SEASAR 2023: Applications

Maria Michela Corvino, Benjamin Holt, Cathleen Jones

May 4, 2023

Outline

TOPIC 1 – Maritime Security / Navigation / Ship Identification (Maria Michela Corvino)

TOPIC 2 – Marine Slicks / Spills (Cathleen Jones)

TOPIC 3 – Others (Ben Holt)
Macro Algae / Algal Blooms
Oil in Arctic Ice
Iceberg Detection

-- Coastal Bathymetry
-- Tide & Wind-driven Flooding and Submergence
-- Coastal Erosion (abstract submitted to Methodology & Techniques, M. Gade)

Breakout Meeting Organization

Breakout #1 Thursday PM
- **Maritime Security presentations by submitters (1 hr)**
- **Maritime Security discussion (1 hr)**

Breakout #2 Friday AM1
- **Maritime Security discussion (1 hr)**
- **Slicks presentations by submitters (1 hr)**

Breakout #3 Friday AM2
- **Slicks discussion (2 hr)**

Breakout #4 Friday PM1
- **Other topics discussion (2 hr)**

No WEBEX today; will have WEBEX tomorrow

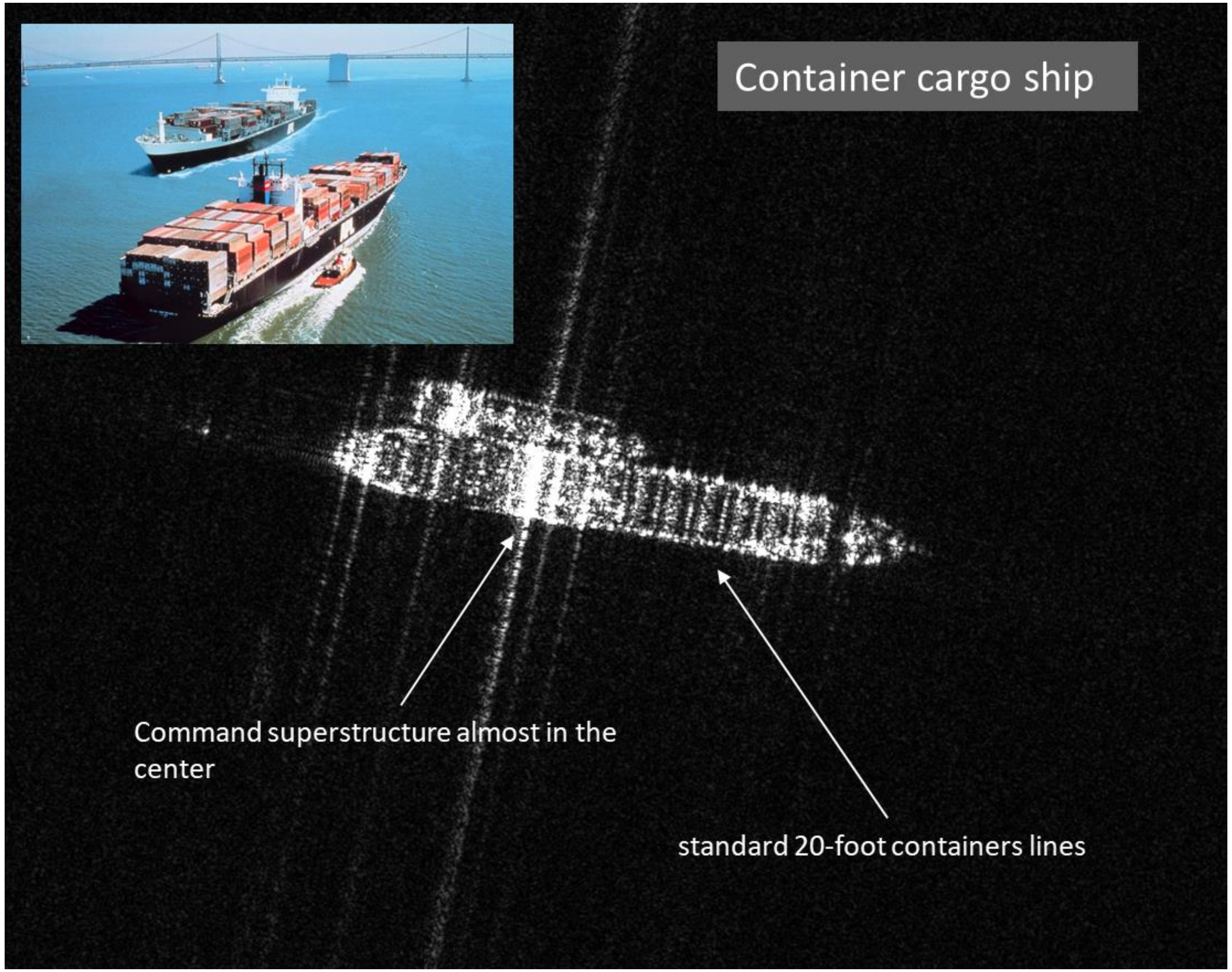
SEASAR 2023: Applications – Maritime Security

May 4, 2023

Maritime Security

Main areas of development related to the operational exploitation of Earth Observation (EO) for maritime situational awareness can be identified as follows:

- a more persistent temporal coverage;
- methods improved in speed and accuracy for target detection, identification, and tracking.
- a faster access to satellite acquisitions/vds and reduction of latency time, focusing on tip and cuing capabilities and cloud processing/on board techniques;



Moving targets

- Moving targets on SAR images are smeared and defocused
- Techniques exist to detect (GMTI) and focus (ISAR) moving targets
- To detect and extract position and velocity information on the moving target

GMTI

To detect and extract position and velocity information on the moving target

- on data from multi-channel SAR systems e.g. Chirp Scaling (CS) is used to detect and focus moving targets
- CS has also been applied for GMTI on single-channel data by splitting the antenna into sub-apertures (poorer performance compared to GMTI from multi-channel data)

ISAR

To focus moving targets and extract velocity information:

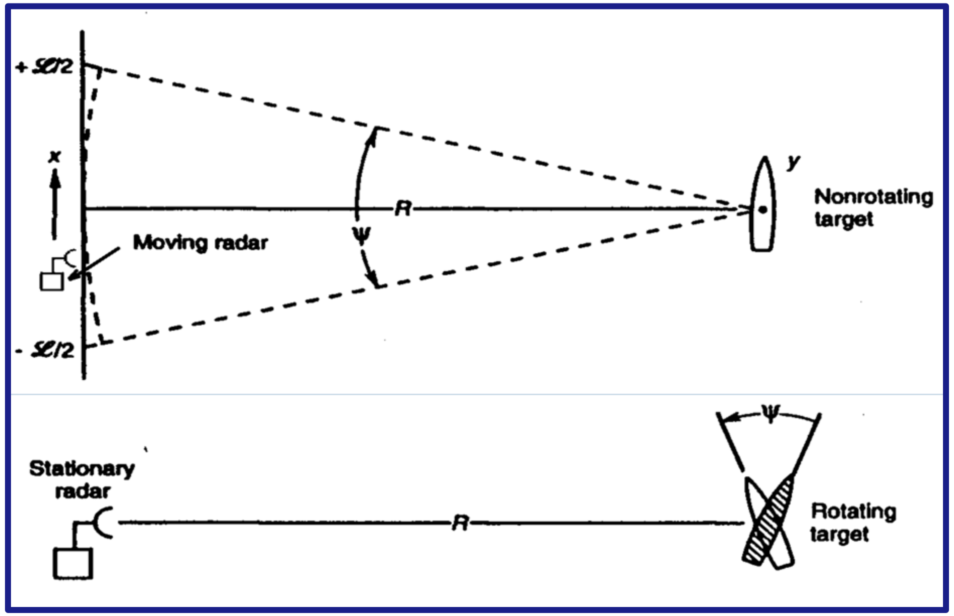
- target translational motion compensated e.g. through autofocusing techniques (e.g. Phase Gradient Autofocus)
- target rotational motion compensated and rotational parameters extracted e.g. through Cross-Range Scaling:
    - slope-based technique for motion parameters estimation
    - exploiting the quadratic component of the phase induced by the rotation motion

ISAR imaging

- SAR systems are active sensors on moving platform for imaging of stationary targets.
- On the other hand, the ISAR approach exploit the target motion and not the radar platform motion, to achieve the synthetic aperture needed for radar imaging
- This perspective change has a strong impact in the radar image formation. Indeed, the motion of the target in unknown and must be estimated from the radar data itself.
- In both cases the across-range imaging is re-solved by the relative radar-target motion that can be characterized by the composition of:

  i. Linear relative translation between sensor and target → across-range component of the relative movement contributes to image formation for all target scatterers

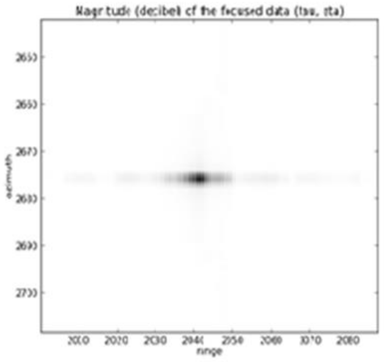
  ii. Rotation motion → scatterers undergo different dopplers depending on the distance from the rotation center.

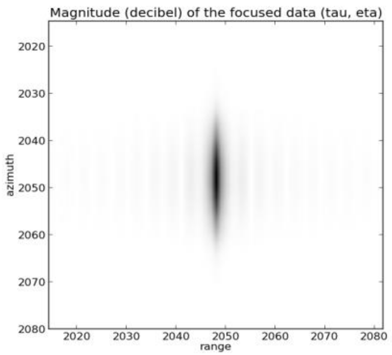


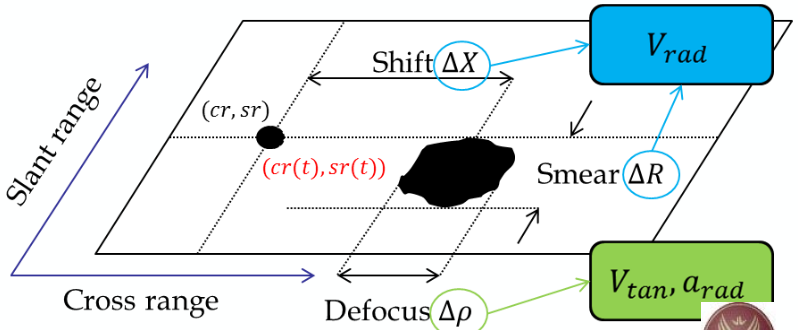
Typical SAR defocusing effects

For moving targets the application of standard focusing produces defocusing effects that degrade range and azimuth resolutions and produce azimuthal displacements. In particular:

- Range velocity component (V_{rad}) produces:
  - shift of the target imaging along the azimuth direction
  - smearing along the range (walking through different ranges)
- Range acceleration (A_{radial}) and azimuth velocity (V_{tan}) components produce:
  - smearing (walking through different azimuths) and defocusing (change of the Doppler rate) along the azimuth direction.
  - SNR losses
- ISAR refocusing process attempts to remove smearing effects and to estimate motion parameters

