CV for Skylight: Addressing the dark vessel detection problem

NOAA CoastWatch Seminar
14 July, 2022

PRIOR
Perceptual Reasoning & Interaction Research

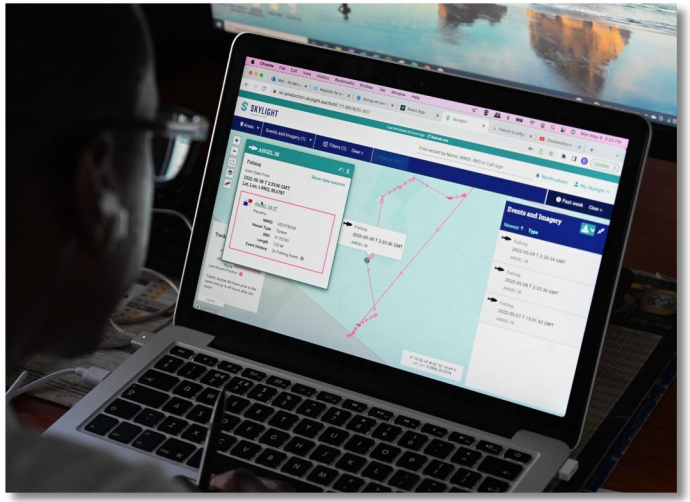
SKYLIGHT
A product of AI2

AI2

What is Skylight?

A maritime analyst tool for identifying vessel behavior that may be illegal or non-compliant with fisheries and maritime regulations.

VISION: Healthy, productive, and resilient oceans where targeted monitoring and enforcement actions support transparency and effective governance of marine resources.



KEY ELEMENTS

- One tool with two easy ways to **access**: web platform and API
- Focus on application of **advanced technologies like AI** to surface anomalous activity
- **Custom configurations** of events and areas of interest with corresponding alerting capabilities
- Provided at **no cost to national and regional agencies**

Our Home

ALLEN INSTITUTE FOR ARTIFICIAL INTELLIGENCE (AI2)
Non-profit based in Seattle, USA.

- Founded by the late Paul G. Allen, Microsoft Co-Founder, Investor and Philanthropist.
- Allen family is passionate about reducing illegal fishing and improving ocean health. Out of this came Skylight.



Skylight Team

Engineering



Product



AI Collaborators



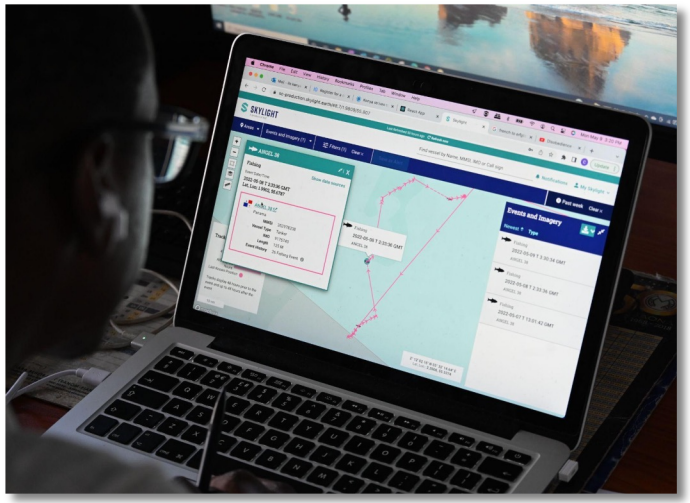
Interns



What is Skylight?

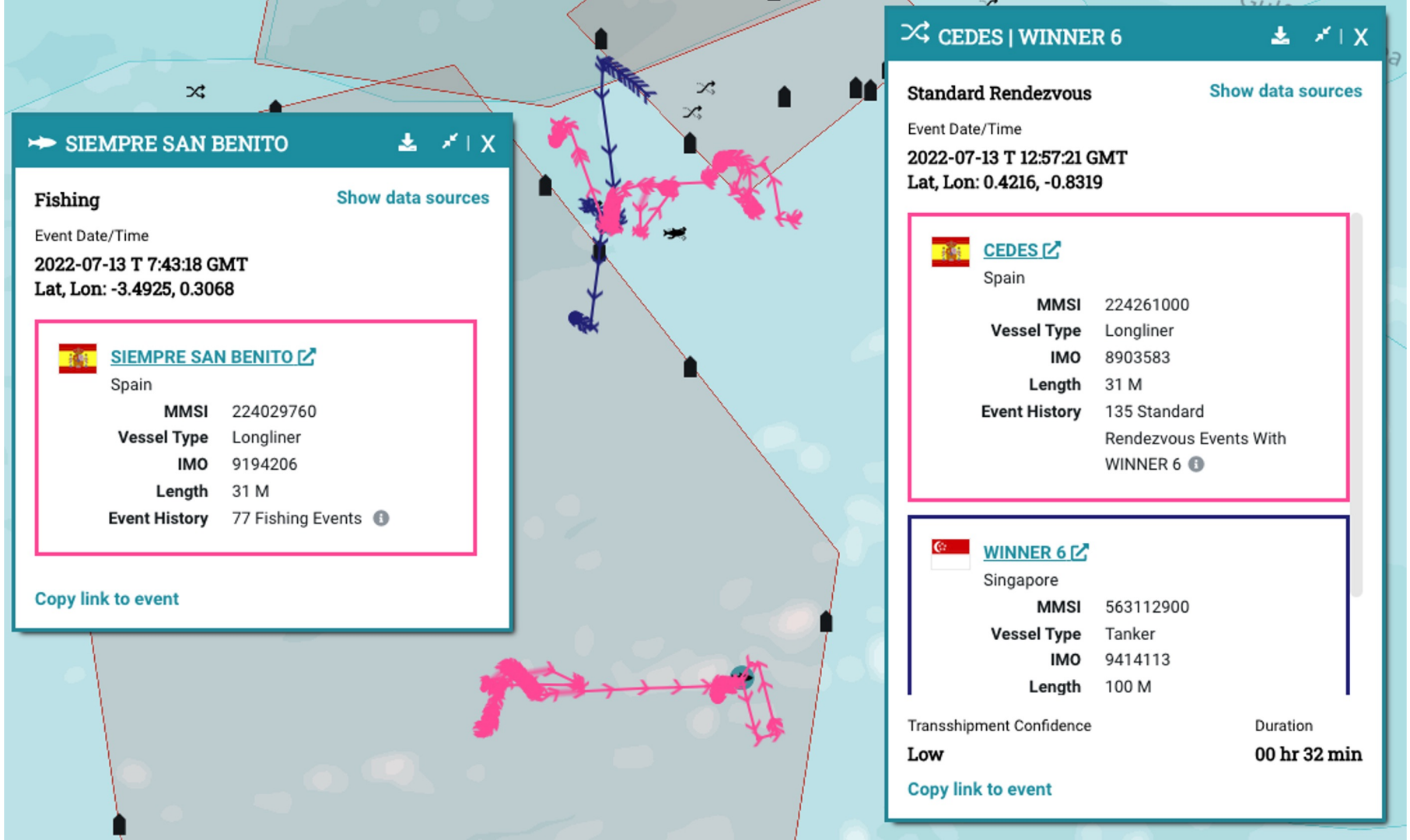
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SIEMPRE SAN BENITO
Fishing
Show data sources
Event Date/Time
2022-07-13 T 7:43:18 GMT
Lat, Lon: -3.4925, 0.3068
SIEMPRE SAN BENITO
Spain
MMSI 224029760
Vessel Type Longliner
IMO 9194206
Length 31 M
Event History 77 Fishing Events
Copy link to event
CEDES | WINNER 6
Standard Rendezvous
Show data sources
Event Date/Time
2022-07-13 T 12:57:21 GMT
Lat, Lon: 0.4216, -0.8319
CEDES
Spain
MMSI 224261000
Vessel Type Longliner
IMO 8903583
Length 31 M
Event History 135 Standard Rendezvous Events With WINNER 6
WINNER 6
Singapore
MMSI 563112900
Vessel Type Tanker
IMO 9414113
Length 100 M
Transshipment Confidence
Low
Duration
00 hr 32 min
Copy link to event

Find vessel by Name, MMSI, IMO or Call sign

Notifications

My Skylight

ts and Imagery (5)

Filters (0)

Clear ×

Save as Alert

Past 24 hours

Clear ×

Koforidua

Lomé

Benin City

Nnewi

Aboisso

Accra

Warri

Aba

Uyo

Port Harcourt

Sekondi-Takoradi

Douala

Malabo

Gulf of Guinea

Equatorial Guinea

São Tomé and Príncipe

Equatorial Guinea

Libreville

Port-Gen

Lambar

Equatorial Guinea

Gamba

Tchibanga

SENSEBAR

SENSEBAR

Sierra Leone

MMSI	667602000
Vessel Type	Unknown
IMO	-
Length	34 M
Event History	2 Satellite Radar Imagery Events

Estimated Length from Radar

41 m

Estimated Heading

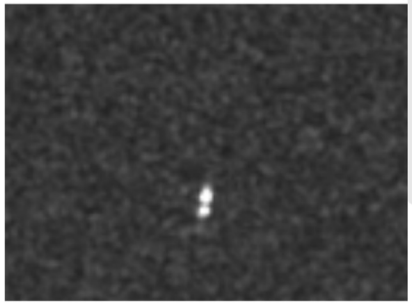
-

Estimated Width from Radar

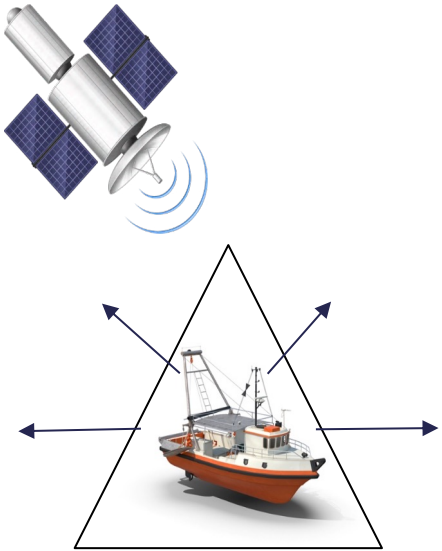
- m

Score

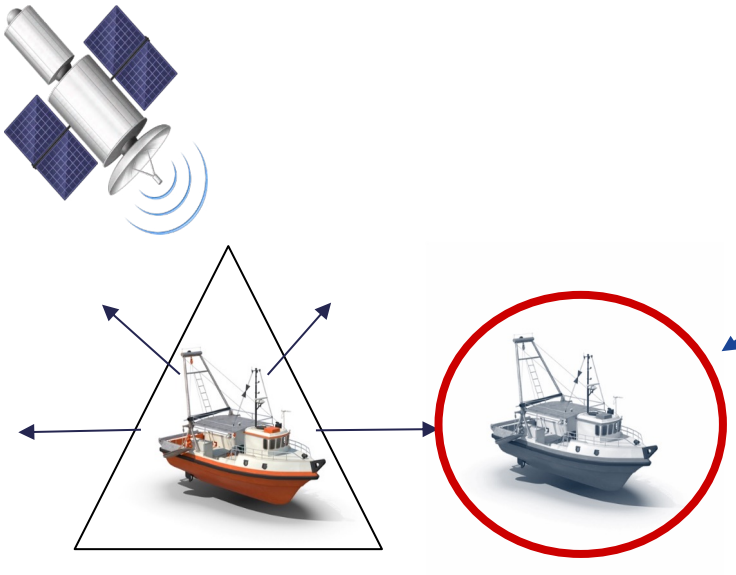
0.9974



Automatic Identification System (AIS) Primer



Automatic Identification System (AIS) Primer



How can Skylight better surface vessels that are not transmitting AIS?

