WP6 – NOVELTIS Contribution

Novel EO Derived Products for Marine Litter Accumulation

Daria ANDRIEVSKAIA & Elise BELAKEBI-JOLY

31/05/2023

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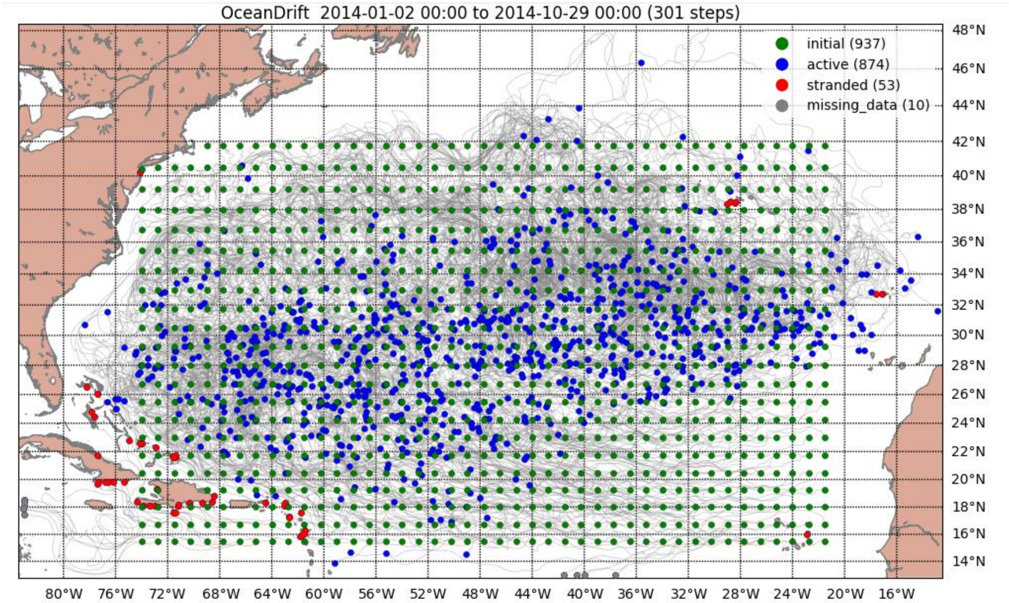
Marine Litter Monitoring in the North Atlantic Ocean