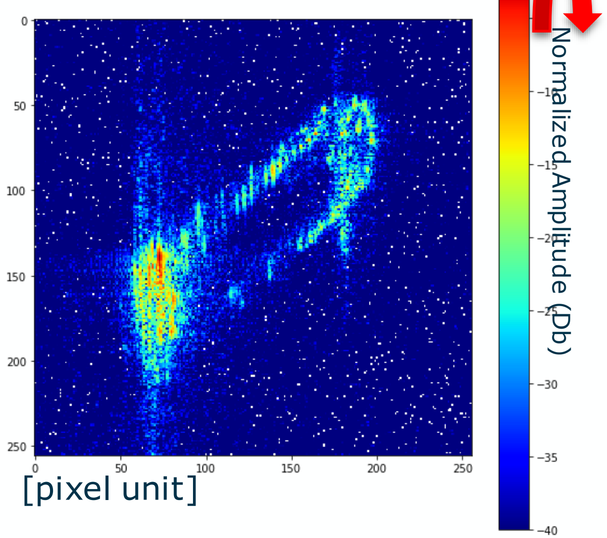


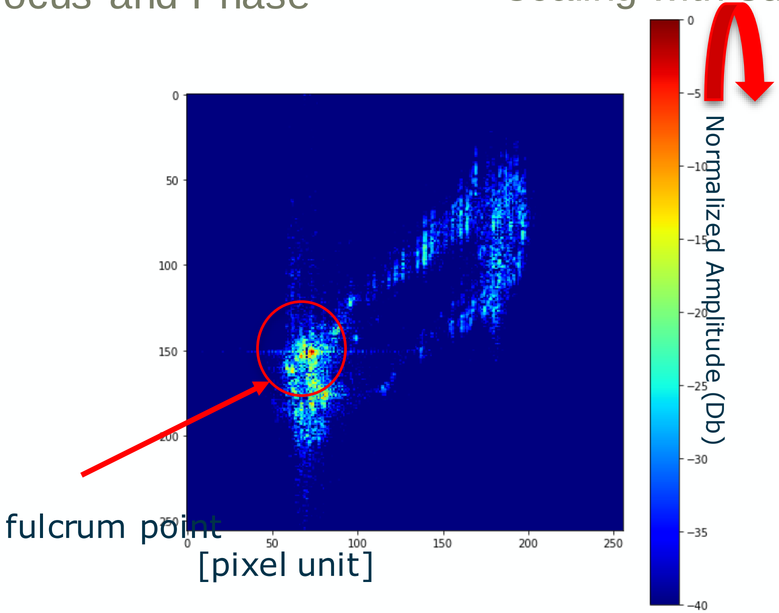


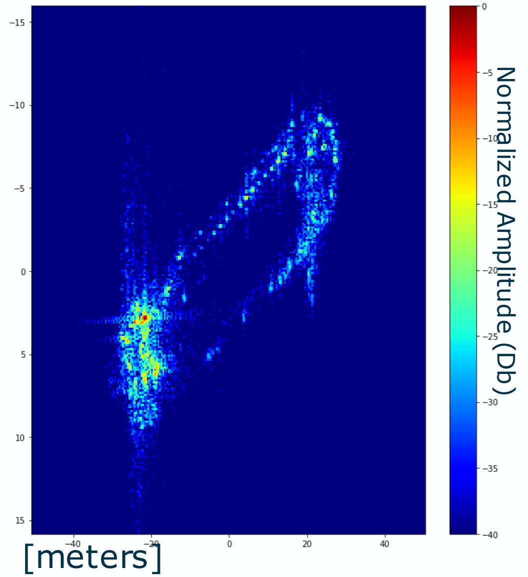


Processing outline

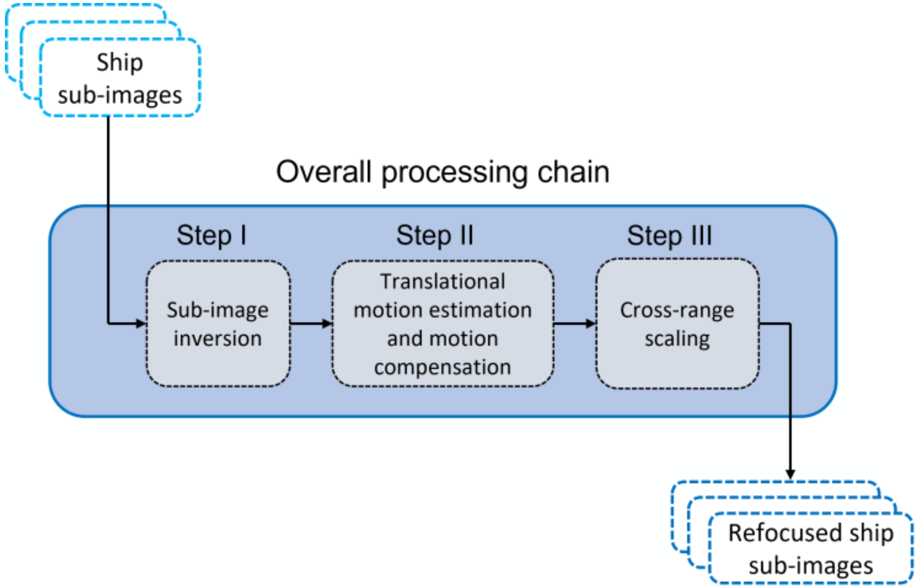
- In ISAR systems, the composition of the radar platform and target movements is modelled as the superposition of:
  - Relative translation motion between the radar platform and the considered target;
  - Relative 3D rotation between the radar platform and the considered target (roll, pitch, yaw)
- In order to retrieve these motion parameters and correct defocusing effects, ISAR processing maximizes the image contrast by:
  - Compensation with respect to translation motion and stabilization of a fulcrum point (Autofocus and Phase Gradient Algorithm (PGA))
  - Compensation with respect to rotations (cross-range scaling with sub-apertures, and PGA)



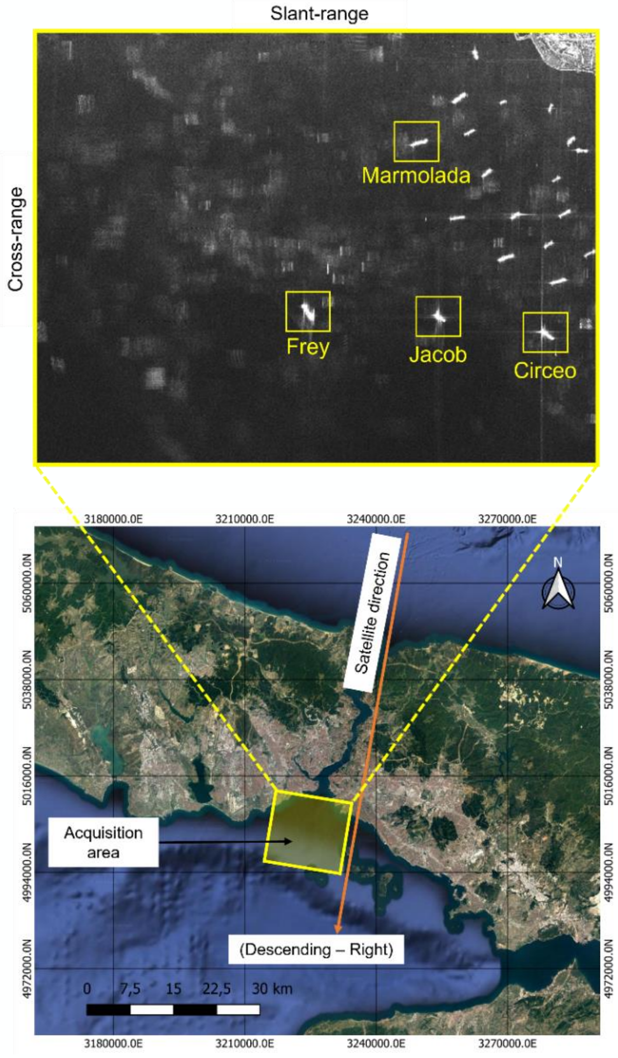


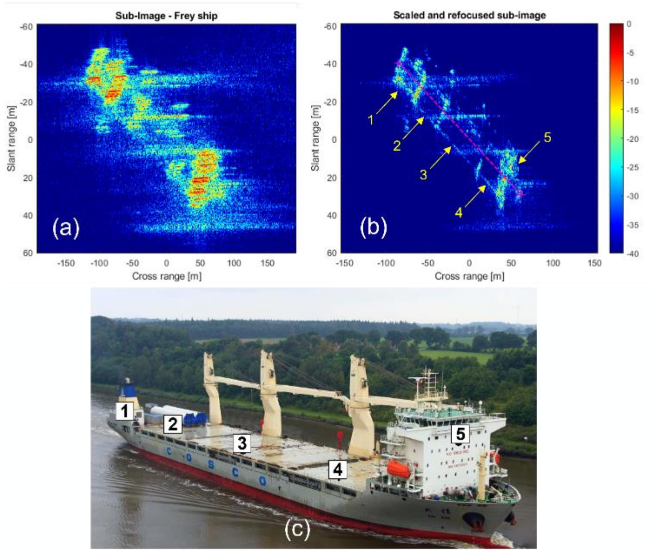


Examples of results



- **Inverse SAR processing allows:**
  - image contrast enhancement
  - the removal/mitigation of target defocusing due to its motion
  - the retrieval of motion parameters of the target





- The refocusing is strongly dependent on the vessel motion
- A contrast improvement is generally achieved

B-Open

Future – What Can be done in the Future

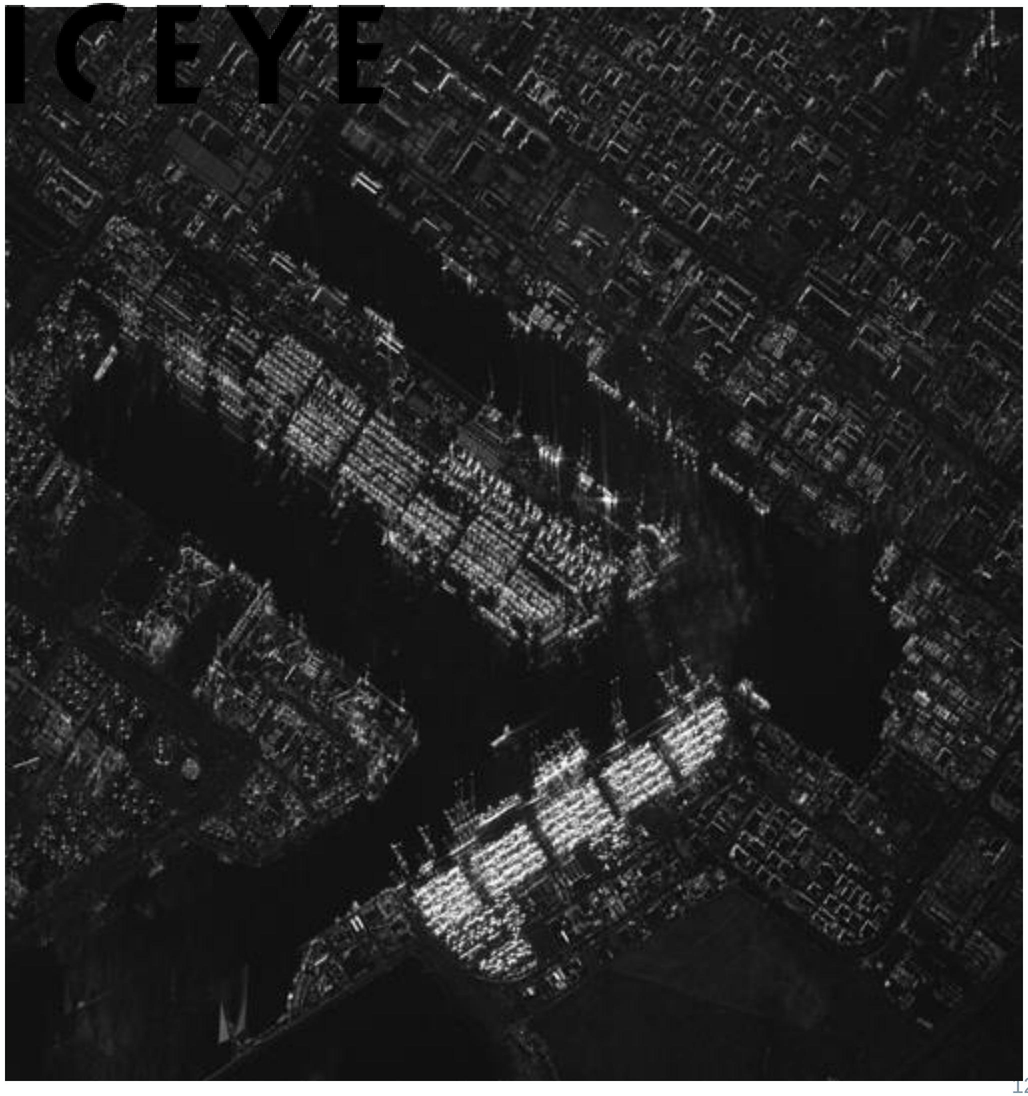
1. Improvements to existing ISAR algorithms and workflows in order to increase accuracy in the motion parameter estimation and refocusing, in particular for MSA use cases where complex rotational manoeuvres of the vessels can determine changes of the imaging planes and require more complex cross range scaling algorithms.

2. Possible exploitation of raw data

3. New ISAR processing solutions:
   - exploitation of multiple frames (sub-apertures) showing the same target on different image projection planes (i.e. VideoSAR)
   - consider bistatic and/or multistatic SAR satellite constellations
   - multiple polarimetric channels can be exploited by means of adequate processing algorithms capable to enhance the target information space (e.g. different target characteristics/scatterers observable by changing the polarization) and to improve the accuracy of the estimated motion.

Spaceborne Video-SAR

- SAR video are generated by focusing adjacent portions of the synthetic aperture. Every focused sub-aperture corresponds to one frame of the SAR video.
- In video SAR the aperture required to achieve the desired cross range resolution typically exceeds the frame rate period. As a result, there can be a significant overlap in the collected phase history used to form consecutive images in the video.
- Image formation algorithms based on sub-aperture extended chirp scaling processing.



Future – What Can be done in the Future

- Moving target recognition is an important application in SAR signal processing.

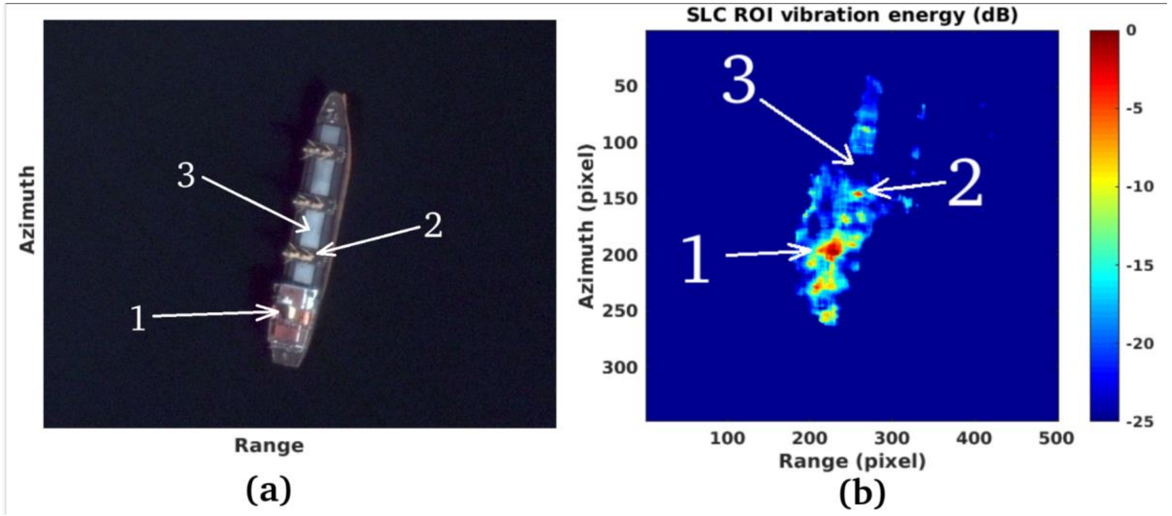
- Video SAR moving target detection methods shall be further analysed and tested over real datasets for surveillance of slow speed moving targets on the ground.

- Optimization is needed to realize real-time refocusing of moving targets.

- Additional applications are under evaluation (e.g. shadow-based methods provide a new approach for ground moving target processing)

Micro-Doppler signature

- Mechanical vibration or rotation of a target, or structures on the target, may induce additional frequency modulations on the returned radar signal which generate sidebands about the target's Doppler frequency, called the micro-Doppler effect.
- Micro-Doppler signatures enable to determine some properties of the target.



