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Research excellence supporting a sustainable ocean

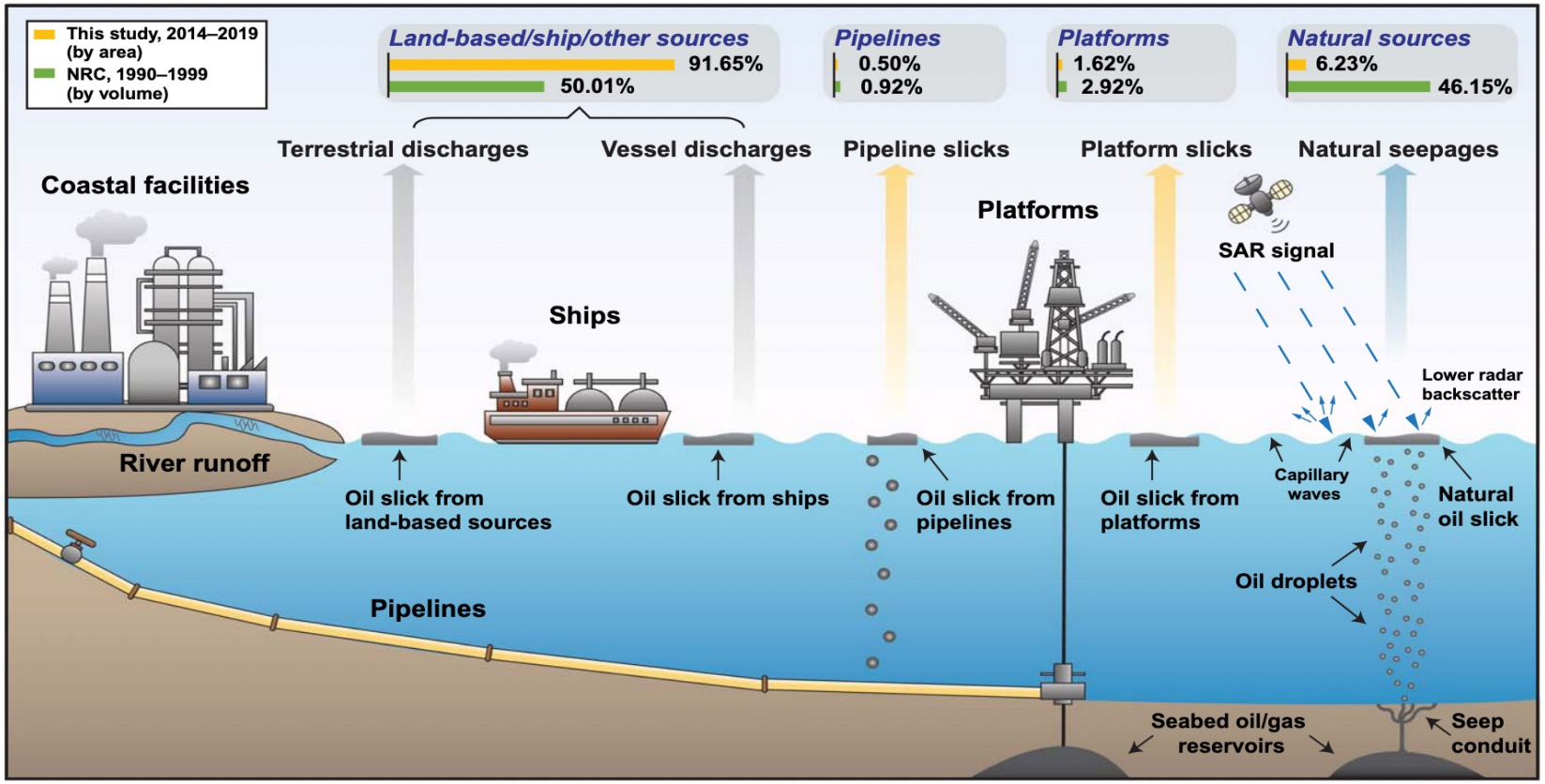
Environmental Stewardship from space
Operational monitoring of oil spills

Dr. Elizabeth C. Atwood
Earth Observation Science & Applications

ITAC, 24-26 October 2023, NOC Southampton

Impact Oil Spills: Large and Small

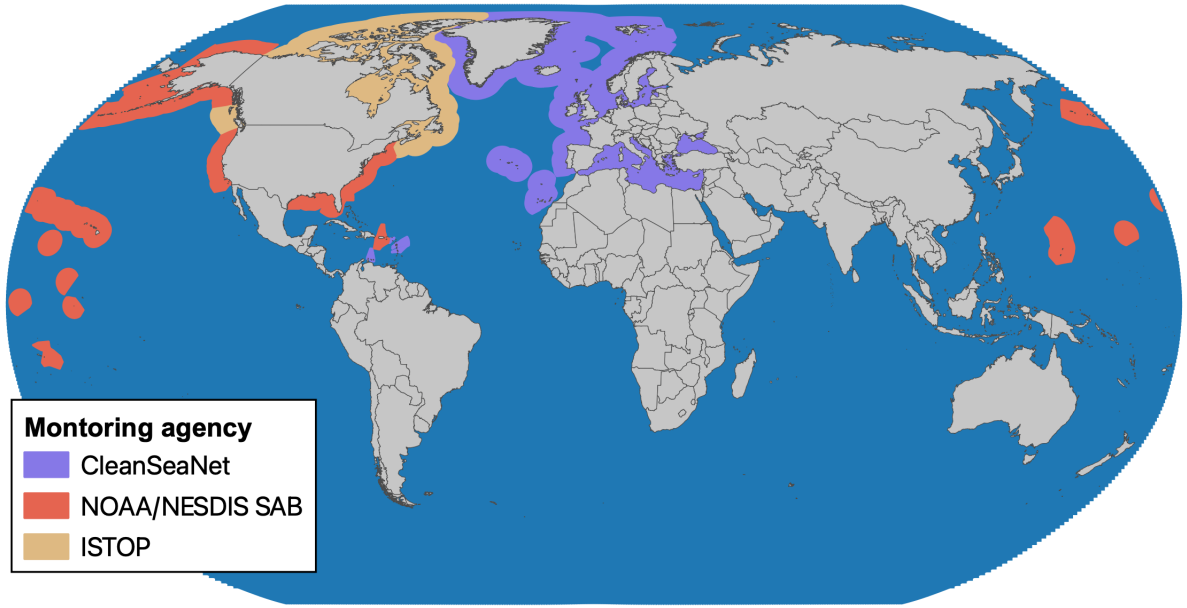
- Devastating effect on marine/coastal environments and economies
- Where spills occur and how they disperse of critical importance
- Smaller unreported slicks much higher percentage annual oil spill totals than previously thought (Dong et al. 2022; Najoui et al. 2022), 90% of detected slicks occur within 160 km of the shore



Oil slick contributions due to different sources, based on analysis 2014-2019. From: Dong, Y., Liu, Y., Hu, C., MacDonald, I. R. & Lu, Y. Chronic oiling in global oceans. *Science* **376**, 1300–1304 (2022).

Global South Needs More Focus

Who incorporates operational satellite oil slick detection products to their system?

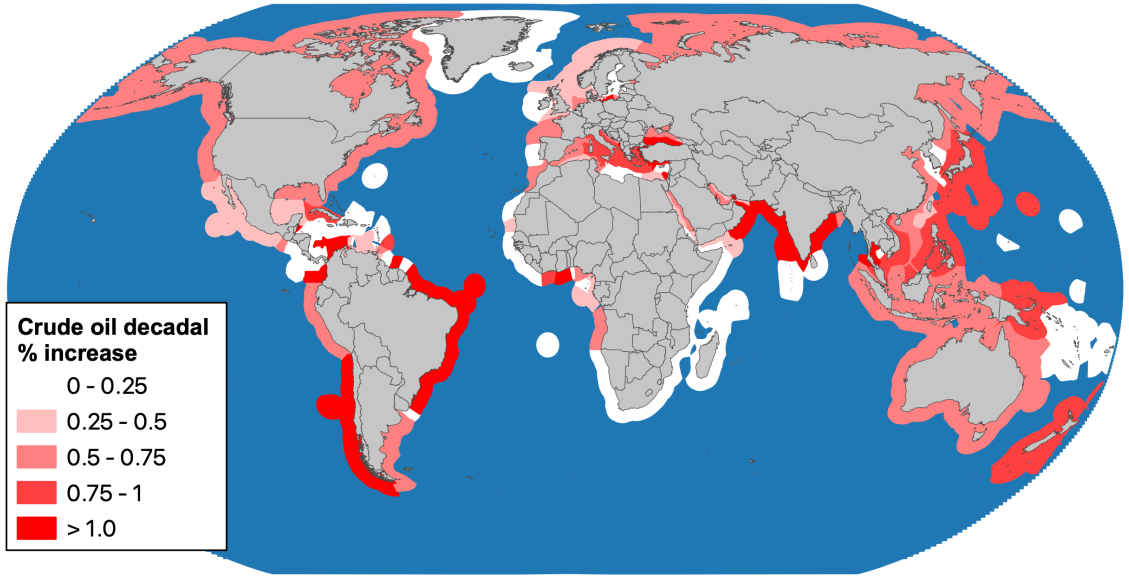


Compare crude oil including lease condensate production from 2001-2010 to 2011-2020, rates represented over a country's Exclusive Economic Zone (EEZ)

Coastal shelf zones

- Small area: <20% planet's surface
- Big impact:
  - provide up to **90%** of global fishery catch
  - **25%** ocean primary production

Where is crude oil production increasing?



