



The Use of Earth Observation and Machine Learning for Waste Crime Identification and Prevention

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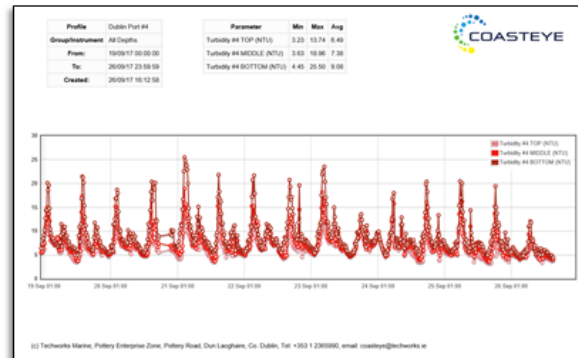
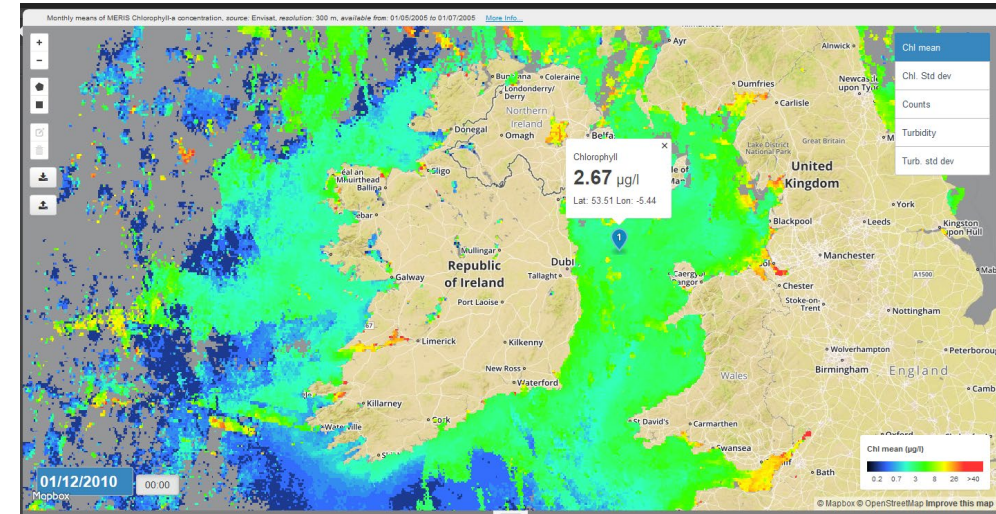


Marine Data Systems
Robust, Reliable, Secure

- Introductions
 - Who we are
 - What is waste crime
 - Water pollution in Ireland
 - What does Irish enforcement need?
- Monitoring of pollution events using Earth Observation (EO)
 - Untreated waste water in saltwater environments
 - Nitrate compliance in freshwater
 - Water quality parameters using EO
- Detecting *E. coli* using EO and Machine Learning (ML) in EADS project
- Conclusions and next steps

International Leaders in Robust, Reliable, Secure Marine Data

- Established in 2002
- 16 staff
- Based in Dublin, Ireland
- Serving a broad range of clients in the coastal zone (internationally)
- *In situ* data buoys and ground-truthed EO models



Desk study funded by EPA Research:

