# Observation of Marine Litter Windrows with Sentinel-2 as a Strategic Target for Plastic Pollution

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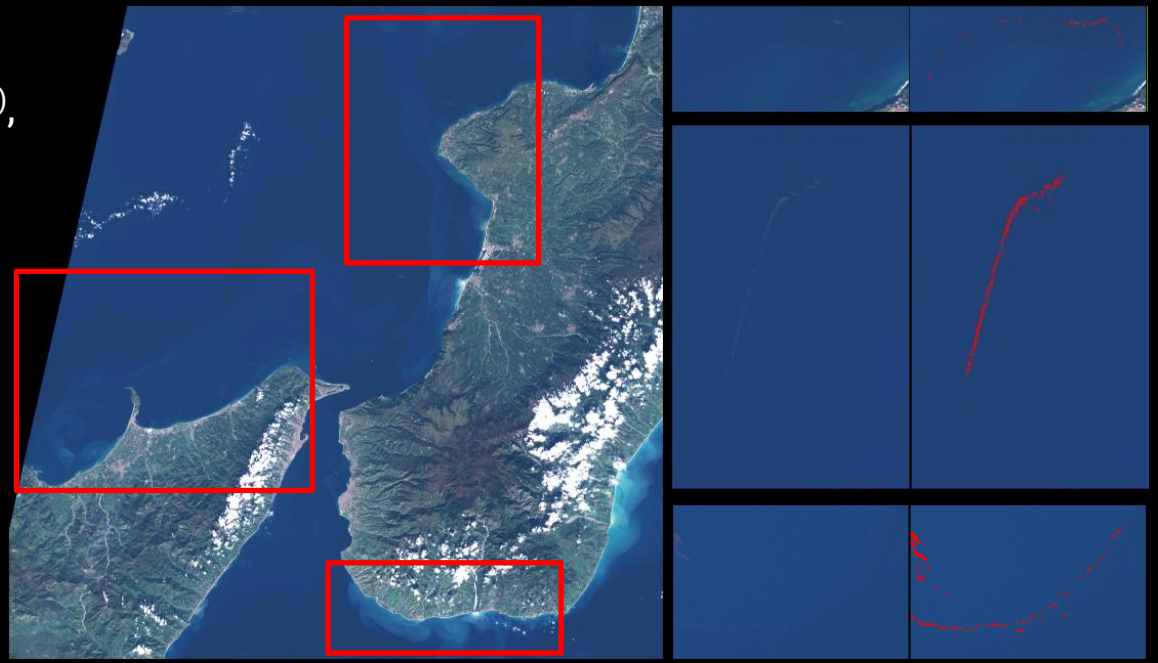

# Windrows As Proxies of Marine Litter

frontiers in Marine Science

PERSPECTIVE article

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## Marine Litter Windrows: A Strategic Target to Understand and Manage the Ocean Plastic Pollution

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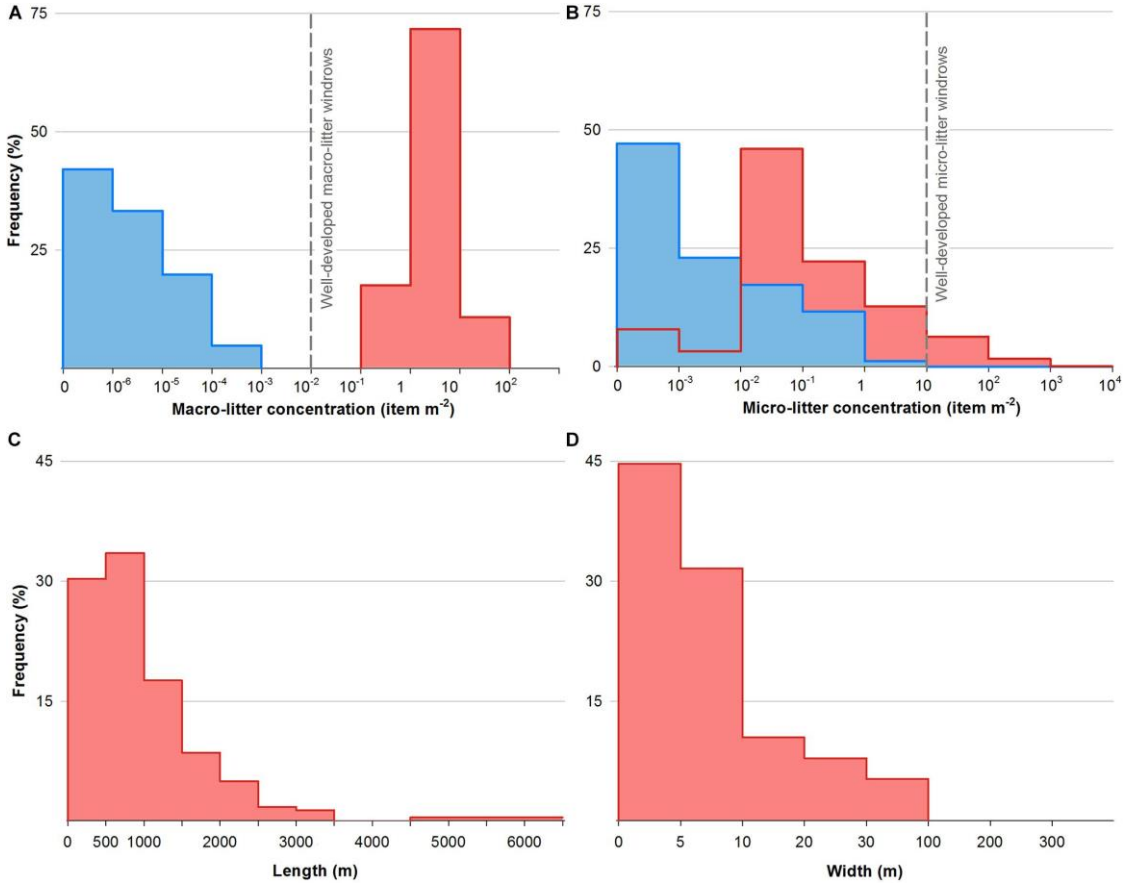
- Any **aggregation** of floating litter at the **sub-mesoscale domain** (<10 km horizontally), **regardless of the force inducing the surface convergence**, be it wind or other forces such as tides or density-driven currents.