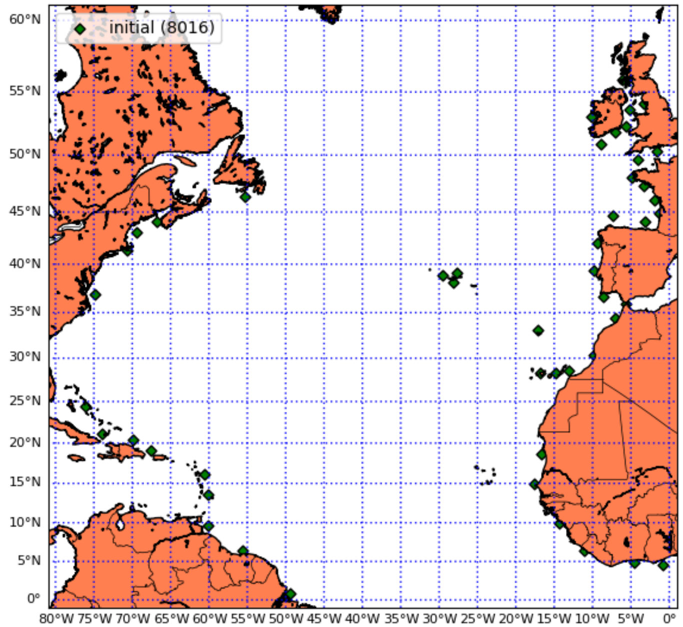
Monitoring marine litter

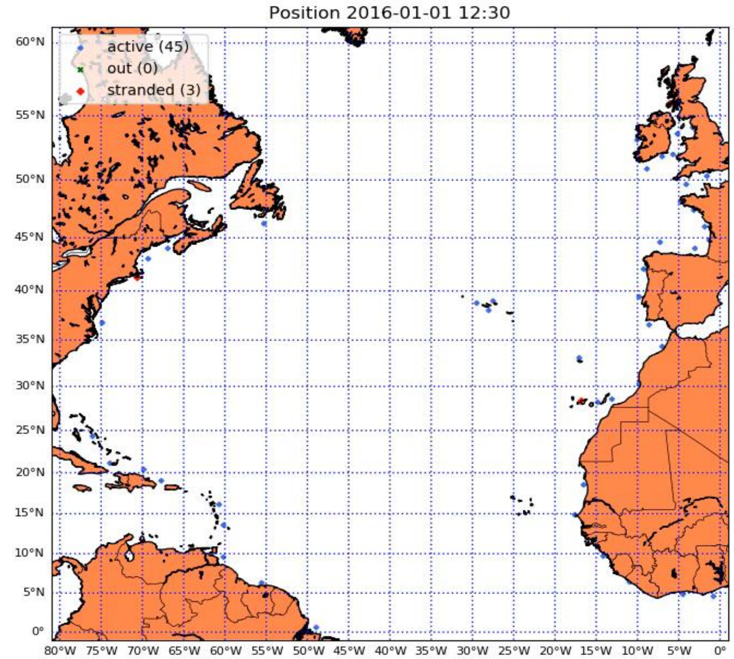
- Elaboration of an **enhanced modelling approach for simulating the trajectories of drifting objects in the ocean**.
- Use of current data: Globcurrent (¼°) and CMEMS (1/12°)
- **Adding tidal component** to global current data to **enhance trajectory modelling results on the continental shelf.**



Modelling scenario

- **Use of Globcurrent products with tide:**
  - Regular marine litter discharges (every 3 days) at various points along the coast
  - 18-month of simulation highlighting the main routes and realistic behaviour in coastal areas





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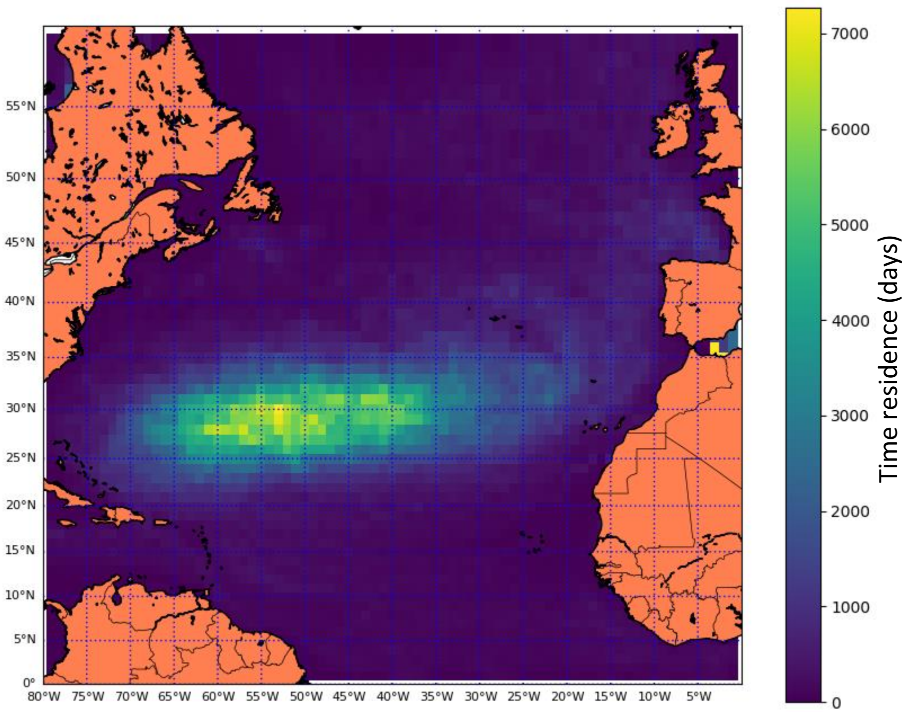
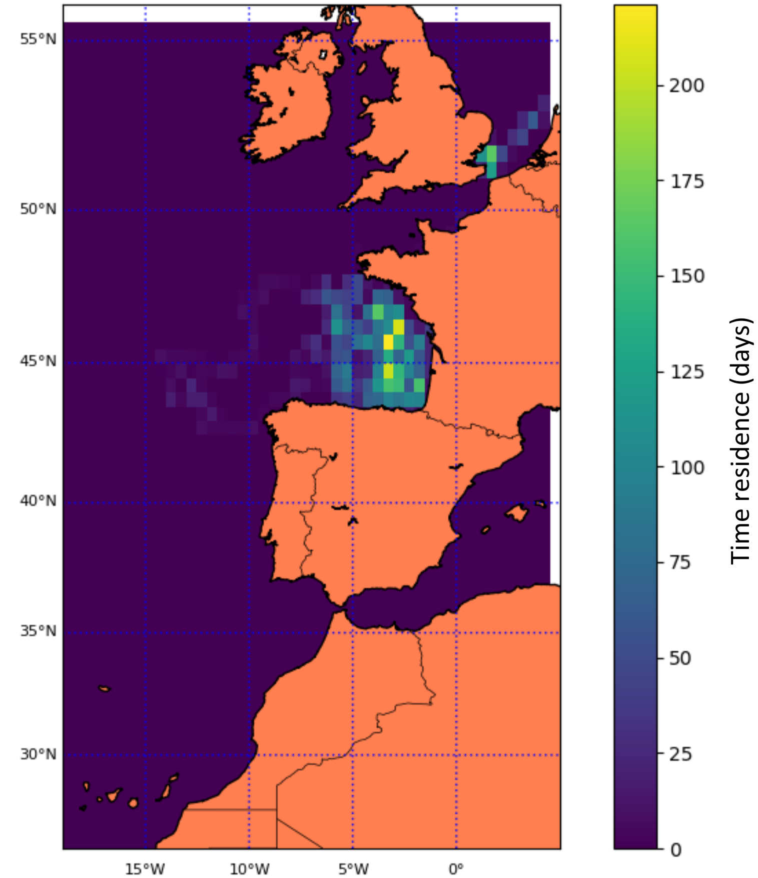
Convergence zones

