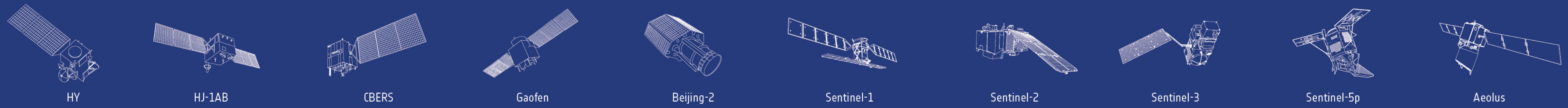


2023 DRAGON 5 SYMPOSIUM

3rd YEAR RESULTS REPORTING

11-15 SEPTEMBER 2023

PROJECT ID. 57979

MONITORING HARSH COASTAL ENVIRONMENTS AND OCEAN SURVEILLANCE USING RADAR REMOTE SENSING (MAC-OS)

DAY 3 – WEDNESDAY 13/SEPT/2023

ID. 57979

PROJECT TITLE: MONITORING HARSH COASTAL ENVIRONMENTS AND OCEAN SURVEILLANCE USING RADAR REMOTE SENSING

PRINCIPAL INVESTIGATORS: FERDINANDO NUNZIATA, XIAOFENG YANG

CO-AUTHORS: X.LI, W.SHAO, T.MENG, Y.DU, S.WANG, A.VERLANTI

PRESENTED BY: FERDINANDO NUNZIATA

Dragon 5 3rd Year Results Reporting

- Inform on the project's objectives
- Detail the Copernicus Sentinels, ESA, Chinese and ESA Third Party Mission data utilised after 3 years (complete slide 4)
- Detail the in-situ data measurements and requirements
- Provide details on field data collection campaigns and periods in P.R. China or other study areas
- Inform on the results after 3 years of activity
- Inform on the project's schedule, planning & contribution of the partners for the following year
- Report on the level and training of young scientists on the project achievements, including plans for academic exchanges
- Report on the peer reviewed publications (nr. of papers, journal name and publication title) after 3 years of activity

Objectives

The project is a very good story of team-working!

Objectives

LB
Rui
CB
Kim
GK
Meret
CB
Rrahmani
RB
Di Lorenzo
DM
Lobotka
CM
Zielinski
CM
Anguissa
LW
Kvaratskhelia
CF
Osimhen
RW
Politano

NAPUL3
CAMPIONE D'ITALIA

Objectives

Objectives

- Ocean & coastal zone thematic area
  - marine dynamic environment
  - sea surface characteristics

The project aims at exploiting Synthetic Aperture Radar (SAR) satellite measurements to generate innovative added-value products to observe coastal areas characterised by harsh environments, even under extreme weather conditions.

Objectives

Nov. 3, 1985 - Napoli-Juventus (1-0)

”The punizione”… not just a free kick

…but “THE free kick”

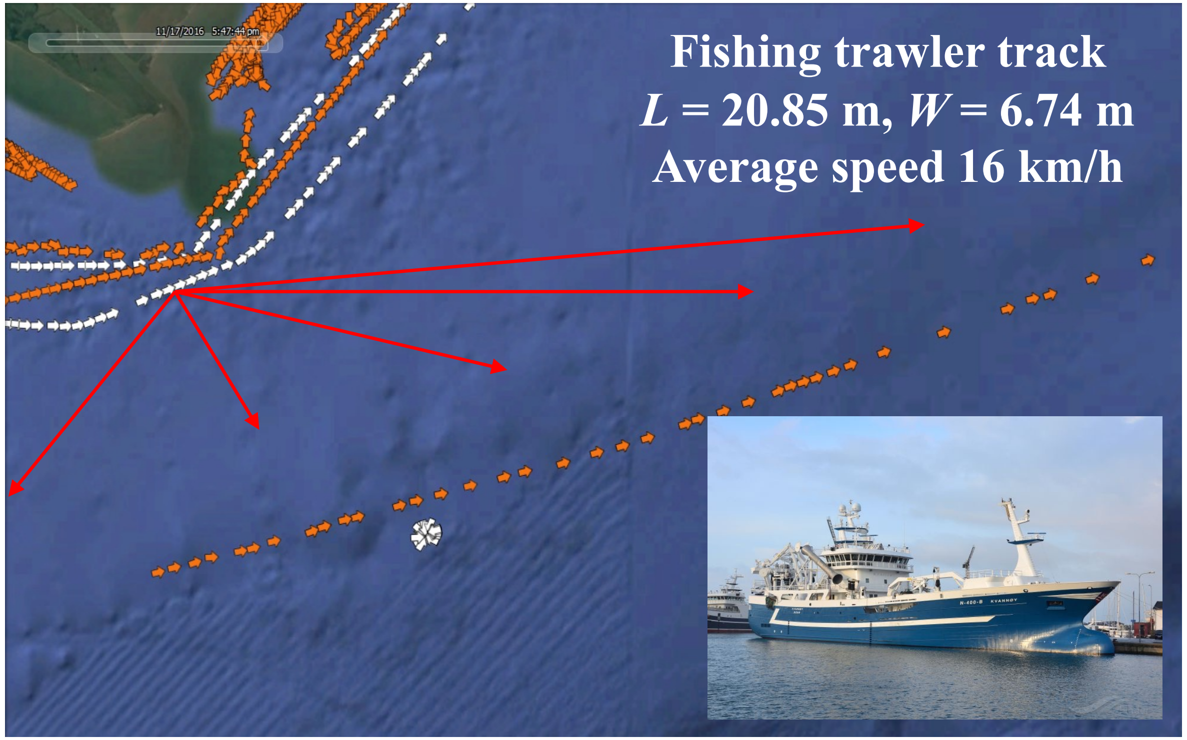
- Observation of metallic targets at sea
  - Ship backscattering vs incidence angles
  - Backscattering from offshore wind farms

- Observation of sea oil pollution
  - Backscattering from oil emulsions
  - Bistatic scattering from oil-covered sea surface
  - Scattering and damping models
  - Inversion of oil parameters using model-based NN

- Observation of sea wind/waves
  - Backscattering under wave breaking conditions
  - Wind field estimation
  - Parametric Model for Hurricane Tangential Wind
  - Green Tide Detection from SAR Images

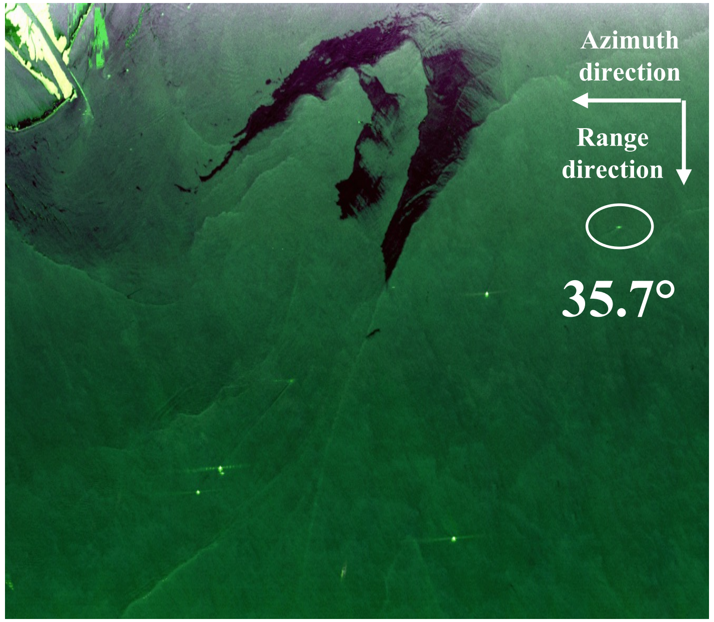
Ship backscattering

- Gulf of Mexico on 17/11/2016.
- Time series of UAVSAR imagery.
- Seven SAR scenes collected over the target spanning two hours acquisitions.
- Wide incidence angle range, 35° - 55°.
- Low-to-moderate sea state conditions, wind speed in the range 1 m/s - 5 m/s.



Ship backscattering

Gulfco_27086_16100_000_161117_L090_CX_01



SAR scenes at different incidence angles

Gulfco_27086_16100_001_161117_L090_CX_01

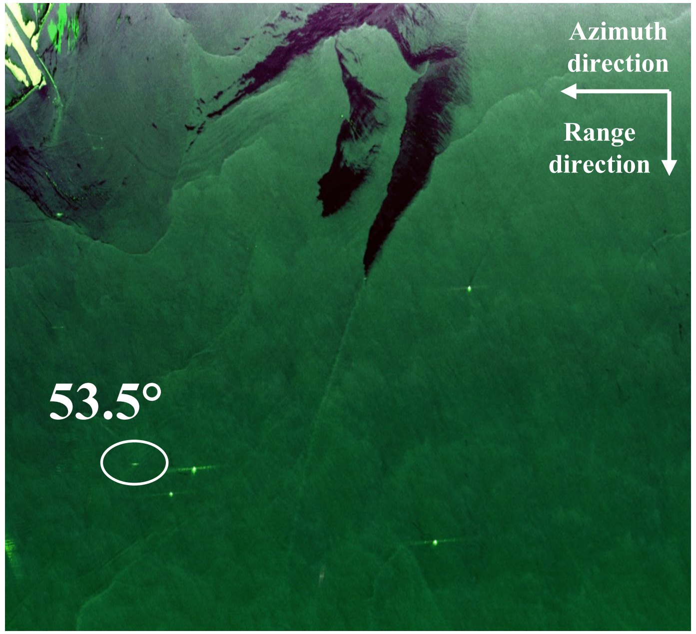
Gulfco_27086_16100_002_161117_L090_CX_01

Gulfco_27086_16100_003_161117_L090_CX_01

Gulfco_27086_16100_004_161117_L090_CX_01

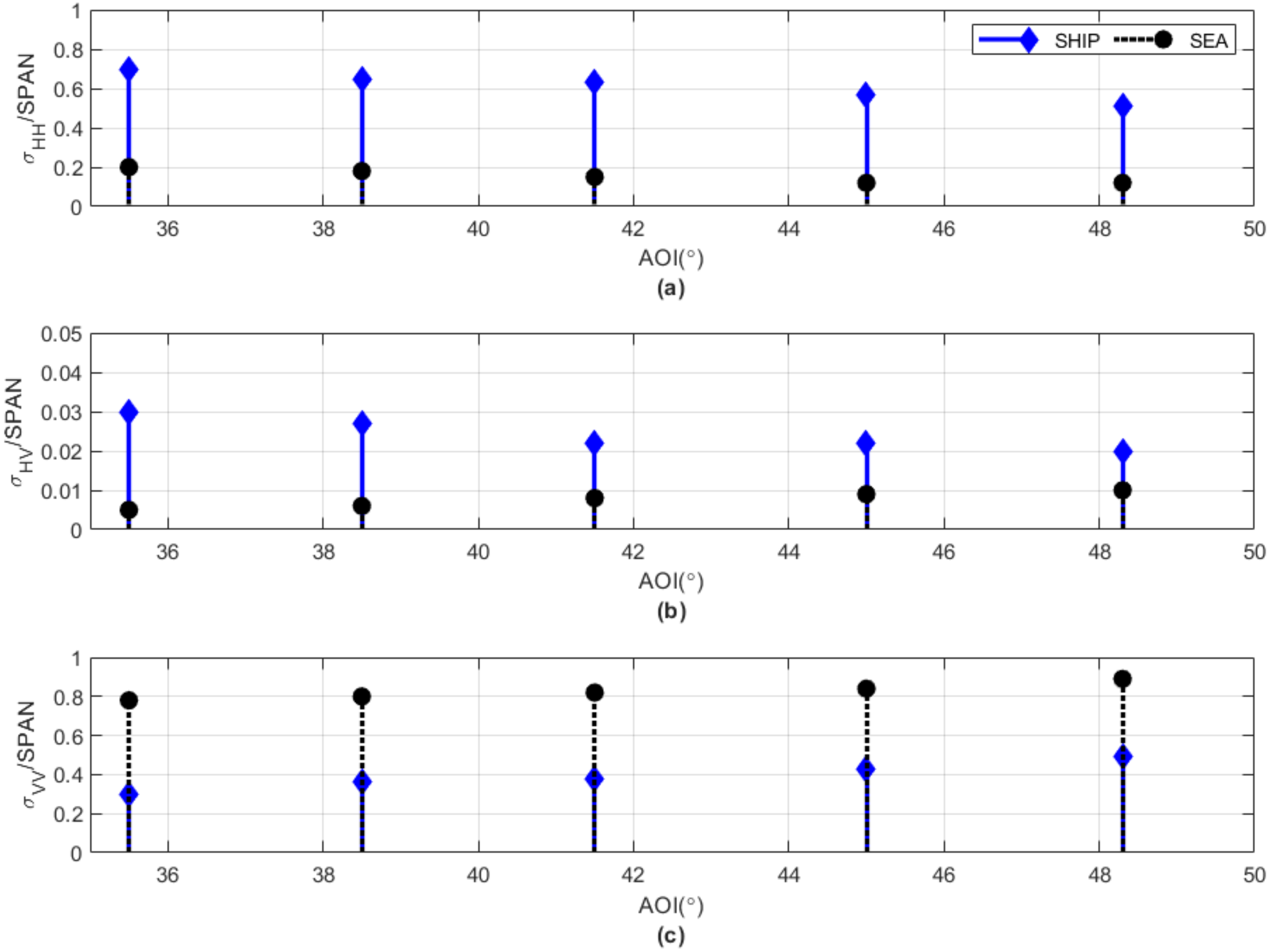
Gulfco_27086_16100_005_161117_L090_CX_01

