AI-based Oil Spill Detection Using the SAR Data from Sentinel-1

Yi-Jie Yang

Maritime Safety and Security Lab Bremen, German Aerospace Center (DLR), Germany

DLR

Motivation

- Large oil spill accidents cause serious environmental damage
- Regular deliberate oil spills continuously influence marine wildlife

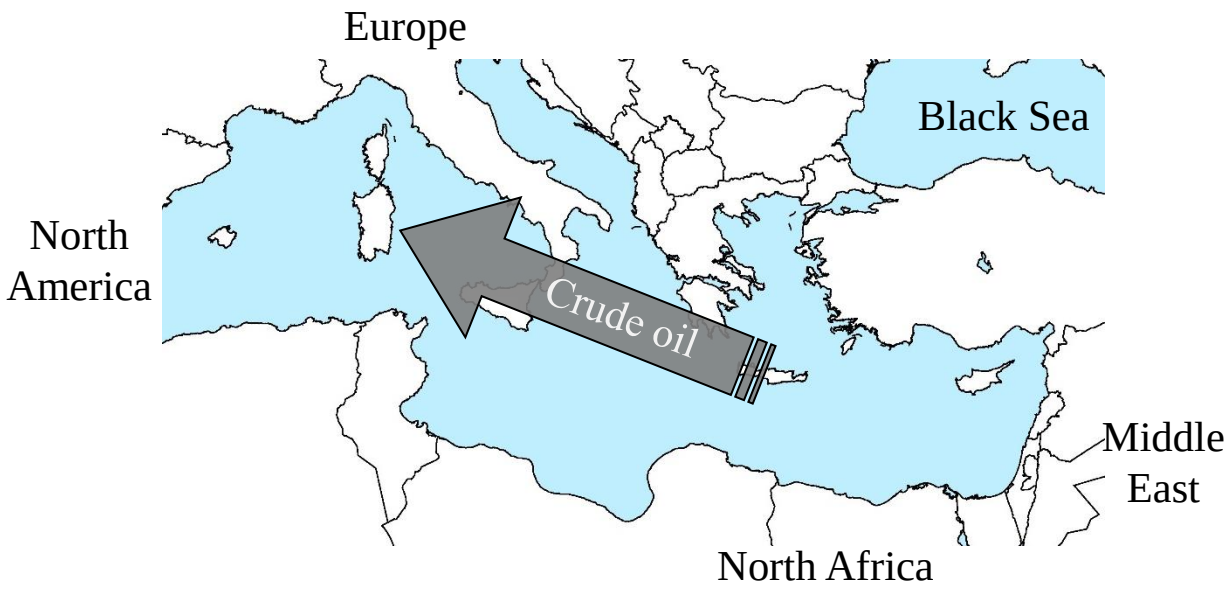
➔ Oil pollution “hotspots”: usually have high maritime traffic

(CNN, 2021)

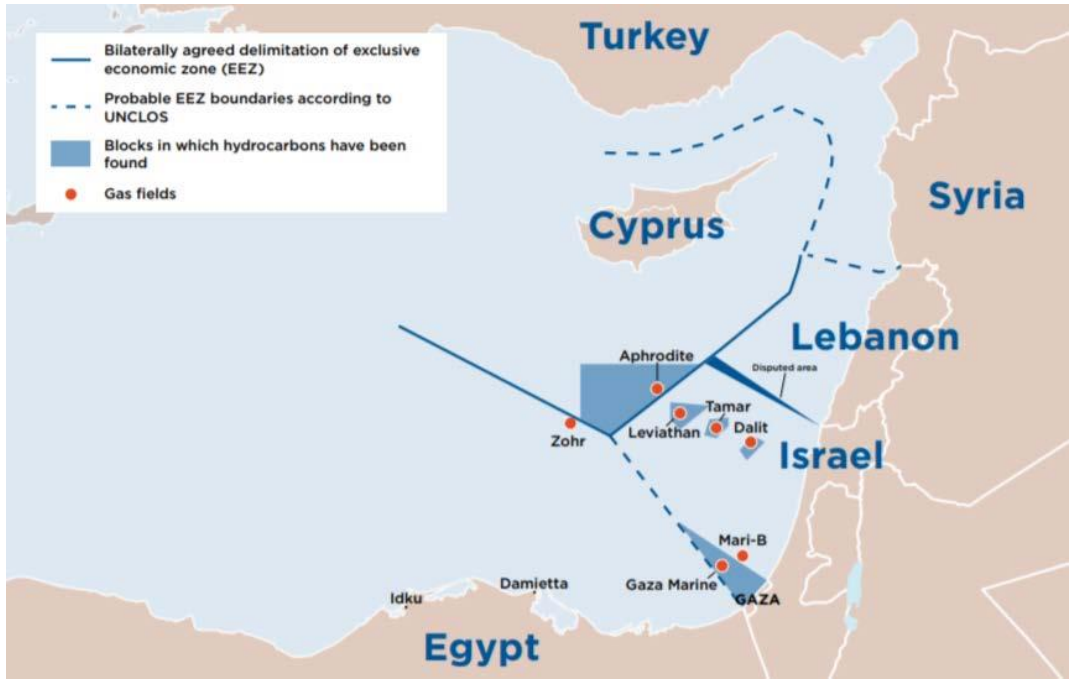

(BBC, 2021)

Eastern Mediterranean Sea

- High Marine Traffic
  - Shortest shipping route from Asia to Europe
  - Oil transit center



- Discoveries of large gas fields in 2010
  - Increasing number of offshore oil and gas exploration and exploitation activities



(European Parliamentary Research Service, 2019)

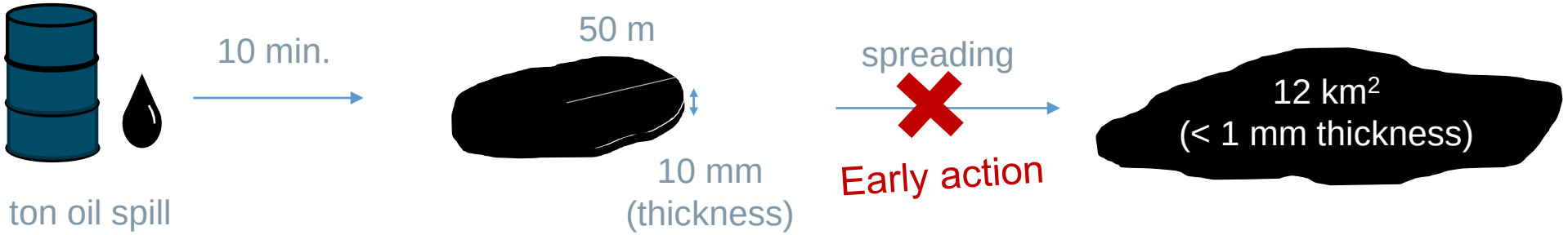
Techniques for Oil Spills Detection

Platforms	Sensors	Properties
Shipborne	Specialised radar	• Very limited coverage
Airborne	Infrared (IR) Ultraviolet (UV)	• Estimate the extent of the oil film • Easily affected by weather condition
	Microwave radiometer (MWR)	• Estimate the oil thickness • Low resolution
	Laser-fluoro-sensor (LFS)	• Classify the oil spills
	Side-Looking Airborne Radar (SLAR)	• High cost • Less efficiency for wide area • Limited coverage
Spaceborne	Synthetic Aperture Radar (SAR)	• Wide coverage • High revisit frequency

Early Warning System

Importance of Early Surveillance System

- Early action to reduce the influence of oil spills



- <u>Strategies:</u>

Surveillance over large area

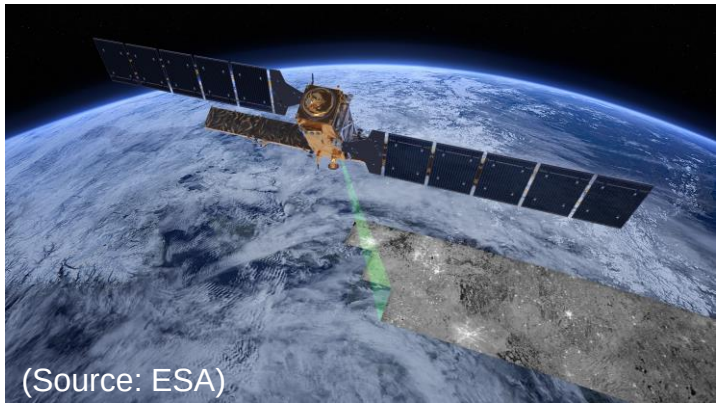
Regular surveillance with spaceborne SAR

- ✓ Wide coverage
- ✓ Frequent visit
- ✓ Low cost
- × Oil thickness
- × Oil type

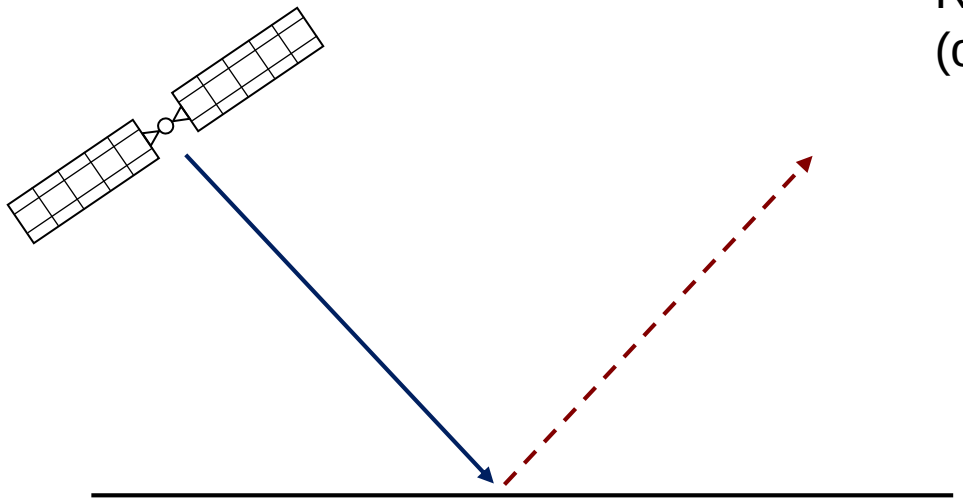
Oil combating response

Further inspection on the detected oil slicks

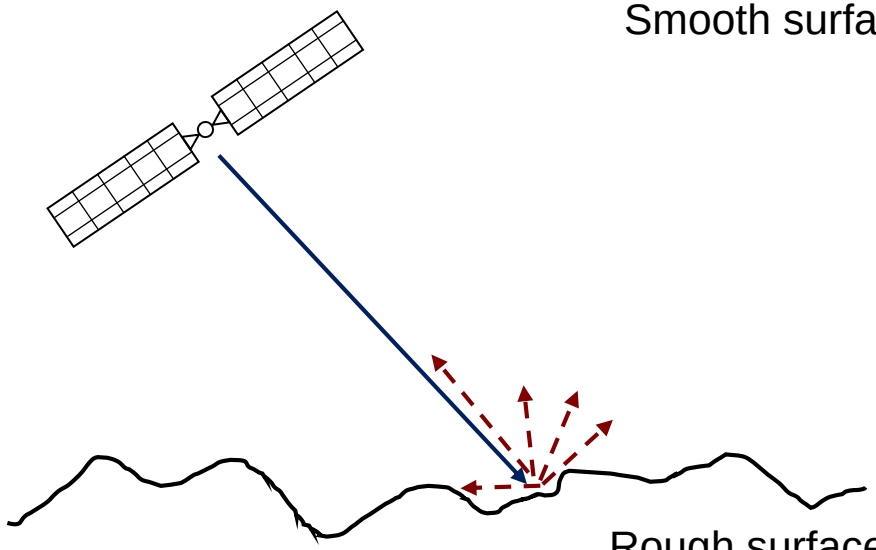
- Oil type
- Oil volume
- Spill conditions
- Physical and ecological characteristics of the spill-covered areas


(Source: ESA)

Oil Spills in SAR Images



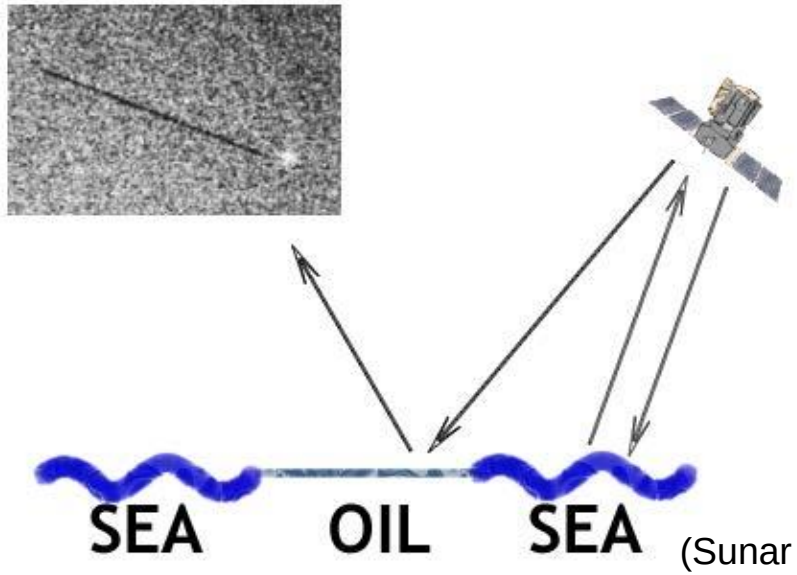
Smooth surface



Rough surface

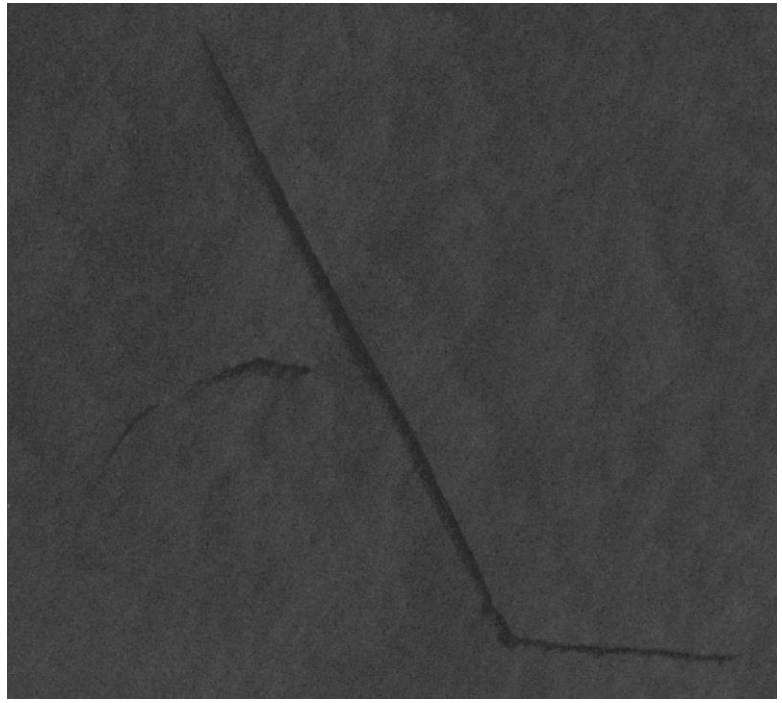
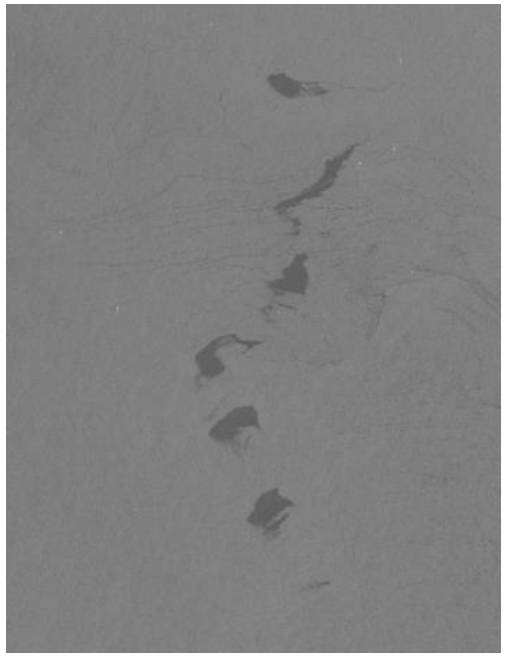
Rough surface
(open water)