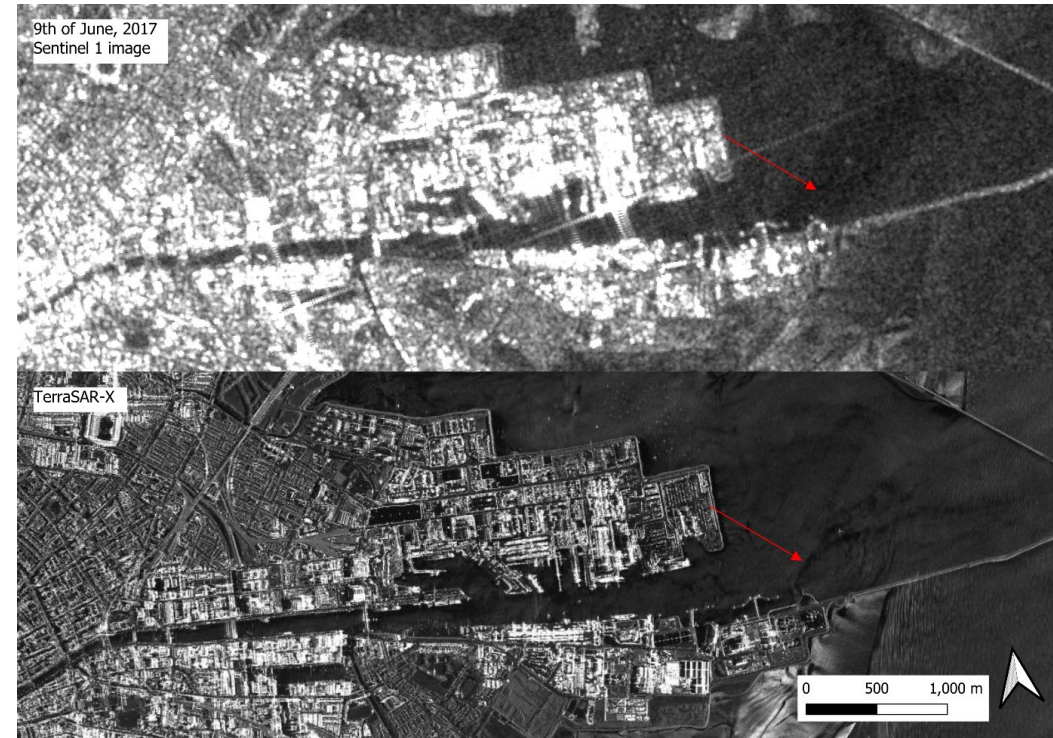
- **Waste Crime** is the illegal or unauthorised handling, disposal, storage or trafficking of waste at any scale: rubbish burnt in a fireplace to illegal landfills.
- **Industrial Non-compliance** is the intentional or negligent activity by an industrial entity which is not in line with regulations.
- Report focused on providing an overview on the existing EO technologies.
- Solutions focused on aiding enforcement resource allocation, not providing actual evidence.



What does Irish enforcement need?

- Legally unclear if EO data can be used as evidence.
- Enforcement have methods of collecting evidence they know they can use, but rely on visiting known problem sites, reports, and random site visits.
- More efficiently allocating enforcement resources would reduce the need for excess random site visits.
- EPA is a national agency, but most enforcement is at the local level.

- Wastewater particularly problematic in Ireland, raw sewage released into environment every day in 32 cities and towns
- In 2018, polluted water reported to EPA by local kayakers and ferry passengers
- Often discharge resulting from heavy rains; inhibit use of optical imagery
- SAR imagery effective at showing pollution on water; seen in both high resolution and publicly available data



Water pollution: a national issue

THE IRISH TIMES

Algal bloom strikes at second large drinking-water reservoir in Co Wicklow

Failure to address problems could result in 'serious, Lough Neagh-style pollution'

Expand



The Journal



File photo IMAGE: Shutterstock/diegorayaces

WASTE WATER

European Commission issues warning to Ireland over pumping waste water into sensitive areas



14 March 2022

A step closer to ending the discharge of raw sewage into the River Fergus and Shannon Estuary

Irish Water progressing plans for Clarecastle Sewerage Scheme as contractor appointed



The Inagh River. Photograph by John Kelly.

