# SUPPORT OF MARITIME AWARENESS FROM SPACE

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**Maritime Safety and Security Lab Neustrelitz**

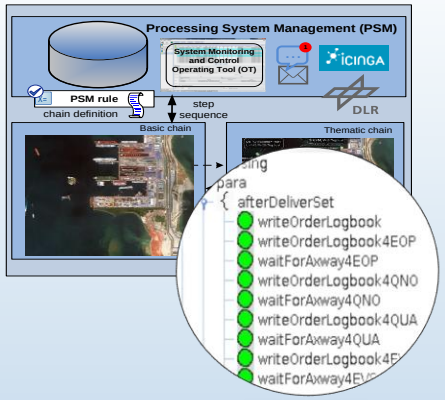
**National Ground Segment, Earth Observation Center**

DLR

# Competencies and fields of research (Neustrelitz)

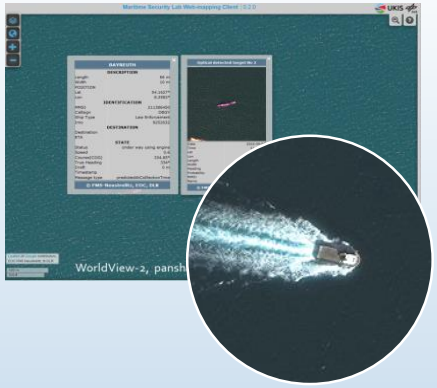
**DFD Department National Ground Segment**

## Software Systems




- Near Real Time NRT Framework solutions
- Replacement of PSM by WMP
- Cloud solution
- Frontend (VisualAnalyst)
- Order handling and product dissemination (MARISS-EO)
- AIS-DB

## Object detection

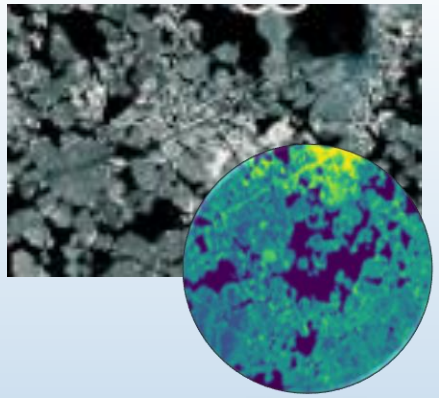



- Object Detection based on Artificial Intelligence (AI) based on high and very high resolution optical satellite imagery (Plèiades, Wordview1-3, GeoEYE, Landsat, Sentinel-2
- Data fusion, e.g. Automatic Identification System AIS data

## Oil spill detection

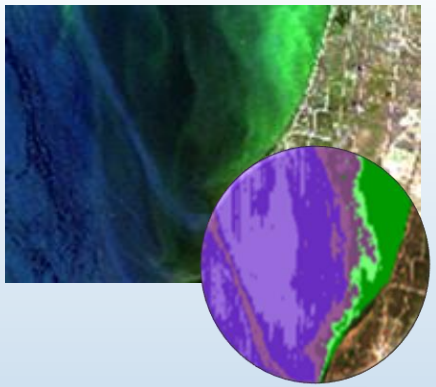
- Oil Spill Detection based on Threshold and Artificial Intelligence (AI) Method
- currently being developed for Landsat-8,9 → Sentinel-2

## Ice classification



- Sea Ice Classification based on Artificial Intelligence (AI)
- currently being developed for Landsat-8,9 → Sentinel-2

## Hazardous Substance Classification

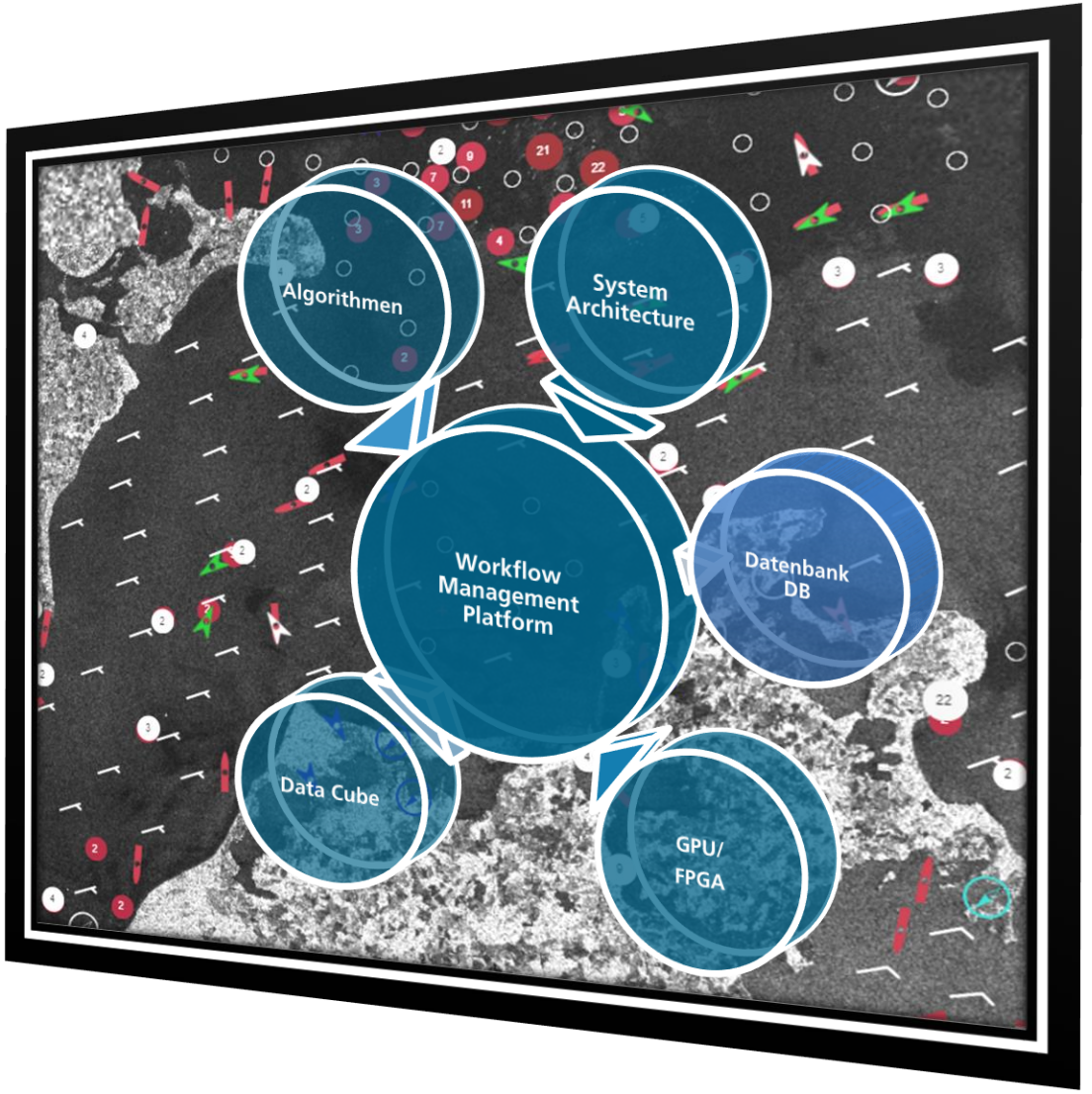


- Classification of Hazardous Substances based on hyperspectral data
- currently being developed for DESIS and EnMAP

# Maritime Safety and Security Lab at DLRs EOC Neustrelitz & Bremen

## Motivation and Objective

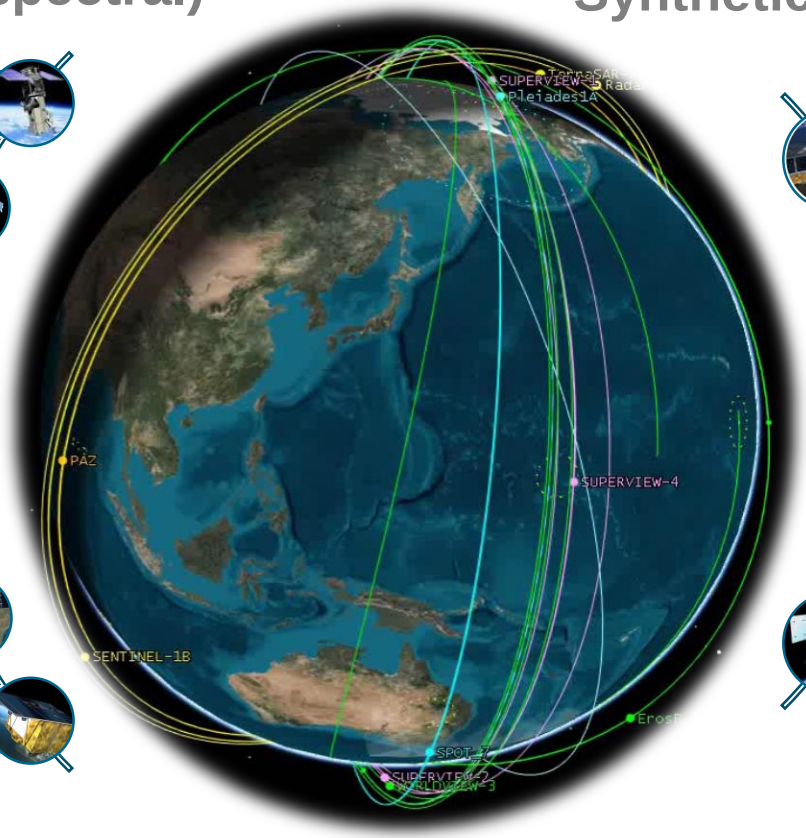
- Optical and SAR-based remote sensing data provide an ideal basis to derive various maritime information with safety relevance, especially for large-scale questions
- Linking thematic research and application development
- Application development directly enable operational validation of the findings
- Development focus on near-real-time (NRT) application



# Multi- Sensor Approach

## Optical (multi- and hyperspectral)

- Worldview-1-3
- GeoEye-1
- Deimos-2
- Plèiades
- Plèiades Neo
- Landsat, Sentinel-2
- DESIS, EnMAP