Gulfco_27086_16100_006_161117_L090_CX_01

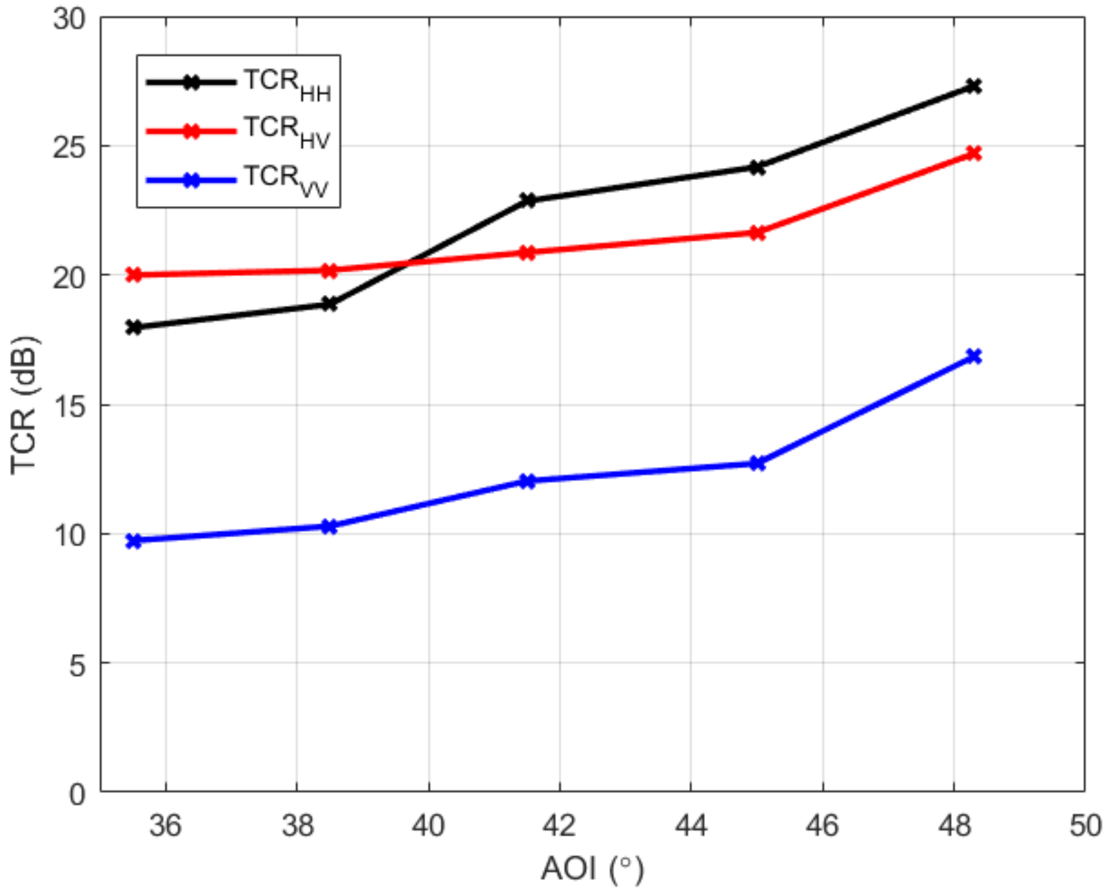


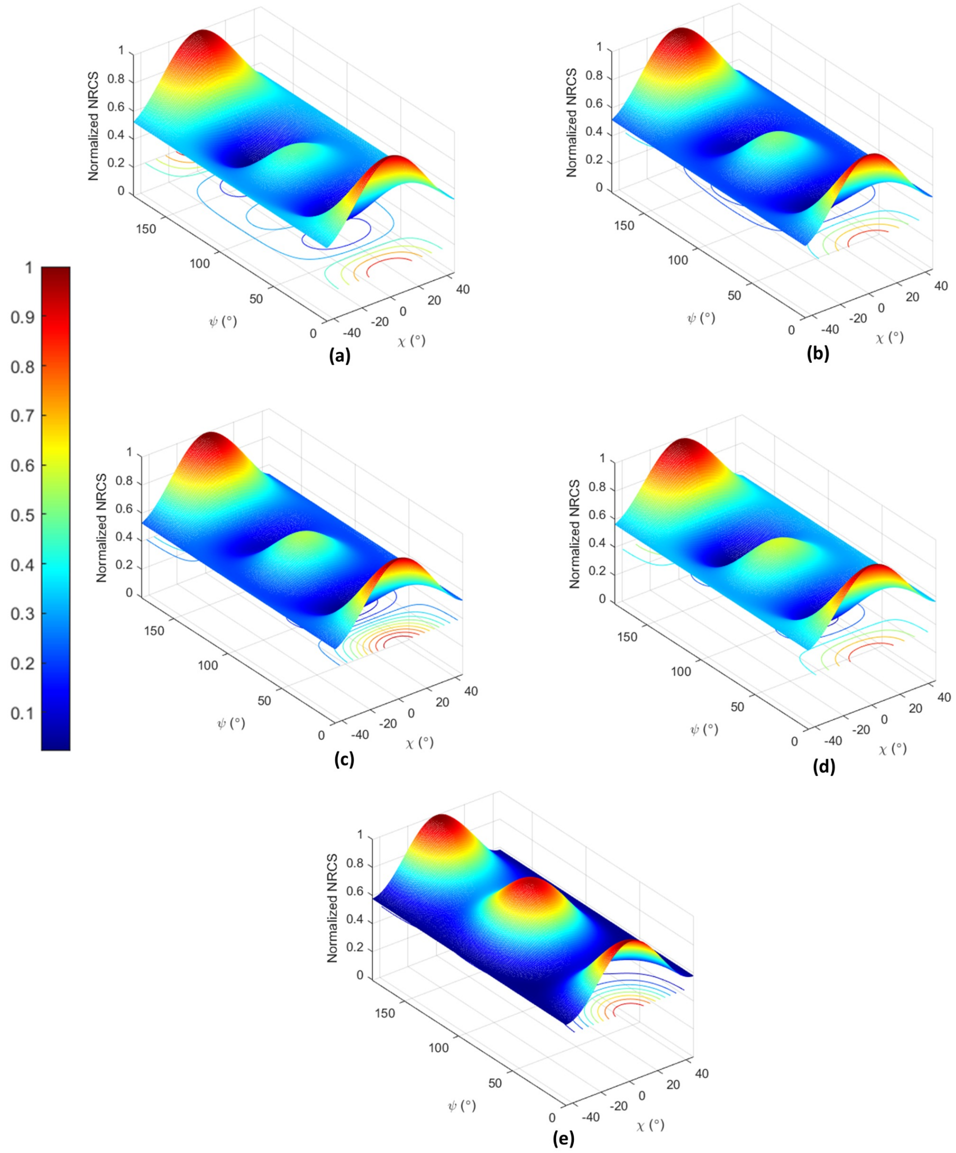
UAVSAR polSAR measurements

Ship backscattering

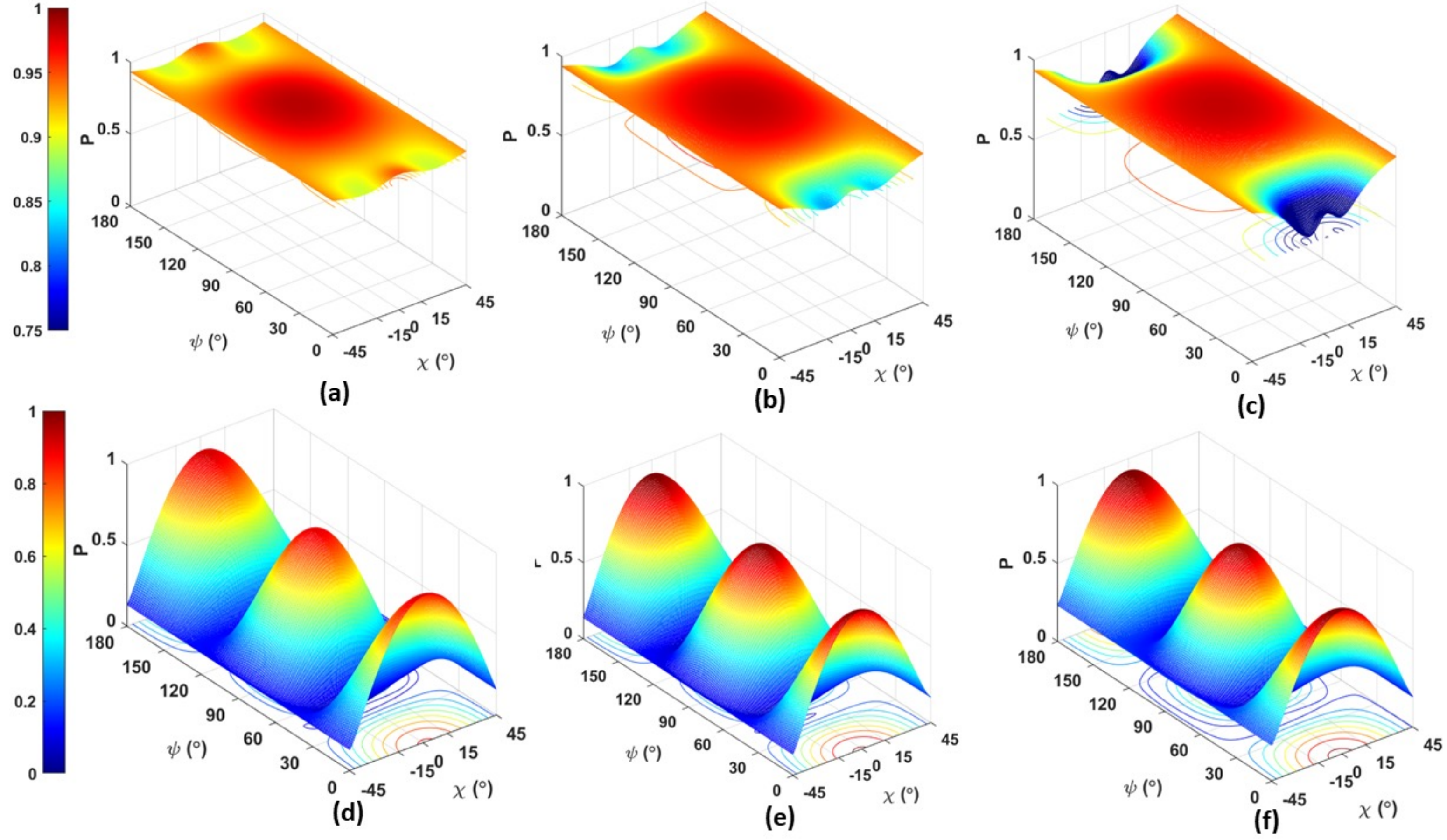


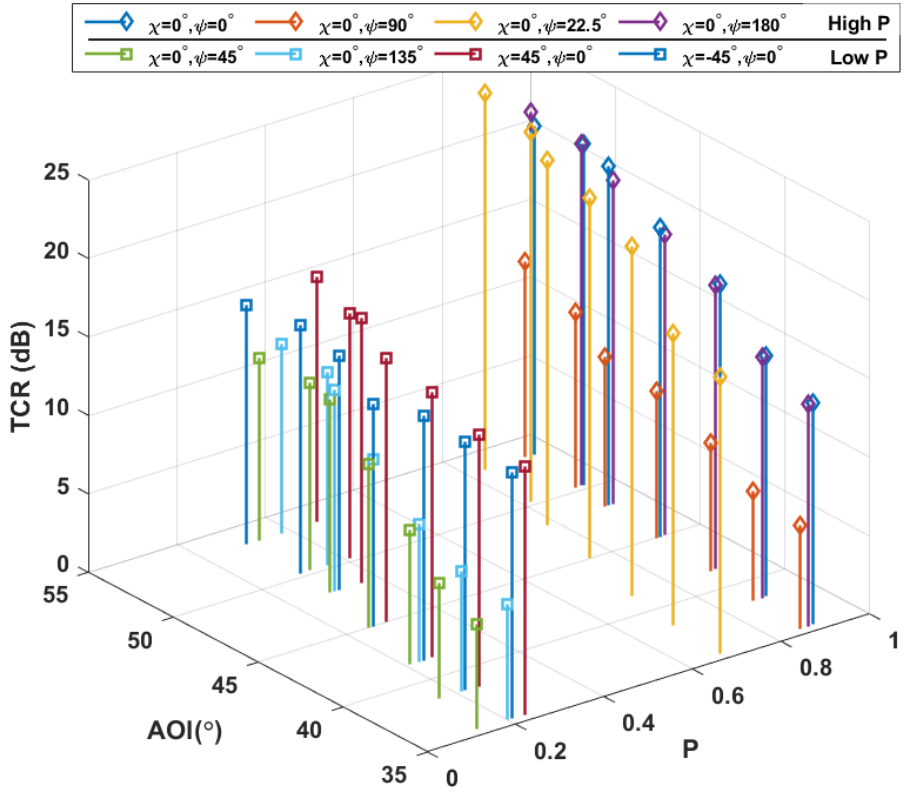
Ship backscattering





Polarimetric Ship backscattering





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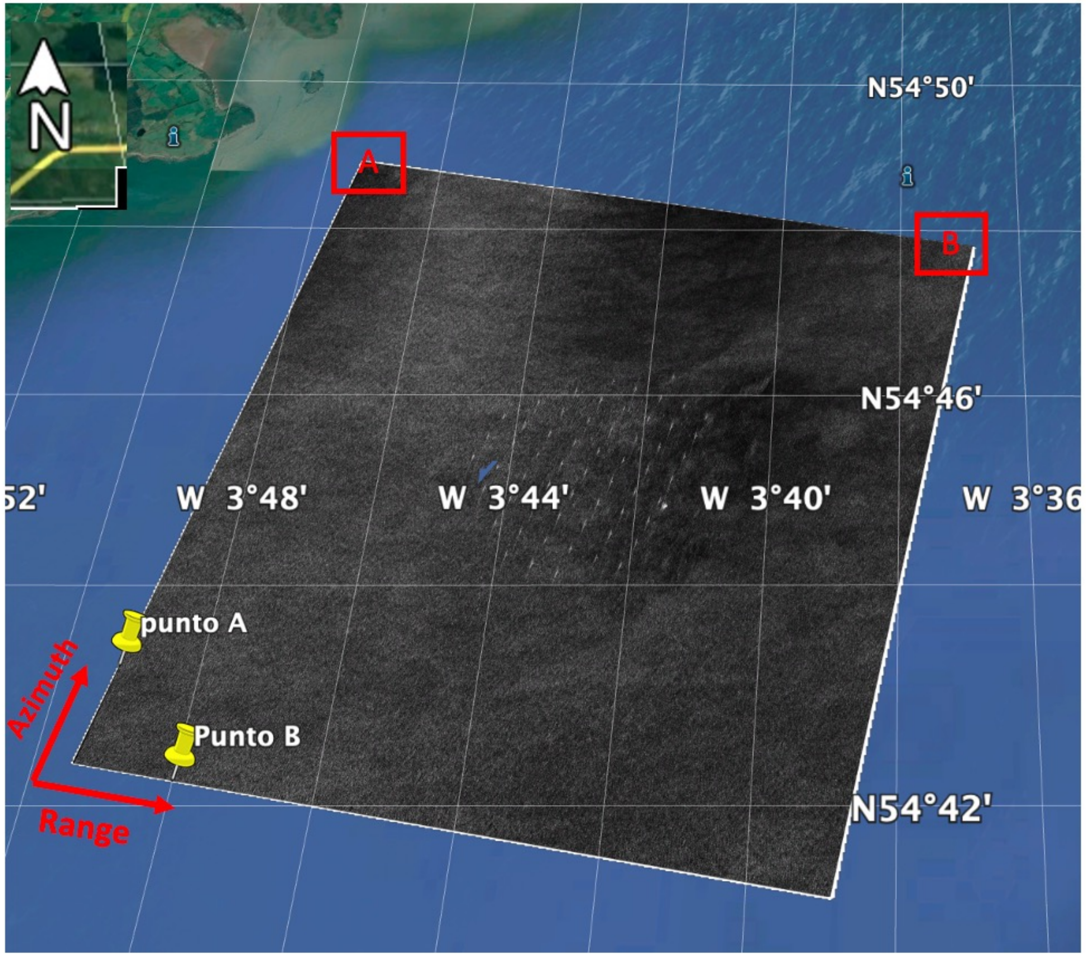
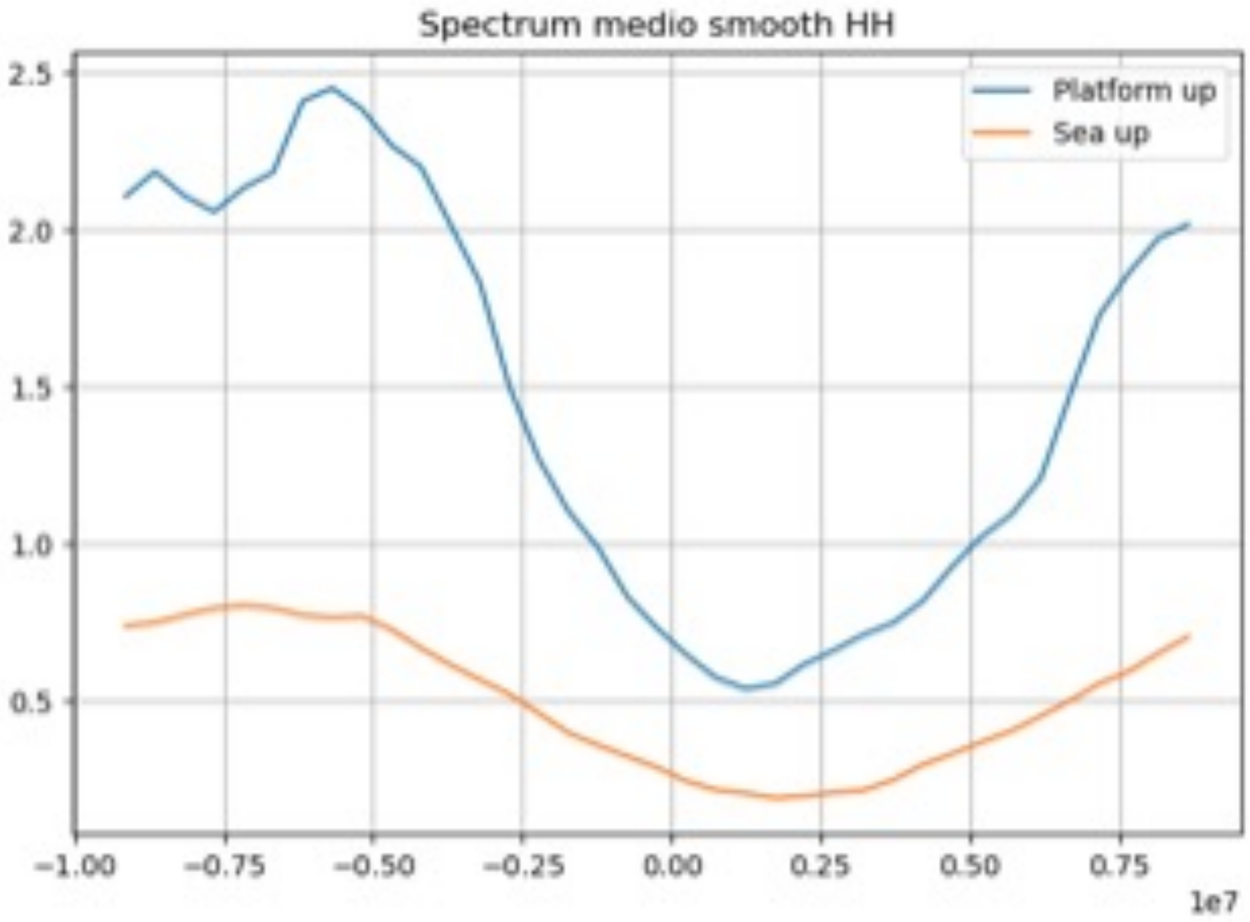
