

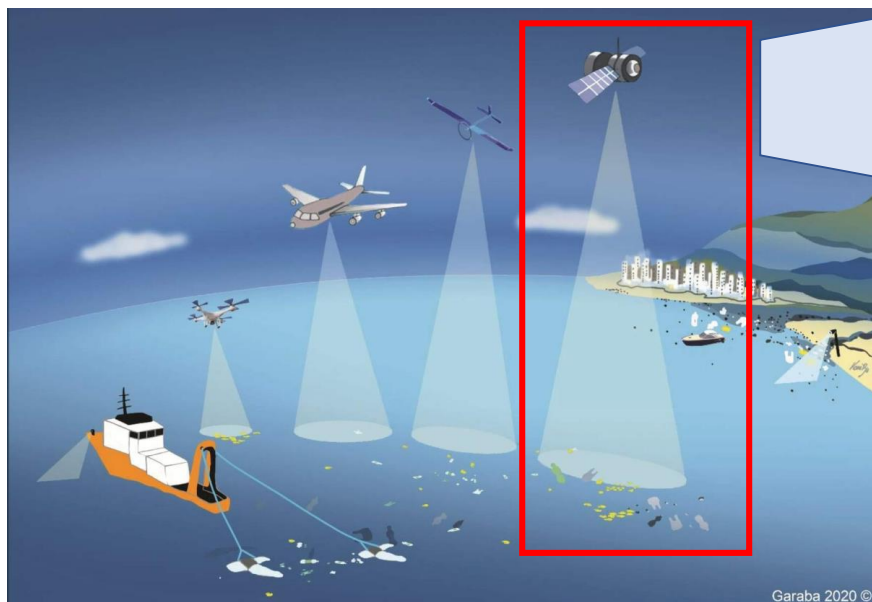
# PRIMO APPROCCIO AL MONITORAGGIO DI MARINE LITTER CON IL SATELLITE ESA *SENTINEL-2*

MARLESS WP3 | ARPA-FVG CRMA | REGIONE FVG |

Dott. Stefano Miniussi

Seminario interno ARPA-FVG/Regione FVG  
Palmanova (UD), 15-12-2021

# Monitoraggio del «Marine litter» con i satelliti



Programma «Copernicus»  
Commissione Europea



Costellazione di satelliti ESA «Sentinel»  
Scopo: monitoraggio ambientale



SENTINEL 2

Coppia di satelliti gemelli ( S2A, S2B )  
per l'imaging nell'ottico e nel vicino infrarosso

# Monitoraggio del «Marine litter» con i satelliti

## Caratteristiche dei satelliti Sentinel 2

**Tipo di orbita:** Eliosincrona ( passaggio su stessa zona della Terra alla stessa ora solare locale)

**Altezza orbitale:** 785 km

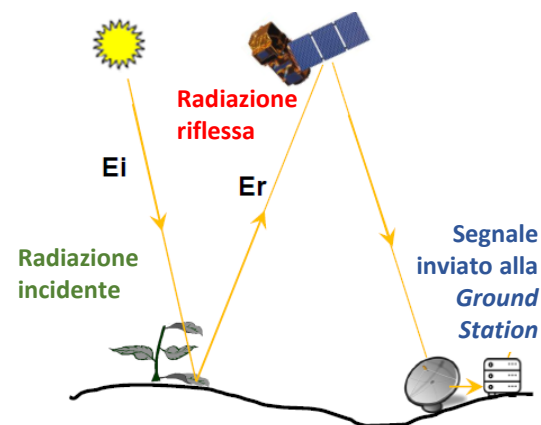
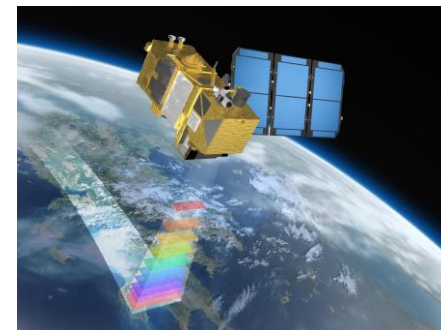
**Sfasamento tra satelliti:** Stessa orbita, ma sfasamento di 180°



Garantisce un passaggio orbitale alle medie latitudini sopra la stessa area ( *revisit time* ) ogni 2 - 3 giorni

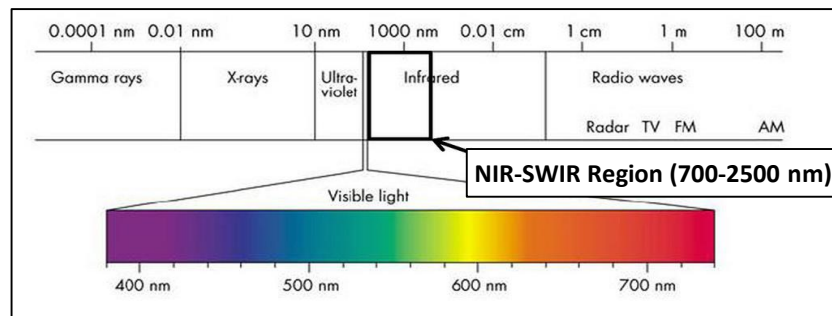
**Payload:** **MSI** ( MultiSpectral Instrument ). 13 bande spettrali dal VNIR al SWIR

**Modalità di acquisizione:** Ciascun satellite effettua un'acquisizione continua della superficie a terra coperta dal campo di vista del MSI man mano che l'orbita avanza ( *push broom scanner* ) .

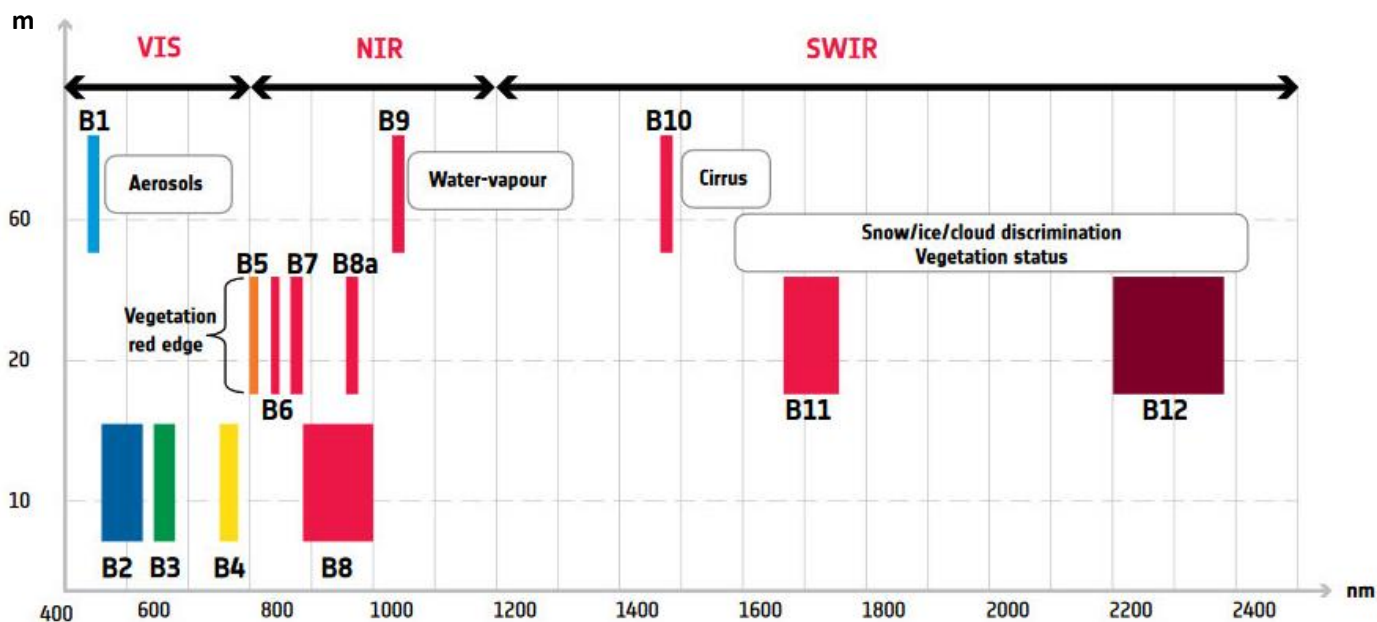


# Monitoraggio del «Marine litter» con i satelliti

Proprietà  
strumentazione  
scientifica

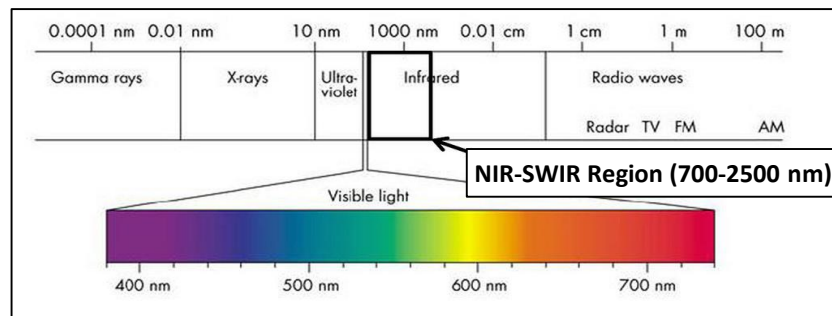


Risoluzione  
Spaziale

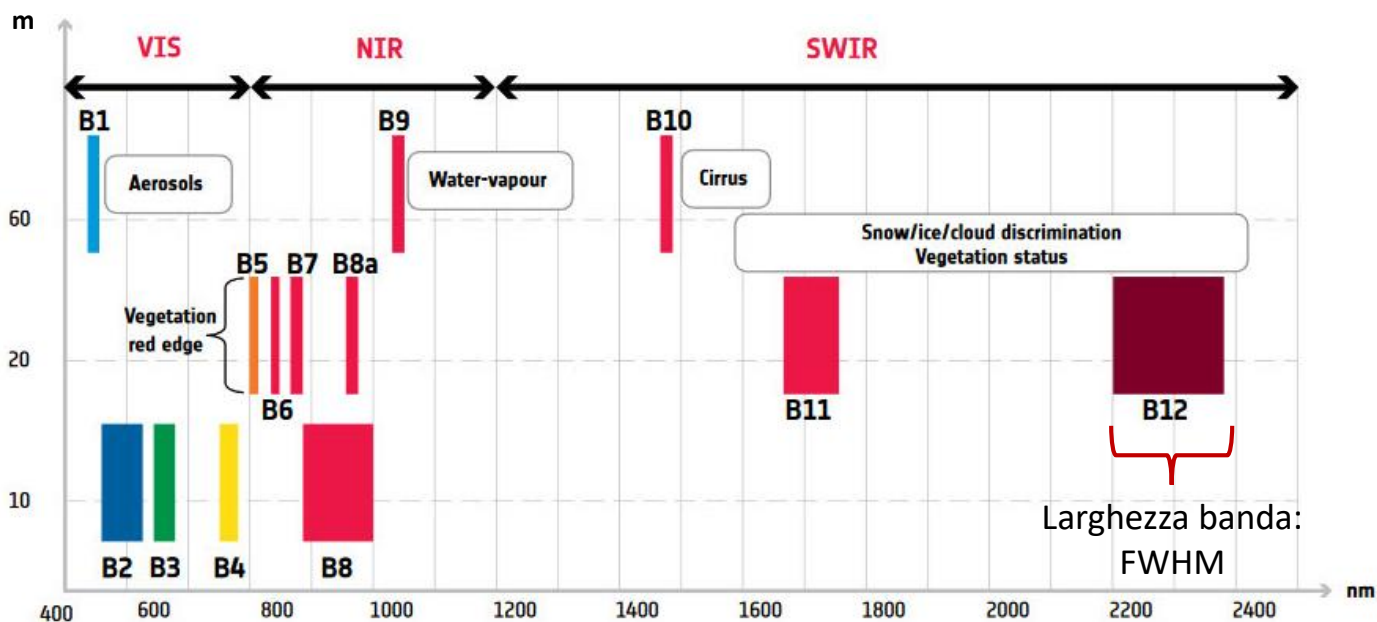


# Monitoraggio del «Marine litter» con i satelliti

Proprietà  
strumentazione  
scientifica



Risoluzione  
Spaziale

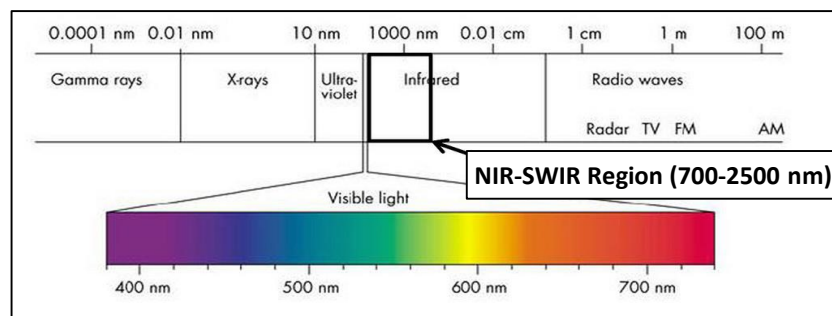


13 bande  
spettrali

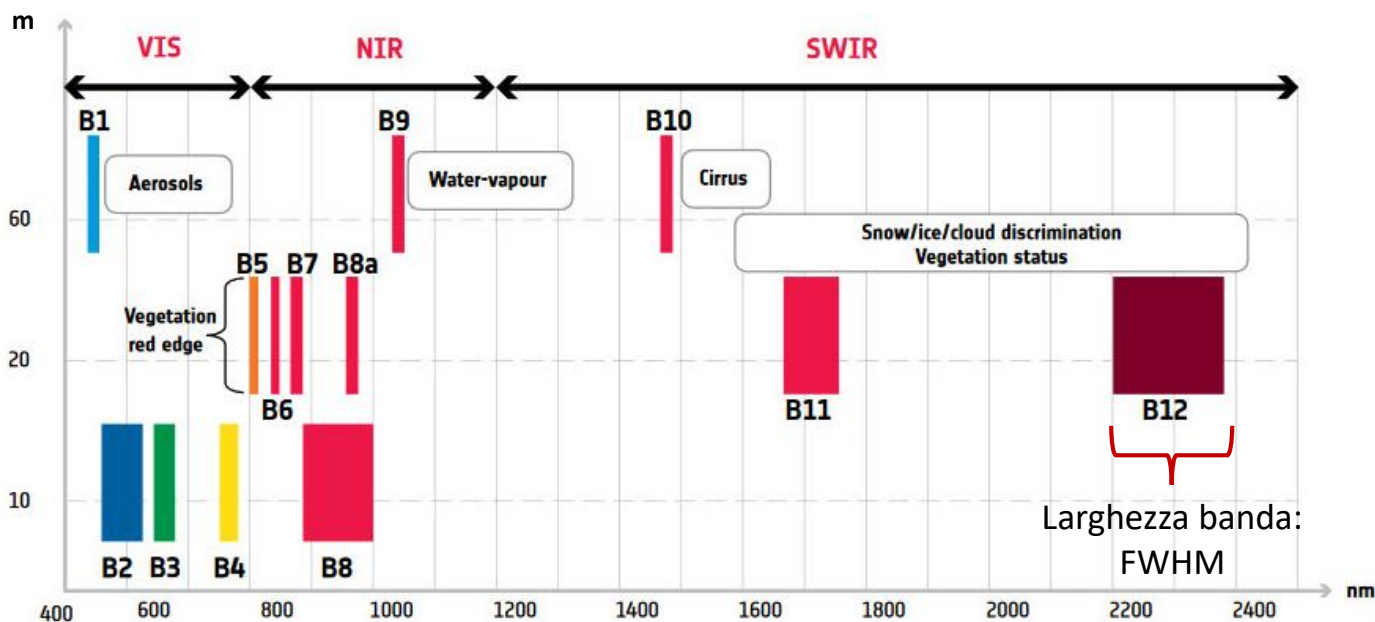
MSI strumento  
«multispettrale»