Modelling and exploitation of radar micro-Doppler effects, to determine the dynamic properties of the target

*Armenise, D., **Biondi, F.,** Addabbo, P., **Clemente, C**. & Orlando, D., Marine targets recognition hrough micro-motion estimation from SAR data; 5 Jul 2020, 2020, IEEE 7th International Workshop on Metrology for AeroSpace (MetroAeroSpace).*

Future – What Can be done in the Future

- The extraction of m-D signatures from radar imaging systems for target classification purposes is an emerging technique. Main **technical issues** in the extraction of micro-Doppler information from SAR images:
  - impact of different sea states on the marine targets' micro-motion extraction
  - spatial resolution and signal to clutter ratio issues for the extraction of signatures from relatively close and small targets
  - the vibration is inherently linked to time dependent aspects, for this reason the ideal conditions for the validation would be to have the ground truth measurement performed simultaneously to the SAR image acquisition

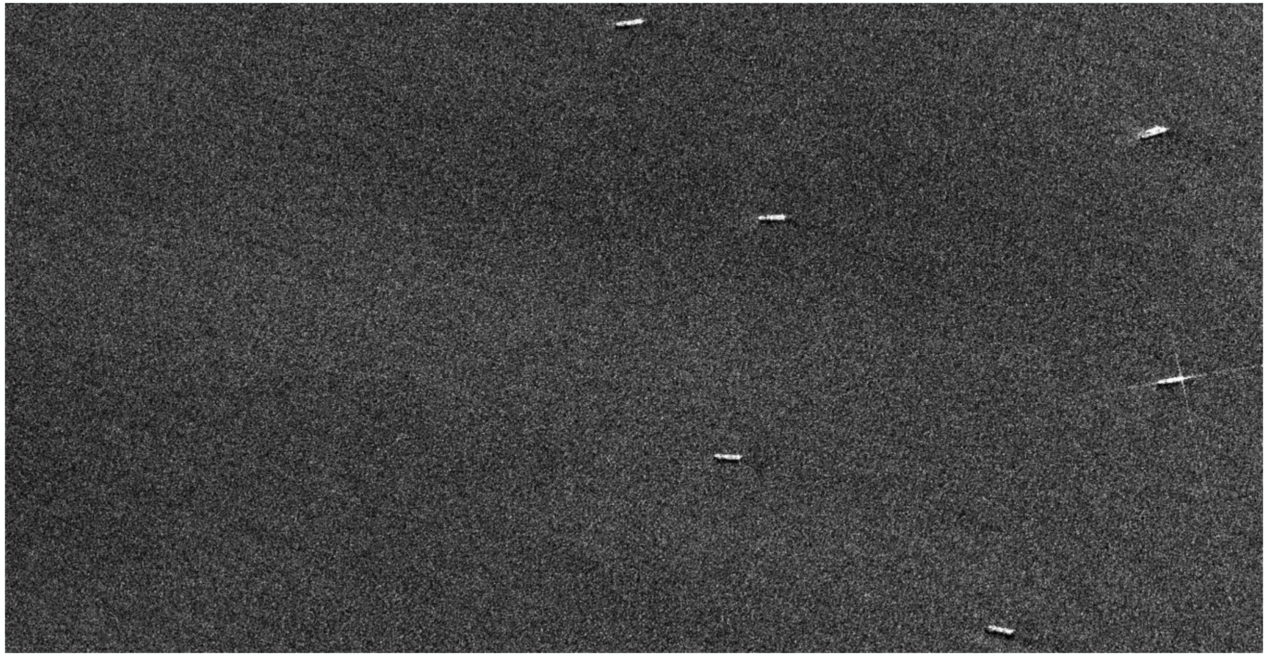
- Additional effort for m-D modelling and extraction

- Increasing interest from ISAR community moved the analysis of the m-D signatures to the most challenging problem of the compensation of the micro-motions in order to obtain good focused ISAR images

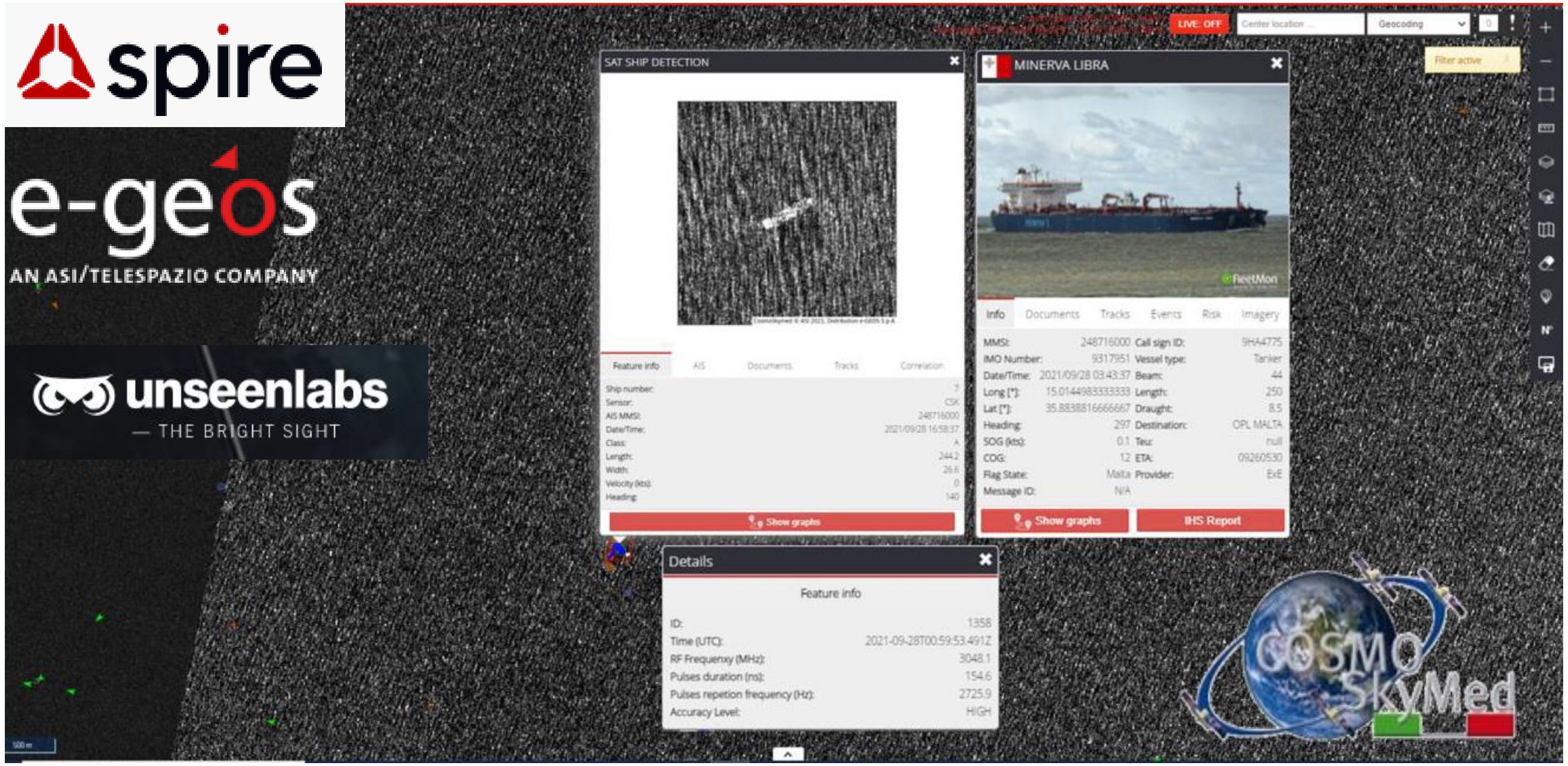
Data fusion

Sensors/Systems:

- Coastal Radar
- Terrestrial AIS
- Satellite AIS
- Optical / IR cameras
- Vessels and airplanes (equipped with specific sensors)
- Synthetic Aperture Radar satellites
- Optical Satellites
- Satellite equipped with RF receivers
- Unmanned systems (UxS)
- High Altitude Pseudo-Satellites (HAPS) – coming soon…
- Civilian and Military vessels databases



Examples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Details
Feature info
ID:
Time (UTC):
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Pulses duration (ns):
Accuracy Level:
HIGH
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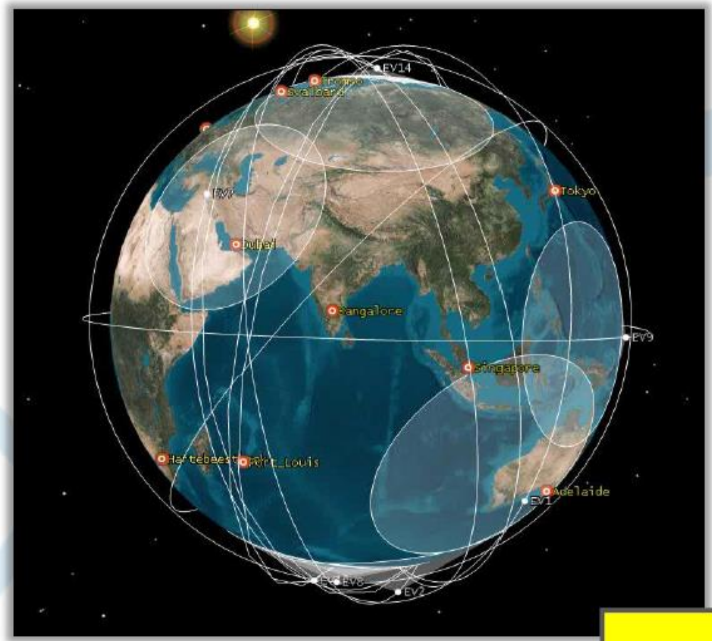
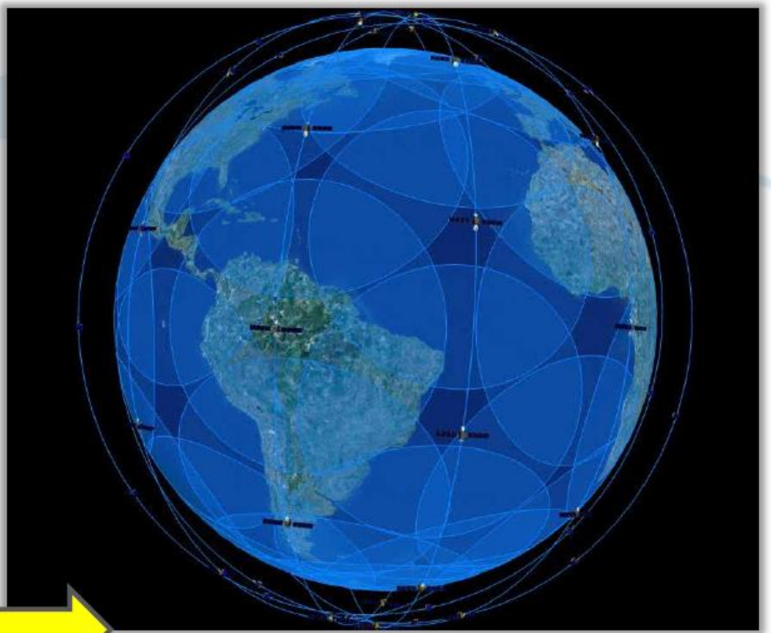
Satellite AIS

exactAIS™ Service – from Gen 1 to Gen 2



- Current Generation 1 System: 5 Satellites
- 10 years continuous operation
- 45 Minute Average Update Rate
- 60 Minute Data Latency



- exactView RT: The only real-time Satellite AIS service
- All 58 payloads fully operational and in service

AIS messages contain information about:

- IMO code
- MMSI code
- Vessel name
- Flag
- Speed
- Heading
- Declared destination

And allow:

- To generate tracks
- Anomaly detection
- Risk assessment
- Pattern of life extraction

exactEarth® A World Without Horizons

Detection, localization and characterization of all navigation radars

Worldwide detection and surveillance of all RF emitters, including low power emitters (small and very small crafts)

Steady detection and position precision rates

- No weather conditions impact

Both large area surveillance and tactical time sensitive surveillance

- Radar profiling

Future – What Can be done in the Future

- Increased availability of RF datasets – this will allow to improve the correlation with EO based VDS

- The heterogeneity and volume of input data may have a direct impact on the data fusion complexity, requiring relevant computational resources and not ensuring a processing time compatible with Near-Real-Time applications

- Improve route prediction and reconstruction tools by estimating the ship position at a specific timestamp in the past (e.g. by interpolation) or in the future (e.g. by extrapolation or prediction), and for matching specific uses cases (e.g. for matching the tasking time of the EO satellites).

- One possible approach is to build a conditional probability distribution in the space of trajectories able to characterize the uncertainty about unobserved parts of the trajectory.