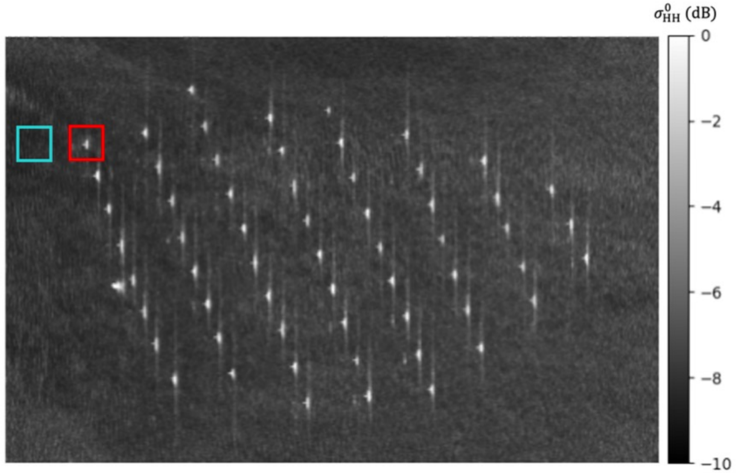
Backscattering from off-shore wind farms



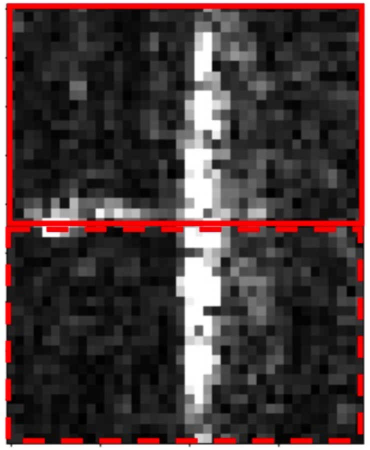
PAZ polSAR measurements



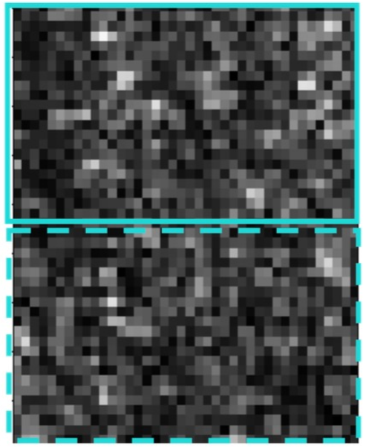
Backscattering from off-shore wind farms



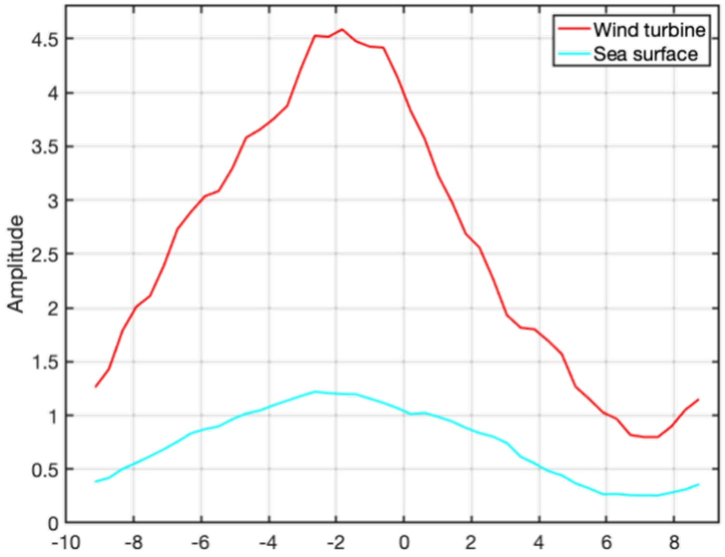
(a)

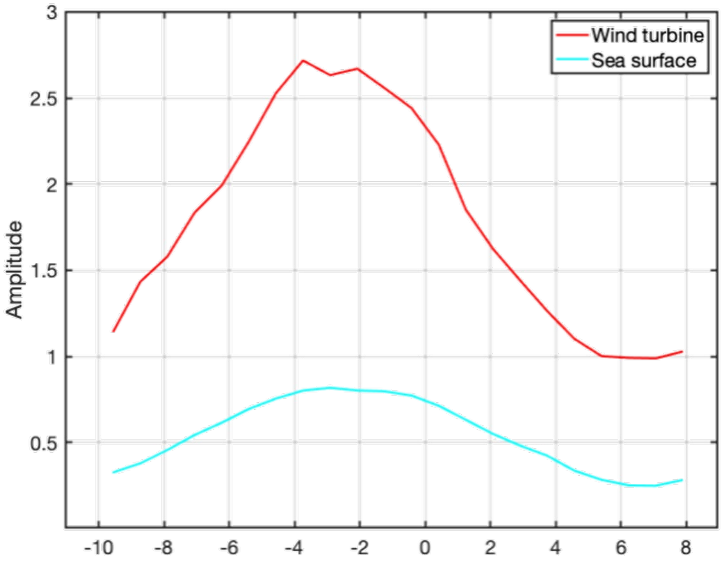


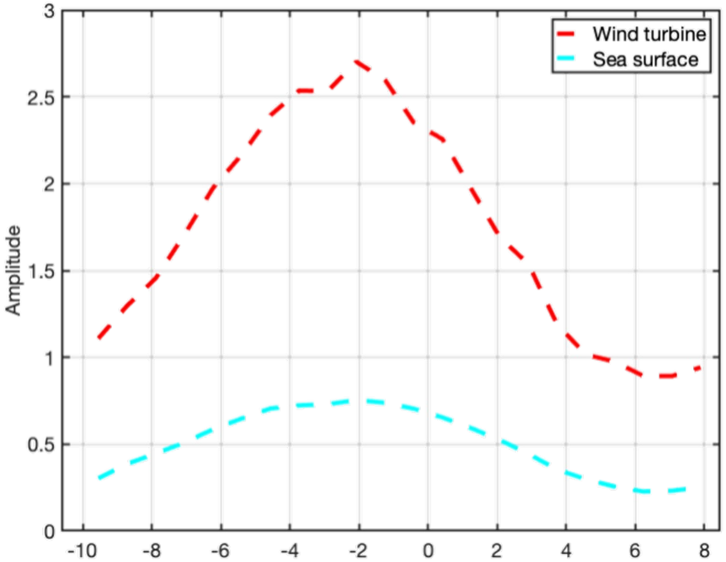
(b)



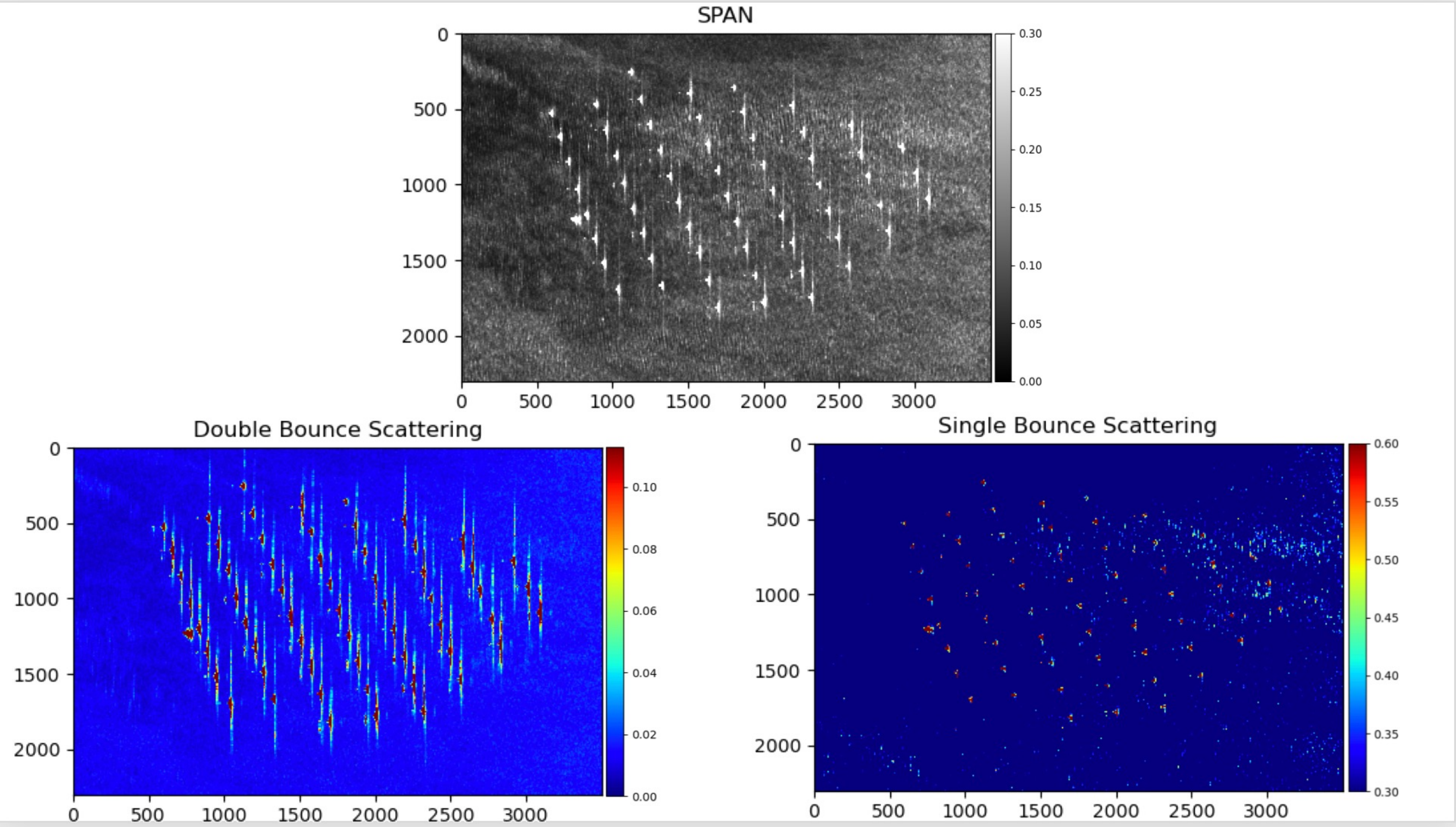
(c)







