Fighting the ocean plastic pollution with the use of satellite images and drone data: Plastic Litter Project (PLP), history and future steps

Konstantinos N. Topouzelis
Assistant Professor

March 2021
Overview

- **University of the Aegean**, Department of Marine Science, Marine Remote Sensing Group (MRSG)

- **Plastic Litter Project (PLP):** Construction and at-sea deployment of floating marine litter and natural debris artificial targets
  - Early stages
  - PLP2018, PLP2019, PLP2020, PLP2021
  - Towards best practices

- **Coastal Marine Litter Observatory (CMLO):** Mapping litter accumulations in the coastal area using drone technology and AI
  - Data collection, management and manipulation
  - Results – reports
  - Spatiotemporal analysis
University of the Aegean

The **University of the Aegean**, Greece was founded in 1984 as a network University; it is spread in 6 campuses on six of the islands of the Aegean Archipelago. It offers 17 undergraduate (BA or BSc) and 28 postgraduate (MA or MSc) programmes.

**Department of Marine Sciences**, (1999) is located in Lesvos island, city of Mytilene. It is the only University Department in Greece that offers Bachelor, Master and Ph.D. degrees in Oceanography.

- **Marine Environmental Quality**
- **Ecosystem Management and Sustainable Fisheries**
- **Oceanography and Coastal Applications**
Marine Remote Sensing Group

[established in Sep 2014]
Plastic Litter Project: Early stages
Plastic Litter Project: Early stages

Marine Litter Detection due to refugees crisis along the eastern coast of Lesvos island (2016)
Plastic Litter Project: Early stages

Marine Litter Detection due to refugees crisis along the eastern coast of Lesvos island (2016)
Plastic Litter Project: Early stages

2018 Class “Introduction to Marine Remote Sensing”

... four types of resolution: **spatial**, spectral, radiometric and temporal ...
Plastic Litter Project

Three artificial plastic targets for Sentinel-2 imagery (S2b launched March 2017) i.e. **10 x 10 m**:  
1) 3600 x 1.5 L plastic bottles,  
2) 135 plastic bags and  
3) 200 sqm fishing net.

One day experiment 7 June 2018 dedicated to:  
World Environment day (5 June)  
World ocean day (8 June)
Plastic Litter Project: Introduction and goals

• Plastic Litter Project: construction and at-sea deployment of floating marine litter and natural debris artificial targets

• Main goals:
  i. acquisition of floating marine debris remote sensing data, using satellite and UAV platforms in near-real environmental conditions

  ii. production of an open-access image database for calibration and validation of floating marine debris detection methodologies

  iii. extraction of meaningful spectral measurements (marine debris spectral library) in near-real scenarios & compare the geospatial information ranging from moderate to very high resolution.
Plastic Litter Projects

Detection and monitoring of artificial plastic targets with satellite imagery and UAV

Plastic Litter Project 2019

Plastic Litter Project 2018

Plastic Litter Project 2020
Plastic Litter Project 2018

**UAS data**

Number of raw images and geo-spatial resolution acquired using a suite of sensors attached to a S900-UAS.

<table>
<thead>
<tr>
<th>Name of Sensor</th>
<th>Number of Images</th>
<th>Resolution (cm/pixel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slantrange 3P</td>
<td>394</td>
<td>4.84</td>
</tr>
<tr>
<td>Parrot Sequoia multispectral</td>
<td>872</td>
<td>7.73</td>
</tr>
<tr>
<td>Parrot Sequoia RGB</td>
<td>187</td>
<td>2.72</td>
</tr>
<tr>
<td>Sony A5100</td>
<td>243</td>
<td>2.14</td>
</tr>
<tr>
<td>FliR DUO R Thermal</td>
<td>575</td>
<td>196.5</td>
</tr>
<tr>
<td>FliR DUO R Visible</td>
<td>575</td>
<td>10.53</td>
</tr>
</tbody>
</table>
Plastic Litter Project 2018

Sentinel-2
7 June 2018

PlanetScope
7 June 2018

Combining Sentinel-2 and UAS data

Percentage plastic coverage calculation for each Sentinel-2 pixel using the A5100 othophotomap
Blue (490 nm): best differences between the targets

Green (560 nm): smaller difference among plastic bottles and fishing net.