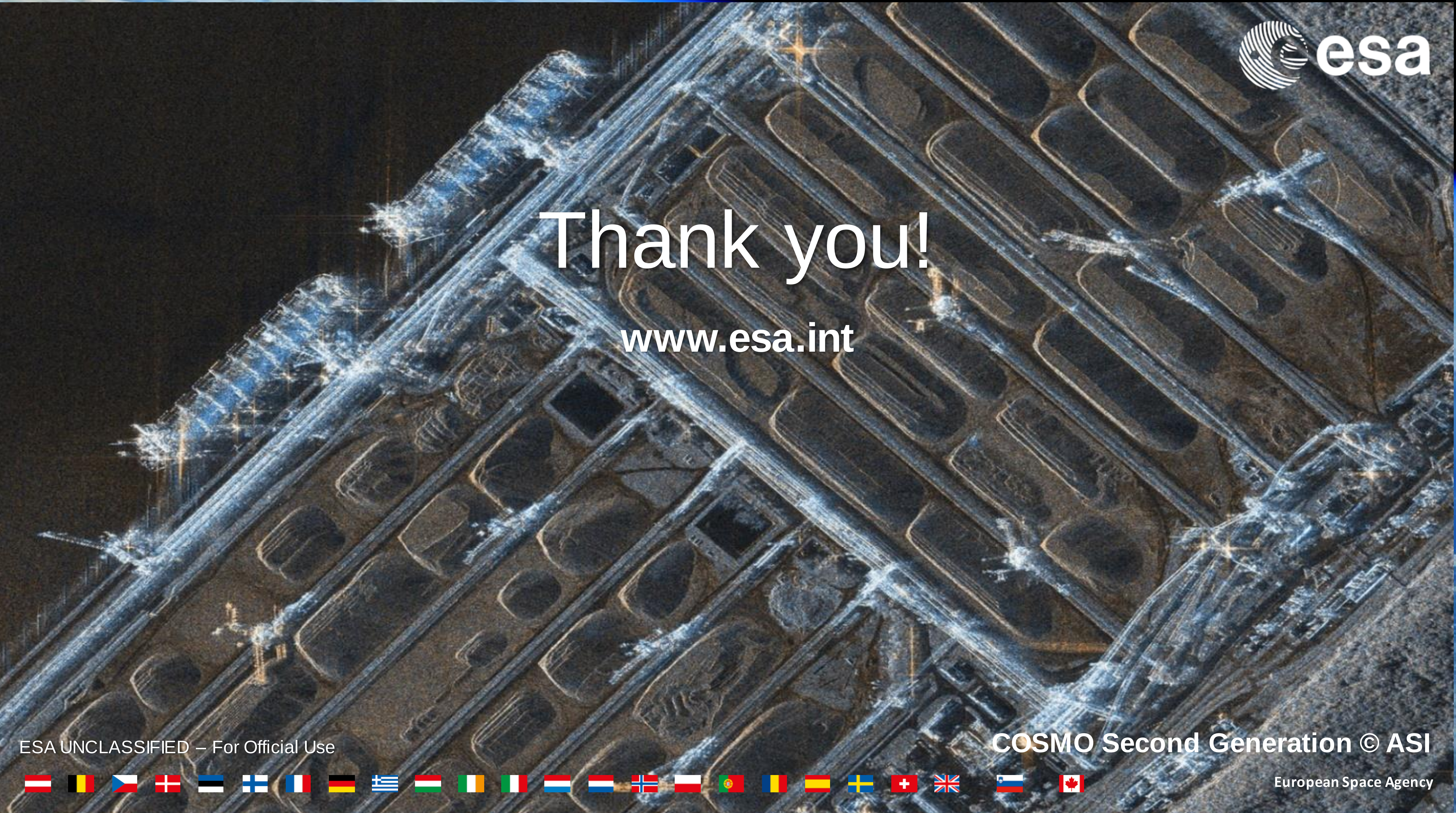
    - supervised learning framework for trajectory predictions based on generative models (e.g. conditional variational autoencoder) to be trained using the available historical data, taking also into account the seasonality of the data and, when possible, high-level semantic information (e.g. type of vessel).

    - statistical techniques based on Bayesian inference, taking into account suitable vessel motion models as well as suitable maritime traffic models.

SeaSAR Applications / Submitted Abstracts

List of submissions in this topic

- AI based route reconstruction on multifrequency multitemporal SAR images - Roberto Del Prete
- Deep Learning For Ship Classification on Medium Resolution SAR imagery - Bou Laouz Moujahid
- Inverse SAR (ISAR) Processing for Maritime Situational Awareness (MSA) - Elena Morando
- Ship Navigation Assistance for Polar Waters by providing information on Sea Ice Drift And Deformation Zones Using TerraSAR-X Data
- A Feasibility Study Into The Use of High-Resolution Synthetic Aperture Radar (SAR) as a Novel Way of Identifying Aids To Navigation - Scott Kaczor
- Automatic Refugee Inflatable Vessel Detection with Polarimetric SAR - Peter Lanz



Thank you!

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SEASAR 2023: Applications - Slicks

May 4, 2023

Slick Applications

Applications:

1. Mineral oil slicks / spills identification and characterization
2. False positive discrimination
3. Shipwreck location from surface slicks





Submitted Abstracts – Applications - Slicks

ID	authors	title
116	Y. Yang, S. Singha, R. Goldman	Integration of a Deep Learning Based Oil Spill Detection System into an Early Warning System for the Southeastern Mediterranean Sea
120	D. Blondeau-Patissier, T. Schroeder, G. Suresh, Z. Li, F. Diakogiannis	Detection Of Marine Oil-like Features In Sentinel-1 SAR Images By Supplementary Use of Deep Learning and Empirical Methods
129	M. Gade, D. King	On the SAR Image Visibility of Heavy Fuel Leaking From the Wreck of a Sunken Vessel
132	C. Jones, M. Johansson, B. Holt	Automation of Slick Detection and Classification for Improved Monitoring with SAR
151	B. Holt, C. Jones, F. Monaldo, O. Garcia	Try, Try Again: Recent Steps Toward An Operational SAR-based Algorithm for Oil Spill Thickness Measurements

State of the Field - Changes in last 10-15 years

Precipitating event: Deepwater Horizon Oil Spill (Gulf of Mexico, 2010)

1. Low noise airborne SARs – UAVSAR, FSAR, SETHI
   - SAR was not limited to slick detection, but characterization is also possible
   - X, C, S, L-band all show signatures of thicker / more emulsified oil within slicks given a sufficiently low noise floor instrument
   - Quantitative evaluation of the impact of instrument noise on observations

2. Availability of quad-pol data from airborne SARs and RS2
   - Systematic studies of the capabilities of different polarizations, frequencies, and polarimetric or polarization-dependent parameters for quantifying oil properties (thickness, emulsification)

State of the Field - Changes in last 10-15 years

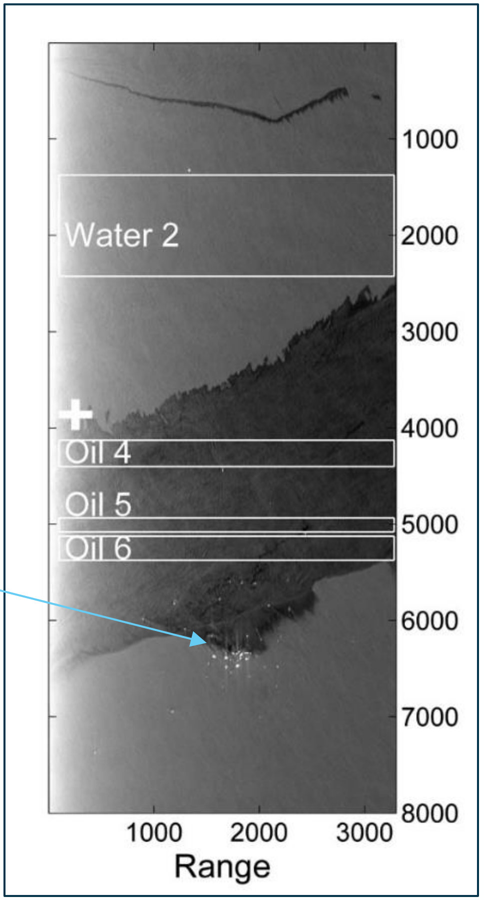
3. SAR usage by operational monitoring agencies & services
    - Free data from Sentinel-1, available quickly
    - Improved coverage & repeat interval from combined satellite optical and SAR instruments

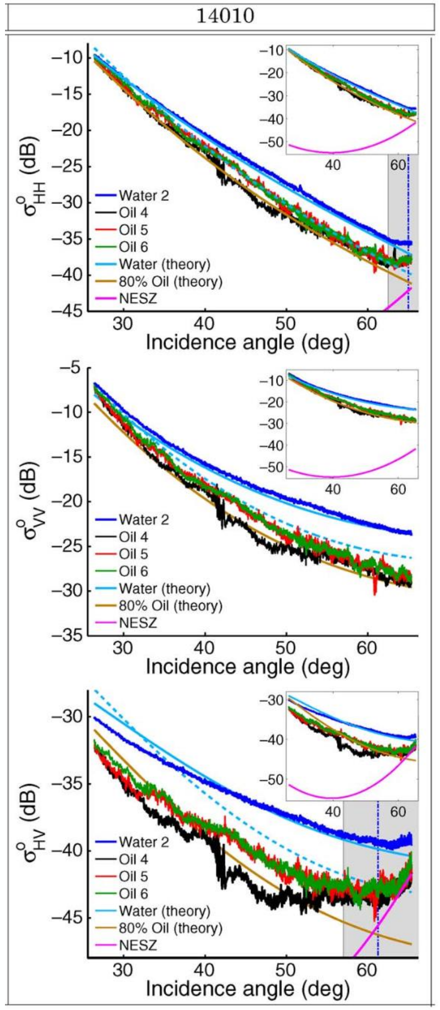
4. Increased computational capability
    - Improved modeling
        - Transport
        - Scattering
    - Machine learning methods
    - Big data sets from Sentinel-1 for studies

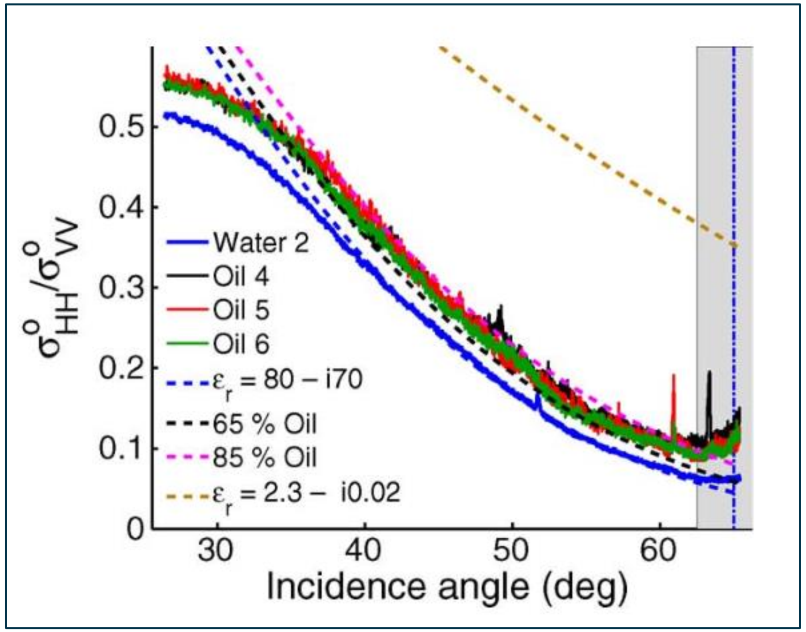
1. Slick Characterization Potential (X-, C-, L-band)

Deepwater Horizon OS – Oil Volumetric Fraction from L-band SAR

Airborne SAR = UAVSAR, L-band
Source: Minchew, Jones, Holt (2012)







Oil:Water Volumetric Fraction from L-band SAR HH/VV

2. Impact of Instrument Noise on Slick NRCS & Derived Parameters

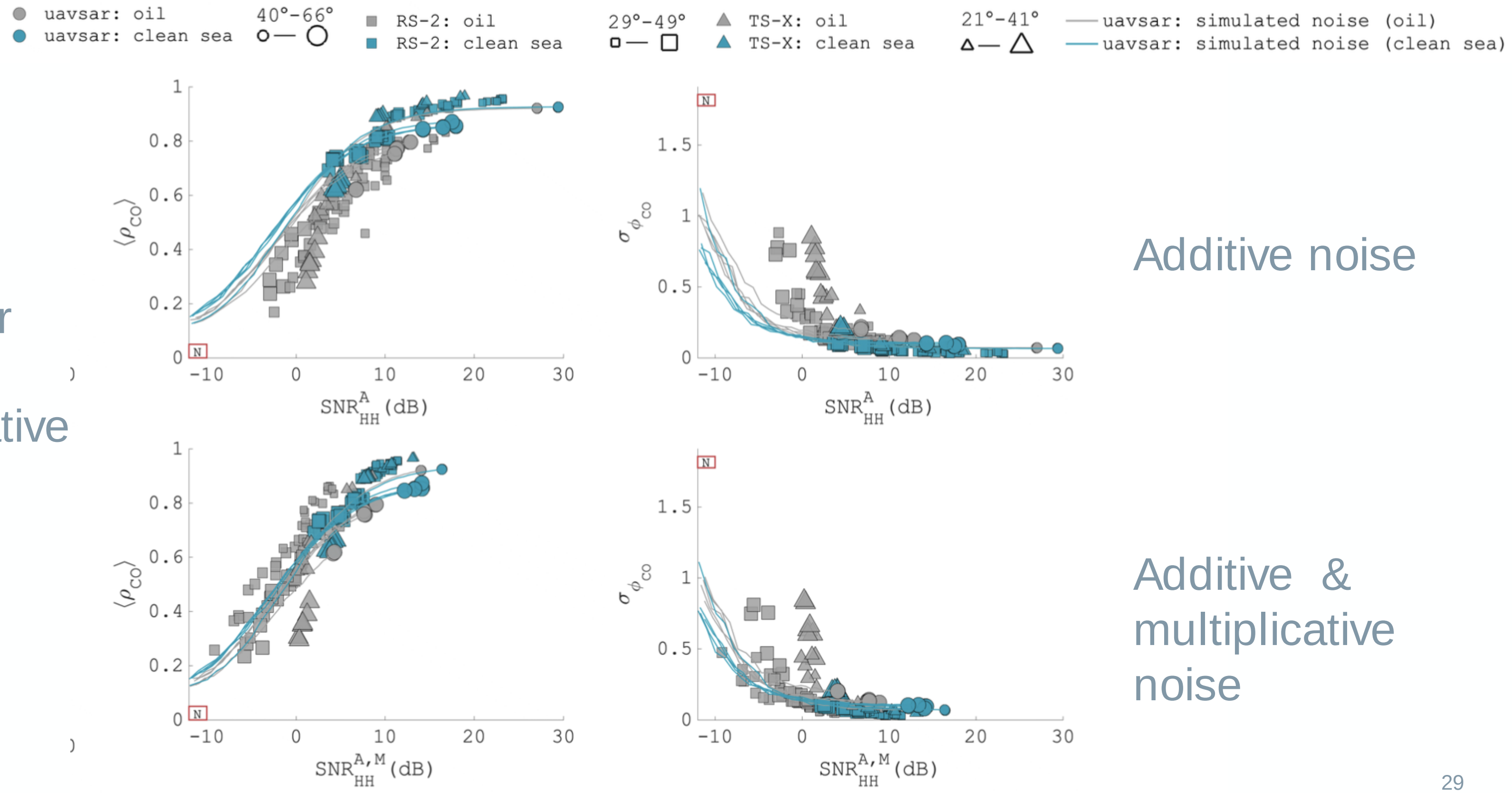
1. Espeseth et al. (2020). The impact of system noise in polarimetric SAR imagery on oil spill observations. *IEEE Transactions on Geoscience and Remote Sensing*, *58*(6), 4194-4214.
2. Alpers, Holt, & Zeng (2017). Oil spill detection by imaging radars: Challenges and pitfalls. *Remote sensing of environment*, *201*, 133-147.