Backscattering from off-shore wind farms



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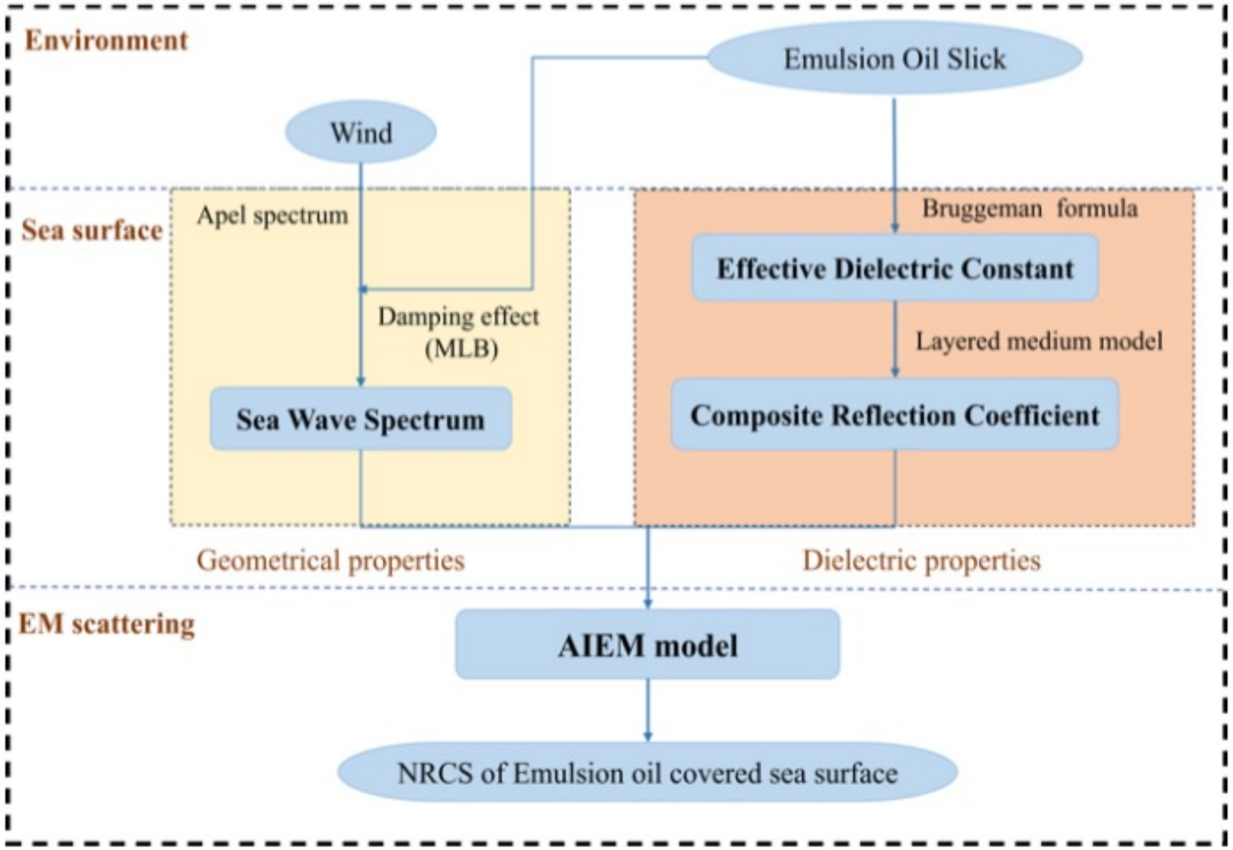
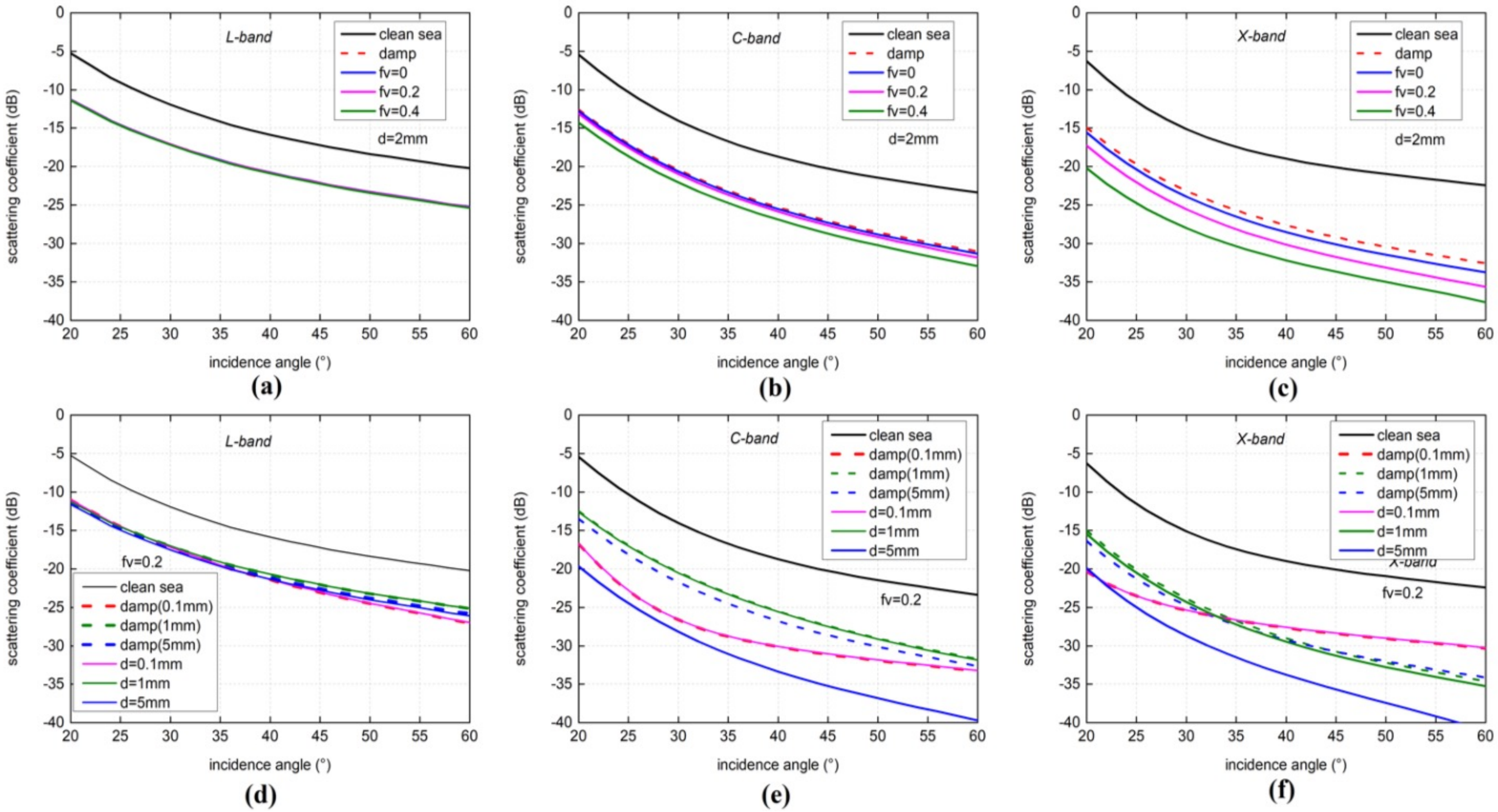
Backscattering from oil emulsions



TSX and UAVSAR measurements

Backscattering from oil emulsions



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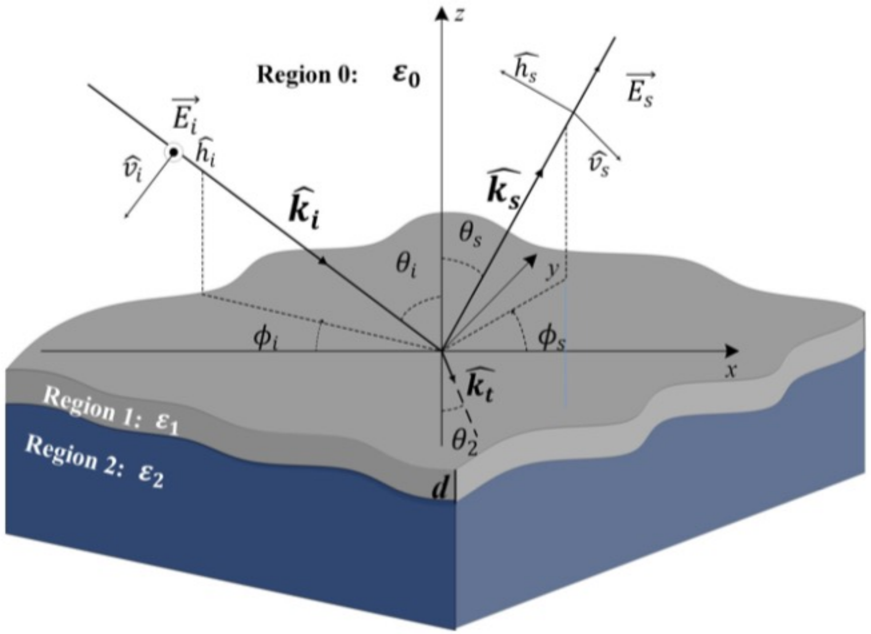
Bistatic scattering from oil-covered sea surface

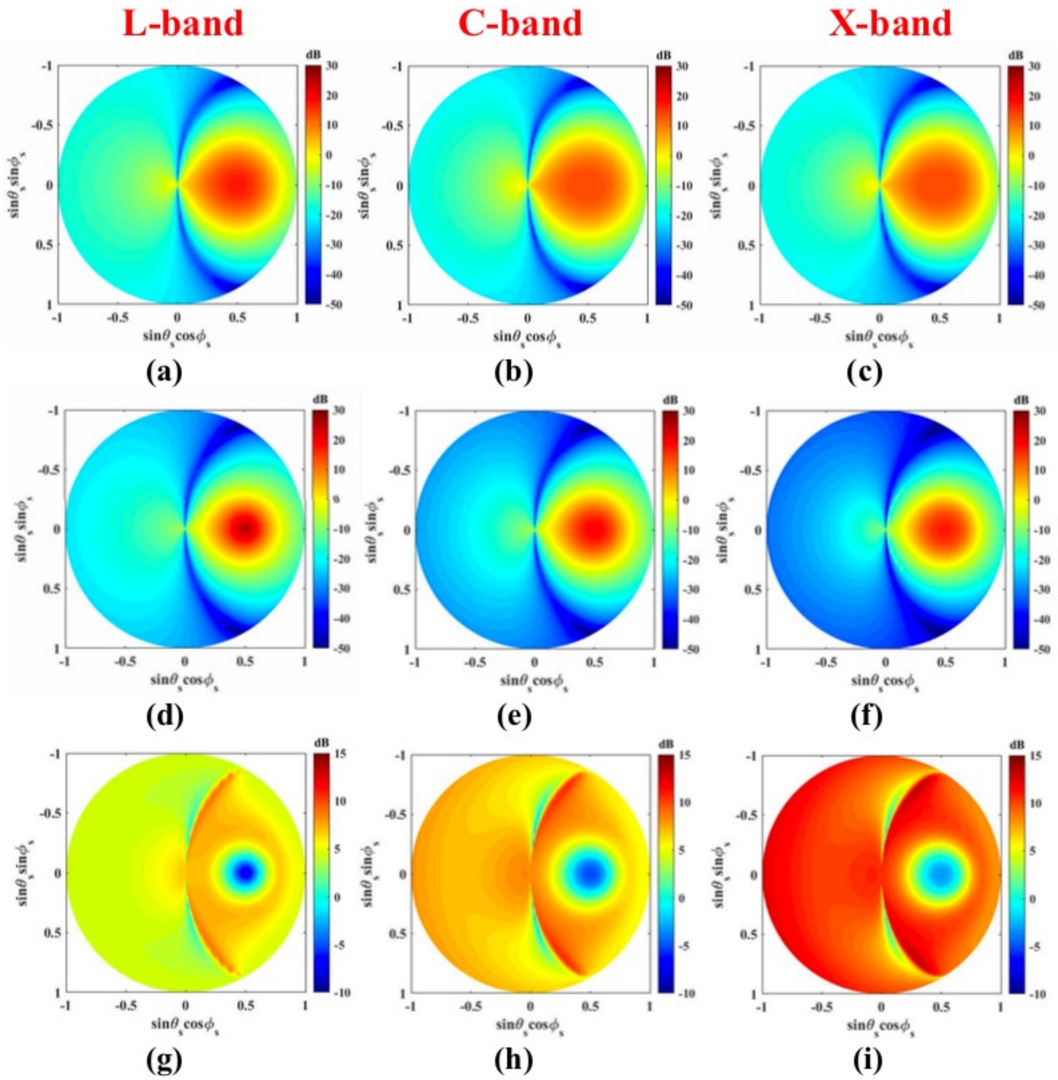


The bistatic radar scattering coefficients related to an oil-covered sea surface are predicted by modeling:

- the oil damping effect on surface roughness
- the oil modification on the dielectric properties of the scattering surface.

