

Guardians of the Coast: ship Monitoring and Coastal Mapping

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While global oceans are monitorable using Synthetic Aperture Radar (SAR), optical imagery, and Automatic Identification System (AIS) data, most implementations remain limited in scale – focused on academic/commercial demonstrations or restricted military domains. This project bridges that gap, operationalizing a scalable and impactful global SAR-based monitoring system. By integrating ESA Copernicus Sentinel-1 data with advanced detection, classification, and deep learning techniques, we deliver persistent, daily coverage of the world's coastal and maritime environments – turning demonstration into real-world decision support.

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Data Sources & Coverage

Main Methodology

Deep Learning

Use Cases

Static Object Detection

Optional Coastal Mapping

Optional RFI Mitigation

Impact and Outcomes

Spatial Scope: Most global coastal regions are covered by Sentinel-1

Temporal Scope: 2017 to present (historic + near real-time)

Data Volume: Up to 5000 Sentinel-1 SAR scenes processed daily

Complementary Data: AIS tracks (terrestrial and satellite-based), Global static maritime infrastructure (wind farms, oil rigs), IHO vector coastlines and bathymetric features. Known hazards: shoals, sandbanks, islands

Ship Detection Pipeline (ENVI SARscape)

- Adaptive thresholding + CFAR filtering
- Land masking and clutter suppression
- Multi-polarization fusion (VV/VH)
- Detection of both moving and static maritime targets

Doppler Velocity Compensation for AIS Matching

- Inputs:** AIS position, Sentinel-1 satellite state vector
- Zero-Doppler estimation** (solving Range-Doppler-Height equation) / **Radial velocity** / **Azimuth shift**
- Map-space projection** of AIS correction vector for precise SAR-AIS fusion

Using TensorFlow-based models trained on SAR-detected ships with matched AIS labels:

- Attributes extracted:** heading, length, width, hull shape
- Classification levels:** 4 primary ship classes, 17 extended ship types, static objects, anomalies
- Ongoing enhancement:** Leveraging global AIS data to mitigate regional biases (e.g. US/Europe-centric training sets)

Detection of non-AIS vessels ("dark ships")

Tipping and cueing for high-resolution follow-up with SAR, RF or optical sensors

Exclusive Economic Zone (EEZ) Monitoring:

- Illegal, unreported, and unregulated (IUU) fishing detection
- Traffic density mapping for enforcement planning

Infrastructure Monitoring:

- Wind turbine installation progress and integrity checks
- Oil rig deployments and decommissioning

Seasonality & Leisure Vessel Analysis:

- Track recreational vessel hotspots
- Derive dynamic traffic charts for hydrographic offices

Wind Turbines:

- Persistent object detection across scenes
- Timeline-based construction tracking
- Quality control for offshore infrastructure mapping

Oil Platforms:

- Activity monitoring across regions (e.g., Gulf of Guinea, North Sea)
- Alerts for unregistered deployments

Coastal Mapping via Tidal SAR Extraction (optional)

- Automated coastline extraction using multi-tidal SAR acquisitions
- Mapping of:**
 - Uncharted islands and shoals
 - Rock outcrops
 - Beach landing gradients
- Supports civil protection, amphibious operations, and conservation planning

Radio Frequency Interference (RFI) Mitigation (optional)

- RFI artifacts in SAR imagery are filtered using spatial-spectral methods
- Geolocation of RFI emitters (e.g., radar jammers or missile defense systems)
- Enables cleaner detection of weak backscatter signals in cluttered RF environments

Impact and Outcomes

- Millions of **vessels** and **static objects** detected globally
- Long-term trend analysis** across 8+ years
- Discovered** previously unmapped offshore assets
- Data actively supports:**
 - Illegal fishing surveillance
 - Dark fleet identification
 - Offshore energy project monitoring
 - Updating global maritime charts

ALJAZEERA

How 'dark fishing' sails below the radar to plunder the oceans

Billions of dollars in illegal and unregulated fish supplies are mixed with legal catches and smuggled into the market.

FRANCE 24

In Iran, Chinese trawlers are damaging marine ecosystems and the livelihood of local fishermen

ENVIRONMENTAL JUSTICE FOUNDATION

ILLEGAL FISHING DESTROYS LIVELIHOODS

DEMAND TRANSPARENCY

npr

How foreign overfishing is driving migration crisis in Senegal

The Guardian

Figure 1: Dark vessels and their impact: Problem statement of various news outlets: Al Jazeera (28 Feb 2020), The Guardian (26 Oct 2022), NPR (6 Feb 2023), France 24 (29 Jul 2020), Environmental Justice Foundation (11 Jun 2021)

Slant Range Intensity

Reference DEM with Land Mask

DEM Geocoded Intensity

Ship Detection & AIS Matching

optional AIS Data (CSV Format)

Geocoded Land Mask

Figure 2: SAR ship & maritime object detection cycle

Ship detections per region

Ship detections by year

Number of static assets

Number of ship detections

Ship detections by month

Number of SAR scenes

Number of static detections

Ship detections by country

Map overview of the east-Mediterranean

Figure 3: SAR ship detection dashboard and map overview of the east-Mediterranean

Static object detection and deep learning results of the North Sea

Figure 4: SAR ship detection based on deep learning: Basic ship types and extended ship types, including ship length, width and heading

SAR coastline / tidal extraction: Extract a series of coastlines detected in the input images, grouped by tide height

Figure 7: Radio Frequency Interference (RFI) detection and mitigation

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