

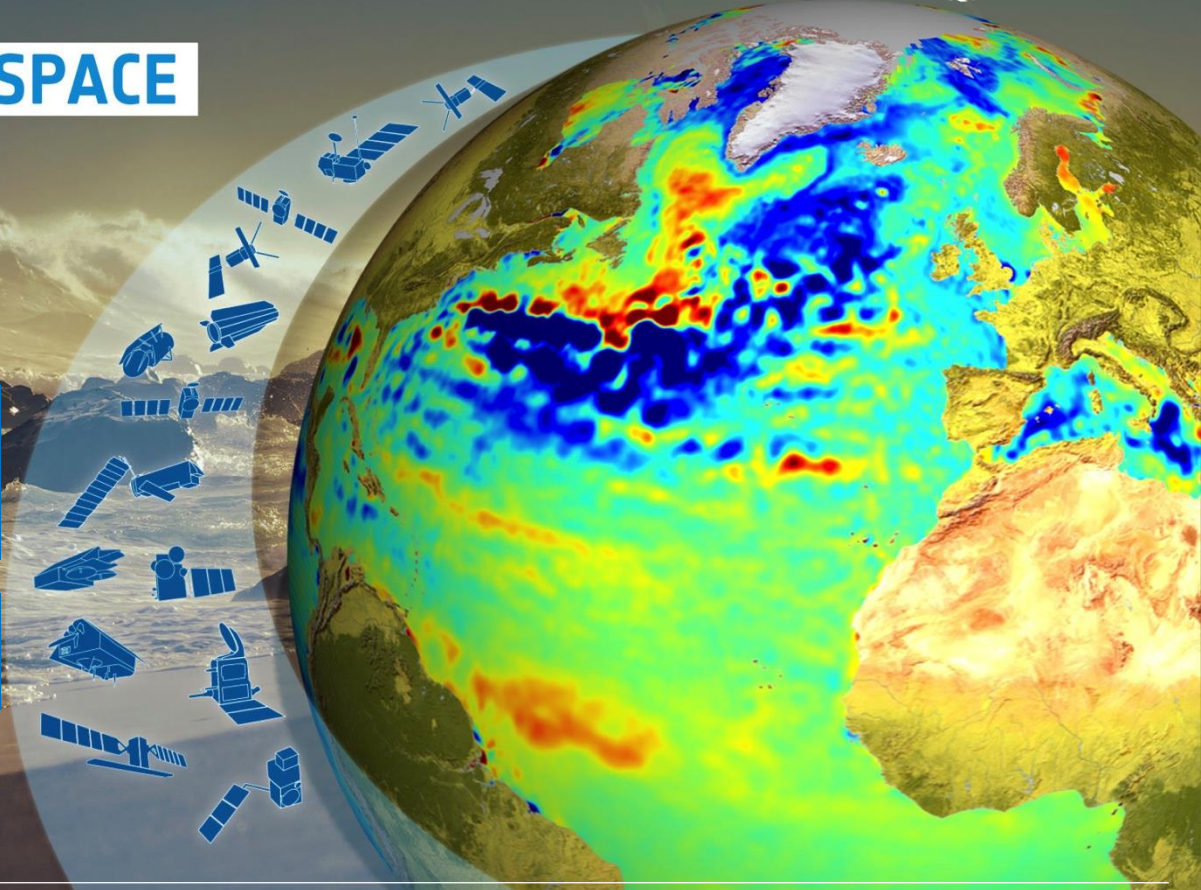
→ ATLANTIC FROM SPACE WORKSHOP

23–25 January 2019
National Oceanography Centre
Southampton, UK

Advancements in Vessel
Monitoring based on
Sentinel-1 and AIS data

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- Synthetic Aperture Radar (SAR) - privileged place in vessel monitoring:
 - Quasi all-weather and day/night observation capacity.
 - Non-cooperative systems.
 - Copernicus Sentinel-1: systematic acquisitions over areas of maritime interests, open access policy data, complex dual polarization data, etc.
- Automatic Identification System (AIS) data flows:
 - Cooperative systems.
 - Comprehension of regular maritime traffic patterns.
 - Validation/cross-comparison.

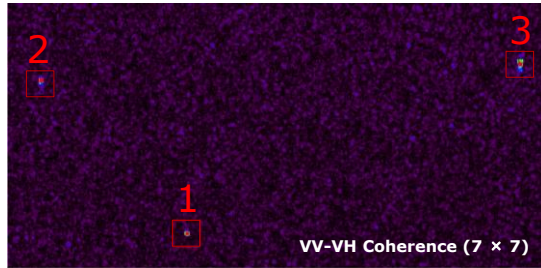
- SAR-based ship detection:
 - Complex coherence between two polarization channels.
 - Comparison with intensity detections (Constant False Alarm Rate).
- SAR-AIS target comparison:
 - Accurate interpolation of AIS positions.
 - Quantitative and qualitative results.
 - Three test cases (English Channel, North Sea, Mexico).
- Coastline delineation from SAR imagery.
- Conclusions.