Red band (665 nm): plastic bags can separated from fishing net and plastic bottles

NIR band (842 nm) plastic bottles can be separated from the rest two targets
Plastic Litter Project 2018
Plastic Litter Project 2018

Plastic Bottle Target

Reflectance (DL) vs. Wavelength

- 34% coverage
- 29% coverage
- 18% coverage
- 15% coverage (dotted line)
- Average (grey line)

Wavelength (nm):
- 443
- 490
- 560
- 665
- 705
- 740
- 783
- 842
- 865
- 945
- 1610
- 2190

Reflectance (DL):
- 0
- 0.01
- 0.02
- 0.03
- 0.04
- 0.05
- 0.06
- 0.07
- 0.08
- 0.09
- 0.1
Detection of floating plastics from satellite and unmanned aerial systems (Plastic Litter Project 2018)

Konstantinos Topouzelis, Apostolos Papakonstantinou, Shungudzenwoyo P. Garaba

Abstract

A rapidly rising amount of plastic litter on land and at sea is becoming a global wildfire environmental problem. Here, we present an innovative exploratory application of unmanned aerial systems (UAS) and open access satellite imagery in remote detection of floating plastics in natural seawater, through a dedicated aquatic environment experiment. We aimed to extract meaningful spectral measurements in semi-real scenarios and to compare the geospatial information ranging from moderate to very high resolution. A set of three artificial floating plastic targets were setup for remote detection in the waters close to Tsamalkia beach in Mytilene on Lesvos Island, Greece. These floating targets consisted of 100 m² PET 1.5 L water bottles, LEDF plastic bags and nylons fishing ghost nets. Spectral properties of the controlled targets as well as surrounding seawater were investigated for Sentinel-2A satellite data. We demonstrate how UAS very high geospatial resolution images can be useful in improving geo-referencing of satellite images and how UAS can be used to assess the plastic percentage coverage of satellite images. We observed very weak to strong relationships between percentage pixel coverage and the spectral reflectance at p.value < 0.1 significance level. Effects of atmospheric correction algorithms was evaluated using falseColor and AODJITE, derive unbiased percentage differences were less than 60%. Our feasibility study demonstrated the importance of very high geospatial resolution UAS datasets in validating and enhancing the geospatial accuracy of satellite data for monitoring plastics in the aquatic environment. Monitoring and identifying plastics needs an integrated suite of sensors, we therefore present how available tools can be utilized to improve current efforts and contribute to advancing relevant future remote sensing technologies.
Plastic Litter Project 2019

EO tracking of marine debris in the Mediterranean Sea from public satellites (ESA: EO Science for Society permanently open call for proposals)

- ARGANS
- University of the Aegean
- CNR-ISMAR
- Universidad de Cádiz

4 new targets
Plastic Litter Project 2019

18/4/2019
Targets in line 100% bottles and 100% bags

03/5/2019 Separated targets 100% bottles and 100% bags & smaller mixed targets

18/5/2019 Pair Targets in line 75% bottles and 75% bags & smaller mixed targets

28/5/2019
Pair Targets in line 50% bottles and 50% bags & smaller mixed targets

07/6/2019
Targets in square 25% bottles and 25% bags & smaller mixed targets

18/4/2019
03/5/2019
08/5/2019
13/5/2019
18/5/2019
23/5/2019
28/5/2019
02/6/2019
07/6/2019
12/6/2019
17/6/2019
22/6/2019
27/6/2019
Remote sensing of sea surface artificial floating plastics with Sentinel-2 and unmanned aerial systems (Plastic Litter Project 2019)

Konstantinos Topouzelis, Dimitris Papageorgiou, Alexandros Karagaitanakis, Apostolos Papakonstantinou, and Manuel Arias Ballesteros

Reference high resolution orthophoto map

Positioning

- GPS
- UAS
- Sentinel-2

Statistics

- OBIA
- Spectral unmixing
- Matched Filtering

Detection

- Spectral behavior

Plastic coverage

Target configuration:
- Single target 5x10 m (5x10 m PET and 5x10 m LDPE)
- Plastic Coverage: 100%

Date: 18/04/2019

Date: 03/05/2019
- Large targets configuration:
  - Four 5x5 m targets; two with PET and two with LDPE
  - Plastic Coverage: 100%

Date: 18/05/2019
- Large targets configuration:
  - Two 5x10 m targets; one with PET and one with LDPE
  - Plastic Coverage: 75%

Date: 28/05/2019
- Large targets configuration:
  - Two 5x10 m targets; one with PET and one with LDPE
  - Plastic Coverage: 50%