- Studies reporting volume & random scattering from oil slicks was not substantiated by low noise instruments.
- Surface scattering dominates.
- SNR >10 dB over additive noise (>0 dB for Add+Mult is required for slick characterization (also evaluated multiplicative noise).

$$PD = \sigma^{0,m}_{VV} - \sigma^{0,m}_{HH}$$
$$r_{CO} = \Re(\langle M_{HH} M^{\star}_{VV} \rangle)$$
$$\gamma_{HH/VV} = \sigma^{0,m}_{HH} / \sigma^{0,m}_{VV}$$
$$\rho_{CO} = \frac{|\langle M_{HH} M^{\star}_{VV} \rangle|}{\sqrt{\langle |M_{HH}|^2 \rangle \langle |M_{VV}|^2 \rangle}}$$
$$\sigma_{\phi_{CO}} = std(\phi_{HH} - \phi_{VV})$$

$$H = -\sum_{i=1}^{3} p_i \log_3 p_i$$
$$H_{CO} = -\sum_{i=1}^{2} p_i \log_2 p_i$$
$$\alpha = \sum_{i=1}^{3} p_i \cos^{-1}(|\boldsymbol{e_i}(1)|)$$
$$DoP = \frac{\sqrt{S_1^2 + S_2^2 + S_3^2}}{S_0}$$
$$\chi = \frac{1}{2} \sin^{-1}\left(-\frac{S_3}{DoP S_0}\right)$$

From Espeseth et al., 2020



Additive noise

Additive & multiplicative noise

3. Optimal Parameters for Slick Detection / Characterization

Sensitivity of Polarization-Dependent & Polarimetric Parameters

Early work with satellite SARs: Skrunes, S., Brekke, C., Eltoft, T., & Kudryavtsev, V. (2014). Comparing near-coincident C-and X-band SAR acquisitions of marine oil spills. IEEE Transactions on Geoscience and Remote Sensing, 53(4), 1958-1975.

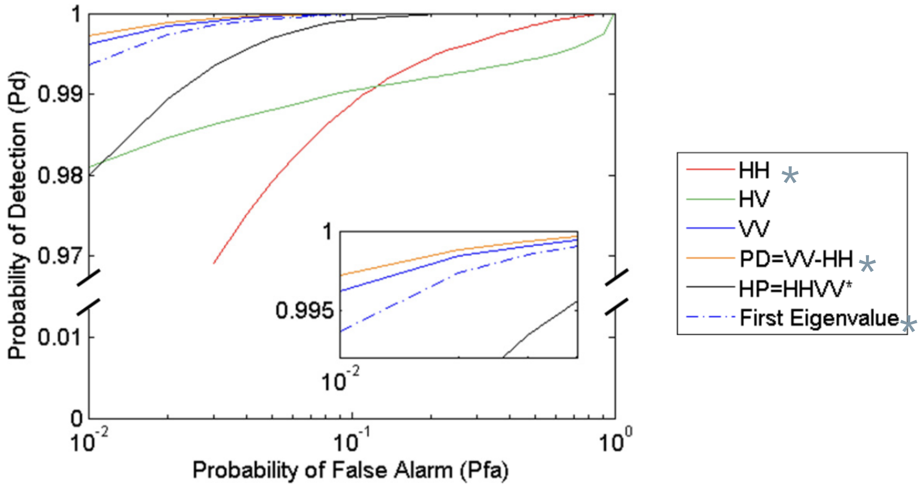
Airborne SAR = UAVSAR (L-band): Espeseth, M. M., Skrunes, S., Jones, C. E., Brekke, C., Holt, B., & Doulgeris, A. P. (2017). Analysis of evolving oil spills in full-polarimetric and hybrid-polarity SAR. IEEE Transactions on Geoscience and Remote Sensing, 55(7), 4190-4210.

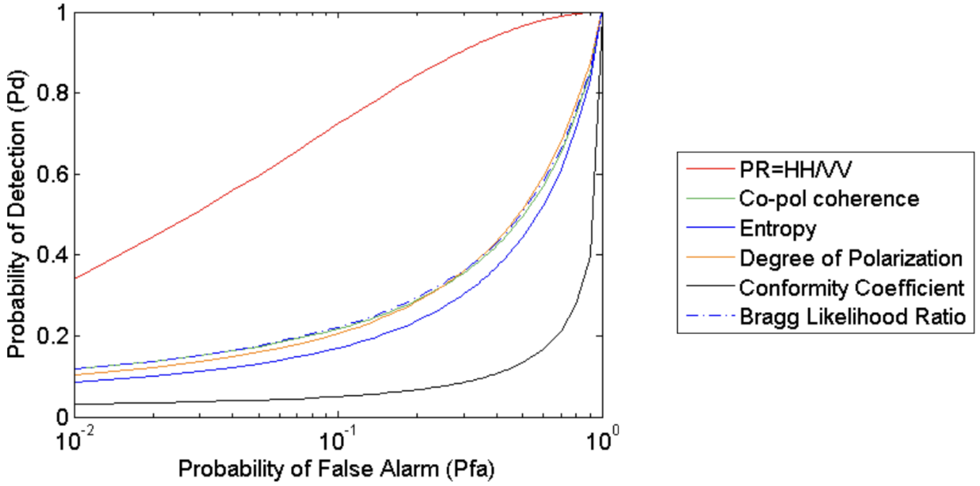
Satellite QP = RS2 (C-band) & UAVSAR (L-band): Garcia-Pineda, O., Staples, G., Jones, C. E., Hu, C., Holt, B., Kourafalou, V., ... & Haces-Garcia, F. (2020). Classification of oil spill by thicknesses using multiple remote sensors. Remote sensing of environment, 236, 111421.

Airborne SAR = SETHI (L-band):Angelliaume, S., Dubois-Fernandez, P., Jones, C. E., Holt, B., Minchew, B., Amri, E., Miegebielle, V. (2018). SAR imagery for detecting sea surface slicks: Performance assessment of polarization-dependent parameters, *IEEE Transactions on Geoscience and Remote Sensing*, 56(8), 4237-4257, doi:10.1109/TGRS.2018.2803216.

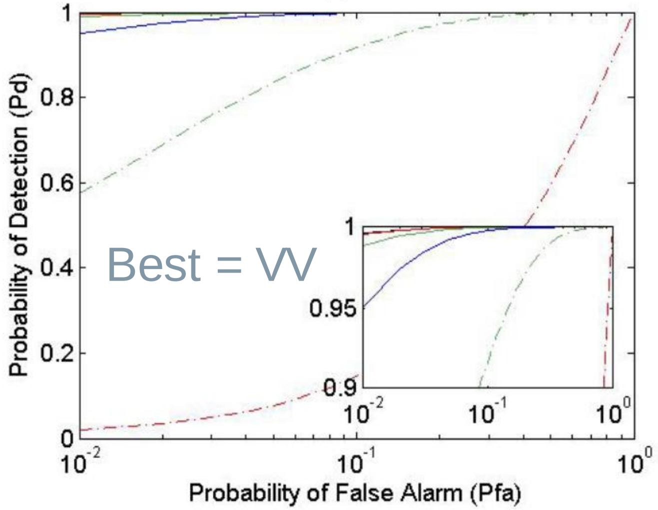
3. Optimal Parameters for Slick Detection / Characterization

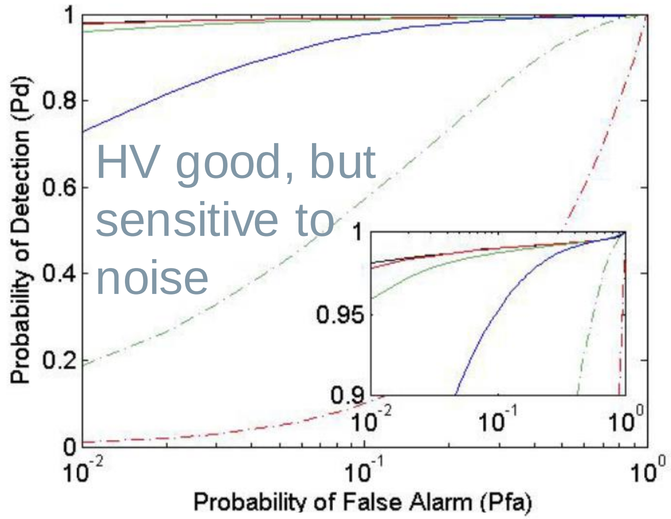
From: Angelliaume et al. (2018). SETHI, L-band

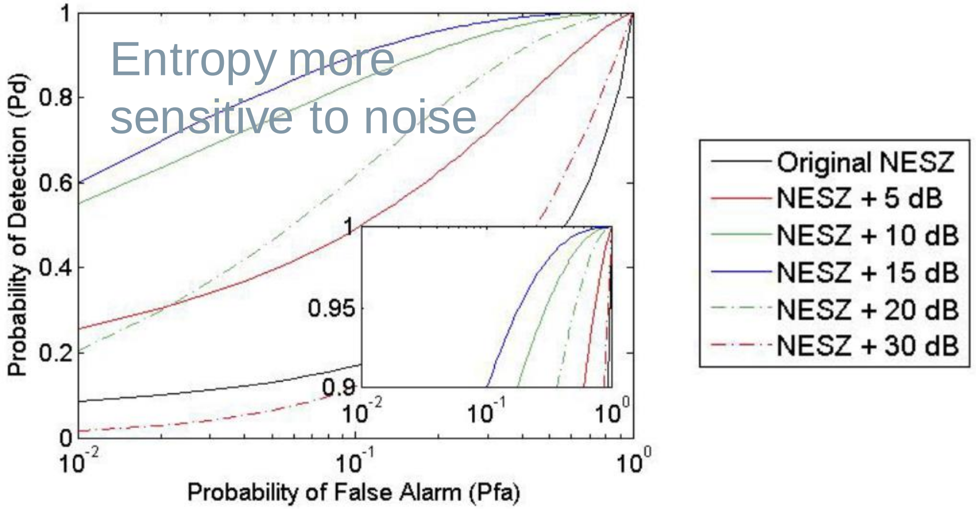




Include impact of noise:







4. Oil Transport & Weathering Models

Model = OpenDrift / OpenOil3D: Röhrs, J., Dagestad, K. F., Asbjørnsen, H., Nordam, T., Skancke, J., Jones, C. E., & Brekke, C. (2018). The effect of vertical mixing on the horizontal drift of oil spills. *Ocean Science*, *14*(6), 1581-1601.

An accurate description of vertical mixing and oil weathering is needed to represent the horizontal spreading of oil released on the ocean surface.

Transport of oil between the surface slick and the water column crucially affects the horizontal transport of oil spills.

The vertical processes are control differences in the drift of various types of oil and in various weather conditions.