# Monitoraggio del «Marine litter» con i satelliti

Proprietà  
strumentazione  
scientifica



Risoluzione  
Spaziale

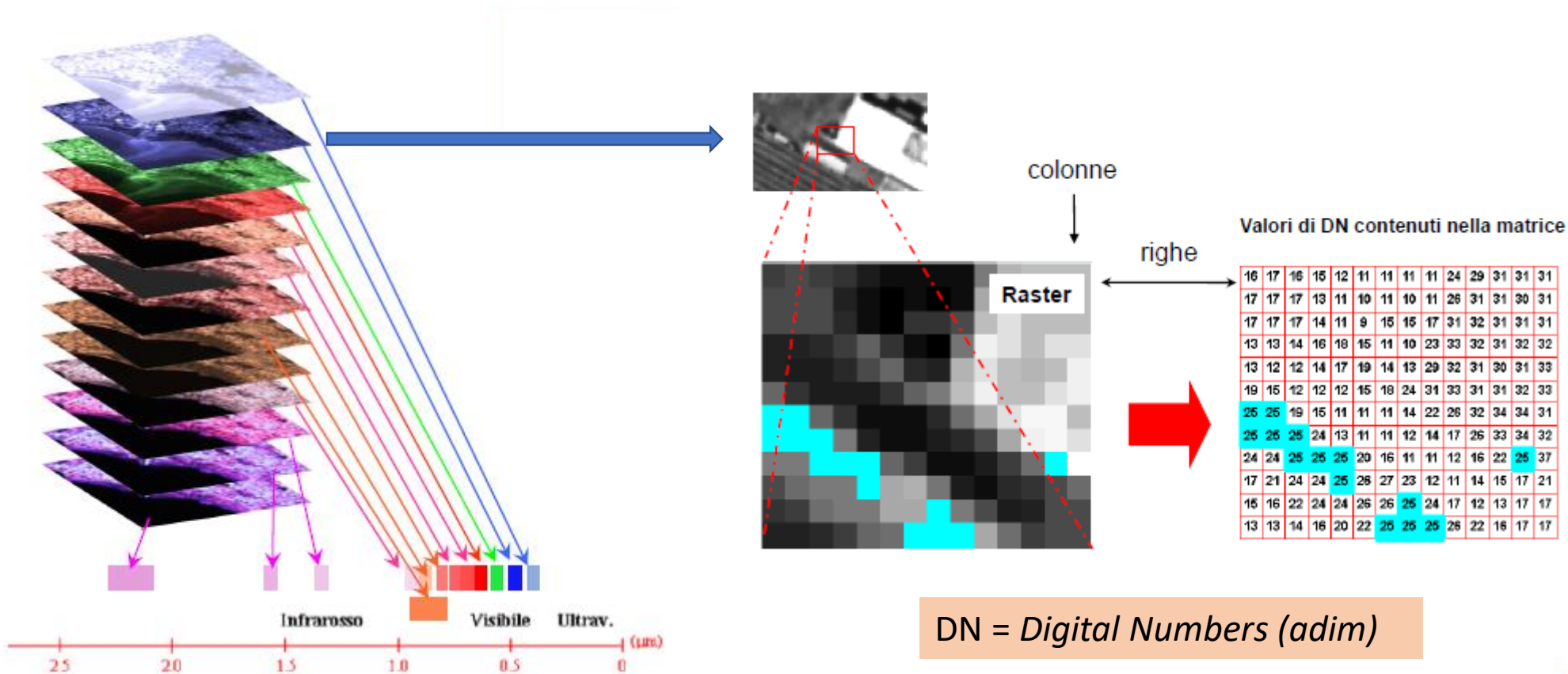


13 bande  
spettrali

MSI strumento  
«multispettrale»

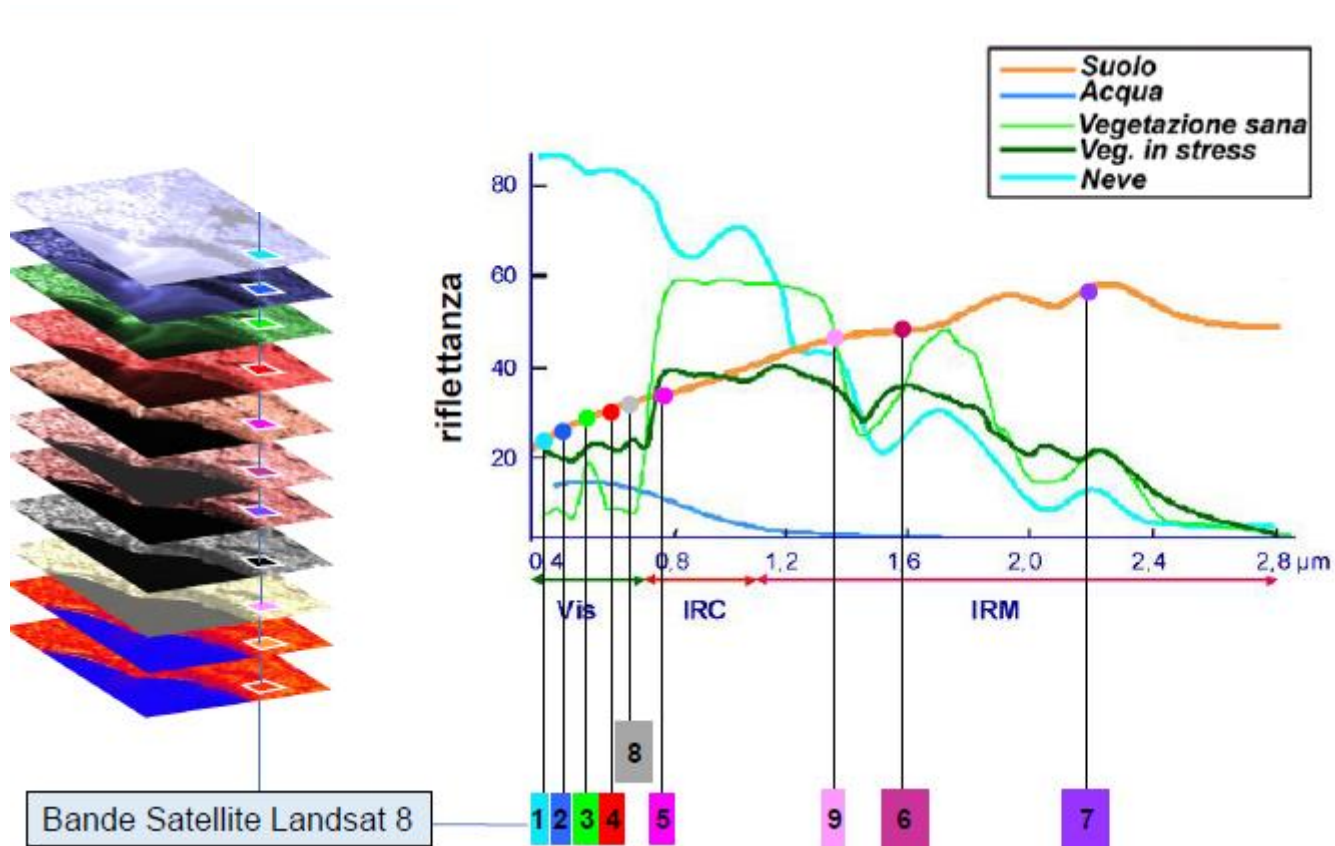
Maggior densità spettrale rispetto al SWIR  
→ Sentinel 2 pensato per studi vegetativi/atmosferici

# Monitoraggio del «Marine litter» con i satelliti



# Ricerca di Marine Litter con Sentinel 2: una questione aperta

Analisi delle informazioni di un raster: Firme Spettrali Vs indici ambientali



## Firma spettrale:

Raggruppamento dei valori di riflettanza per il medesimo pixel visto nelle diverse bande spettrali

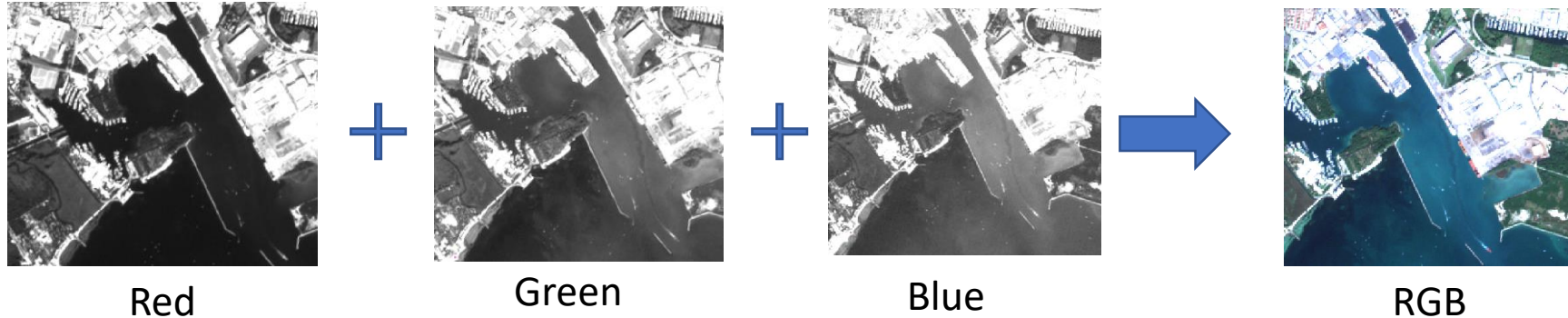


- Migliora con il migliorare della *risoluzione spettrale*
- Identifica in **modo univoco** il materiale contenuto nel pixel
- Tutte le bande devono essere portate alla medesima risoluzione spettrale (*raster band resampling*)



# Ricerca di Marine Litter con Sentinel 2: una questione aperta

Analisi delle informazioni di un raster: Firme Spettrali Vs indici ambientali



$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Normalized Difference  
Vegetation Index

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

Normalized Difference  
Water Index

## Show Indices for selected Sensor

Sentinel-2A

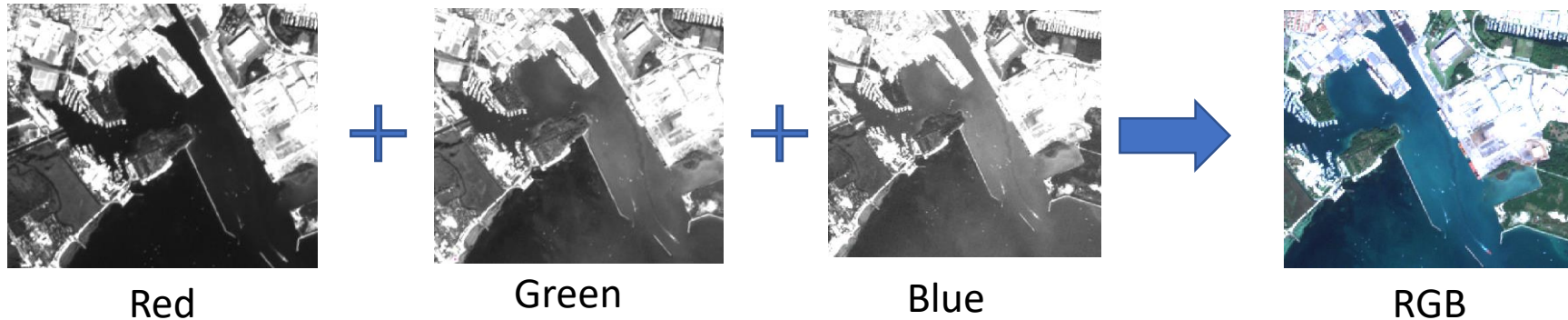
Select other Sensor.

Nr.	Name	Abbrev.
1	Adjusted transformed soil-adjusted VI	ATSAVI
2	Aerosol free vegetation index 1600	AFRI1600
3	Aerosol free vegetation index 2100	AFRI2100
4	Alteration	
5	Anthocyanin reflectance index	ARI
6	Ashburn Vegetation Index	AVI
7	Atmospherically Resistant Vegetation Index	ARVI
8	Atmospherically Resistant Vegetation Index 2	ARVI2

<https://www.indexdatabase.de/db/is.php>

# Ricerca di Marine Litter con Sentinel 2: una questione aperta

Analisi delle informazioni di un raster: Firme Spettrali Vs indici ambientali



$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Normalized Difference  
Vegetation Index

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

Normalized Difference  
Water Index

## Show Indices for selected Sensor

Sentinel-2A

Select other Sensor.

Nr.	Name	Abbrev.
1	Adjusted Vegetation Index	ATSAVI
2	Aerosol Optical Depth	AFRI1600
3	Aerosol Optical Depth	AFRI2100
4	Alteration Index	
5	Anthocyanin reflectance index	ARI
6	Ashburn Vegetation Index	AVI
7	Atmospherically Resistant Vegetation Index	ARVI
8	Atmospherically Resistant Vegetation Index 2	ARVI2

250 INDICI PER  
SENTINEL 2

<https://www.indexdatabase.de/db/is.php>

# Ricerca di Marine Litter con Sentinel 2: una questione aperta

Detection of floating plastics from satellite and unmanned aerial systems (Plastic Litter Project 2018)  
Konstantinos Topouzelis<sup>a,\*</sup>, Apostolos Papakonstantinou<sup>b</sup>, Shungudzemwoyo P. Garaba<sup>c</sup>

...rd the Integrated  
Observing System

... Debris

PLASTIC LITTER PROJECT 2019: EXPLORING THE DETECTION OF FLOATING PLASTIC LITTER USING DRONES AND SENTINEL 2 SATELLITE IMAGES  
Konstantinos Topouzelis<sup>1</sup>, Dimitris Papageorgiou<sup>1</sup>, Alexandros Karagaitanakis<sup>1</sup>, Apostolos Papakonstantinou<sup>1</sup>, Manuel Arias Ballesteros<sup>2</sup>

Advancing Floating Macroplastic Detection from Space Using Experimental Hyperspectral Imagery

...er Law<sup>3</sup>, Erik Van S...  
...ambitt<sup>6</sup>, Francois Galdani<sup>1</sup>.