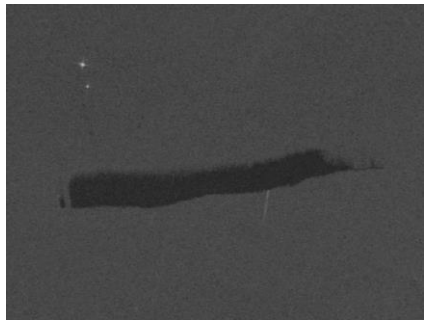
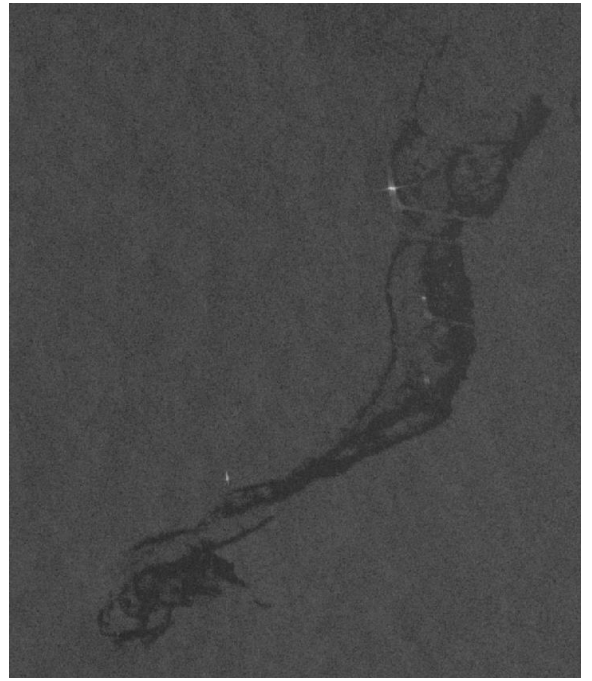
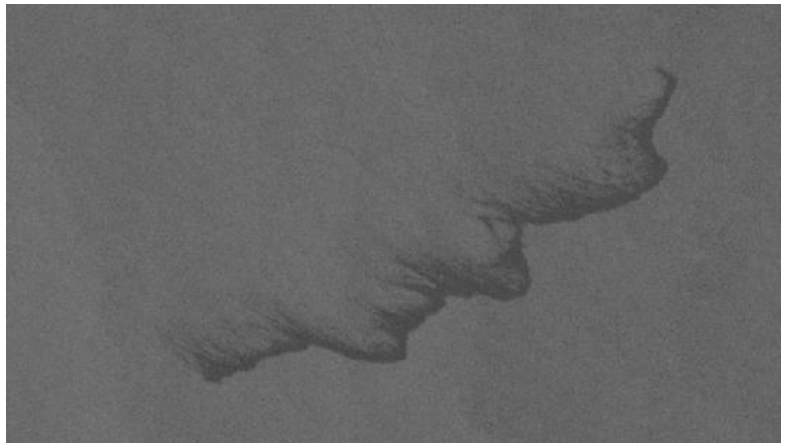
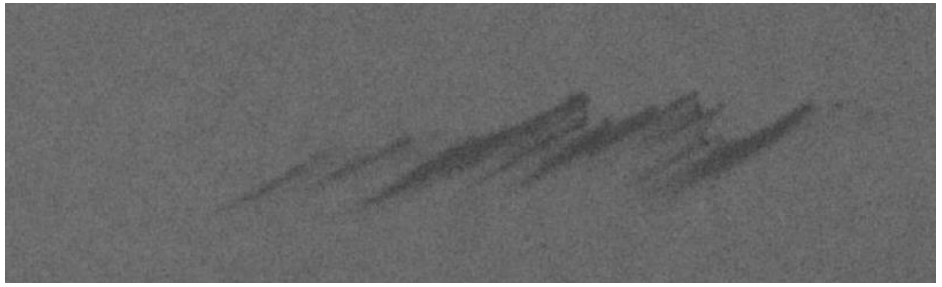
Calm surface
(closed water)



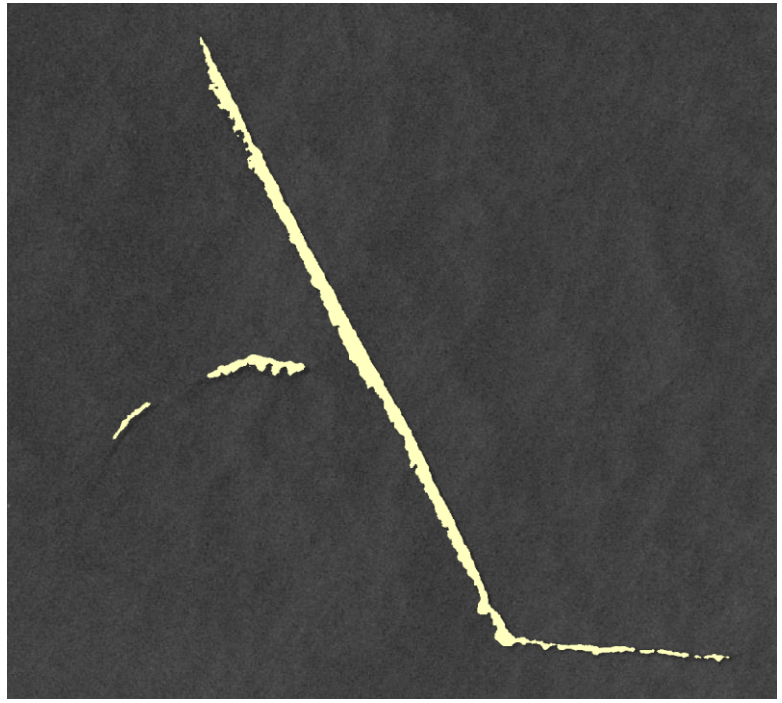
(Sunar et al., 2007)

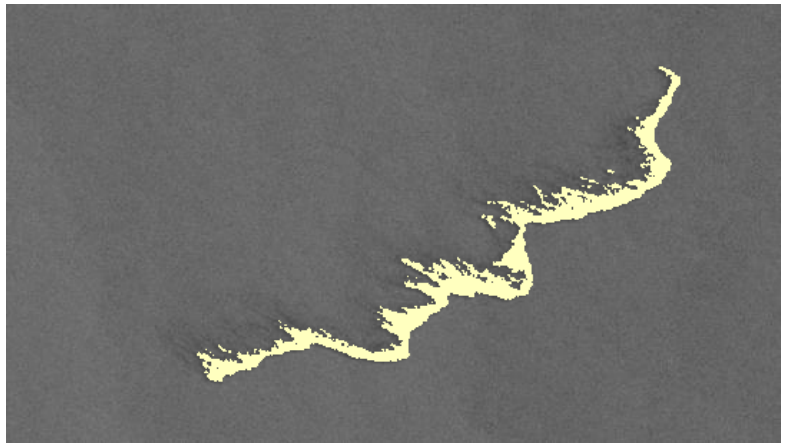
Oil Spills in SAR Images

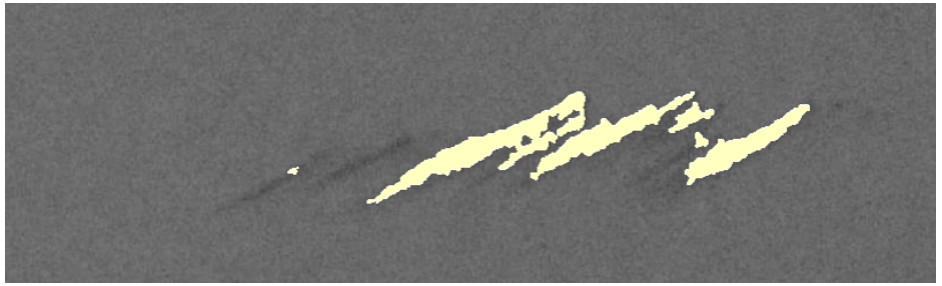



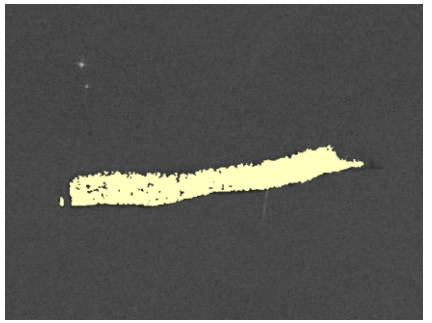





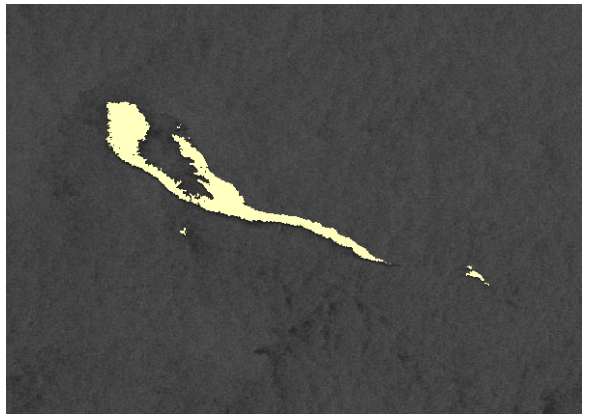

Oil Spills in SAR Images



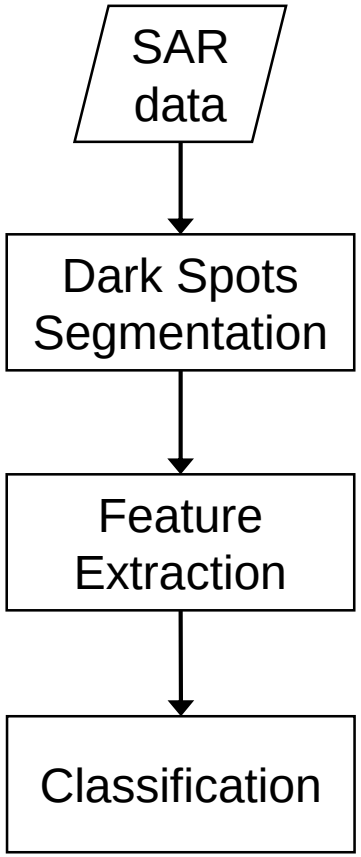


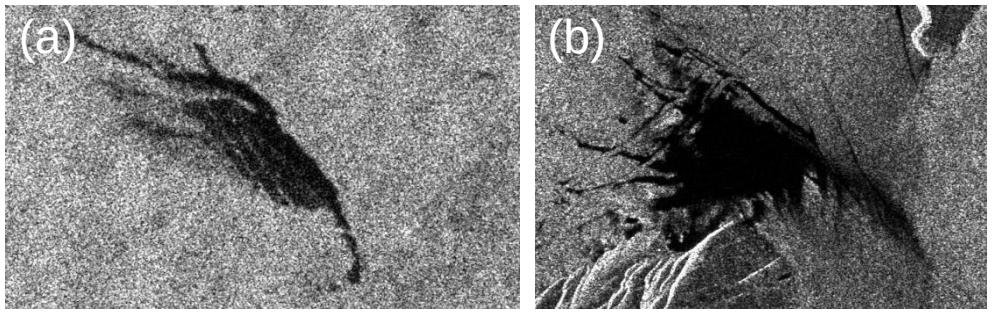






Conventional Workflow for Oil Slick Detection using SAR





- Images of (a) an oil spill and (b) a look-alike (Stathakis et al., 2006)