- The marine litter windrows observed to date usually form **stripes from tens up to thousands of meters long, with litter densities often exceeding 10 small items (<2 cm)** per $m^2$ or 1 large item (>2 cm) per 10 $m^2$

# Windrows As Proxies of Marine Litter




- Presence of **macro-litter** in windrows is **orders of magnitude** higher than surrounding areas.
- **Micro-litter** concentrations appear also in **larger quantities**, if well, only Gove et al (2019) did a preliminary study on windrows, of limited results due to sampling methods.
- **Windrows** observed at sea can reach up to a **few kilometers long and 100 meters width**.
- Thus, windrows are **compatible with Sentinel-2/MSI** resolution **and a target of opportunity** for remote sensing of macro-litter.

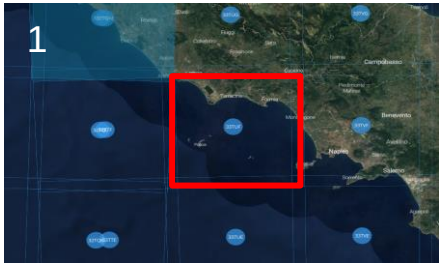
# Sentinel-2/MSI Datasets

**40 Copernicus Sentinel-2 L1c and L2A** products were used for the **algorithm production** and detection principles, including **artificial targets** over Lesvos Island, Greece (Topouzelis et al., 2018, 2019 & 2021)

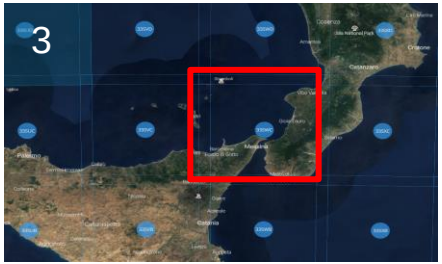
Additional **ASD hyperspectral data** was also used for **spectral characterisation of plastic litter** (Garaba et al, 2018, 2020a & 2020b).

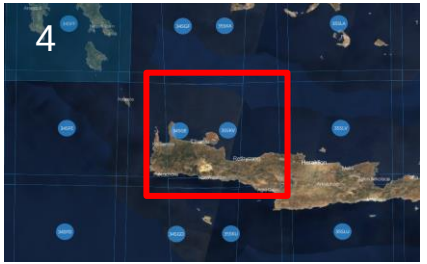
**2,575 Copernicus Sentinel-2 L1c products** were processed from **5 test sites in the Mediterranean Sea** for performance assessment and development.

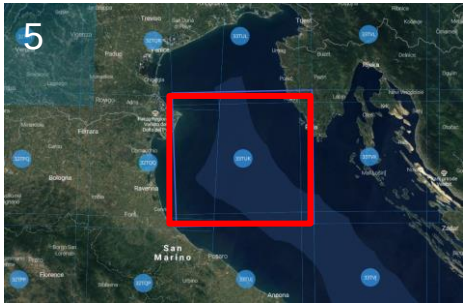
**287,475 Copernicus Sentinel-2 L1c products** over the 410 tiles on the Mediterranean Sea were processed in the **final exercise**