U.S. Energy Information Administration

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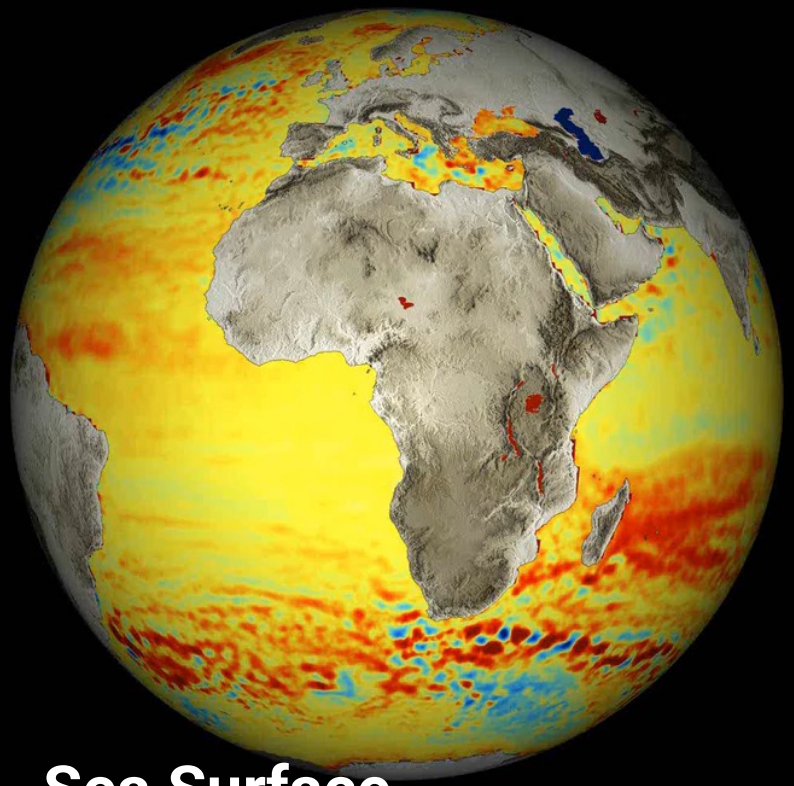
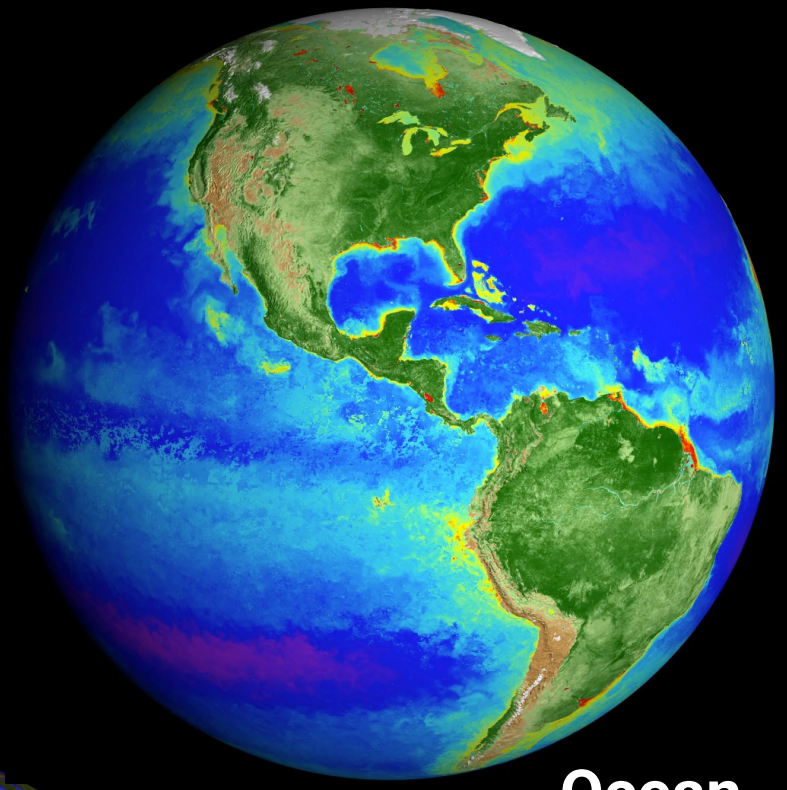
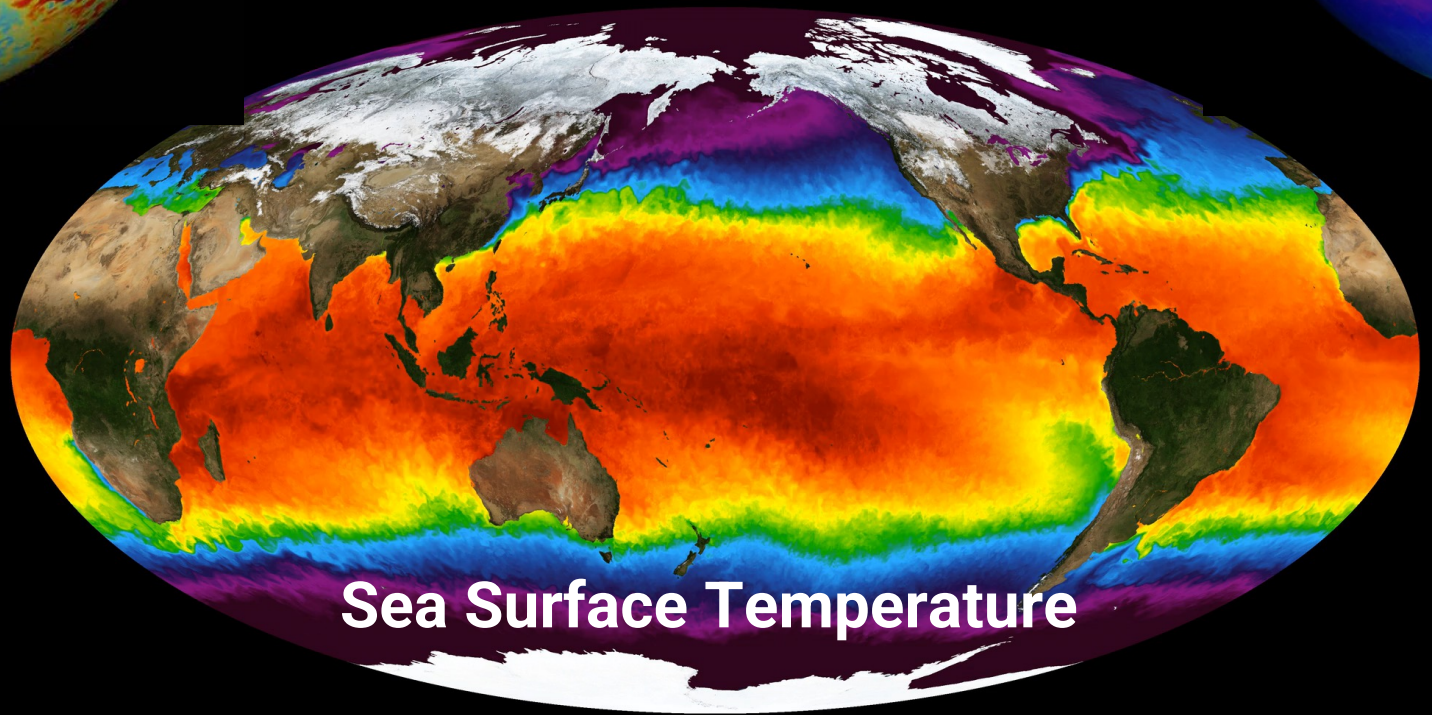
Understanding and Protecting Ocean Systems