- **Time residence indicator of plastic particles**



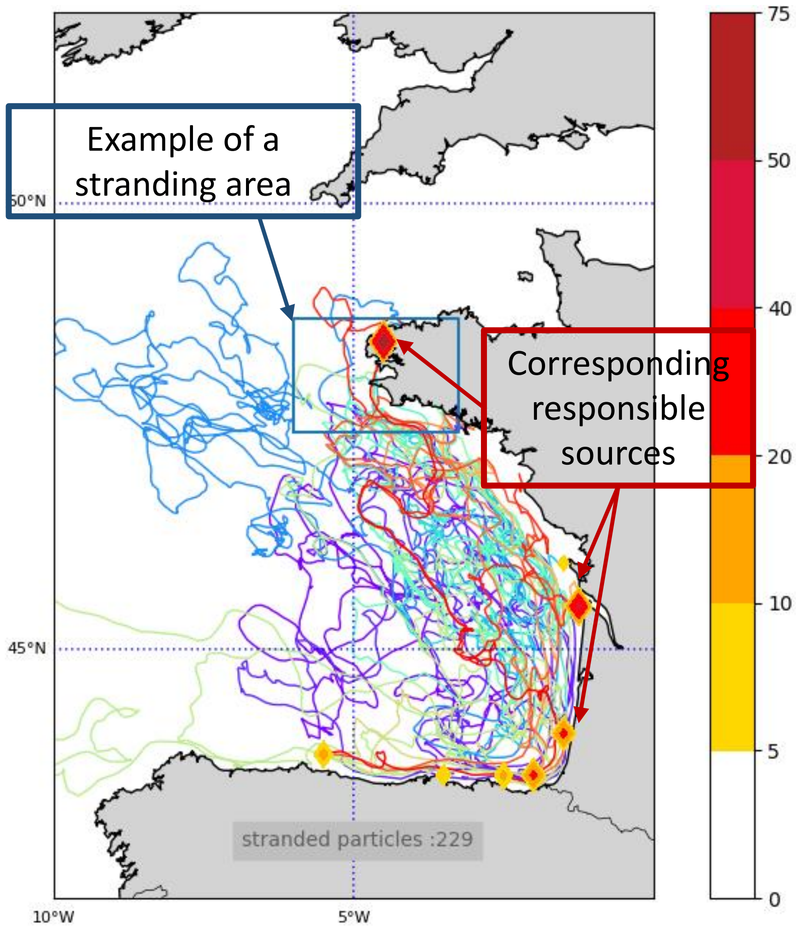
without tides (3 years)