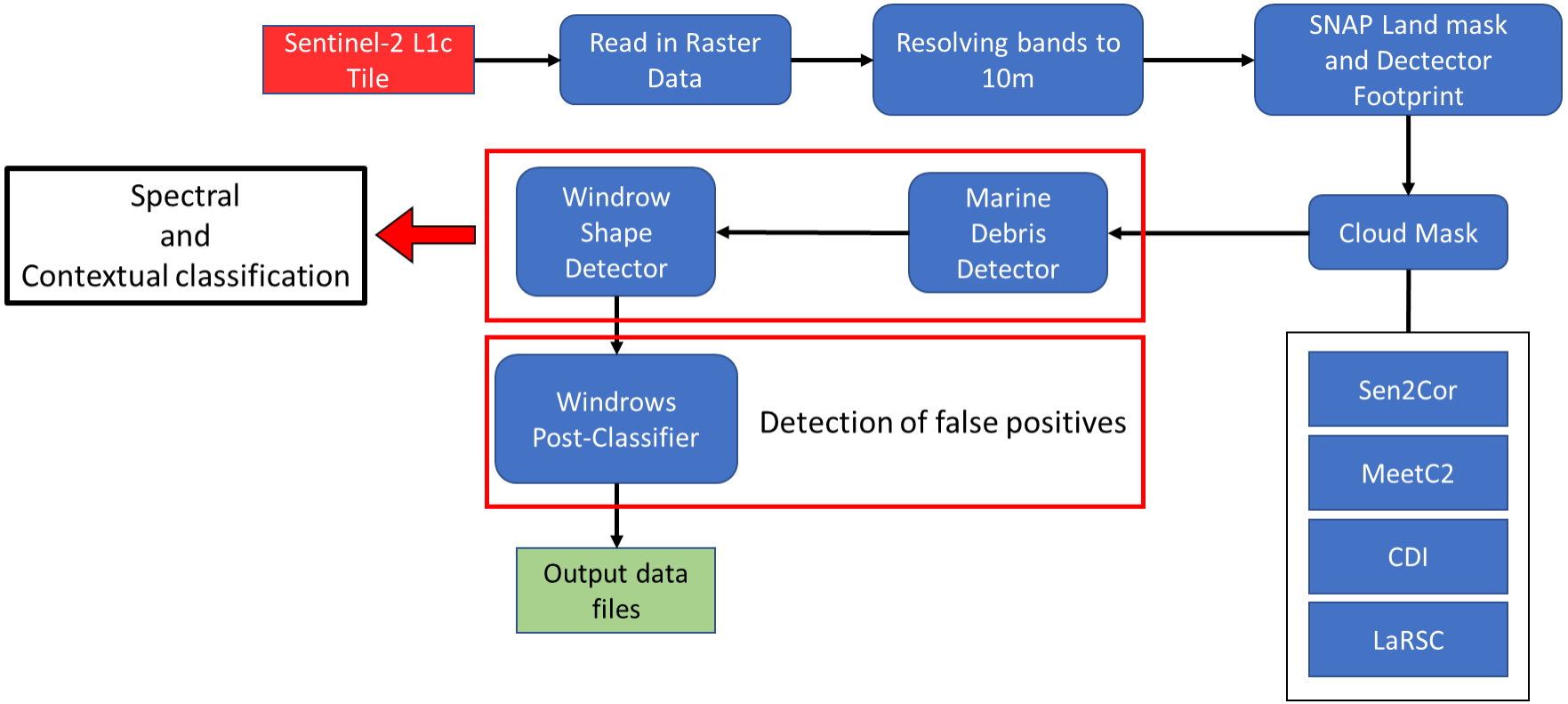




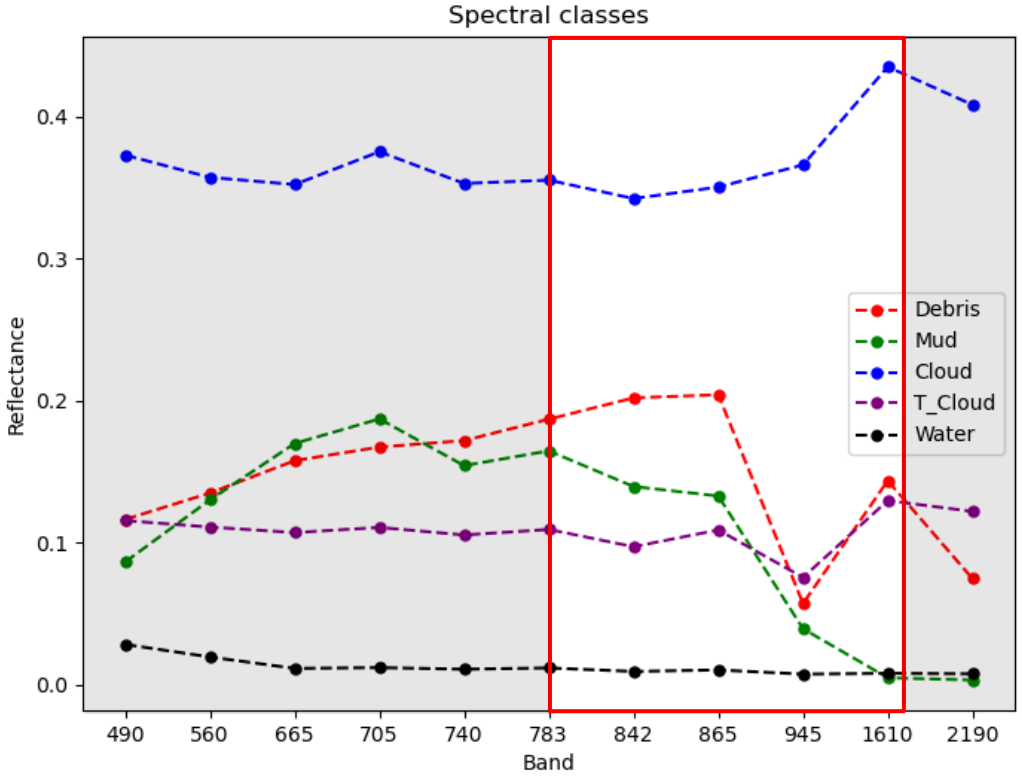



# WASP Data Processor Logic and Steps



# WASP Spectral Index




Spectral information of **common pixel categories** have been analysed.

Marine debris pixel class presents **a consistent spectral features** spamming from NIR to SWIR bands, which is mainly mapped by bands B8A, B09 and B11