Current State

Types of Events

- **Rendezvous** (AIS) (ML/AI)
  - Auto-generated detections of plausible transshipments, loitering, and other anomalous behavior
- **Entries** (AIS)
  - Monitoring vessel movements into any user-defined custom Area of Interest (e.g., Marine Protected Areas, EEZs)
- **Fishing** (AIS) (ML/AI)
  - Auto-generated, global detection of fishing activity
- **Speed Range** (AIS)
  - Enforcing speed regulations or monitoring slow, suspicious behavior (not ‘innocent’ passage)
- **Last Known Position** (AIS)
  - Reporting of vessels’ last known location
- **Port History** (AIS)
  - Reporting of vessels’ port visits
- **Radar Detection** (Satellite Radar)
  - Detection of non-AIS transmitting (dark) vessels upon request for targeted areas and dates


SKYLIGHT
A product of AI2
Find vessel by Name, MMSI, IMO or Call sig
Areas
Events and Imagery (1)
Filters (1)
Clear
Save as Alert
2022-05-19 T 11:05:42 GMT
Radar Source: RADARSAT-2
AIS-Correlated Vessel Detections: 27
Dark Vessel Detections: 18
3
115
9
4
Canada
United States
Cuba
Venezuela
Colombia
Peru
Brazil
Bolivia
Paraguay
Chile
Uruguay
Iceland
Sweden
Finland
Norway
United Kingdom
Poland
Ukraine
France
Romania
Spain
Italy
Turkey
Tunisia
Algeria
Libya
Egypt
Iraq
Iran
Saudi Arabia
Mauritania
Senegal
Niger
Chad
Sudan
Yemen
Nigeria
Cameroon
Ethiopia
Kenya
Tanzania
Angola
Mozambique
Namibia
South Africa
Sri Lanka
Maldives
Malaysia
Indonesia
Philippines
Papua New Guinea
Australia

Welcome to xView3!

A competition to detect dark vessels using computer vision and global SAR satellite imagery

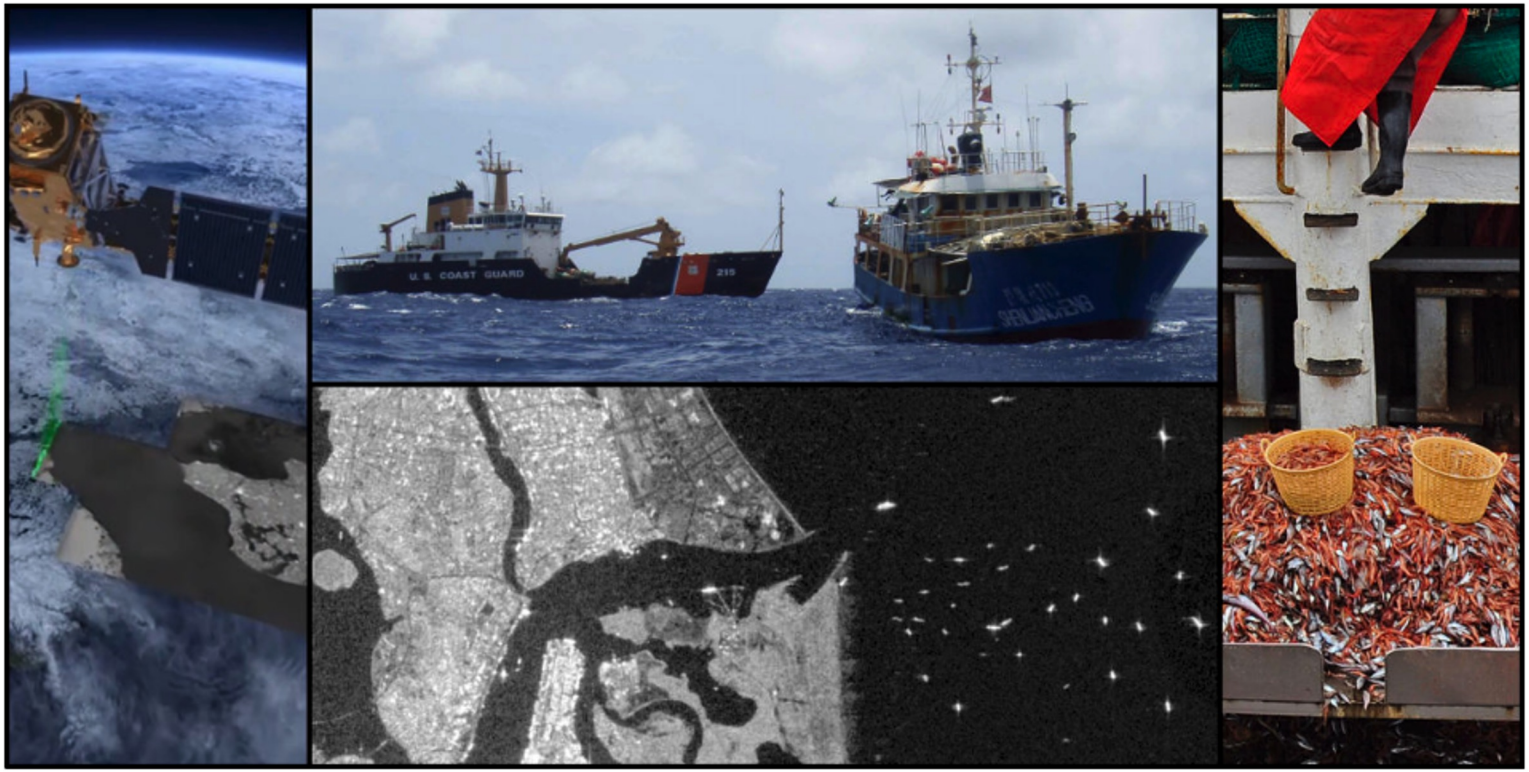
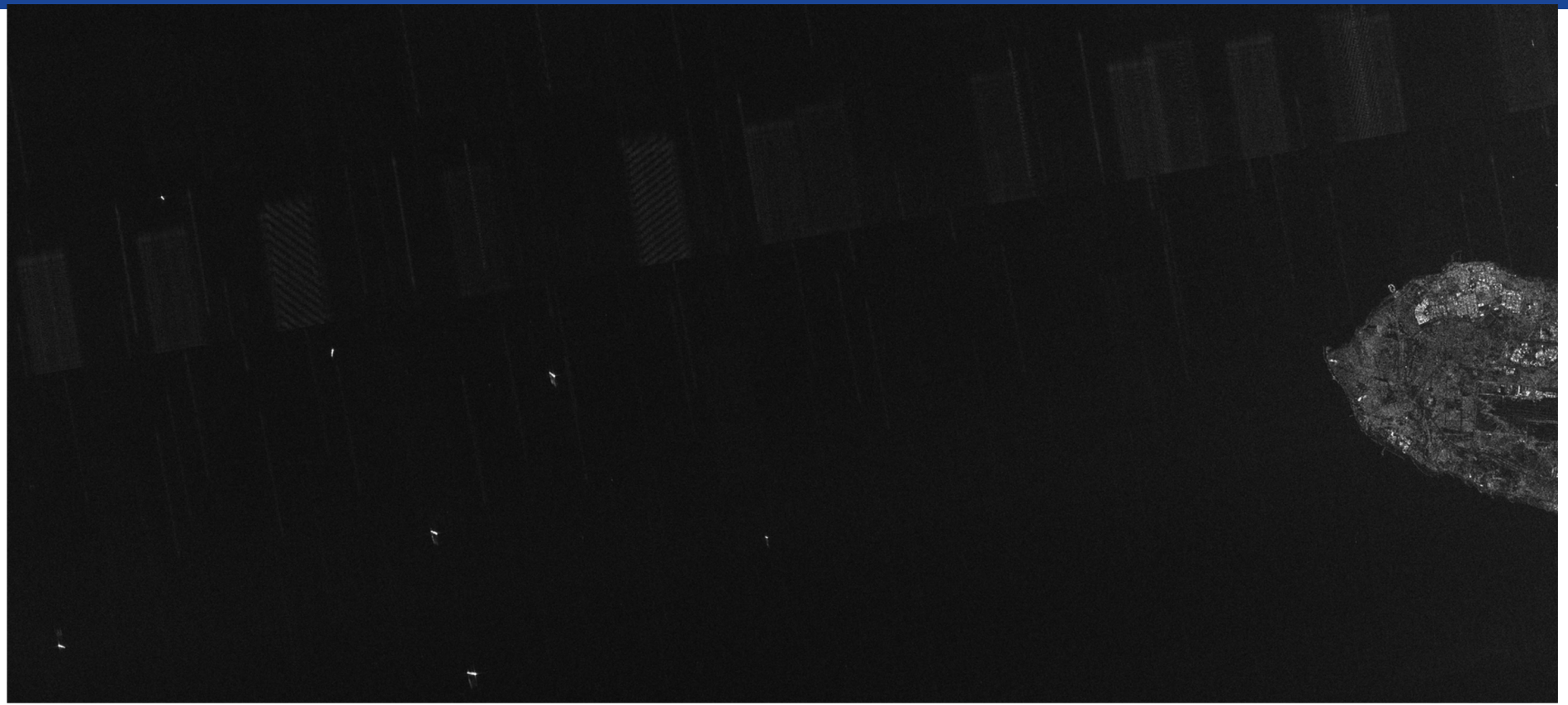
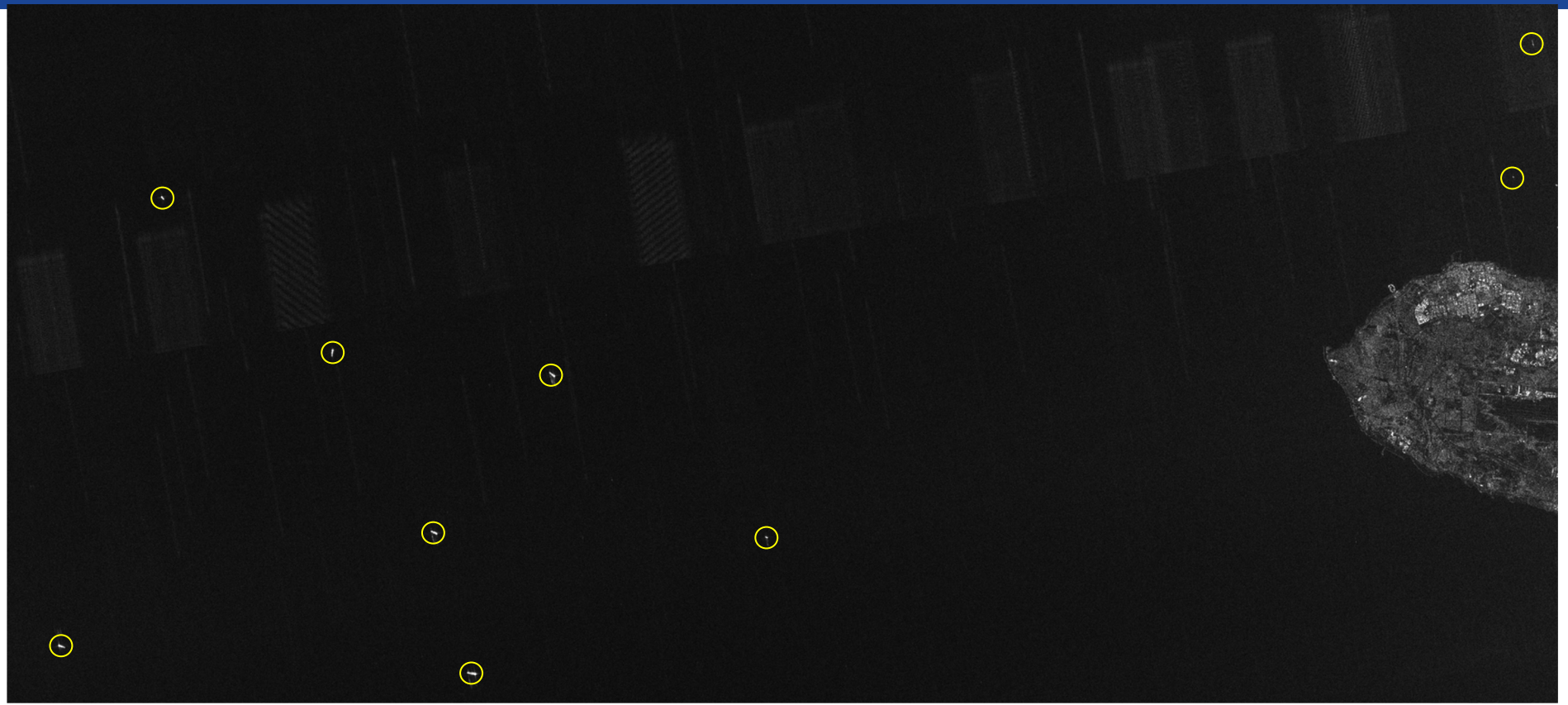


Image credit: U.S. Coast Guard; used with permission. ESA; image contains modified Copernicus Sentinel data (2020). ATG medialab; CC BY-SA IGO 3.0. Composites © Cambrio; rights reserved.