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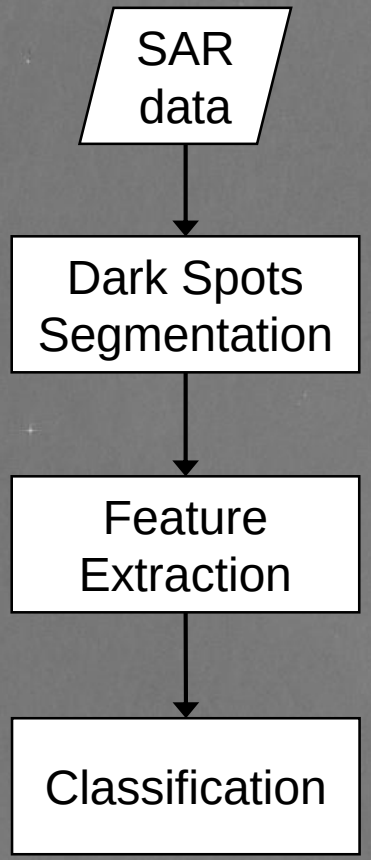
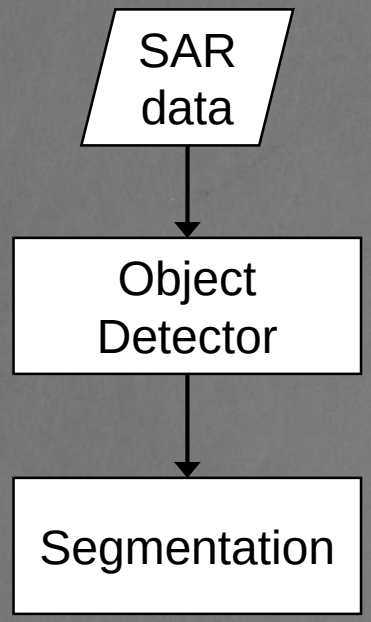
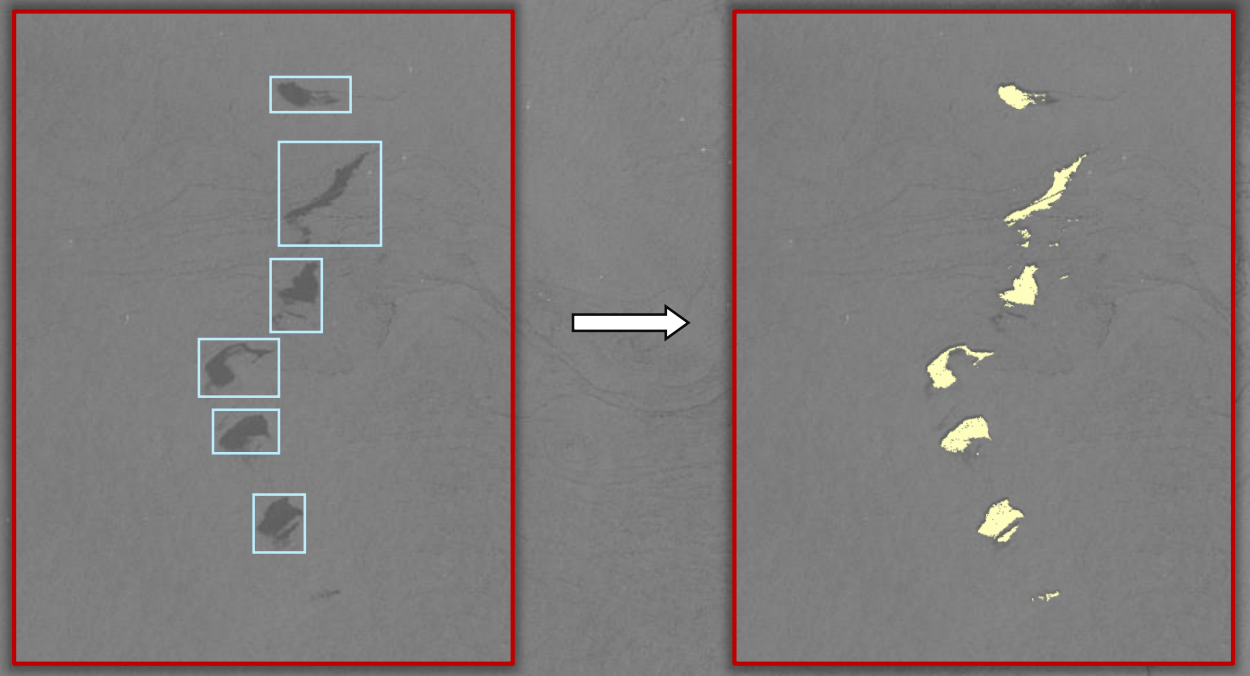


azimuth

range

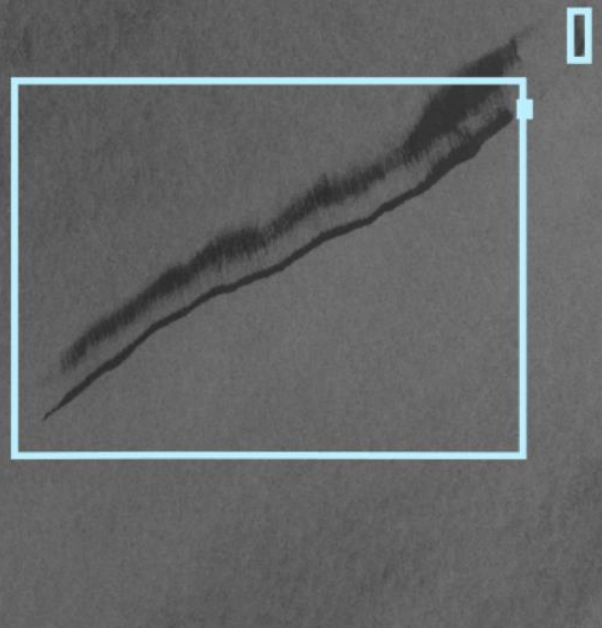
Object detection approach





azimuth

range

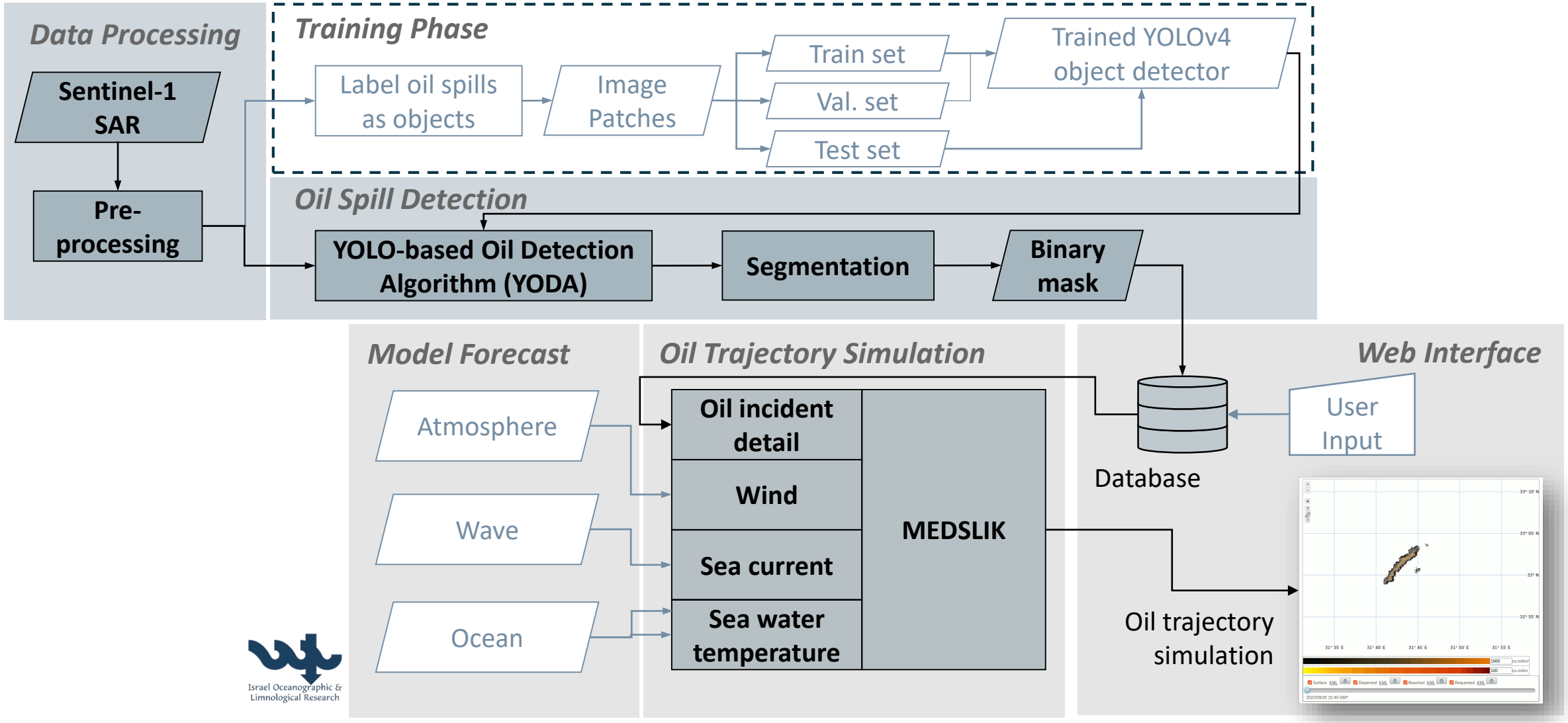


Oil Spill Detection and Early Warning System

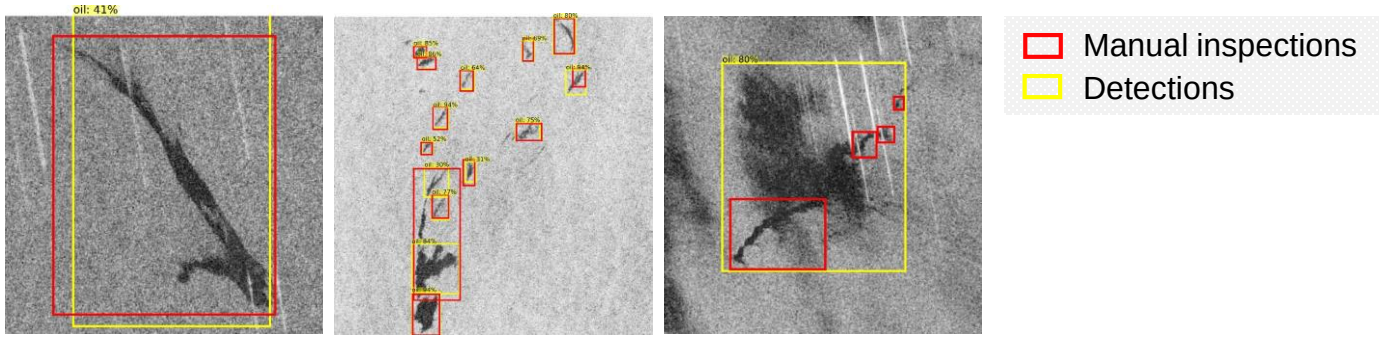
Oil Spill Detection and Early Warning System

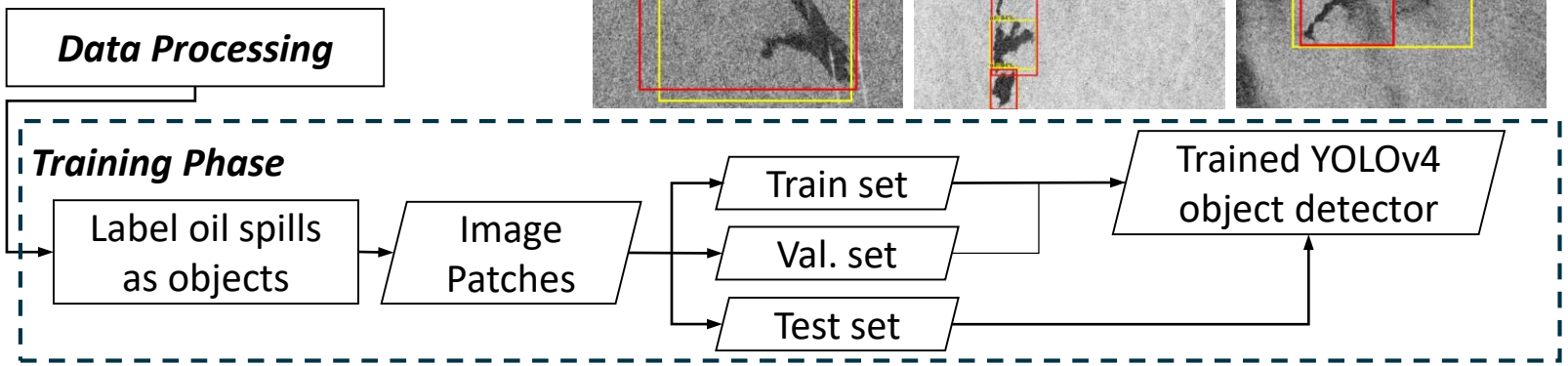
- *Cooperation work with the Israel Oceanographic and Limnological Research (IOLR)*