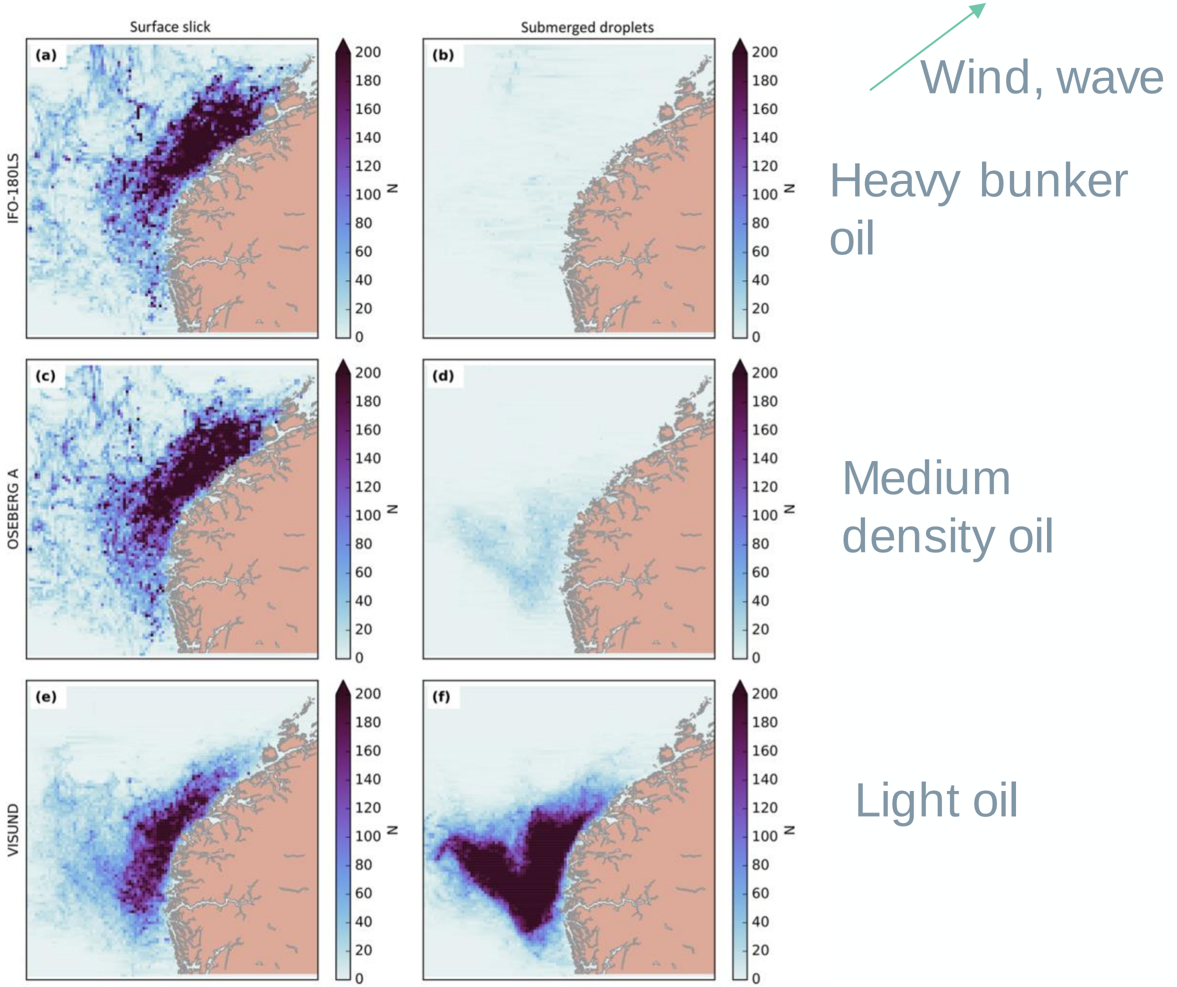


Figure 8. Horizontal concentration maps (number of particles per 100 km^2) for stochastic oil spill simulations after 10 days summed over 72 simulations for each oil type. Submerged oil **(b, d, f)** and surface oil **(a, c, e)** are displayed separately.

Slick ID & Discrimination: Mineral Oil Spills vs. Look Alikes

Machine Learning, Big Data

SeaSAR 2023 abstracts:

1. Integration of a Deep Learning Based Oil Spill Detection System into an Early Warning System for the Southeastern Mediterranean Sea (Yi-Jie Yang et al.)
2. Detection Of Marine Oil-like Features In Sentinel-1 SAR Images By Supplementary Use of Deep Learning and Empirical Methods: Performance assessment for the Great Barrier Reef marine park (David Blondeau-Patissier)

Detection Of Marine Oil-like Features In Sentinel-1 SAR Images By Supplementary Use of Deep Learning and Empirical Methods: Performance assessment for the Great Barrier Reef marine park

David Blondeau-Patissier

Thomas Schroeder, Gopika Suresh, Foivos Diakogiannis, Zhibin Li, Paul Irving, Christian Witte, and Andy Steven

04/May/2023

Research manuscript and dataset for this project

Both are Open Access

ELSEVIER

Marine Pollution Bulletin
Volume 188, March 2023, 114598

Detection of marine oil-like features in Sentinel-1 SAR images by supplementary use of deep learning and empirical methods: Performance assessment for the Great Barrier Reef marine park

David Blondeau-Patissier [a] [b], Thomas Schroeder [a], Gopika Suresh [c], Zhibin Li [d], Foivos I. Diakogiannis [e], Paul Irving [f], Christian Witte [g], Andrew D.L. Steven [a]

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CSIRO Sentinel-1 SAR image dataset of oil- and non-oil features for machine learning (Deep Learning)

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About this collection

Blondeau-Patissier, David , Schroeder, Thomas , Diakogiannis, Foivos , Li, Zhibin

Location

Collection description
What this collection is:
A curated, binary-classified image dataset of grayscale (1 band) 400 x 400-pixel size, or image chips, in a JPEG format extracted from processed Sentinel-1 Synthetic Aperture Radar (SAR) satellite scenes acquired over various regions of the world, and featuring clear open ocean chips, look-alikes (wind or biogenic features) and oil slick chips.

This binary dataset contains chips labelled as:
- "0" for chips not containing any oil features (look-alikes or clean seas)
- "1" for those containing oil features.

This binary dataset is imbalanced, and biased towards "0" labelled chips (i.e., no oil features), which correspond to 66% of the dataset.
Chips containing oil features, labelled "1", correspond to 34% of the dataset.

Why:
This dataset can be used for training, validation and/or testing of machine learning, including deep learning, algorithms for the detection of oil features in SAR imagery. Directly applicable for algorithm development for the European Space Agency Sentinel-1 SAR mission (https://sentinel.esa.int/web/sentinel/missions/sentinel-1), it may be suitable for the development of detection algorithms for other SAR satellite sensors.

Data

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Rights statement

Methodology: Deep learning + Empirical rules

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- Up to 5 scenes /day acquired over the marine park (IW_GRDH_)

- Acquisitions occur at 6am local time

- Processing using SNAP (GPT command line)

Sentinel-1 SAR Image processing

1st opinion

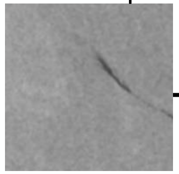
Use of convolutional neural networks (image based)

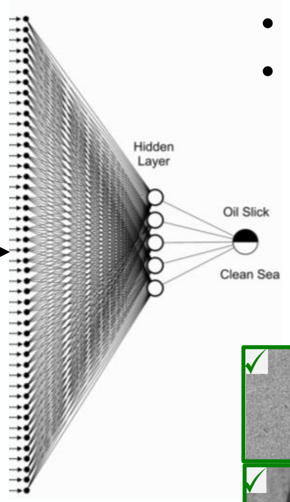
2nd opinion

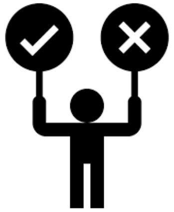
Rule-based approach (selected parameters)

Input

400 x 400 pixels







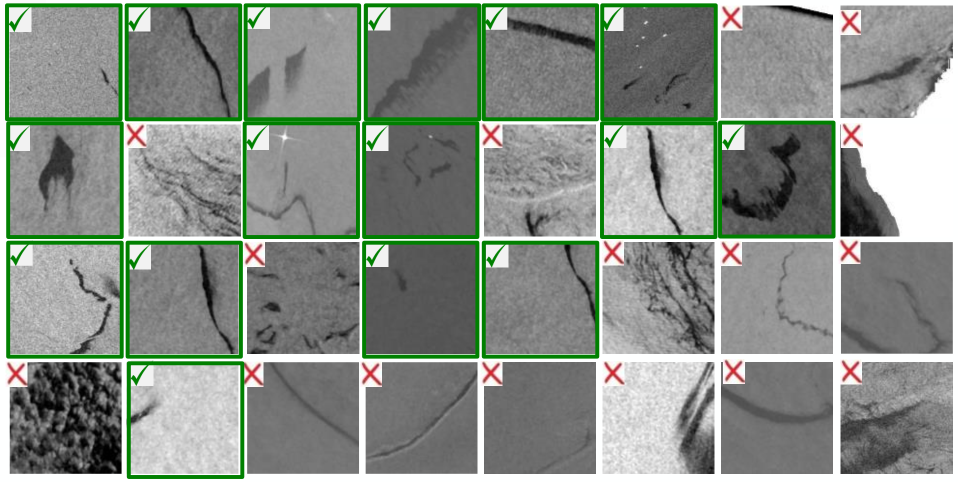
Decision

Dataset used for CNN training & testing

- **More than 5,000 chips** from the O&A curated database
- 400 x 400 pixel size chips
- Binary class
- Chip extraction & labelling: manual, time consuming

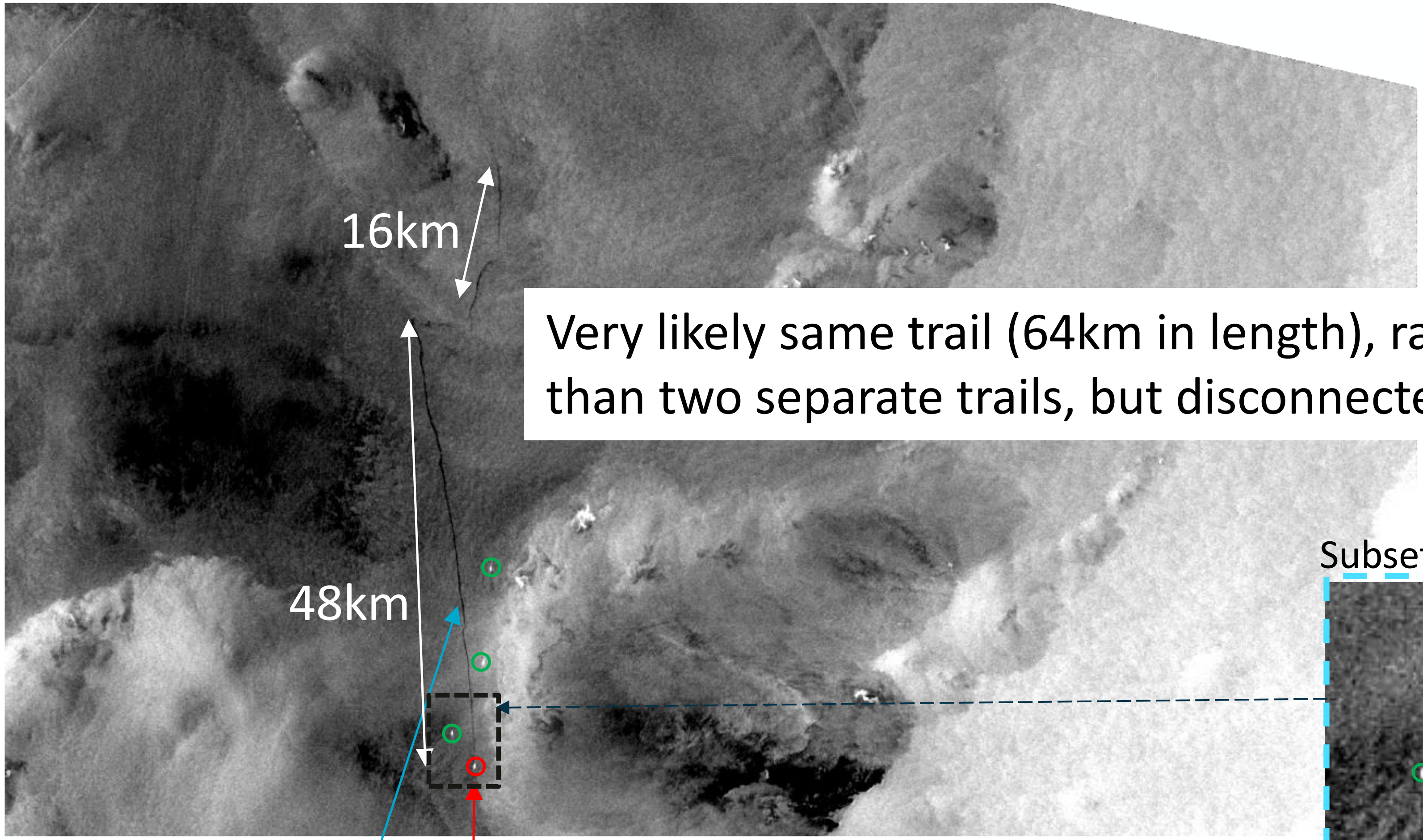
N>2,000 Oil ✓

N>3,000 Not oil ✗



Example of application

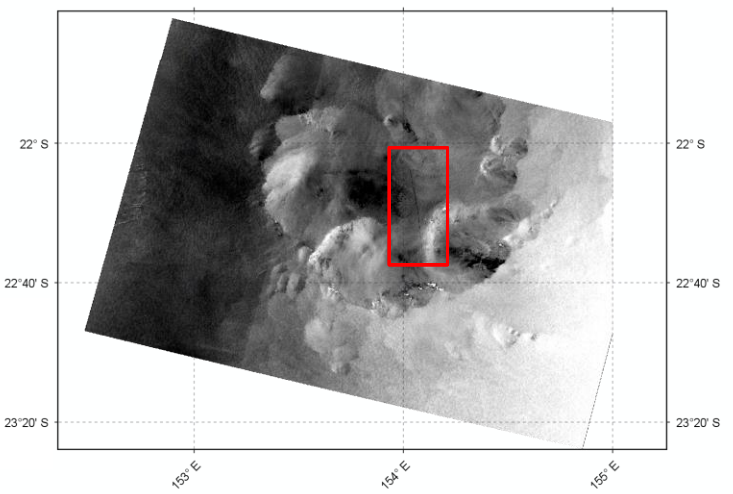
Synthetic Aperture Radar scene, zoomed-in.



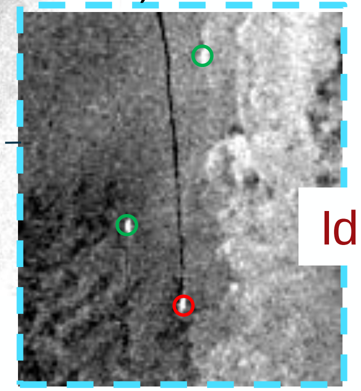
Oil

Ship #2
154.09 ˚-22.55˚

Event of Sunday **19 February 2023**, at 0512am (AEST), S-1A SAR



Subset, enhanced



Identified by algorithm

Gaps & Future Development

1. **Mineral oil releases vs. look-alikes**
- ML methods
- Data sets for training/testing

2. **Characterization of mineral oil properties (thickness, oil:water ratio, type)**
- Need more field experiments for algorithm development & validation
- In combination with multi-SAR sensor imaging (multi-frequency, satellite, airborne instruments)

3. **Modeling**
- Transport: Wave breaking, wave entrainment of oil
- SAR NRCS vs. slick properties (how well can slicks be characterized from backscatter alone?)
  - Multi-frequency studies

4. **New fuel types (biogenic fuels)**
- Prepare for spills
  - How do these fuels evolve in the ocean environment?
  - How do they manifest in SAR imagery?