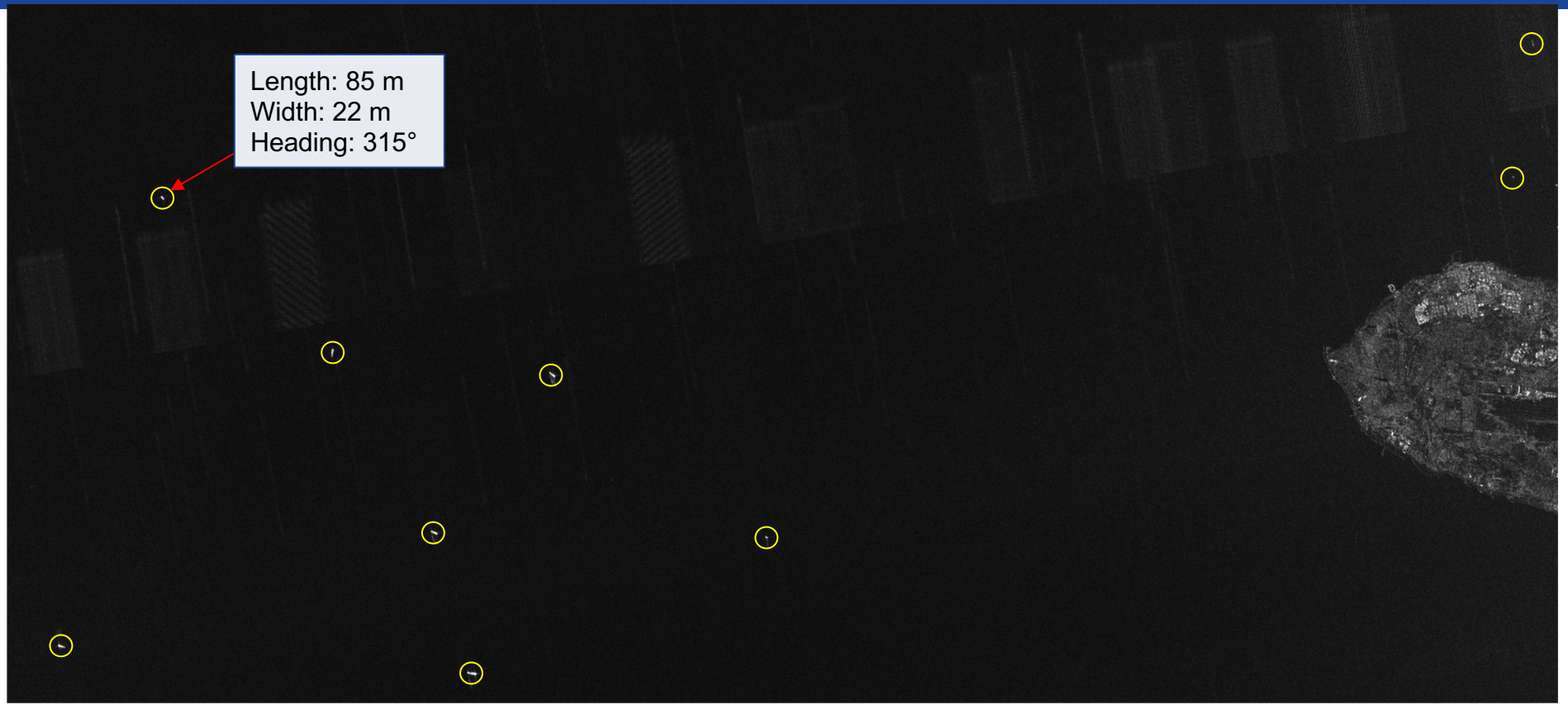
Vessel Detection in Sentinel-1 SAR Imagery



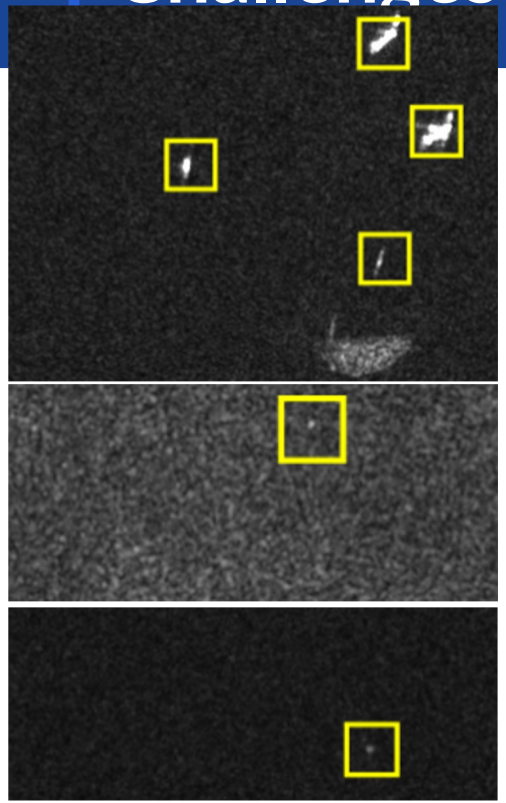
Vessel Detection in Sentinel-1 SAR Imagery



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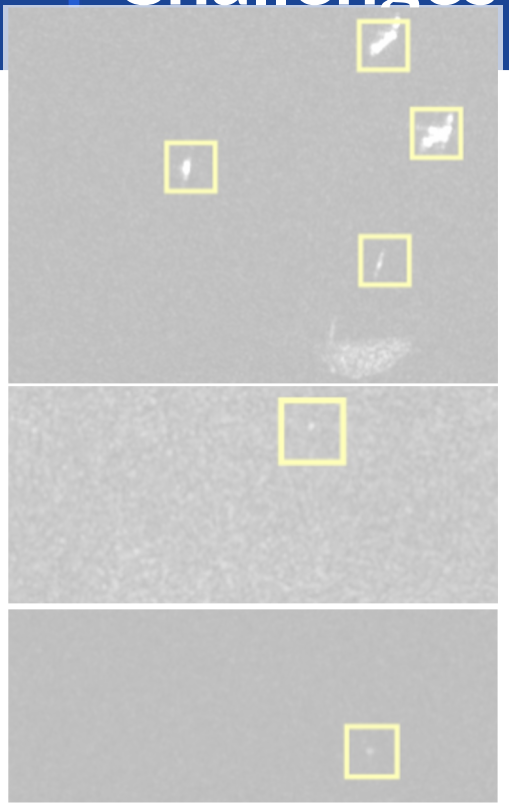


Challenges

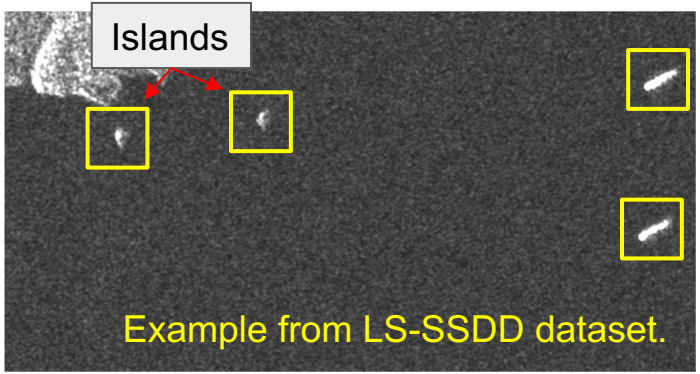


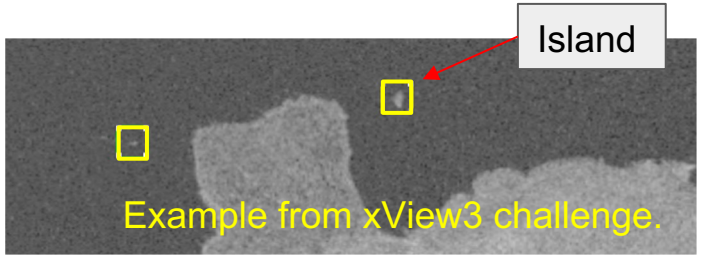
Challenge 1:
Vessels are Small

Challenges



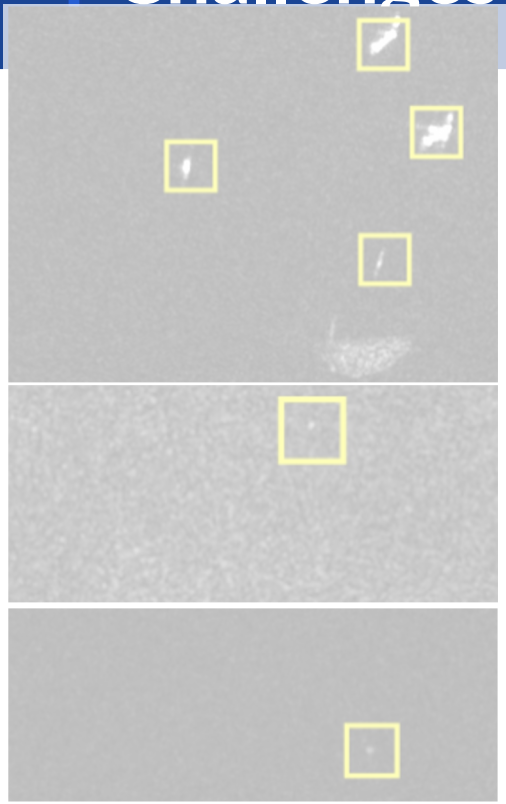
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Vessels are Small





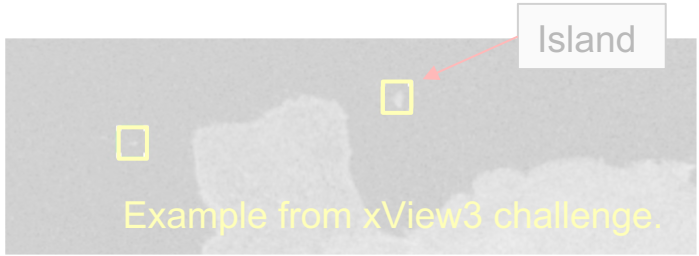
Challenge 2:
Existing Datasets have Quality Issues