The bistatic scattering is predicted using the advanced integral equation method

Bistatic scattering from oil-covered sea surface



The bistatic scattering is depicted in the form of the unit circle:

- the left semicircle corresponds to backscattering
- the right semicircle corresponds to forward scattering
- the horizontal axis crossing the origin of the circle represents the plane of incidence ($\phi_s = 0°$ or $180°$)
- the vertical axis crossing the origin represents the cross-plane ($\phi_s = 90°$ or $270°$);

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Scattering and damping models

2 scale BPM

$$\sigma^0_{pq} = \sigma^0_{pq0} + \sigma^0_{pq1}$$

$$\sigma^0_{pq0} = \frac{\pi}{cos^4\tau_{sp}} |R_{pq,eff}|^2 T_{sl}(\alpha,\beta)$$

$$\sigma^0_{pq1} = \frac{k^2}{4\pi(v_z/k)^2} \iint_{-\infty}^{\infty} |H_{pq}(\alpha,\beta)|^2 \gamma_R(K_x,K_y)\, T_{sl}(\alpha,\beta)\, d\alpha d\beta$$

AIEM

$$\sigma^0_{pq} = \sigma^k_{pq} + \sigma^c_{pq} + \sigma^x_{pq}$$

$$\sigma^0_{pq} = \frac{k^2}{2} e^{-\sigma^2(k^2_{sz}+k^2_{iz})} \sum_{n=1}^{\infty} \frac{\sigma^{2n}}{n!} |I^n_{pq}|^2 W^n$$

$$DR_{BPM} = \frac{\sigma^0_f}{\sigma^0_c} = \frac{\sigma^0_{f0} + \sigma^0_{f1}}{\sigma^0_{c0} + \sigma^0_{c1}}$$

The slick modifies:

1) The ripple spectrum γ_R
2) The slope PDF T_{sl}

$$DR_{AIEM} = \frac{\sigma^0_f}{\sigma^0_c} = e^{-[(\sigma^2_f-\sigma^2_c)(k^2_{sz}+k^2_{iz})]} \sum_{n=1}^{\infty}\left[|I_f|^2 \frac{\sigma_f^{2n} W_f^n}{n!}\right] / \left[\sum_{n=1}^{\infty} |I_c|^2 \frac{\sigma_c^{2n} W_c^n}{n!}\right]$$

The slick modifies:

1) The surface rms height σ
2) The sea surface spectrum and its multiple-convolution W^n

Damping model

Marangoni

$$y_{\mathrm{Mar}}(K;|E|,\theta) = \frac{1+X(cos\,\theta-sin\,\theta)+XY-Y\,sin\,\theta}{1+2X(cos\,\theta-sin\,\theta)+2X^2}$$

Model of Local Balance

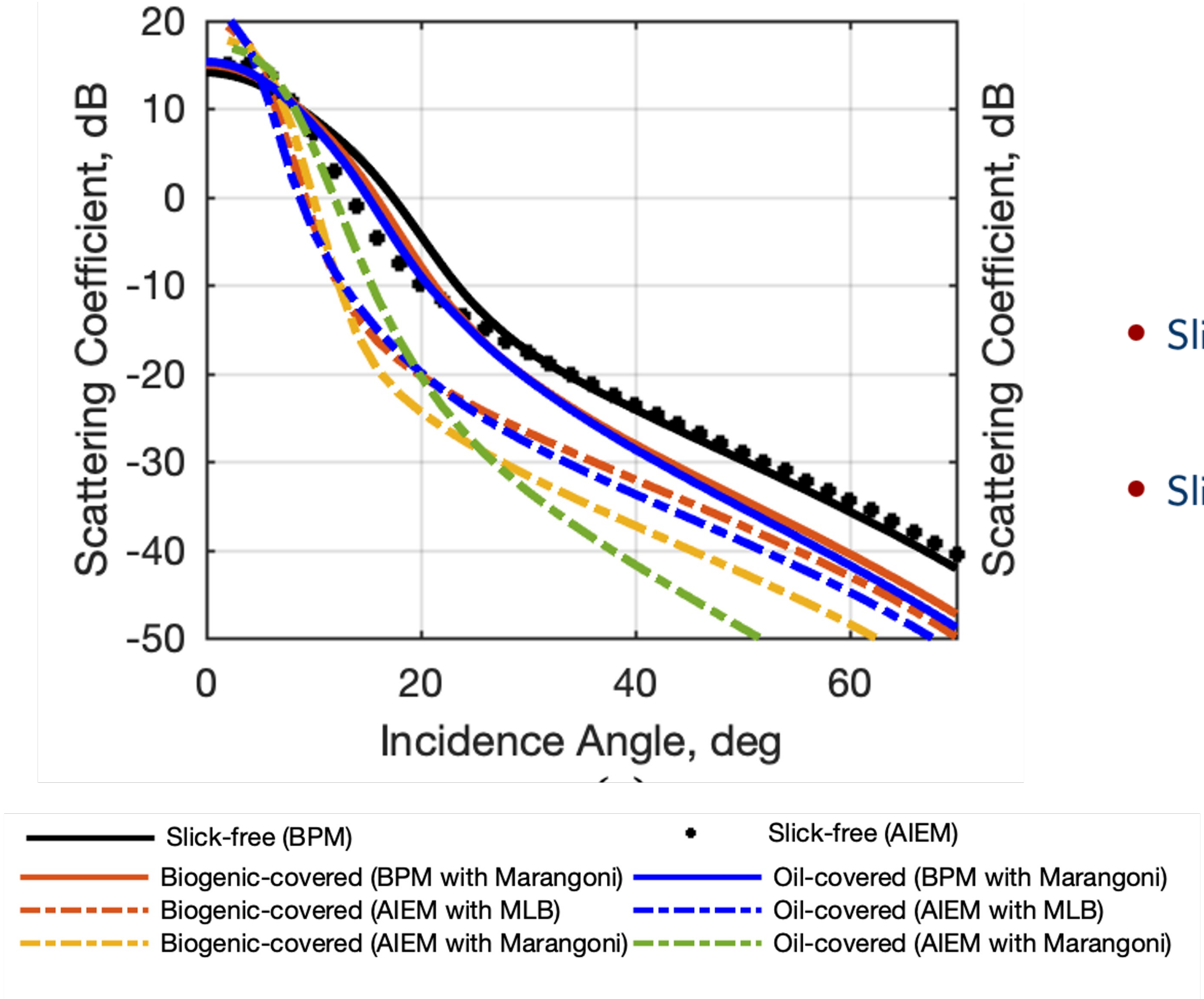
$$y_{\mathrm{MLB}}(K,u_{*,s},y_{\mathrm{Marg}}) = \frac{\beta(u_{*,s})-2(\Delta\cdot y_{\mathrm{Mar}})c_g+(\alpha+\Delta\alpha)}{\beta(u_*)-2\Delta c_g+\alpha}$$

$$u_{*,s} = \mu\cdot u_*$$

$$S_s(K,u_{*,s};|E|,\theta) = \frac{S(K,u_*)}{y_{\mathrm{Mar}}(K;|E|,\theta)}$$

$$S_s(K,u_{*,s},y_{\mathrm{Mar}}) = \frac{S_W(K)}{y_{\mathrm{MLB}}(K,u_{*,s},y_{\mathrm{Mar}})}$$

Scattering and damping models



- Slick-free
  - Differences @ low AoI. Similar predictions at larger AoI.
  - BPM resulting in the best fit.
- Slick-covered
  - BPM working best for biogenic.
  - AIEM working best for oil.

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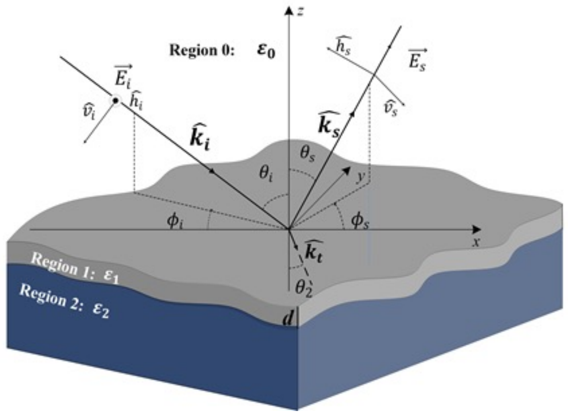
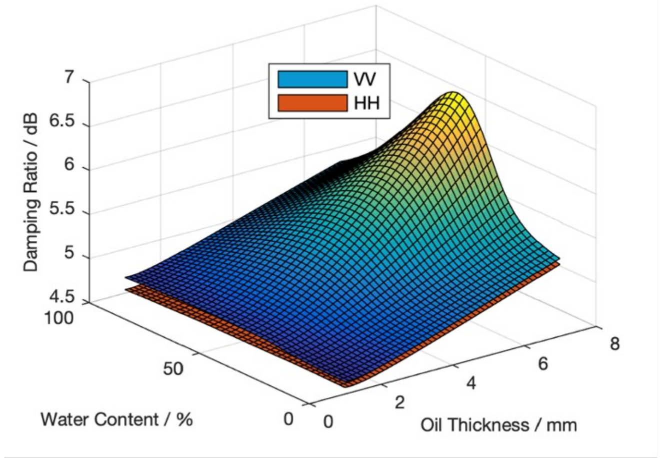
Model-based NN to retrieve thickness and fraction of water into the oil



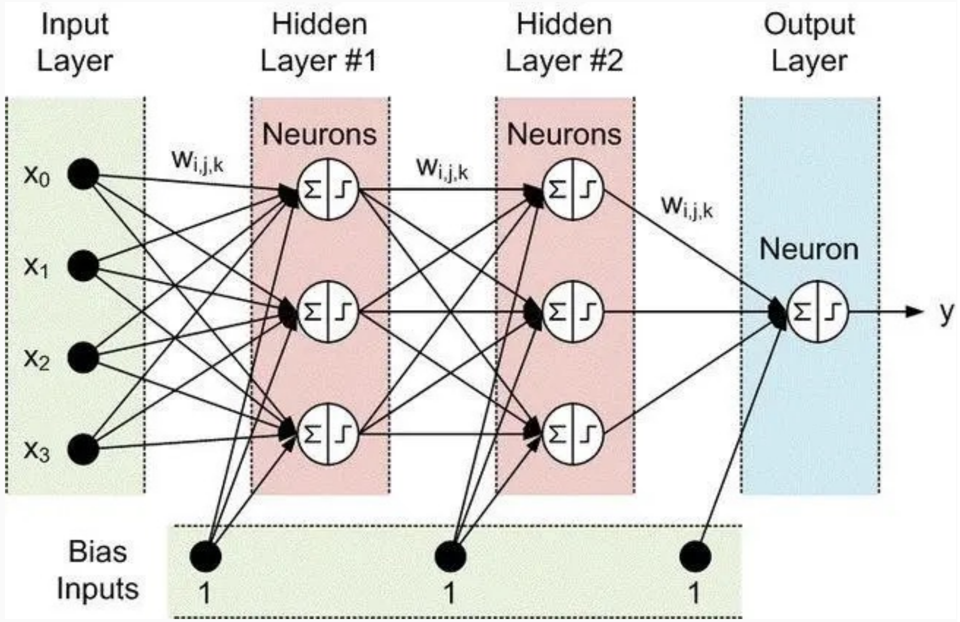
$$DR_{pp}(\theta_i, d, f_v) = \frac{\sigma_{pp}^{0,\text{free}}}{\sigma_{pp}^{0,\text{slick}}}$$

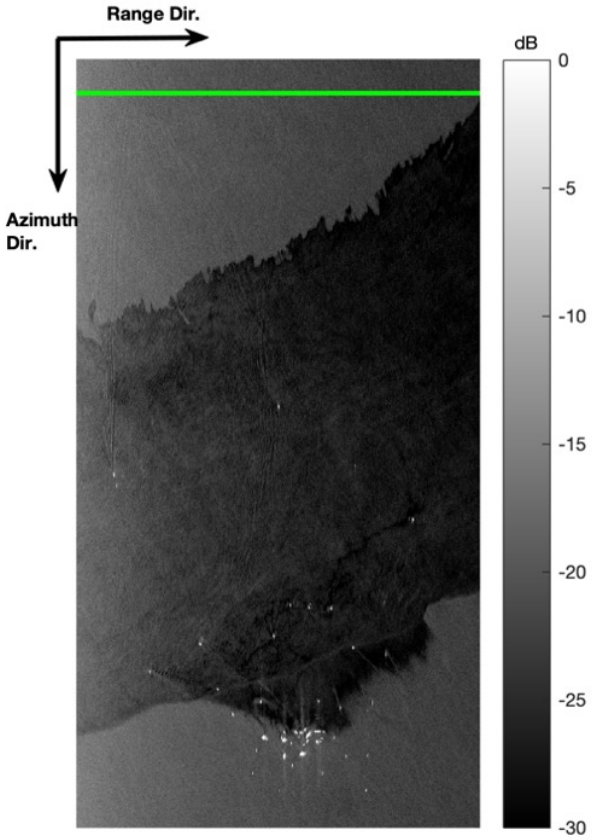


- EM scattering model: AIEM
- Damping model: MLB
- Composite reflection model
- Effective dielectric constant