...ing Floating Macroplastic Detection from Space Using Experimental Hyperspectral Imagery

Paolo Tasserou<sup>1,4</sup>, Tim van Emmerik<sup>1</sup>, Joseph Peller<sup>2</sup>, Louise Schreyers<sup>1</sup> and Lauren Biermann<sup>3</sup>

Marine plastic litter detection offshore Hawai'i by Sentinel-2

An airborne remote sensing case study of synthetic hydrocarbon detection

Remote Sensing of Sea Surface Algae and Plastic Targets with Sentinel-2 and Unmanned Aerial Systems (Plastic Litter Project 2019)

Visual observations of floating macro litter around Italy (Mediterranean Sea)

Claudia CAMPANALE<sup>1</sup>, Giuseppa SUARIA<sup>2,3</sup>, Giuseppa BAGNUOLO<sup>1</sup>, Matteo BAINI<sup>1</sup>, Matteo GALLI<sup>1</sup>

Article  
Development of Novel Classification Algorithms for Detection of Floating Plastic Debris in Coastal Waterbodies Using Multispectral Sentinel-2 Remote Sensing Imagery

Article  
Remotely Sensing the Source and Transport of Marine Plastic Debris in Bay Islands of Honduras (Caribbean Sea)

Floating marine litter detection algorithms and techniques using optical remote sensing data: A review

Konstantinos Topouzelis<sup>a,\*</sup>, Dimitris Papageorgiou<sup>a</sup>, Giuseppe Suaria<sup>b</sup>, Stefano Aliani<sup>b</sup>

Waters using Optical Satellite

Lauren Biermann<sup>1\*</sup>, Daniel Clewley<sup>1</sup>, Victor Martinez-Vicente<sup>1</sup> & Konstantinos Topouzelis<sup>2</sup>

...g Detection of Floati  
Space Using Sentinel-2 Imagery

...measuring ma...  
...ine Plastic Debris from Space:  
Initial Assessment of Observation Requiremen

Detection of marine floating plastic using Sentinel-2 imagery and machine learning models

CleanAtlantic  
Tackling Marine Litter in the Atlantic Area

# Investigating Marine Litter with Remote Sensing

Ricerca di Marine Litter: articoli a disposizione a partire dal 2018



Diversi indici testati su oggetti di natura ignota o plastica



*remote sensing*

Auth: Vicente et al

*Perspective*

**Measuring Marine Plastic Debris from Space:  
Initial Assessment of Observation Requirements**

$$NDVI = (B08 - B04)/(B08 + B04)$$

$$NDWI = (B03 - B08)/(B03 + B08)$$

$$NDBI = (B11 - B8)/(B11 + B8)$$

$$PI = B08/(B08 + B04)$$

$$FDI = B08 - B06 - (B11 - B6) * K$$

$$SR = B08/B04$$

$$B812 = B08 - B12$$

# Investigating Marine Litter with Remote Sensing

Ricerca di Marine Litter: articoli a disposizione a partire dal 2018



*remote sensing*

Auth: Vicente et al

*Perspective*

**Measuring Marine Plastic Debris from Space:  
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$$NDVI = (B08 - B04)/(B08 + B04)$$

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$$PI = B08/(B08 + B04)$$

$$FDI = B08 - B06 - (B11 - B6) * K$$

$$SR = B08/B04$$

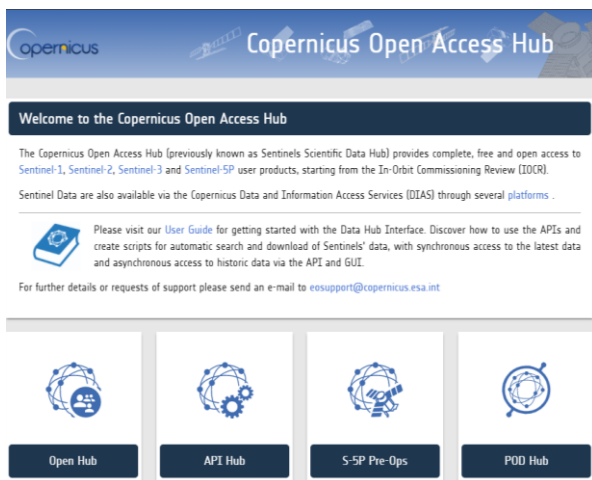
$$B812 = B08 - B12$$

Conclusioni differenti di studio in studio.

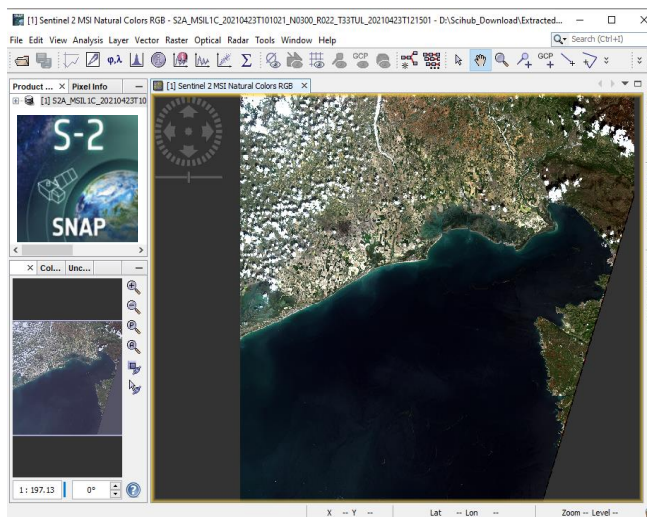
Dibattito aperto sul (sui?) metodo risolutivo e replicabile più efficace

# Processo di elaborazione di un raster Sentinel 2

1. Selezione e download dei file da portale <https://scihub.copernicus.eu/>



2. Indagine visiva del Raster con ESA Sentinel Toolbox <http://step.esa.int/main/download/snap-download/>



3. Analisi di *casi studio*, ossia sottoselezioni del raster, con librerie e codici basati su Python

```
31 # 0.IMPORTING ALL THE NECESSARY LIBRARIES
32 #-----#
33 print('Importing all the necessary libraries...')
34 import os, shutil, re, glob
35 import rasterio
36 from rasterio.plot import show
37 from pyproj import Transformer
38 from geomet import wkt
39 import json
40 from rasterio.mask import mask
41 import matplotlib
42 import matplotlib.pyplot as plt
43 print('...Done')
44
45 #-----#
46 # 1. GETTING SUBKEYWORDS TO DEFINE LOG AND WKT FILENAMES
47 #-----#
48
49 KEY = 'TH'
50 START_DIR = '\\Sentinel2\\CASE_STUDIES'
51 LOAD_DIR = '\\Sentinel2\\SETTINGS\\LOAD'
52
53 id_list = []
54
55 with open(LOAD_DIR+'\\Current.txt','r') as log:
56     for l in log:
57         id_list.append( l.split()[2].strip() )
58
59 ID = id_list[0]
60 SUB_ID = id_list[1]
61 FT = id_list[2]
62 ATMO = id_list[3]
63 PLAT = id_list[4]
64 SAFENAME = id_list[5]
65 HOMO = id_list[6]
```

- Riproducibilità
- Automatizzazione
- Portabilità

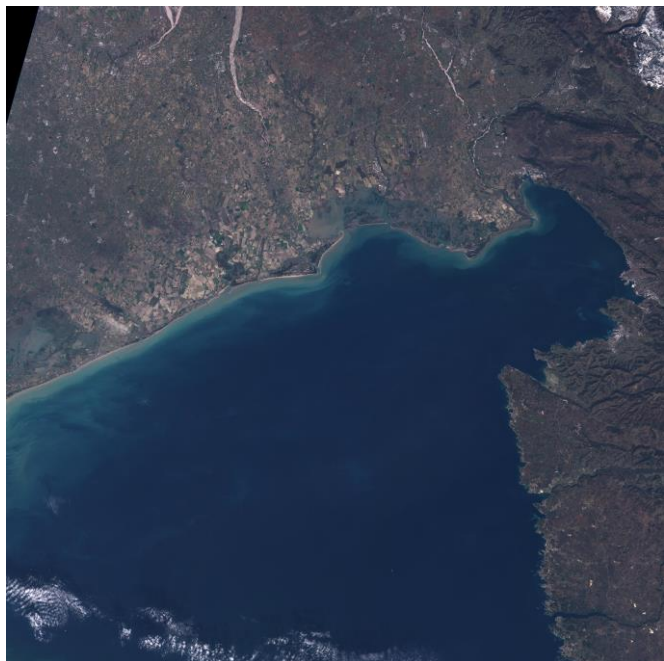
# 1. Selezione e download dei file da portale

The screenshot displays the Copernicus Open Access Hub interface. On the left, there are search filters for 'Sensing period' (2021/12/01 to 2021/12/13) and 'Ingestion period'. Below these are three mission selection options: Sentinel-1, Sentinel-2, and Sentinel-3. The Sentinel-2 mission is selected, with 'S2MS1C' chosen as the Product Type and 'Cloud Cover % (e.g. [0 TO 9.4])' as the sensor mode. A map in the center shows a highlighted area in the Friuli Venezia Giulia region. On the right, a list of products is displayed, including details like 'Request Done', 'Download URL', 'Mission', 'Instrument', and 'Sensing Date'. The first product is S2B\_MSI\_S2B\_MSIL1C\_20211211T100319\_N0301\_R122\_T33TUL\_20211211T105127.

Raster  
Preview

# Classificazione visiva delle immagini

Cloud Free ROI



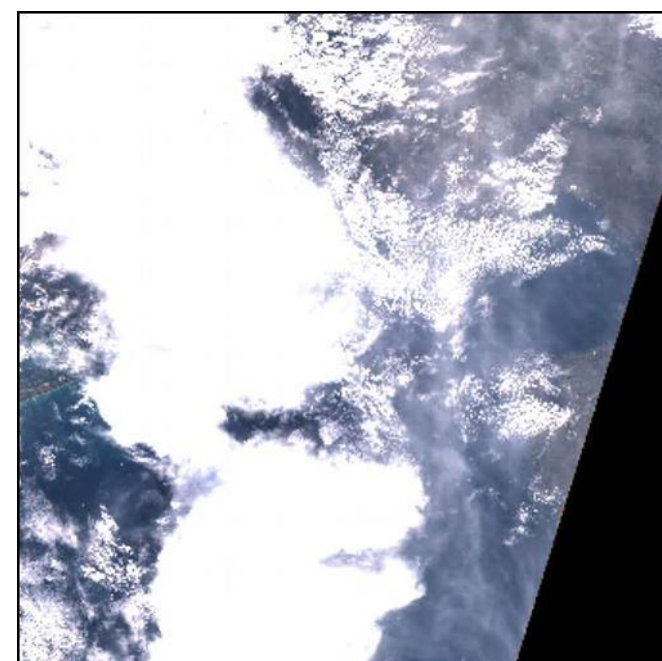
L1C\_S2B\_06-03-2021

Partly Covered ROI



L1C\_S2B\_12-07-2021

Cloud Covered ROI



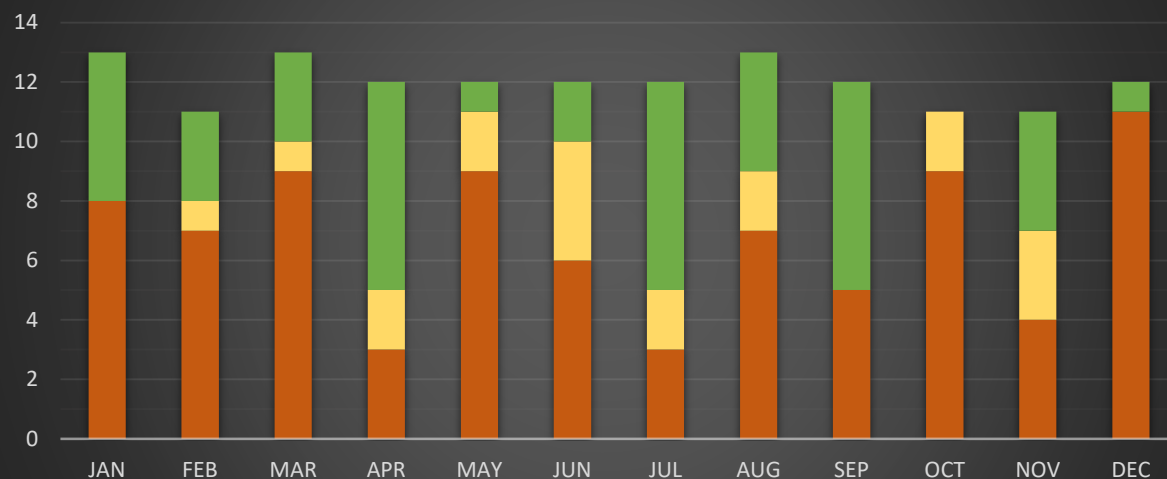
L1C\_S2B\_11-11-2021

ROI = Regione di Interesse, ottenuta dalla selezione di un poligono all'interno di una *tile*

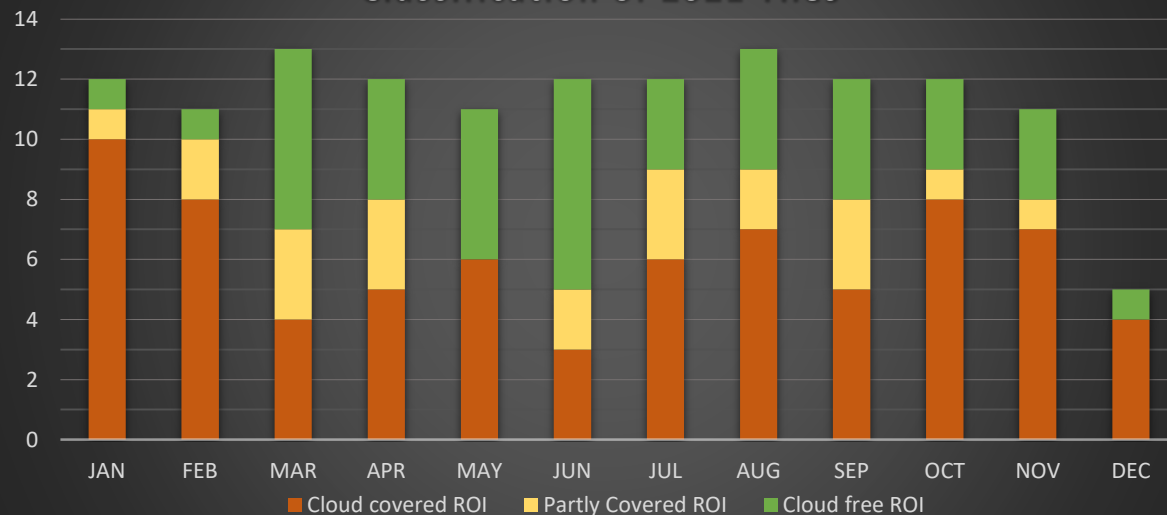


# Classificazione visiva delle immagini

Classification of 2020 Tiles



Classification of 2021 Tiles



Annual Orbits
144
Mean Monthly Orbits
12,0
Most 2021 Cloud Covered Month
December
Most Cloud Free Orbit Month
July

% Cloud Covered ROI
54%
% Cloud Free ROI
30%

↓  
43 GIORNI  
NEL 2020

Annual Orbits
136
Mean Monthly Orbits
11,9
Most 2021 Cloud Covered Month
January
Most Cloud Free Orbit Month
June