Date: 07/06/2019
- Large target configuration:
  - Single target 10x10 m (5x10 m PET and 5x10 m LDPE)
  - Plastic Coverage: 25%
Defining a floating debris index

\[ FDI = R_{rs,NIR} - R'_{rs,NIR} \]

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

Plastic Litter Project 2019

Exploratory work
Plastic Litter Project 2020

Plastic Litter Project: Detection and monitoring of artificial plastic targets with satellite imagery and UAV (PLP)

ES 牛 Discovery and Preparation – OSIP
ESA contract no. 4000131040/20/NL/GLC
Plastic Litter Project 2020

- Be closer to reality with actual litters
- Need of semi-permanent targets!
- Design, construct and test 2 new types of circular targets – aquaculture cage type and biscuit type
- Test large-scale 28 m diameter prototype
- Acquire licenses for long-term deployment of large-scale targets in the Gulf of Gera
- Consider various plastics as reference targets material (shade balls, HDPE tarps, 4L containers, mesh, buoys)
Plastic Litter Project 2020

- defining a semi-permanent target for cal/van purposes
- define a minimum detection threshold for marine debris abundance fraction in a mixed pixel.

Type-A: Aquaculture cage-type target

Type-B: Biscuit-type target

Three 7 m diameter circular targets were constructed
Plastic Litter Project 2020
Plastic Litter Project 2020
Plastic Litter Project 2020

- defining a semi-permanent target for cal/van purposes
- define a minimum detection threshold for marine debris abundance fraction in a mixed pixel.

7 m ø HDPE mesh target

7 m ø various marine litter target
Plastic Litter Project 2020

20200616 Sentinel 2 L1C

20200616 S2 L2W ACOLITE

20200701 Sentinel 2 L1C

20200701 S2 L2W ACOLITE

20200706 Sentinel 2 L1C

20200706 S2 L2W ACOLITE
Plastic Litter Project 2020

Prototype of 28 m diameter target

20201014
Plastic Litter Project 2020
Plastic Litter Project 2020

REACT Project: Crowdsourcing, Copernicus and hyperspectral satellite data for marine litter detection, quantification and tracking (ESA contract 4000131235/20/NL/GLC)

Experiments with a series of 12 rectangular targets:

4 sets of 3 each of size:

- 0.6x0.6 m
- 2.4x2.4 m
- 5.1x5.1 m

3 different materials: HDPE tarps, PET bottles and XPS foam.
square targets deployed at Tsamakia beach
Plastic Litter Project: Current Issues and recommendations

- **Need of stable “reference plastic target” big enough to cover full S2 pixel**
  - Examine the atmospheric models
  - Alternation of spectral signal due to water content on the plastic target
  - Alternation due to sea state (turbidity, waves, etc)
  - Unmixing algorithm.

- **Need of “look-alikes targets” [big enough to cover full S2 pixel]**
  - Discrimination of plastics with lookalikes
  - Percentage plastic coverage on mix targets (sub pixel presence).

- **Targets positioning Vs satellite pixel positioning**
  - Need of accurate positioning of target (Drone data and DGPS measurements)
  - Fractions of plastic coverage in S2 pixels
  - Uncertainty of S2 pixel positioning
For creating “reference plastic targets” decisions are need it for:

1. Size,
2. Mooring,
3. Shape,
4. Frame material,
5. Type of litter,
6. Retaining material,
7. Geographical position,
8. Temporal usage,
9. Maintenance - storage
Plastic Litter Project 2021 (in a Covid free era)

Goal: Semi-permanent target in controlled environment

New semi-permanent target (28 m diameter with white mesh)

New target types (scalable, portable, transferable)
Plastic Litter Project 2021

Up to now 11 licenses:

1. Marine Exploration Permits Committee (Ministry of Foreign Affairs)
2. Ministry of Culture, Ephorate of Underwater Antiquities
3. Ministry of Culture, Ephorate of Antiquities of Lesvos
4. Ministry of Finance, Lesvos Office of Public Property
5. Ministry of Environment, Department of Environment and Urban Planning of North Aegean
7. Ministry of Maritime Affairs
8. Ministry of Finance
9. Ministry of Shipping and Island Policy, Port Authority
10. Ministry of Shipping and Island Policy, Cost Guard
11. Joint Ministerial Decision
Plastic Litter Project value proposition

- Recycled plastics from field campaigns
- Public involvement
- Public awareness
- Scientific value
Plastic Litter Project
Coastal Marine Litter Observatory (CMLO)

- Marine Litter Density Mapping in the coastal areas in a harmonized method
- Drone RGB images as input data
- Marine Litter accumulation visualized as density maps
- Automatic reporting through an open geospatial portal
- System functionalities connecting results with raw images (detected plastics)
- Supporting decisions and policies e.g. EU (MSFD) and UN (SDG14.1.1b)
Coastal Marine Litter Observatory (CMLO)

**Marine Litter Density Mapping in the coastal areas:**
UAS data acquisition protocol combined with deep learning techniques for the automatic detection and mapping of litter concentrations in the coastal zone.