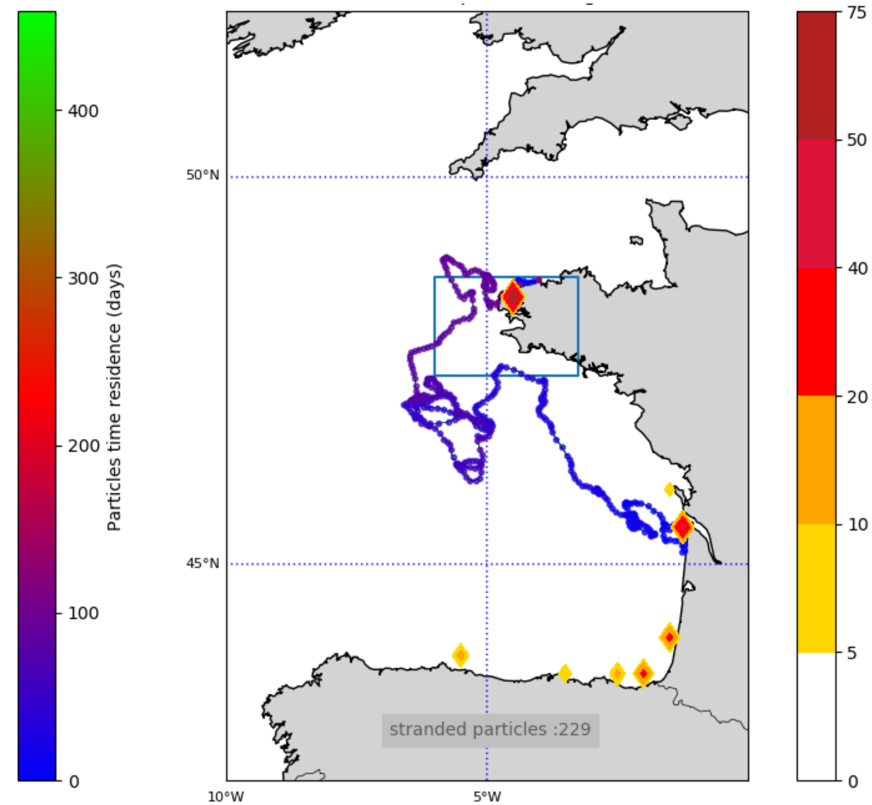


with tides (18 months)

"Polluter-polluted" indicator

- **Selection of stranding area:** release sources, trajectories, travel-time can be displayed





Detection of Plastic Marine Litter from Sentinel-2 Images

Detecting marine litter

- **Objective:** development of an automated Artificial Intelligence based algorithm to detect marine litter from satellite observations