Sea Surface Height



Ocean Colour

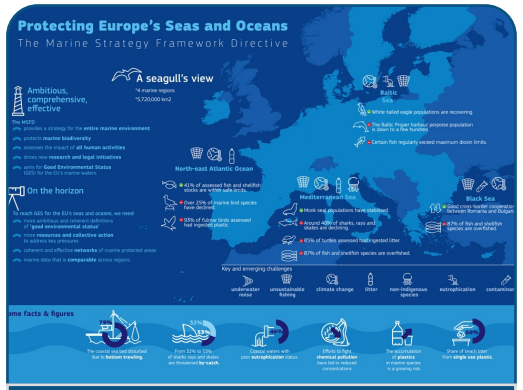


Sea Surface Temperature

Earth Observation Science & Applications

Nearshore and inland water quality indicator projects support EU directives and global conventions

EU Water Framework Directive



EU Marine Strategy Framework Directive

UN Sustainable Development Goals

DOORS BLACK SEA

EOCIS

ERTO

lakes cci

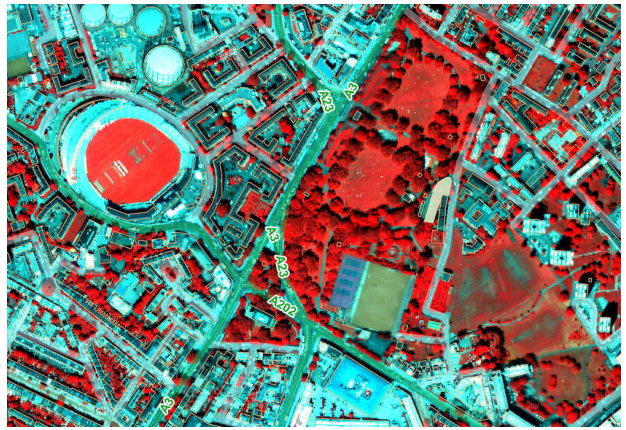
Interreg France (Channel Manche) England
S-3 EUROHAB
European Regional Development Fund

MONOCLE

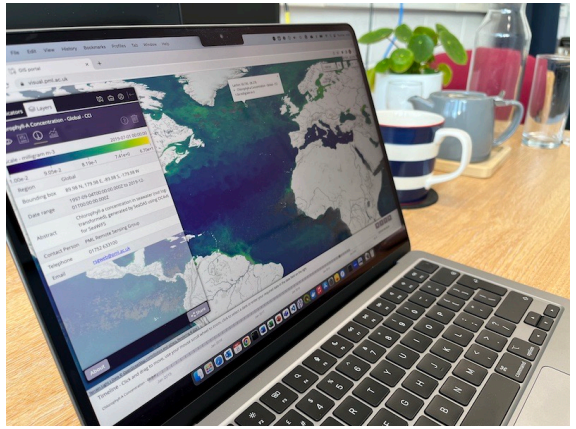
Commercial Extension of PML Science

PML | Applications

- **PML Applications Ltd.**
  - Offer access to the scientific knowledge and services on a commercial basis
  - All profits are returned to PML
- **Applied science for the blue economy**
- **Provide:**
  Scientific research, consulting and training services to help understand marine environment's impact on your business, and your impact on the marine environment
- **Mission**:
  Accelerate new technologies for a sustainable blue economy



Land Classification Mapping



Data Visualization & Analysis

Commercial Drone Operations & Surveys

EO Training & Capacity Development

‘PML Group’ Business Model

***PML is a company limited by guarantee with charitable status**

***PML Apps Ltd. is a wholly owned subsidiary**

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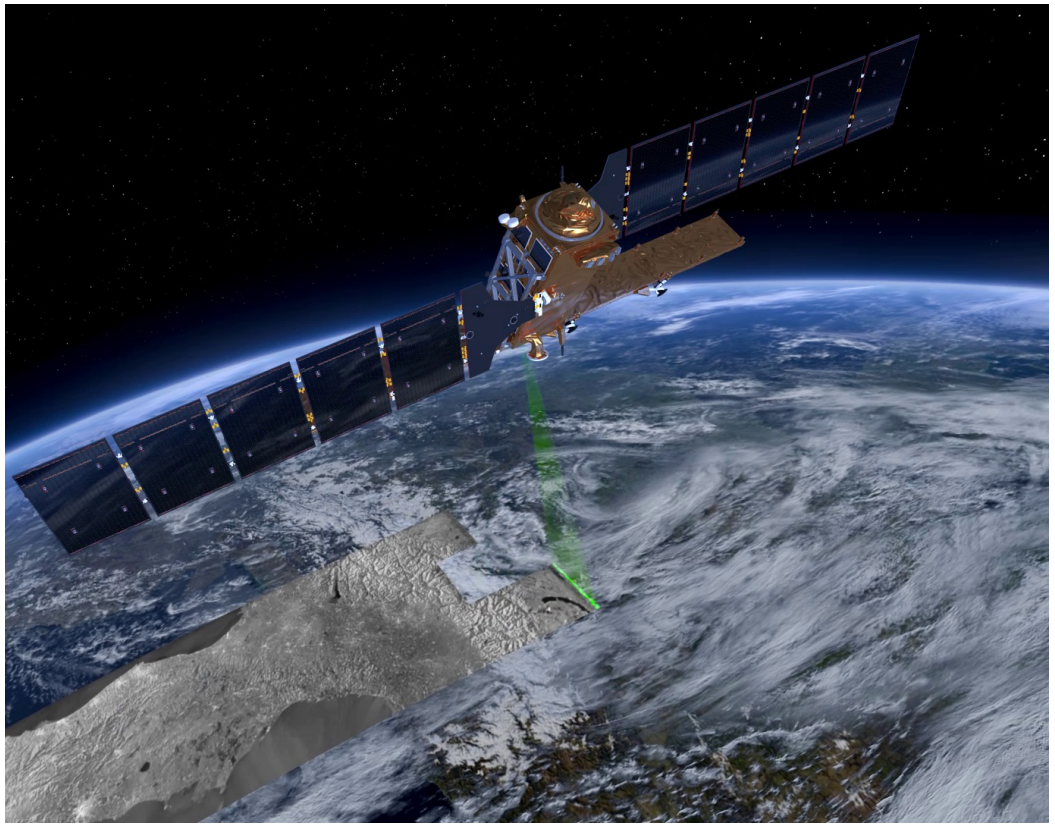
Profit, OH, Flexibility, IP
Knowledge Exchange
Innovation, IMPACT

PML | Applications Ltd

- RCUK Science
- Commissions

- Services
- Products

Synthetic Aperture Radar Slick Detection from Space

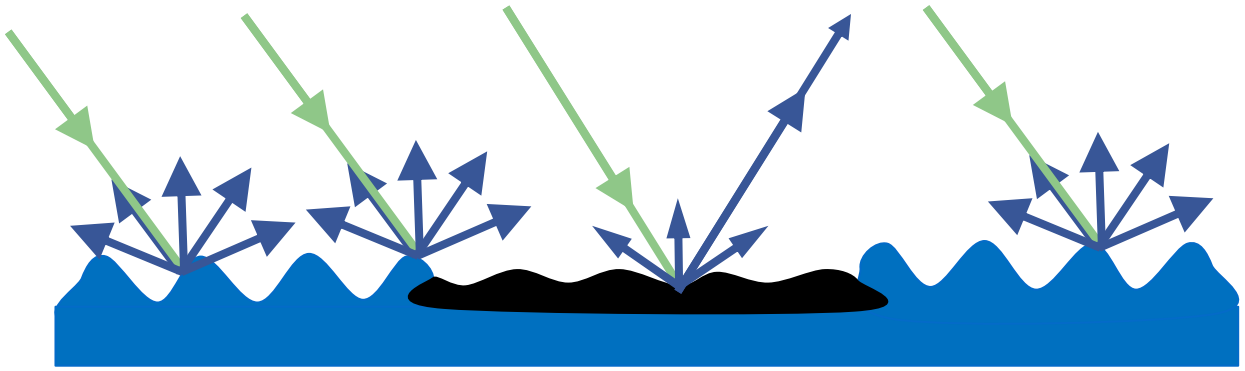


Synthetic-aperture radar (SAR)

- useful tool for oil slick mapping
- long-term timeseries freely available (ERS-1 in 1991, ERS-2 in 1995, Envisat in 2002, Sentinel-1A in 2014, Sentinel-1B in 2016)
- planned freely available until at least 2030
- extensive study past and future pollution, plus operational detection of oil slicks