Inversion of oil parameters using model-based NN

Model-based NN to retrieve thickness and fraction of water into the oil





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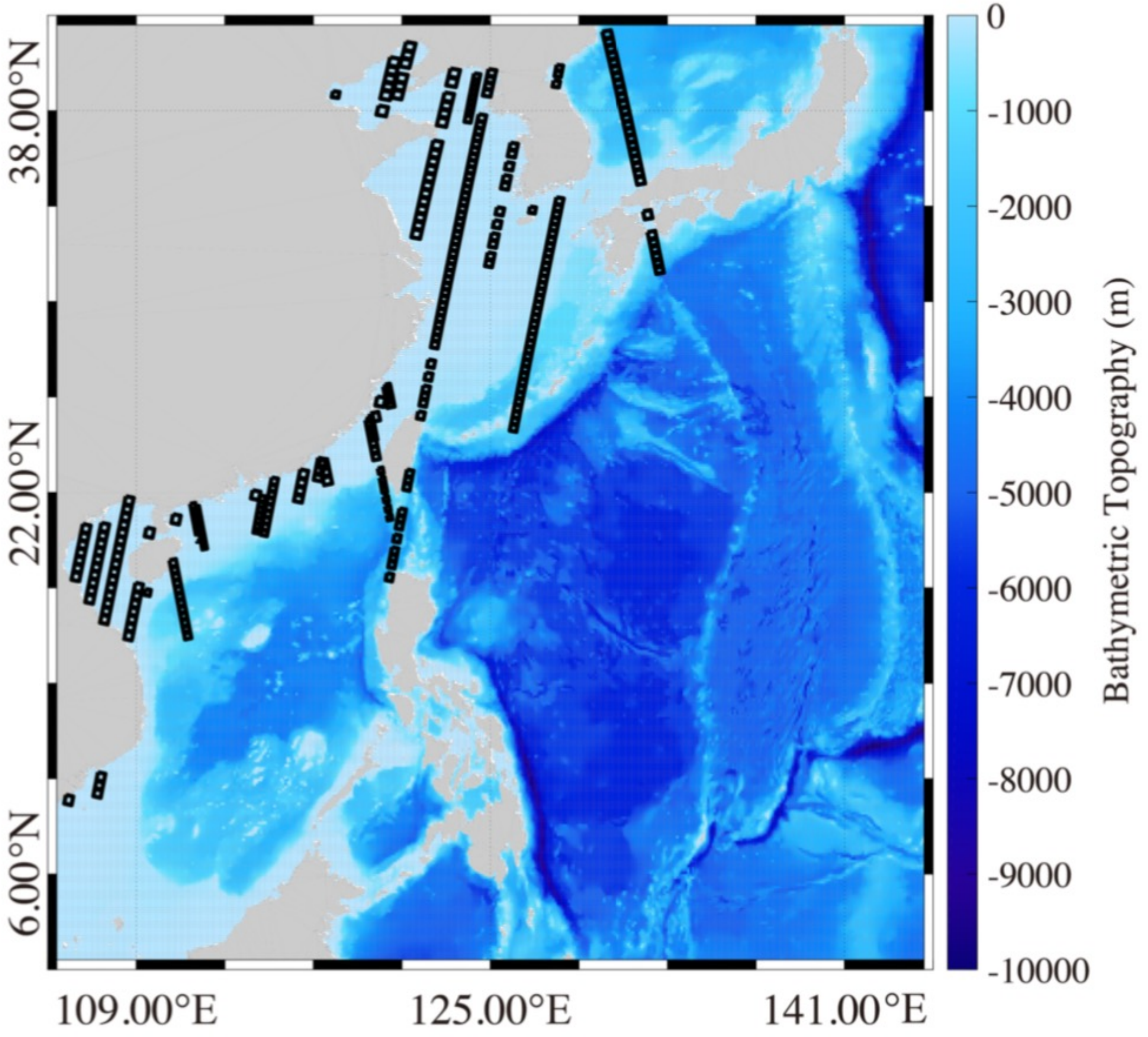
Backscattering under wave-breaking conditions

$$\sigma_0^{pp} = \sigma_{0Br}^{pp} + \sigma_{sp}^{pp} + \sigma_{wb}$$

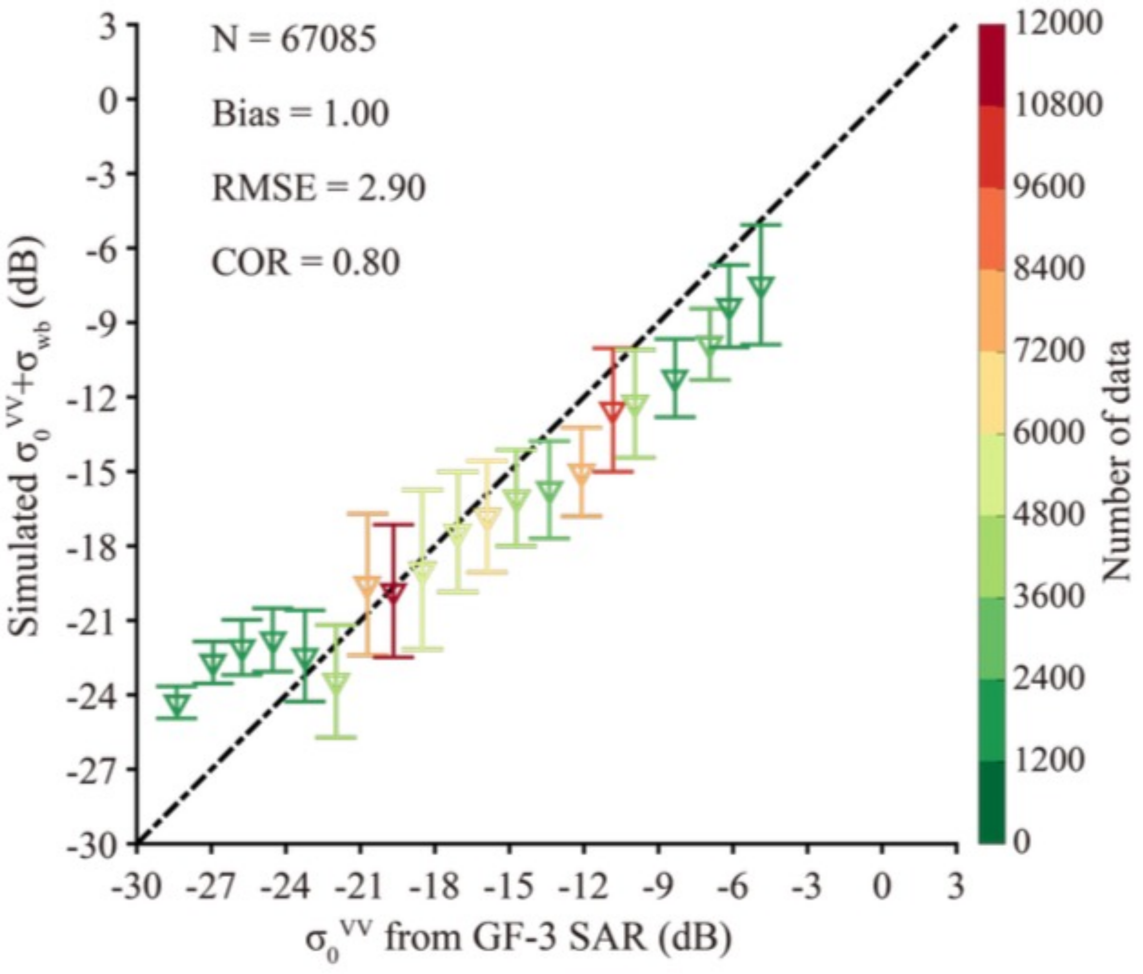
$$\sigma_{wb} = \sigma_0^{VV} - \frac{\Delta\sigma_0}{1 - p_B}$$

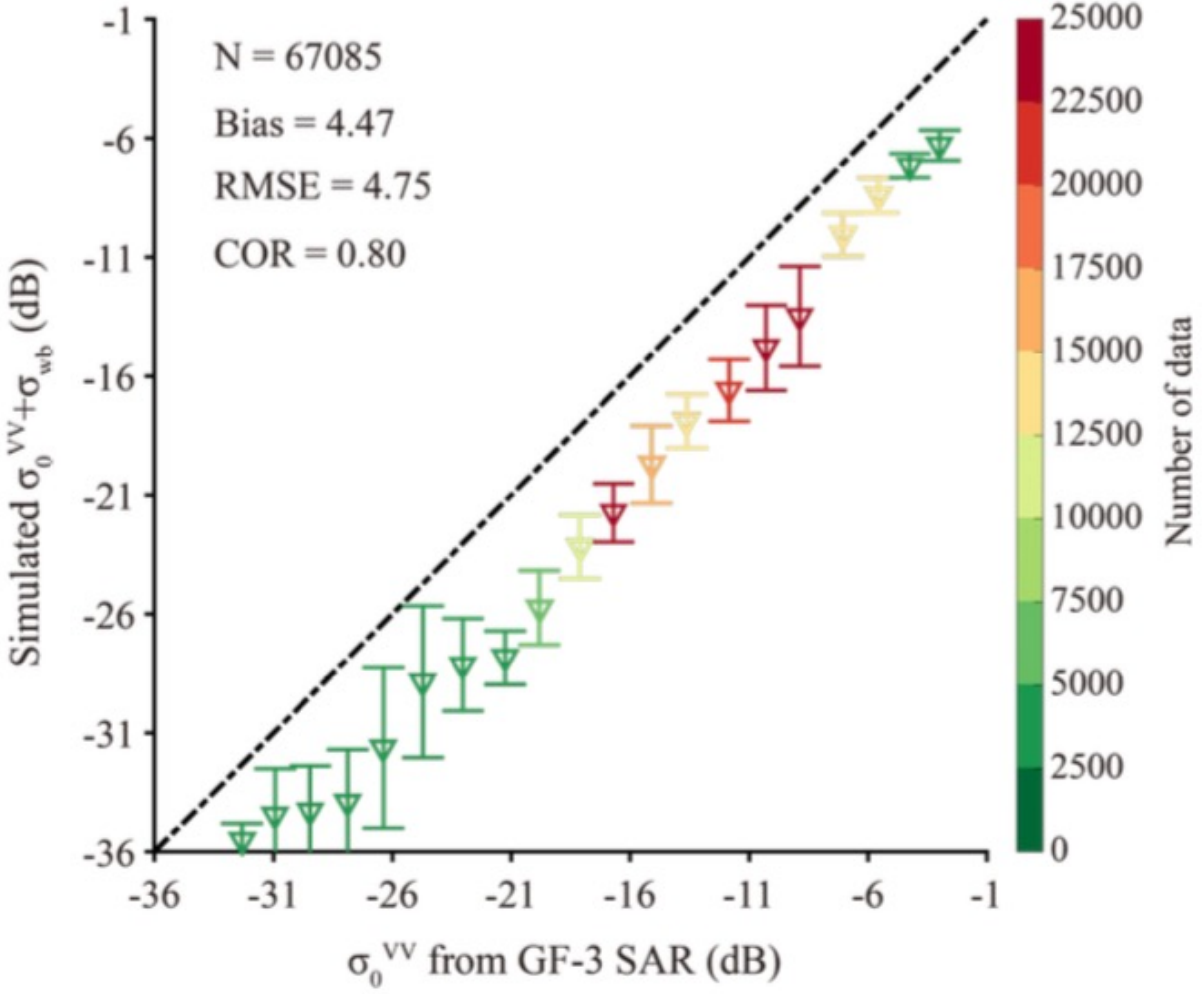
1. 2scale scattering model
2. Simplified approach