## Synthetic Aperture Radar (SAR)

- Sentinel-1
- ICEYE
- TerraSAR-X
- TanDEM-X
- Radarsat-2

## Automatic Identification System

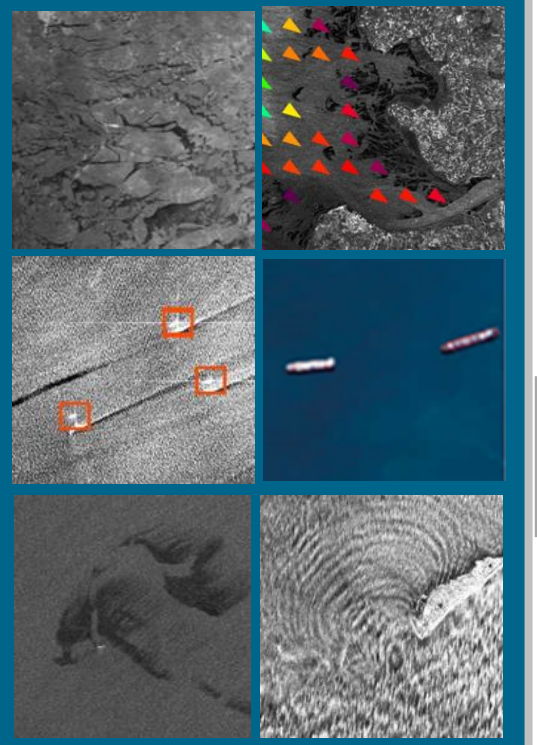
- Terrestrial AIS
- Satellite AIS

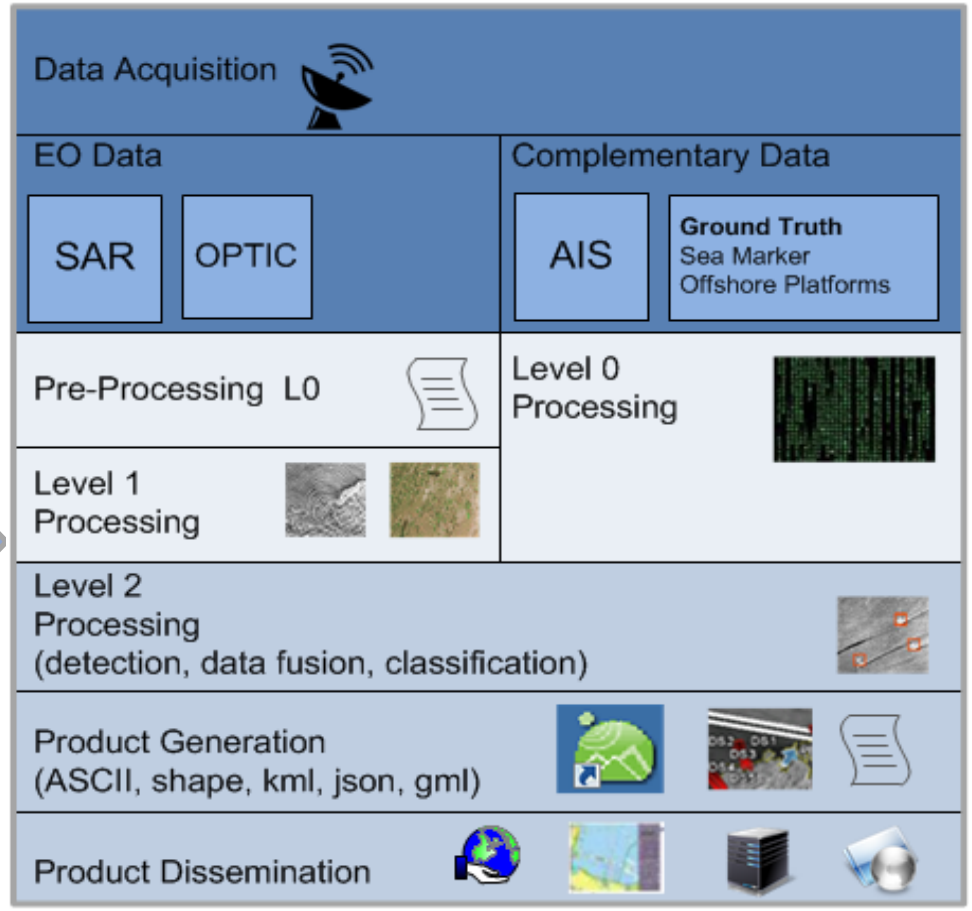
# Maritime Safety and Security Lab at DLRs EOC Neustrelitz & Bremen

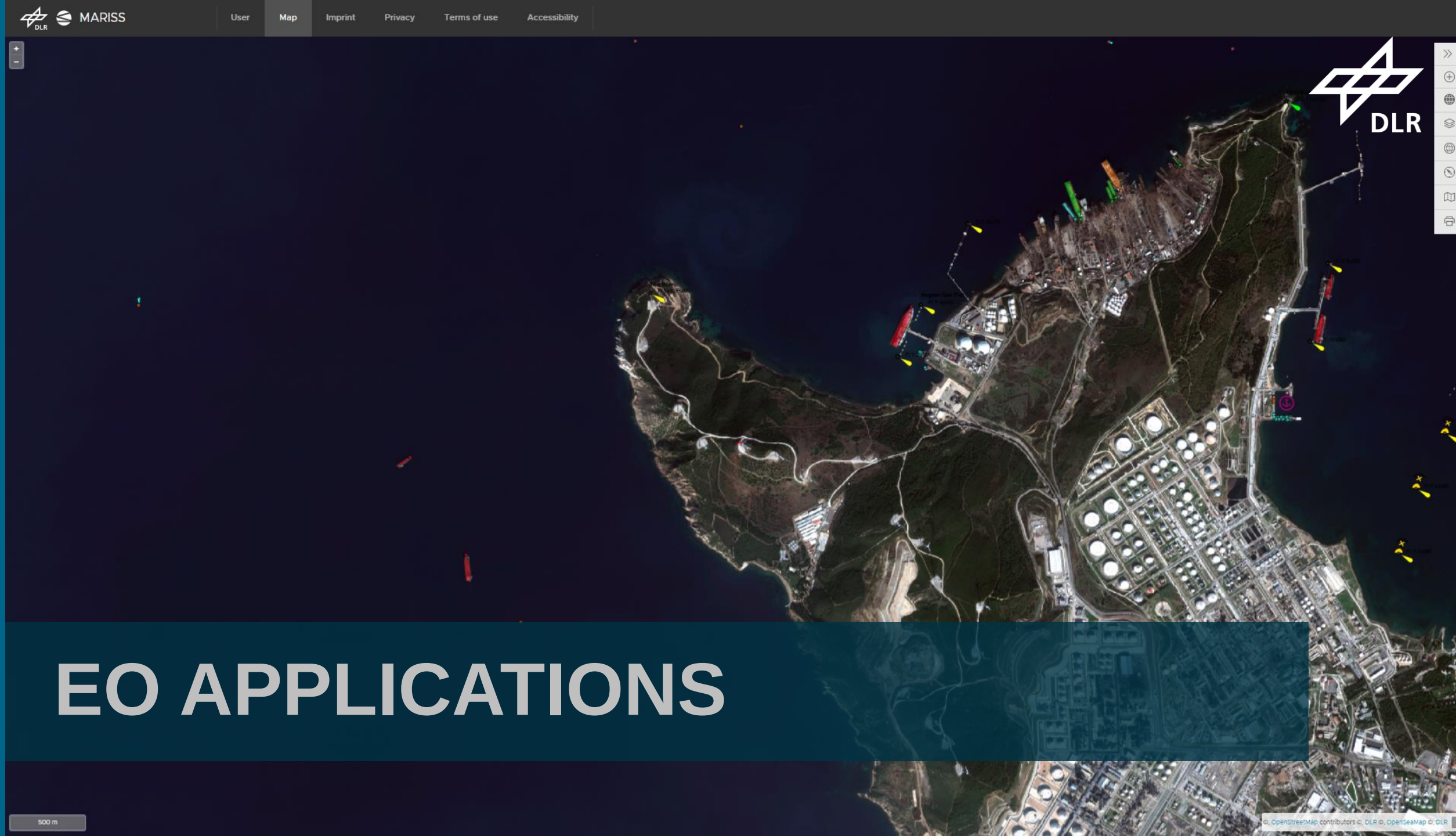
## Motivation and Objective

Application

- Oil Spill Detection
- Hazardous material detection
- Object Detection
- Wind- and Sea-state-information
- Sea Ice Classification
- Sea Ice Drift