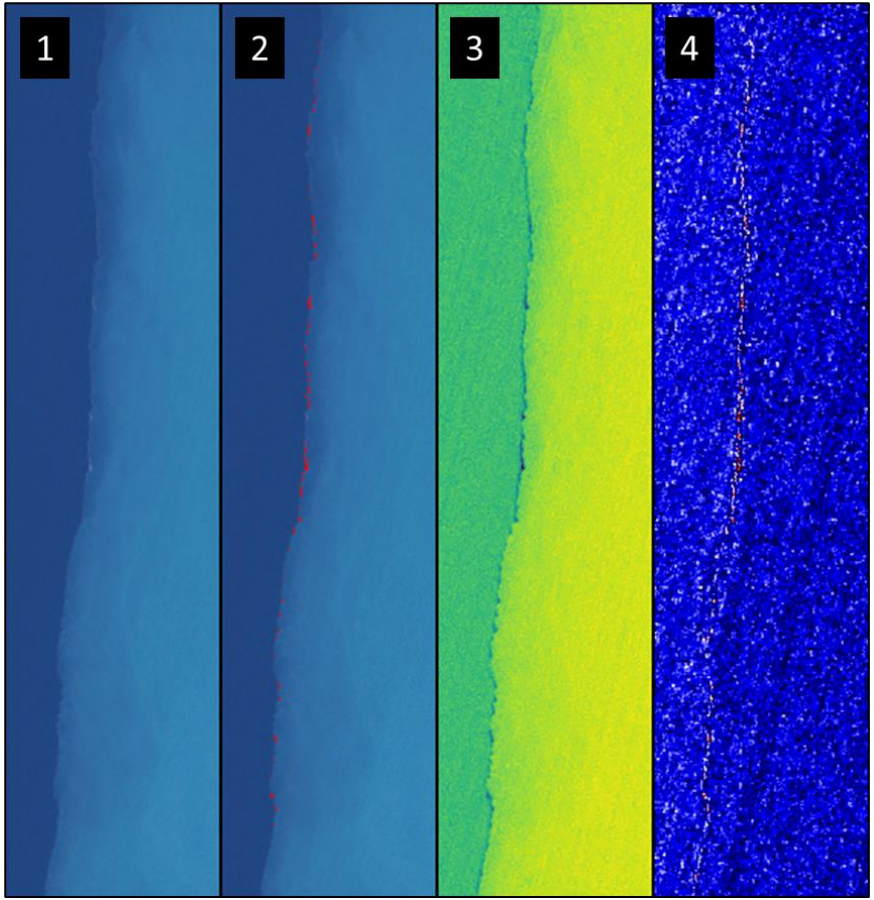
Possible **false positives** could be found in cloud classes, due to the **spectral proximity of C-H chains to water absorbtion features**.

Combination of a **multi-band index** gives a **distinguishable signal** for marine debris

*Arias et al (2021). Advances on Remote Sensing of Windrows as Proxies for Marine Litter Based on Sentinel-2/MSI Dataset.*