The Clare Champion

PROTEST RALLY IN SUPPORT OF CLARE WATER QUALITY

Investigation after 5,000 fish die in Cork river

Updated / Tuesday, 11 Jun 2024 15:54

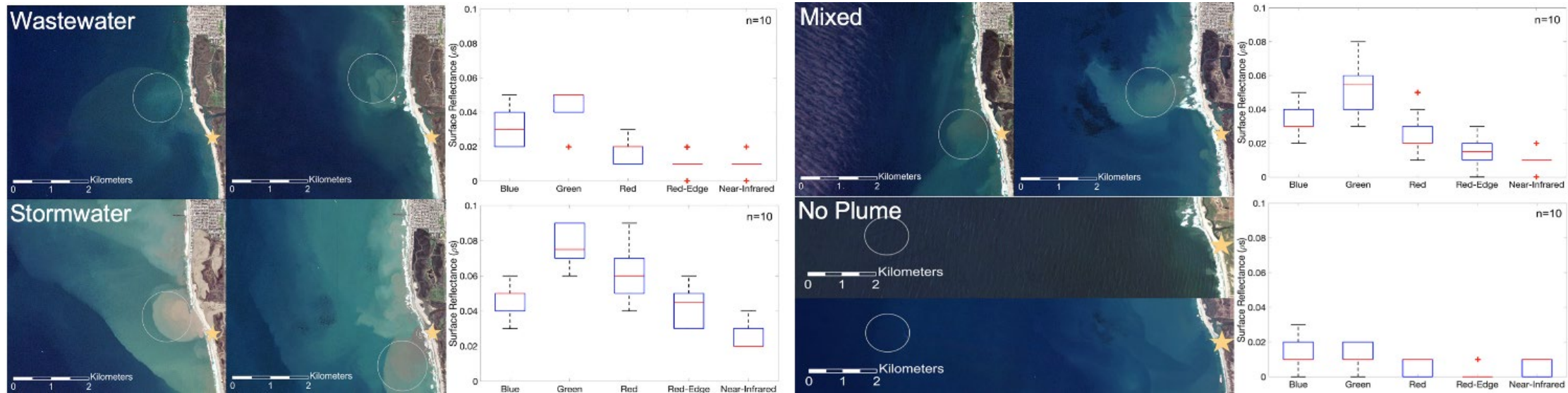


BREAKING | Authorities in Wexford and Wicklow investigating major oil spill as dead birds found on beaches