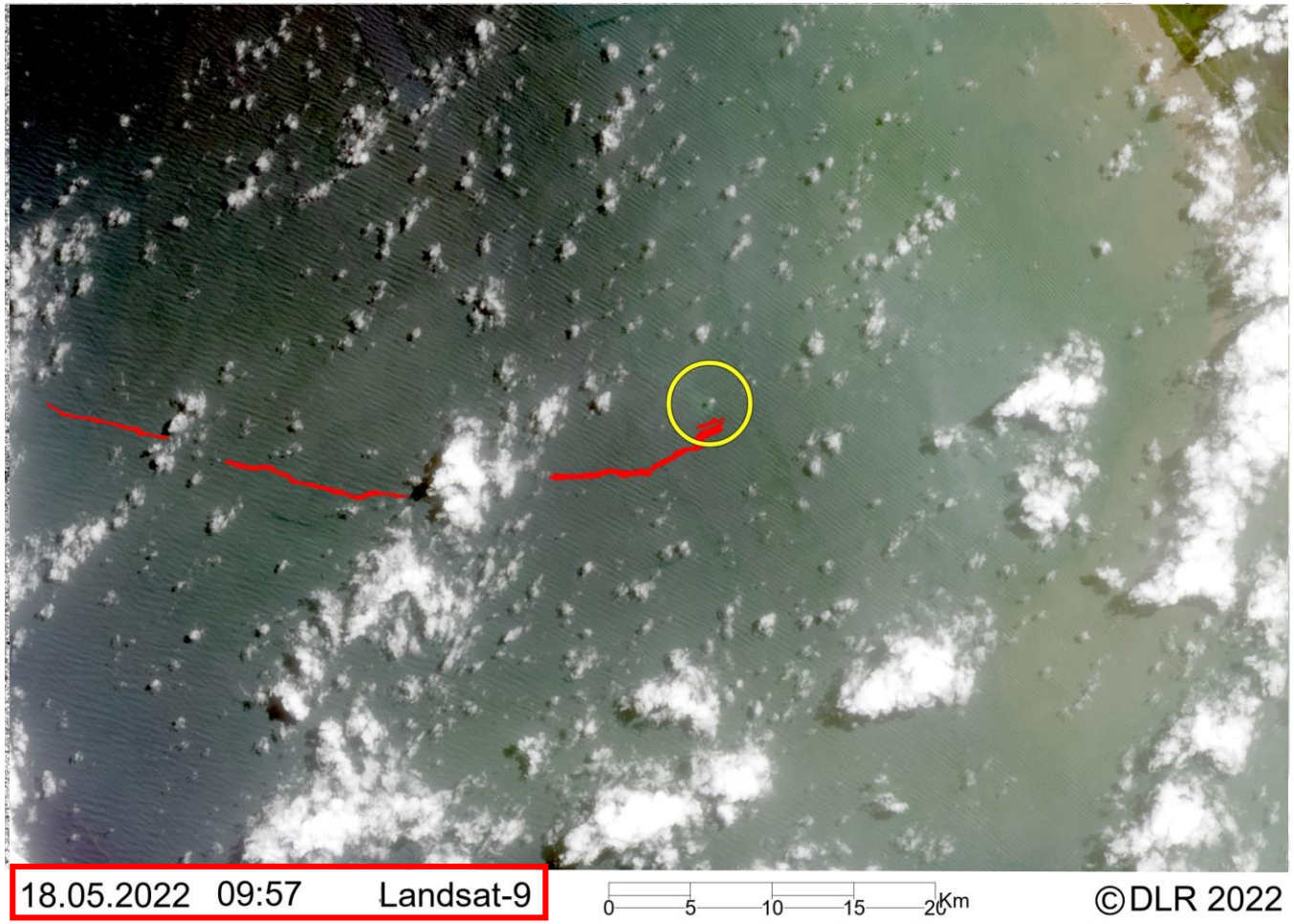



# EO APPLICATIONS

# Oil Spill Detection, Development Bremen | Neustrelitz

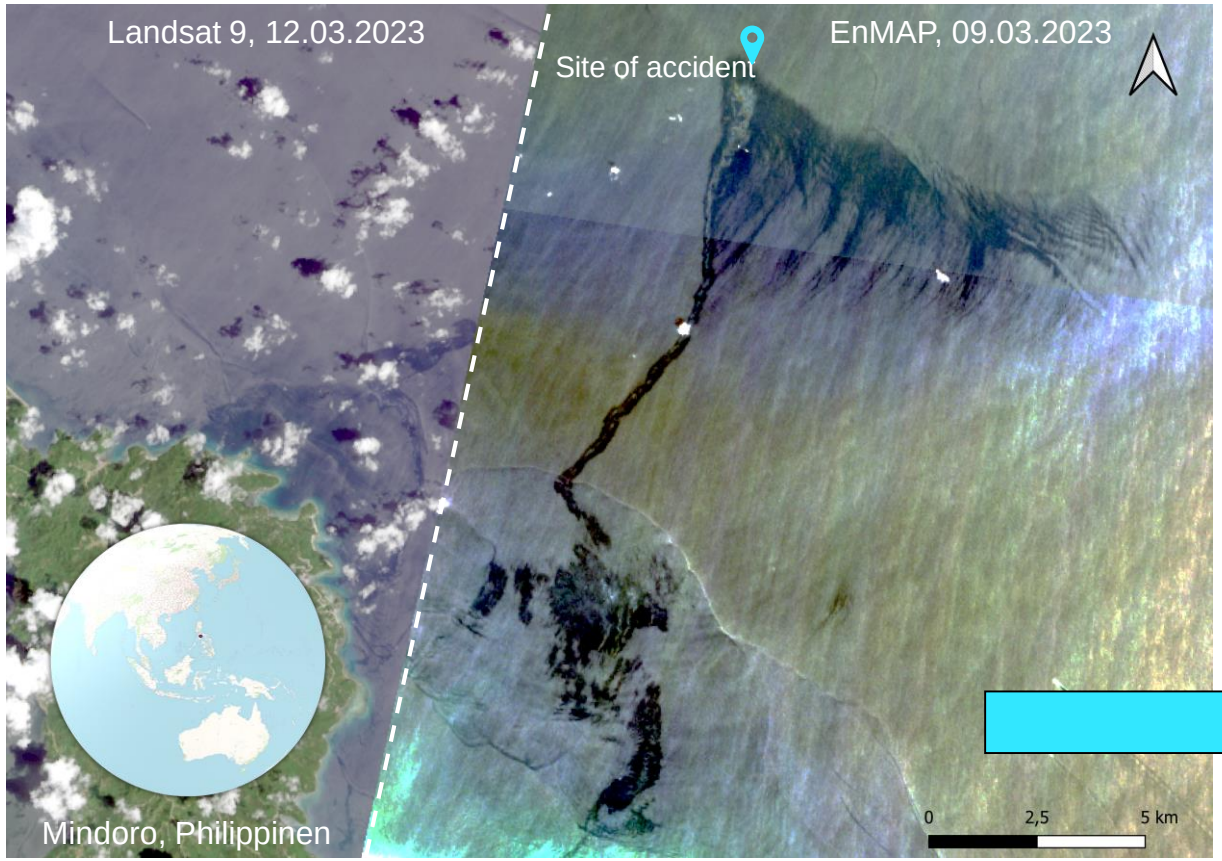
**Environmental disaster caused by the sinking of the oil production ship Trinity Spirit**

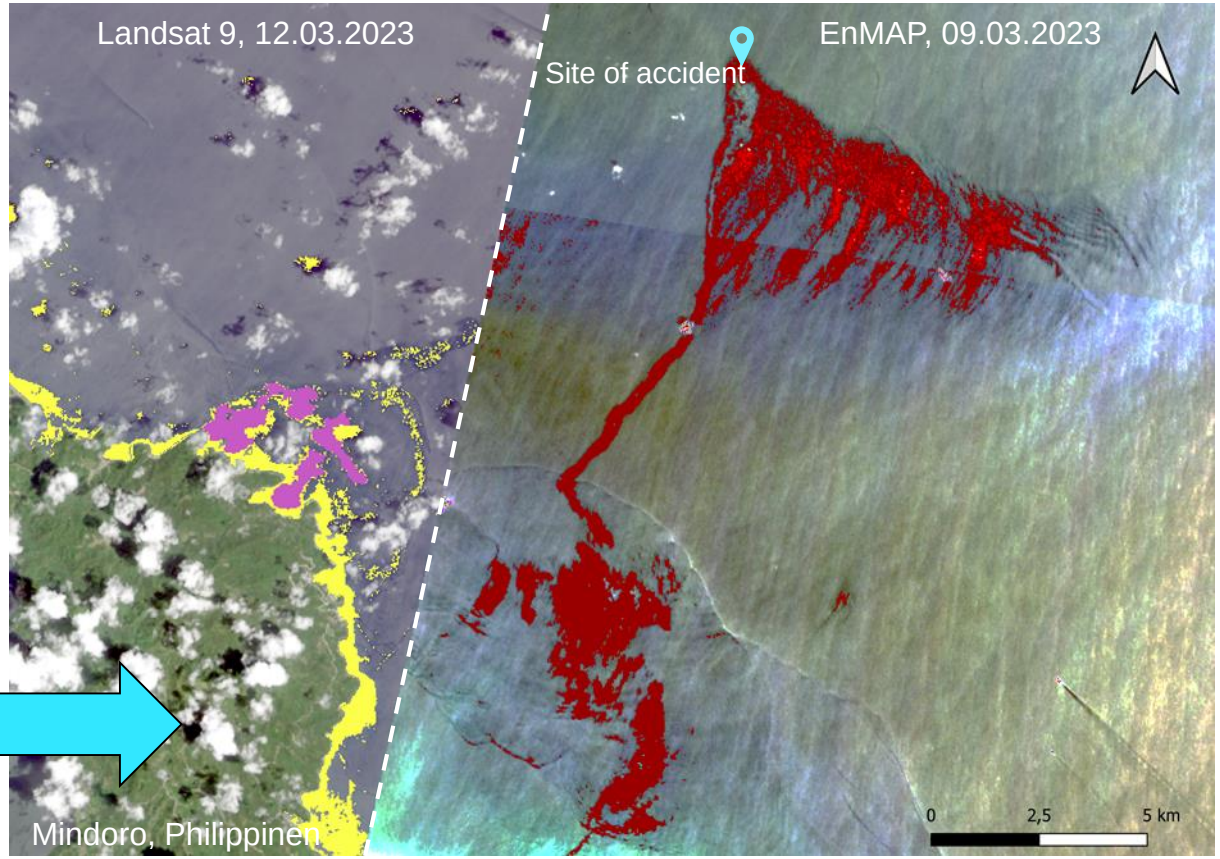
- Oil Spill detection based on **Sentinel-1** data, SAR, Bremen, AI – Model, Yi-Jie Yang
- Oil Spill detection based on **Landsat-8,9** data Neustrelitz, Empirical Model Carolin Wloczyk




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

# Oil Spill Detection based on Multi-Sensor Approach




Sinking of the tanker MT Princess Empress, loaded with 800,000 liters of industrial oil, on February 28th 2023 off the Philippine Island Mindoro.