10.1109/IGARSS47720.2021.9555139

# Results – WASP Snippets

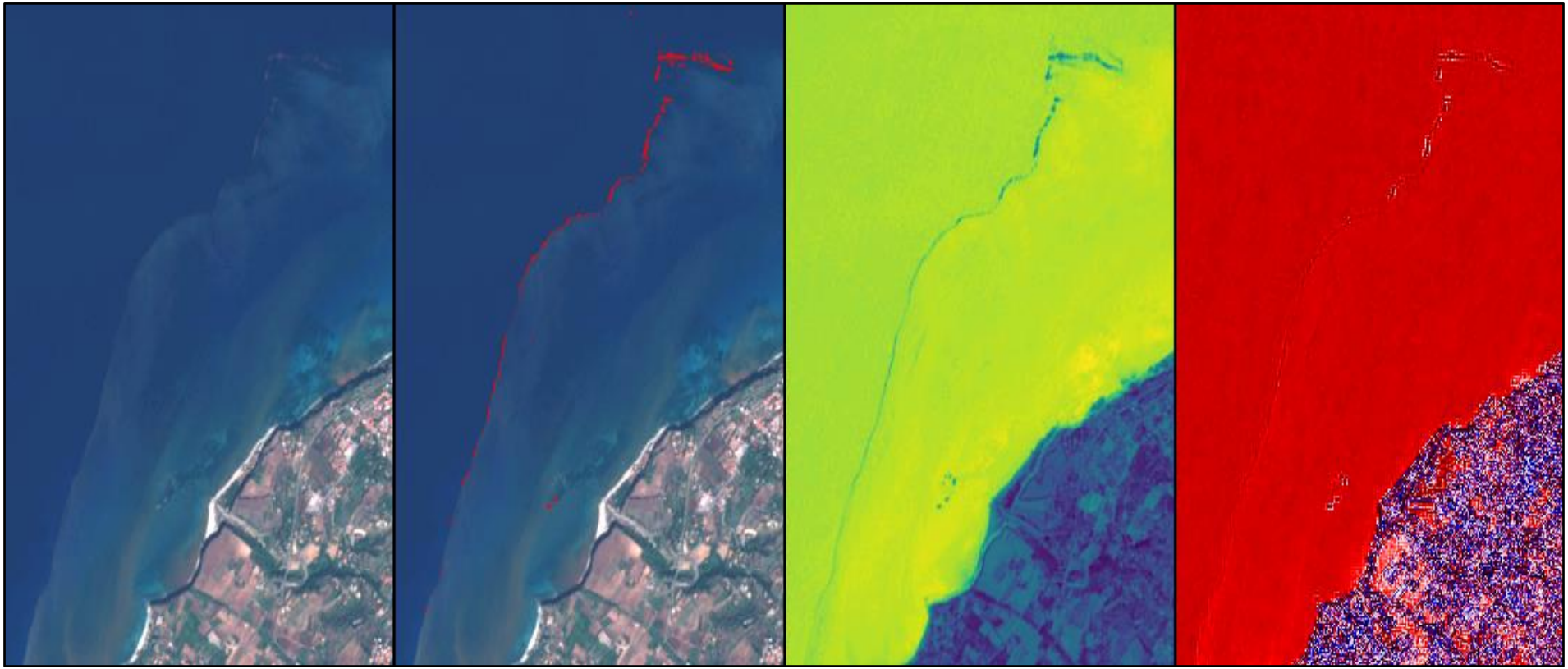



## WASP Snippets Outputs

1. True Colour image (RGB: B04, B03, B02).
2. True Colour image with detected marine debris pixels reported by WASP in red.
3. NDWI image to help visual inspection of false detections.
4. Image of the spectral slope between bands B8A and B09

*Snippets are used by the post-classifier and for manual inspection by means of human operators*

# Results – WASP Snippets



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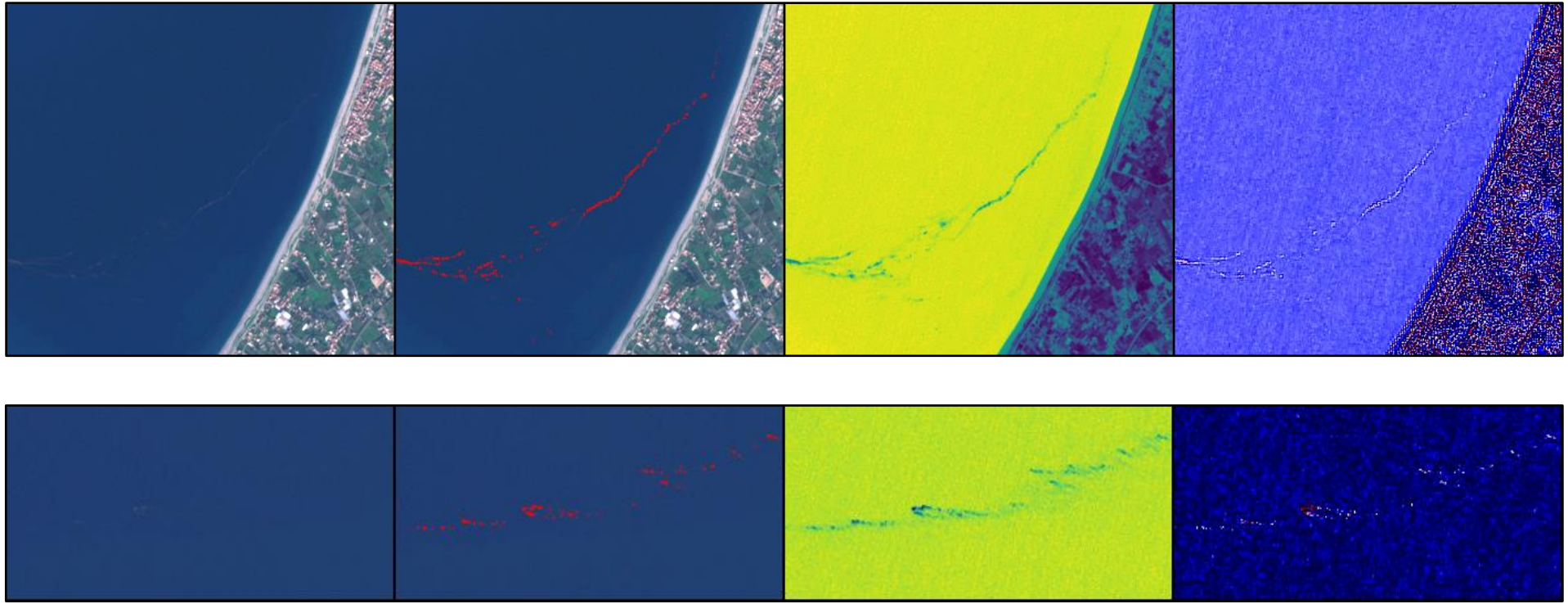