SAR-based ship detection

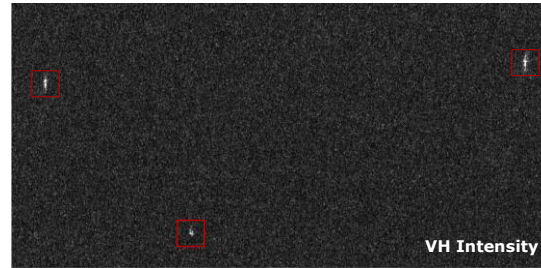
- Dual-polarization complex coherence coefficient:

$$C_{VV-VH} = \langle S_{VH} S_{VV}^* \rangle$$

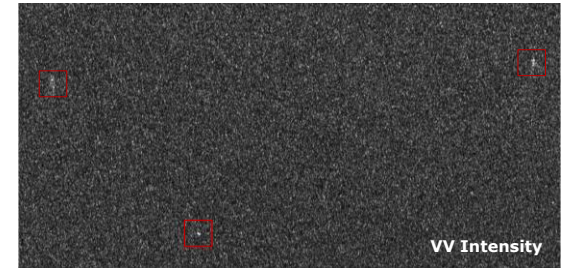
- Vessels signatures are usually highly correlated between co- and cross polarization channels whereas the sea-surface presents low correlation values.
- Adaptive thresholding depending on SAR swath.