** YOLO = You Only Look Once (object detection algorithm)*



Oil Spill Detection Subsystem

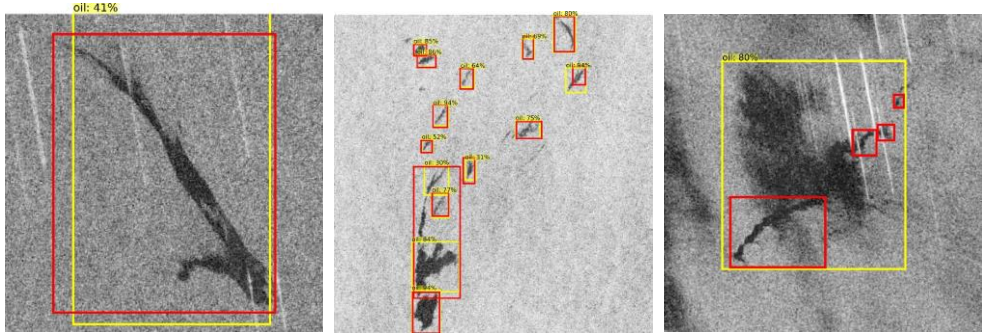


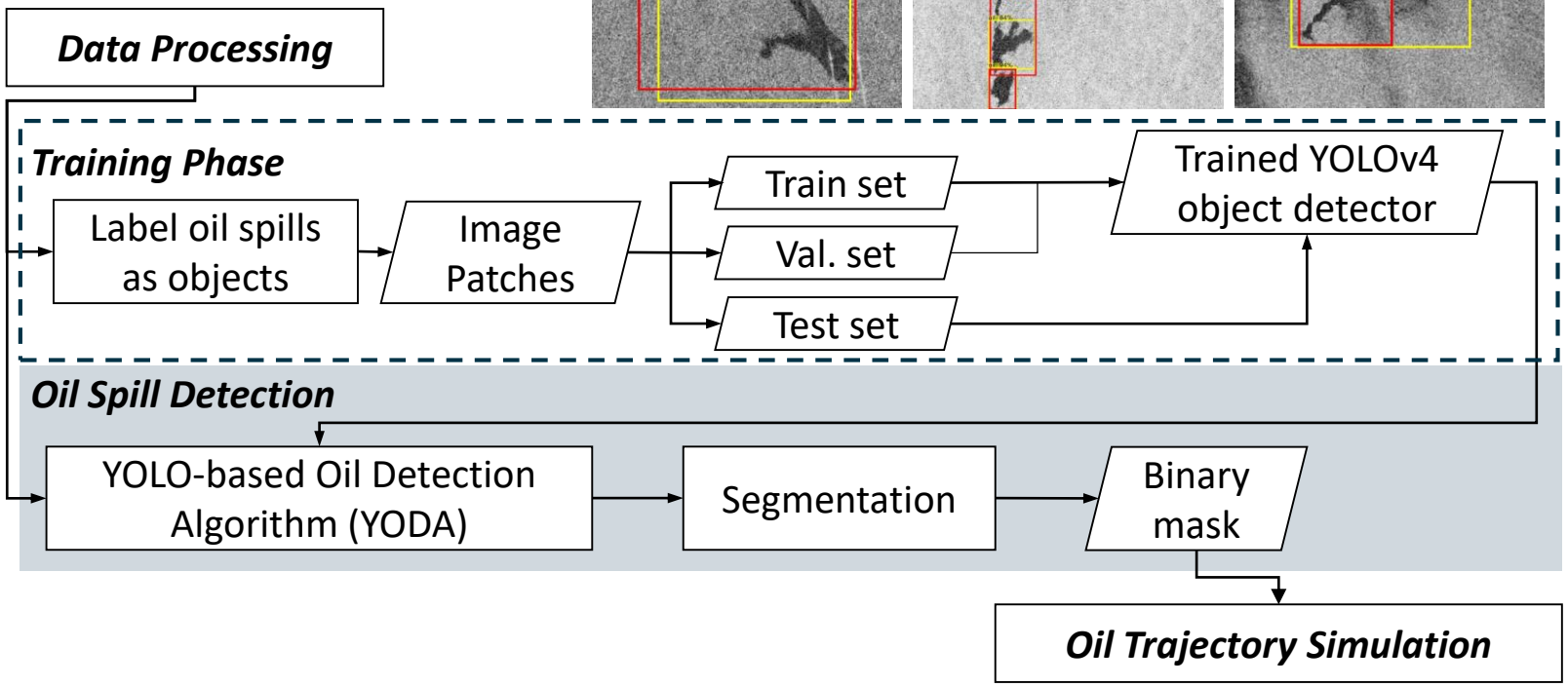


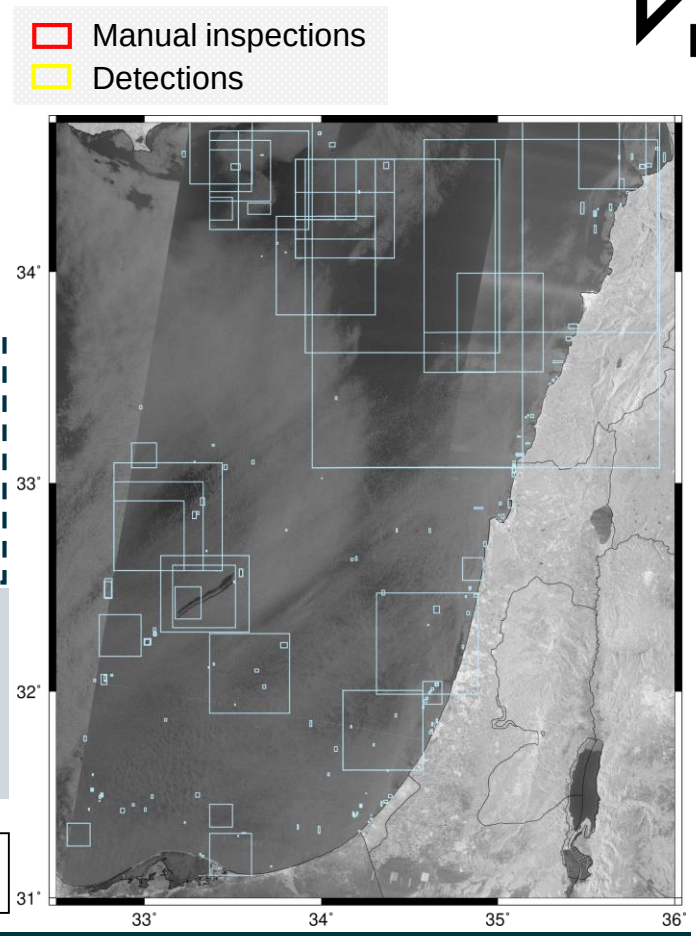
Dataset	Average Precision [%]
Validation	69.10
Test	68.69

- The ability of a detector on targeting oil spills inside the user defined dataset.

Oil Spill Detection Subsystem







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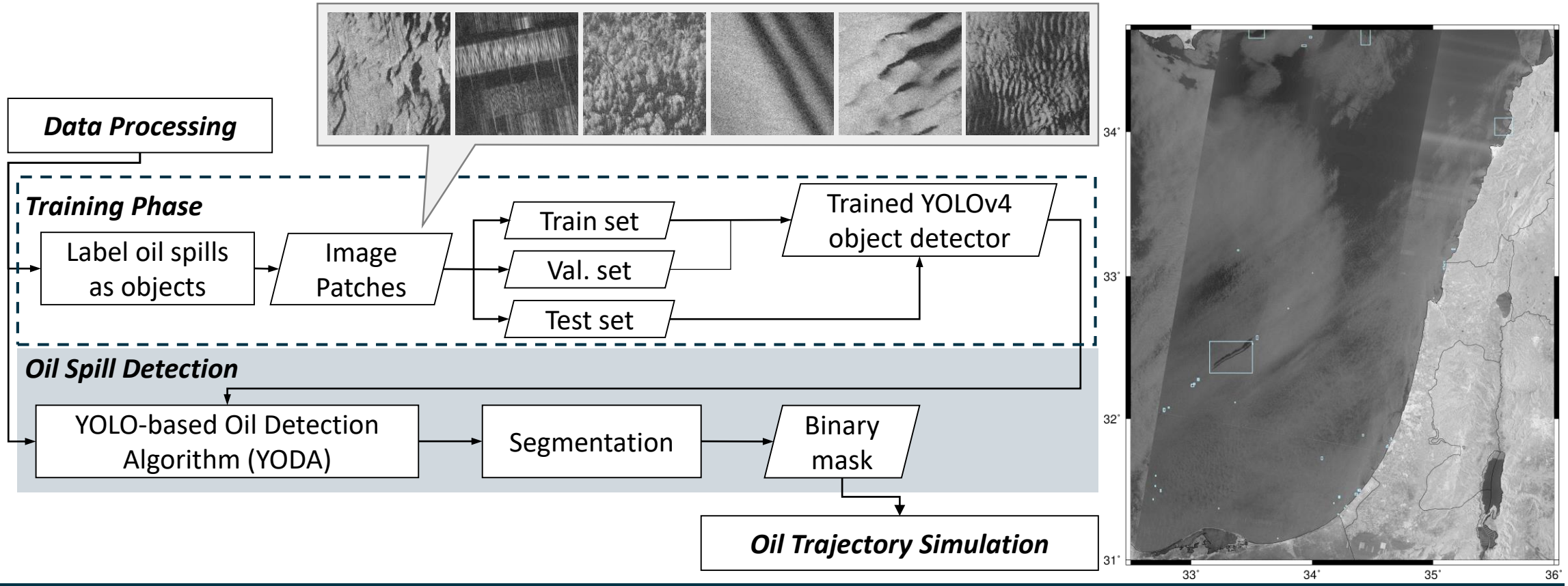
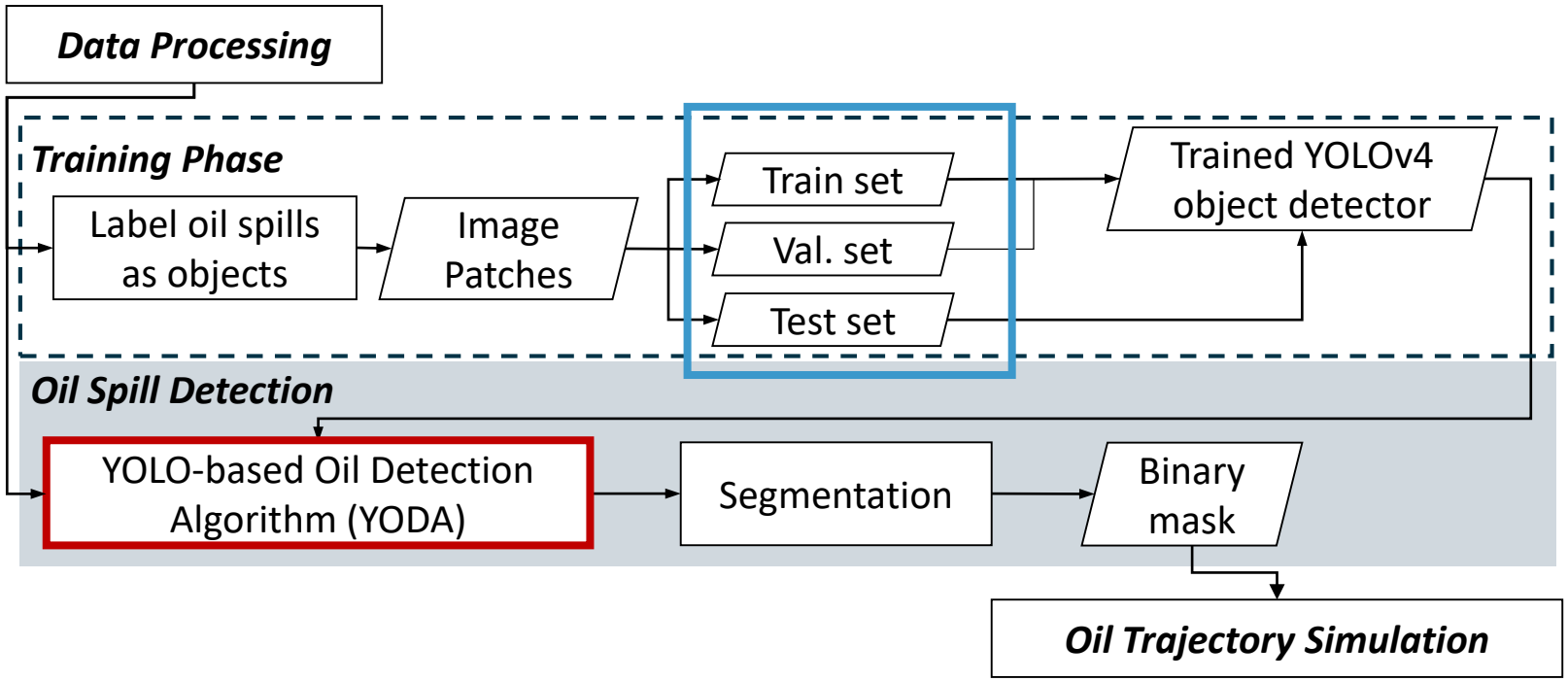


- The ability of a detector on targeting oil spills inside the user defined dataset.
- The feasibility of building an automated oil spill detection subsystem based on the trained object detector.

Oil Spill Detection Subsystem



- Training, validating and testing the object detector
- Testing YODA

Year	# scenes	# objs
2015	709	995
2016	1290	2288
2017	1910	2767
2018	2021	3418
2019	2057	1883
Total	7987	11351

- The ability of a detector on targeting oil spills inside the user defined dataset.
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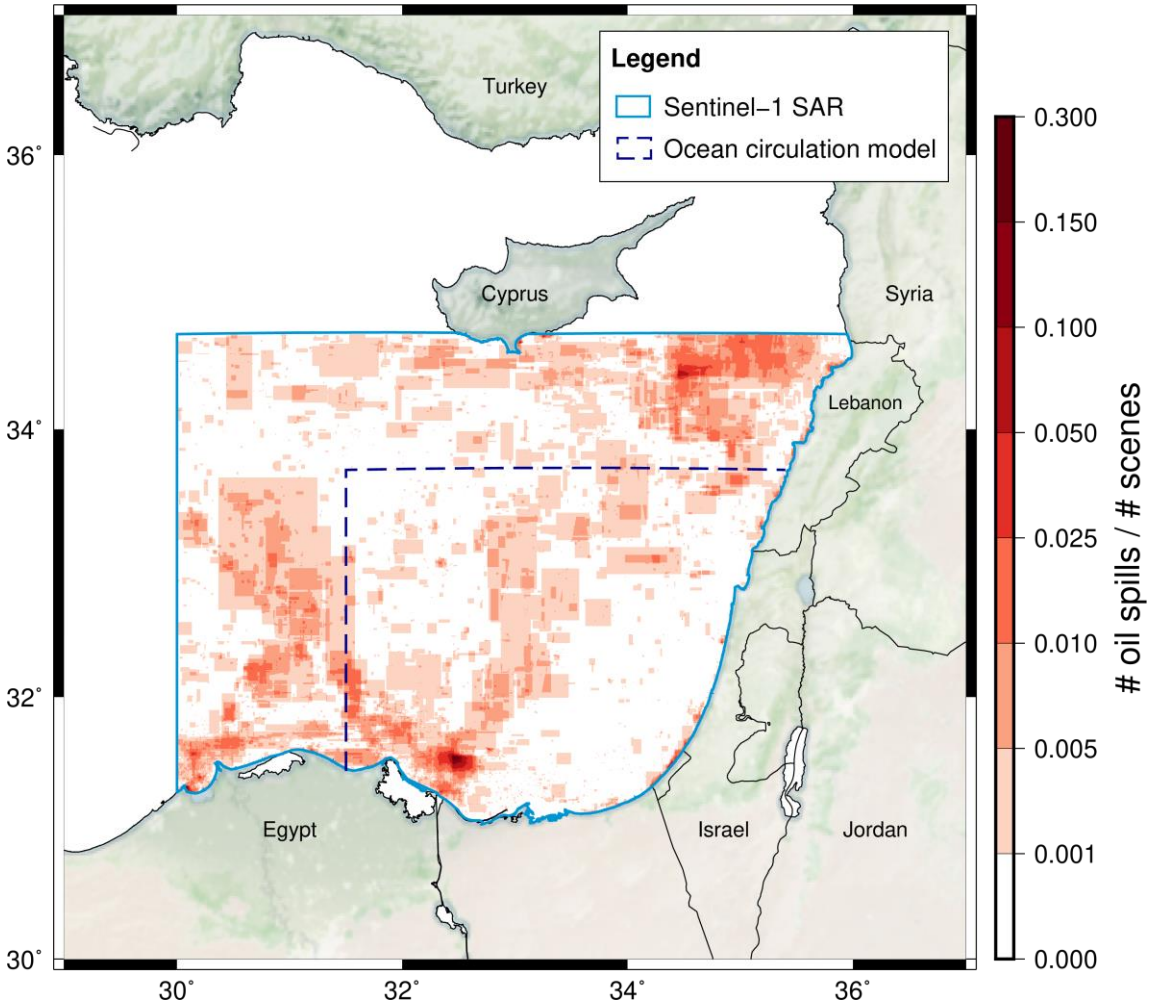
Oil Spill Detection Subsystem



- The frequency of oil spills appearing on each pixel based on the manual inspected oil spills from 2015–2018 with a total of 9468 oil spills in 5930 Sentinel-1 scenes.