Backscattering SAR signal in the presence or absence of oil

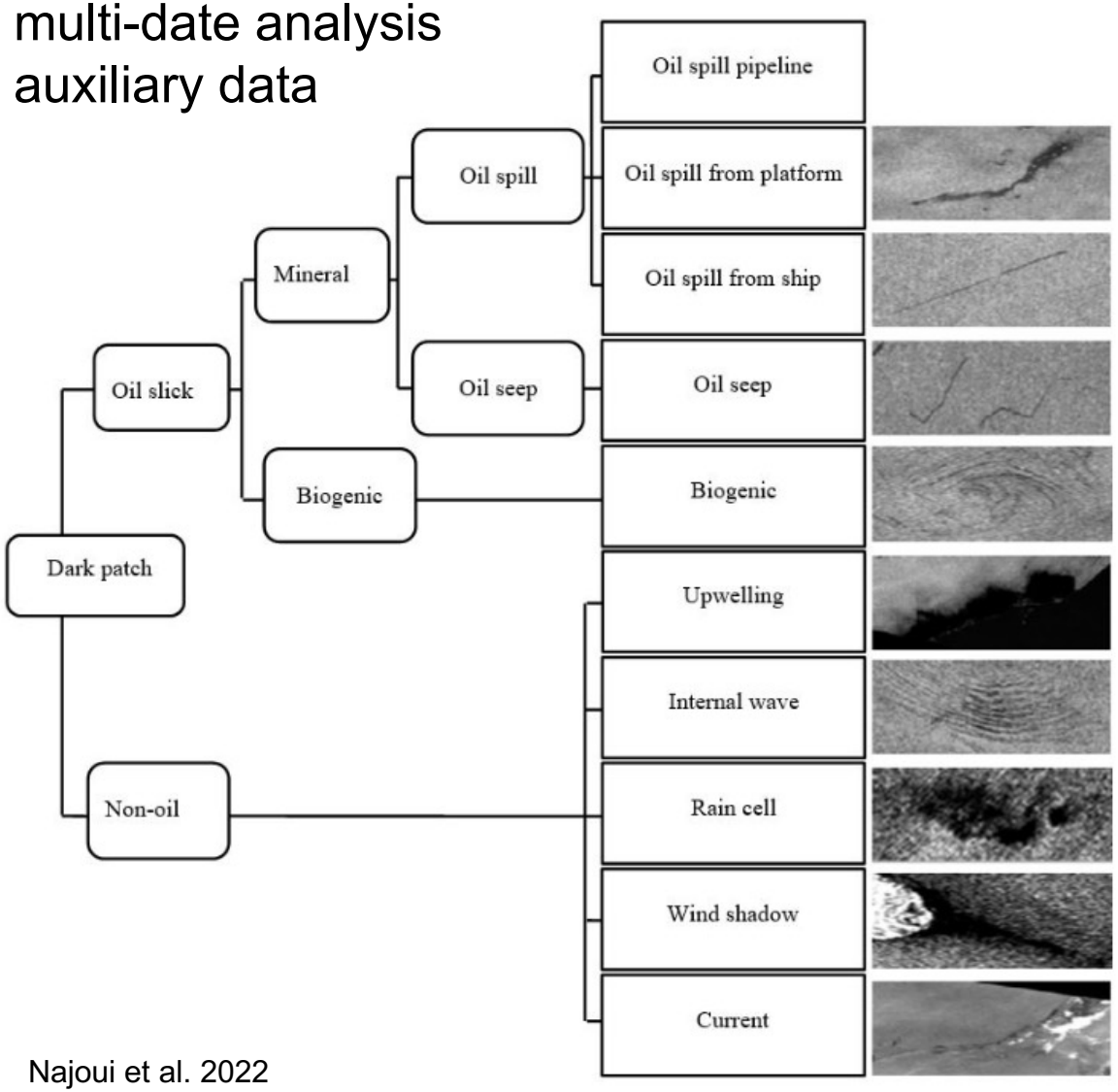
- dampening effect on capillary and small wind waves (i.e. Bragg waves)
- slicks appear darker compared with nearby undampened water surface



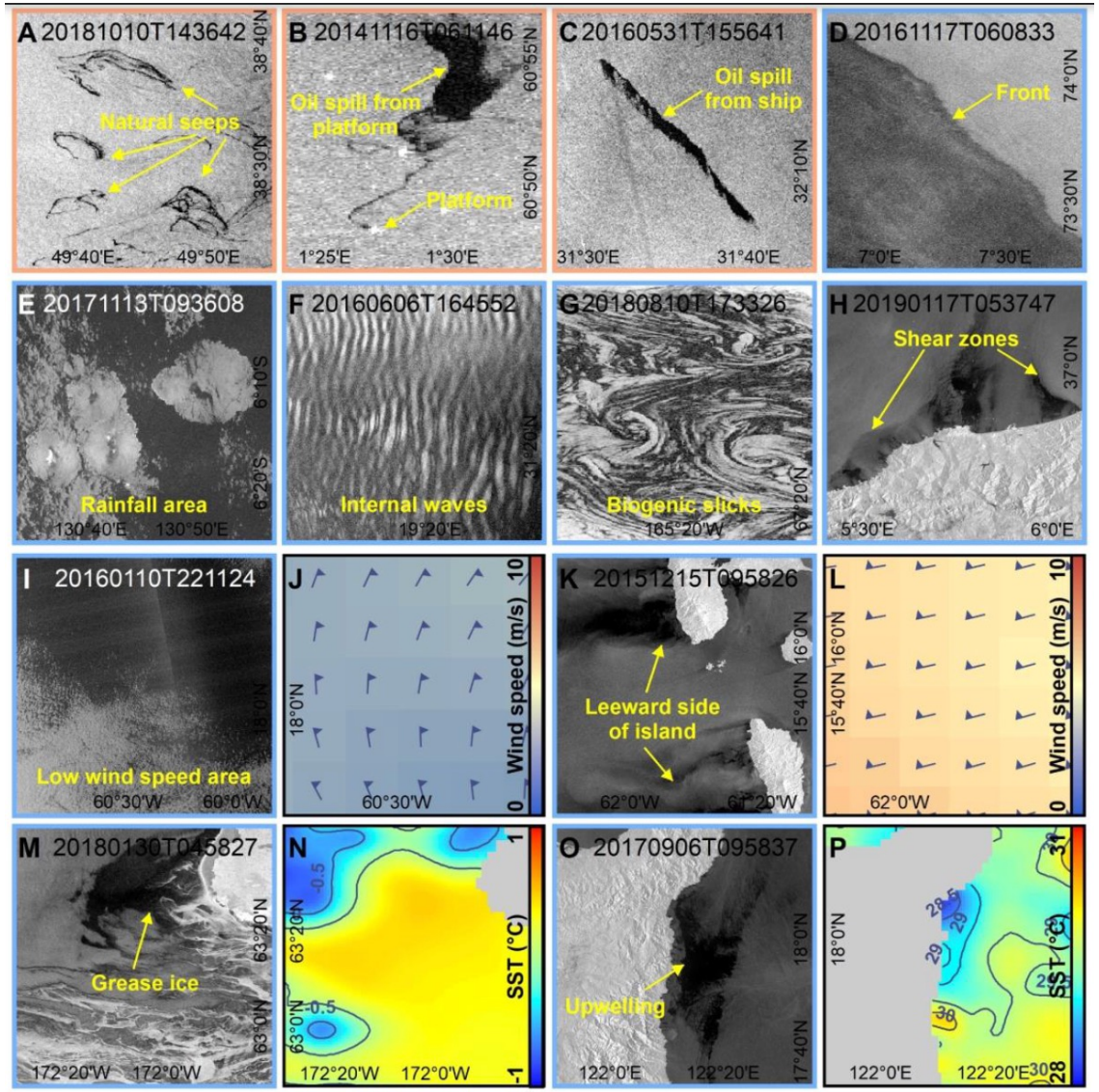
Differentiating "Look-alike Features"

Manual detection based on discrimination criteria, such as:

- morphology and texture
- multi-date analysis
- auxiliary data



Najoui et al. 2022



Dong et al. 2022

Highly Automated Oil Spill Detection Algorithm

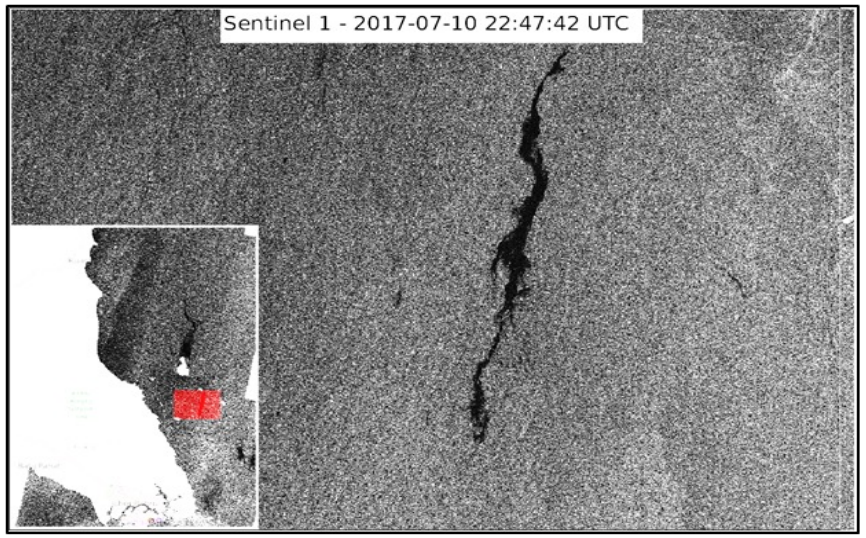
Oil Spill Detection Methodology

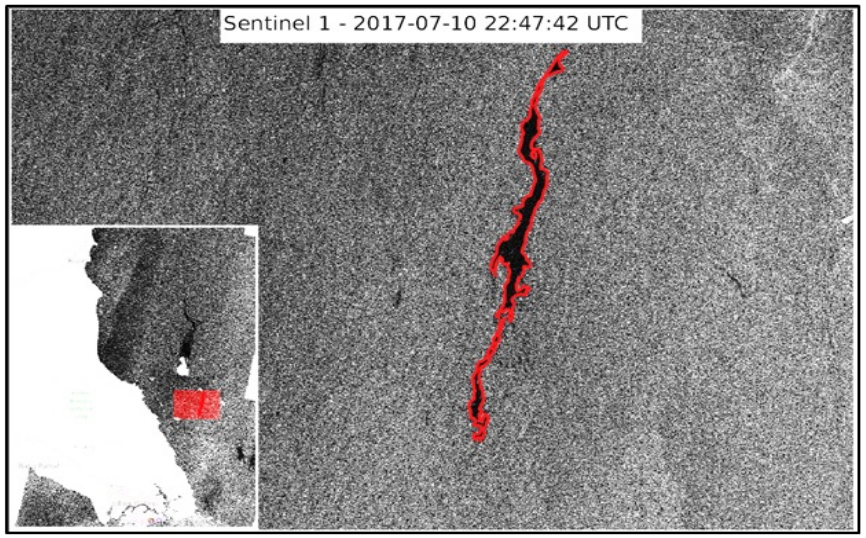
A Kurekin, D Clewley, M Warren, P Miller, E Atwood

Satellite oil detection

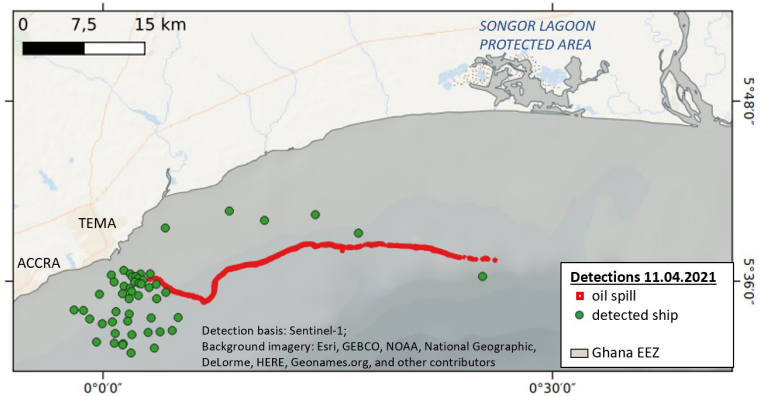
- Automated Satellite data delivery
- Oil detection algorithms

» **Spill *location* and *extent***





- Uses features of how an expert human interpreter differentiates slicks from look-alikes (e.g. contrast, size, shape)
- Competitive machine learning classification algorithms
- Confidence score for all potential slicks, those below are ignored
- True positive rate for oil of 77.8%



EASOS Marine Watch project

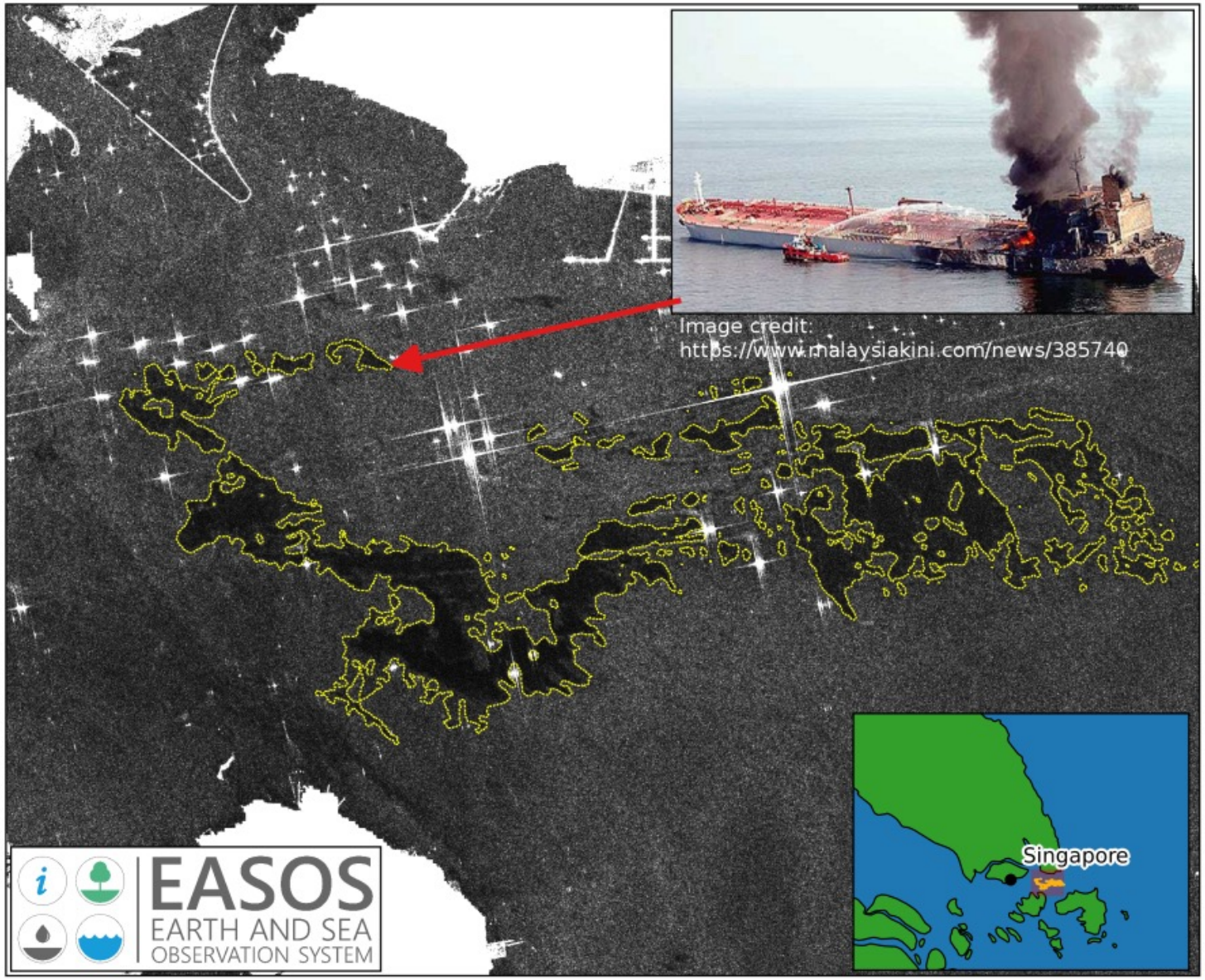
Service observing illegal oil discharge from commercial vessels in the Malacca strait, comprising:

- Fast and efficient systematic monitoring
- Identification of ship locations from satellite data, regardless of AIS status
- AIS integration for ship detection/location to associate vessel to a pollution event
- Interactive dashboard for communication and alert
- In collaboration with RiskAware,
  - forward/backward modelling of observed oil spills,
  - integrated data management for sharing intelligence between agencies to improve coordinated response

Application Example, MT Putri Sea Accident:

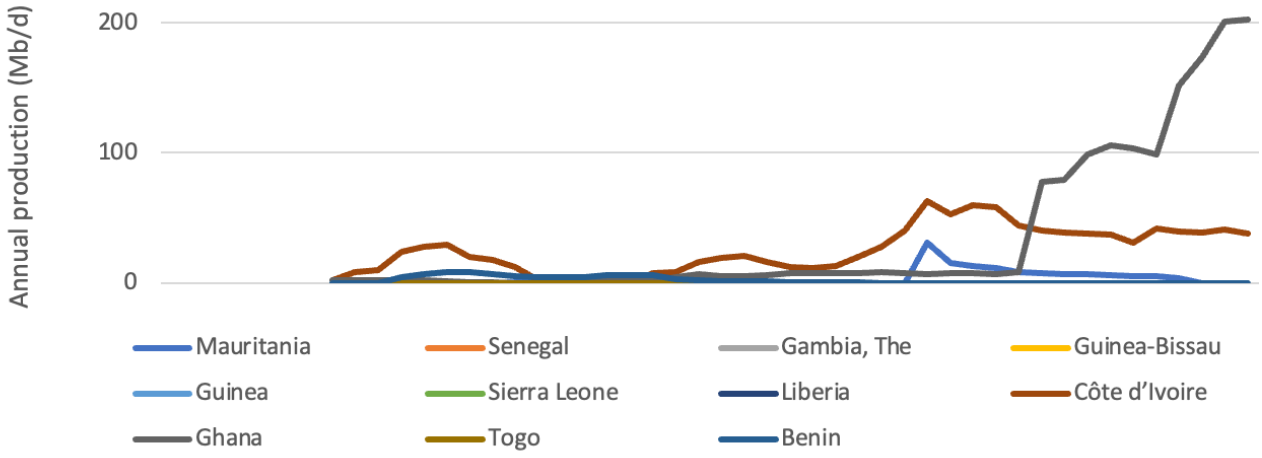
- Tanker caught fire and sank near Pengerang on 15 June 2017
- Believed to be carrying crude oil
- Six crew of the tanker went missing