Challenges

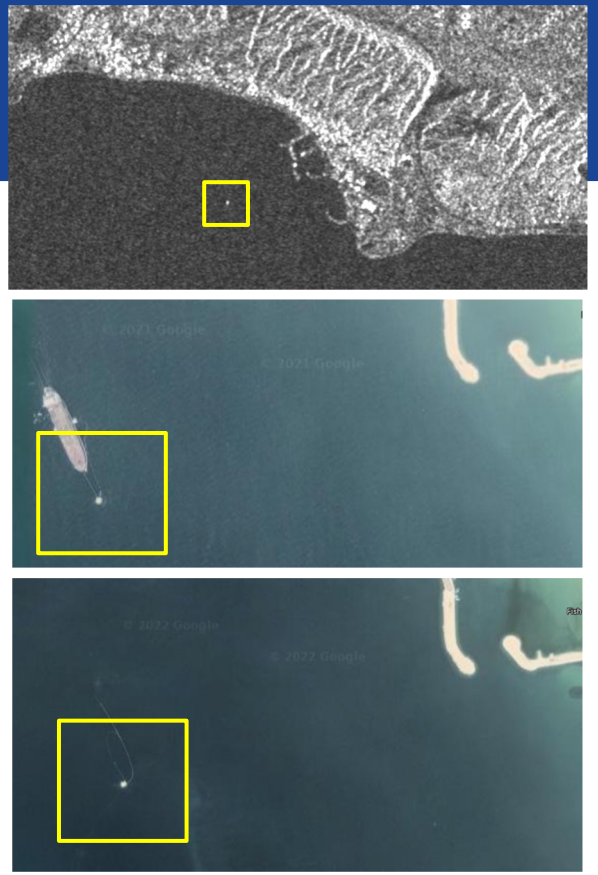


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Vessels are Small



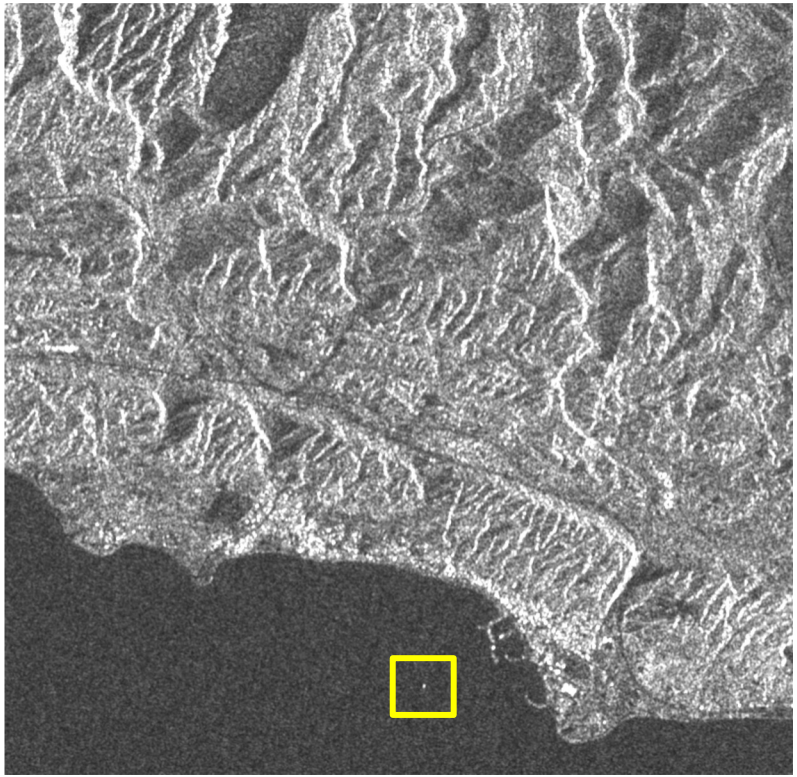


Challenge 2:
Existing Datasets have Quality Issues

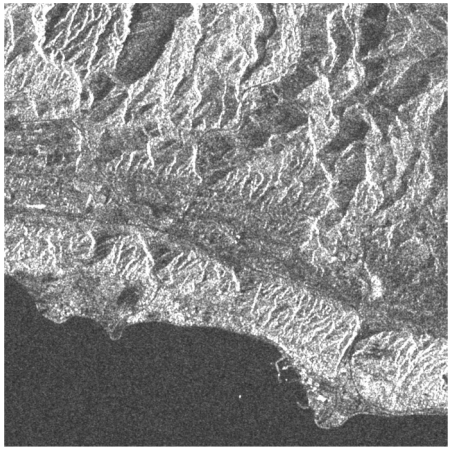


Challenge 3:
Confounding Objects have Near-Identical Appearance

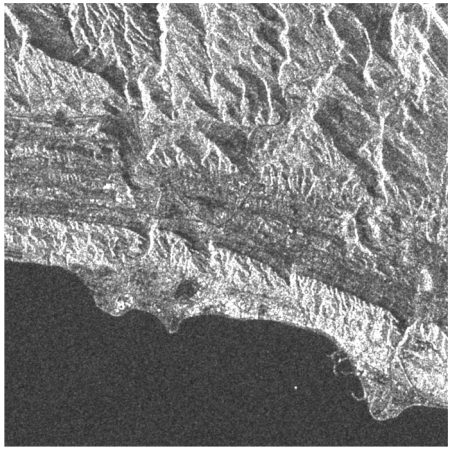
Compare Images over Time



June 2022

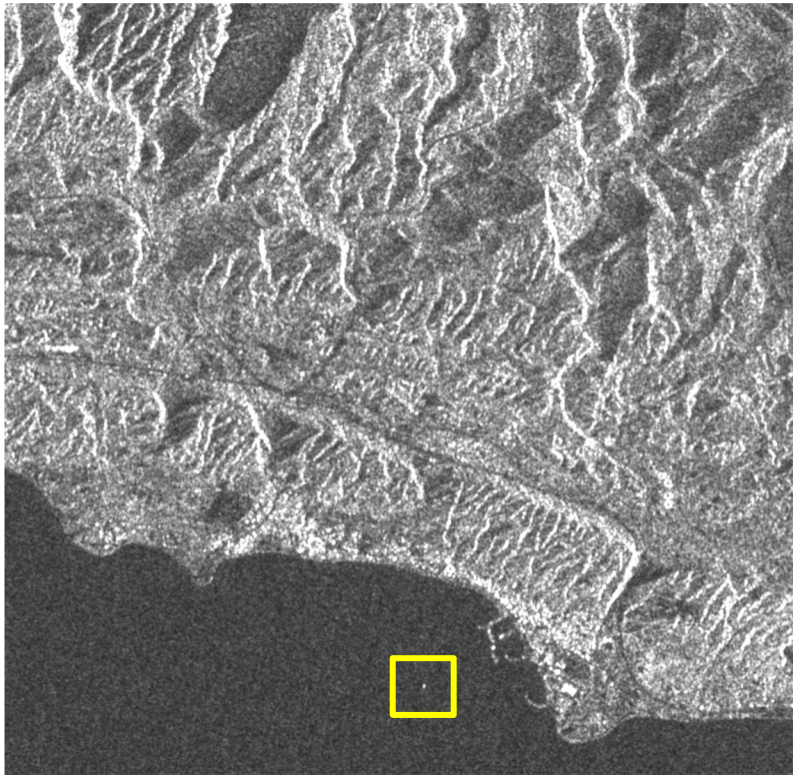


May 2022

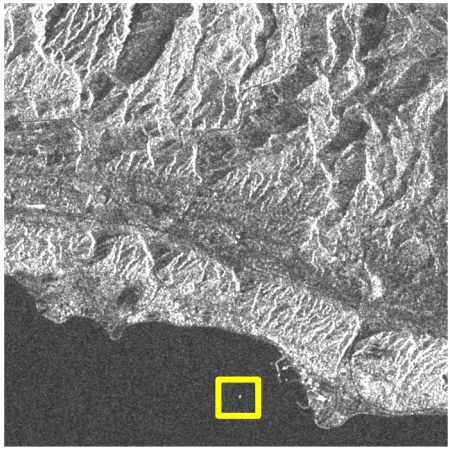


April 2022

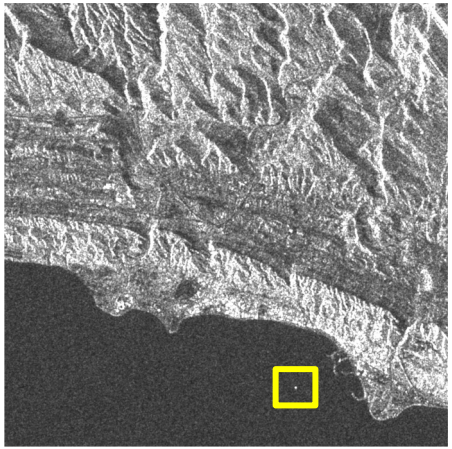
Compare Images over Time



June 2022

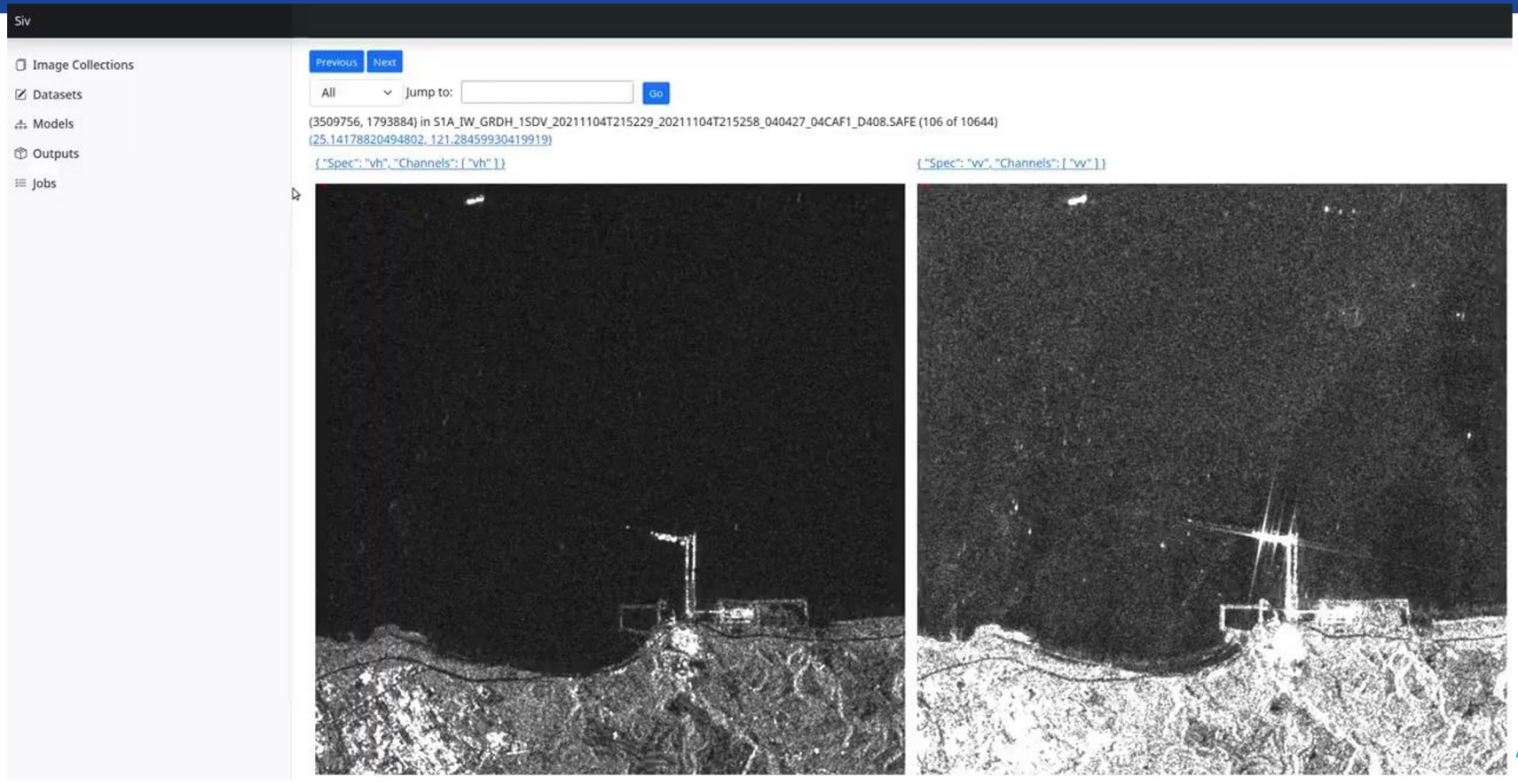


May 2022



April 2022

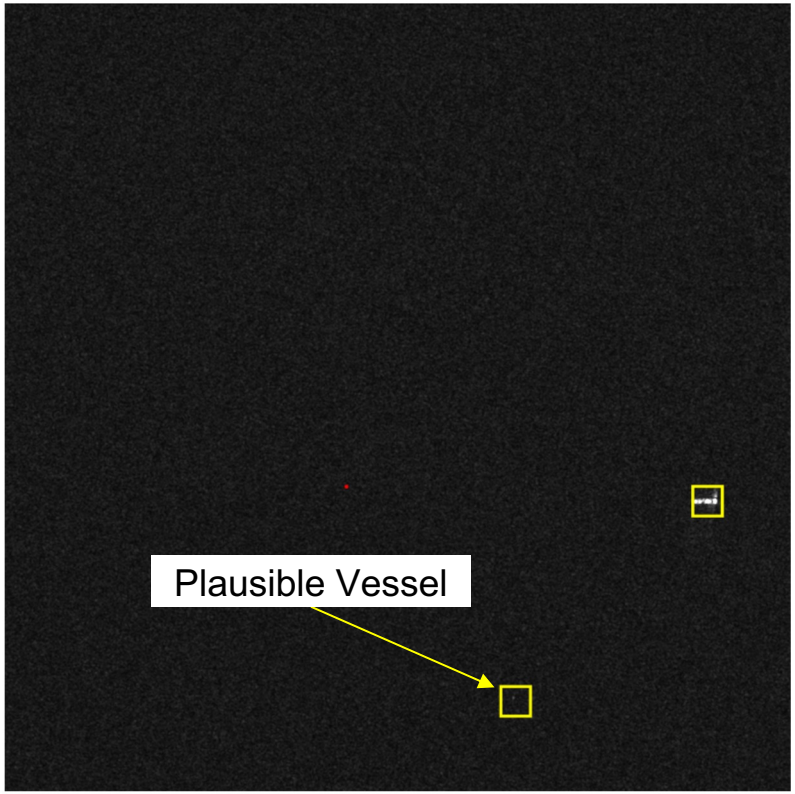
Compare Images: During Annotation



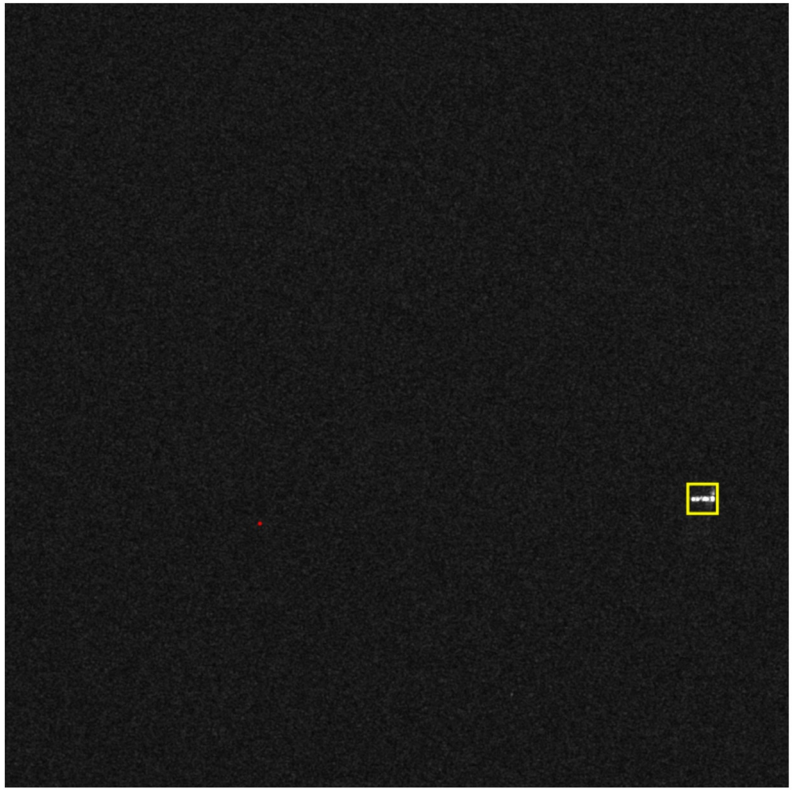
Compare Images: During Annotation

- Annotated ~5K vessels in ~10K windows
- Focus on high-quality annotations over quantity
- Blind annotation round of 50 windows in our dataset and xView3
    - Agreement: 90% in ours, 52% in xView3