GF3 measurements

Backscattering under wave-breaking conditions





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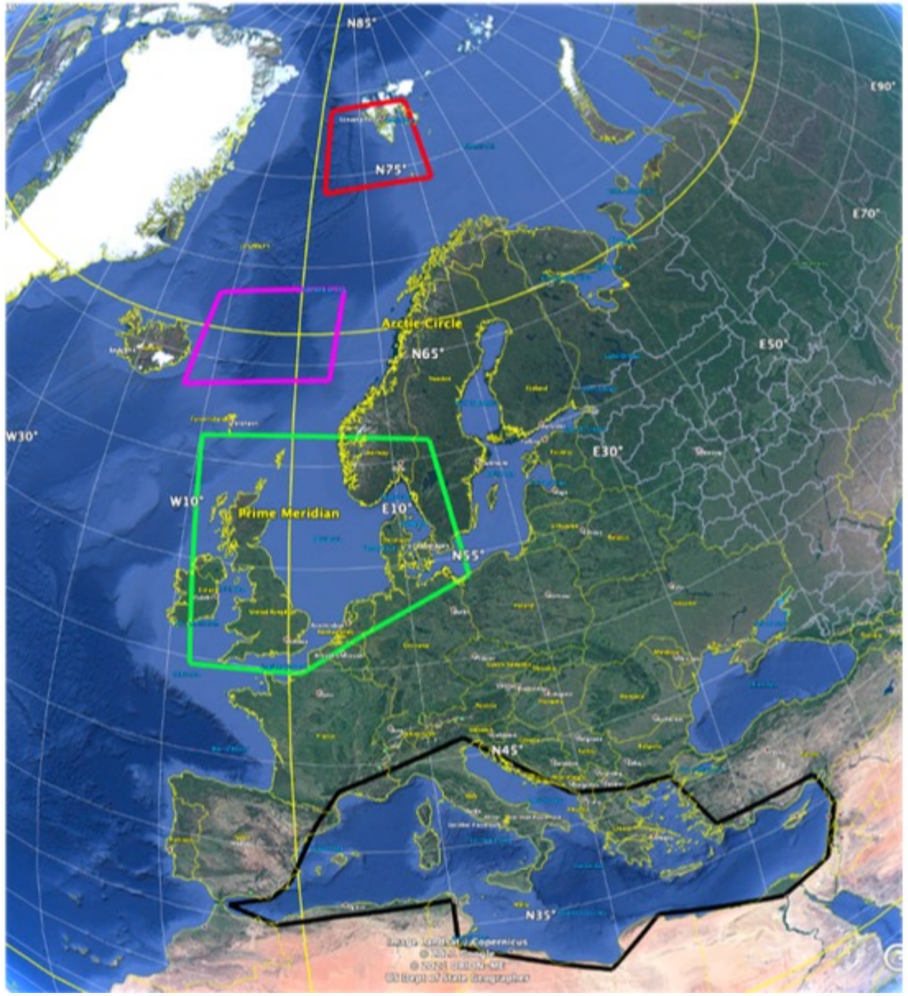
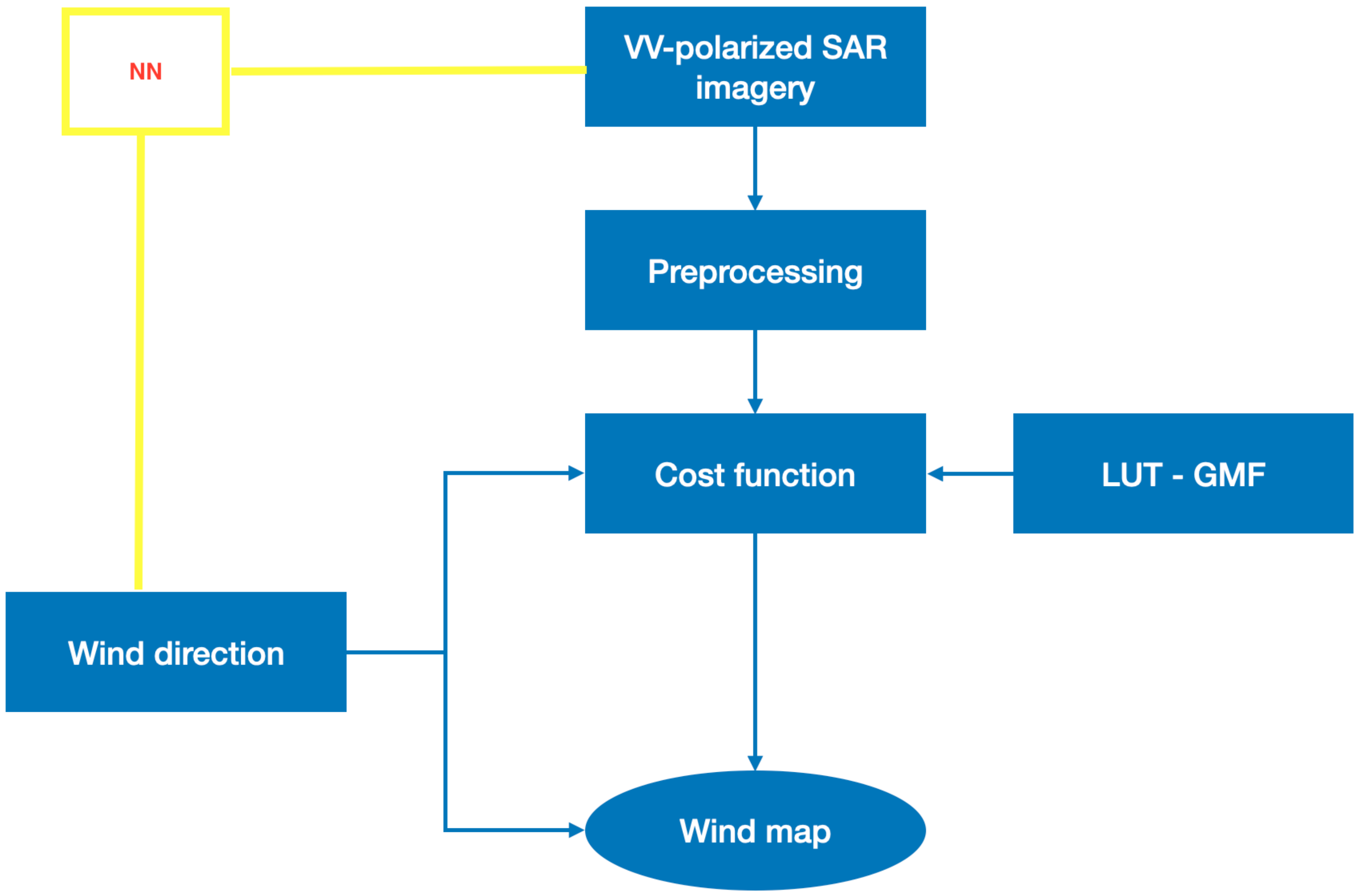
Wind field estimation

Sensor	AoI	Number of scenes
Sentinel-1A/B	Mediterranean Sea	340
Collocated ASCAT products		
ECMWF model data interpolated at the SAR acquisition time		
Sentinel-1A/B	Hawaii	58
Sentinel-1A/B	Eastern Atlantic (North Europe)	41
Collocated HY2 products		
CSK GEC_B SCN_WIDE	All the AoI but the Mediterranean one	475
Collocated ASCAT products		
ECMWF model data interpolated at the SAR acquisition time		
CSG SCS_B SCANSAR-2	Off Greenland coast	16
CSG SCS_B QUADPOL		16
CSG GEC_B SCANSAR-2		1
Not yet collocated		
CSG SCS_B SCANSAR-2	Adriatic Sea - Ravenna Coast	3
CSG GEC_B SCANSAR-2	Po River - Piacenza	4
CSK GEC_B STR_HIMAGE		2
SAOCOM	Zona di esclusività	17
Collocated with ECMWF		



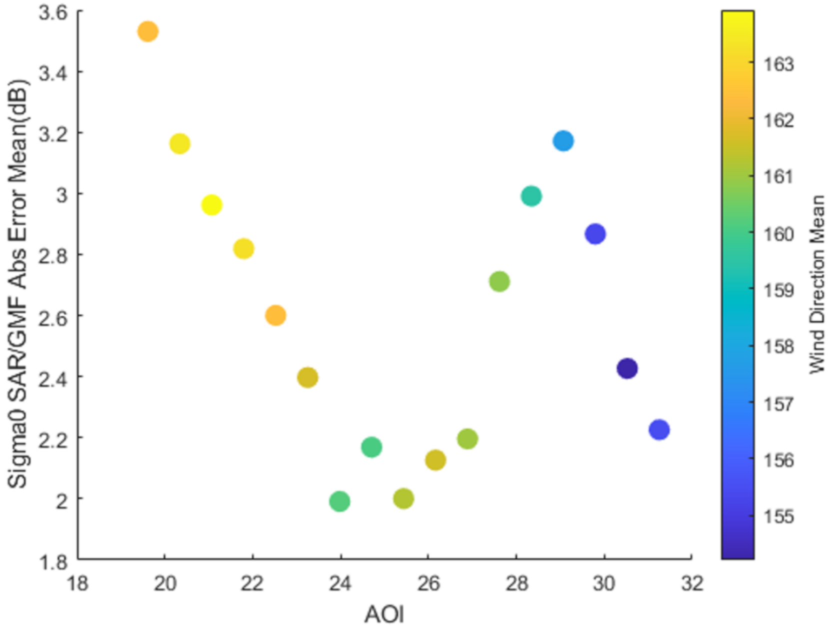
Wind field estimation

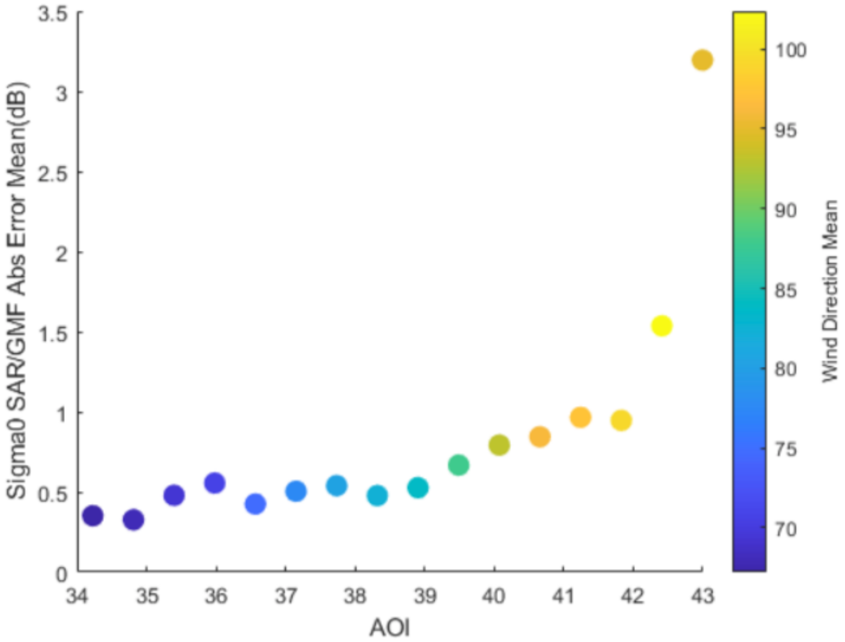


- VV-pol X-band CSK ScanSAR GEC scenes
- DLR XMOD2 GMF
- ASCAT/ECMWF collocated winds

- Wind direction estimated from the SAR scene by NN

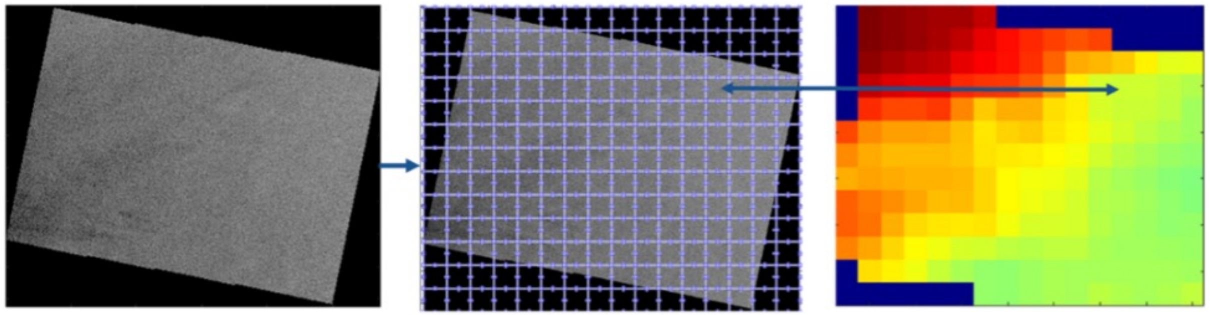
Wind field estimation





	XMOD vs ASCAT	XMOD vs ECMWF
CMRSD	1.5806	1.5688
Mean Bias	-2.6335	-2.8168
Correlation	0.8374	0.8098

Wind field estimation



Pre-processing

- 19 CSK imagery.
- Each image is split into tails whose size matches the SCAT one.
- Data augmentation is applied by rotating each tile.
- The final data set consists of 6608 images (85% training; 10% validation; 5% test set).

YS contribution – Anna Veralnti
Poster n.180

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A SAR-based Parametric Model for Tropical Cyclone Tangential Wind Speed Estimation

➢ Design of Proposed TWP Model

Principle for model function design:

- ☐ High estimation accuracy
- ☐ Smooth transition in TC eyewall area
- ☐ Concise functional form

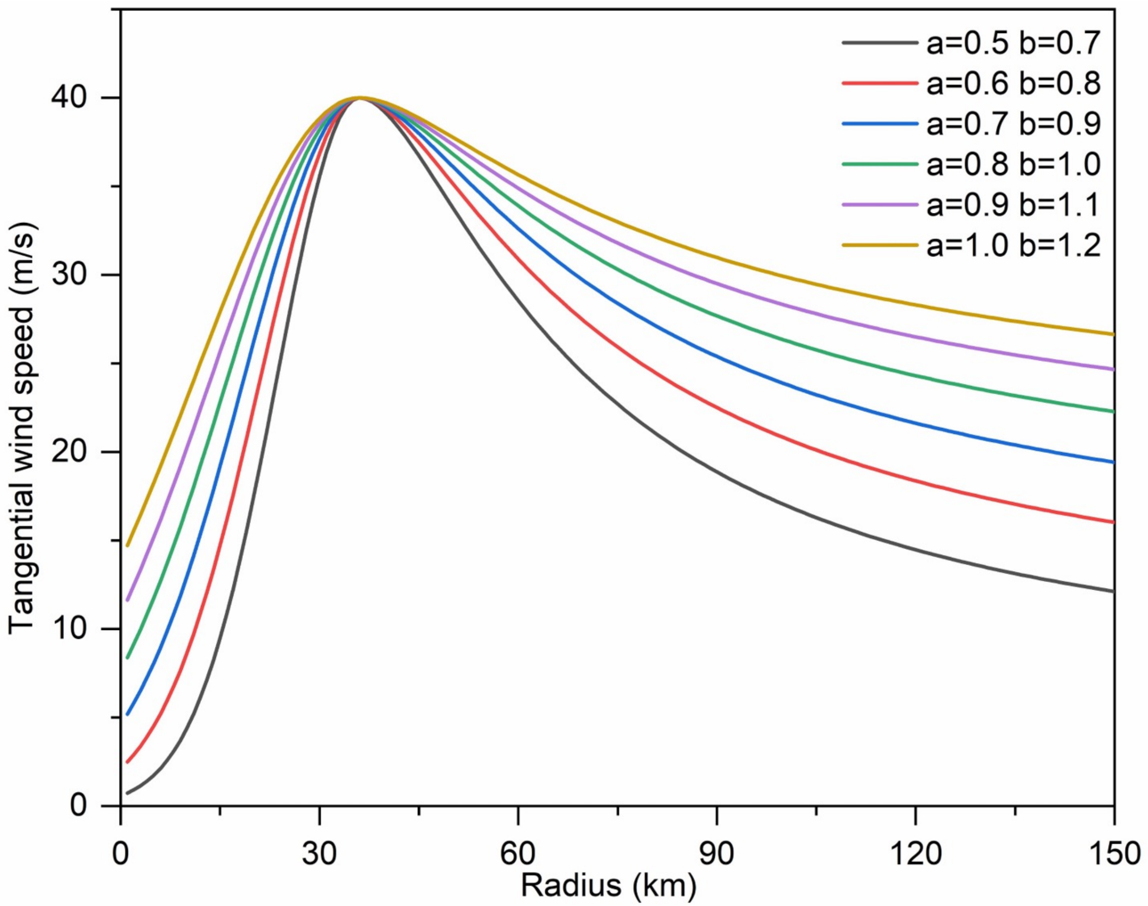
$$V = \begin{cases} V_{max} \exp\left(-\left(\frac{1}{a}\left(\frac{r}{R_{max}} - 1\right)\right)^2\right) & r \le R_{max} \\ V_{max} \exp\left(-\left(\frac{1}{b}\left(\frac{R_{max}}{r} - 1\right)\right)^2\right) & R_{max} < r \le 150\ km \end{cases}$$

a: growth factor

b: decay factor

⇨ **Describe basic features**

Constant "1" : smooth transition



a ↑ rate of wind speed increase ↑

b ↑ rate of wind speed decrease ↓

A SAR-based Parametric Model for Tropical Cyclone Tangential Wind Speed Estimation