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

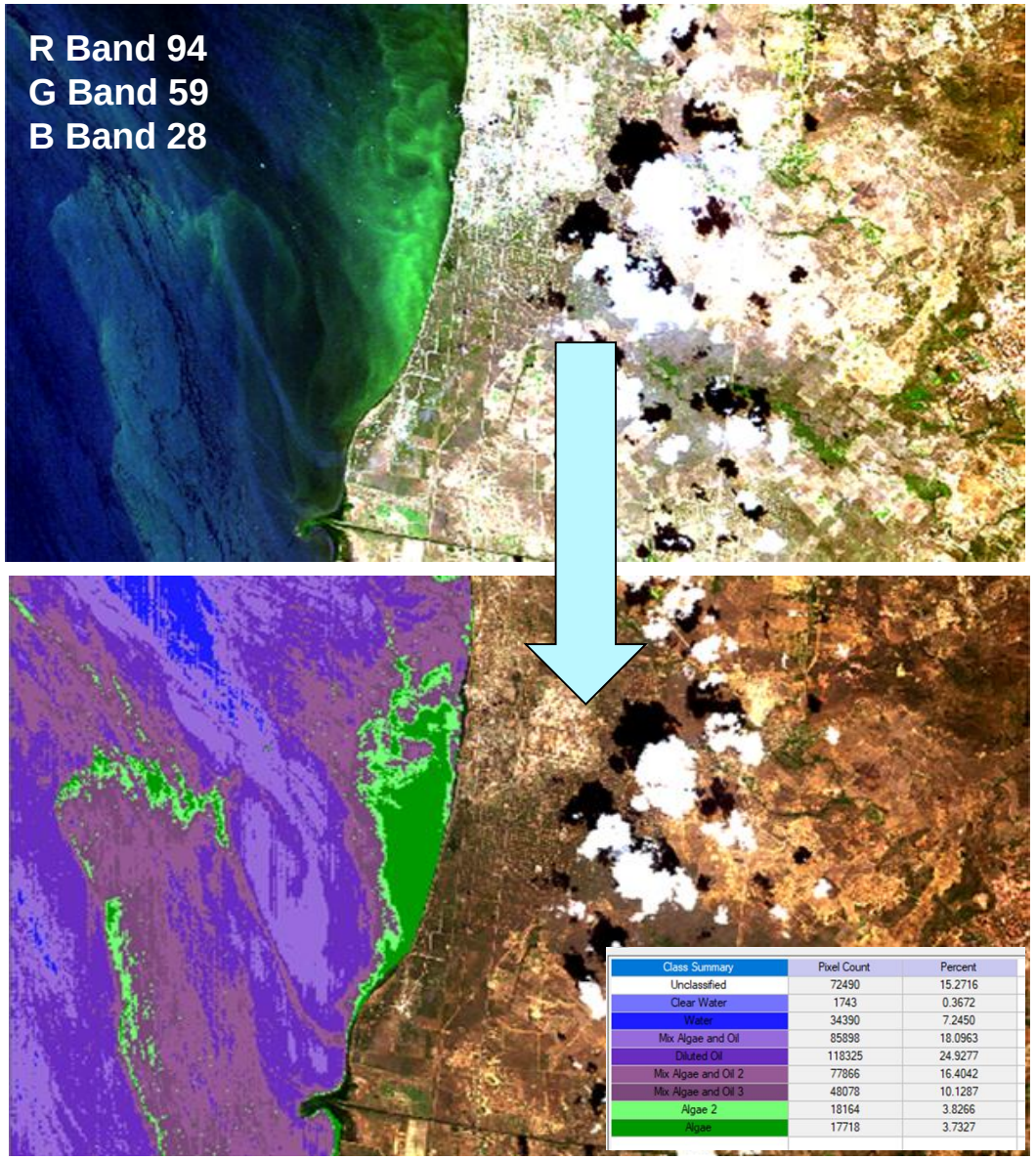
- Threshold method (Landsat, 11 bands)
- Deep Neural Network (Landsat, 11 bands)
- Unsupervised classification, k-means (EnMAP, 230 bands)

# Hazard Material Classification based on Hyperspectral Data, DESIS

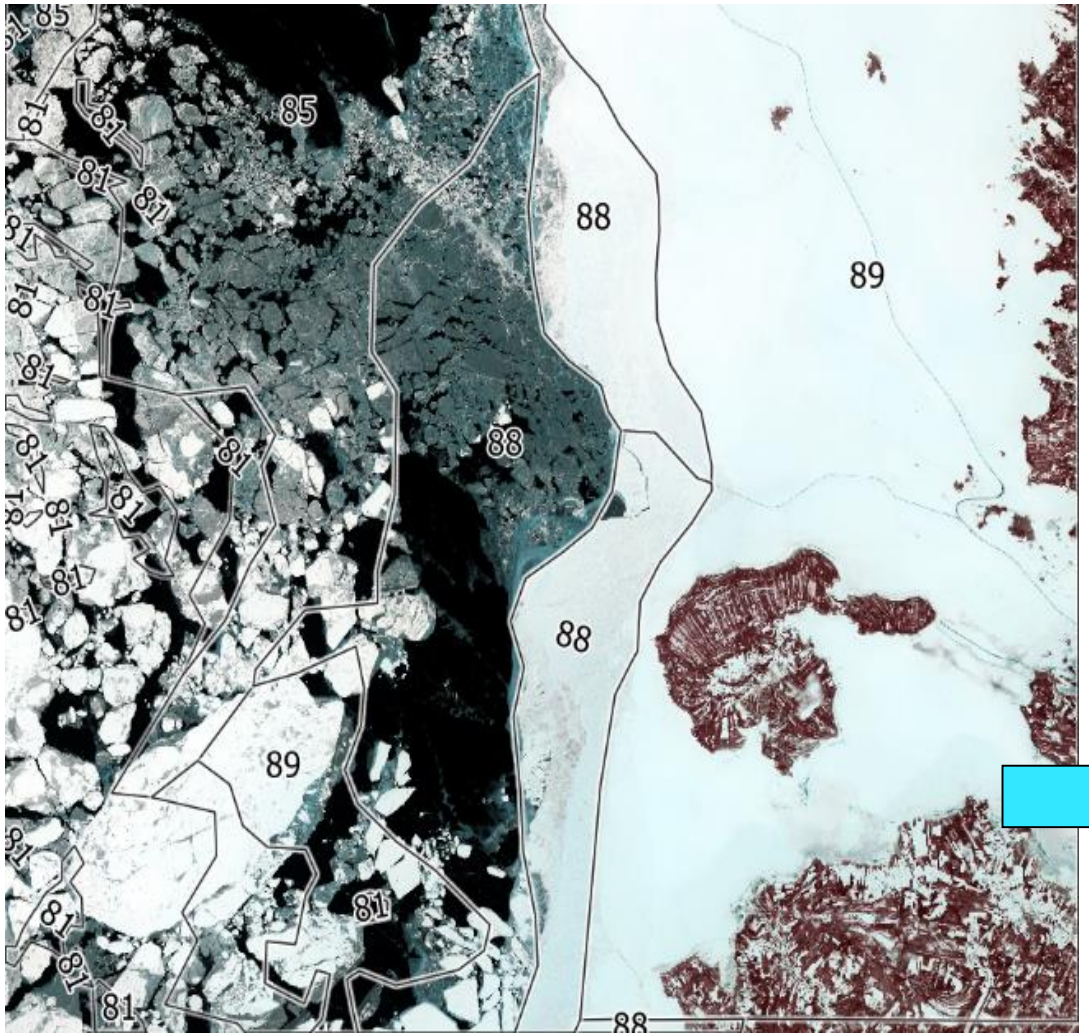
## Pixel-based classification

- K-Means Classification, preliminary result, Neustrelitz, Carsten Mönnig
- DESIS input bands 11-225
- Classification resolution 30 m
- Current classes
  - Clear Water
  - Mix of Algae and Oil Type 1
  - Mix of Algae and Oil Type 2
  - Mix of Algae and Oil Type 3
  - Algae Concentration Type 1
  - Algae Concentration Type 2

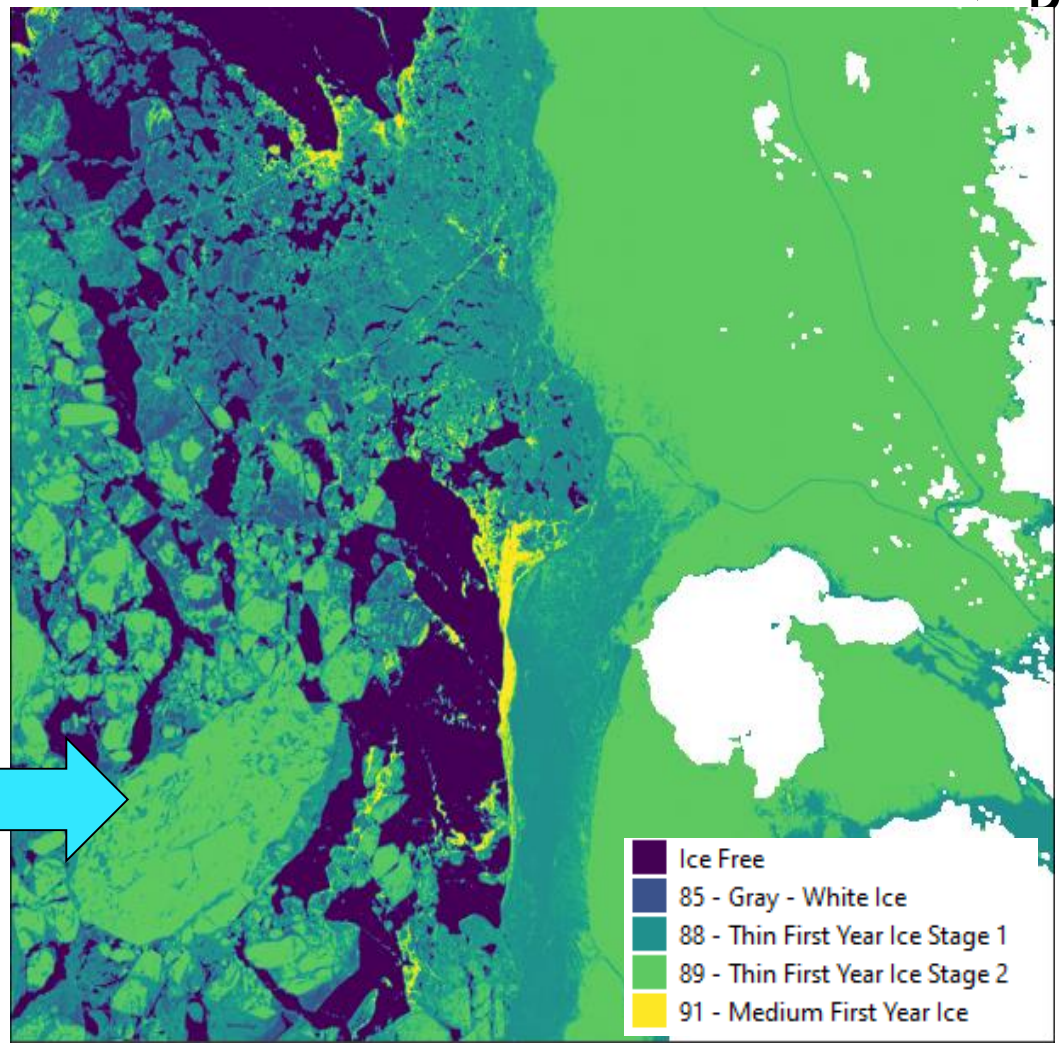
DESIS Image, Lake Maracaibo, Venezuela, 03.03.2021



