirrus</td>
<td>1375 nm</td>
<td>60 m</td>
</tr>
<tr>
<td>Band 11</td>
<td>SWIR 1</td>
<td>1610 nm</td>
<td>20 m</td>
</tr>
<tr>
<td>Band 12</td>
<td>SWIR 2</td>
<td>2190 nm</td>
<td>20 m</td>
</tr>
</tbody>
</table>

The bands are color-coded as follows:
- **Red Edge**: 700-750 nm
- **Visible**: 400-700 nm
- **Near Infrared (NIR)**: 750-1000 nm
- **Short Wave Infrared (SWIR)**: 1000-2500 nm
Processing and sub-pixel detection

Atmospheric Correction:

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

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:

$$ FDI = R_{rs, NIR} - R_{rs, RE} - (R_{rs, SWIR} - R_{rs, RE}) \frac{(\lambda_{NIR} - \lambda_{RE})}{(\lambda_{SWIR} - \lambda_{RE})} $$
10 m x 10 m Plastic Targets

Sentinel-2 MSI
‘true colour’

Sentinel-2 MSI
FDI
10 m x 10 m Plastic Targets

Macrolgae

- Sargassum seaweed is increasingly widespread.
- Floating ‘rafts’ can be up to seven meters deep.
Study Site: South Gabriola, Canada

- Timber rafting site with woody debris evident in high res. data.
- Also documented plastic pollution.
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Study Site: Durban, South Africa

• Over several days in April 2019, the coastal city of Durban, South Africa, experienced severe flooding.

• 60 people died, houses and roads were washed away, and enormous amounts of debris including plastics choked the harbour and beaches.

• Photos kindly shared by Grant Blakeway, with permission to share.
Seaweed
X Plastics
○ Seawater
+ Debris
Study Site: East Coast of Scotland, UK

- Marine Conservation Society: across 135 Scottish beaches, litter (mainly plastics and polystyrene) increased by 14% since 2017.
- No *in situ* data or high resolution imagery from PLANET.
- Sea Mammal Research Unit student @MattIDCarter shared pictures showing pervasiveness of litter along the Firth of Forth.
### Stage 1: Exploring

**READ**
Review the literature and social media for new posts and / or publications.

**SEARCH**
‘By Eye’: select cloud-free and wavecap-free Sentinel-2 imagery with fronts / eddies.

**DATA DOWNLOAD**

### Stage 2: Data Processing

**CORRECT**
ACOLITE (20181210.0) atmospherically corrected reflectance.

**DETECT**
Open RGB image in SNAP; apply the FDI and NDVI algorithms. ‘By Eye’:

- **Library**: Boats, foam, buoys, glint.
- **Vegetation**: Floating plant materials, macroalgae.

### Stage 3: Identification

**MAP ref**
Extract FDI and NDVI values; examine against MAP_ref scatter plot to identify potential macroplastics.

**FDI detections**

**Brightened RGB**

**Suspected Plastics.**
Late Island, Tonga

Rafts of pumice

Seaweed
Plastics
Seawater
Timber
In conclusion:

• Plastic has a distinct spectral signature.
• The FDI has proven to be successful at detecting floating objects on subpixel scales.
• In a 2-variable feature space, plastics can already be distinguishable from other floating objects, especially pumice and plants.
• Inherent uncertainty resulting from target ambiguity - ruling out other forms of debris helps, but *in situ* validation is needed.
• More work to be done on the atmospheric correction, and for unmixing of pixels to determine composition.
• The future is automated!
With special thanks to:

Sevrine Sailley (NERC JaSS project), Stephen Goult and the NEODAAS team.
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.
- Trialling with Sen2Cor and POLYMER.
- ACOLITE processor (RBINS) for Sentinel-2 conserves NIR to SWIR wavelengths - Dark Spectrum Fitting AC approach.