- Training, validating and testing the object detector
- Testing YODA

Year	# scenes	# objs
2015	709	995
2016	1290	2288
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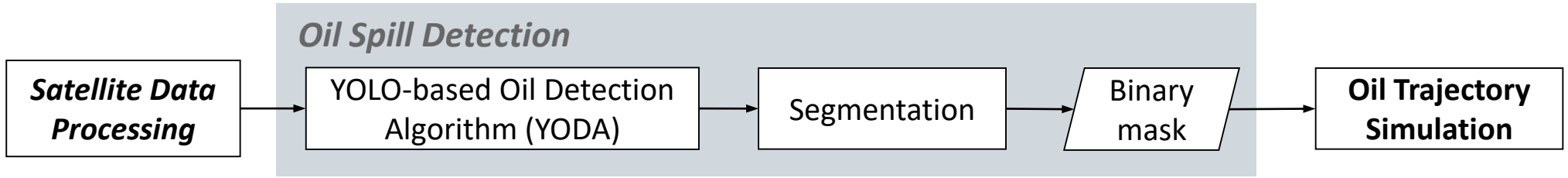
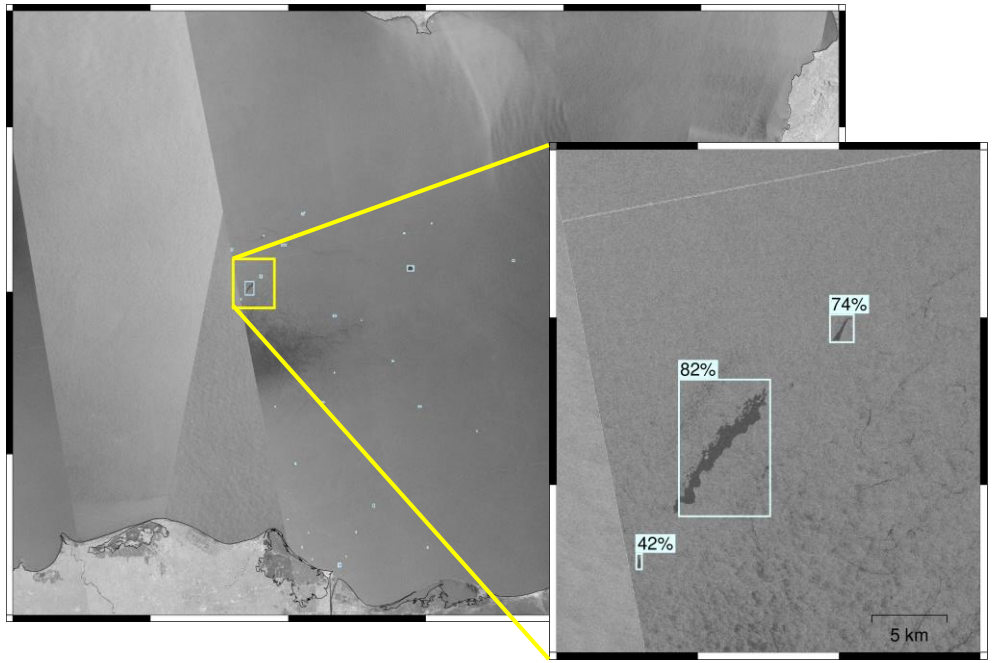
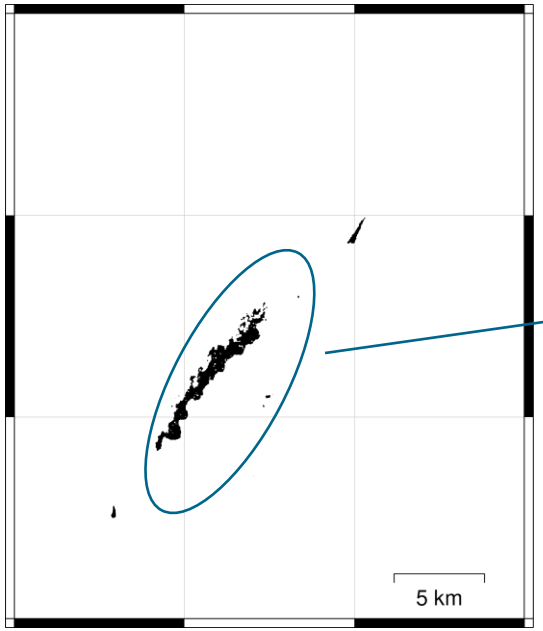
Illustration of the oil spill detection system

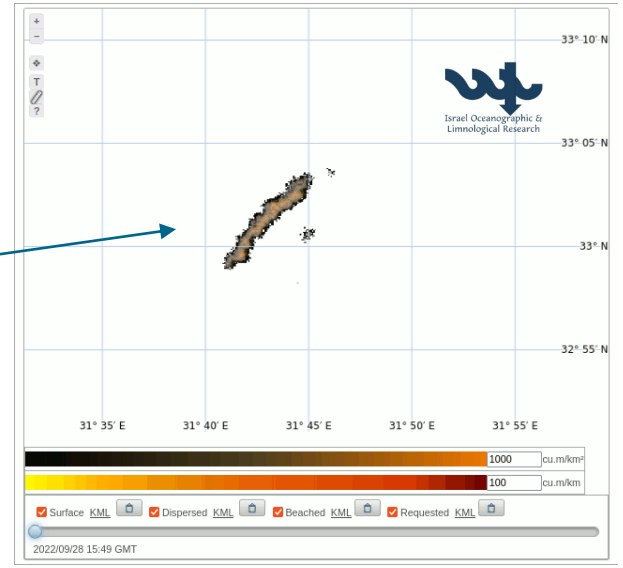




Oil slick detection



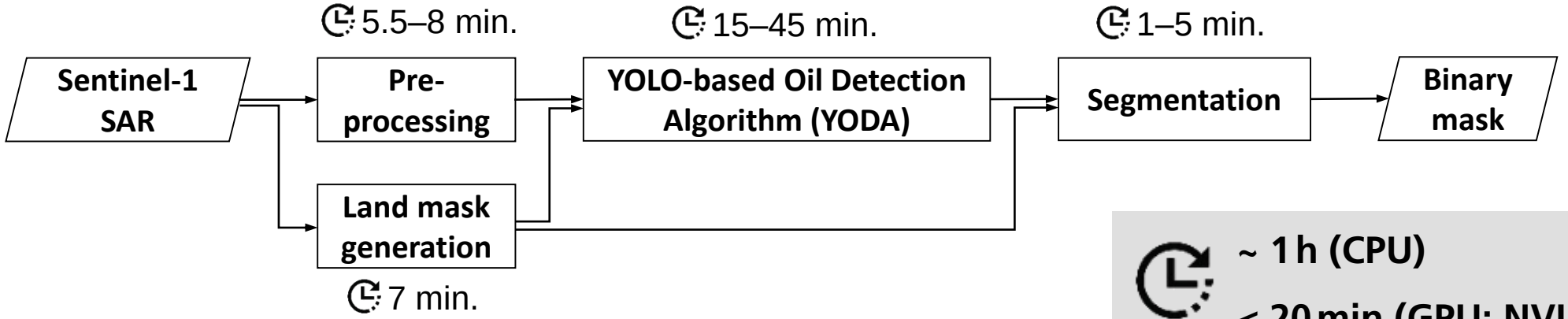
Binary mask



Oil trajectory simulation

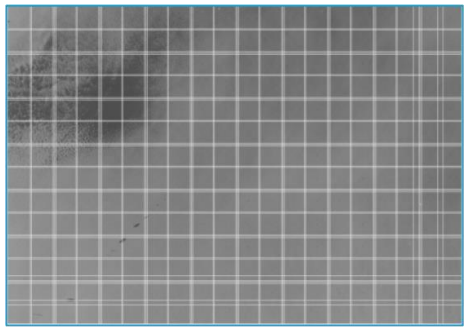
Latency for Operational Procedure

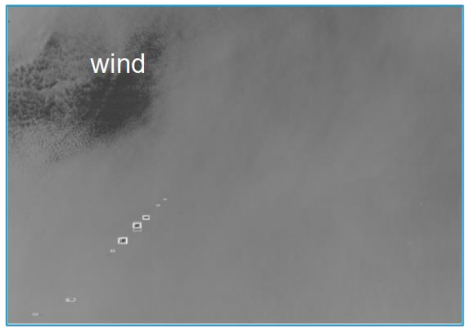
Testing with processing 4 scenes:

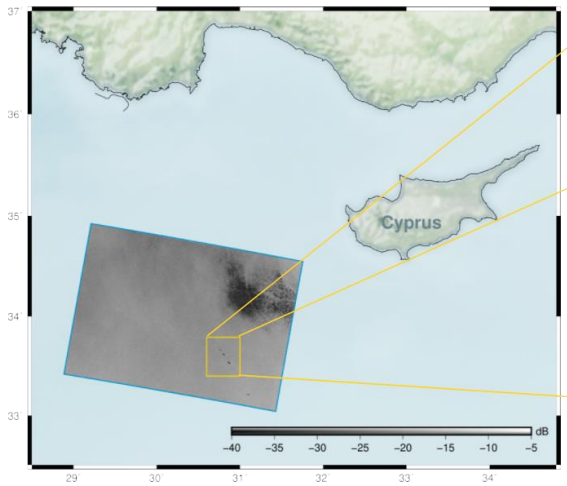


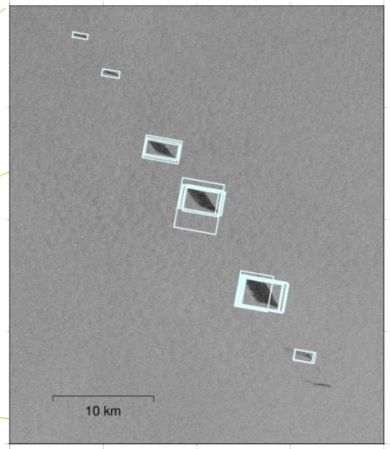
~ 1 h (CPU)

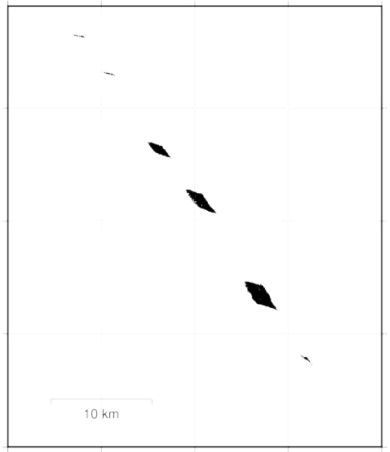
< 20 min (GPU: NVIDIA RTX 2080)