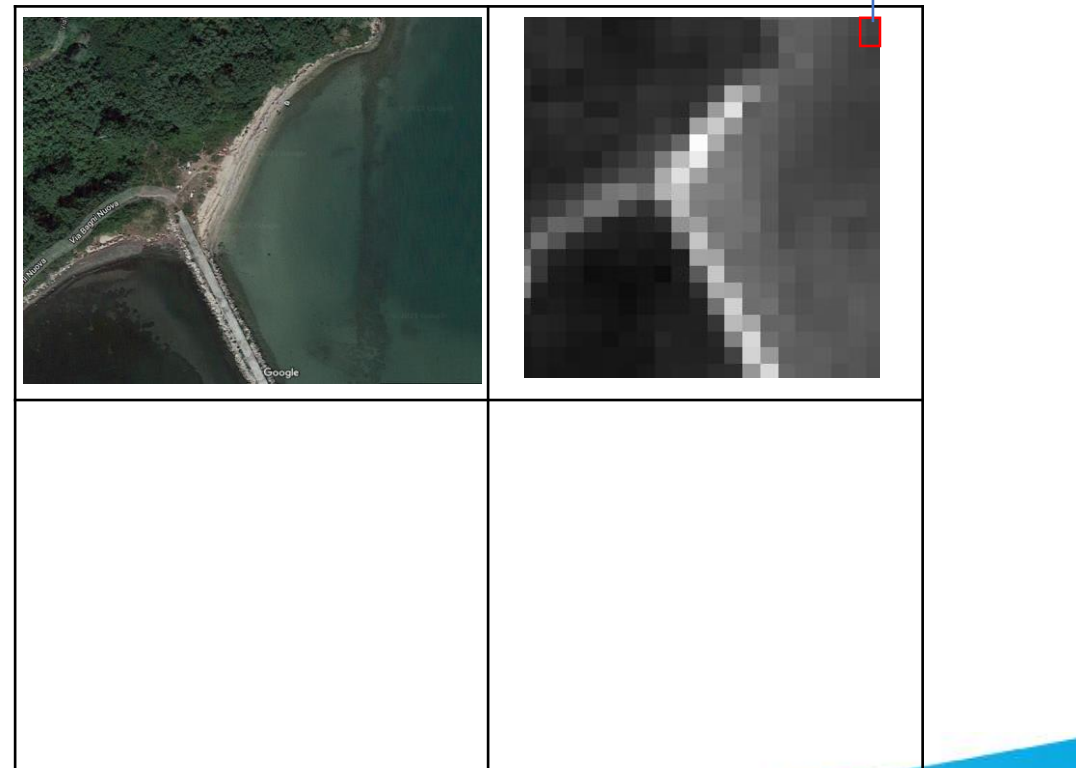
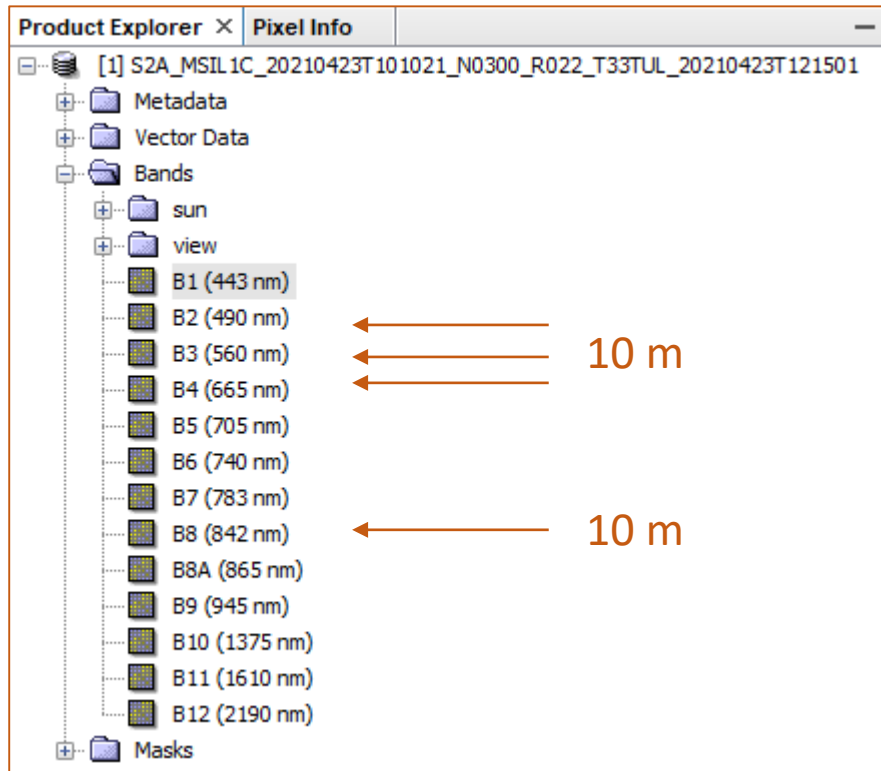
% Cloud Covered ROI
56%
% Cloud Free ROI
31%

↓  
44 GIORNI  
NEL 2021

## 2. Indagine visiva del Raster con ESA Sentinel Toolbox

S2A\_MSIL1C\_20210423T101021\_N0300\_R022\_T33TUL\_20210423T121501.SAFE

← RASTER



## 2. Indagine visiva del Raster con ESA Sentinel Toolbox

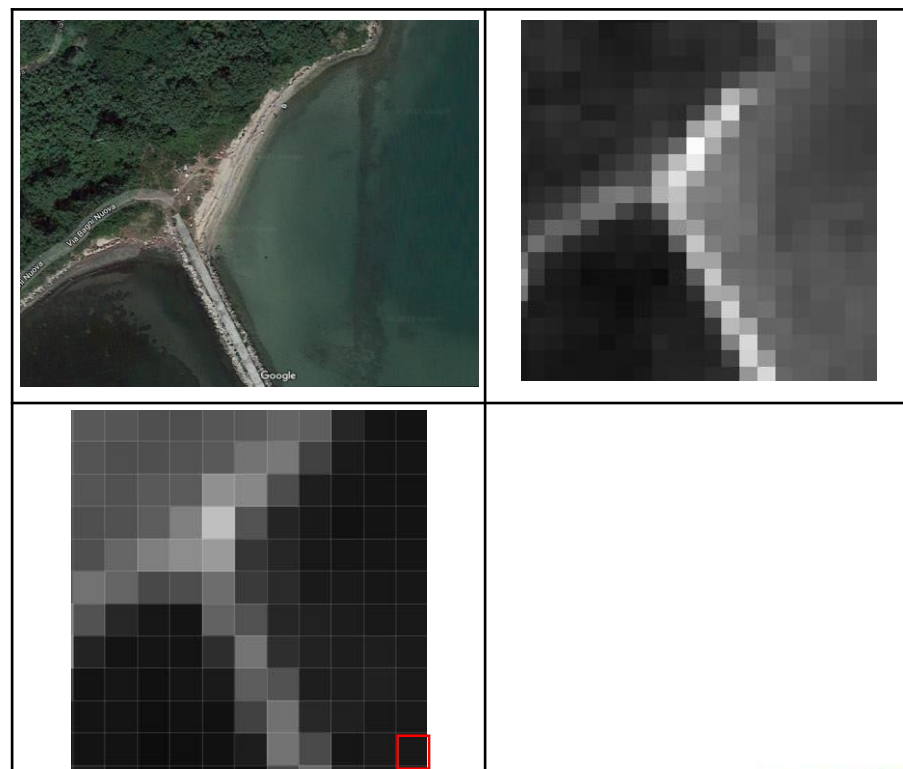
S2A\_MSIL1C\_20210423T101021\_N0300\_R022\_T33TUL\_20210423T121501.SAFE

← RASTER

Product Explorer x Pixel Info

[1] S2A\_MSIL1C\_20210423T101021\_N0300\_R022\_T33TUL\_20210423T121501

- Metadata
- Vector Data
- Bands
  - sun
  - view
    - B1 (443 nm) ← 10 m
    - B2 (490 nm) ← 10 m
    - B3 (560 nm) ← 10 m
    - B4 (665 nm) ← 10 m
    - B5 (705 nm) ← 20 m
    - B6 (740 nm) ← 20 m
    - B7 (783 nm) ← 20 m
    - B8 (842 nm) ← 10 m
    - B8A (865 nm) ← 20 m
    - B9 (945 nm) ← 20 m
    - B10 (1375 nm) ← 20 m
    - B11 (1610 nm) ← 20 m
    - B12 (2190 nm) ← 20 m
- Masks



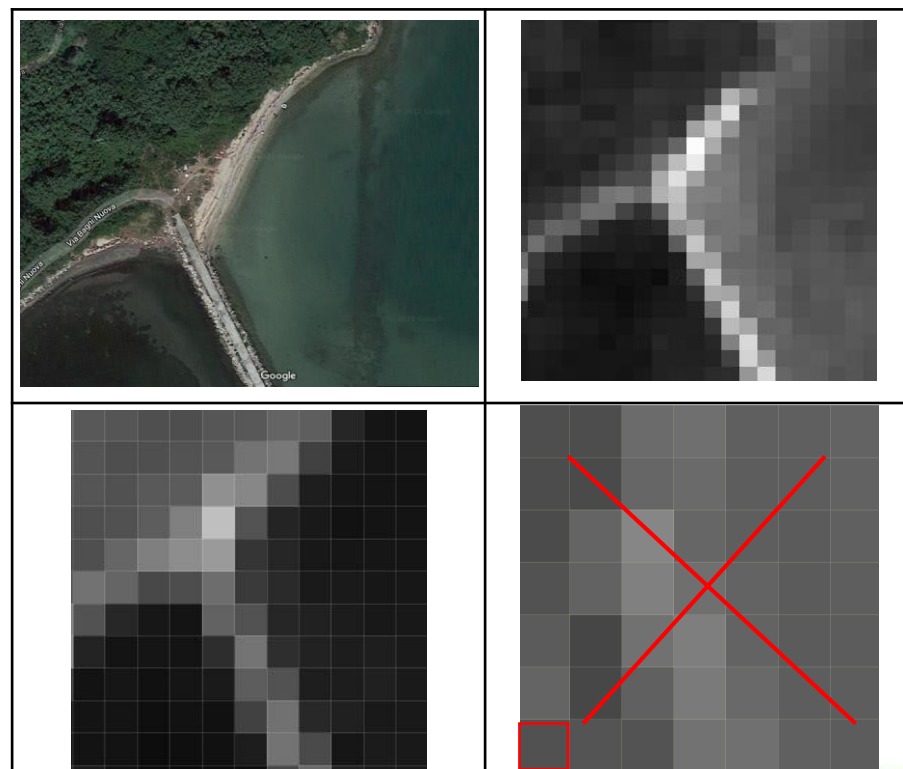
↳ 400 m<sup>2</sup>

## 2. Indagine visiva del Raster con ESA Sentinel Toolbox

S2A\_MSIL1C\_20210423T101021\_N0300\_R022\_T33TUL\_20210423T121501.SAFE

← RASTER

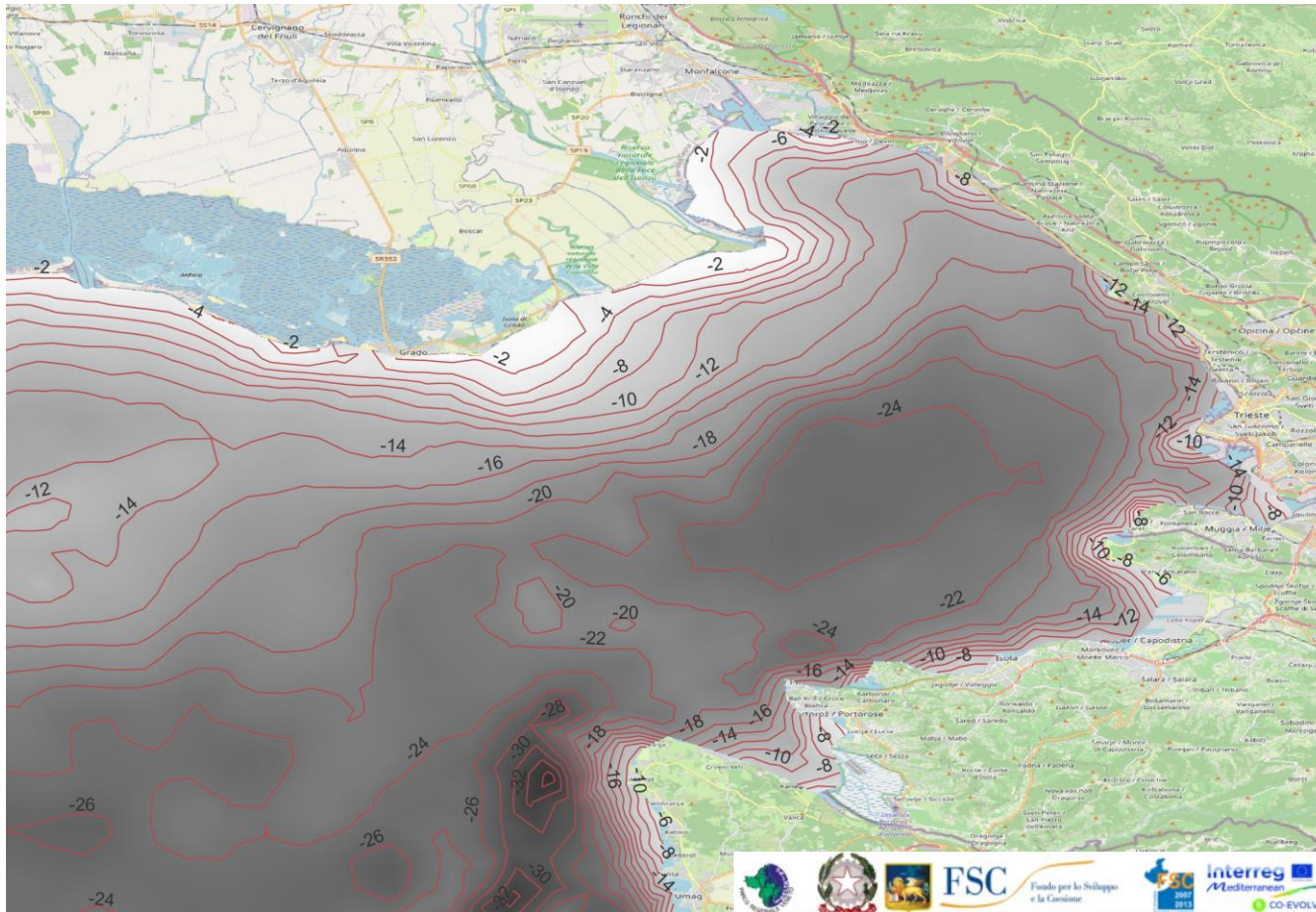
Band	Resolution
B1 (443 nm)	60 m
B2 (490 nm)	10 m
B3 (560 nm)	10 m
B4 (665 nm)	10 m
B5 (705 nm)	20 m
B6 (740 nm)	20 m
B7 (783 nm)	20 m
B8 (842 nm)	10 m
B8A (865 nm)	20 m
B9 (945 nm)	60 m
B10 (1375 nm)	60 m
B11 (1610 nm)	20 m
B12 (2190 nm)	20 m



→ 3600 m<sup>2</sup>

# 3. Analisi di particolari casi studio

## 1) Studio dell'acqua di mare



### 3 fasce batimetriche:

- $-10 \leq h < -5$  (BAT5)
- $-20 \leq h < -10$  (BAT10)
- $h \leq -20$  (BAT20)

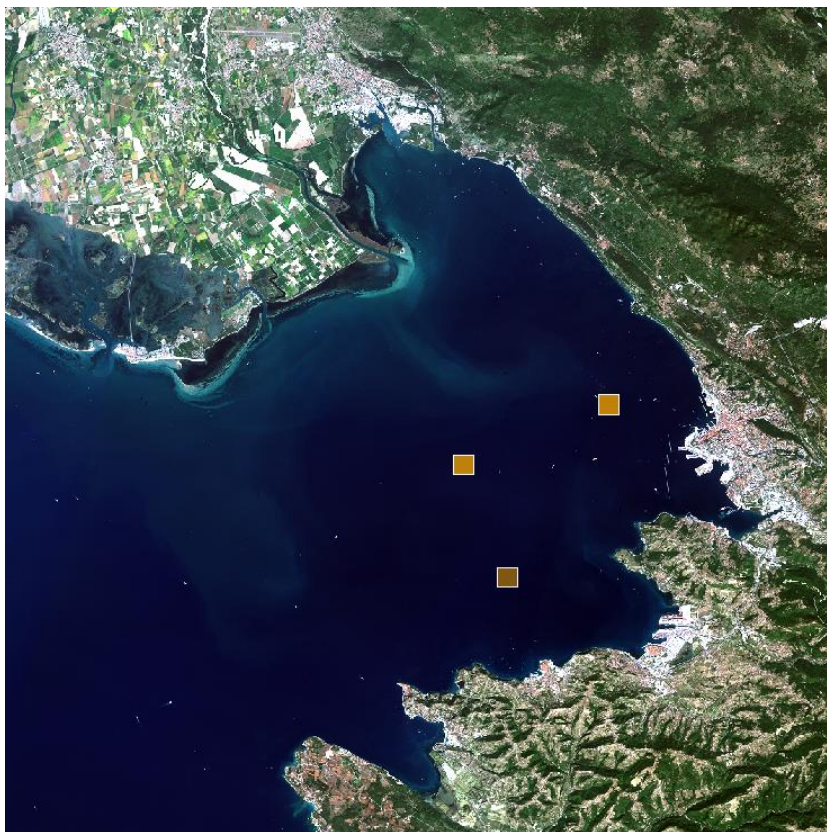
### Zone vicine alla costa:

- $h > -5$  (SHWT)
- + Distinzione  
alta/bassa marea  
(Low/High Tide)

# 3. Analisi di particolari casi studio

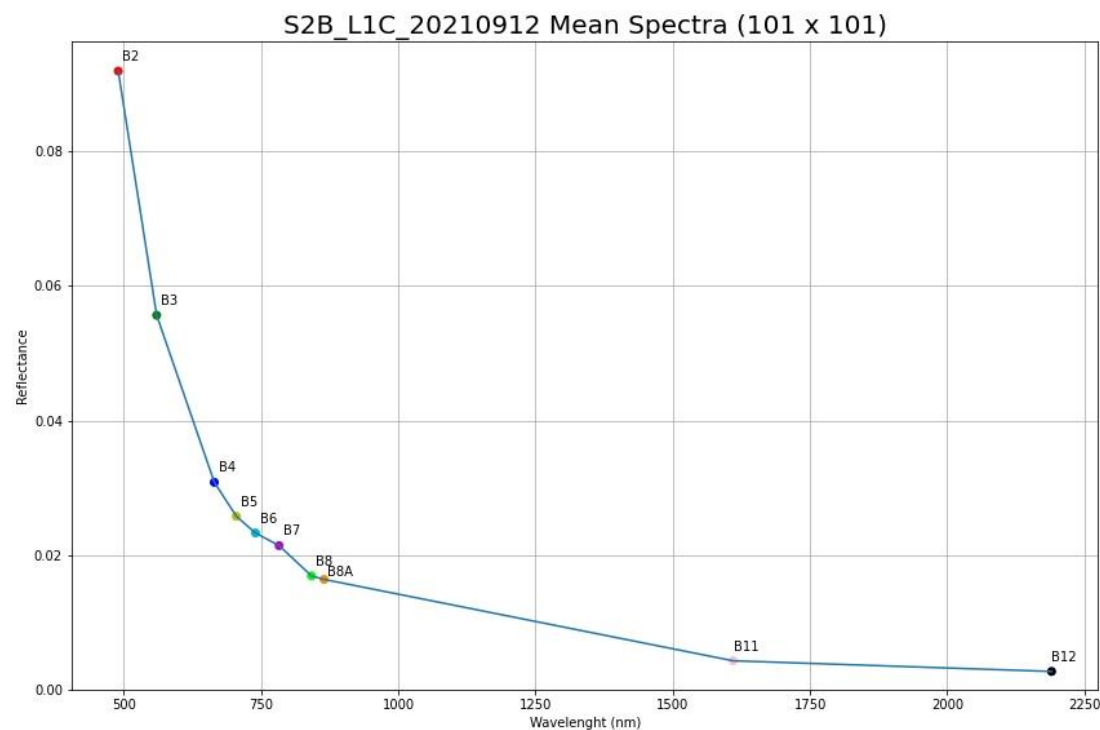
## 1) Studio dell'acqua di mare

### BAT20



ROI :: 100 x 100 pixels

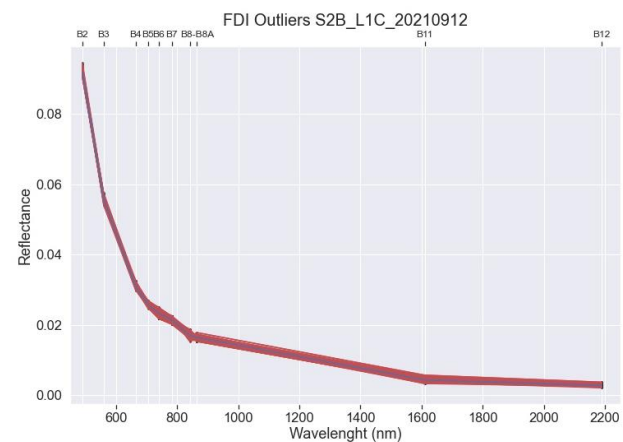
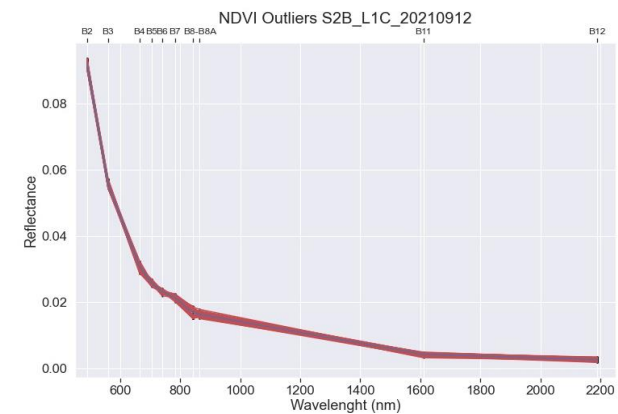
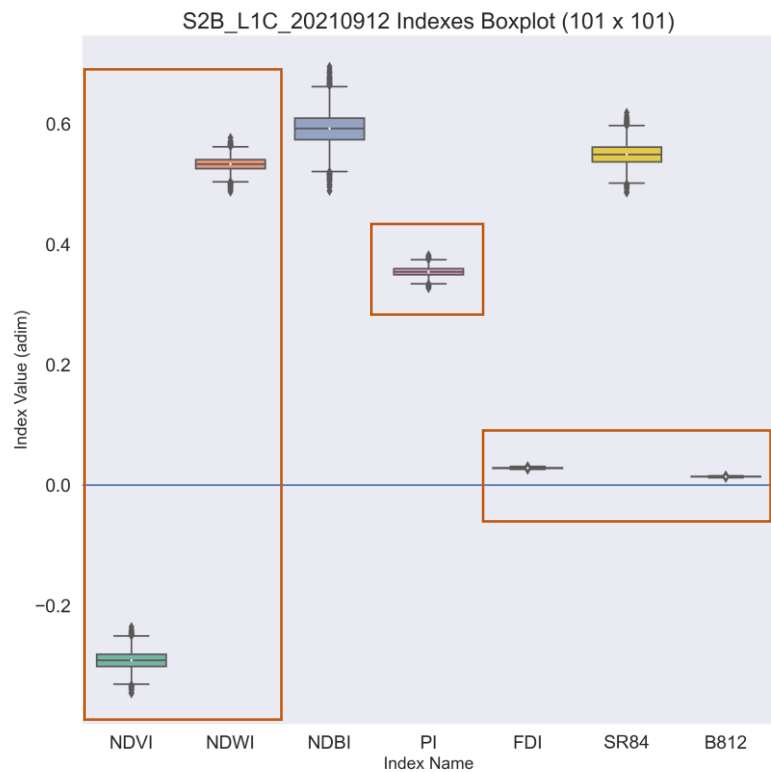
Date, Time :: 12-09-2021 , 10:03:00 UTC



# 3. Analisi di particolari casi studio

## 1) Studio dell'acqua di mare

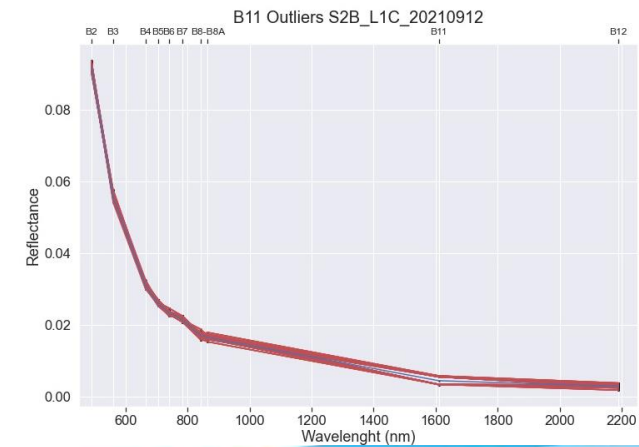
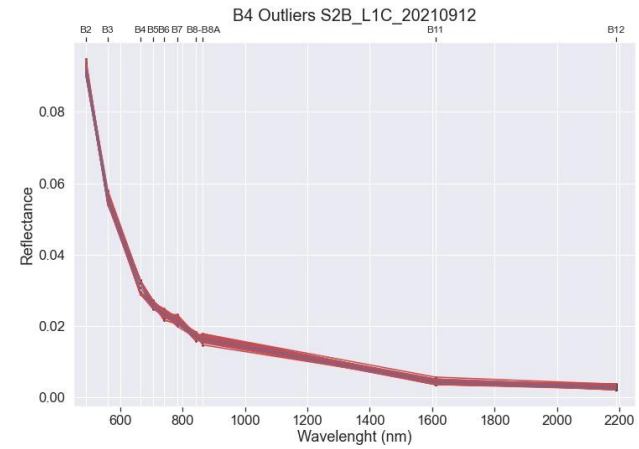
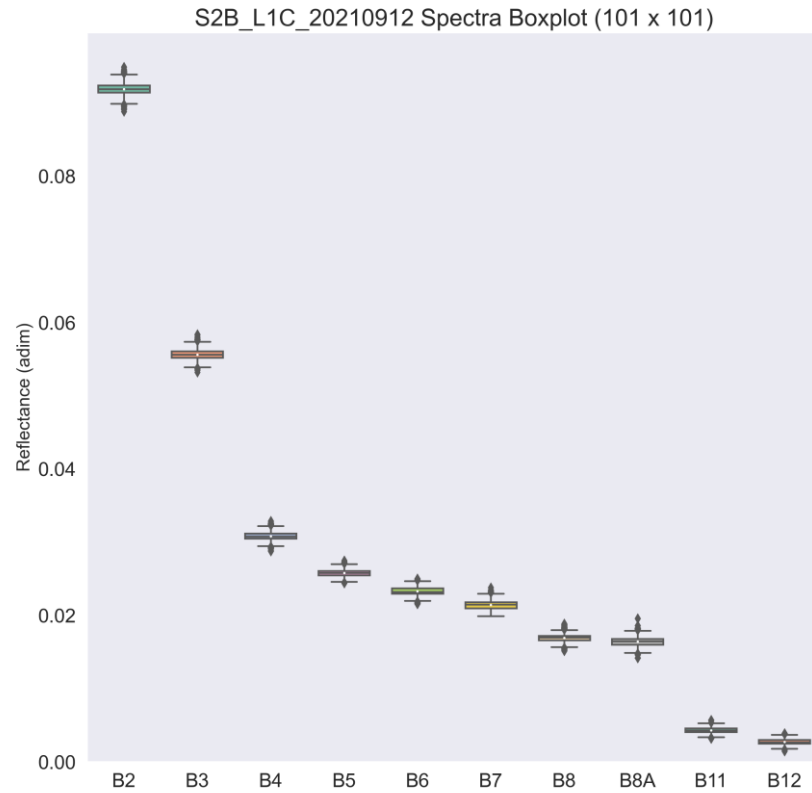
### BAT20