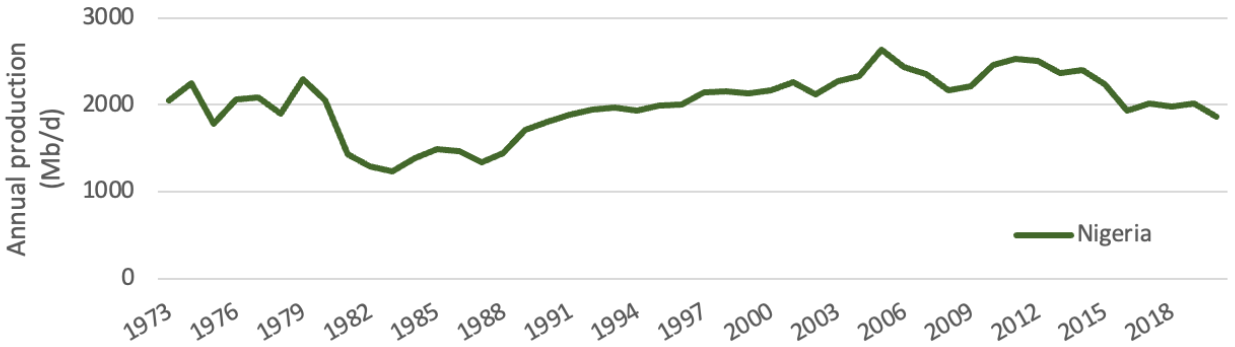
Sentinel 1 image of oil spil from Putri Sea tanker (2017-06-15)



Increasing Oil Production in West Africa

- Historical oil & gas extraction concentrated in the Gulf of Guinea (Nigeria, Gabon, Angola)
- Côte d'Ivoire, Ghana, Mauritania, Benin at production stage
- Ghana's energy sector expanding crude oil production
- Exploitation of oil at sea has started in Senegal between 2022 and 2023, representing increased risk

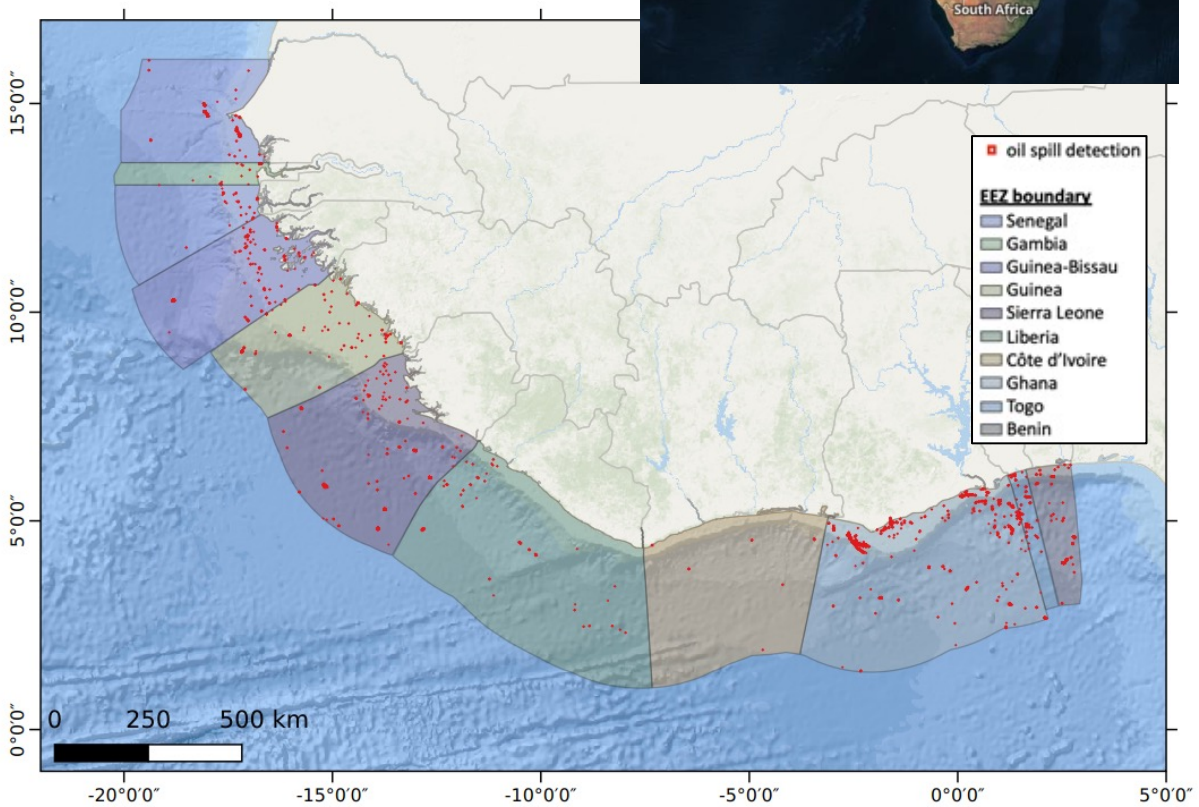




https://eia.gov/international/data/country/MRT/petroleum-and-other-liquids/monthly-petroleum-and-other-liquids-production

Operational Oil Spill Monitoring in West Africa

- Support of the West Africa Coastal Areas Management Program (WACA)
- Between 2020-2022, alerts sent on an ‘as detected’ basis and as a weekly summary to a range of government and agency stakeholders
- Alerts detailed spill location, detection time & extent
- Next step would be integration of AIS data
- Regional partnering to facilitate validation of detections and geospatial analysis of occurrence



marine resources e04sd

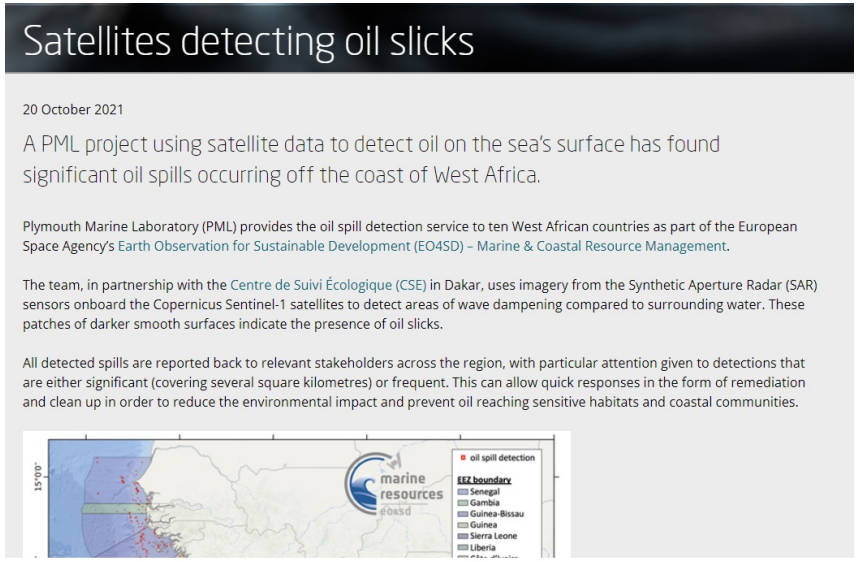
CSE Centre de Suivi Ecologique

WACA West Africa Coastal Areas Management Program

Images: (top) Sentinel-1 service coverage, (bottom) 2021 summary of oil spills detected within the Economic Exclusive Zone (EEZ) of 10 West Africa countries