1)
Sailing Vessel
28.3m × 6.66m



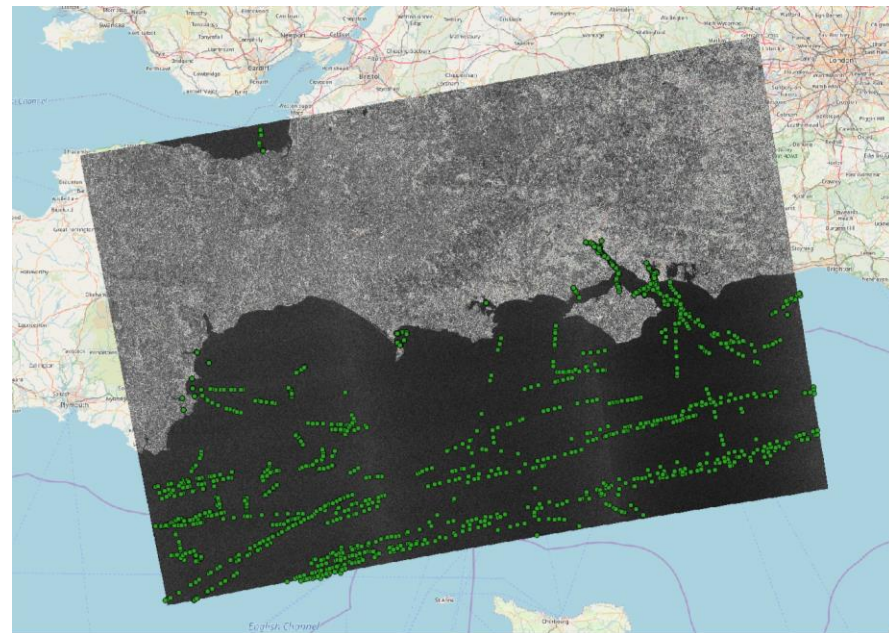
2)
Tug
32.04m × 11.65m



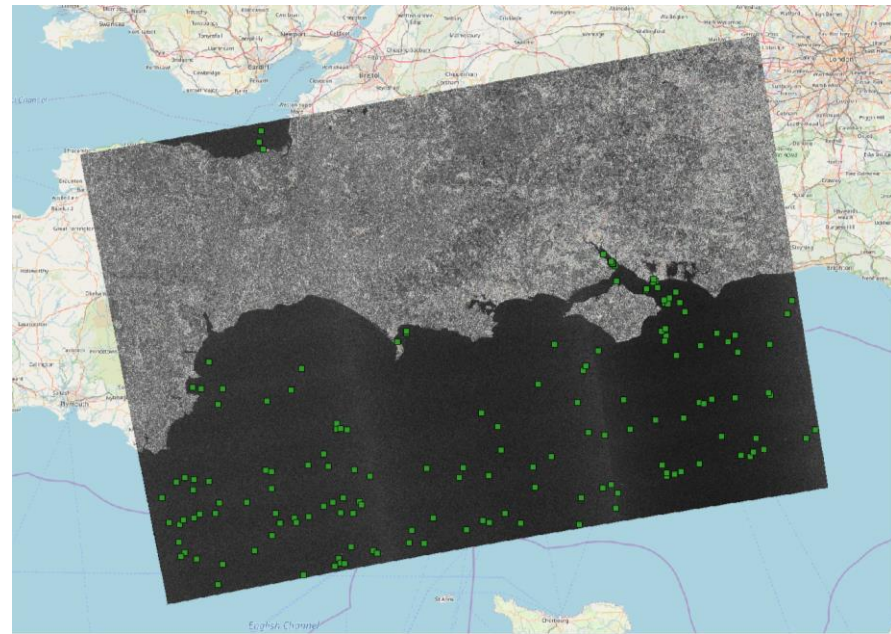
3)
Tug
26.16m × 8.5m



- AIS dataset containing positions in a time range of ± 15 mins with respect to SAR acquisition time T_{SAR} .
- AIS positions are interpolated in order to predict the position at T_{SAR} :
 - extract trajectories for ships that reported more than one position.
 - the ship position is predicted for a time interval that equals the difference in seconds between T_{SAR} and the AIS timestamp.
- the projected AIS positions are compared with SAR detections within an iterative methodology based on minimizing the SAR-AIS Euclidean distance.

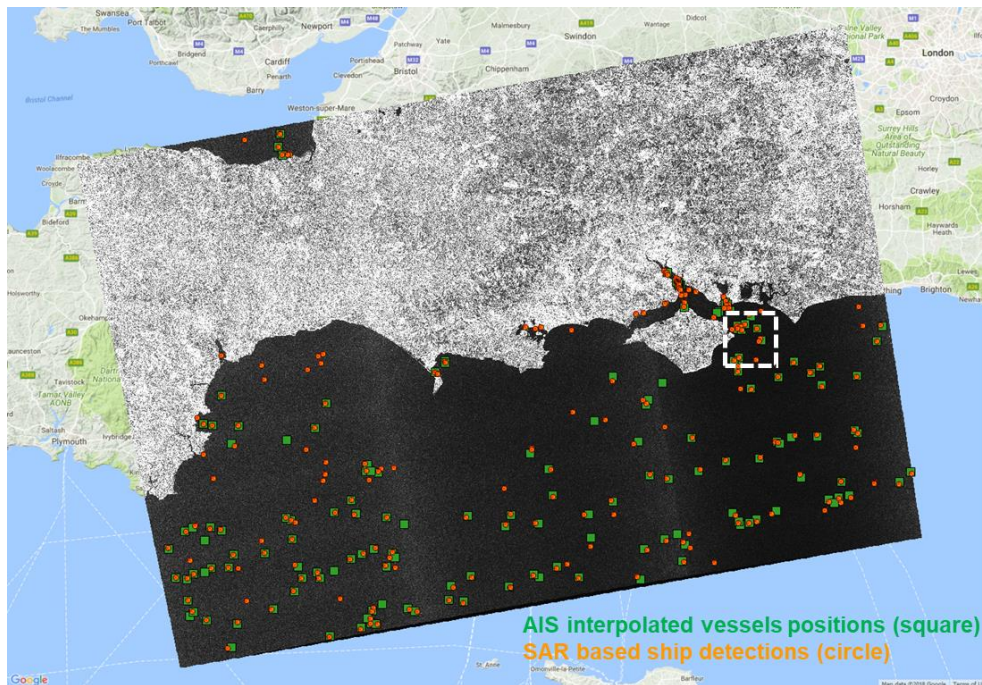


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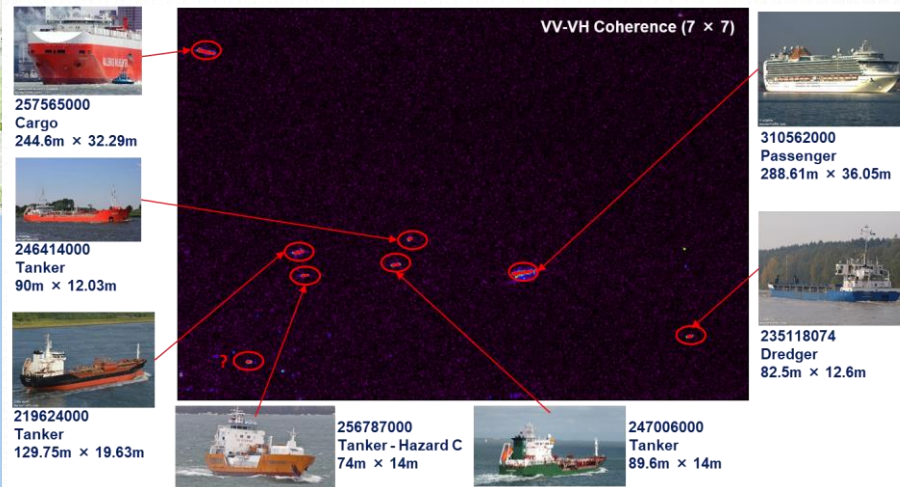