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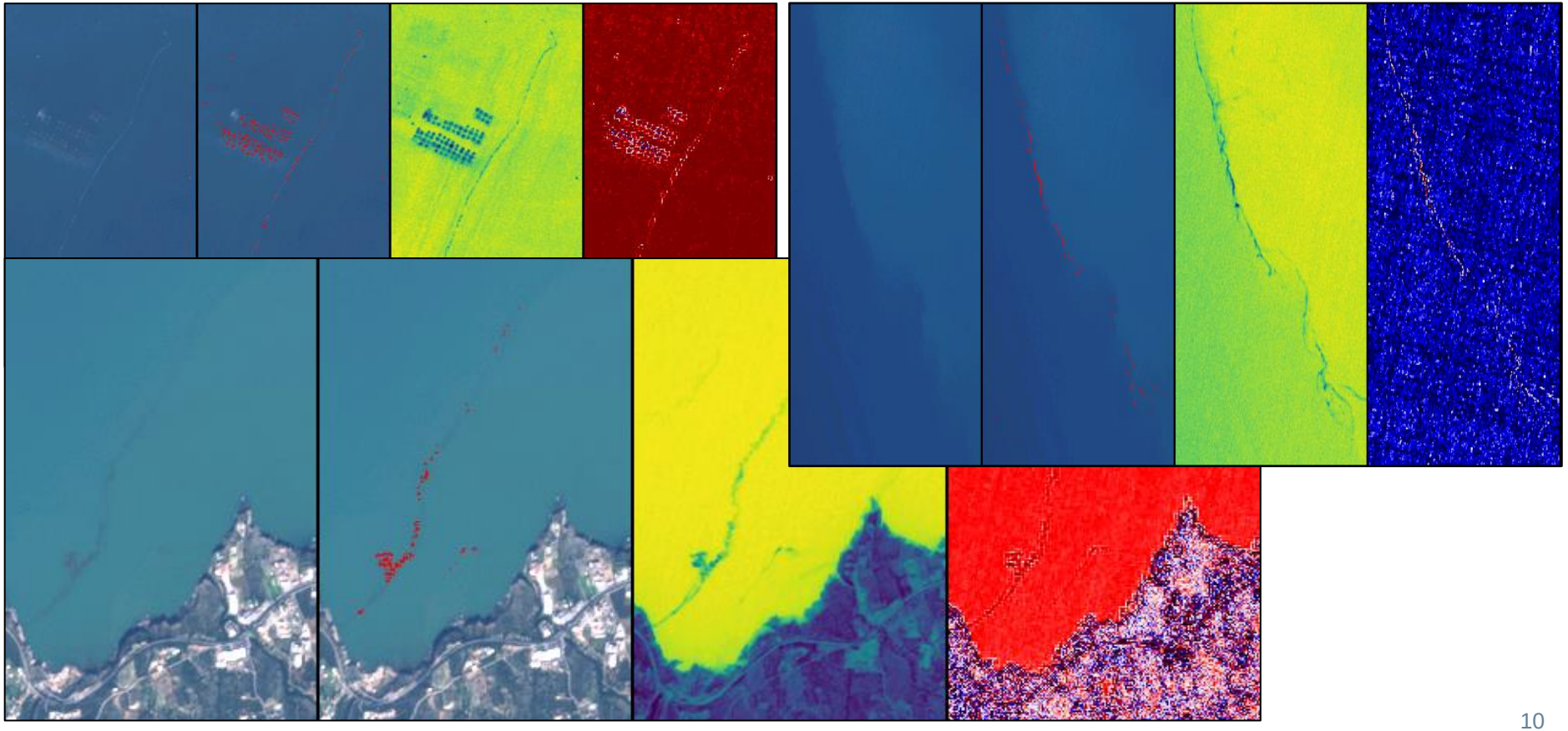