West Africa Engagement and Uptake

- On-detection and weekly summaries provided to teams in 10 different countries, 74 users total and growing
- CSE leads the MOLOA West Africa Coastal Areas assessment reporting
- Senegal coastal habitat risk assessment in support of national reporting requirements, conducted by CSE in Dakar with support from PML
- Articles in regional MOLOA bulletin, news piece announcements



https://www.pml.ac.uk/News_and_media/News/Satellites_detecting_oil_slicks

Impact West Africa Oil Spill Monitoring Service

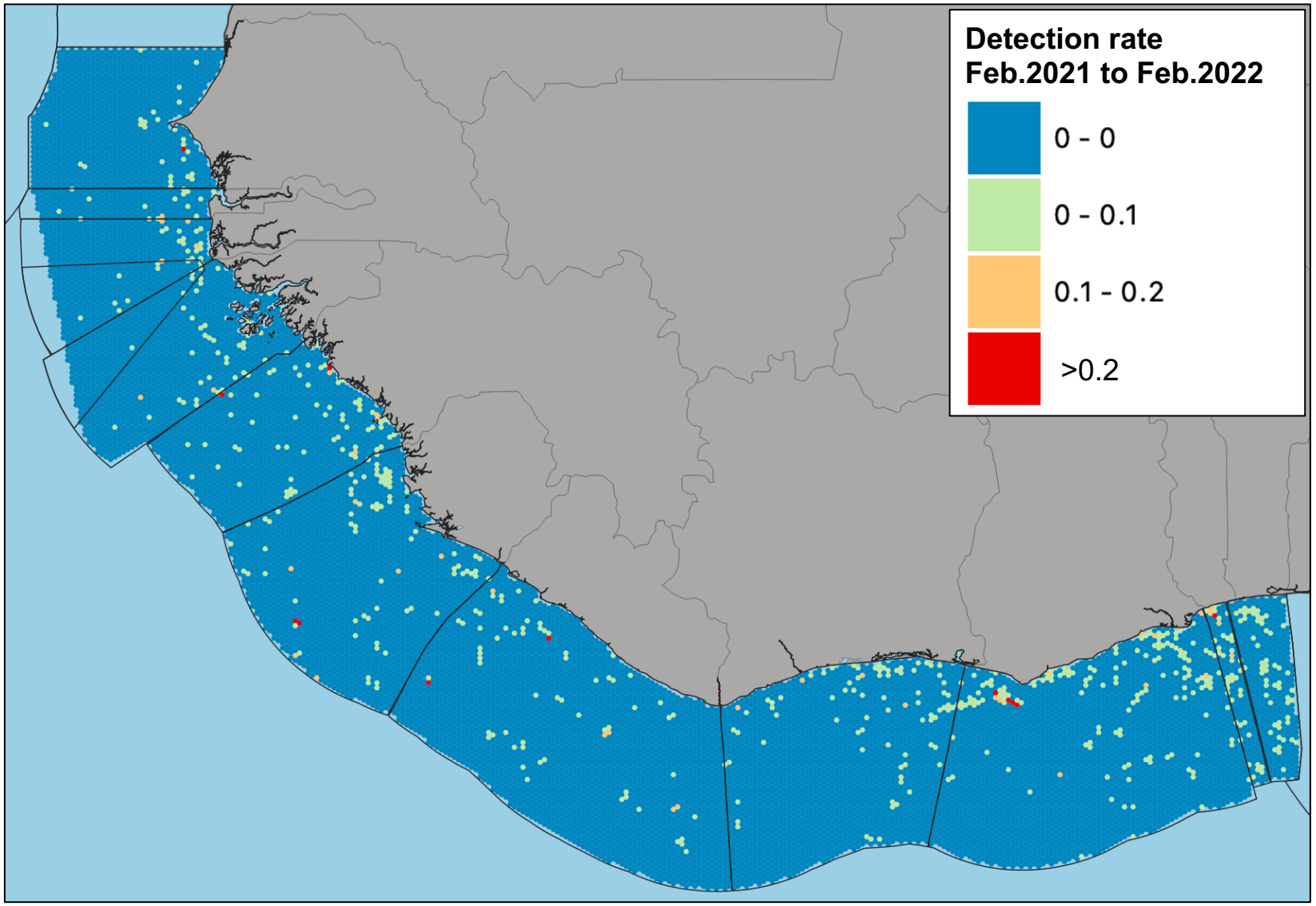
"The detection of oil spills on the West African coast is of great importance in the fight against marine pollution… The forthcoming establishment of the regional observatory and national observatories will, in the medium and long term, make it possible to tackle the issue in a sustainable manner at the local level." **Dr Moussa Sall, Coordinator West African Coast Observation Mission, Centre de Suivi Écologique, Dakar, Senegal**

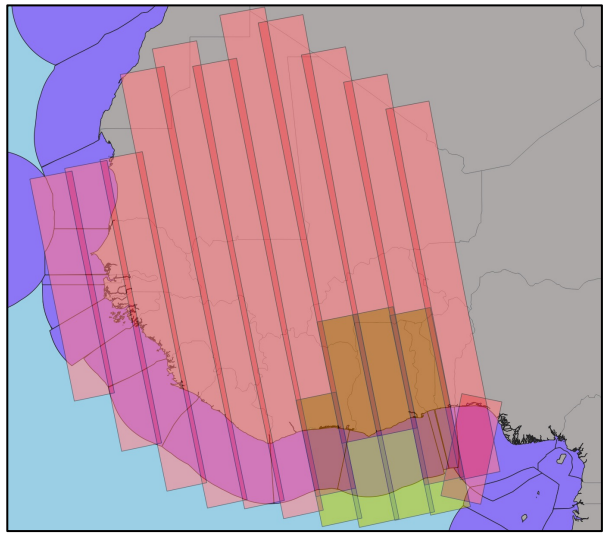
"It is imperative that institutions in the region take advantage of this technical-know how PML is bringing onboard and adopt innovative technology in safeguarding the maritime space" **Dr. Kwame A. Agyekum, Dept. Marine & Fisheries Sciences, University of Ghana**

"We also appreciated this… and should establish collaboration with the Maritime Rescue Sub-coordination Center (MRSC) for field mission." ***Josias Mahan, Ingénieur Agro-Environnement, Centre Ivoirien Antipollution (CIAPOL)***

"Understanding the rate at which our coastline is eroding is a major priority … in order to plan and implement the necessary adaptation and mitigation measures." ***Anthony Kullie, Director Liberian Hydrological Service, Instructor Department of Geology, University of Liberia***

Patterns in Occurrence Over Time





Sentinel-1 overpasses in 2021 over West Africa EEZ regions

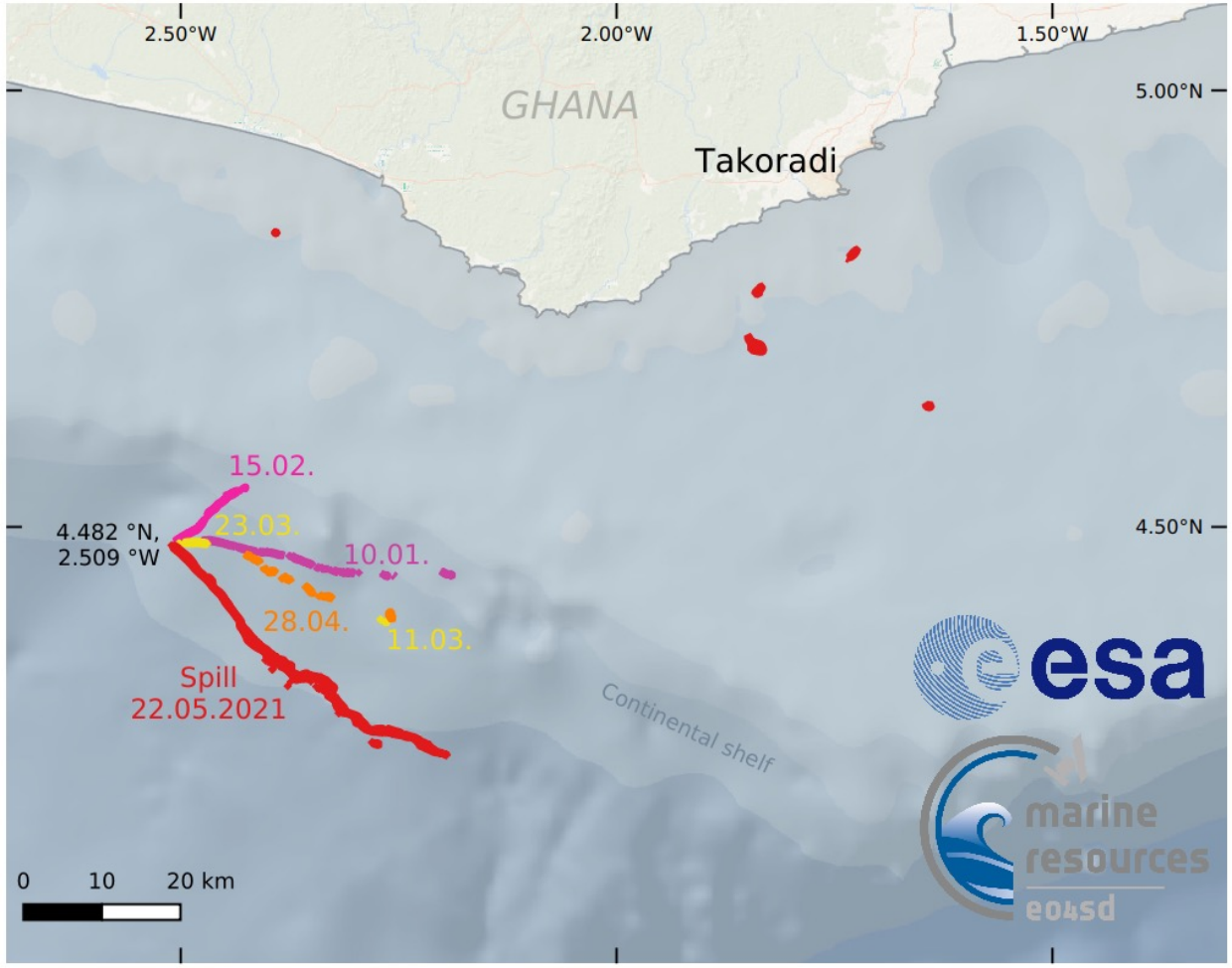
$$rate_{(i,j)} = \frac{n_{(i,j)}}{O_{(i,j)}}$$