SAR-AIS cross-comparison

- Qualitative results - English Channel

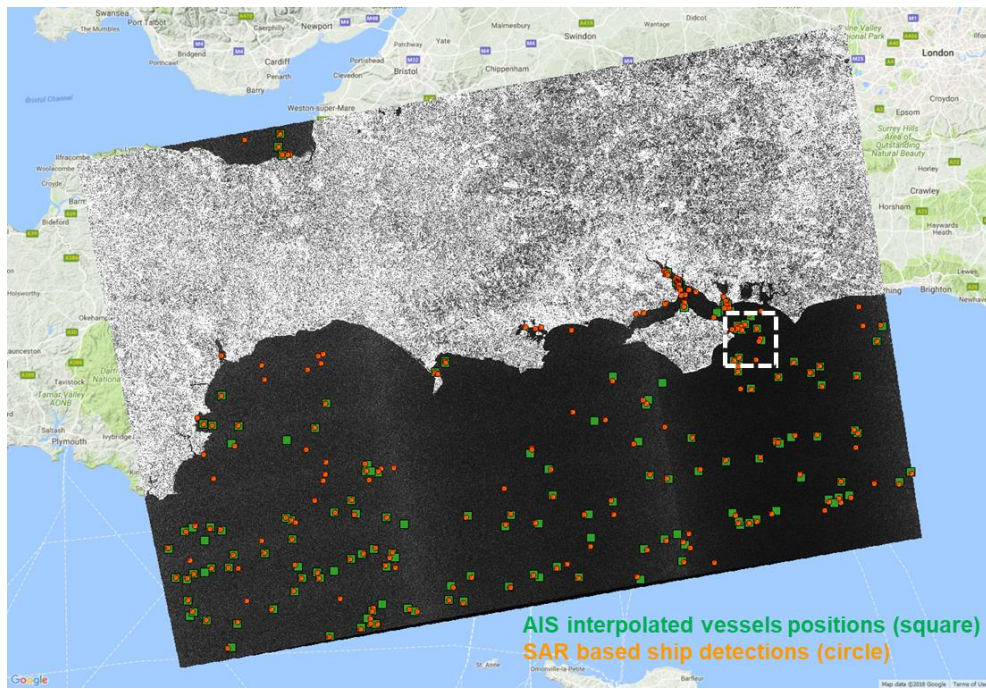


Sentinel-1 image, IW mode (20 m spatial resolution)

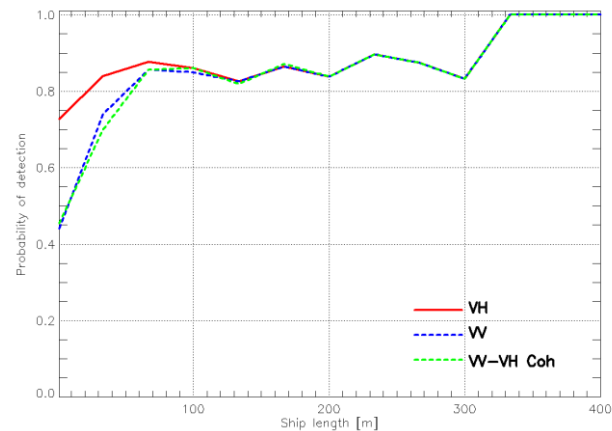


SAR-AIS cross-comparison

- Quantitative results - English Channel



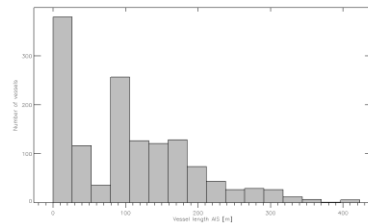
Statistical analysis of the detection performances derived for 2000 vessels extracted from 10 SAR images and the corresponding AIS data flows.