# Results – WASP Performance

| WASP Output \ HUMAN Operator Output | True | False | Total |
|---|---|---|---|
| **Positive** | 11,756 | 74,328 | 86,084 |
| **Negative** | 619,648 | 2,623 | 622,271 |
| Total | 631,404 | 76,951 | 708,355 |

| Metric | Formula | Result |
|---|---|---|
| Sensitivity | TP / P | **86.47%** |
| Selectivity | TN / N | **87.81%** |
| Precision | TP / (TP + FP) | 39.86% |
| Miss Rate | FN / P | 13.51% |
| Fall-Out | FP / (FP + TN) | 12.19% |
| Accuracy | (TP + TN) / (P + N) | **87.72%** |

WASP shows **very good sensitivity, accuracy and selectivity** of windrows (over 85%)

On the contrary, **precision is not at operational levels**, requiring further work to improve it.

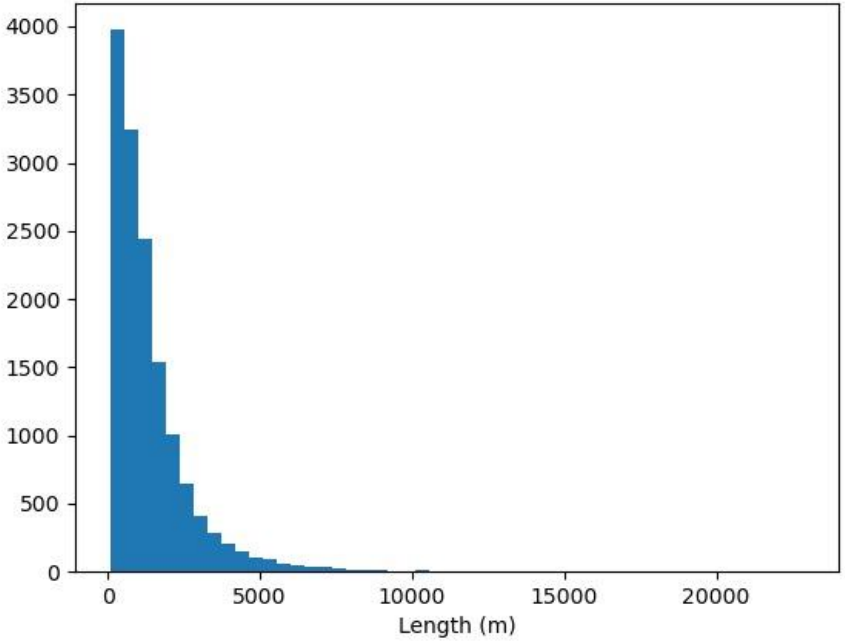
**Main issue** relates to appearance of relatively high concentrations of **water vapor content not detected by cloud detection algorithms**.

Those tend to happen at the **edge of clouds** or when **clouds are thin/small** enough.

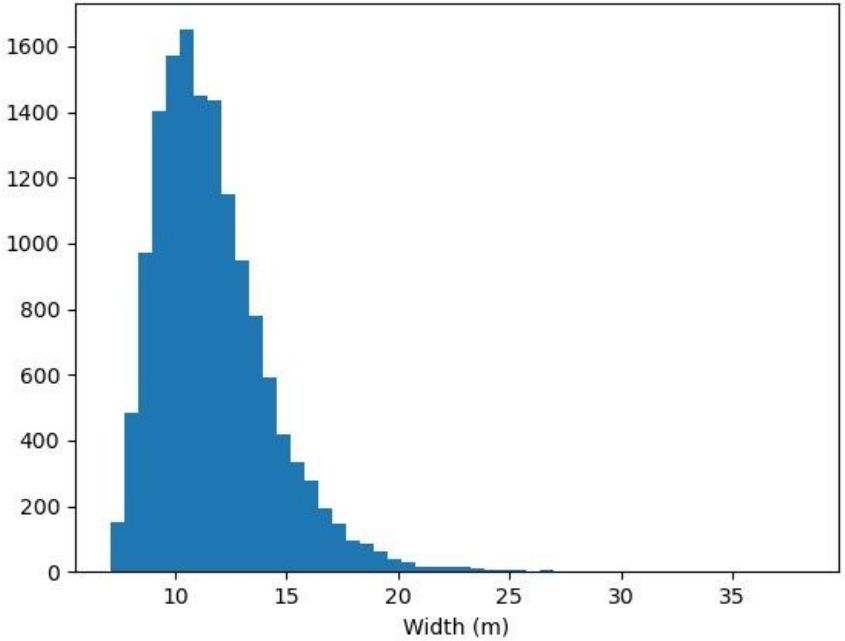
**Post-classification is very efficient** and identifies vast majority of bad filaments for the other cases.