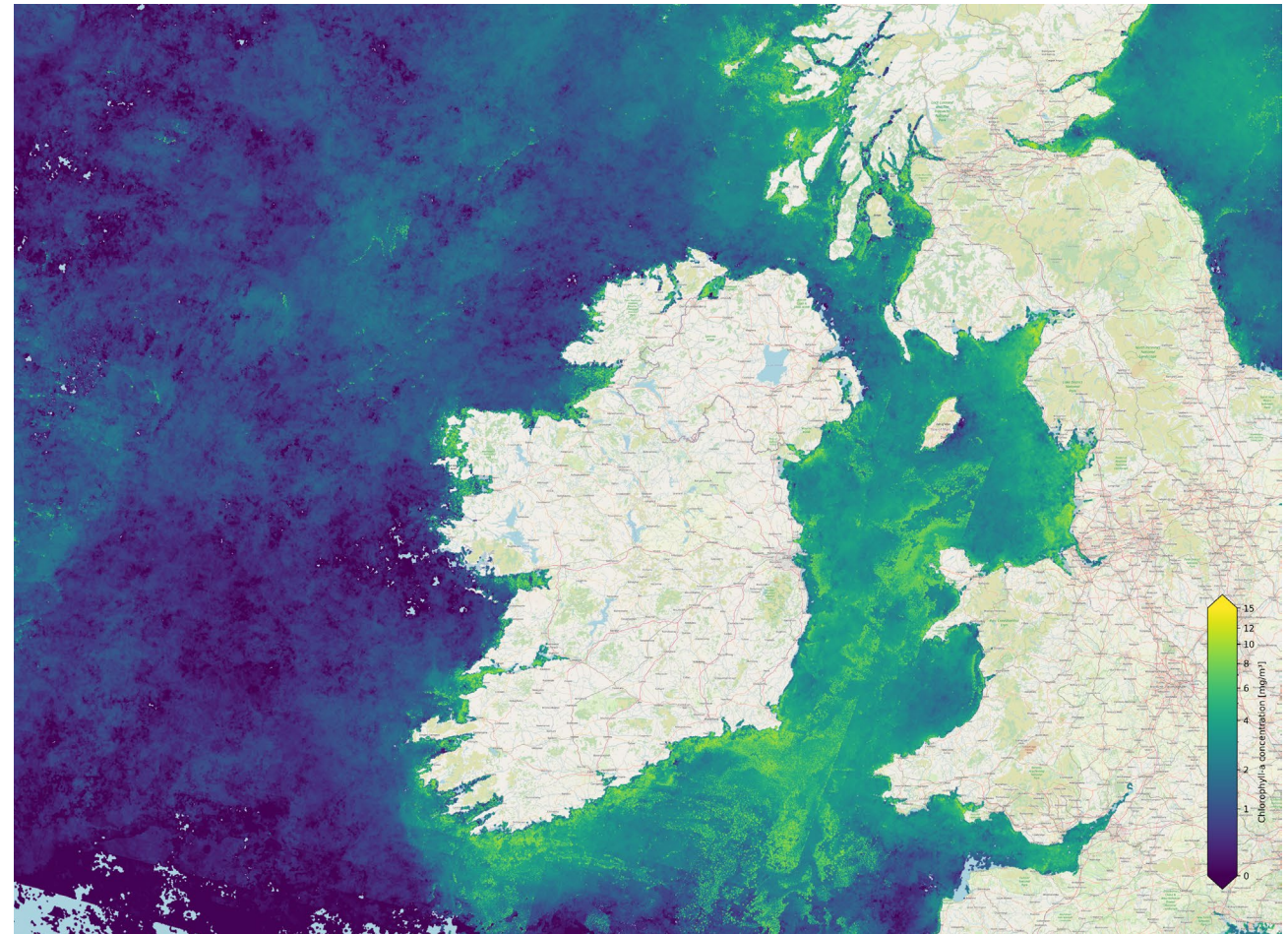
Irish Independent

- Commercial RapidEye satellite has been used to examine reflectance of wastewater plumes off of California
- Clustering enabled categorizing of plumes by spectral qualities; determine if wastewater or stormwater
- California has very different climate, but wastewater is important focus of Irish industrial non-compliance
- Data may not be reliable in Ireland due to weather, but methodology could help determine cause



Ayad et al. (2020)

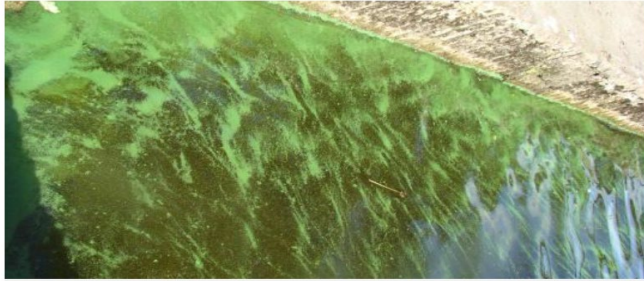
- We use C2RCC and Sentinel-3 OLCI for water monitoring
- Data buoys provide ground truthing for our ML models
- Chlorophyll-a, turbidity, and total suspended matter (TSM) are useful measures for water pollution in marine and inland waterbodies
- Chlorophyll-a is used as a proxy for algae or other photosynthetic activity. Algae may bloom due to excess nutrients in coastal or freshwater regions.
- Turbidity is a measure of water clarity. Water clarity may be negatively affected by pollutants.



Monthly mean Chlorophyll-a, August 2023



Tipperary County Council advises public to exercise caution on Lough Derg due to presence of Algal Bloom



THE IRISH TIMES

Ireland

Bathers warned of Lough Derg algal blooms

Lough Derg is out of bounds to bathers because of the presence of a potentially toxic substance. Cian McCormack reports.

Thu Jul 31 2003 - 01:00



The diversity of aquatic plant life in Lough Derg has been badly hit by declining water quality. PHOTO: ODHAN DUCIE

Lough Derg plant species hit by pollution

Freshwater Pollution: Lough Derg



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Bathing prohibition at Ballycuggeran

2 September 2023

On the advice of the HSE, Clare County Council has today (2nd September, 2023) issued a bathing prohibition at the Ballycuggeran bathing area on Lough Derg. The red flag will be flying at this location until further notice.