Intensity VV/VH: $P_{fa} = 10^{-3.2}$

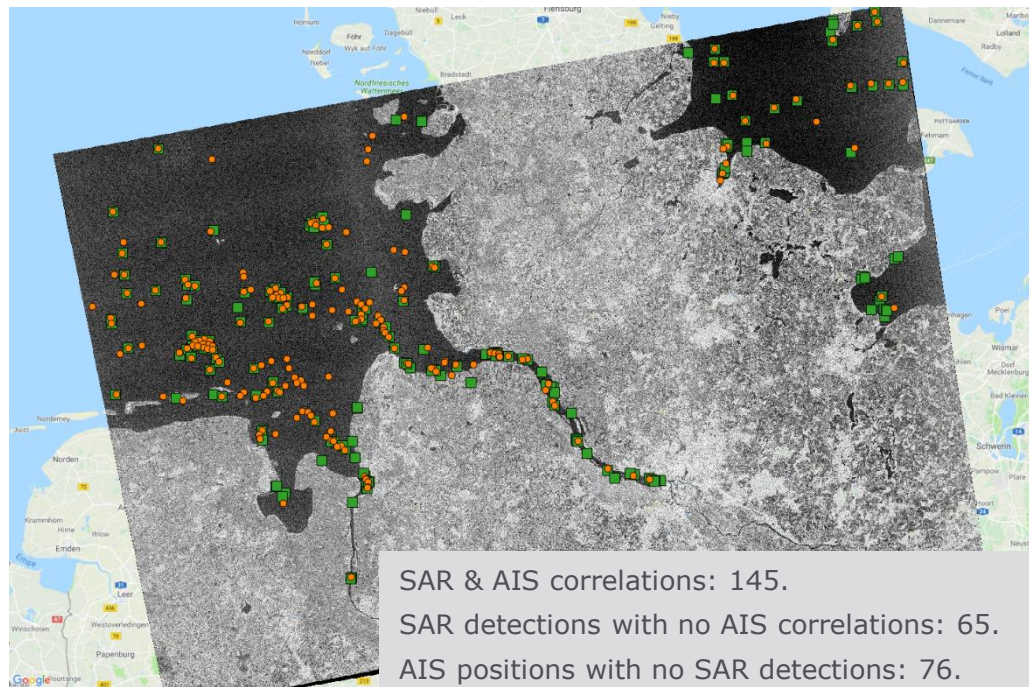
Coherence VV-VH: $P_{fa} = 10^{-3.3}$

AIS non-correlations: 15-20%.



SAR-AIS cross-comparison

- Quantitative results – North Sea



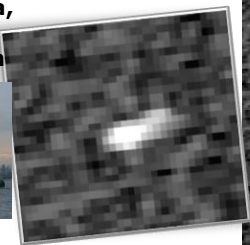
Ramona Pelich | Atlantic from Space Workshop | 23-25/01/2019 | Slide 9

SAR-AIS cross-comparison

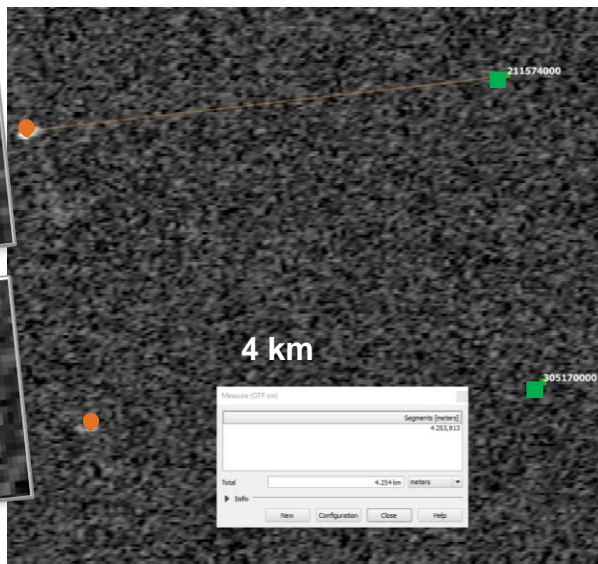
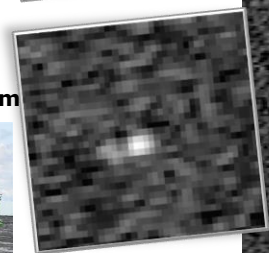
- Interpretation of SAR & AIS non correlations – North Sea

SAR and AIS distance inaccuracy.

Antigua Barbuda,
Cargo
80.28m × 12.5m



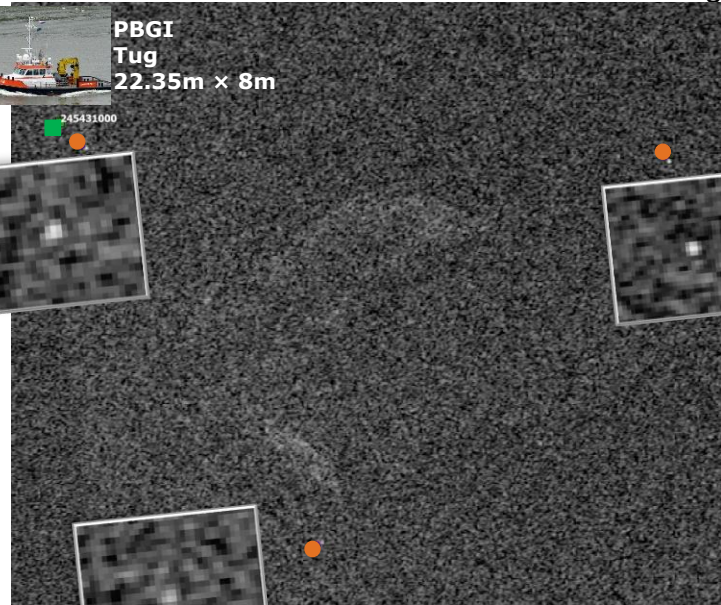
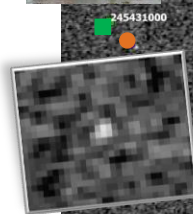
DIBL
Tug
78.29m × 16.53m



Vessels without AIS? / AIS not sent in the 30 min range?