# 3. Analisi di particolari casi studio

## 1) Studio dell'acqua di mare

### BAT20

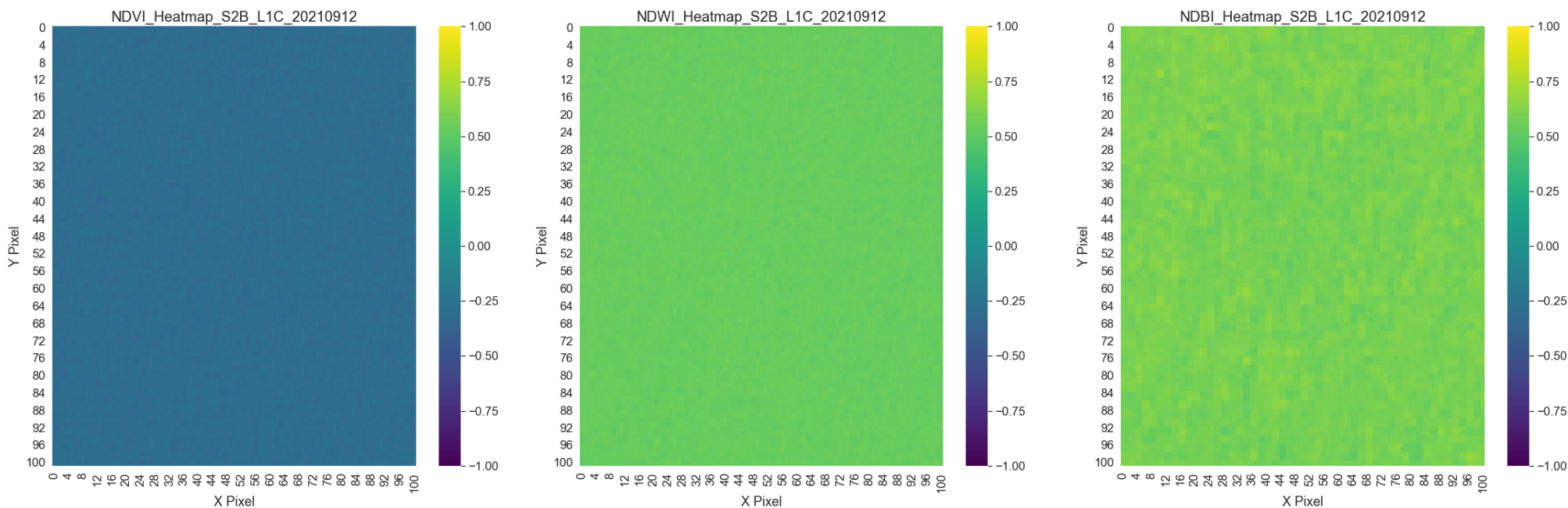




# 3. Analisi di particolari casi studio

## 1) Studio dell'acqua di mare

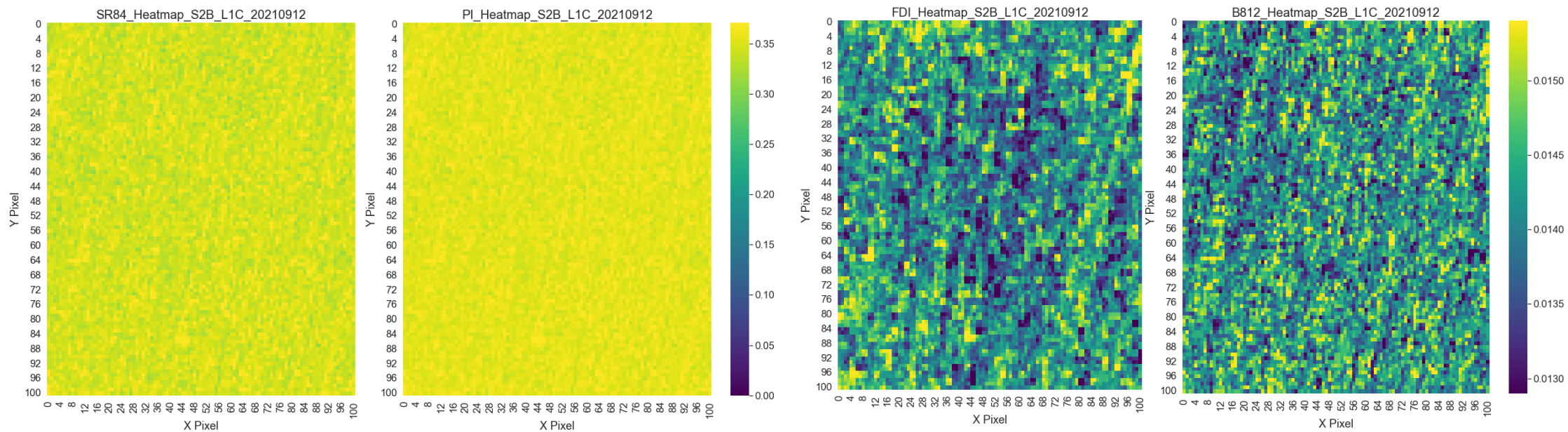
### BAT20



# 3. Analisi di particolari casi studio

## 1) Studio dell'acqua di mare

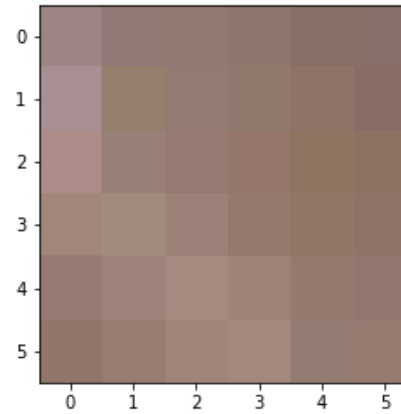
### BAT20



# 3. Analisi di particolari casi studio

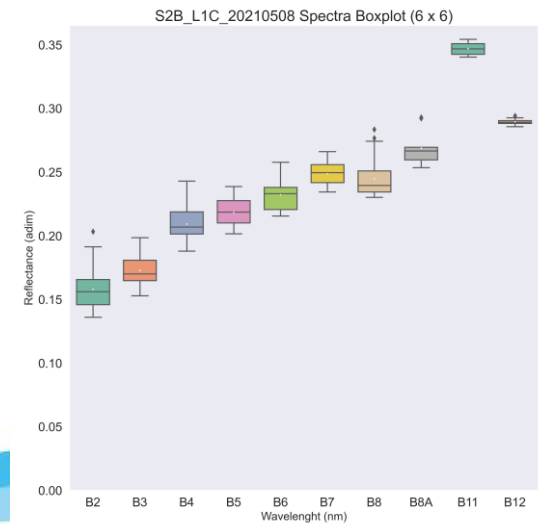
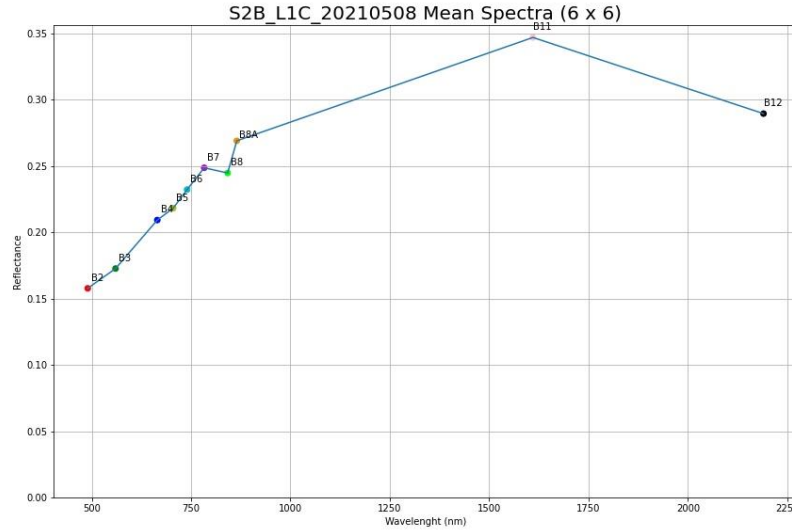
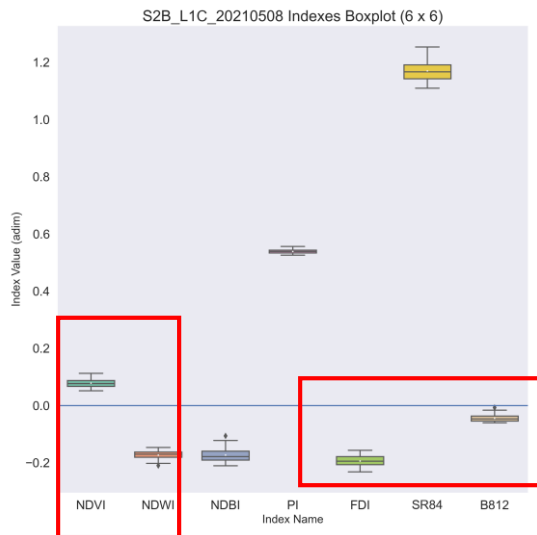
## 2) Studio della sabbia

### Spiaggia di Lignano Sabbiadoro



ROI :: 5 x 5 pixel

Date, Time :: 08-05-2021  
10:05:49 UTC



# 3. Analisi di particolari casi studio

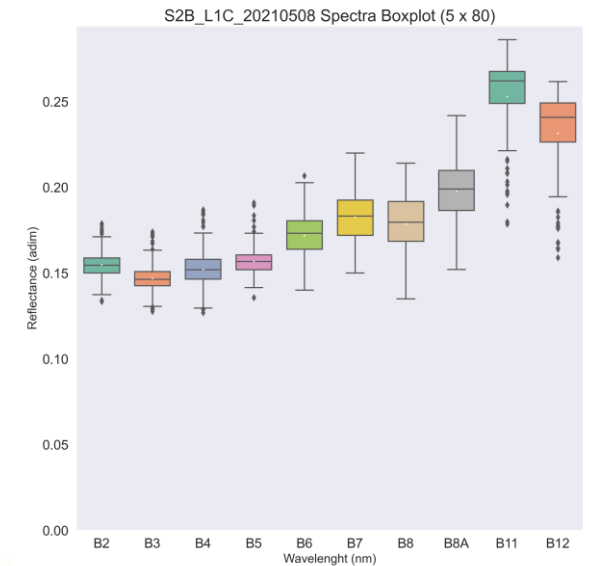
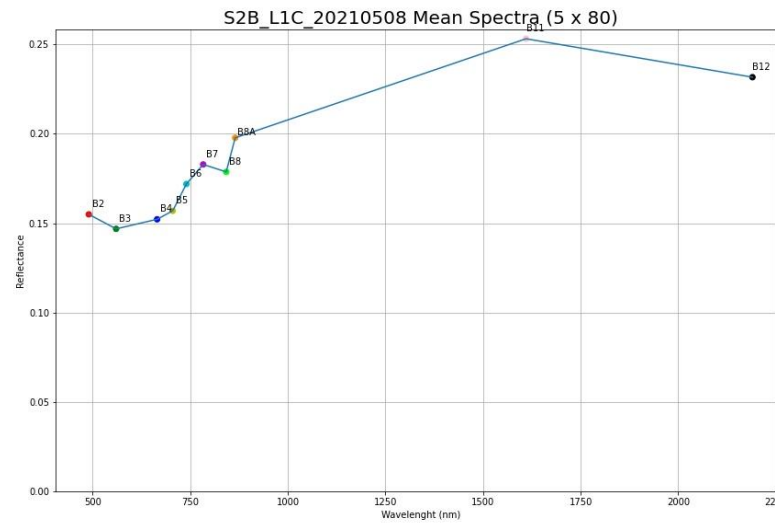
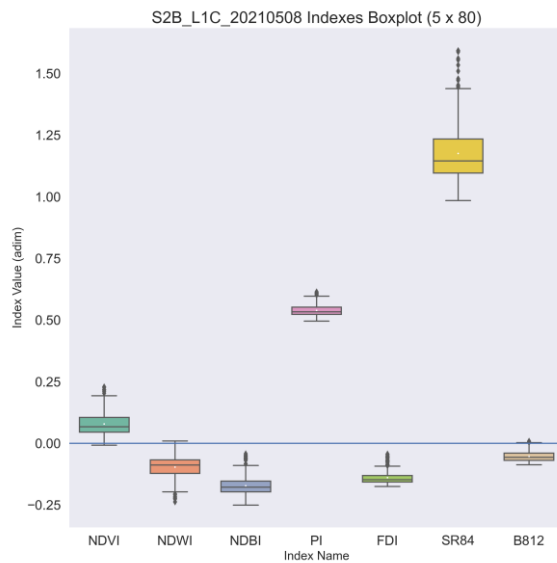
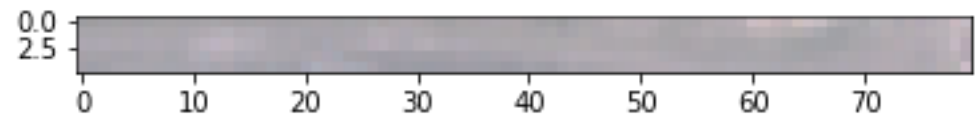
## 2) Studio della sabbia

### Spiaggia dell'Isola di Sant'Andrea



ROI :: 80 x 5 pixel

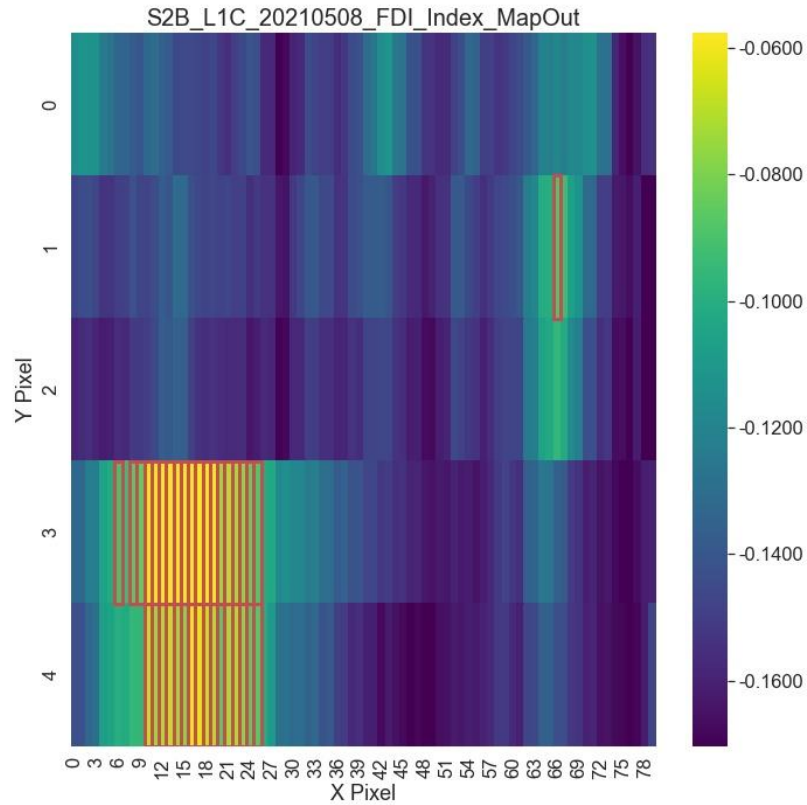
Date, Time :: 08-05-2021 , 10:05:49 UTC



# 3. Analisi di particolari casi studio

## 2) Studio della sabbia

### Spiaggia dell'Isola di Sant'Andrea



# 3. Analisi di particolari casi studio

## Finding Plastic Patches in Coastal Waters using Optical Satellite Data

Lauren Biermann<sup>1\*</sup>, Daniel Clewley<sup>1</sup>, Victor Martinez-Vicente<sup>1</sup> & Konstantinos Topouzelis<sup>2</sup>



Figure 5. Substantial quantities of plastics and debris covered waters of Durban harbour on the 23<sup>rd</sup> of April 2019, after flooding over the Easter weekend. Within two days, the macroplastics had been washed out to sea. Photos kindly shared with informed consent to publish.

## Marine plastic litter detection offshore Hawai'i by Sentinel-2

Achille Carlo Ciappa

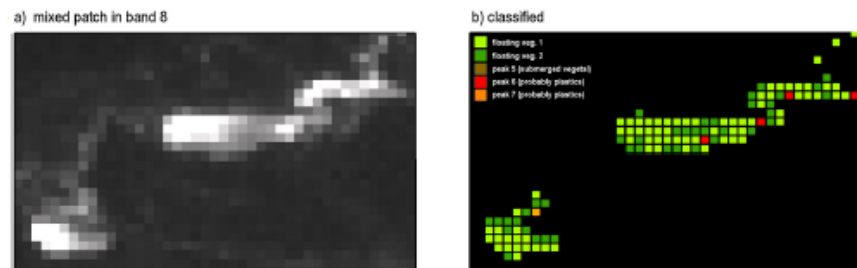
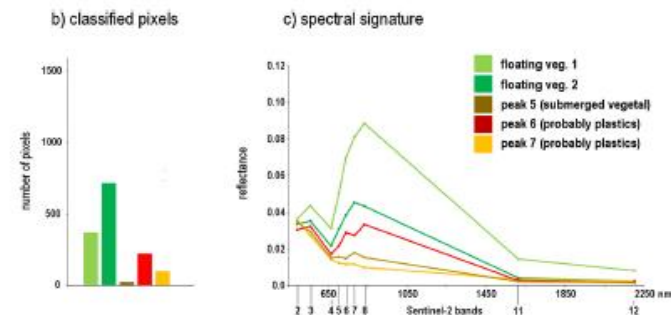


Fig. 5. (a) Mixed patch detected in North Adriatic in band 8 and (b) classified pixels (20 m spatial resolution).



# 3. Analisi di particolari casi studio

## 3) Studio della *Noctiluca Scintillans*

23 Aprile 2021

**ARPA FVG** agenzia regionale PER LA PROTEZIONE DELL'AMBIENTE DEL FRIULI VENEZIA GIULIA

Sistema Nazionale per la Protezione dell'Ambiente

aria | **acqua** | suolo | rifiuti | rumore | radiazioni | rischi industriali | laboratorio

sei in: [home page](#) » [acqua](#) » [news](#) » Fioritura di *Noctiluca scintillans* e le acque del Golfo si colorano di rosso

### Fioritura di "Noctiluca scintillans" e le acque del Golfo si colorano di rosso

20/04/2021

Strisce galleggianti rossastre nel Golfo di Trieste hanno caratterizzato in questi giorni il colore delle acque marine costiere regionali.

Il 16 aprile 2021, i tecnici di Arpa FVG hanno effettuato dei prelievi di acqua superficiale nell'area centrale del Golfo e hanno appurato la presenza della microalga *Noctiluca scintillans* quale responsabile di questo fenomeno noto come "bloom fitoplanctonico".

Nel campione di acqua marina le cellule, delle dimensioni che variavano dai 250 ai 600 µm, erano presenti in quantità di circa 30.000 cellule/L.

Nel periodo primaverile l'aumento della temperatura e l'apporto di nuovi sali nutritivi che giungono attraverso l'azione delle piogge e dello scioglimento delle nevi, stimolano e favoriscono in mare la riproduzione di numerose specie microalgali che frequentemente danno origine a fioriture facilmente osservabili per le diverse colorazioni che imprimono alle acque marine superficiali.