Bathing prohibition at Ballycuggeran

Warning Over Invasive Quagga Mussel in Shannon Waters

15th July 2021 MacDara Conroy



AFLONT



Algae bloom on Lough Derg

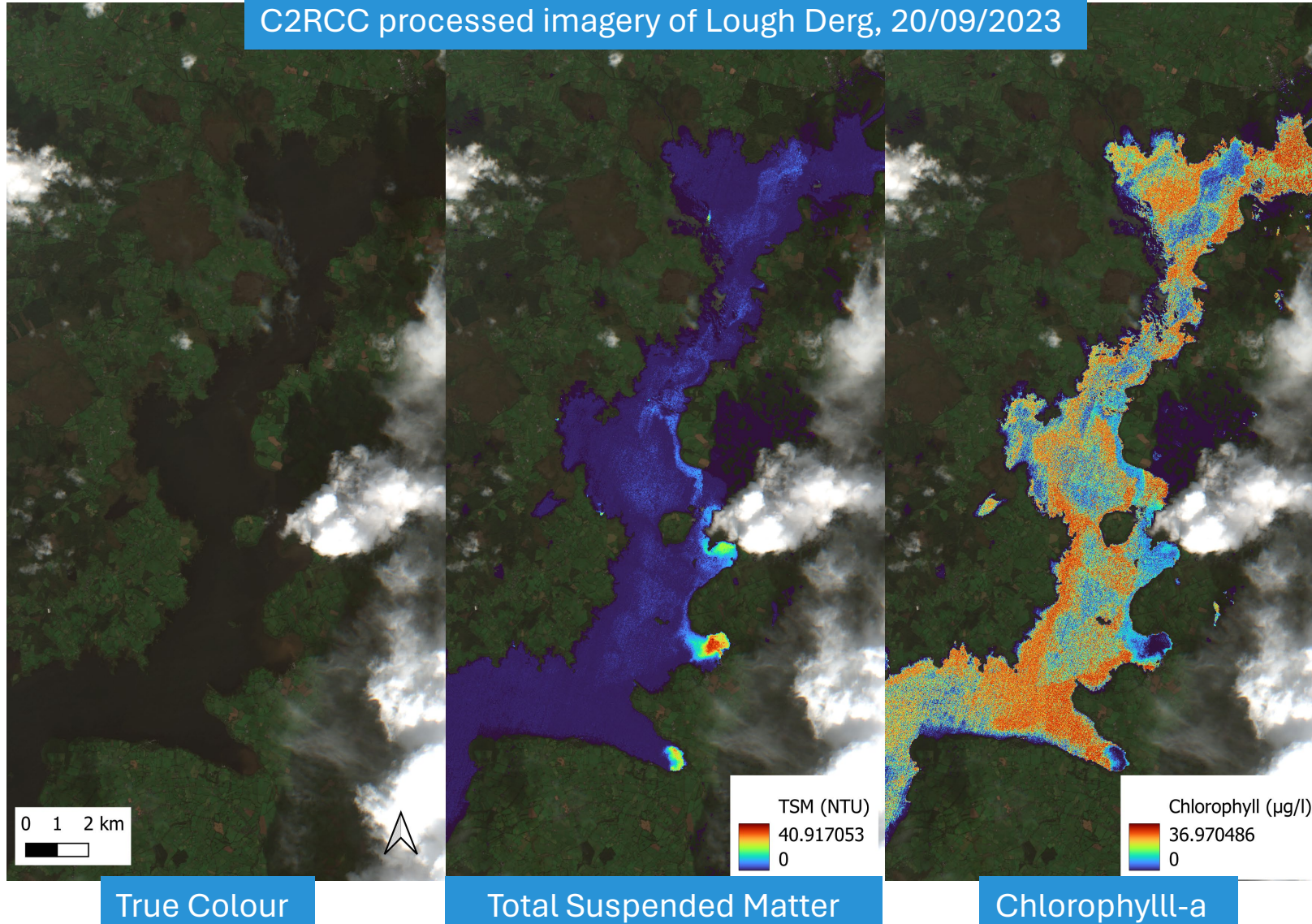
Boil Water Notice on Killaloe Public Water Supply lifted with immediate effect

News / Boil Water Notice on Killaloe Public Water S...



Secure Marine Data

C2RCC processed imagery of Lough Derg, 20/09/2023



- Ireland is exempt from the European Nitrates Directive, which has resulted in significant amounts of excess nitrates being washed into freshwater bodies.
- Lough Derg has been significantly affected by nitrates, which have caused large algal blooms.
- We can see both plumes of pollutants as well as measured chlorophyll.

Detection of *E. coli* using ML

- Wastewater can create risk for infectious diseases in bathing waters.
- *E. coli* Alert Data Service (EADS) was aimed at detecting the presence of *E. coli* using Copernicus EO data, ML models, and water quality data.
- EADS was an ESA contract that was part of the Permanent Open Call programme.