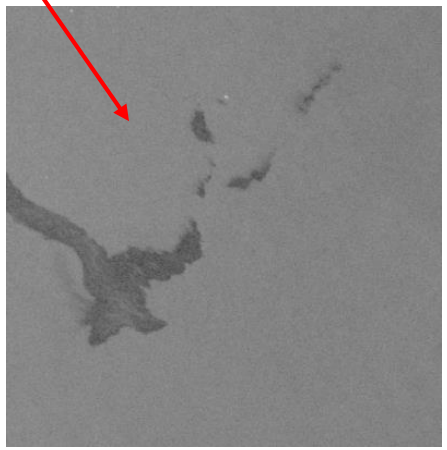




Testing the System for Other Oil Pollution Hotspots

Oil spills caused by ships

Natural seeps

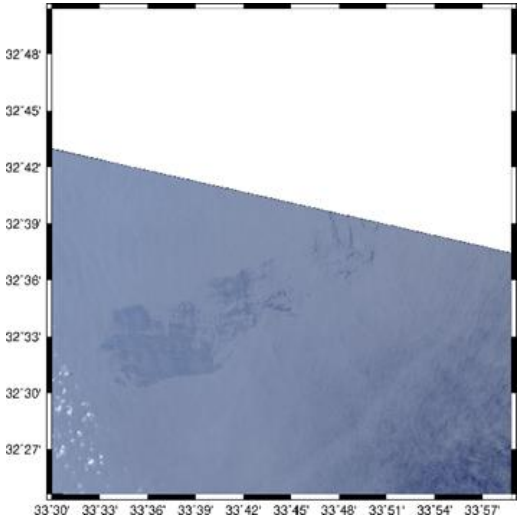


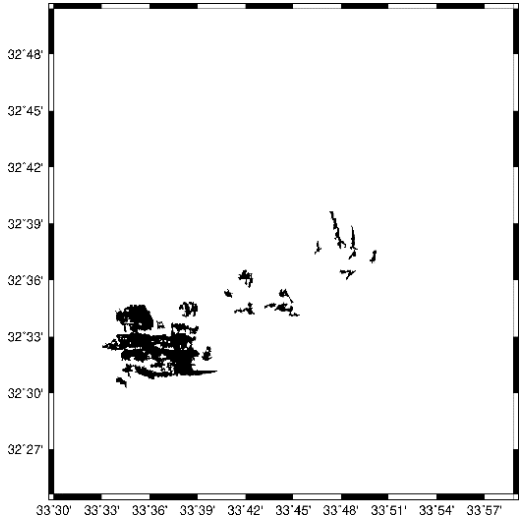
Leaks from oil platforms and pipelines

Oil Spill Detection Results – SAR & optic: additional value

Landsat-8

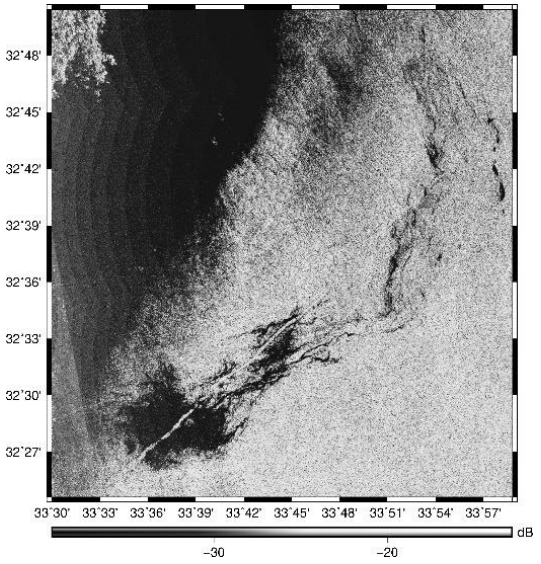
2019/06/10
08:17:04

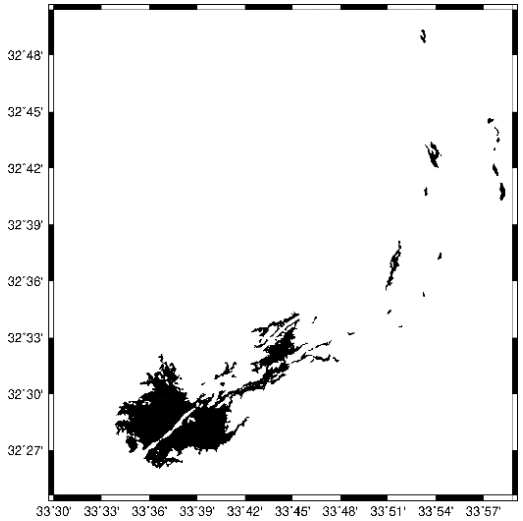


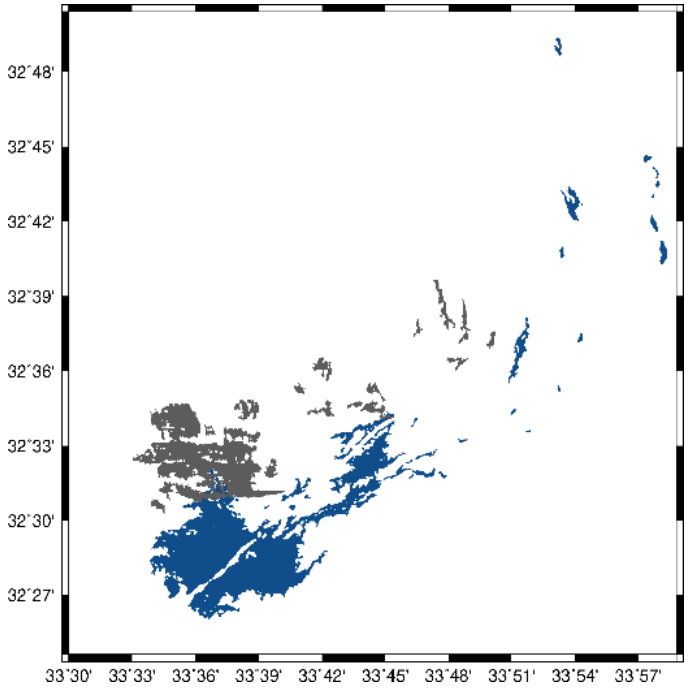


Sentinel-1

2019/06/10
15:47:48

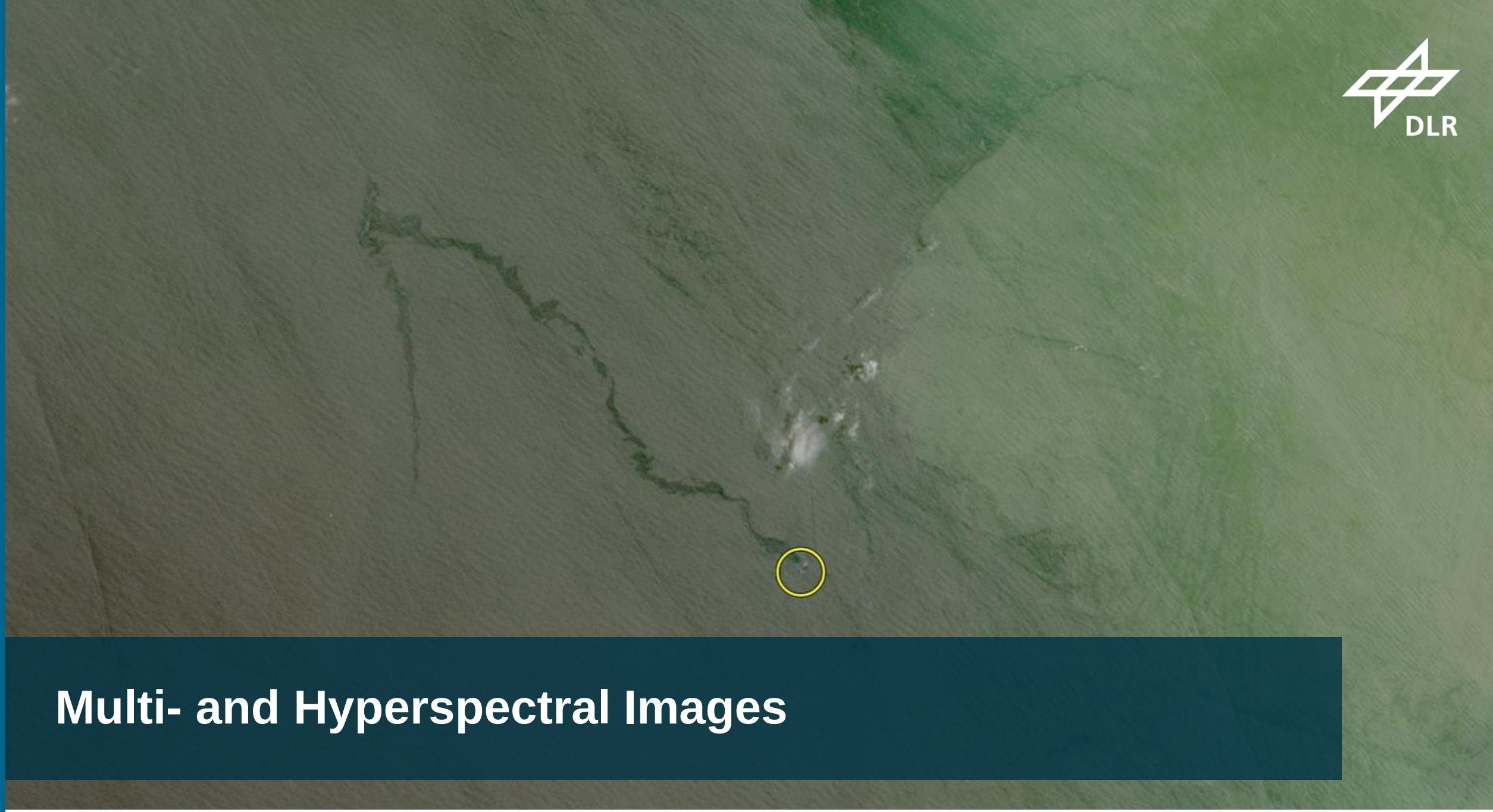






Landsat-8

Sentinel-1



Multi- and Hyperspectral Images

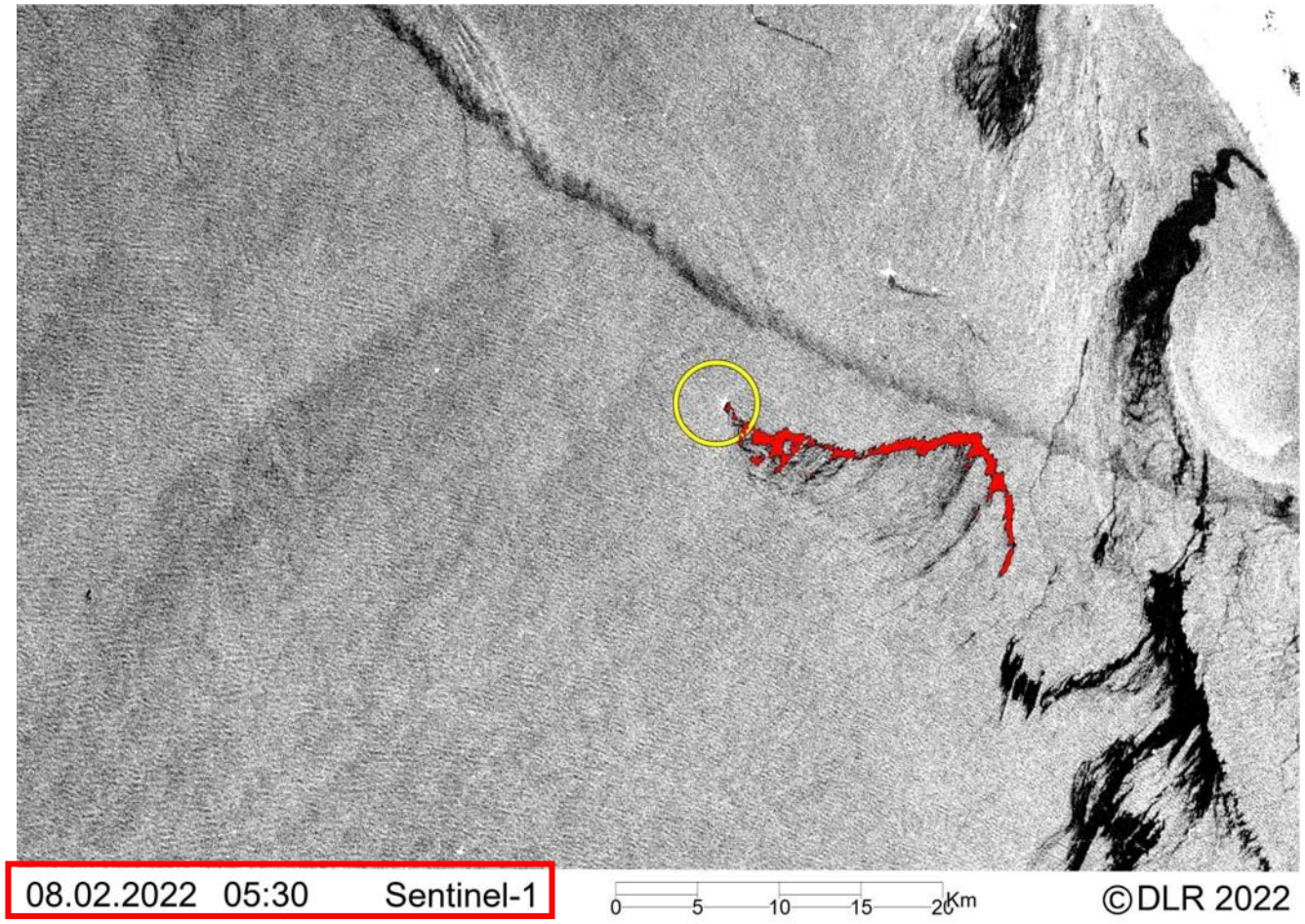
16.04.2022

0 2 4 6 8 10 Km

Oil Spill Detection, Development Bremen | Neustrelitz

Environmental disaster caused by the sinking of the oil production ship Trinity Spirit

- Oil spill detection based on **Sentinel-1** data, DLR Bremen
- Oil spill detection based on **Landsat-8,9** data, DLR Neustrelitz



Oil production vessel "Trinity Spirit" explodes off the coast of Nigeria and sinks on 02.02.2022