Try, Try Again: Recent Steps Toward An Operational SAR-based Algorithm for Oil Spill Thickness Measurements

Ben Holt, Cathleen Jones, Frank Monaldo, Oscar Garcia

04/May/2023

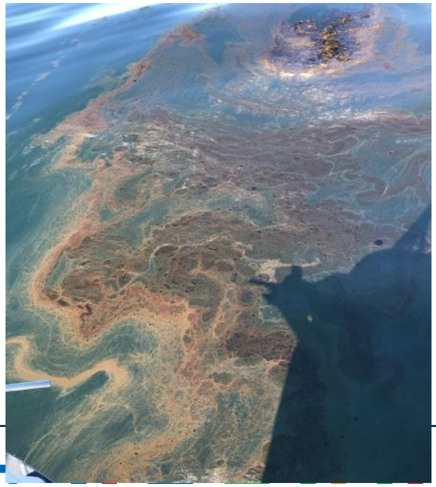
Overview

Develop a quantifiable SAR algorithm for determining the thicker components of oil spills/slicks for operational implementation based on in situ validation collections, including drone imagery. Utilized UAVSAR L-band and satellite C-band sensors.

•Field campaigns Gulf of Mexico, Santa Barbara and Norway

Santa Barbara Field Program

Tube Oil Sampler



Validation – Drone-based Optical Survey

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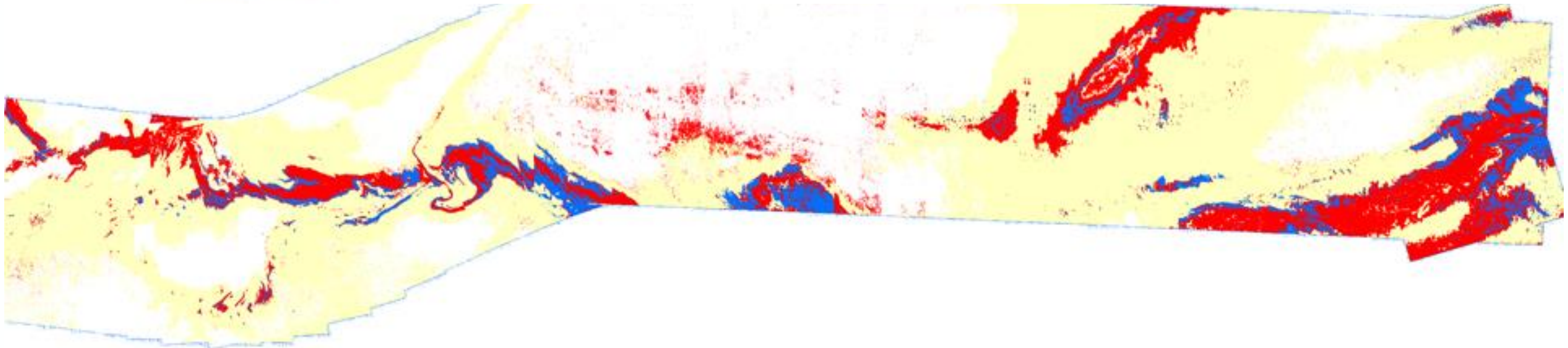
Water Mapper Drone - May 12 – Multispectral Sensor

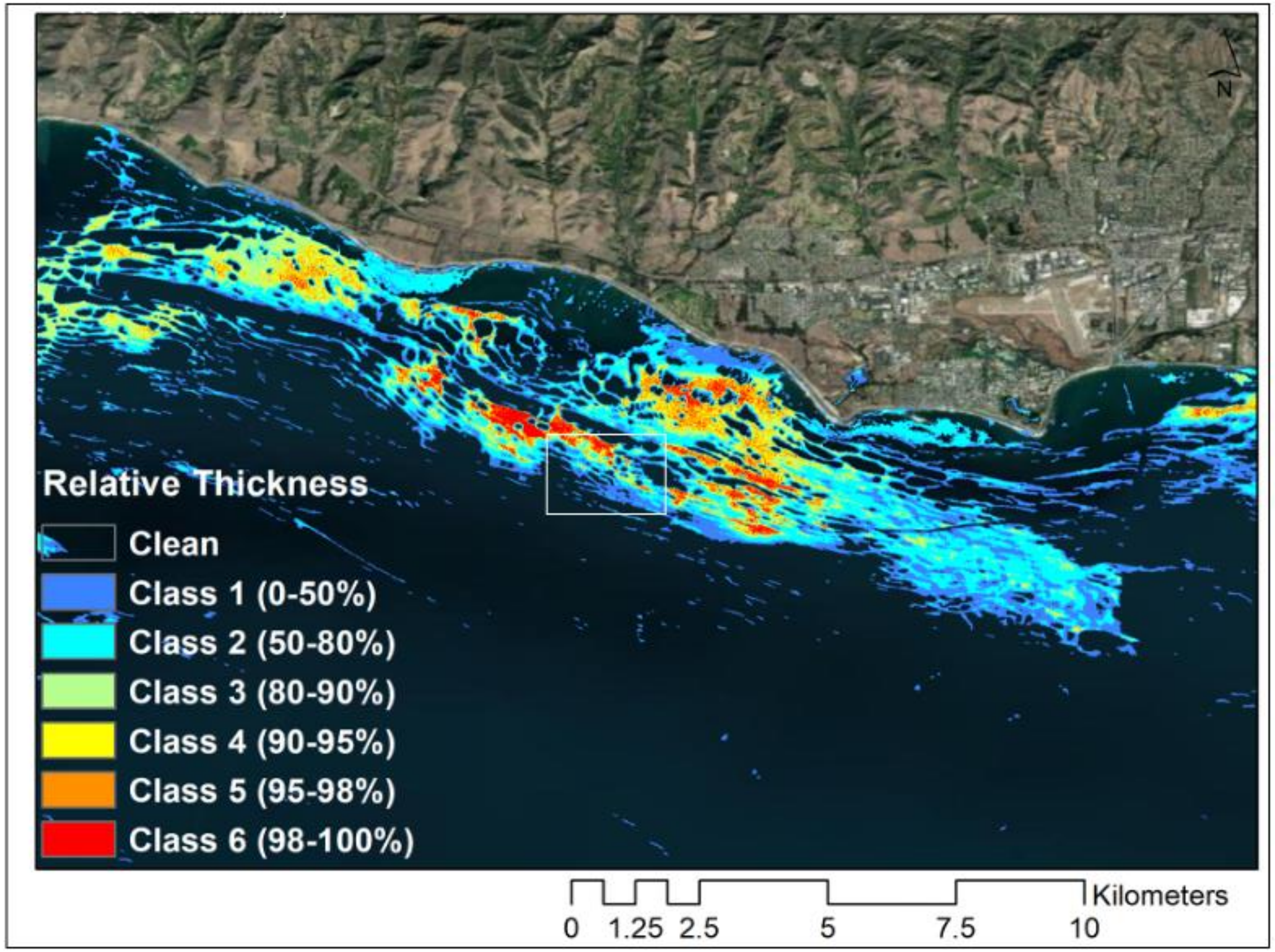


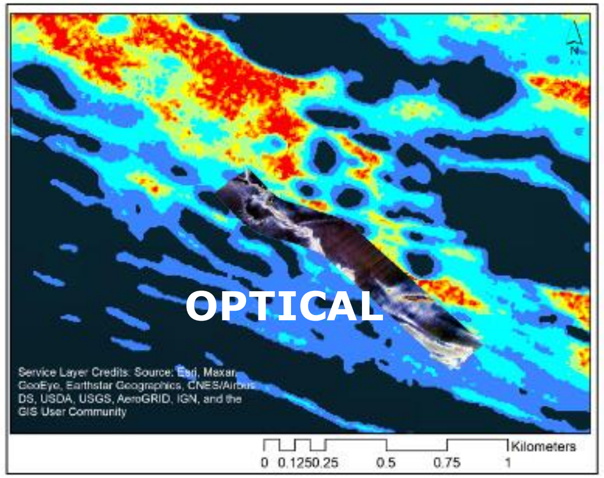
Red – actionable, transitional/dark
Blue – metallic sheen
Yellow- thin sheen
White – clean ocean

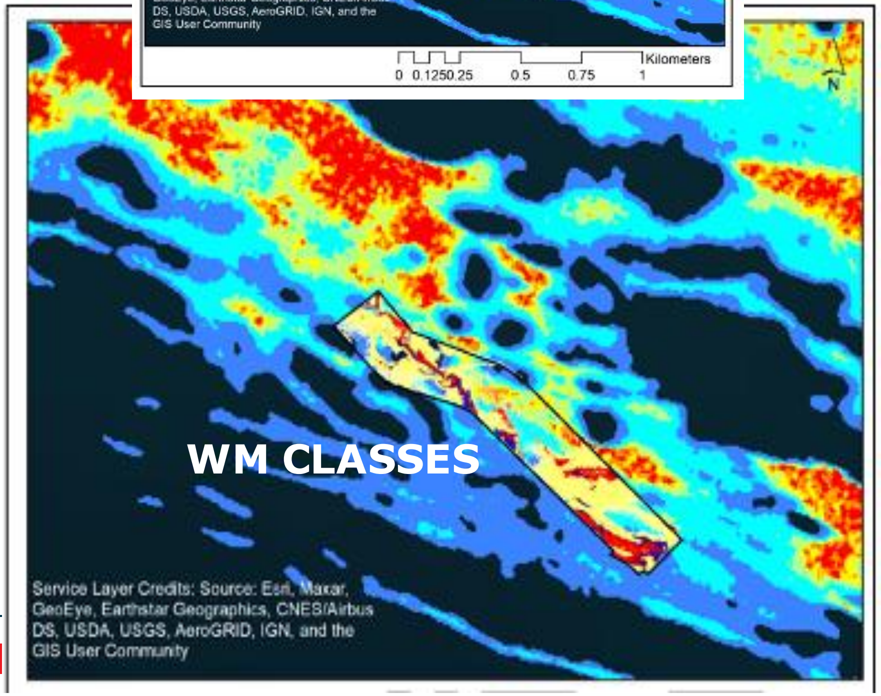
Oscar Garcia-Water Mapping

Relative Thickness Results

Algorithm Description: SeaSAR2023 Abstract Automation of Slick Detection and Classification for Improved Monitoring with SAR, submitted by Jones, Johansson & Holt







Application Gaps

Ben Holte

May 4, 2023

Applications

- Gaps in abstracts/knowledge
  - Oil in Ice Detection
  - Iceberg detection
  - Macroalgae
  - Surfactants

- Others – numerous
  - Water quality

Iceberg Detection and Tracking - Avoidance

•USCG International Ice Patrol (IIP) is charged with tracking icebergs in North Atlantic Ocean that drift southward into shipping lanes below 48°N and provide daily messages to shipping to avoid accidental collisions within major shipping lanes.

•IIP utilizes aerial reconnaissance, ship sightings, ocean circulation, iceberg drift and deterioration models, and more recently extensive (RSat2, S-1, RCM, and S-2) satellite imagery to identify, track, and predict iceberg drift. This is done as a cooperative effort with Canada, Denmark, and US national ice services.

⇒ Need for finer resolution imagery for ships to avoid icebergs ~ 10 m in size

⇒ Reduced data latency

•For Southern Ocean iceberg monitoring, identification of location and calving event identification for Antarctic icebergs for USNIC would reduce the time and improve accuracy for current analysis.

Oil in Ice

What if:

•Oil spill in marginal ice zone – how to separate low backscatter returns from oil slicks from new and young sea ice, related to ex. shipping accident?

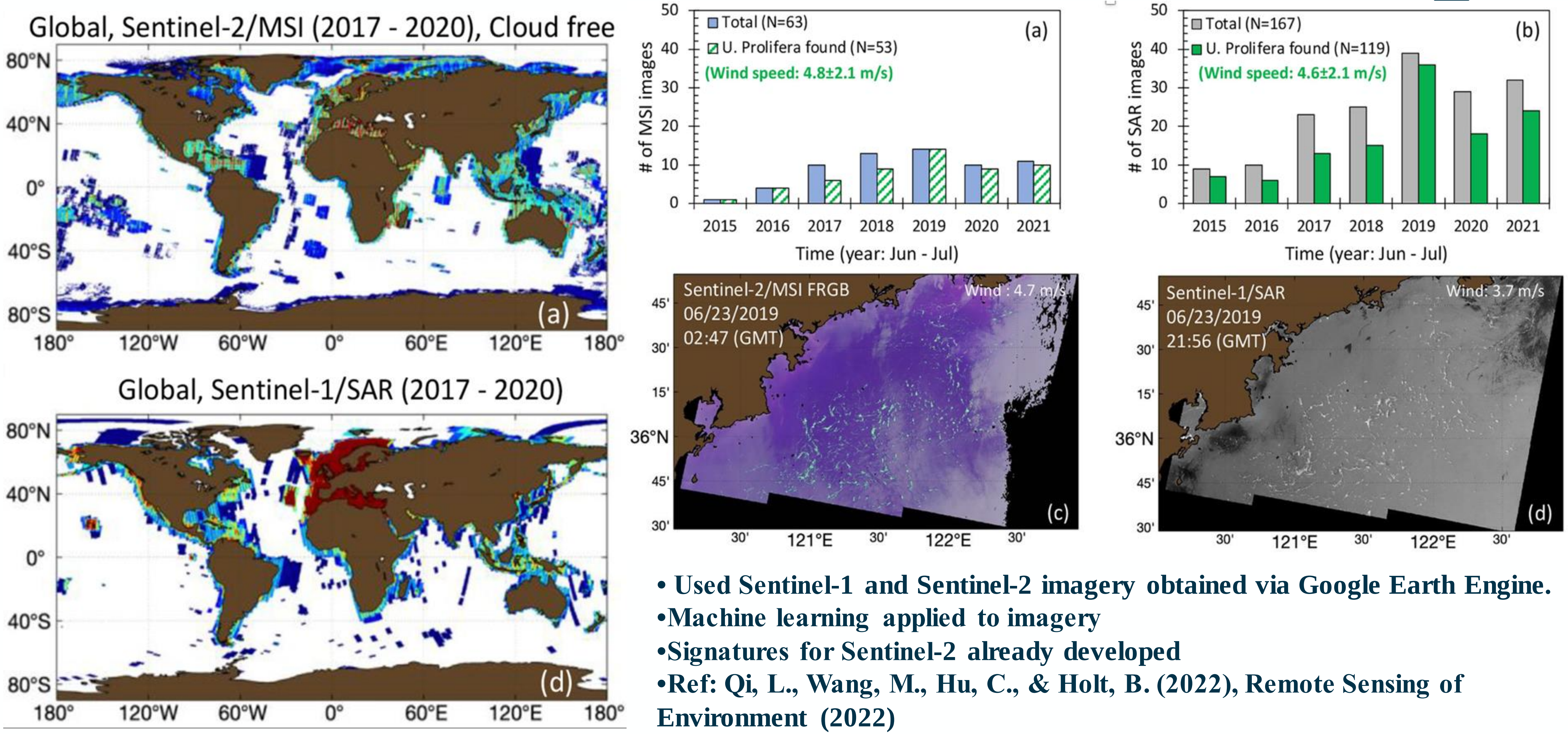
Ref: Brekke, Holt, Jones, Skrunes (RSE 2014)
Ref: Johansson, Espeseth, Brekke, Holt (JSTARS 2020)

-Utilized airborne SAR imagery of L- and C-band polarimetric data for sea ice and oil slicks (Gulf of Mexico).
-Developed a simple model based on dielectric, surface and volume scattering, sea ice properties
->Multipolarization would be useful for separation at several frequencies
-> Low noise floor important

•Oil spill in/on/under sea ice – i.e. from a platform within older sea ice?