# Ice Classification, Landsat-8




Landsat-8 RGB, 22.03.2019

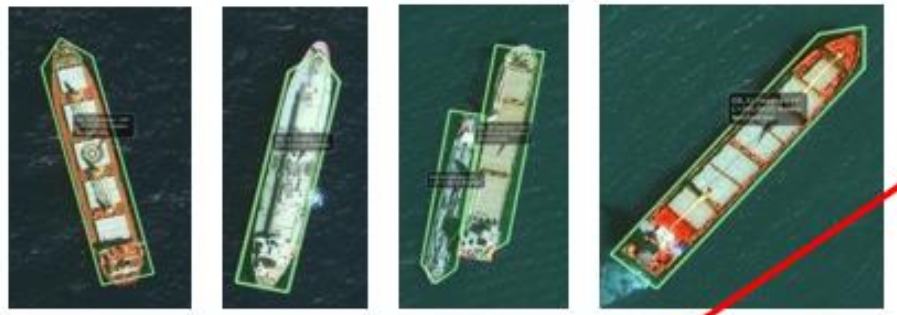


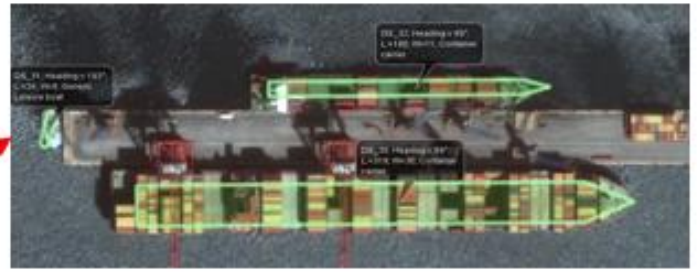

Ice Classification

# Object - Detection Application (AI)

**Very High resolution optical images**

- Deep Neural Network (DNN), Neustrelitz, Sergey Voinov
- vessel type recognition currently extended from 9 to 14 classes
  - Center coordinates
    - Pixel/Line
    - Geographical
  - Min/Max bounding boxes
  - Rotated bounding boxes
  - PNG masks
  - True heading
  - Object state (moving or stopped)





- Tested on 20 WorldView and GeoEye images
- 82.5% detection score in open waters

- 48.7% detection score in port areas
- 65% classification score

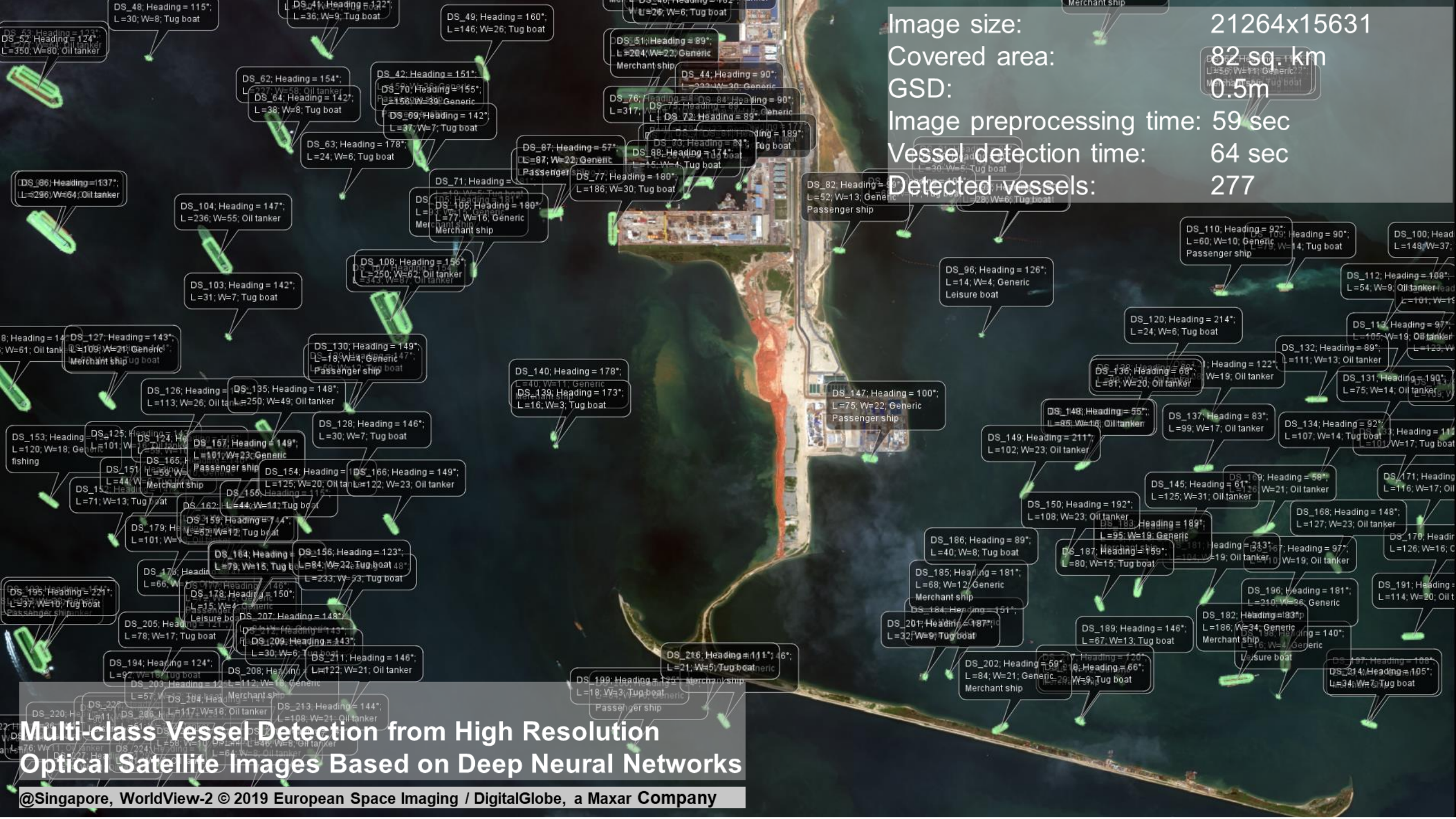
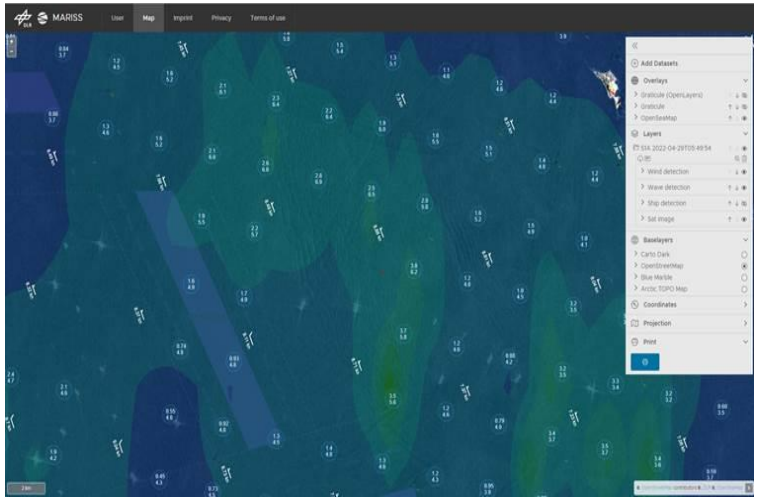


Image size: 21264x15631
Covered area: 82 sq. km
GSD: 0.5m
Image preprocessing time: 59 sec
Vessel detection time: 64 sec
Detected vessels: 277
Multi-class Vessel Detection from High Resolution Optical Satellite Images Based on Deep Neural Networks
@Singapore, WorldView-2 © 2019 European Space Imaging / DigitalGlobe, a Maxar Company

# Maritime Surveillance Applications (NRT)

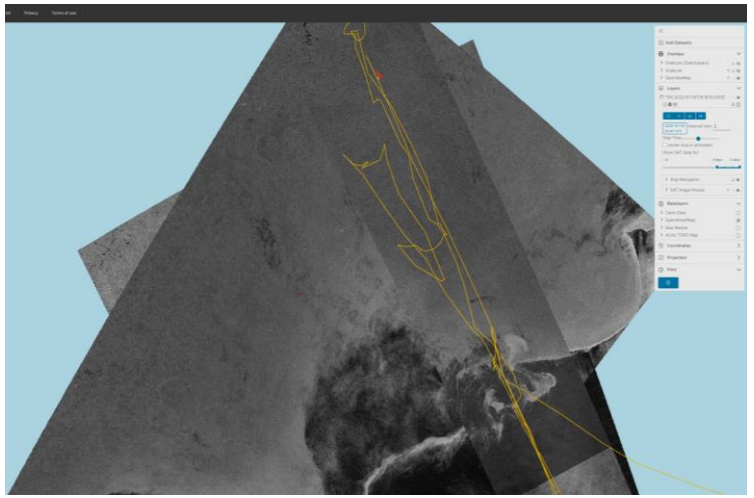
## Marinekommando (Navy) Rostock MGeo



- Provision of wind and sea state products* derived from Sentinel-1 data for the North Sea and Baltic Sea.

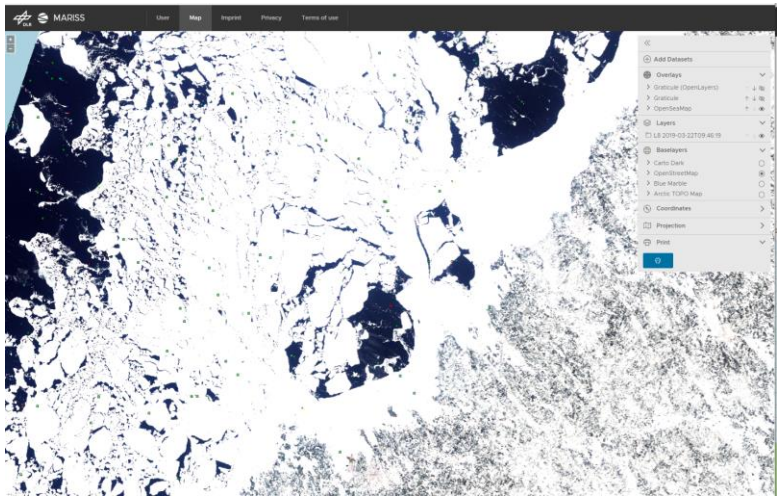
  *Processors provided by FMS Bremen

## Support Navigation in Ice Covered Areas (AWI)



- NRT support of research vessel POLARSTERN during the campaign in the Arctic and Antarctic based on TerraSAR-X/ TanDEM-X

## Bundesamt für Seeschifffahrt und Hydrographie BSH



- Provision of L1b products (Baltic Sea) from the Sentinel-1, Landsat-8/9, Aqua and Terra missions in NRT for the ice service.

# Maritime Surveillance Service Application

## European Maritime Safety Agency EMSA

- NRT application for the provision of very high-resolution optical satellite images, as well as value added products for maritime situational awareness.