Compare Images: During Annotation

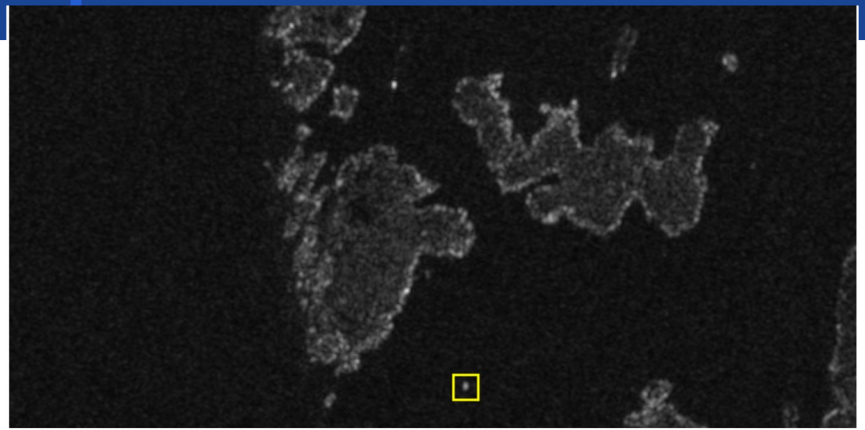


Our Dataset

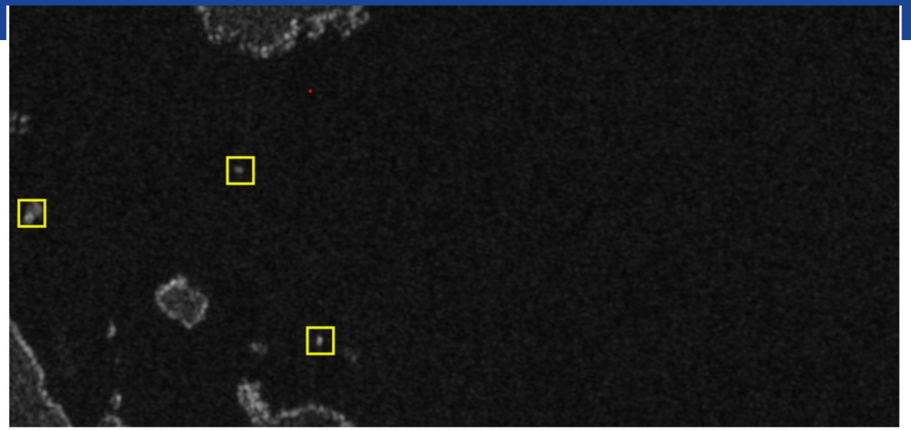


New Annotation Round

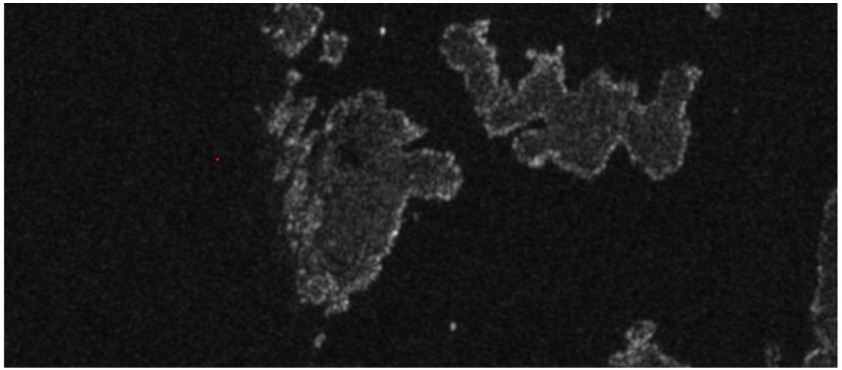
Compare Images: During Annotation



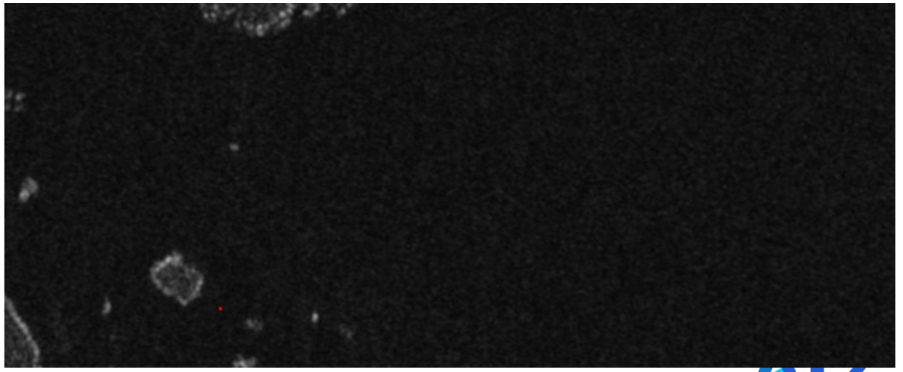
xView3 Dataset



xView3 Dataset

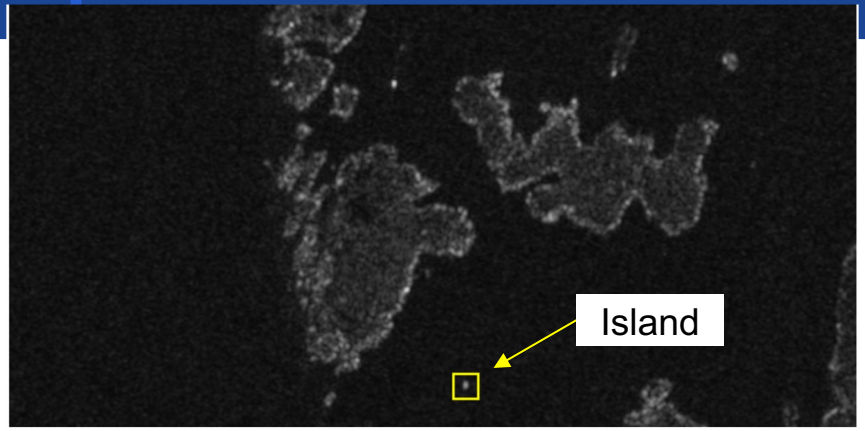


New Annotation Round

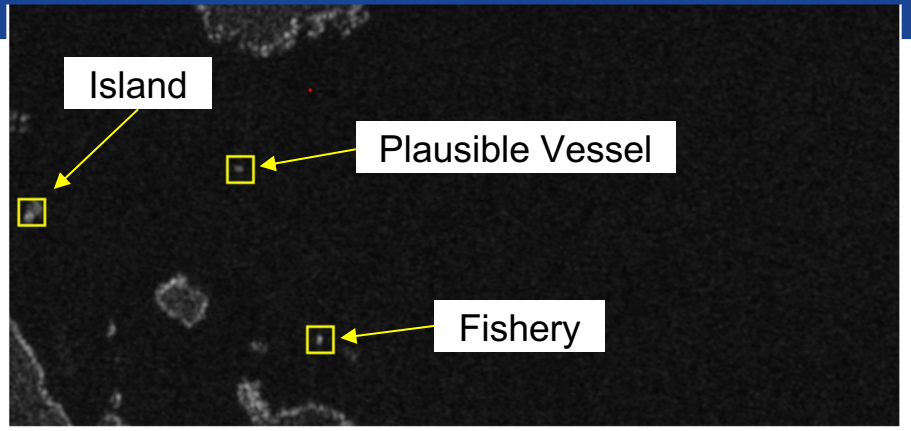


New Annotation Round

Compare Images: During Annotation



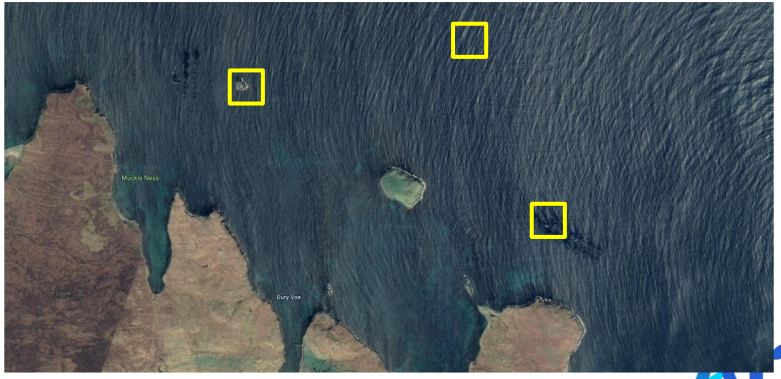
xView3 Dataset



xView3 Dataset

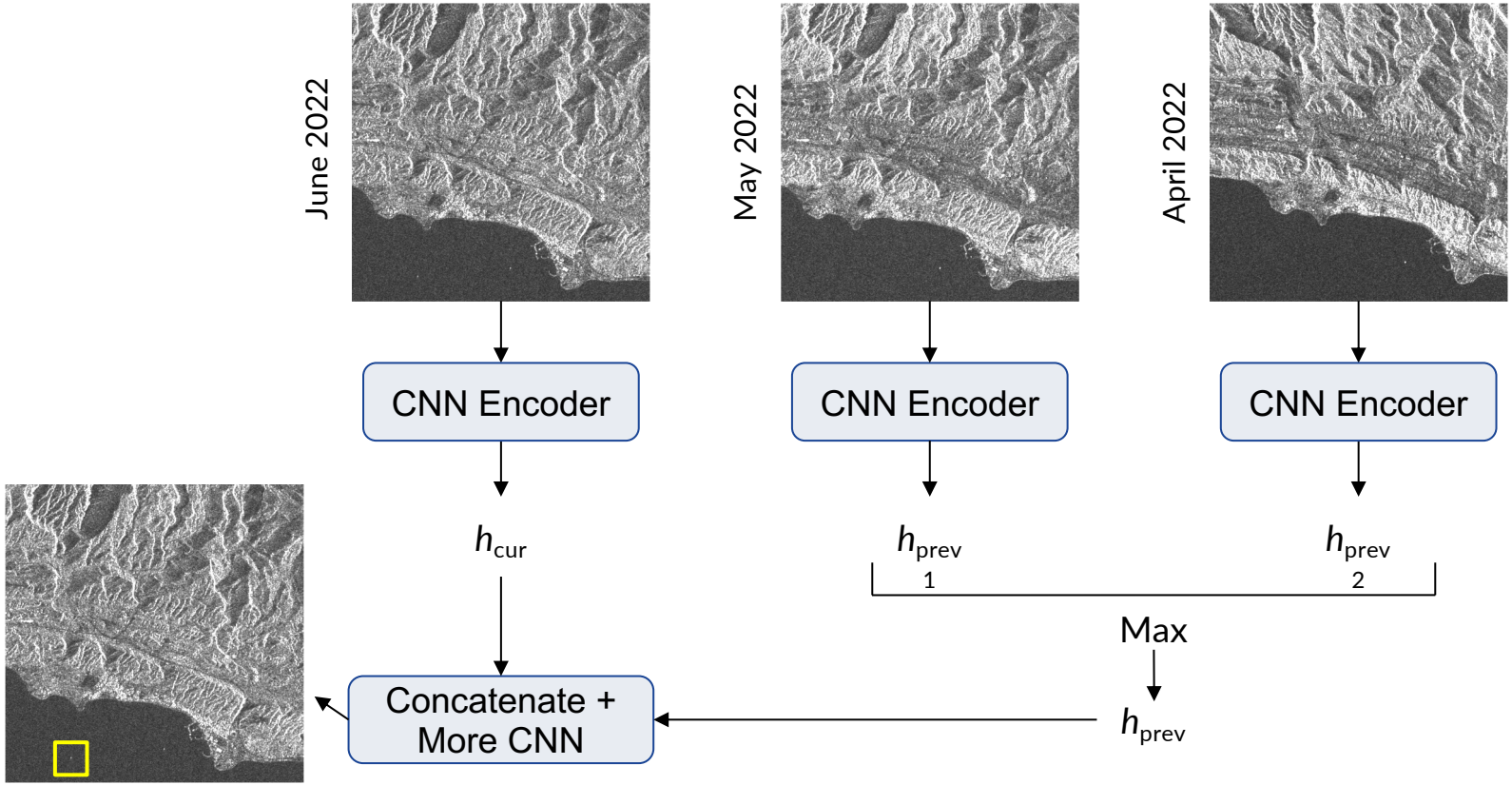


Google Maps Comparison

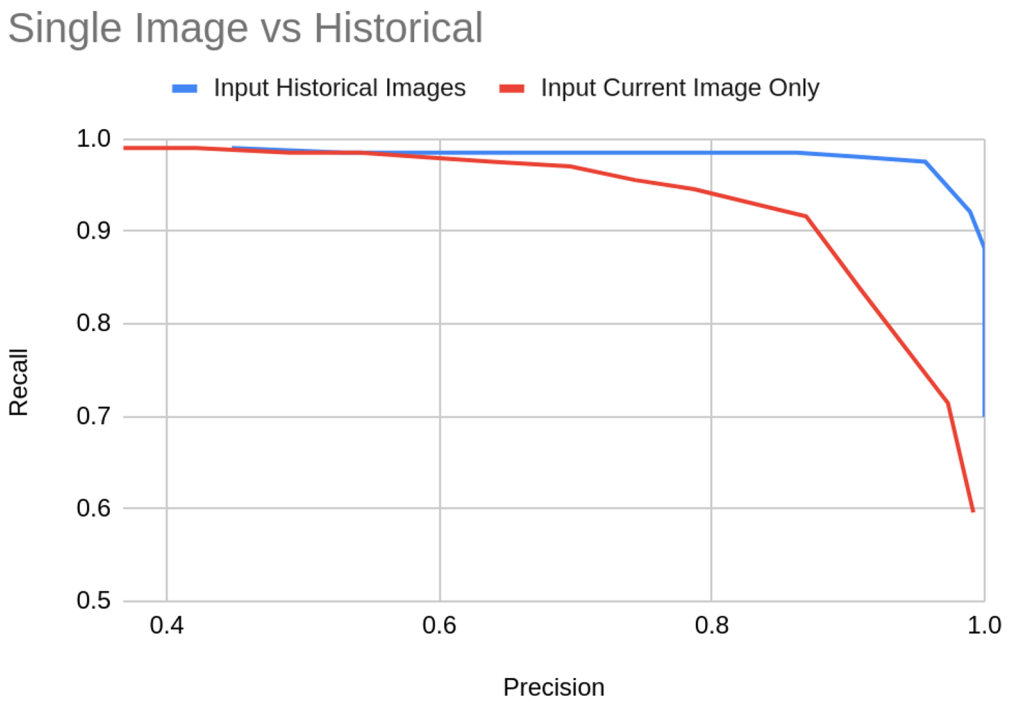


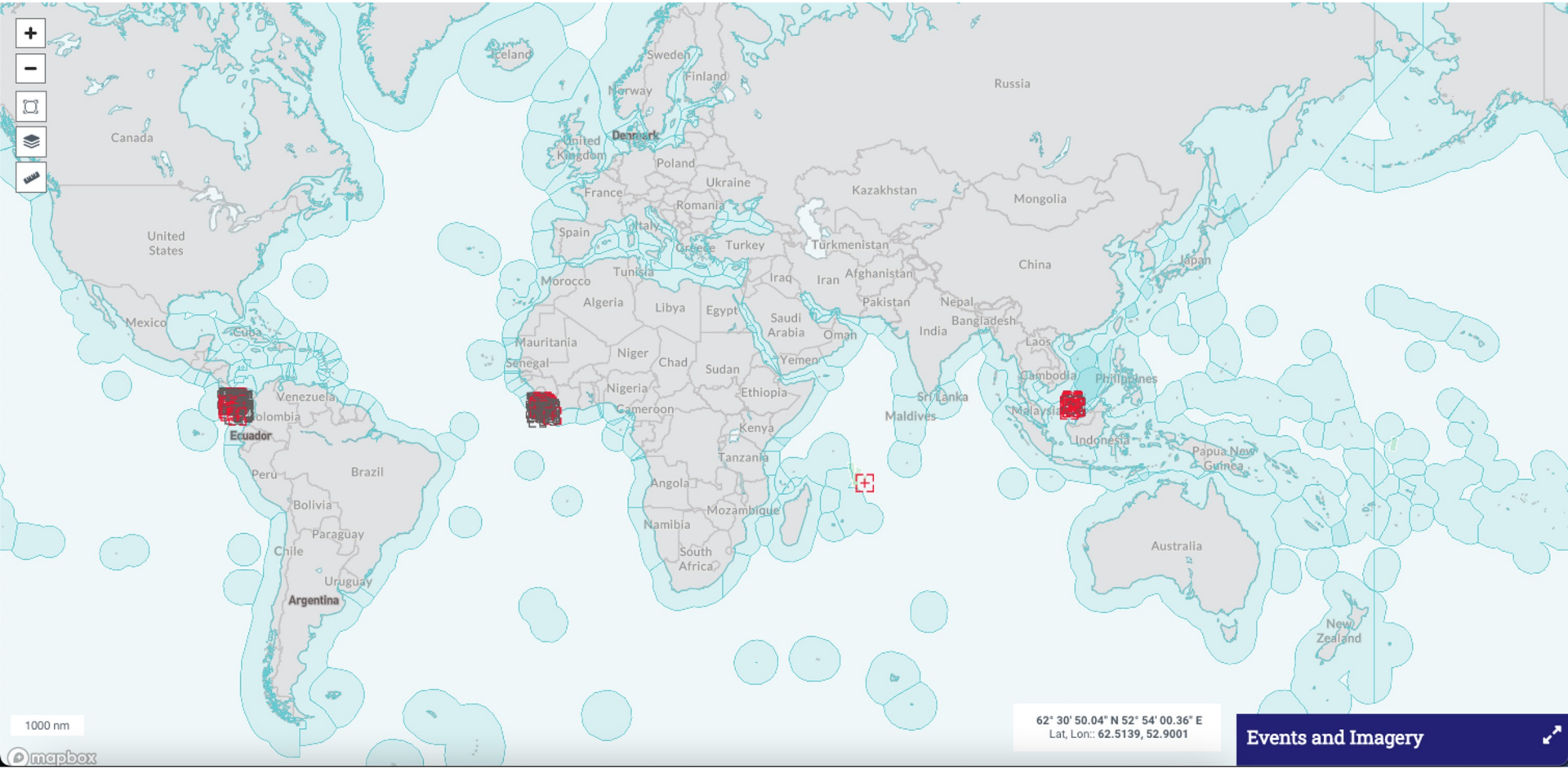
Google Maps Comparison

Compare Images: In the Model

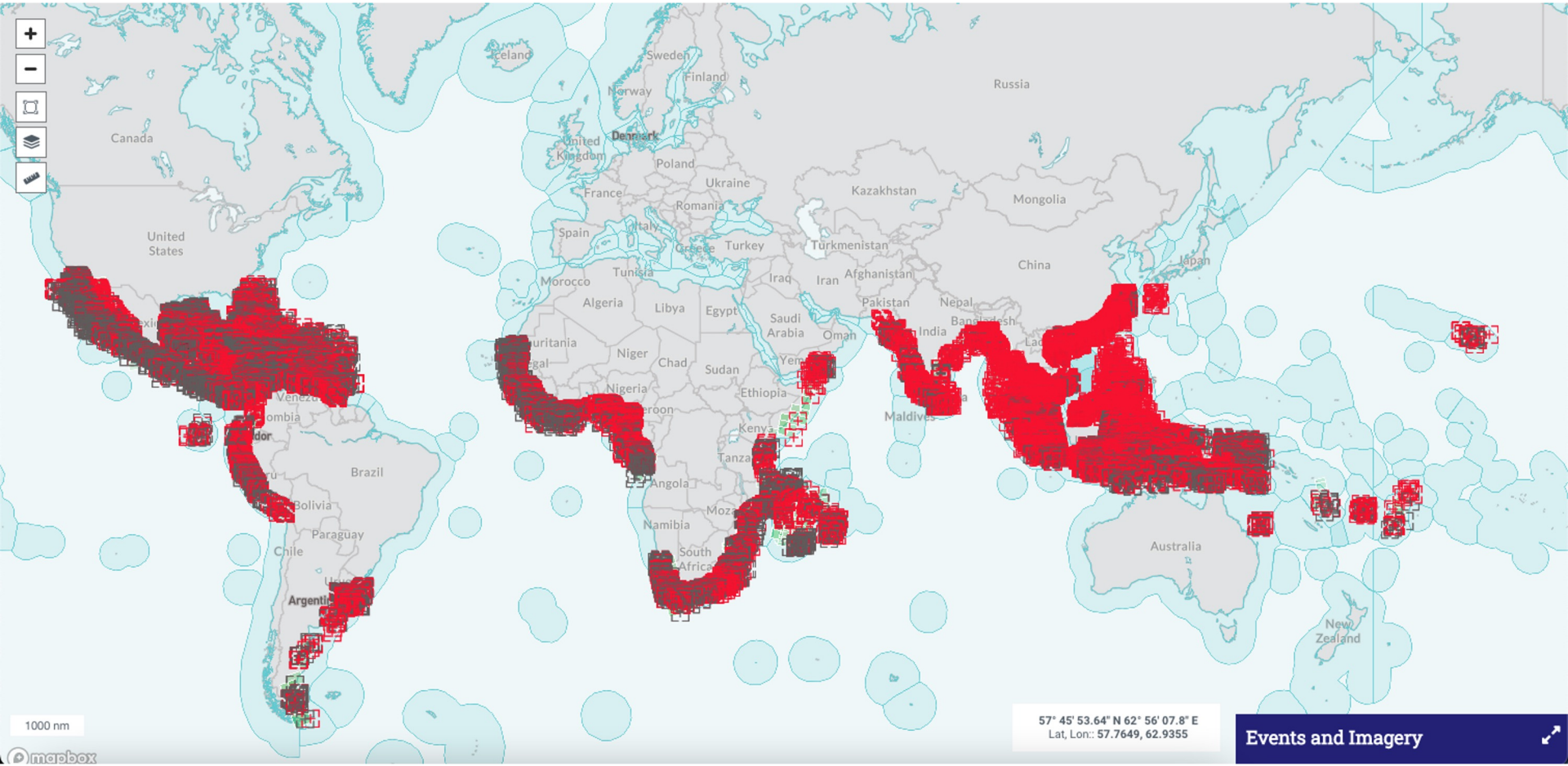


Compare Images: How important is it?





RADARSAT-2 only (June 1- 30)



SENTINEL-1 only (June 1- 30)

SKYLIGHT
A product of AI2

Find vessel by Name, MMSI, IMO or Call sign

Notifications

My Skylight

Areas | Events and Imagery (1) | Filters (1) Clear × | Save as Alert | Past month Clear ×

Events Clear ×

Satellite Radar Imagery (1) Clear ×

Estimated Vessel Length (m)

Minimum Maximum

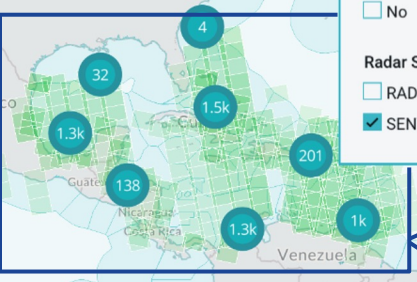
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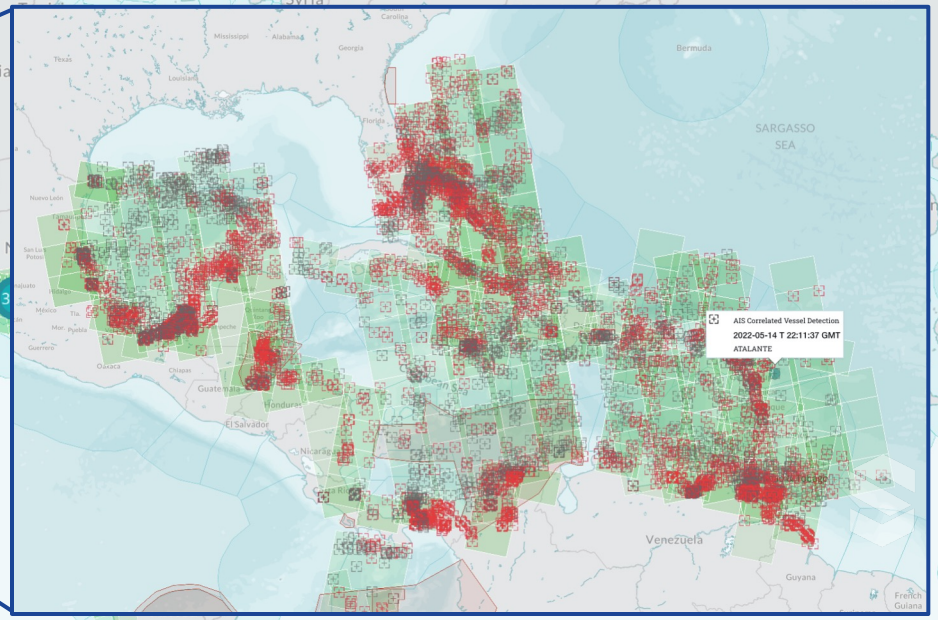
Correlation with AIS