Ref: Wilkinson et al. Ambio 2017. Overview of response options
Ref: Various authors using penetrating radar, SAR including in situ/lab work
-Key issue is similarity in dielectric constant between thicker sea ice and oil (~3-5)
-At cold temperatures oil will change properties and become possibly separable from ice

SAR Detection of Macroalgae



- Used Sentinel-1 and Sentinel-2 imagery obtained via Google Earth Engine.
- Machine learning applied to imagery
- Signatures for Sentinel-2 already developed
- Ref: Qi, L., Wang, M., Hu, C., & Holt, B. (2022), Remote Sensing of Environment (2022)

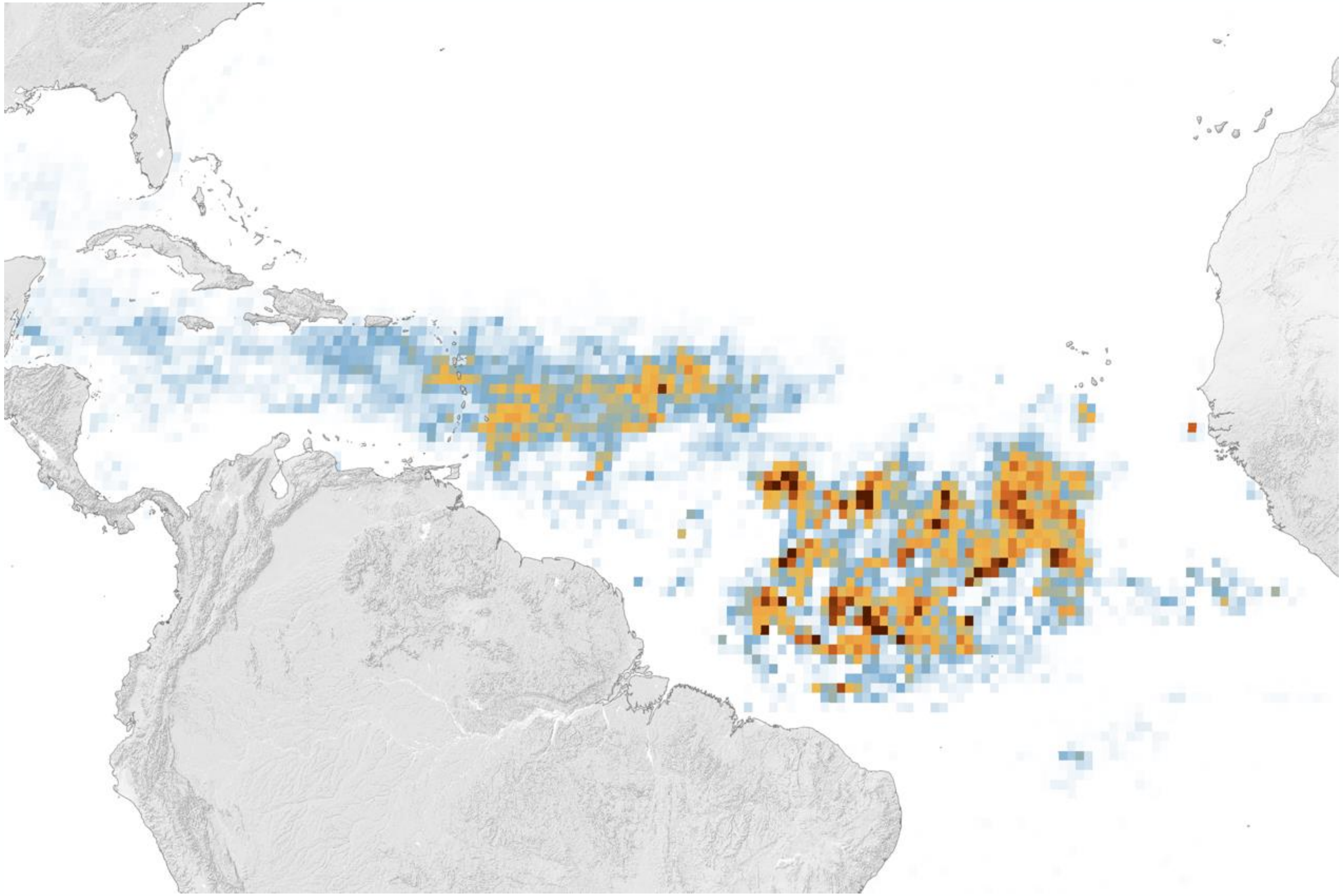
- Related studies by ex. Gade 1998, Shen and Perrie 2014

SAR Detection of Macroalgae

Fig. 1. Floating macroalgae rafts/mats of *Ulva Prolifera* (a-1&a-2), *Sargassum horneri* (b-1&b-2), and *Sargassum fluitans/natans* (c-1&c-2) in the YS, ECS, and CS, respectively. Their approximate locations are annotated in the inset maps. Note different color tones and morphology even for the same type of macroalgae.

- SAR has signatures brighter than the ocean due to leaves/stalks being pushed above sea surface
- *Ulva* had higher detection rates than Sargassum
- Combined sensors improves numbers of total observations

‘A Massive Seaweed Bloom in the Atlantic’



•Significant problem in last decade for Islands in Caribbean and Gulf of Mexico - beach fouling

•Reason for recent explosion unknown but thought to have contribution from humans: ex. Fertilizer runoff

•Left - MODIS imagery from U. So. Florida

https://earthobservatory.nasa.gov/images/151188/a-massive-seaweed-bloom-in-the-atlantic

Surfactants – Biogenic Slicks

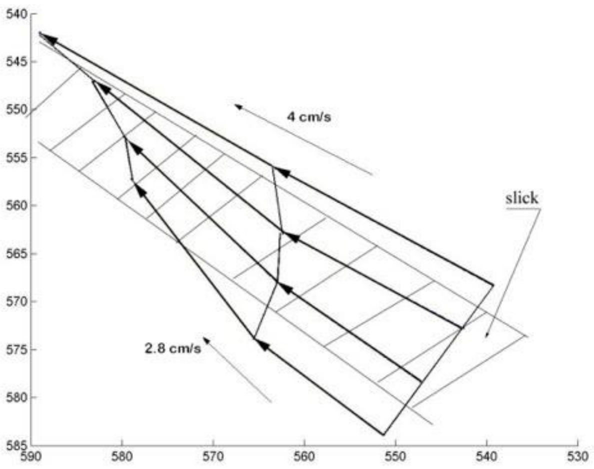
- Biogenic slicks composed of exudates of plant and animal life cycles
- Global distribution, found to have impact on air-sea fluxes - energy, heat, gas exchange, indicative of underlying near-surface circulation
- Low radar signatures similar to low winds, macroalgae, mineral oil – may need co-polarization.
- Ripe for machine learning to generate product using multiple sensors – feature identification, association with biological production, surface presence during lower wind states,
  - -SAR
  - -Wind speed retrieval – scatterometer
  - -Chlorophyll

Papers by ex. Alpers, Gade, Wurl, Espedal, others

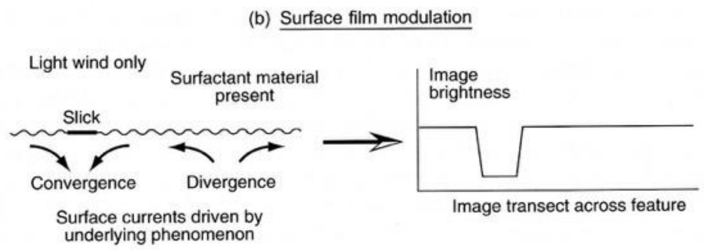
Natural Marine Surface Films

Slicks & eddies

ERS SAR Image (C-VV; 70 km × 70 km)
Bering Strait
(24 June 1997, 22:30 UTC, © ESA)



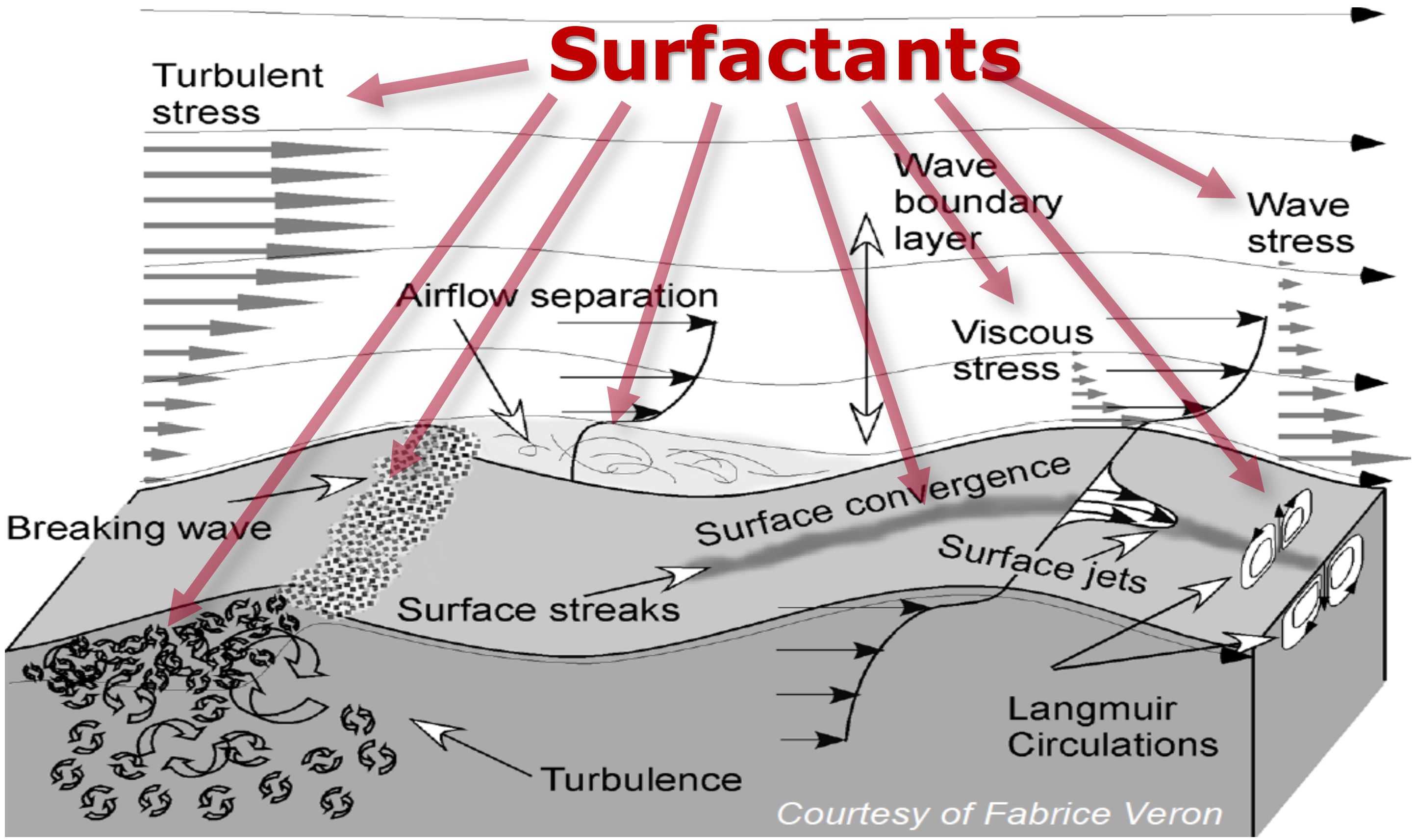
[Gade et al., 2014]



[Robinson, 2003]

Impact of Surfactants on Air-Sea Interactions

•From Martin Gade



- Coupled air-wave-water dynamics control bulk air-sea fluxes
- SML composition / surfactants modify the waves
- Need for hi-res measurements within first millimeters above/below the waves in presence of surfactants

Helmholtz-Zentrum hereon

UHH Universität Hamburg