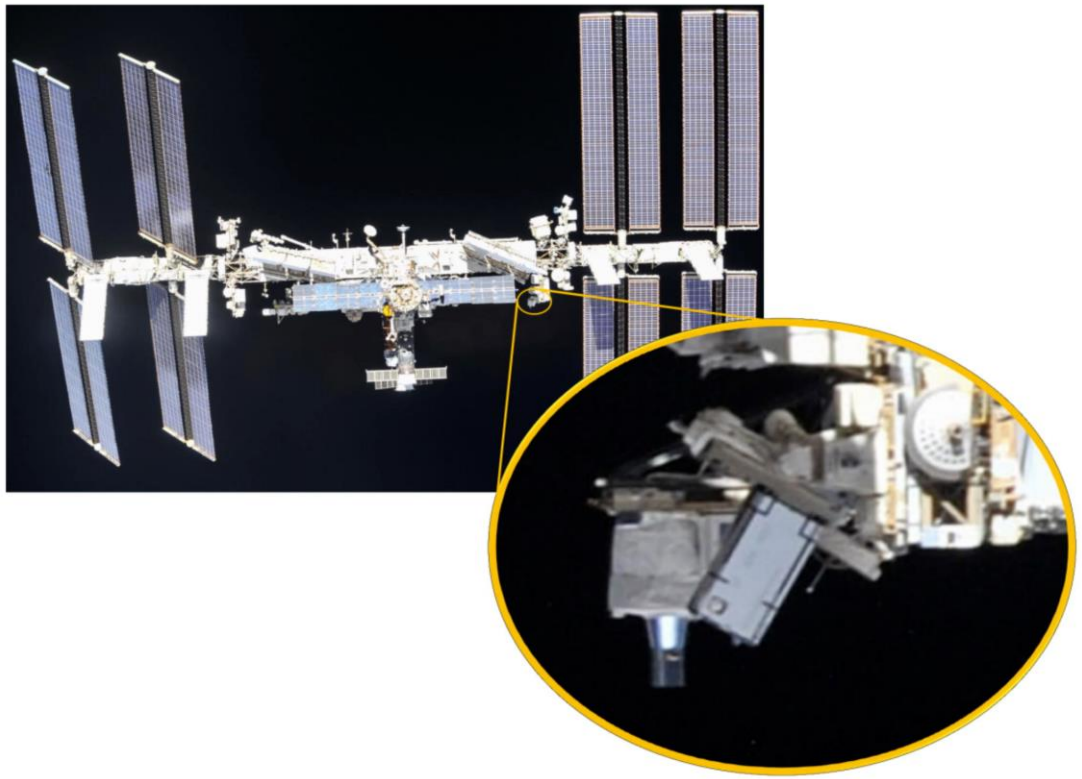
## Maritime Surveillance Service AIRBUS DS UK Ltd.

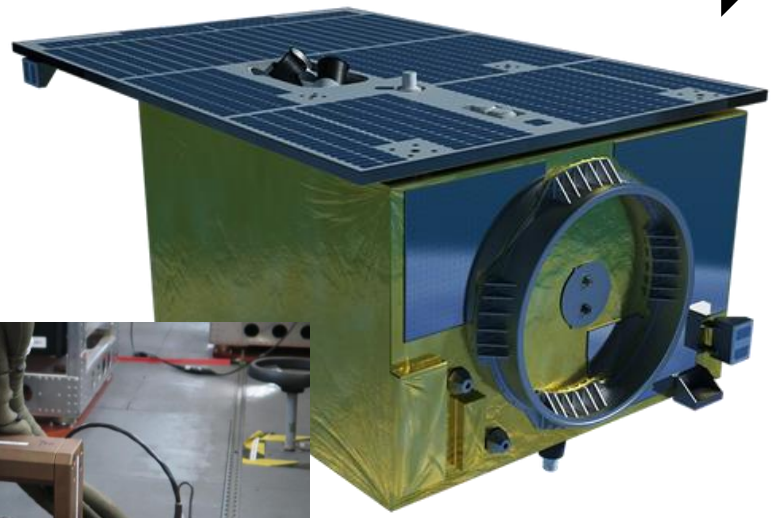
- NRT application for the provision of Sentinel-1 images on demand

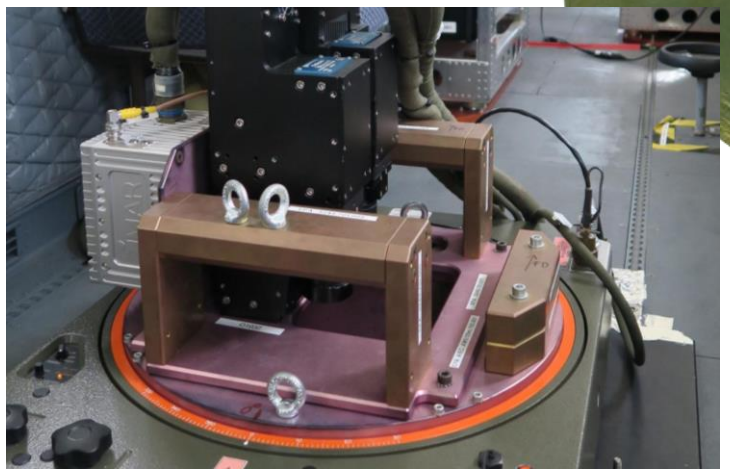
# Use of hyperspectral data for detection of harmful substances at sea

- **Detection and differentiation of harmful/non harmful algae (Dinoflagellates and Cyanobacteria)**
- **Detection and differentiation of oily substances**
- **Improving unsupervised classification with machine/deep learning an AI**
- **Data fusion of information, derived from multispectral, hyperspectral and SAR analysis**
- **Development of an semi-automated early warning system of both harmful substances**