*Noctiluca scintillans* è un'alga unicellulare appartenente al gruppo tassonomico dei

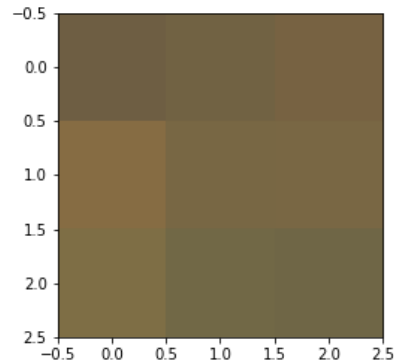


Colorazione delle acque costiere per la presenza del bloom di *Noctiluca scintillans*



# 3. Analisi di particolari casi studio

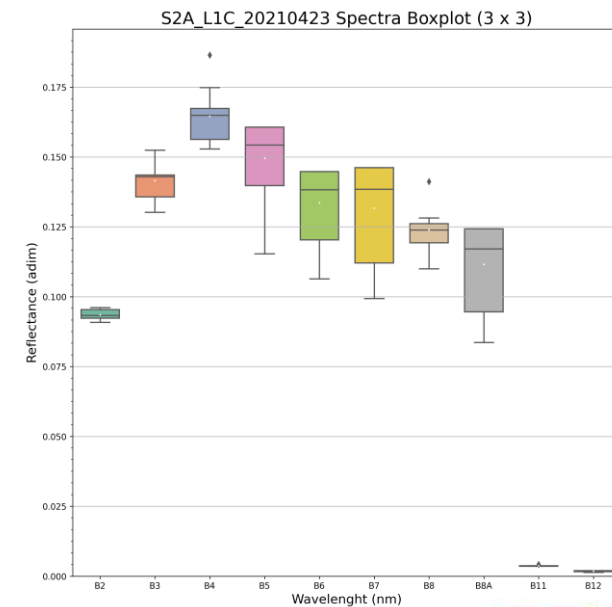
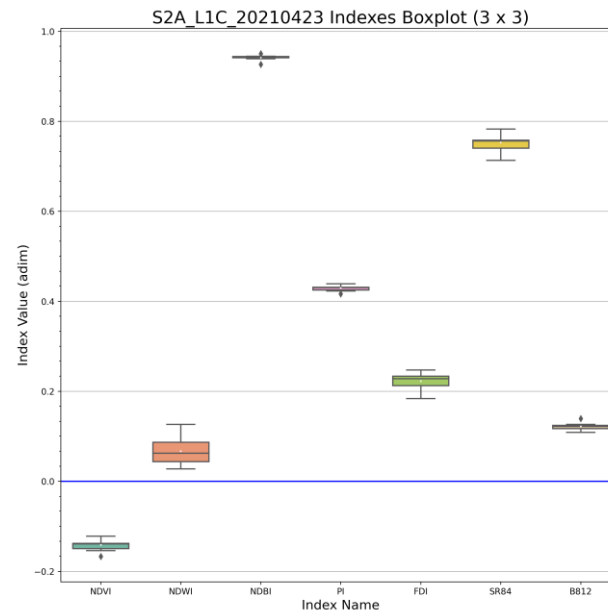
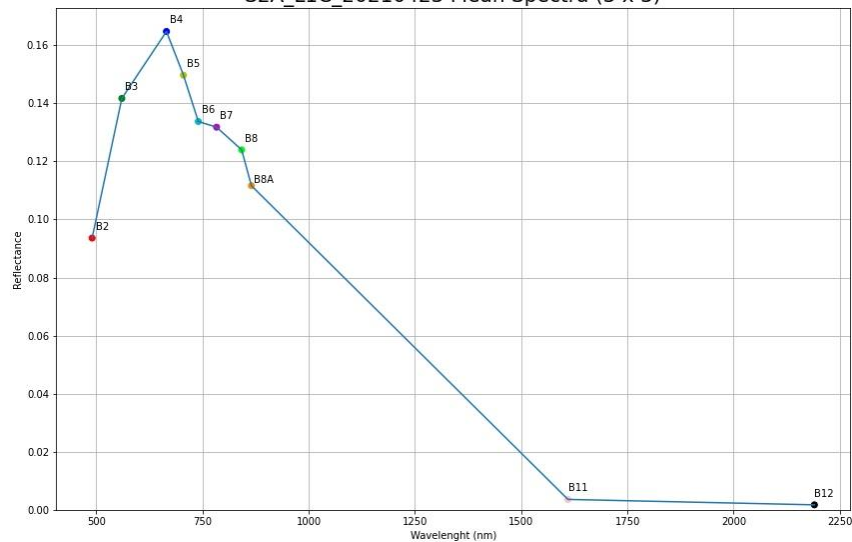
## 3) Studio della *Noctiluca Scintillans*



ROI :: 3 x 3 pixel

Date, Time :: 23-04-2021 , 10:10:21 UTC

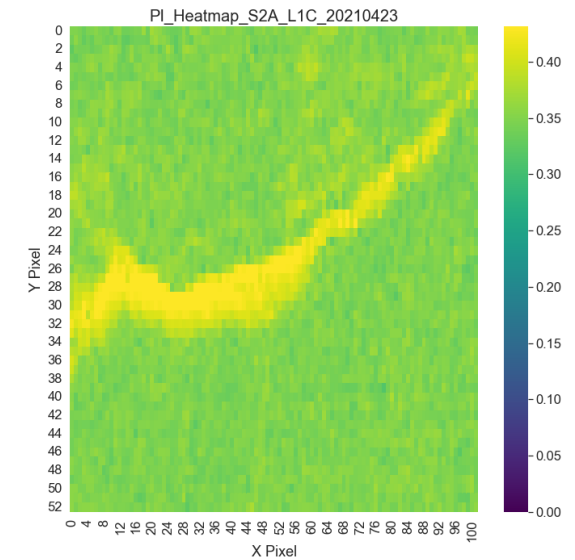
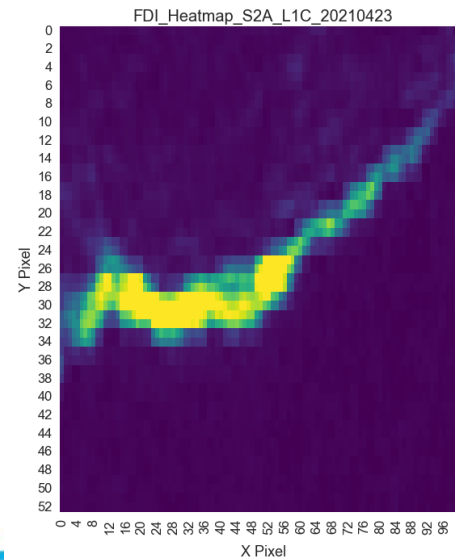
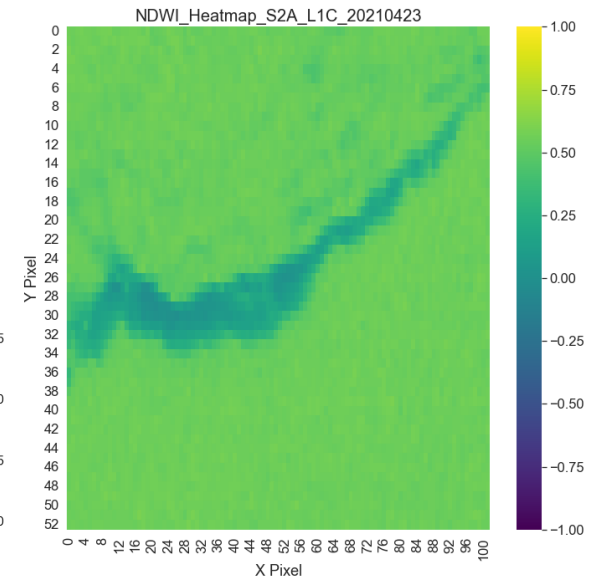
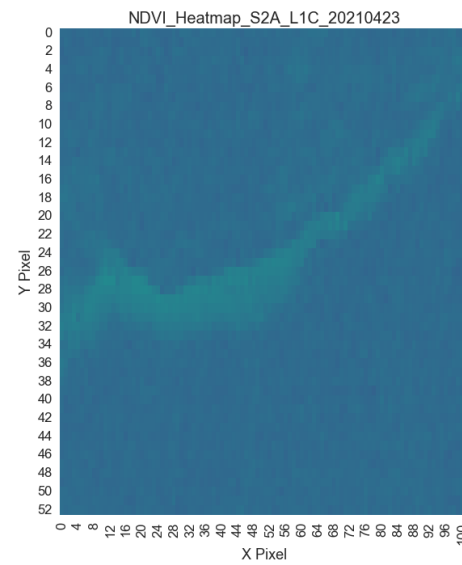
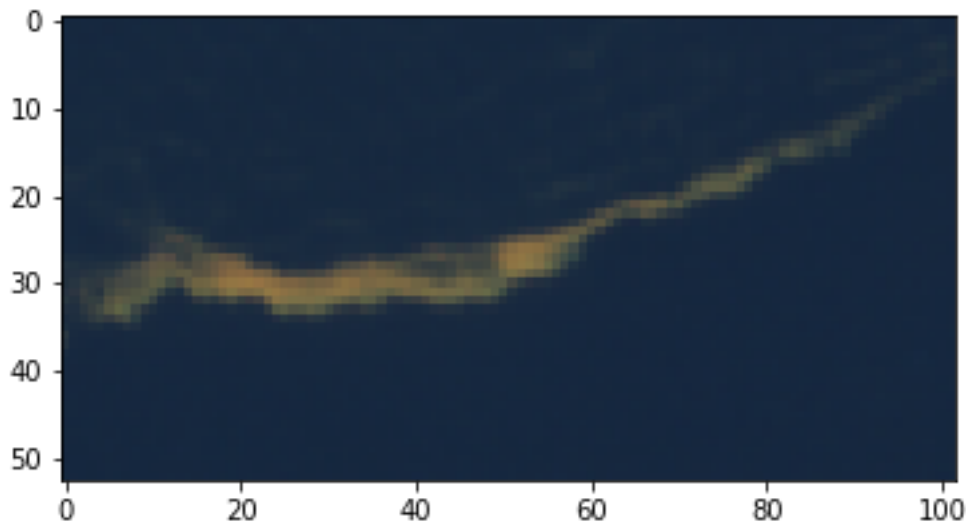
S2A\_L1C\_20210423 Mean Spectra (3 x 3)





# 3. Analisi di particolari casi studio

## 3) Studio della *Noctiluca Scintillans*

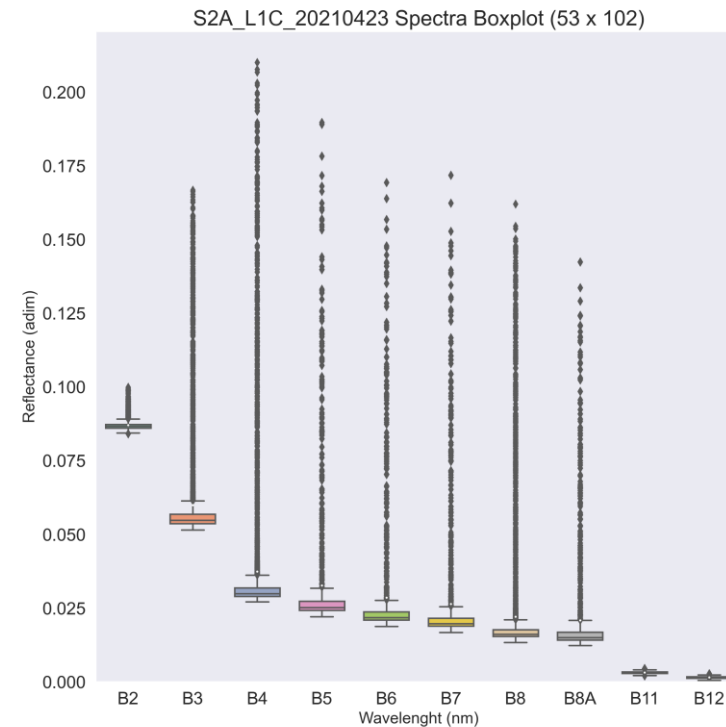
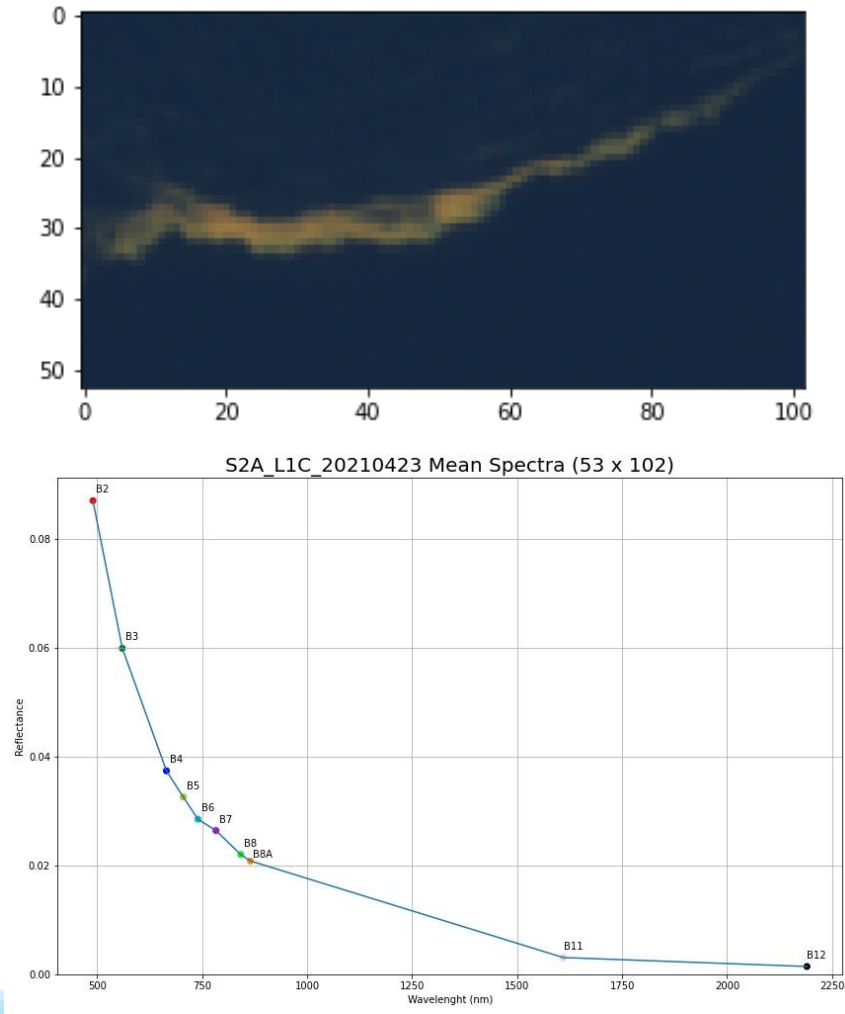