Oil Spill Detection, Development Bremen | Neustrelitz

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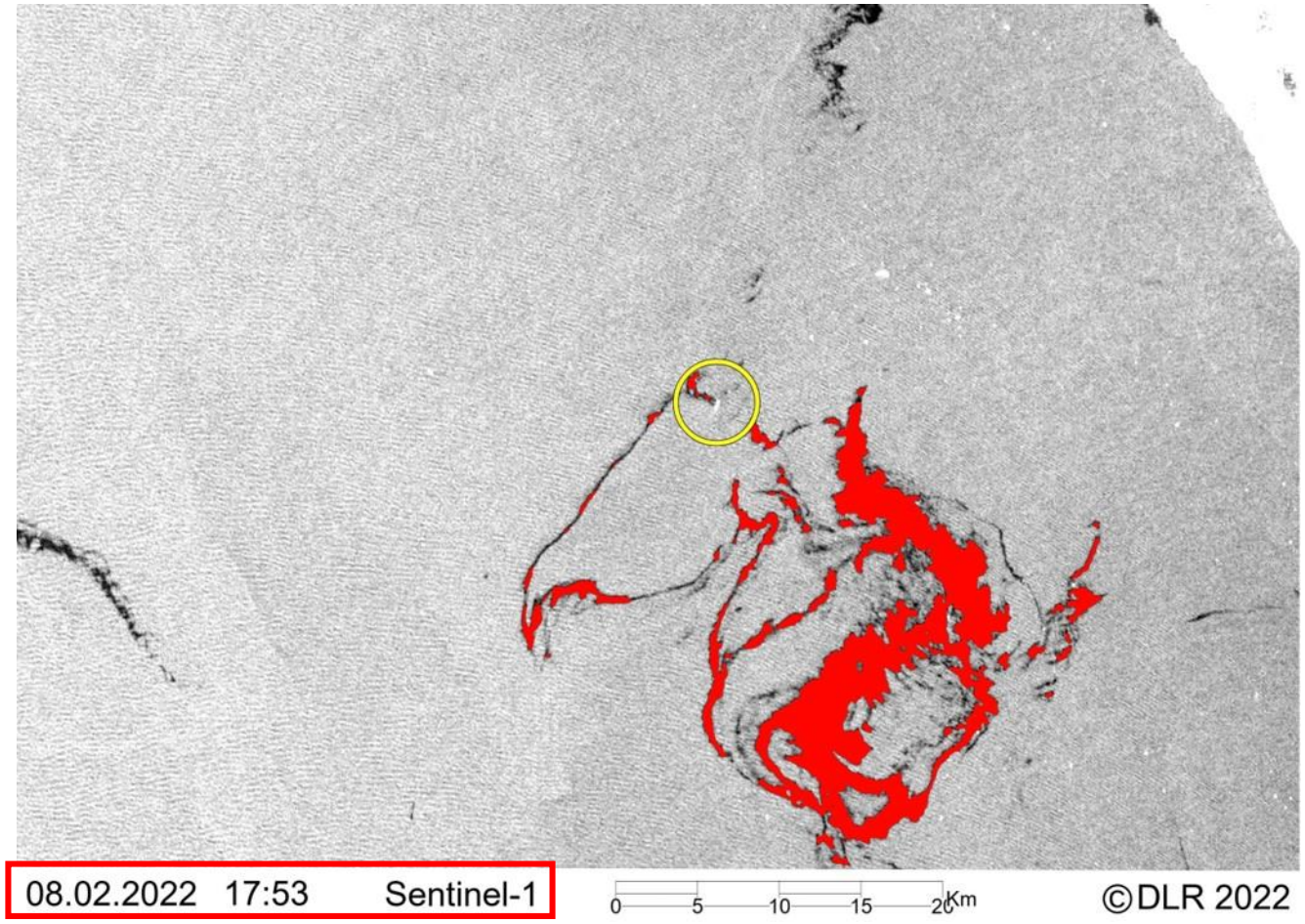
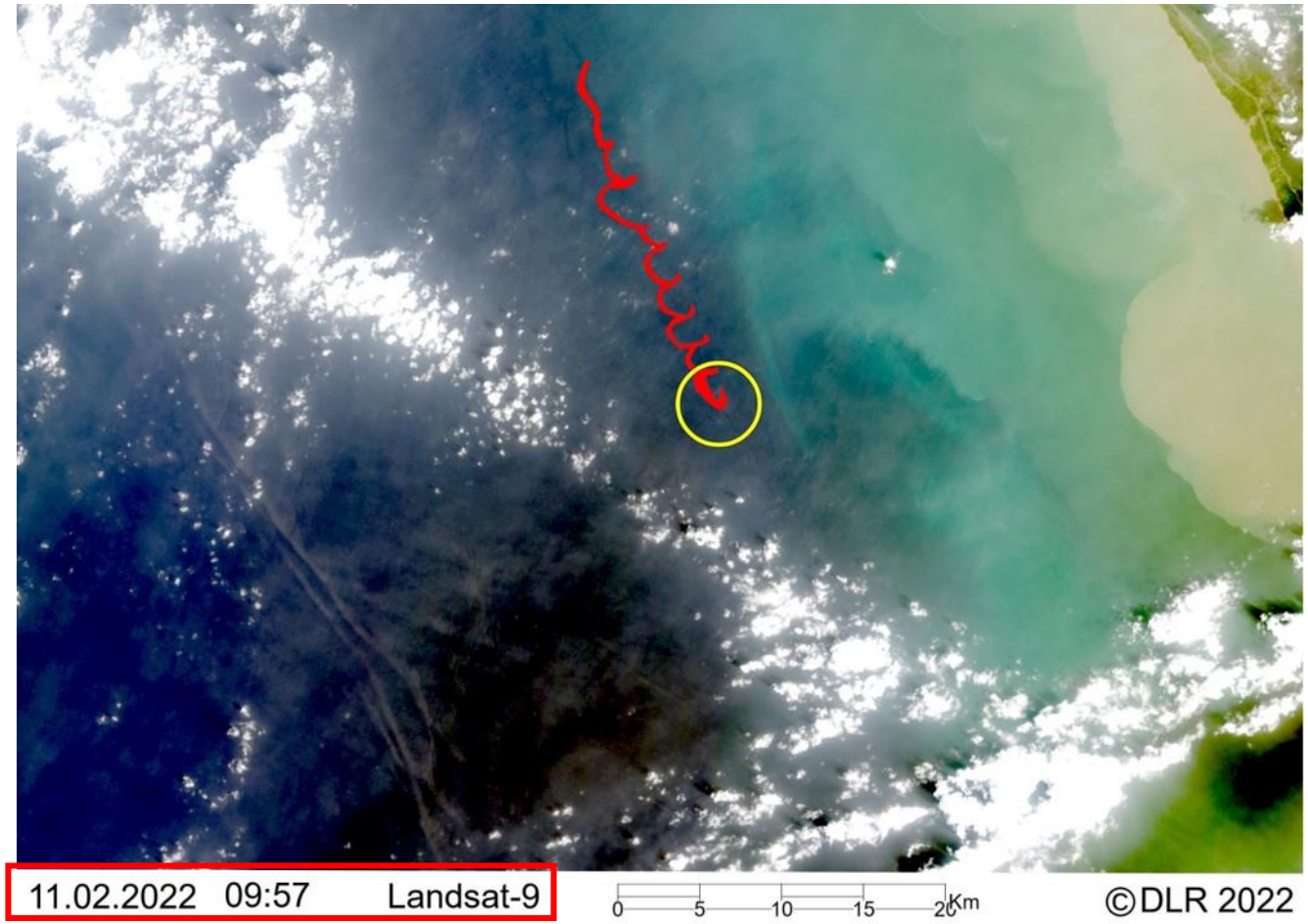


Oil production vessel "Trinity Spirit" explodes off the coast of Nigeria and sinks on 02.02.2022

Oil Spill Detection, Development Bremen | Neustrelitz

Environmental disaster caused by the sinking of the oil production ship Trinity Spirit

- Oil spill detection based on **Sentinel-1** data, DLR Bremen
- Oil spill detection based on **Landsat-8,9** data, DLR Neustrelitz



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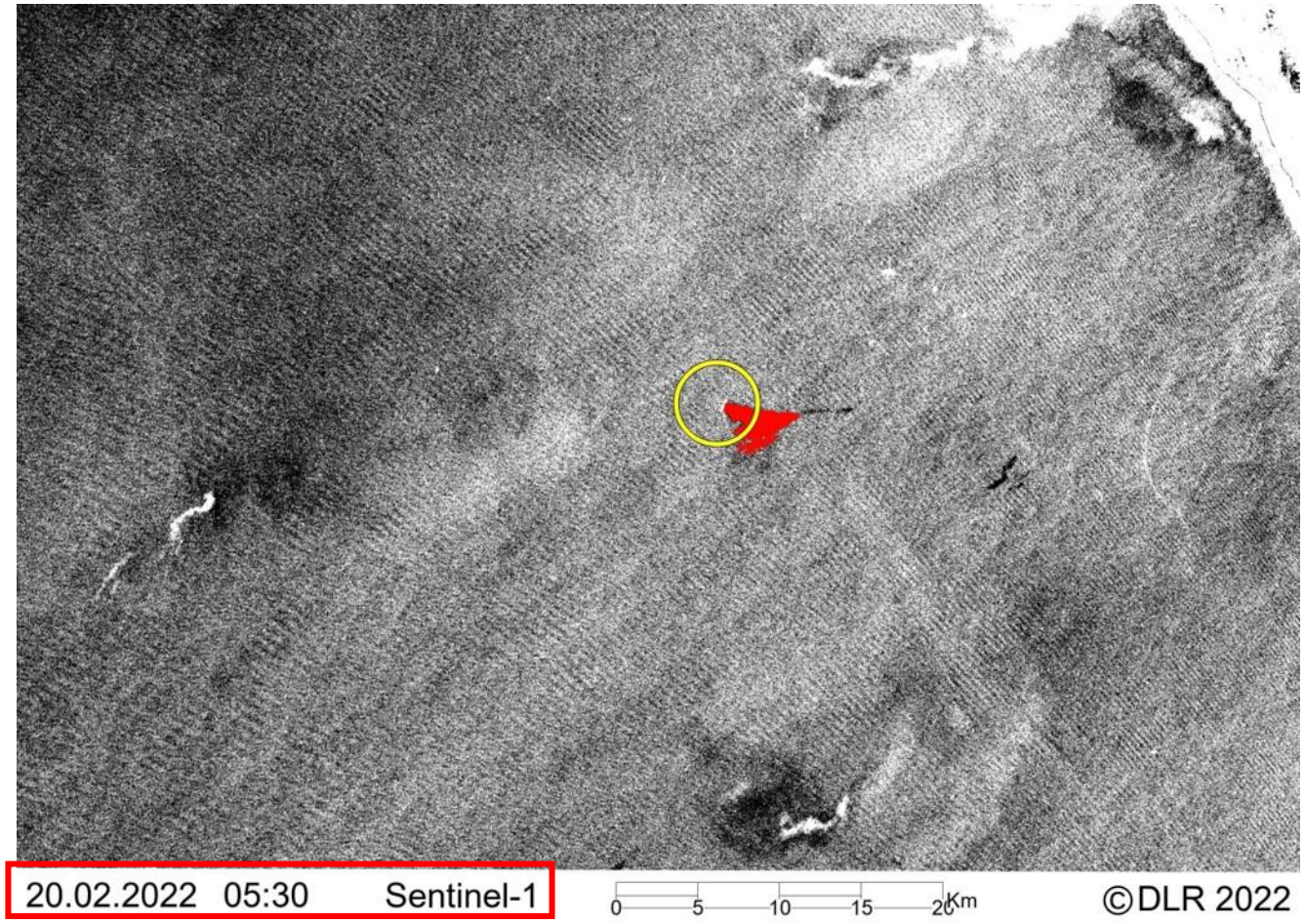

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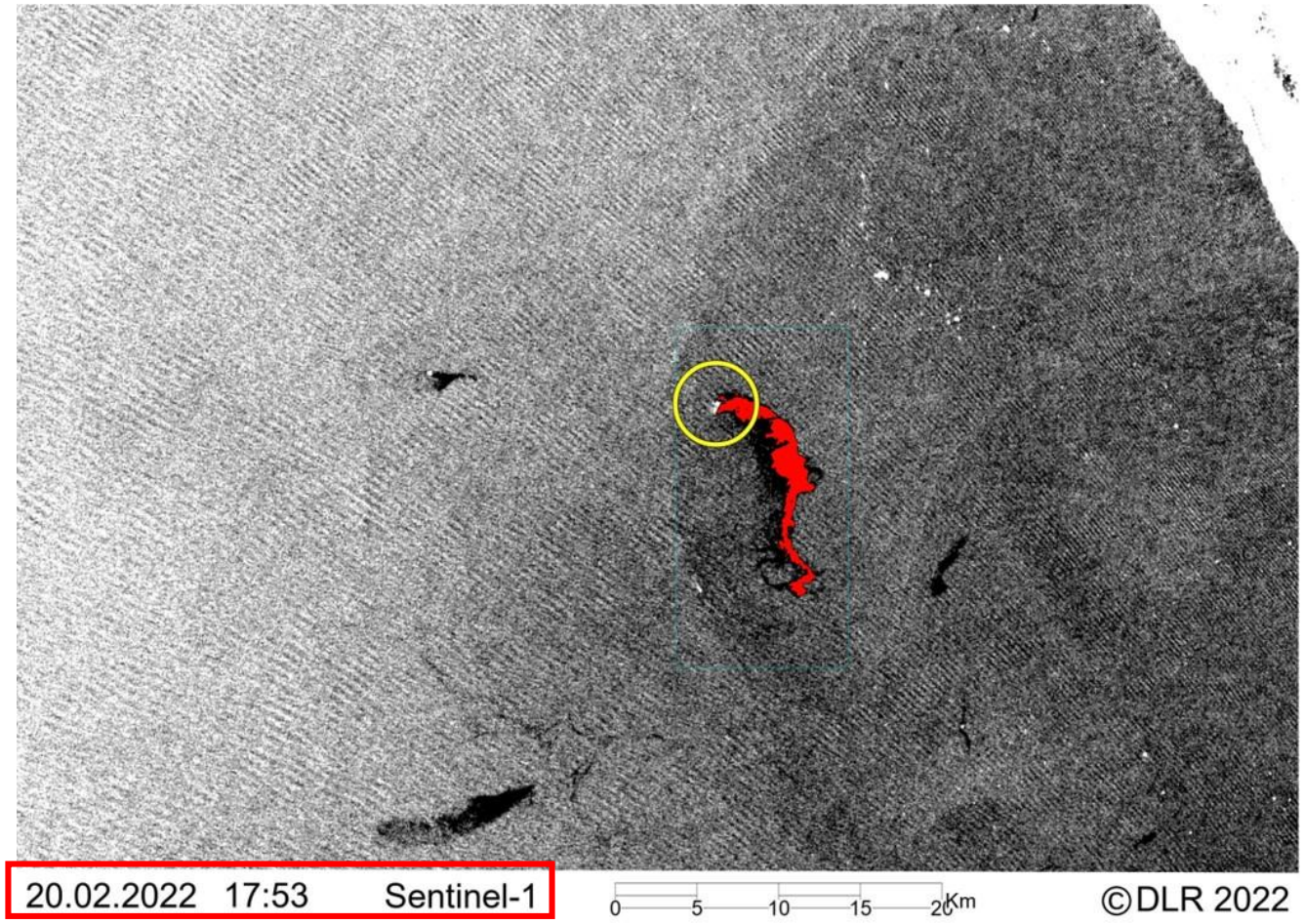