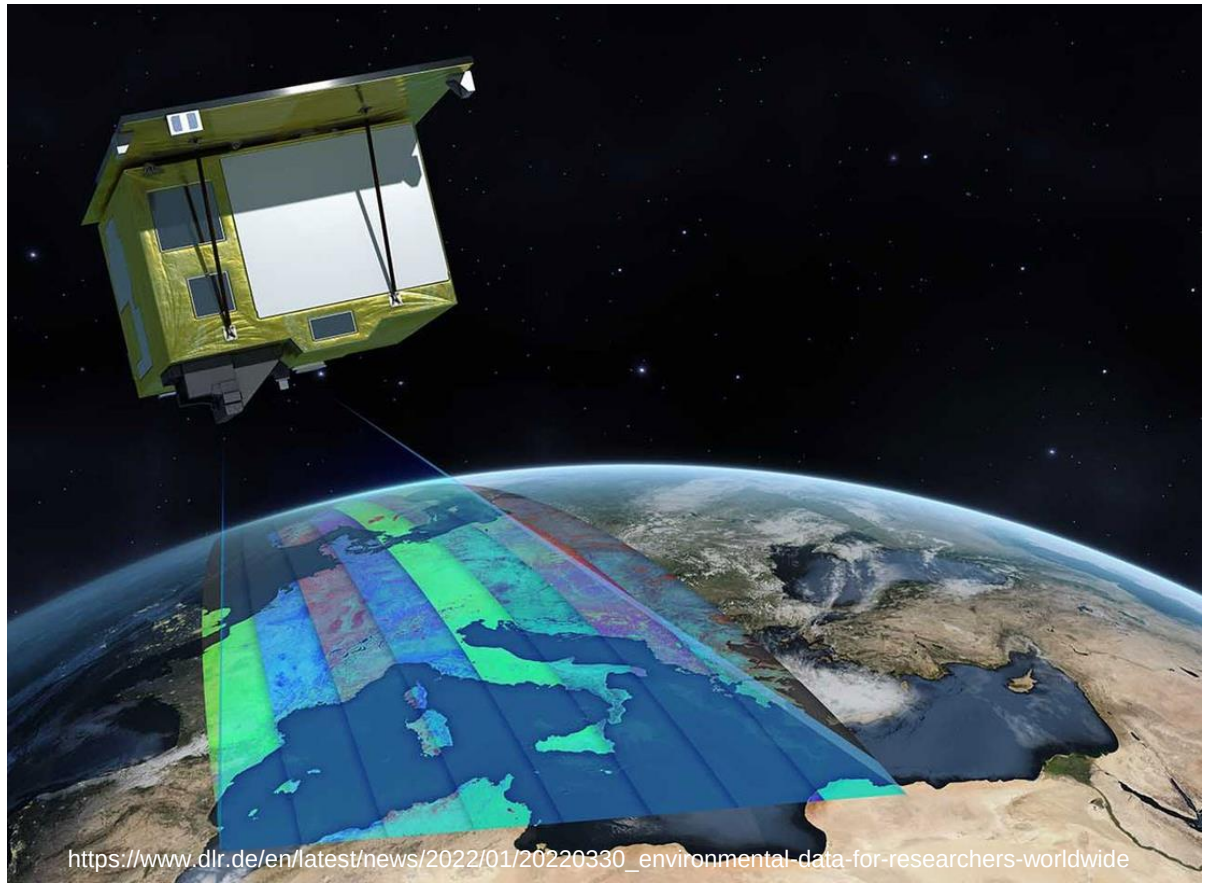

Baltic Sea, Landsat-8 2019





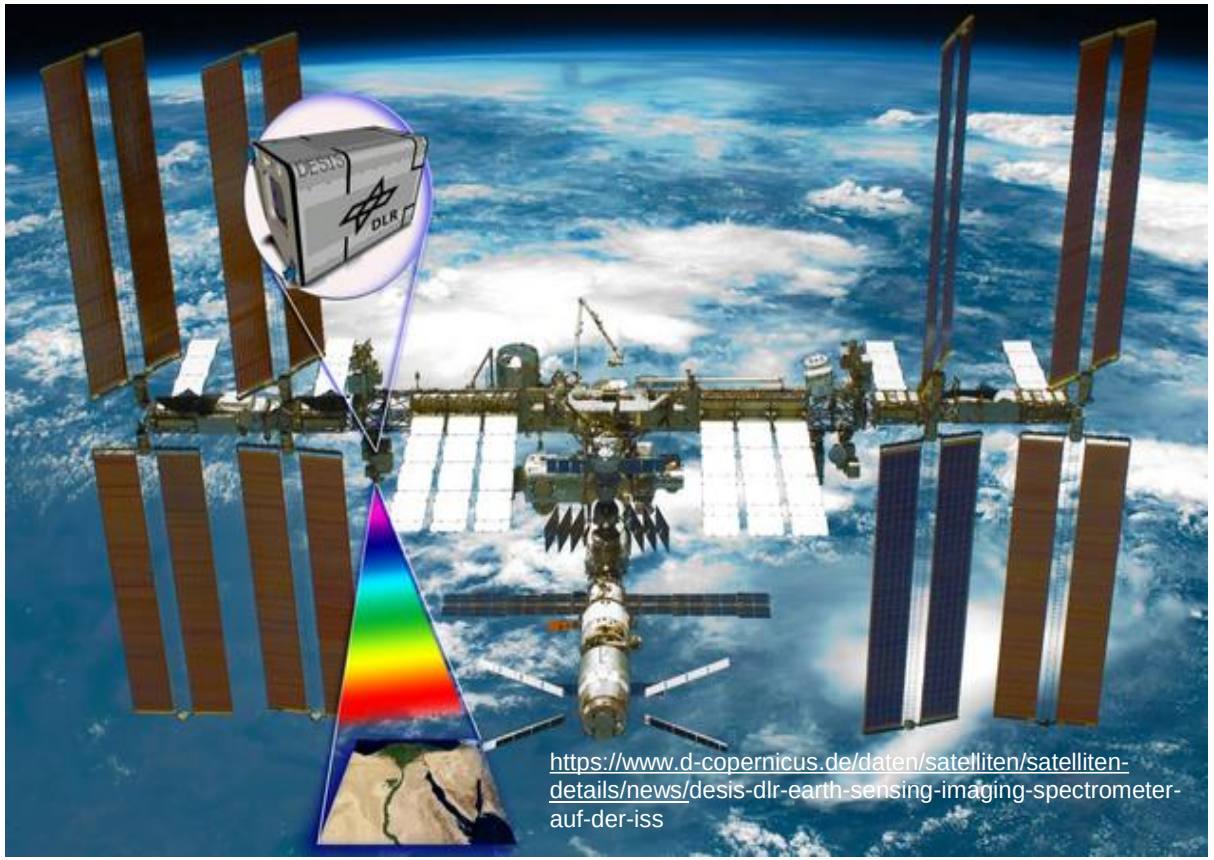


# HYPERSPECTRAL SENSORS USED




| | |
|---|---|
| Launch date: | 2022 |
| Operational lifetime: | > 5 years |
| Orbit altitude: | 653 km |
| Repeat cycle | 27 days and 398 orbits (polar, sun-synchronous) |
| Local time descending node: | 11:00 h ± 18 min. |
| Revisit: | 4 days (±30° off-nadir tilt)<br>27 days (±5° off-nadir tilt) |
| Spectral range: | 420 nm - 2450 nm |
| Spectral sampling distance: | 6.5 nm (420 nm - 1000 nm; VNIR)<br>10 nm (900 nm - 2450 nm; SWIR) |
| Radiometric resolution: | 14 bits |
| Geometric resolution: | 30 m × 30 m (swath: 30 km)<br>(5000 km per day with 512 Gbit<br>on-board mass memory) |

# ENMAP: ENVIRONMENTAL MAPPING AND ANALYSIS PROGRAM




https://www.d-copernicus.de/daten/satelliten/satelliten-details/news/desis-dlr-earth-sensing-imaging-spectrometer-auf-der-iss

| | |
|---|---|
| Imaging sensor | BAE CMOS CIS2001 |
| Line pixels | 1024 |
| Focal length | 320 mm |
| Target GSD | 30 m |
| Swath | 300 m |
| Spectral range | 400 – 1000 nm VIS/NIR |
| Spectral resolution | 2.5 nm |
| Number of channels | 235 |
| BRDF angle | +/- 40° |
| SNR | >150 (Sept 15, 11 am, 30° sun) |
| Polarization sensitivity | < 2% |
| Dimensions | 430 x 190 x 135 mm (spectrometer) |

# DESIS: DLR EARTH SENSING IMAGING SPECTROMETER

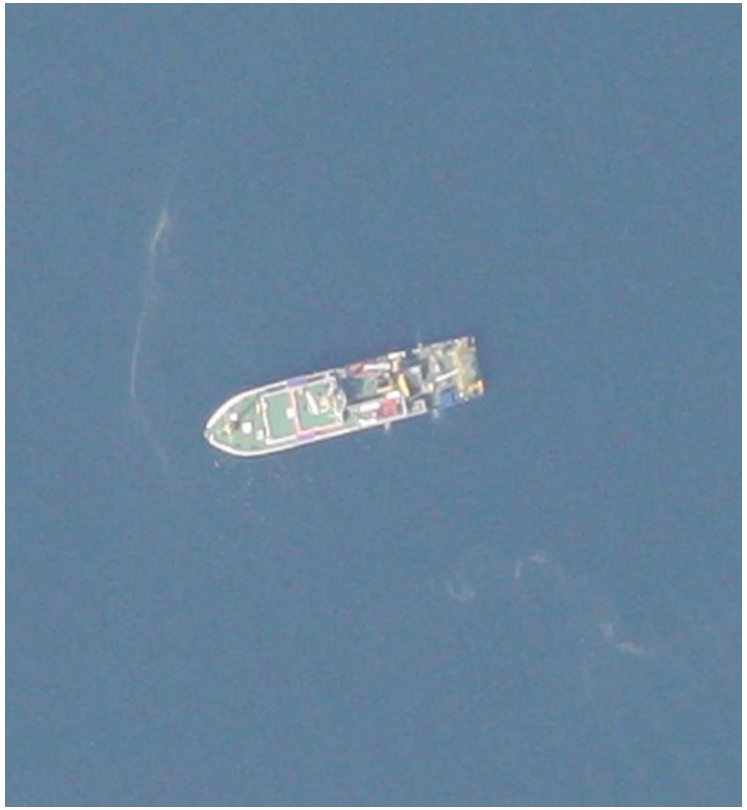
https://www.dlr.de/en/research-and-transfer/research-infrastructure/dornier-228-212-en

https://www.dlr.de/de/forschung-und-transfer/forschungsinfrastruktur/grossforschungsanlagen/hyspex

| Parameter | VNIR 1600 | SWIR 320m-e |
|---|---|---|
| Detector | Si CCD-Array | MCT Array |
| Spectral range [nm] | 416-992 | 968-2498 |
| Spectral channels [Anzahl] | 160 | 256 |
| Sampling interval [nm] | 3.6 | 6.0 |
| Spectral resolution [nm] | 3.5 - 6.0 | 5.6 - 7.0 |
| Spatial resolution pixels [number] | 1600 | 320 |
| Max. spatial resolution [cm] | 30 | 70 |
| Dynamic range [bit] | 12 | 14 |