---

Coastal Marine Litter Observatory (CMLO)

Standard drone data acquisition protocol
Coastal Marine Litter Observatory (CMLO)

Data upload and and pre-processing
Coastal Marine Litter Observatory (CMLO)

Dataset Preparation
Coastal Marine Litter Observatory (CMLO)

Automatic Reporting
1. UAS Data Acquisition (Accuracy and Repeatability of Data Acquisition)
2. Run Crowdsourcing Annotation Campaigns
3. Machine Learning Classification of UAS Data
4. MPL Detection & Classification
5. Density Map Generation
Coastal Marine Litter Observatory (CMLO)

**Marine Litter Density Map**

Drone imagery - artificial intelligence - computer vision

Routine monitoring by both citizens and regulatory bodies, for monitoring litter accumulation in the coastal zones, in inaccessible locations or sensitive areas

Visualization of the litter distribution through a gridded density map
Coastal Marine Litter Observatory (CMLO)

http://mrsrg-srv.lesvos.aegean.gr/marinelitter/sdi/
Coastal Marine Litter Observatory (CMLO)

Spatial analysis
Coastal Marine Litter Observatory (CMLO)

Next steps: Image detection Vs Image classification

1. Ready 750K tiles as training data (help!!!)
2. Ready for annotation with 500 K tiles (help ^2!!!)

![Image detection example](image)

**Input**

![Input image](image)

**CNN**

Class: "plastic bottle"
Probability: "90% plastic bottle"

**Output**

![Output image](image)

**YOLO**

Plastic bottle: 95.5%
Plastic Litter Project
http://plp.aegean.gr/

Marine Remote Sensing Group
https://mrsg.aegean.gr/

Web sites

Plastic Litter Project (PLP)

Plastic (Litter) Project (PLP) history and future steps | March 2021 | Slide 54

Web sites

Plastic Litter Project
http://plp.aegean.gr/

Marine Remote Sensing Group
https://mrsg.aegean.gr/

**RESEARCH**

The Marine Remote Sensing Group (MRSG) in the University of the Aegean conducts research for the exploration, analysis, and visualization of the satellite and UAV data in the coastal environment. We combine state of the art algorithms and in situ measurements to develop new methods, technologies, and products for the visual representation of marine geospatial information. The group has gained expertise in several disciplines of marine remote sensing including oil spill detection, oceanic phenomena identification, seagrass mapping, coastal bathymetry and coastline detection. Hereafter we present ongoing and completed research projects.

**Aquasafe**

AQUASAFE is a research project that aims to create an integrated geoinformatics system for remote monitoring and early warning in aquaculture. This project is funded under the call RESEARCH - CREATE - INNOVATE.

**ARGO Hellenic USV**

ARGO is a research project for the experimental application and creation of a USV to collect fast, easily accessible data concerning the aquatic environments under the call RESEARCH - CREATE - INNOVATE.

**Collaboration with the IIASA team for marine litter tile sorting**

A collaborative project for classifying marine litter in IAS data with the use of a crowdsourcing platform.

(UAS) data for the remote detection of floating marine litter in natural waters. Three large artificial 10 x 10 m plastic targets were designed and constructed, matching the Sentinel-2 RGB and NIR bands spatial resolution. During the second PLP (PLP2019), 10 smaller targets were created in order to be closer to reality and to examine the limitations of the detection with Sentinel-2 images. In PLP2020 we work towards creating reference target for the scientific community and extending the duration of the targets in real conditions with the creation of semi-permanent targets.
Acknowledgments

Apostolos Papakonstantinou
Dimitris Papageorgiou
Alexandros Karagaitanakis
Ioanna Kosma
Olympos Andreadis
Spyros Spondylidis
Ioannis Moutzouris
Marios Batsaris
Maria Eleftheriadou
Argyris Moustakas
Alexandra Tsoulimprk
Michaela Doukari
Andromachi Chatziantoniou

Students class 2018
Students class 2019
Students class 2020