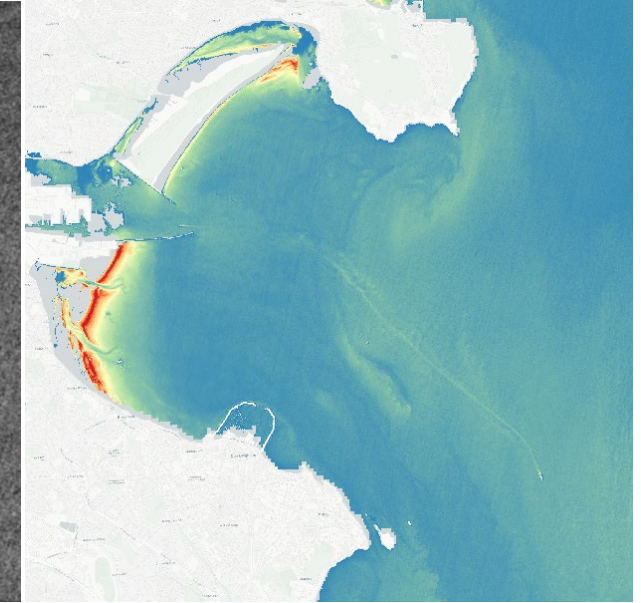


PARAMETER	TIMESPAN	SOURCE
Precipitable water	2009-2021	NCEP CFSR
Water temperature	2009-2021	NCEP CFSR
Rainfall	2009-2021	Met Eireann
Air temperature	2009-2021	OpenWeatherMap
Dew point	2009-2021	OpenWeatherMap
Air pressure	2009-2021	OpenWeatherMap
Cloud percentage	2009-2021	OpenWeatherMap
Wind speed/direction	2009-2021	OpenWeatherMap
Tidal heights	2009-2021	Marine Institute
Global Horizontal Irradiance (GHI)	2009-2021	Solcast

Satellite processing chains

Sentinel-1

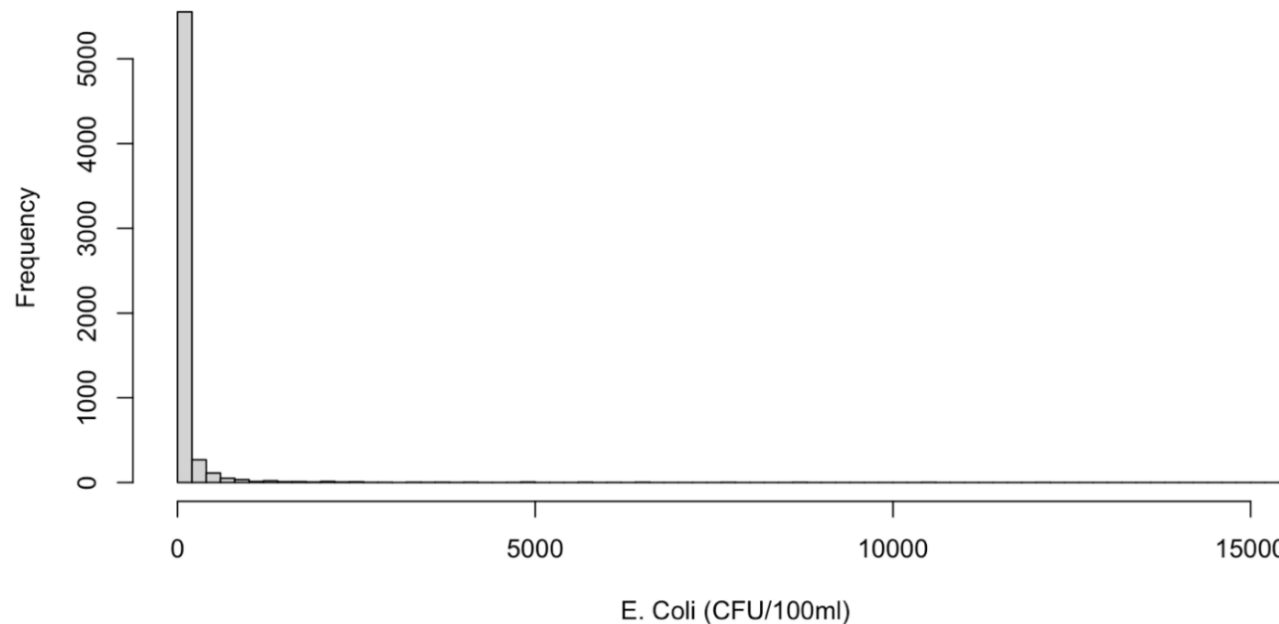
Sentinel-2



SENTINEL-1	SENTINEL-2
VV (vertical/vertical polarisation)	Turbidity
VH (vertical/horizontal polarisation)	Chlorophyll-a
	Total Suspended Matter
	Normalised water-leaving reflectance for B1 -> B5