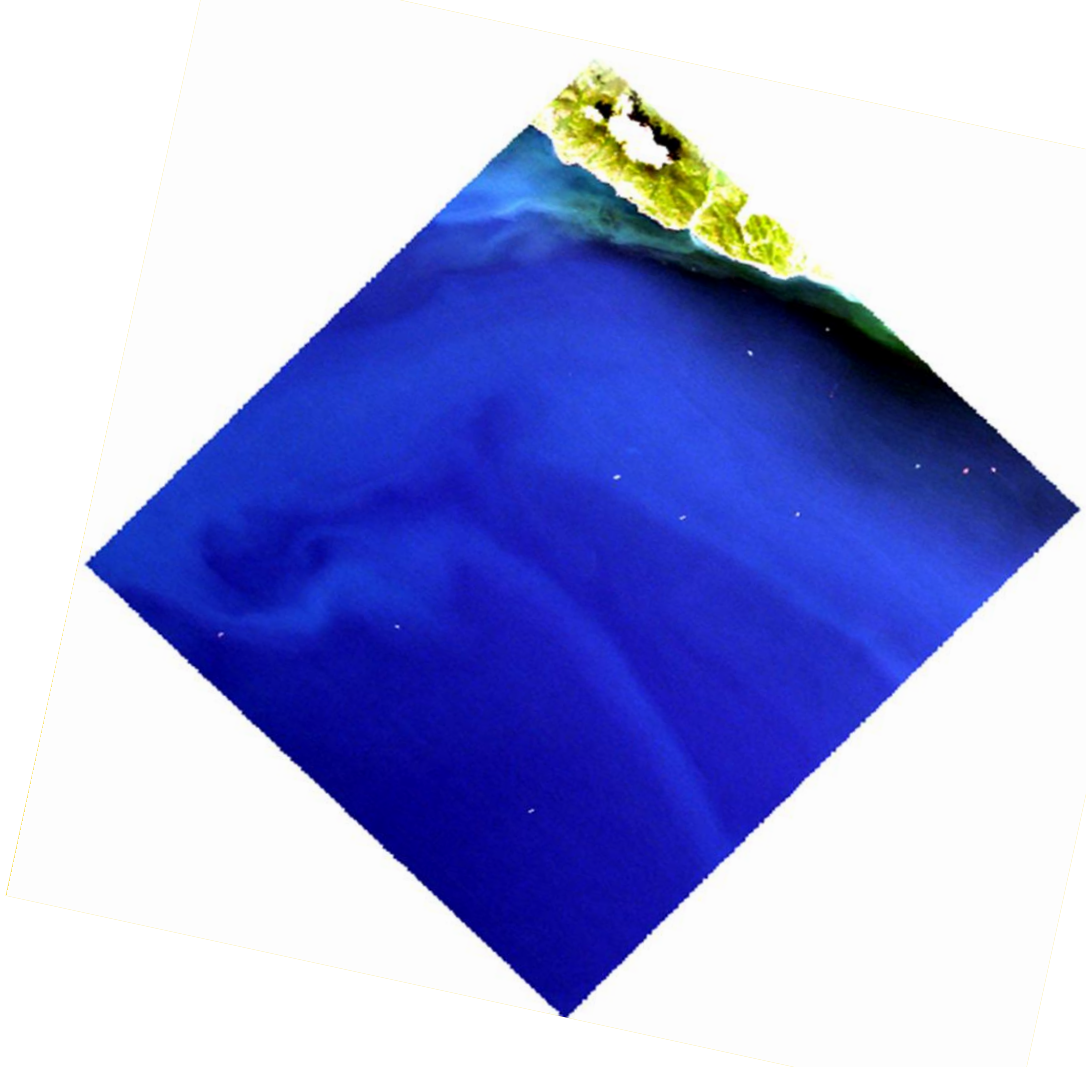
# AIRBORNE HYSPEX (NEO) SENSOR

# DLR HySpex aerial surveys in the coastal area of the Rostock region 03./04.08.2022



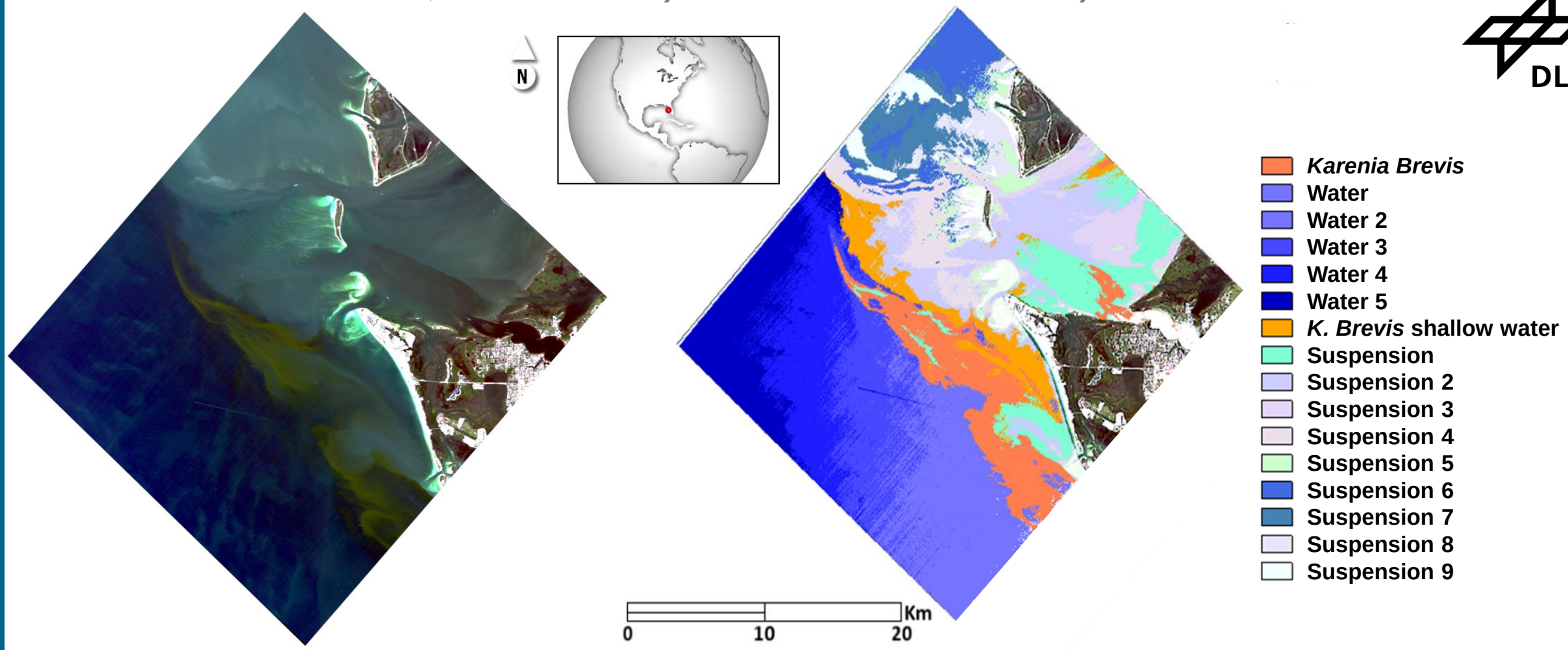

**RGB IMAGE OF THE RESEARCH VESSEL „ELISABETH MANN BORGESE“ OF THE LEIBNIZ INSTITUTE FOR BALTIC SEA RESEARCH WARNEMÜNDE DURING ALGAE SAMPLING ON 04.08.2022**


# EXAMPLE OF HYSPEX IMAGE OF THE RESEARCH VESSEL „ELISABETH MANN BORGESE“ OF THE LEIBNIZ INSTITUTE FOR BALTIC SEA RESEARCH WARNEMÜNDE DURING ALGAE SAMPLING ON 04.08.2022



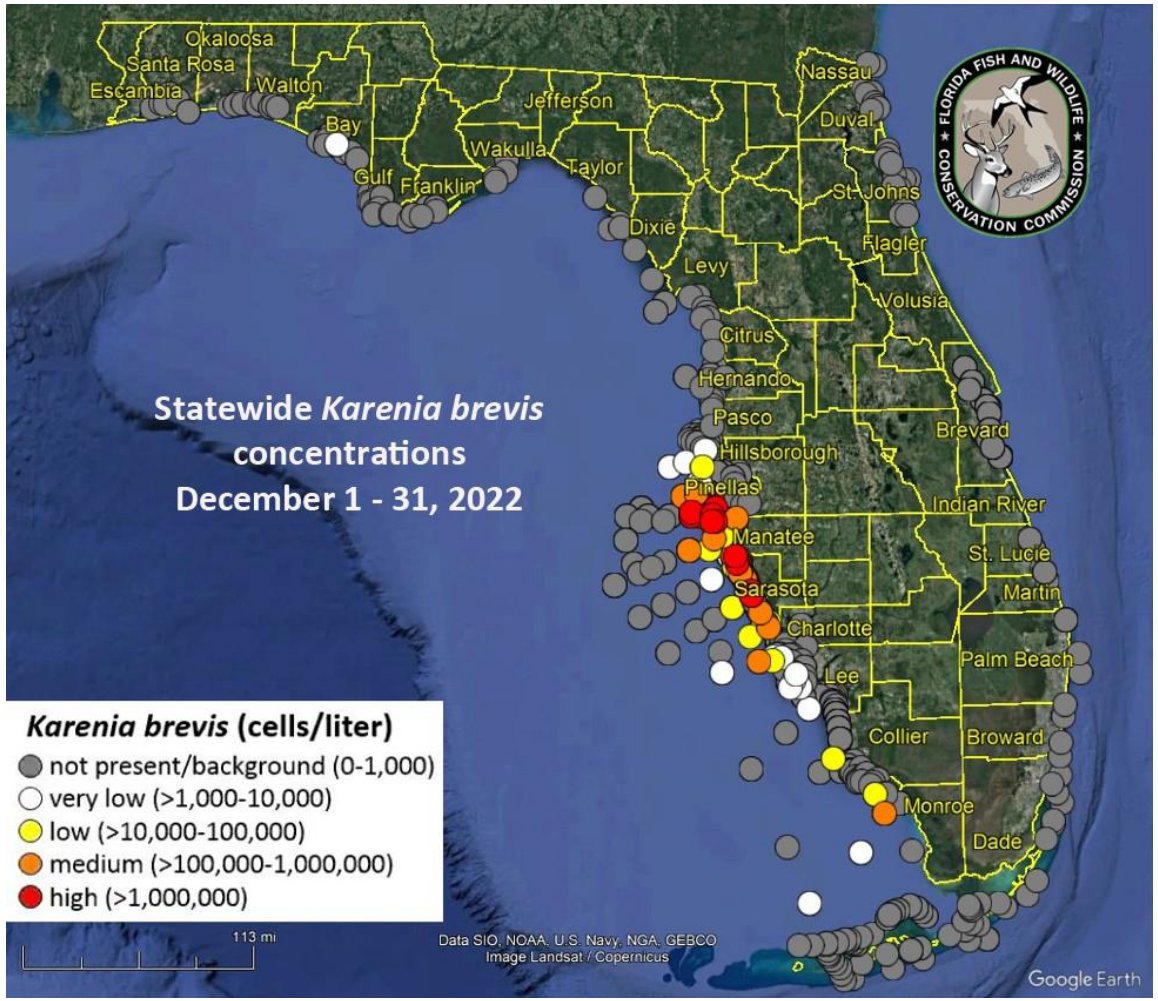
# EXAMPLES OF HYPERSPECTRAL DETECTION OF HARMFUL SUBSTANCES AT SEA

# *Karenia Brevis* detection, Southern Florida, US

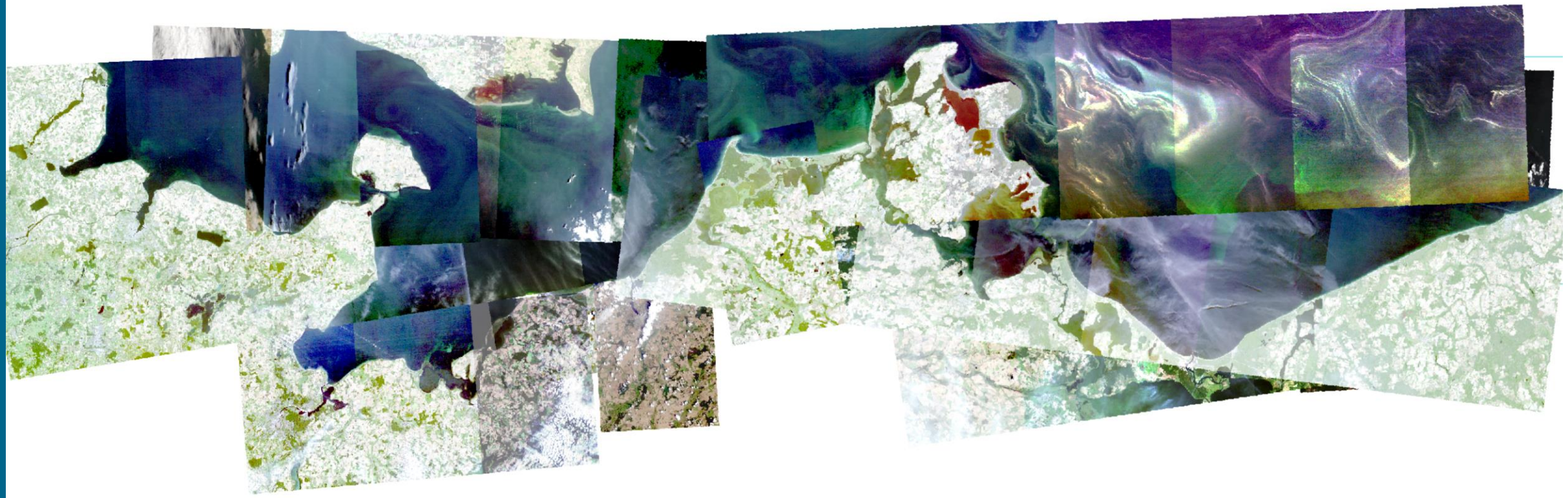



**ON THE LEFT A DESIS IMAGE OF 03.12.2022 BANDS R 94, G 59, B 28. ON THE RIGHT AN UNSUPERVISED K-MEANS CLASSIFICATION WITH MASKED LAND AREA IN RGB.**

# *Karenia Brevis* distribution, Southern Florida, US




**FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION: DETECTION OF *KARENIA BREVIS* WITH NOAA SATELLITE W/1,1KM RESOLUTION** HTTPS://MYFWC.COM/RESEARCH/REDTIDE/CONTACT/



# DESIS MOSAIC SOUTHERN BALTIC SEA ALGAE/ CYANOBACTERIA DISTRIBUTION 08.08-22.08.2022



Carsten Mönnig, Egbert Schwarz, DFD-NBS, 15.11.2023


# Thank you very much for your kind attention!

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