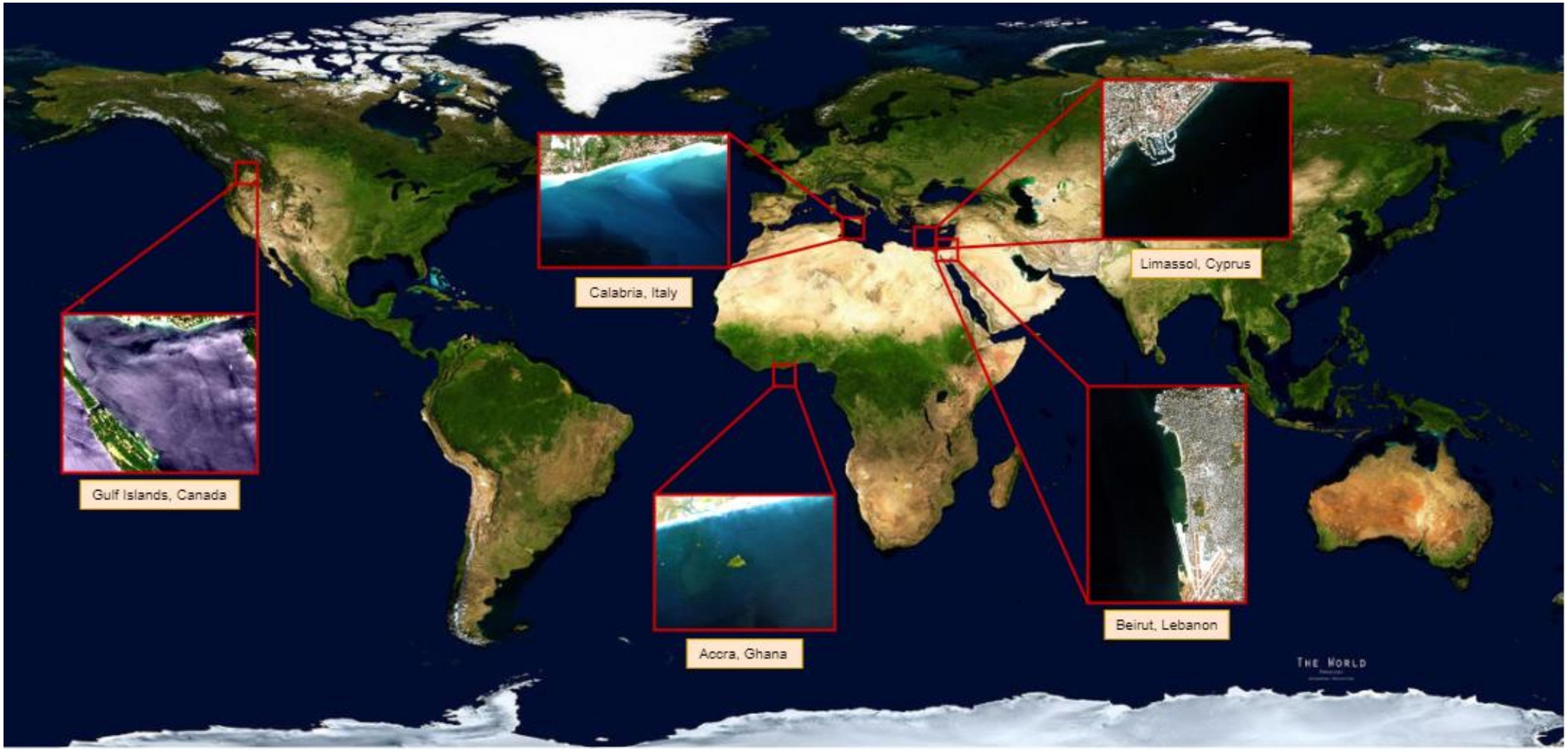
Source : www.unep.org

Source : Le Parisien 2018

Project's phases:

- Identification of marine litter accumulation sites
- Downloading and pre-processing of Sentinel-2 images
- Preparation of a database for Machine Learning (ML) model training
- ML model definition, tunning, training and validation
- Automation of the process

Marine litter accumulation sites



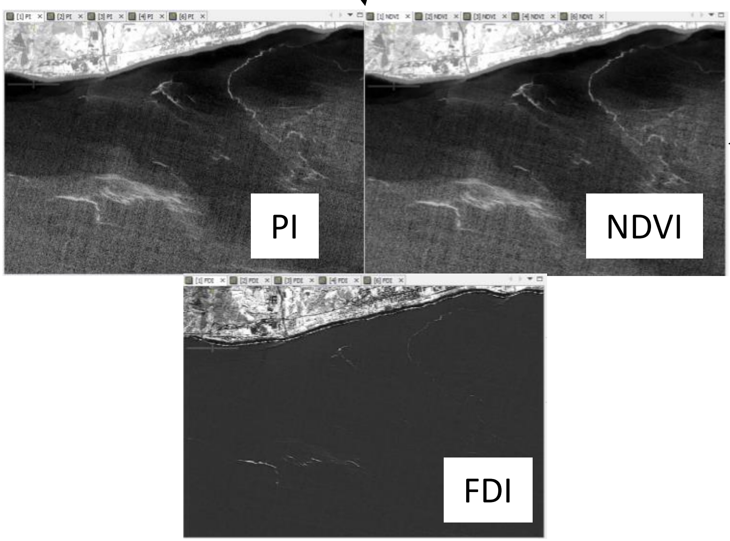
Sources: [1] Biermann, L., Clewley, D., Martinez-Vicente, V. et al. Finding Plastic Patches in Coastal Waters using Optical Satellite Data. Sci Rep 10, 5364 (2020). – for Accra (Ghana) and Gulf Islands (Canada).
[2] Sannigrahi, S., Basu, B., Basu, A. S., & Pilla, F. (2021). Detection of marine floating plastic using Sentinel-2 imagery and machine learning models. – for Calabria (Italy), Beirut (Lebanon), Limassol (Cyprus), and Accra (Ghana).

Images pre-processing

- Pre-processing consists of two main steps: **atmospheric correction** and **indices calculation**.

Atmospheric correction:
from Top-of-Atmosphere to Top-of-Canopy reflectance

Sentinel-2 L1C products + ACOLITE (Atmospheric Correction for OLI lite version 20181210.0)



Calculation of indices:

- NDVI (Normalized Difference Vegetation Index) detects vegetation:

$$NDVI = \frac{B_{08} - B_{04}}{B_{08} + B_{04}}$$

- FDI (Floating Debris Index) detects floating objects:

$$FDI = B_{08} - \left(B_{06} + (B_{11} - B_{06}) \frac{\lambda_{B08} - \lambda_{B04}}{\lambda_{B11} - \lambda_{B04}} \right)$$