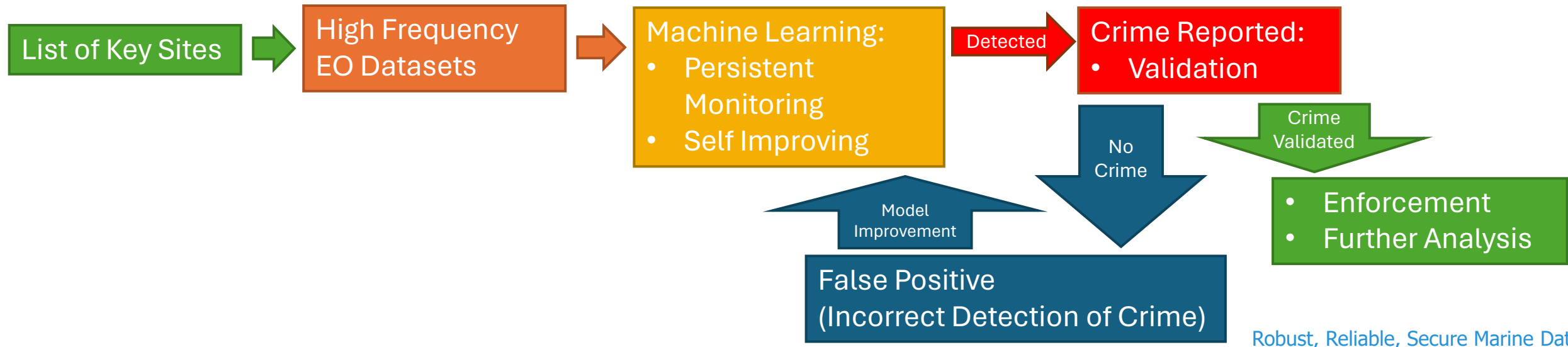
- Water quality (*E. coli*) data were cleaned and formatted for merging with other datasets
- *E. coli* samples available from **86 different beach locations** around Ireland
- Dataset highly imbalanced



- Investigated the viability of developing an *E. Coli* alert data service.
 - Three different ML models (M1, M2, M3) trained.
- Trained ML models give an indication of *E. coli* blooms, but the overall accuracy is relatively low.
 - More investigation into data and relevant features needed.
 - Salinity and rainfall were considered important proxies for water inflow.
- Optical satellite imagery limited due to cloud cover and daylight hours.
 - Especially unlikely in Ireland due to heavy cloud cover.
- SAR (e.g. Sentinel-1) can overcome some challenges faced by optical sensors.
 - VV polarisation mode backscatter values are sensitive to water surface topography, higher values indicate rougher seas.
 - Importance of the VV parameter for the prediction of *E. coli* levels is interesting and warrants further investigation.

Proposed Waste Crime Monitoring Service

- Currently, solutions are done on a case-by-case basis, but what if we had an automated service solution?
- Service would leverage the large Copernicus archive and long history of EPA non-compliance reports to build a training dataset.
- Interested in furthering this work either nationally or internationally.



Conclusions and Next Steps

- We are keen on further investigating waste crime and non-compliance monitoring in Irish waters, depends on government interest
- EO is yet to be fully exploited in Ireland, a large opportunity for further development
- Irish enforcement officials don't want to use EO data as evidence, but to aid enforcement efforts in where to collect evidence
- Wastewater plumes can be seen, analysed through Earth Observation – SAR particularly useful for spotting plumes regardless of weather
- *E. coli*, which can be a result of wastewater, can also be detected through satellite imagery with some level of accuracy. We are talking with Irish Water about further developing the ML models using more of their data, currently investigating funding options.
- We are also keen on expanding our efforts beyond Ireland



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