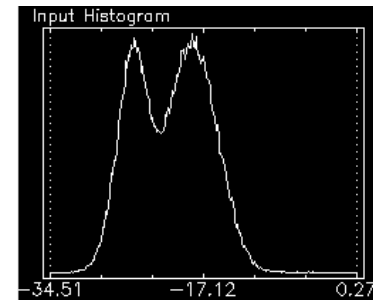
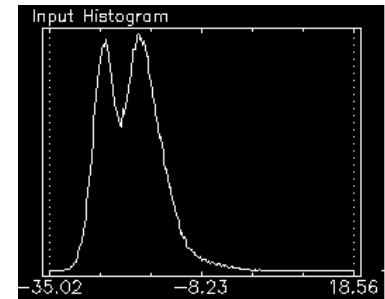
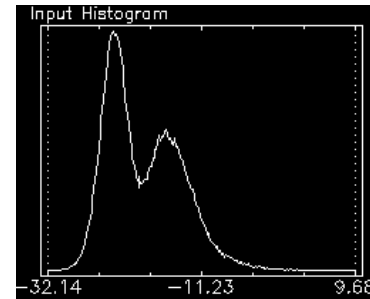
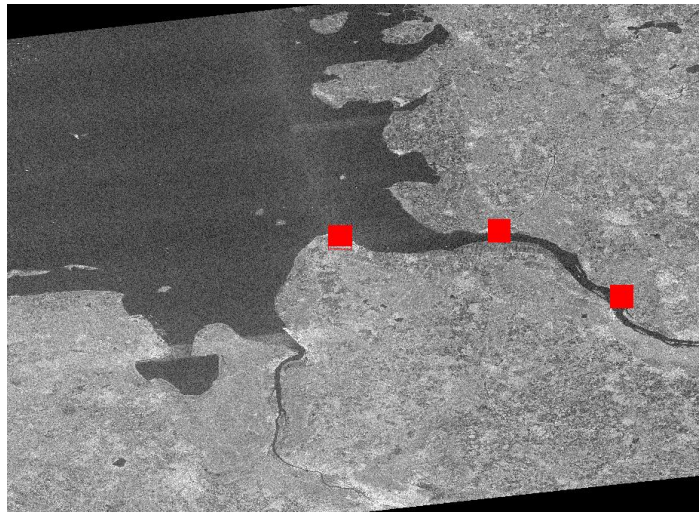


PBGI
Tug
22.35m × 8m



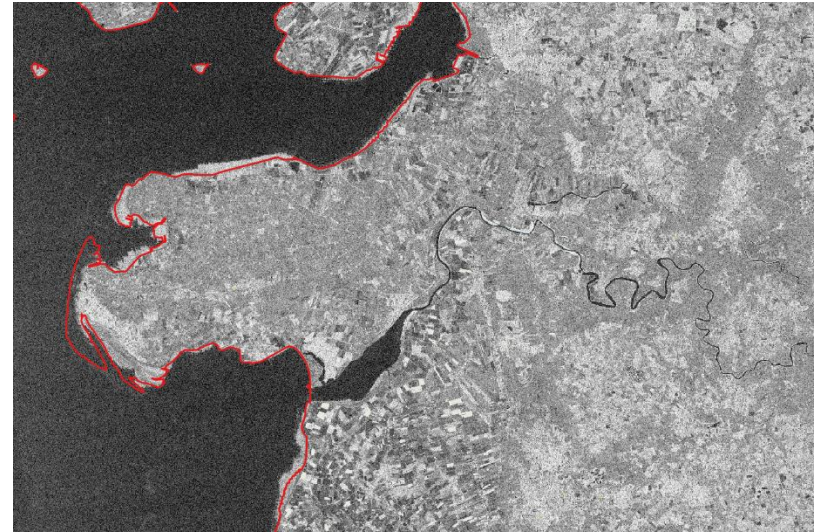
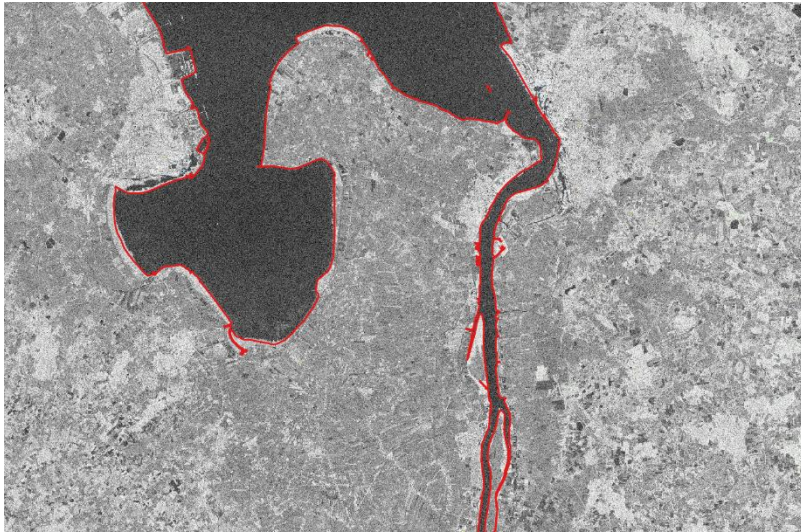
SAR-based coastline delineation