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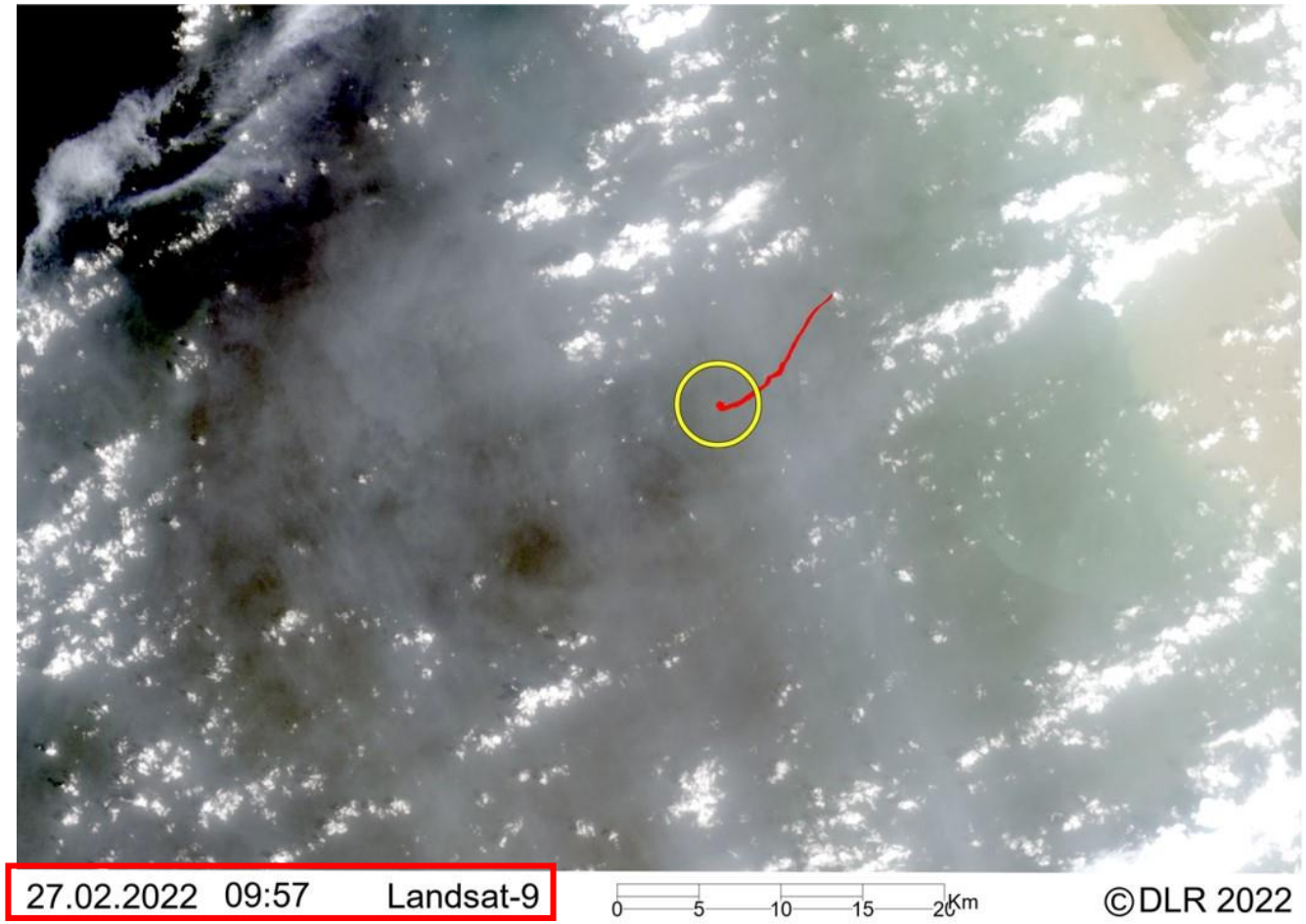

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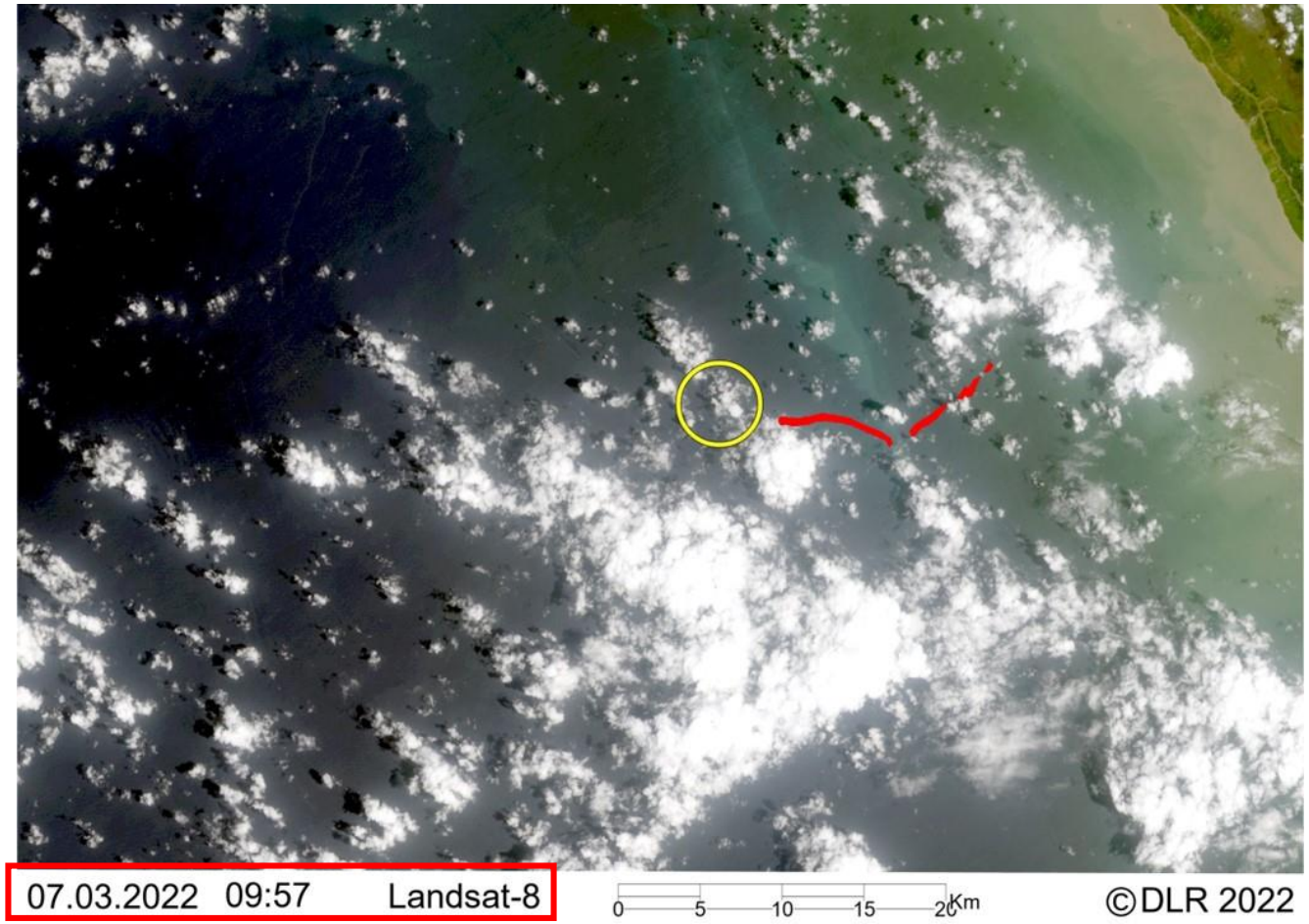

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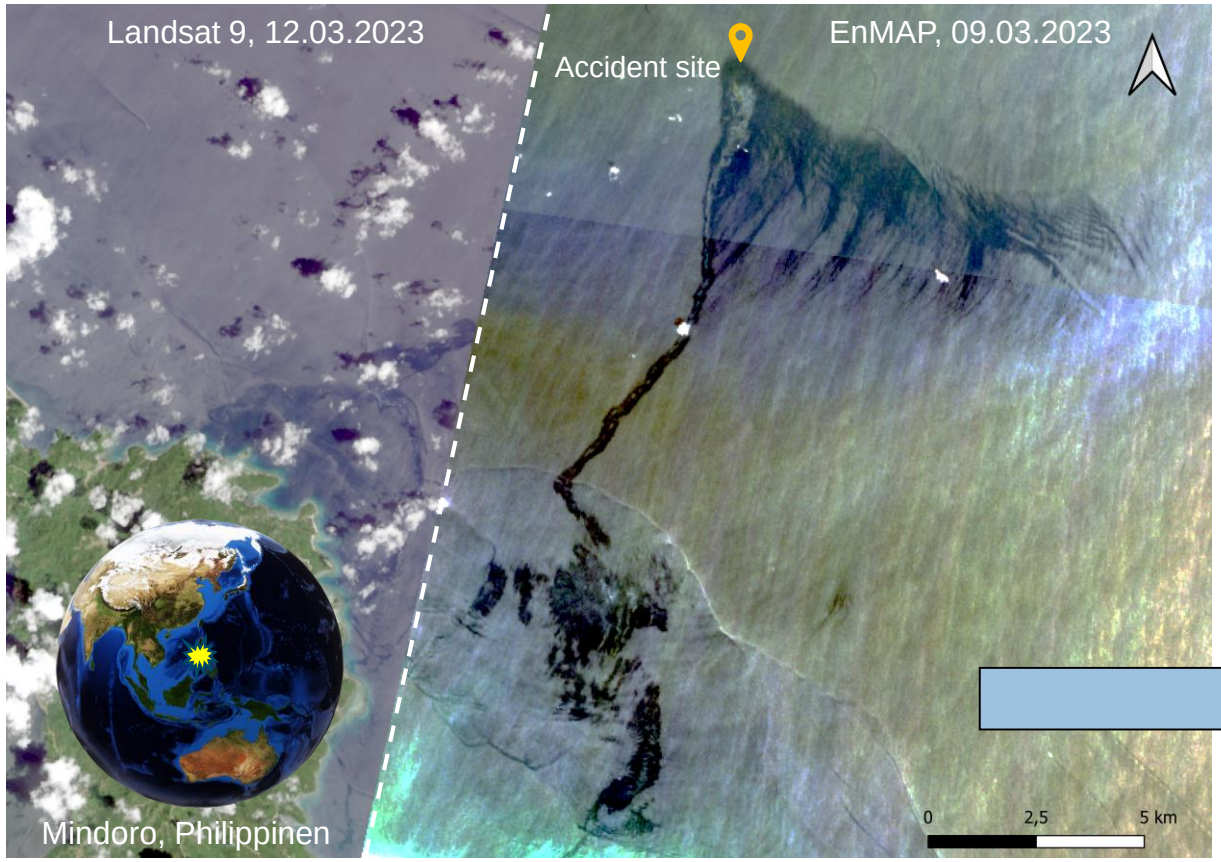
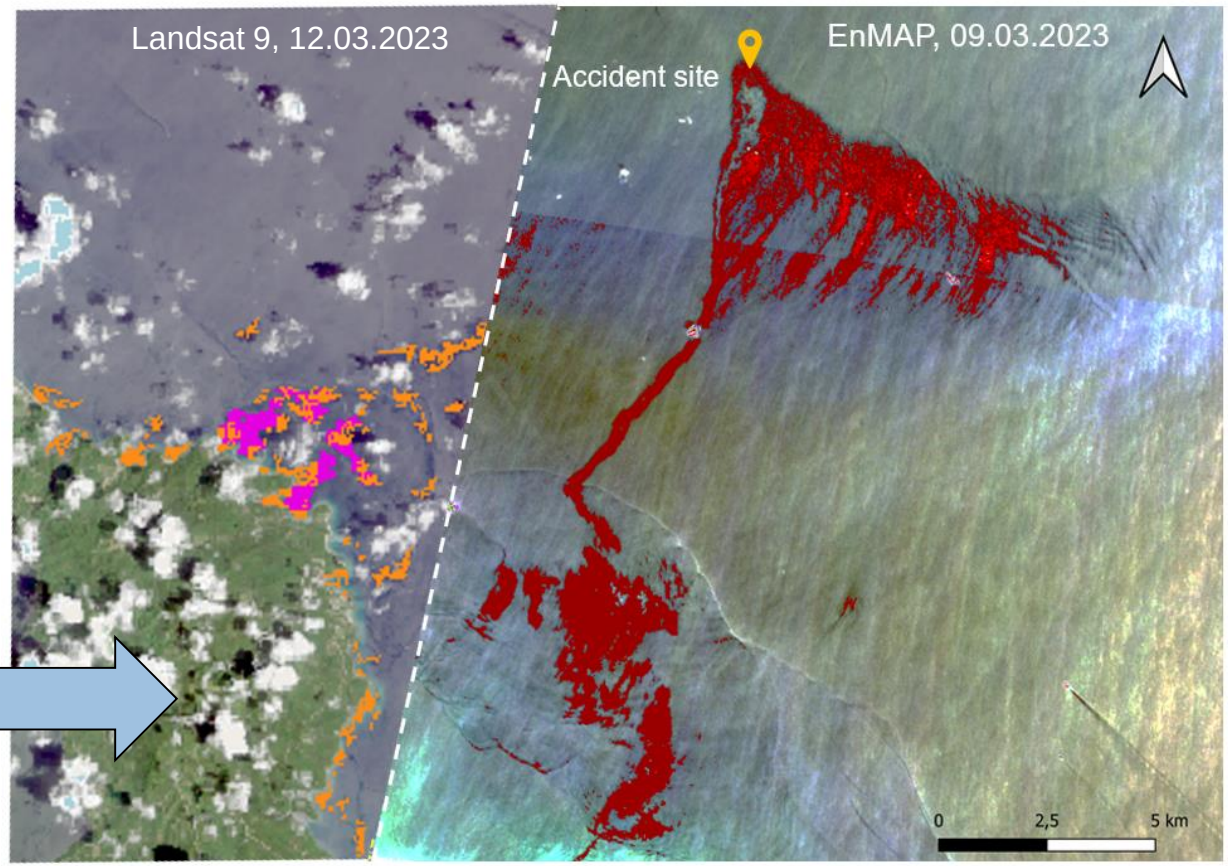
Oil Spill Detection on Multi- and Hyperspectral Images





Sinking of the tanker MT Princess Empress, loaded with 800,000 liters of industrial oil, on February 28 off the Philippine Island Mindoro, Naujan.

Automatic oil spill detected on two days with different data and methods :

- Threshold method (Landsat, 11 bands)
- Convolutional Neural Network (Index Method)
- Unsupervised classification, k-means (EnMAP, 230 bands)

C. Mönnig, O. Schmidt, E. Schwarz, C. Wloczyk (DLR Neustrelitz)

- DARTIS project (2019–2022):
  Development of an automated real-time intelligent information system for early warning and preparedness of offshore oil and gas operations off the coast of Israel
- Sentinel Success Stories:
  Copernicus Sentinel-1 data enable oil spill detection in South-eastern Mediterranean Sea
- Y.-J. Yang, S. Singha, and R. Mayerle “A Deep Learning Based Oil Spill Detector Using Sentinel-1 SAR Imagery,” *International Journal of Remote Sensing* 43.11(2022): 4287–4314. doi: 10.1080/01431161.2022.2109445
- Y.-J. Yang, S. Singha, and R. Goldman, “A Near Real-Time Automated Oil Spill Detection and Early Warning System using Sentinel-1 SAR imagery in the Southeastern Mediterranean Sea,” *International Journal of Remote Sensing* (2024). doi: 10.1080/01431161.2024.2321468

Thank you!

Yi-Jie Yang
Yi-Jie.Yang@dlr.de

Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
German Aerospace Center
Remote Sensing Technology Institute | SAR Signal Processing
Maritime Safety and Security Lab Bremen | Germany