# Results – Preliminary Analysis of Database

## Sentinel-2/MSI Windrows characteristics



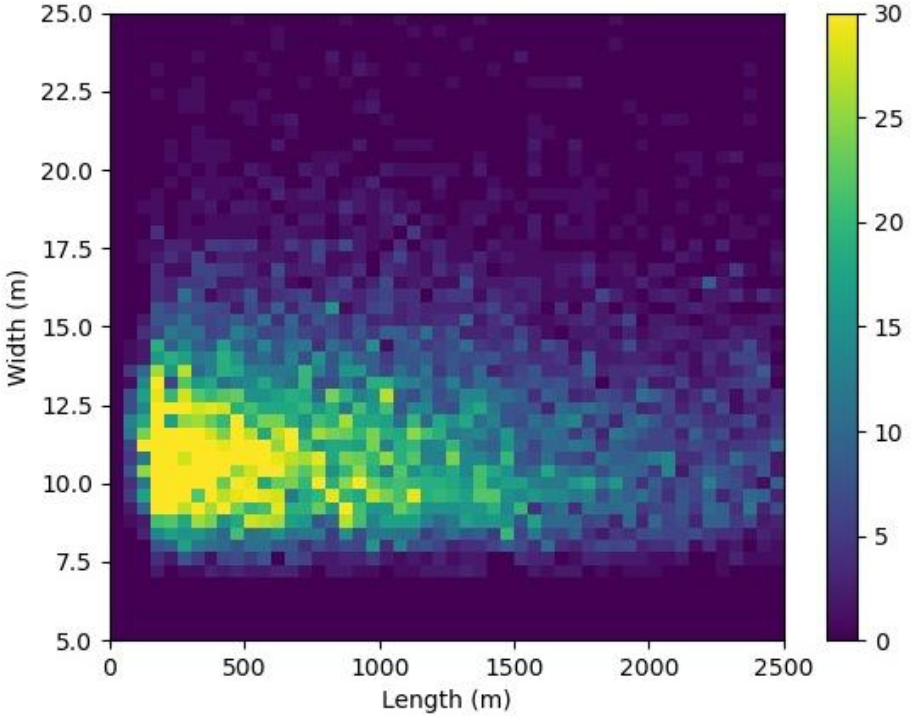

Typical windrow length < 500m

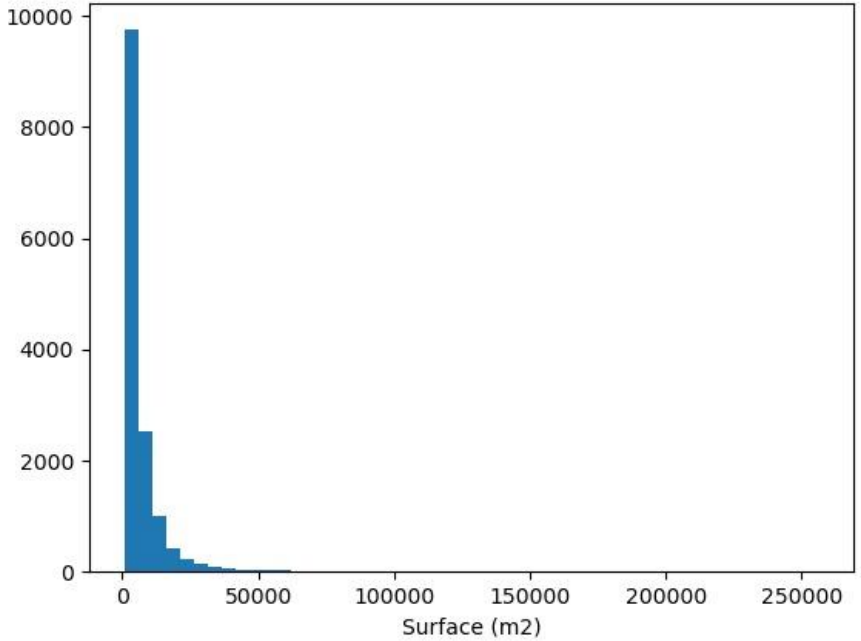



Typical windrow width is 10 to 15m

# Results – Preliminary Analysis of Database

## Sentinel-2/MSI Windrows characteristics




Typical windrow surface < 5,000 m2

# Conclusions

1. A **novel classification algorithm**, including both **spectral and spatial information** has been developed for the **detection and classification of windrows as proxies of marine litter**.

2. Spectral bands within the **NIR and SWIR regions are sufficient to detect floating materials with high probability of containing plastic debris**. Visible bands are also needed for the discrimination of false detections.

3. WASP has a **sensitivity**, **selectivity and accuracy higher than 85%,** but precision requires improvement in future versions, which can be achieved with a better detection of clouds.

4. Monitoring of windrows is a **target of opportunity to support plastic pollution monitoring**, **orientate mitigation efforts and prevention**. An improved tool for operational regional monitoring is on the way, as well as peer-reviewed publication with the full analysis.

# Thank you for your attention

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