- In SAR images, the sea and land classes are represented with distinctive backscattering values.
- Estimate a general parametrization of the bimodal distribution that characterizes sea-land areas.
- Classify the image in two classes, land and sea, by using a thresholding and region growing procedure.



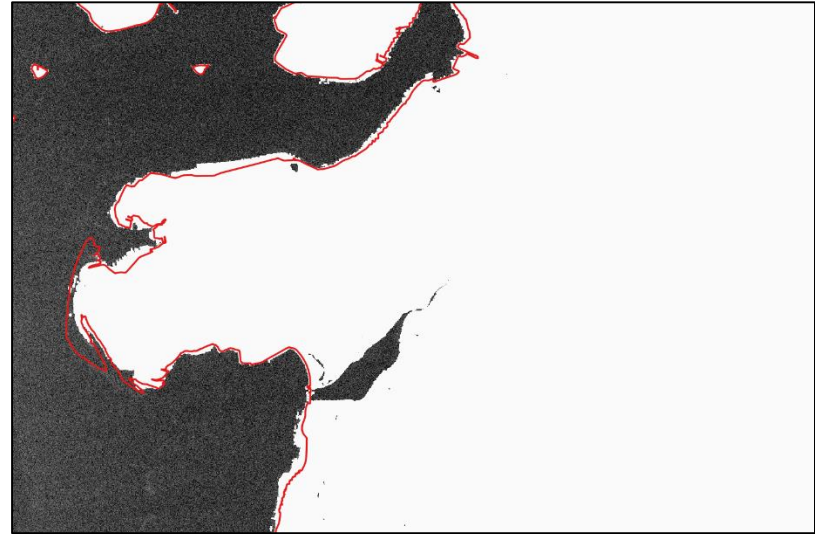
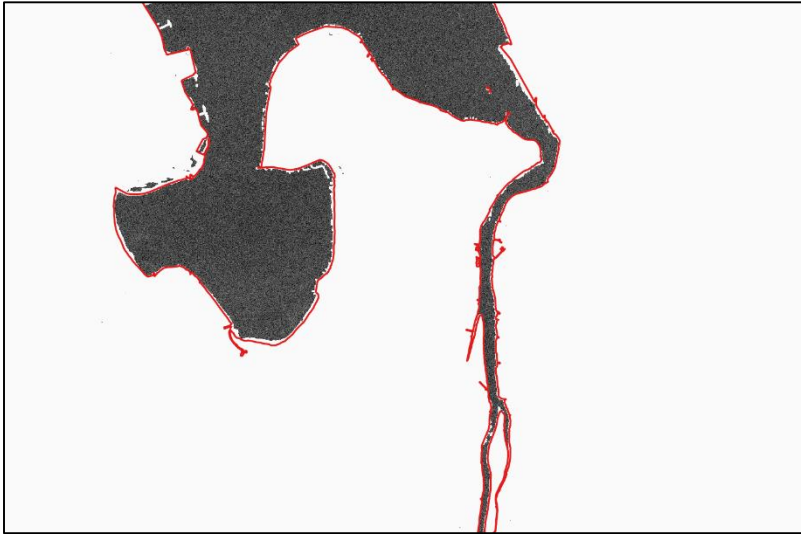
SAR-based coastline delineation

- Accurately delineate the coastline with respect to the SAR image scene.
- Masks structures belonging to harbour area.
- Makes it possible to detect vessels located near the coastline.