- [ ] Yes
- [ ] No

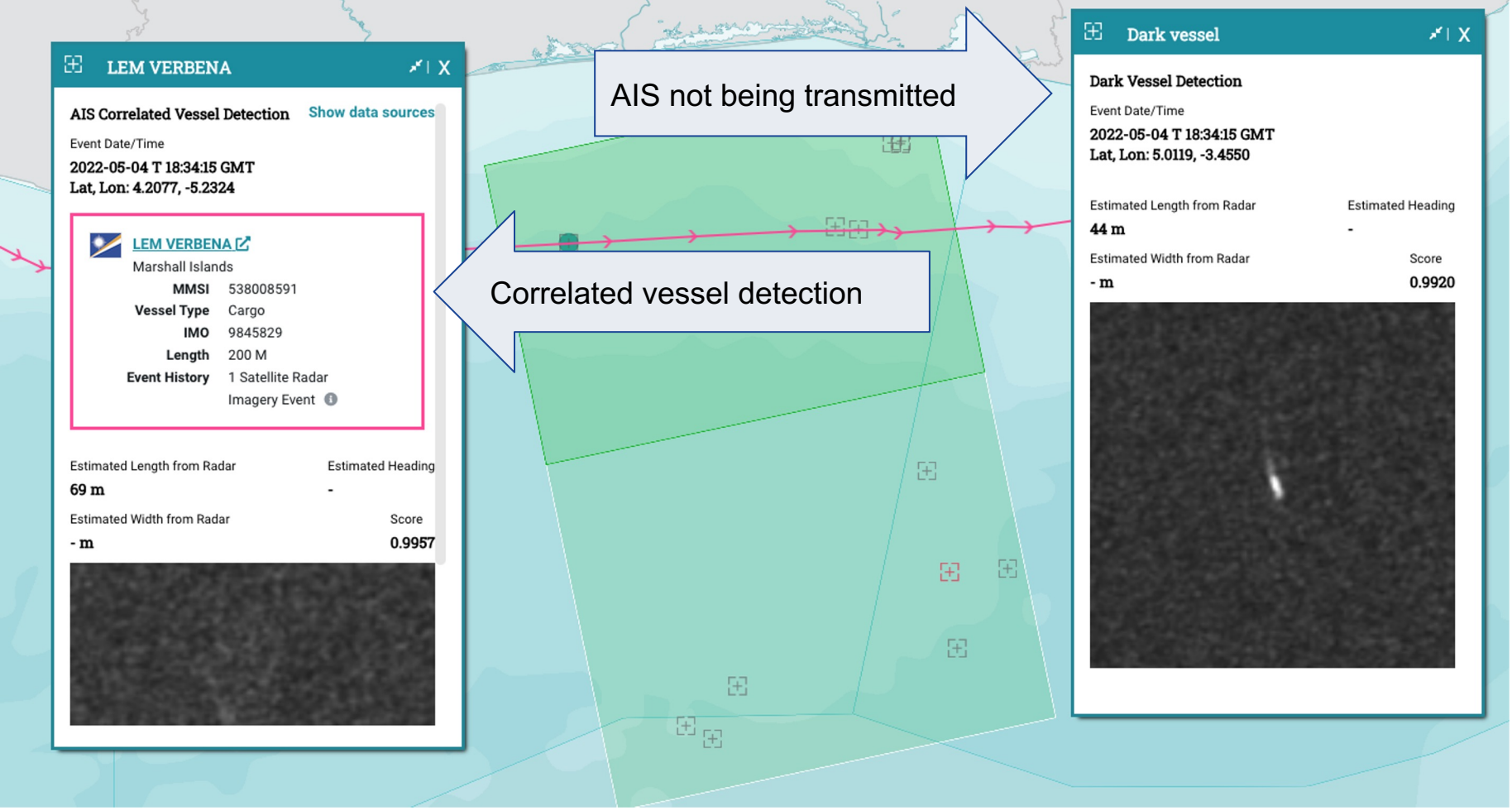
Radar Source

- [ ] RADARSAT-2
- [x] SENTINEL-1





Denmark
Latvia
Lithuania
Belarus
Poland
Germany
Czechia
Ukraine
Austria
Croatia
Romania
Serbia
Bulgaria
Italy
Greece
Turkey
Georgia
Azerbaijan
Kazakhstan
Mongolia
Uzbekistan
Kyrgyzstan
Turkmenistan
Tajikistan
Syria
China
United States
Colombia
Suriname
Brazil
Bolivia
Paraguay
Chile
SOUTH ATLANTIC OCEAN
Burkina Faso
Guinea
Ivory Coast
Togo
519
861
16
74
207
SARGASSO SEA
Bermuda
Venezuela
Guyana


LEM VERBENA
AIS Correlated Vessel Detection
Show data sources
Event Date/Time
2022-05-04 T 18:34:15 GMT
Lat, Lon: 4.2077, -5.2324
LEM VERBENA
Marshall Islands
MMSI 538008591
Vessel Type Cargo
IMO 9845829
Length 200 M
Event History 1 Satellite Radar Imagery Event
Estimated Length from Radar
69 m
Estimated Heading
-
Estimated Width from Radar
- m
Score
0.9957
AIS not being transmitted
Correlated vessel detection
Dark vessel
Dark Vessel Detection
Event Date/Time
2022-05-04 T 18:34:15 GMT
Lat, Lon: 5.0119, -3.4550
Estimated Length from Radar
44 m
Estimated Heading
-
Estimated Width from Radar
- m
Score
0.9920

"As Admiral Bennett, the Commandant of the Belize Coast Guard, stated during your visit, Skylight, Global Fishing Watch and SeaVision present a complete solution they have been waiting years for. I have no doubt that as a member