# 3. Analisi di particolari casi studio

## 3) Studio della *Noctiluca Scintillans*

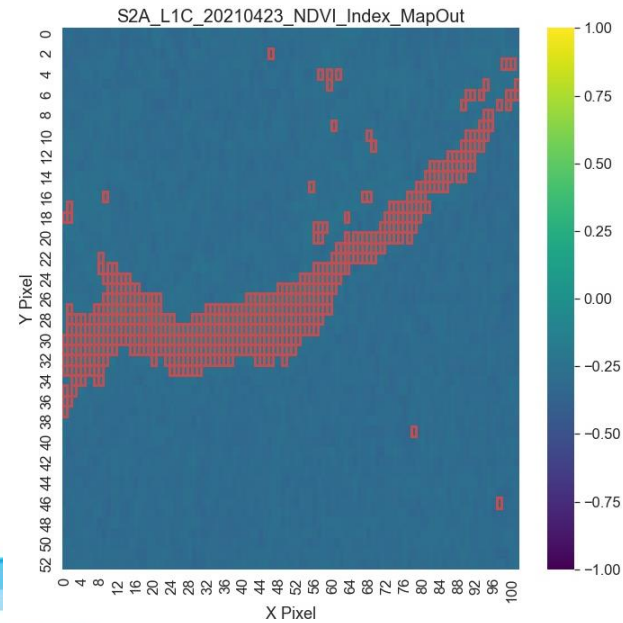
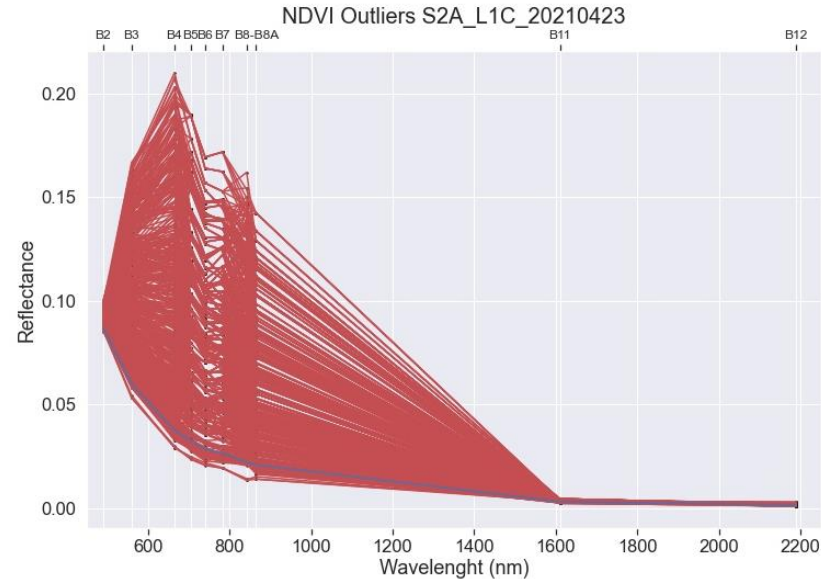
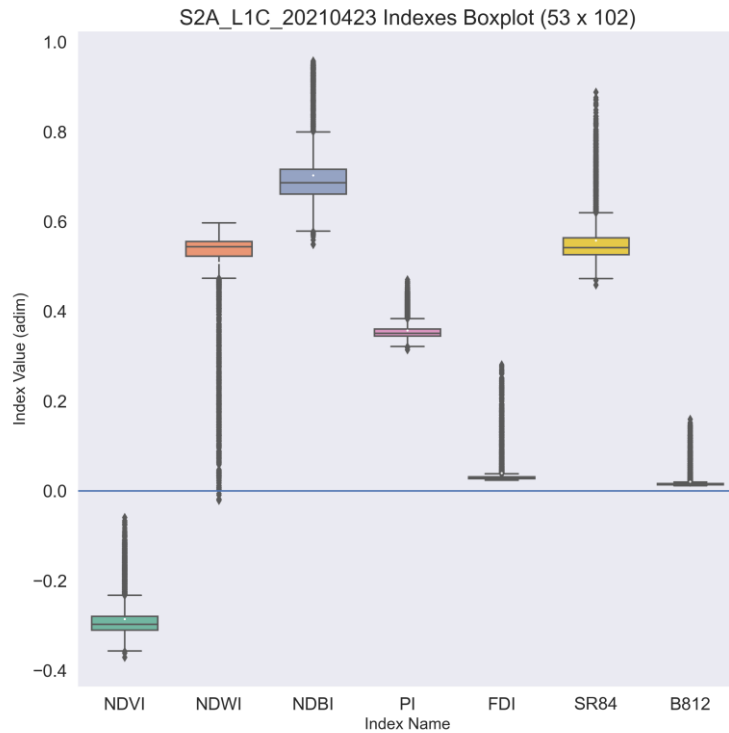
ROI :: 100 x 50 pixel

Date, Time :: 23-04-2021 , 10:10:21 UTC



# 3. Analisi di particolari casi studio

## 3) Studio della *Noctiluca Scintillans*

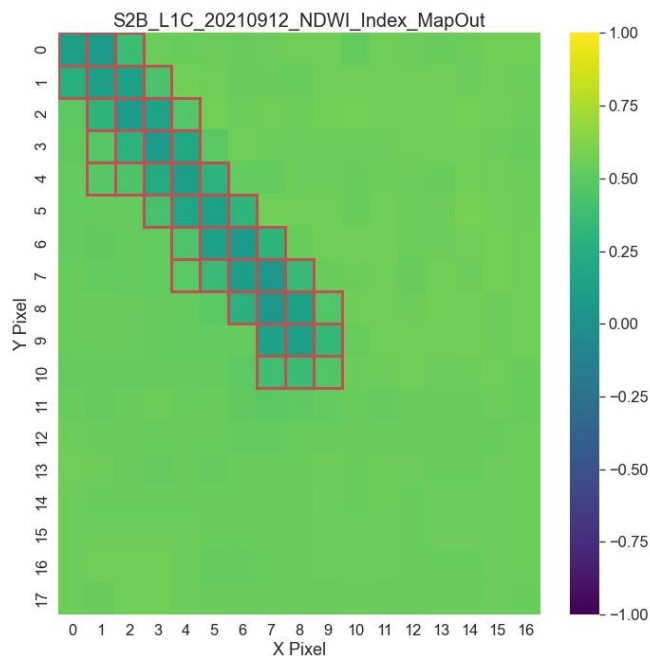
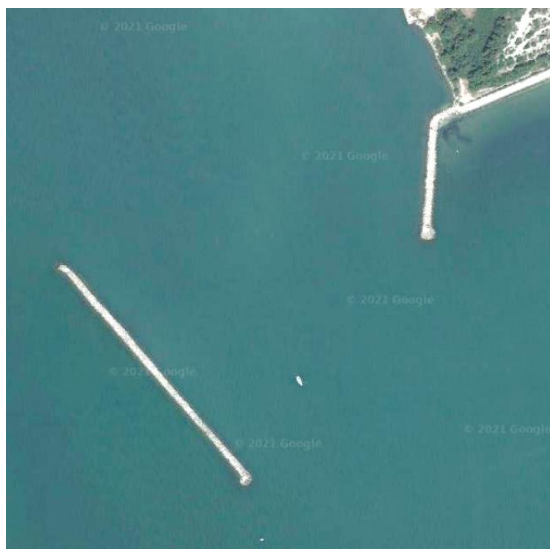


# 3. Analisi di particolari casi studio

## 4) Studio di oggetti in contrasto con il mare: diga frangiflutti

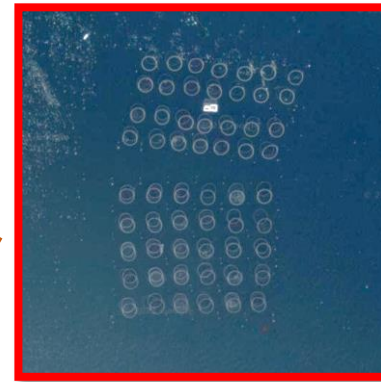
ROI :: 17 x 18 pixel

Date, Time :: 12-09-2021 , 10:03:00 UTC



# 3. Analisi di particolari casi studio

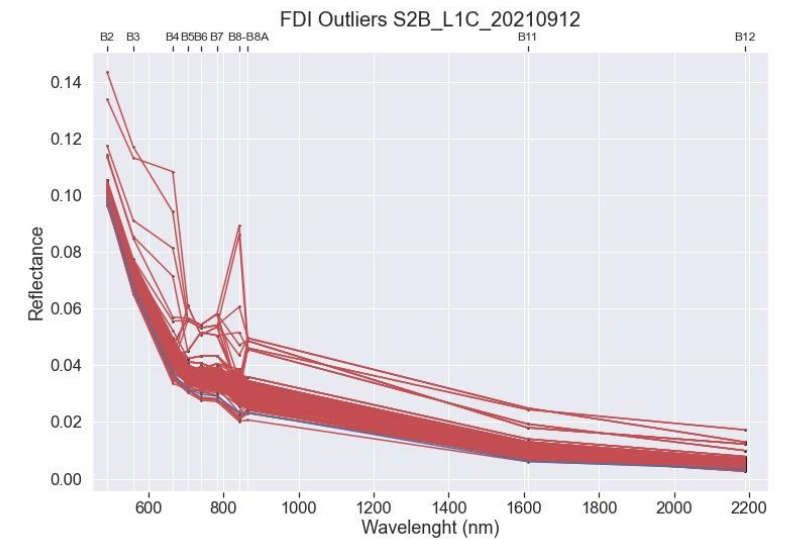
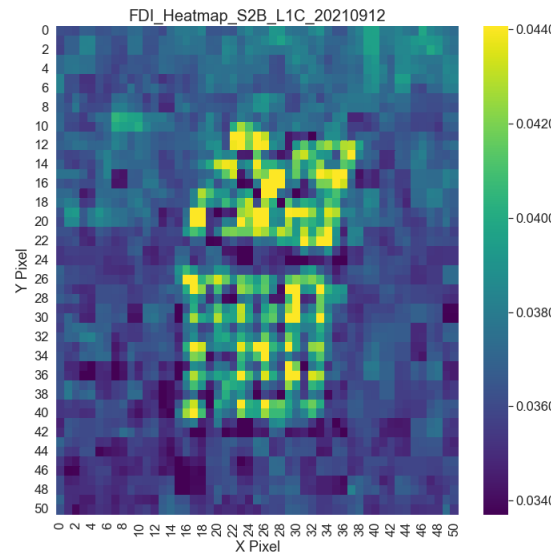
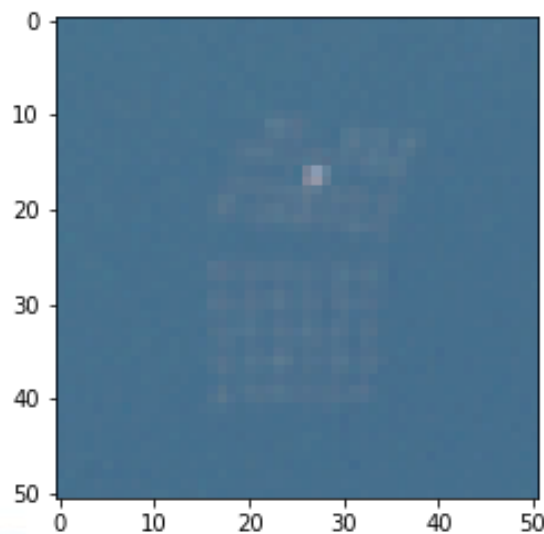
## 5) Studio di oggetti in contrasto con il mare: culture di mitili



ROI :: 50 x 50 pixel

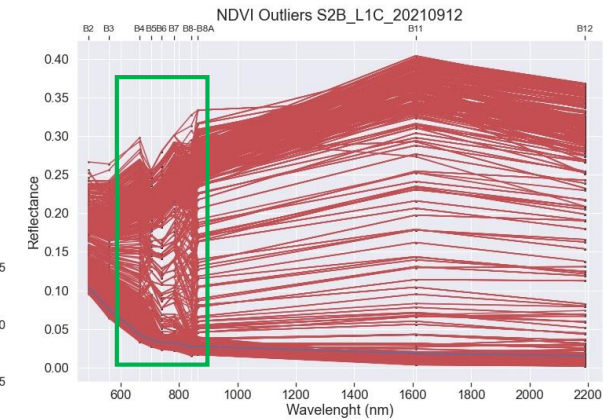
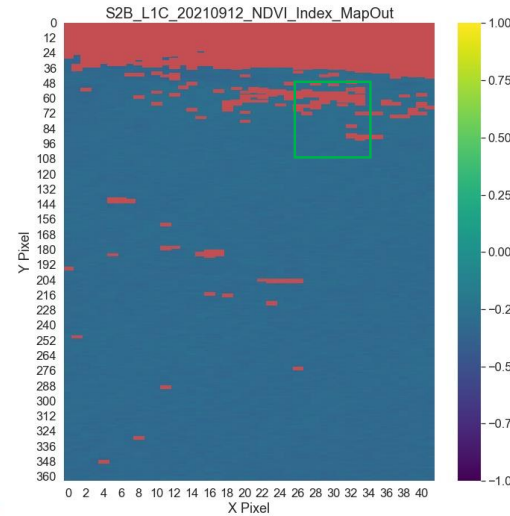
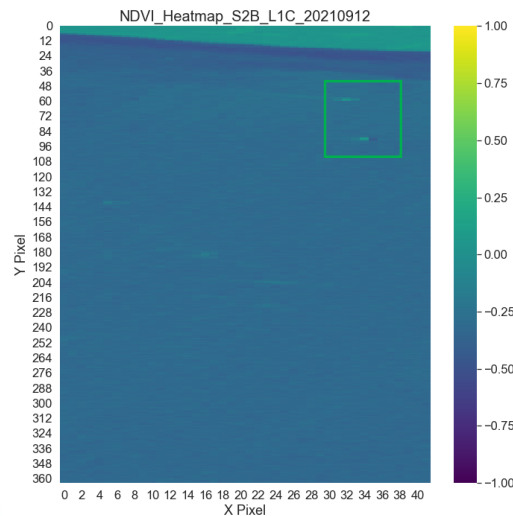
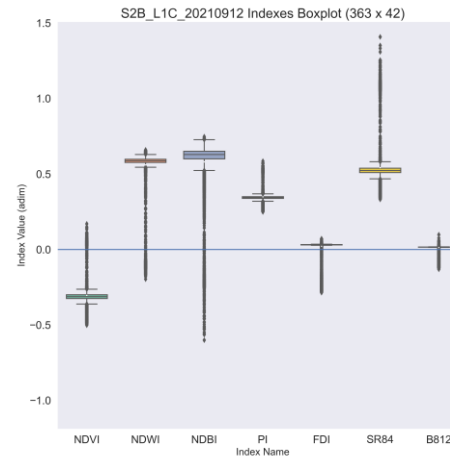
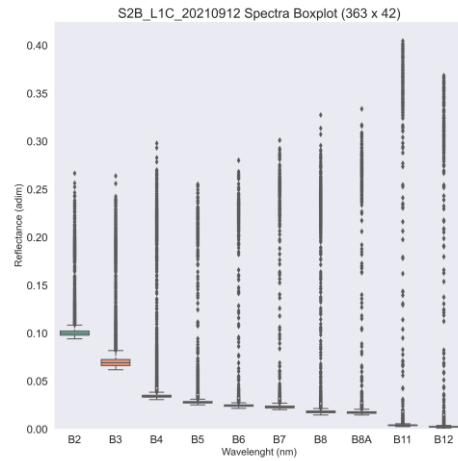
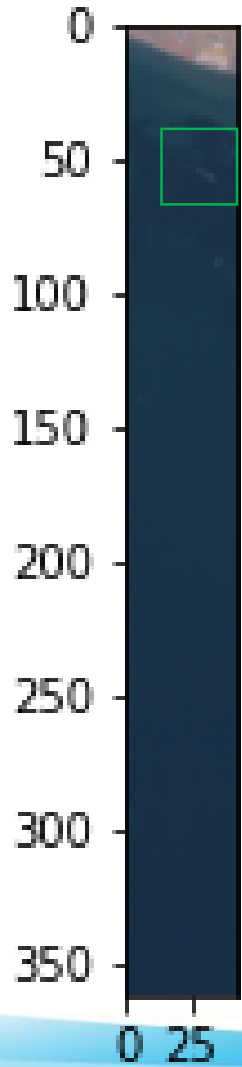
Date, Time :: 12-09-2021

10:03:00 UTC



# 3. Analisi di particolari casi studio

## 5) Studio di oggetti in contrasto con il mare: «casi misti»



# Conclusioni

1) Indagine di casi studio con poligoni semplici su aree omogenee e statisticamente significative



Identificazione di «zone di popolamento» degli indici ambientali  
+ determinazione firme spettrali

Tecnica di estrazione spettrale per contrasto → Inefficiente su  
aree non omogenee (casi realistici)

2) Necessità di sviluppare algoritmi di classificazione affiancati a filtri sugli indici ambientali  
per individuare casi sospetti di marine litter/pixel di natura ignota



3) Sviluppo di un database di casi studio:

→ Individuazione tramite di informazioni da monitoraggi *in situ*/ stampa

→ Indicazioni di potenziali «hotspot» provenienti da simulazioni



4) Creazione di un *database* di casi noti su cui addestrare una rete neurale.

# FINE

## Grazie per l'attenzione