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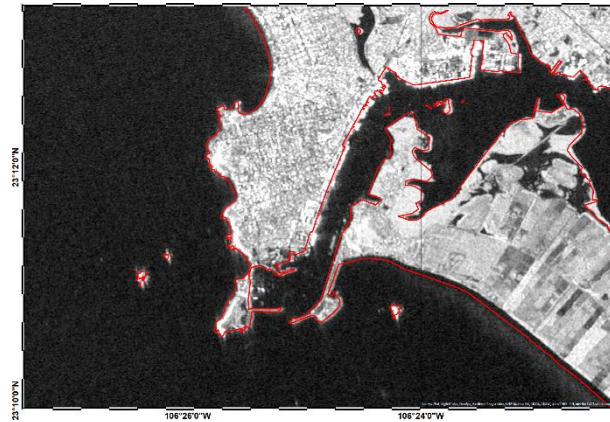


SAR-based coastline delineation

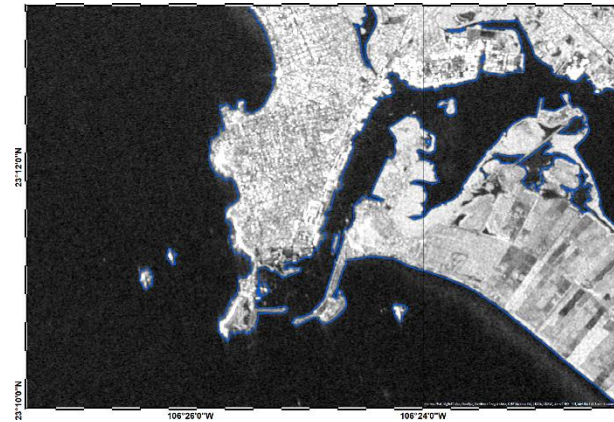
- Mexican coastline, Mazatlan harbor
- Accurate detection of coastline.
- Useful for embargo breaches, illegal fishery, etc.



Sentinel-2 image acquired over the Mazatlan harbour

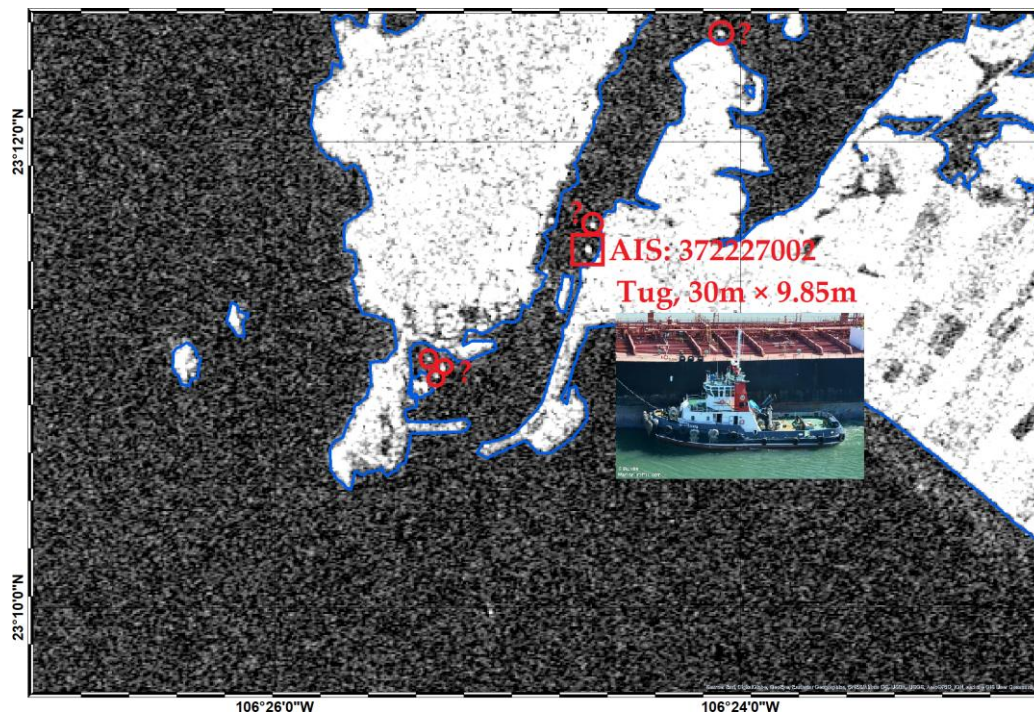


Sentinel-1 image & OSM coastline



Sentinel-1 image & SAR-based coastline

SAR detection of vessels nearby coastlines, harbours, etc.



- proof of concept for:
 - VV-VH coherence for ship detection.
 - SAR & AIS position matching.
 - accurate delineation of the coastline from the SAR image.
 - projection of AIS positions in order have the location at the time instant equal to the one of SAR image acquisition.
- ☞ SAR-based coastline: sea/land masking, temporal evolution, monitoring of deltas, etc.
- ☞ improve the AIS-SAR matching methodology: increase AIS time range, adapt to local traffic patterns.
- ☞ kinematic analysis of Sentinel-1 SAR vessel signatures in order to analyze dark targets, close gaps in AIS data, etc.

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THANK YOU!

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