- PI (Plastic Index) detects plastic objects:

$$PI = \frac{B_{08}}{B_{08} + B_{04}}$$

FDI bright & NDVI dark → possible marine litter

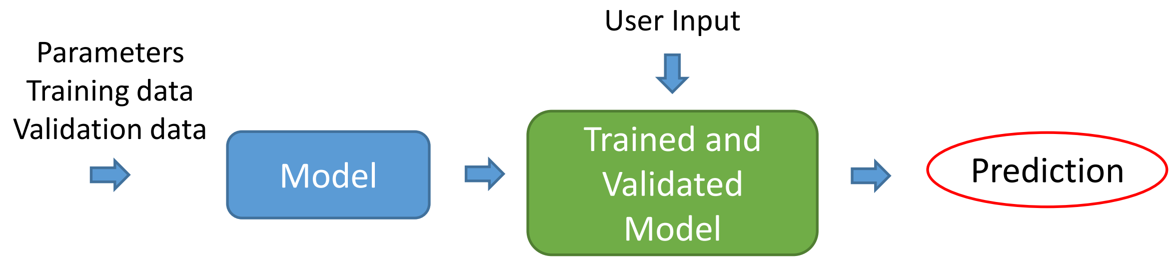
Source: [2]

Definition of Machine Learning model

- Database preparation:

  - The data of multiple pixels has been extracted from each site to represent 4 different classes: **‘litter’**, **‘water’**, **‘potential litter’** and **‘clouds’**.
  - Each pixel’s data consists of **spectral bands values, calculated indices, pixel’s coordinates, as well as its class and location** (Calabria, Accra, etc.).

- ML model methodology:



  - Training and Validation data – data from the database of pixels with ratio 80% : 20%, respectively
  - Prediction – class predicted for each pixel
  - User Input – image chosen by User, decomposed into pixels

Evaluation of ML models

- **Objective:** Find the ML model with the highest performance
- **Method:** Evaluate the well-known ML models for classification problems through training on different combinations of spectral bands and indices [2]

4 models:
- Naive Bayes (NB)
- K-Nearest Neighbours (KNN)
- Random Forest (RF)
- Support Vector Machines (SVM)

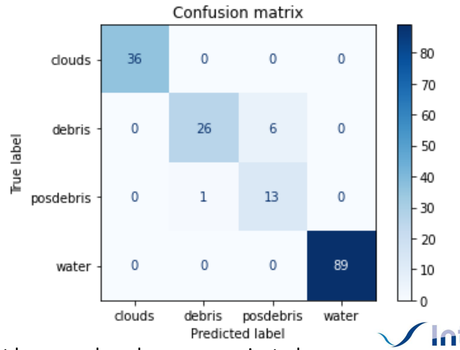
X

5 combinations:
- FDI, PI, NDVI
- FDI, PI, NDVI + B4 B3 B2
- FDI, PI, NDVI + B6 B8 B11
- FDI + B6 B8 B11
- NDVI + B6 B8 B11