Where for $pixel_{(i,j)}$:
$n_{(i,j)}$ is number spill detections, and
$O_{(i,j)}$ is number observations

Identify Sources of Repeated Slick Detections

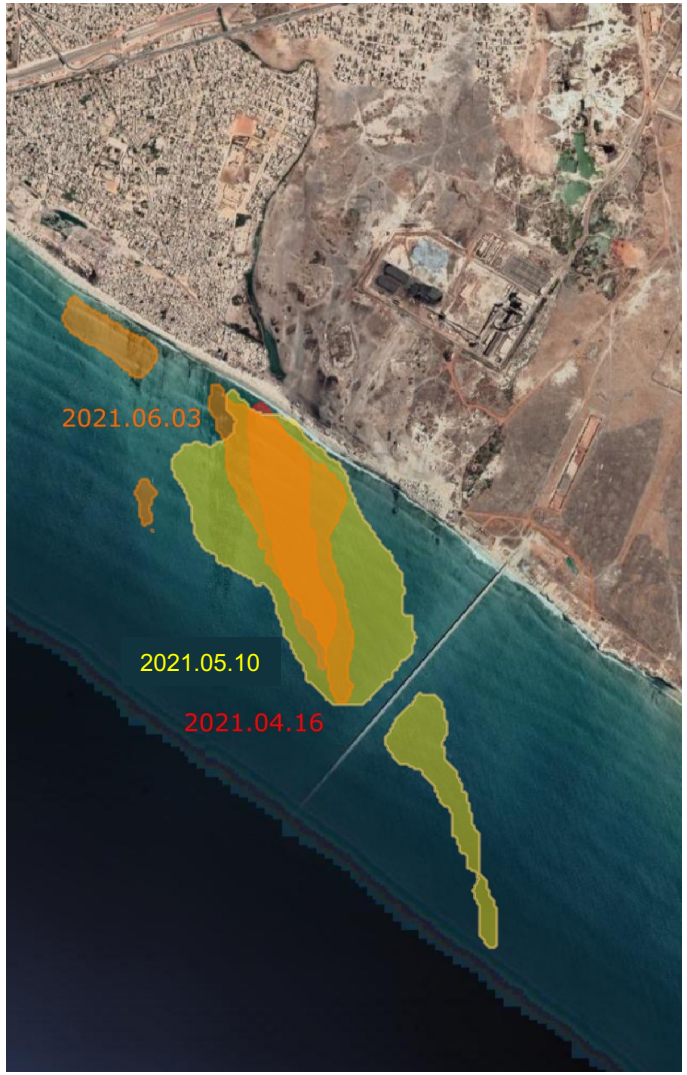
Example from Ghana

- Spill detections >10 km^2 which appear to come from the same location
- Occurring on a semi-monthly basis



Coastal Source Slick Detections

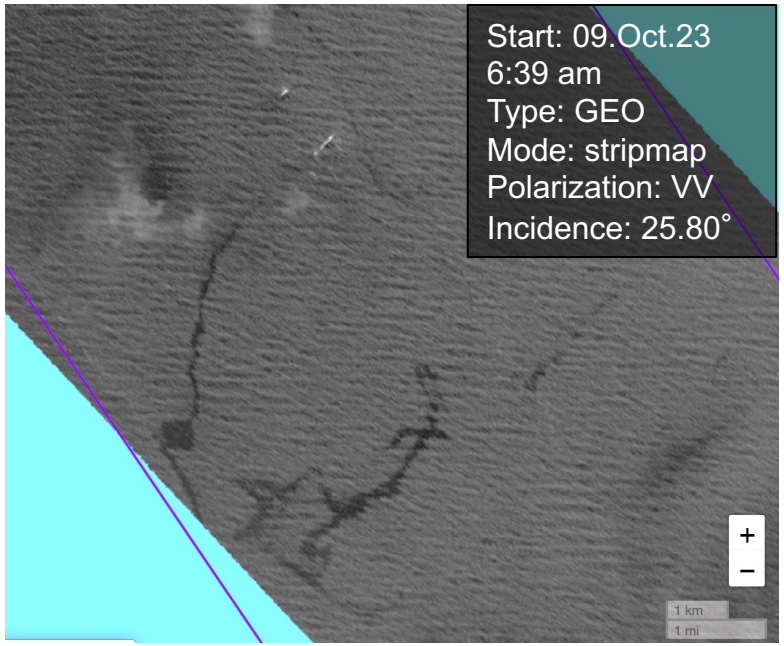
Example from Senegal

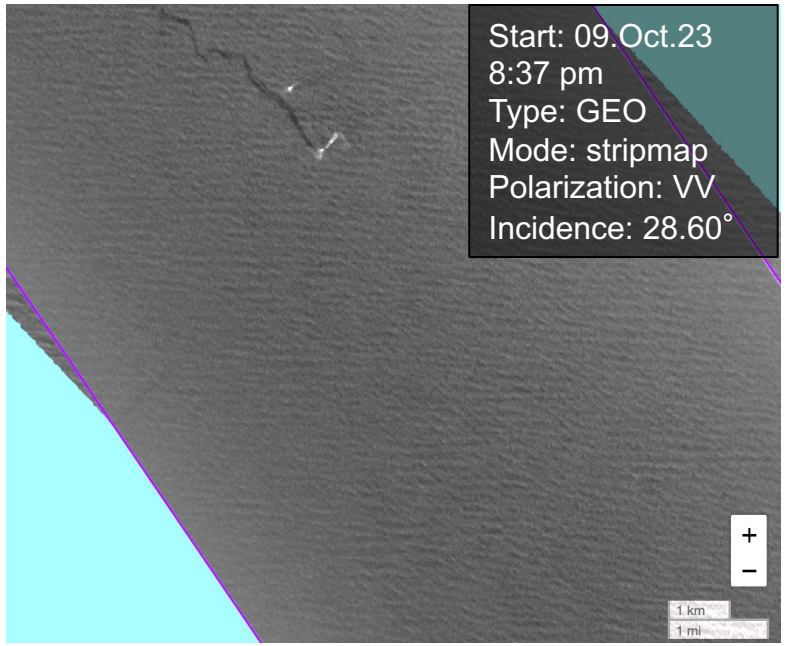


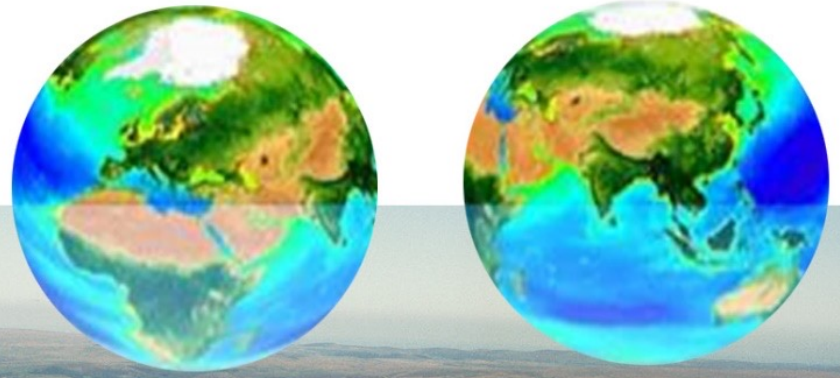
Estimating dispersion pathways with ocean surface currents

Sub-daily Detection of Oil Spill Dispersal

- Collaboration with commercial SAR data provider
- Multiple detections per day possible from multi-platform constellation
- Very high resolution imagery (spatial resolution <5m)
- Monitor directly how oil slicks disperse in nearshore environment over a timescale of hours, regardless of cloud conditions





Capella Space

Thank you, happy for discussion!