of the Maritime Domain Awareness team for TRADEWINDS 2022, you have left a lasting impact on the region. ***You have elevated Belize's ability to*** *access timely vessel tracking data and* ***leverage for the first time high resolution satellite imagery coupled with machine learning to identify dark targets of interest in their waters."***

US Coast Guard Lieutenant Commander Richard Russell-



Hi Andrew, here is Toky from the National Center in Madagascar (CFIM). We received images from radar on Skylight this morning (I'm off during week end 😜). I think their are suspecious fishing vessels practicing IUU fishing inside our EEZ. We'll share the informations with CSP today. Thanks for the platform Skylight, it's very helpful.

12:40 AM



Hey Derrick, here's a look at the last week of satellite radar imagery from SENTINEL-1. All the red icons are dark vessels. This will be available in the platform for all users in the coming week.

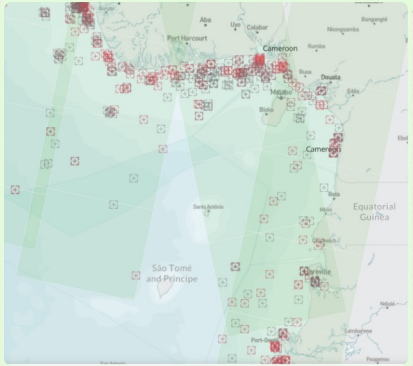
9:51 AM ✓✓

TODAY

More dark vessels in the Bight of Benin 2:56 PM

Very useful intel 2:56 PM

Looks closer to coast so could be investigated by coastal navies and CGs 2:57 PM



A little closer look 3:07 PM ✓✓

This capability is going to be regularly available, about one image per week or so 3:08 PM ✓✓

Fantastic 3:11 PM

New Areas of Exploration

What's Next?