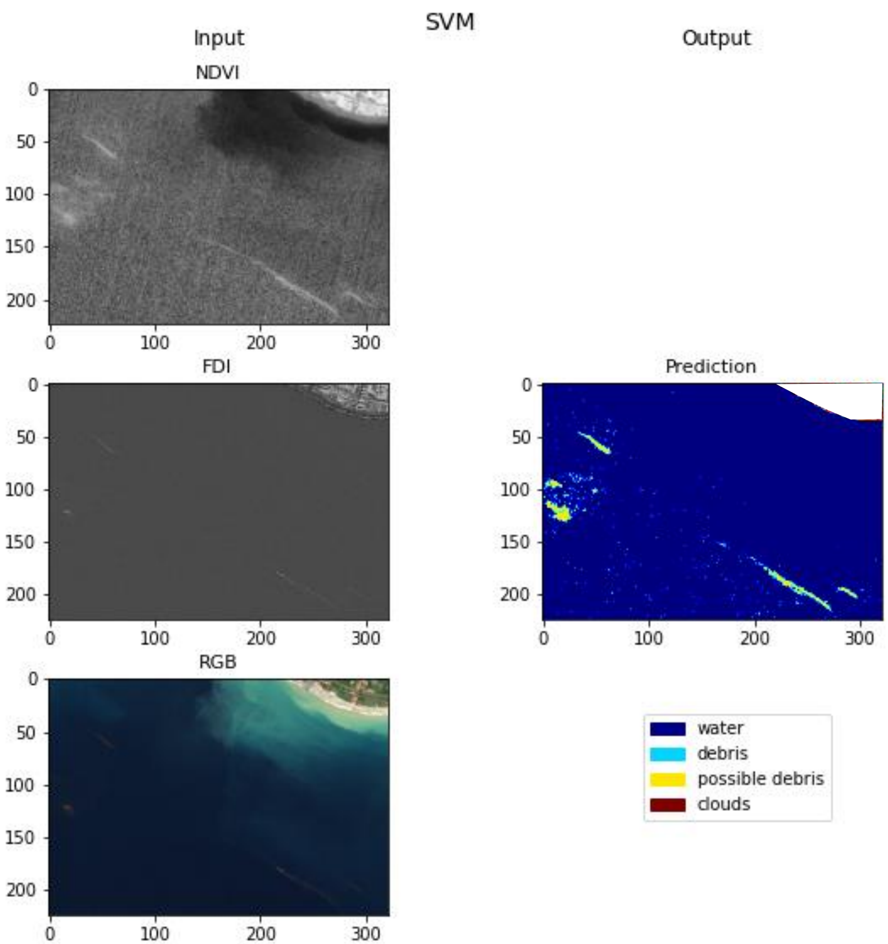
= 20 evaluated cases

- **Result:** Support Vector Machine (SVM) + NDVI B6 B8 B11 shows the best performance:

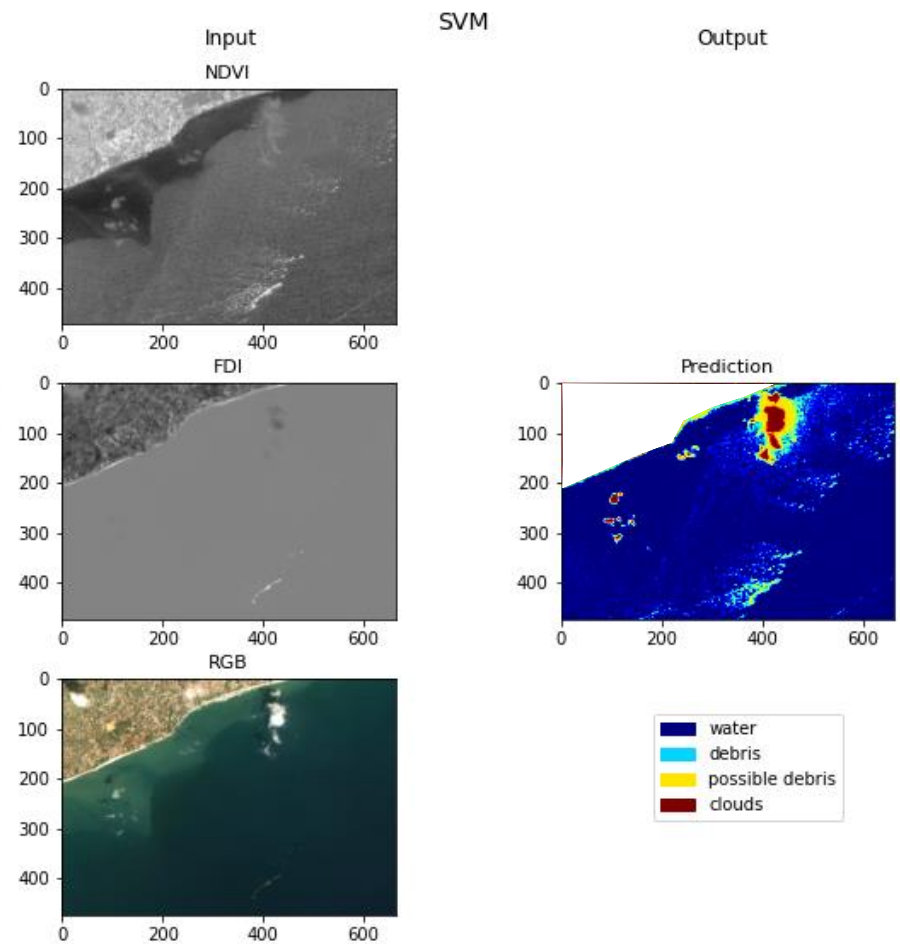
Performance:
Global accuracy – 0.96
Accuracy for 'litter' class – 0.96



Prediction results



Calabria, Italy



Accra, Ghana

Automation

- An **automatic integrated module** has been developed to merge all processes into a single flow in order to facilitate User access to the algorithm:

This module includes all pre-processing, processing and post-processing steps:

- Definition of the area of interest
- Search for the relevant satellite image on the Copernicus Hub platform
- Downloading of the requested image
- Pre-processing of the acquired image:
  - Atmospheric correction
  - Spatial subset
  - Spectral band subset
  - Calculation of indices
- Definition of a Machine Learning model
- Training and validation of the model
- Image prediction
- Post-processing of results

```
#%% ########### Functions
def set_AOI(aoi):
    """
    Function to define a desired AOI to download images from Copernicus

    Parameters
    ----------
    aoi : str. List of points coordinates, shall be given in format: 'lon1 lat1 lon2 lat2 lon3 lat3 lon4 lat4
    Returns
    -------
    coords : list of tuples. List of tuples of points coordinates
    """
    lats = list(aoi.split(' '))[1:][::2]
    lons = list(aoi.split(' '))[0:][::2]
    coords = list(((float(lons[0]), float(lats[0])),(float(lons[1]), float(lats[1])),
                   (float(lons[2]), float(lats[2])),(float(lons[3]), float(lats[3]))))
    points = [Point(coords[0]), Point(coords[1]), Point(coords[2]), Point(coords[3])]

    features = []
    for point in points:
        features.append(Feature(geometry=point, properties={"polygon": "AOI"}))
    feature_collection = FeatureCollection(features)
```

Anaconda Powershell Prompt (Anaconda3)

```
(imgprocess) PS N:\1340-FE_IFADO\REALISATION\Technique\Daria\python> python .\automated.py -h
usage: automated.py [-h] [--aoi AOI] [--username USERNAME] [--password PASSWORD] [--startDate STARTDATE]
                    [--endDate ENDDATE] [--download] [--productID PRODUCTID] [--productNumber PRODUCTNUMBER]
                    [--path PATH] [--imageName IMAGENAME] [--verbose VERBOSE] [--band BAND]

This script downloads Sentinel-2 image and detects floating marine debris. Requires 1) AOI (area of interest), start
and end dates to find image on Copernicus hub site; 2) username and password to log in; 3) download and productNumber
to initiate the donwloading process of the chosen product; 4) path to save chosen product to specified directory

options:
  -h, --help            show this help message and exit
  --aoi AOI             Points' coordinates for Area of Interest (AOI) in format: 'lon1 lat1 lon2 lat2 lon3 lat3 lon4
                        lat4'
  --username USERNAME   Username to access scihub.copernicus.eu
  --password PASSWORD   Password to access scihub.copernicus.eu
  --startDate STARTDATE
                        Start sensing date in format: 'yyyymmdd'
  --endDate ENDDATE     End sensing date in format: 'yyyymmdd'
  --download            Marker to decide whether download product(s) or just show their names and metadata to decide
                        later, which one to choose. By default does the latter and stops further script execution
  --productID PRODUCTID
                        OPTIONAL: Product ID if known
  --productNumber PRODUCTNUMBER
                        Number of the product to download (from the list of products matching criteria
  --path PATH           Full path to store downloaded unzipped products
  --imageName IMAGENAME
                        Name for processed image for floating marine debris detection in .tif format
  --verbose VERBOSE     Marker to enable (1) / disable (0) printing of the machine learning algorithm
  --band BAND           Name and number of the band of a satellite image to plot next to the resulted prediction image
                        in format: 'BandName BandNumber' (ex: 'NDVI 16 FDI 17'
(imgprocess) PS N:\1340-FE_IFADO\REALISATION\Technique\Daria\python>
```

The module is executed from the **command line** with various **user-defined options → ease of configuration**

Conclusions

- An enhanced modelling approach for simulating the trajectories of drifting objects in the ocean was successfully developed. Various indicators to monitor marine litter trajectories were also elaborated.
- Accounting for tides shows the main pathways of plastic particles and their behaviour in coastal areas.
- The use of Artificial Intelligence methods to automatically detect areas of marine plastic waste was successfully explored. Use of Sentinel-2 satellite images.
- Multiple techniques such as Naive Bayes, K-Nearest Neighbours, Random Forest, and Support Vector Machines were considered.
- The Support Vector Machine-based approach demonstrated high performance in prediction accuracy and execution time.
- An automated integrated module was developed for obtaining litter presence predictions from Sentinel-2 data.
- The results will have significant value for future operational applications and research endeavors.

Thank you for your attention!

References

[1] Biermann, L., Clewley, D., Martinez-Vicente, V. et al. Finding Plastic Patches in Coastal Waters using Optical Satellite Data. Sci Rep 10, 5364 (2020).

[2] Sannigrahi, S., Basu, B., Basu, A. S., & Pilla, F. (2021). Detection of marine floating plastic using Sentinel-2 imagery and machine learning models.

[3] Themistocleous K, Papoutsa C, Michaelides S, Hadjimitsis D. Investigating Detection of Floating Plastic Litter from Space Using Sentinel-2 Imagery. *Remote Sensing*. 2020; 12(16):2648.

[4] Vitale, S., Ferraiolo, G. & Pascazio, V. (2020) Exploiting the Deep Learning Potential for Sea Plastic Detection. IMEKO TC-19 International Workshop on Metrology for the Sea, Naples, Italy, October 5-7, 2020