- Sentinel-2 A & B: Optical Imagery from ESA
- Landsat 8 & 9: Optical Imagery from USGS
- Visible Infrared Imaging Radiometer Suite (VIIRS) from NOAA

Sentinel-1 + Sentinel-2 + Landsat = 37% of ocean covered 1x/month; 10% covered 8x/month

VIIRS

VIIRS Vessel Detection

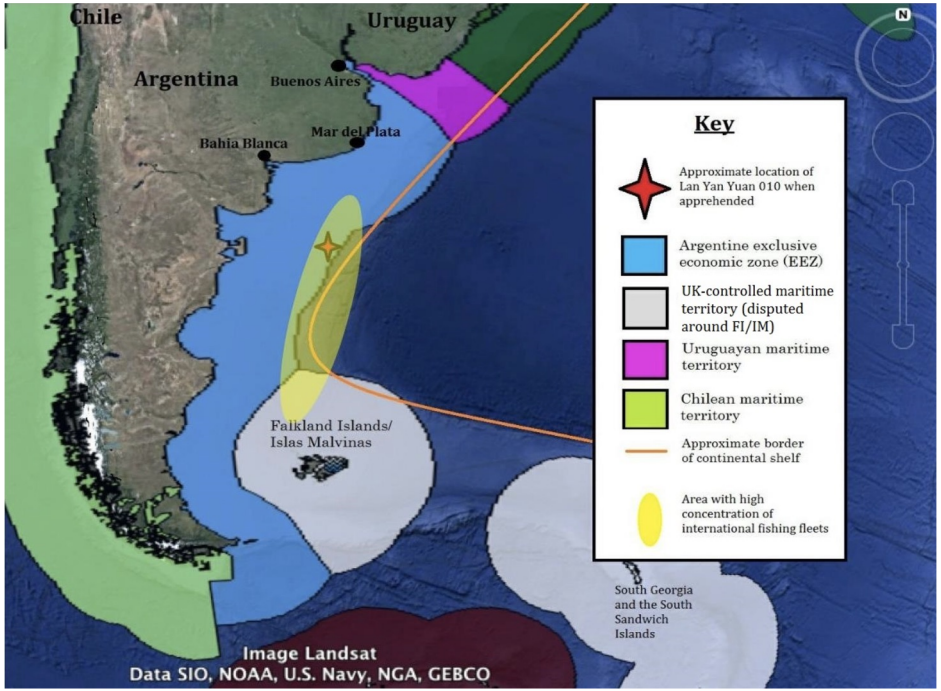
- Visible Infrared Imaging Radiometer Suite (VIIRS) - launched on 2 satellites in 2011 and 2017
- DN band can be used to detect lights from more than just cities.





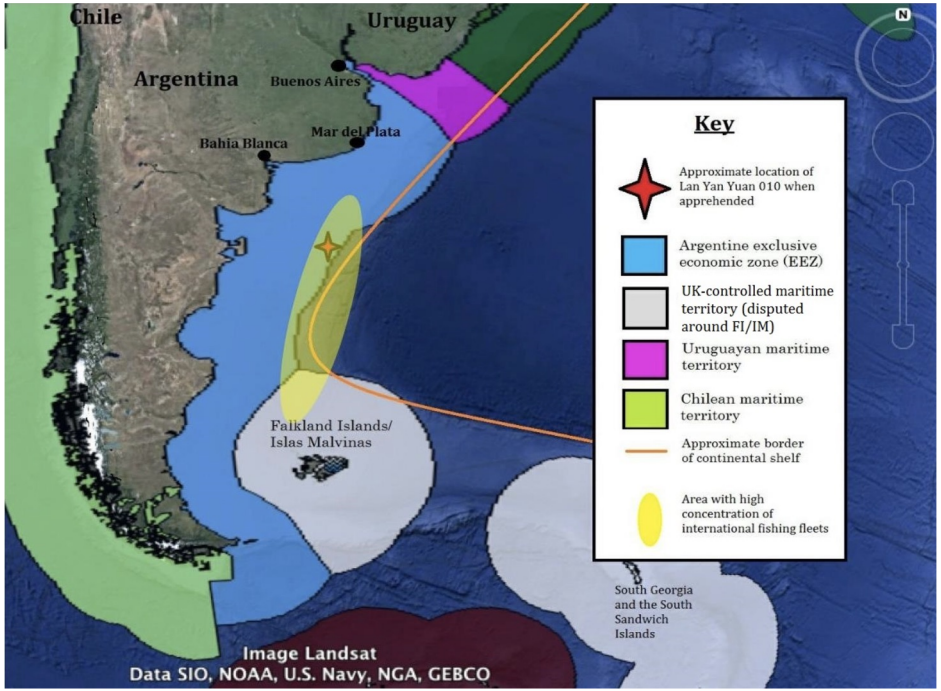


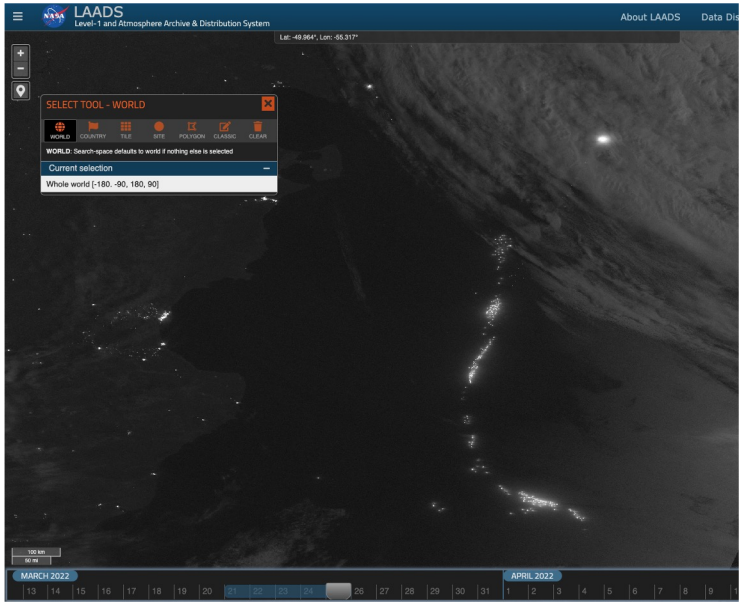
VIIRS


Chile
Uruguay
Argentina
Buenos Aires
Bahia Blanca
Mar del Plata
Falkland Islands/
Islas Malvinas
South Georgia
and the South
Sandwich
Islands
Key
Approximate location of Lan Yan Yuan 010 when apprehended
Argentine exclusive economic zone (EEZ)
UK-controlled maritime territory (disputed around FI/IM)
Uruguayan maritime territory
Chilean maritime territory
Approximate border of continental shelf
Area with high concentration of international fishing fleets
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO



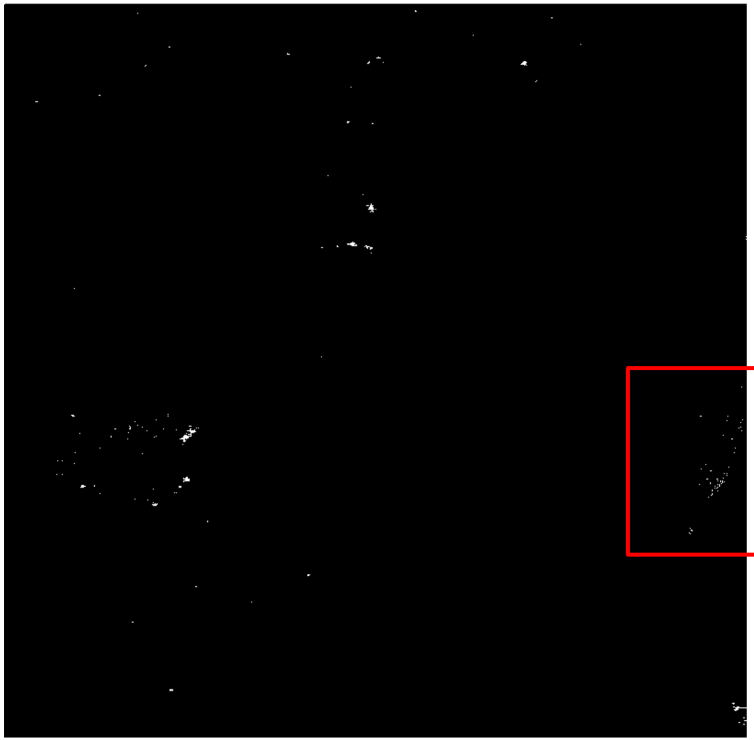
VIIRS


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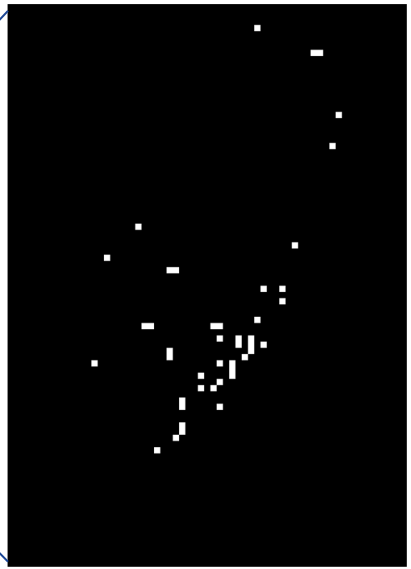

LAADS
Level-1 and Atmosphere Archive & Distribution System
About LAADS
SELECT TOOL - WORLD
WORLD
COUNTRY
TILE
SITE
POLYGON
CLASSIC
CLEAR
WORLD: Search-space defaults to world if nothing else is selected
Current selection
Whole world [-180, -90, 180, 90]
MARCH 2022
APRIL 2022

VIIRS

Blue Hole at Night



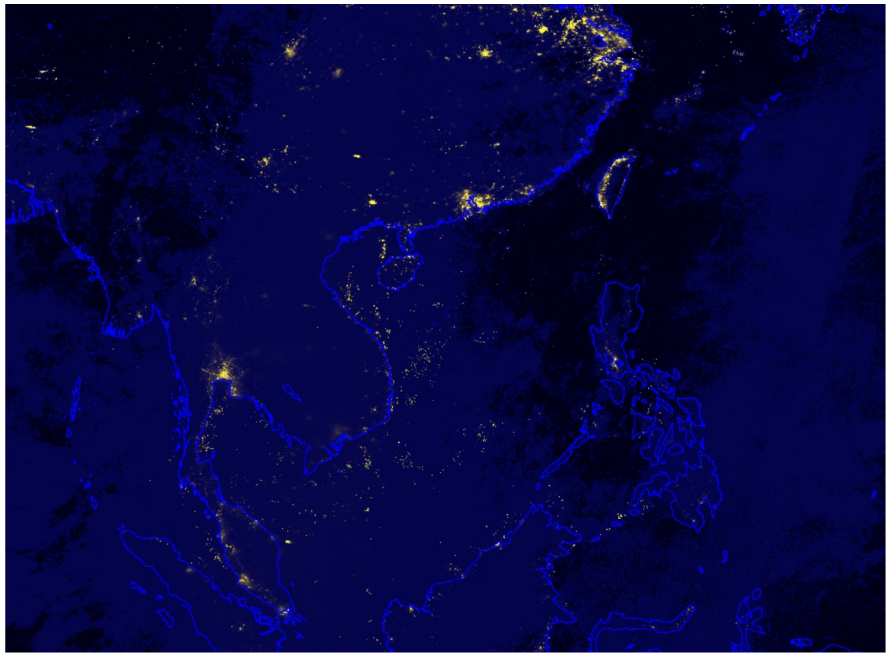
Zoomed in Vessels



VIIRS

Challenges

- Poor spatial resolution - 750m ppx
- Lack of well defined Ground truth for training ML models and method evaluation
- Dependent on weather conditions and stray lights



Solution

- Classical Heuristic CV methods to roughly detect light sources
- Training an ML detection model on pseudo labels