➢ Model Validation

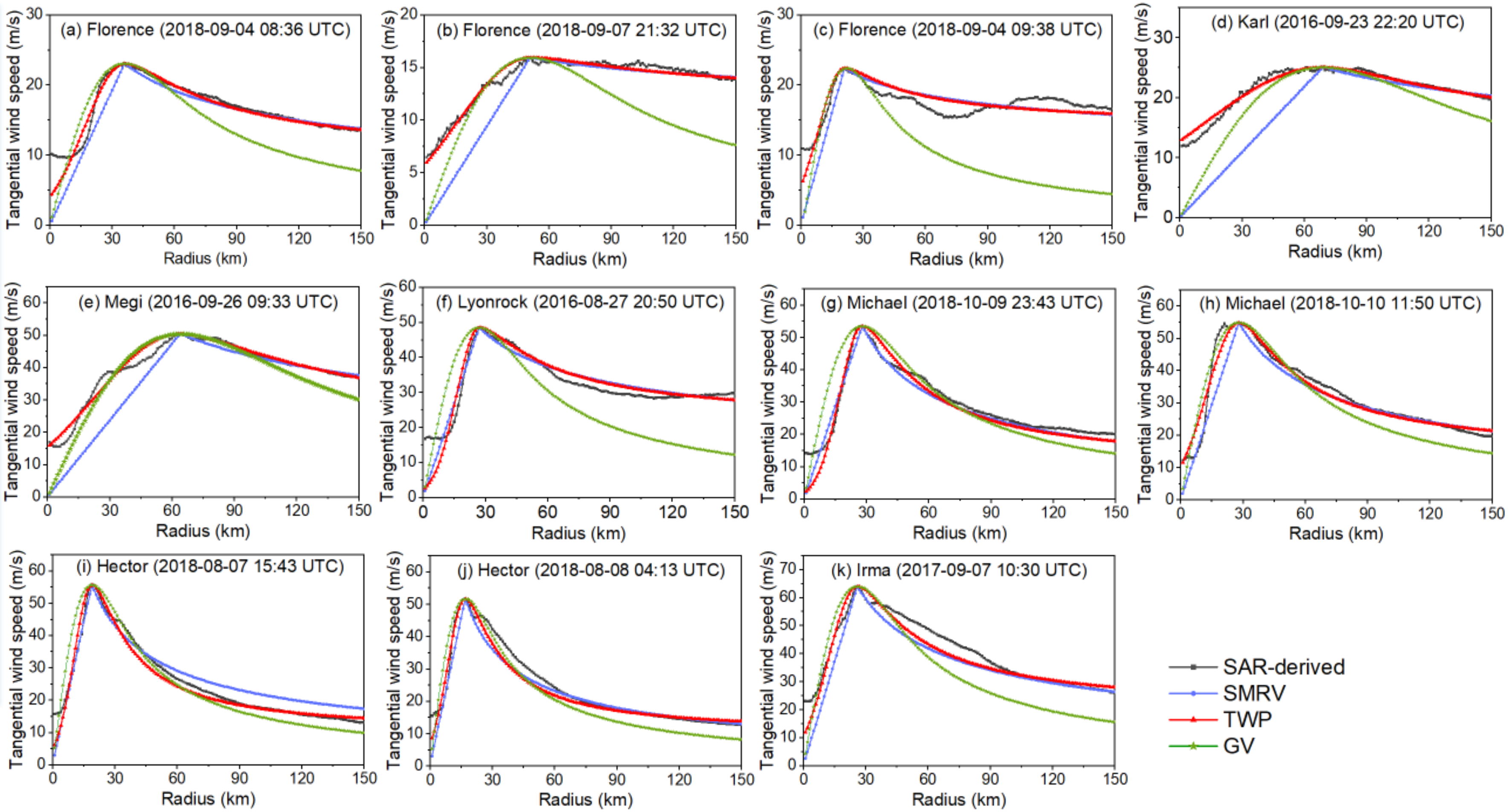
Advantages of TWP model:

- Fits the SAR-derived wind speed best
- Smooth transition in the high wind speed area
- High-accuracy reconstruction

Wind speed at TC center:

- SAR wind speed > 0
- TWP $= V_{max}(-1/a^2) > 0$
- SMRV, GV = 0

TWP model combines the advantages of existing models



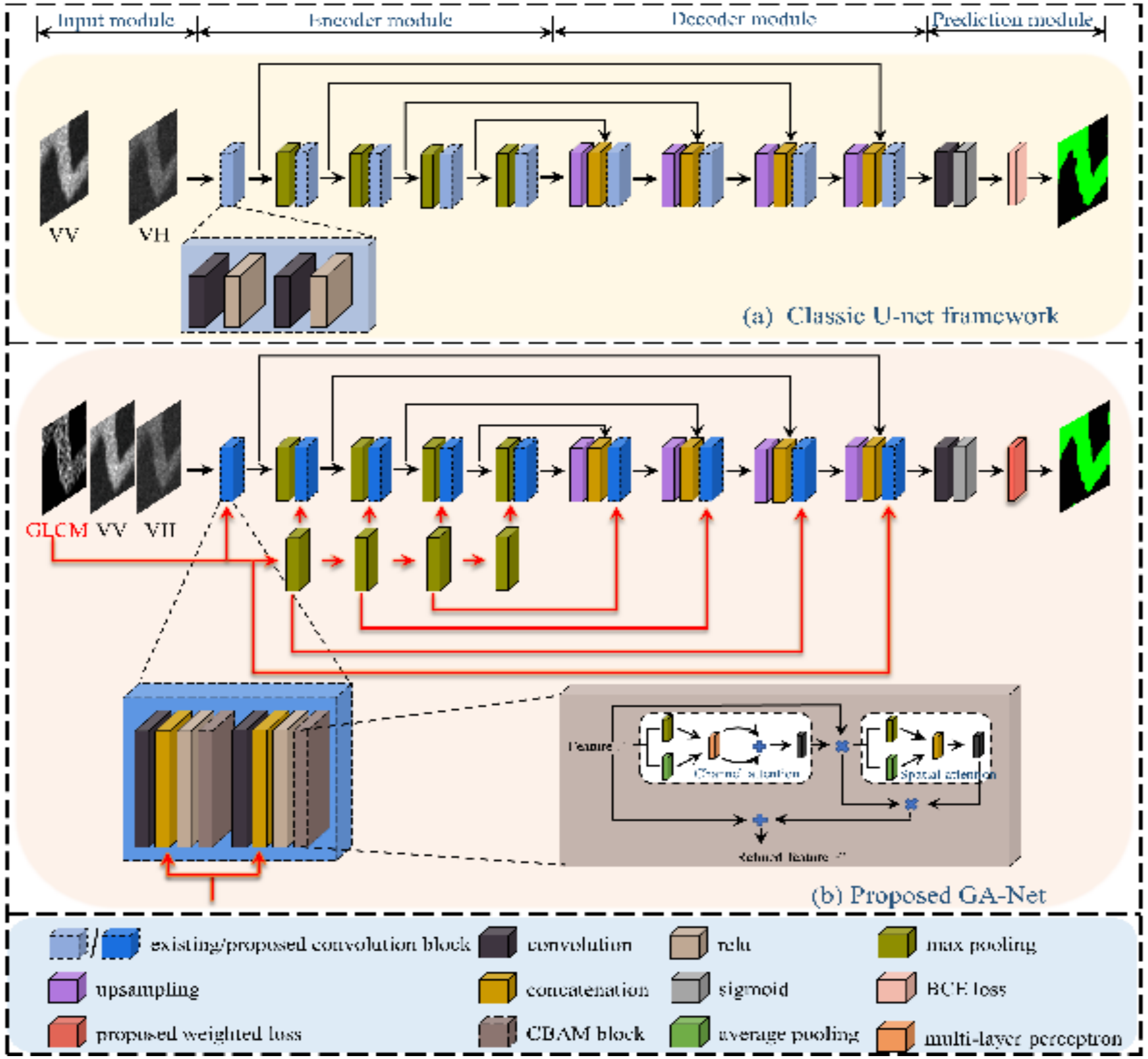
- Observation of metallic targets at sea
  - Ship backscattering vs incidence angles
  - Backscattering from offshore wind farms

- Observation of sea oil pollution
  - Backscattering from oil emulsions
  - Bistatic scattering from oil-covered sea surface
  - Scattering and damping models
  - Inversion of oil parameters using model-based NN

- Observation of sea wind/waves
  - Backscattering under wave breaking conditions
  - Wind field estimation
  - Parametric Model for Hurricane Tangential Wind
  - Green Tide Detection from SAR Images

Green Tide Detection from SAR Images

GA-Net Model

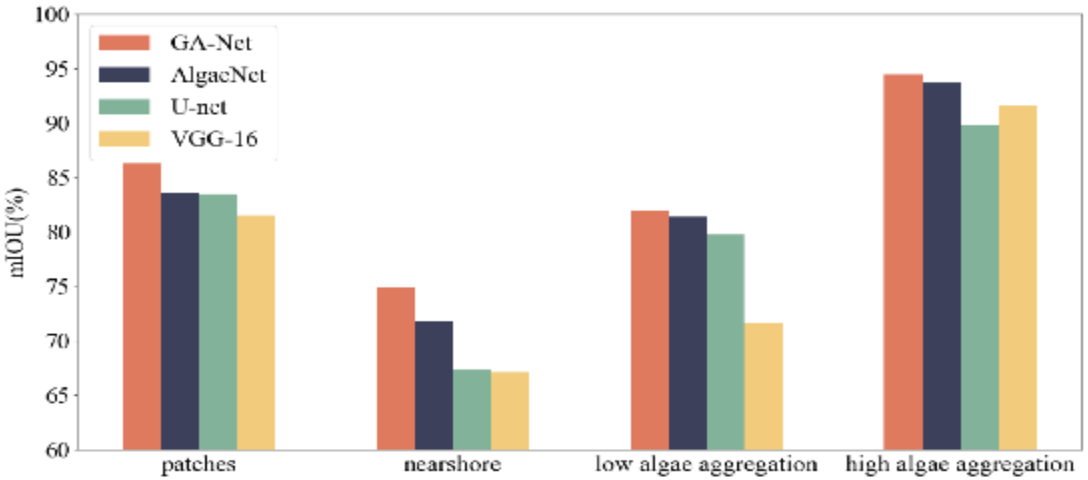


- ✓ 4421 / 1896 / 2124 groups of patches as the training / validation / testing dataset

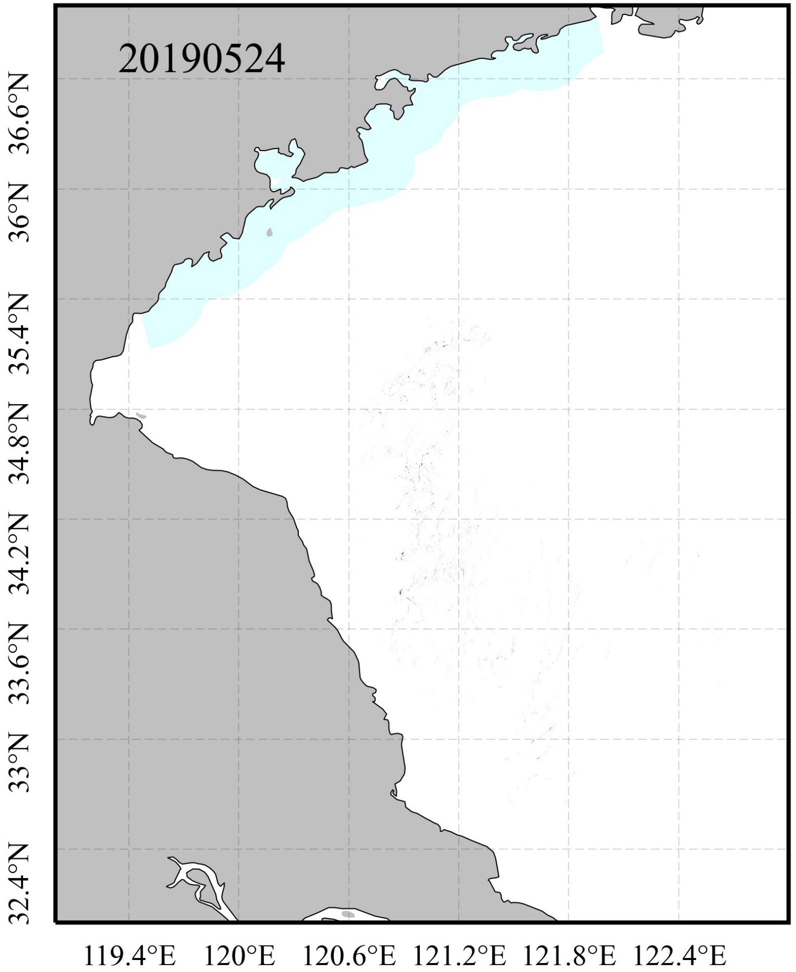
Tailored modifications based on U-net

Modification 1	Adopt a texture-fused(GLCM) input strategy
Modification 2	Build a texture-enhanced path
Modification 3	Design a weighted loss function
Modification 4	Embed the CBAM

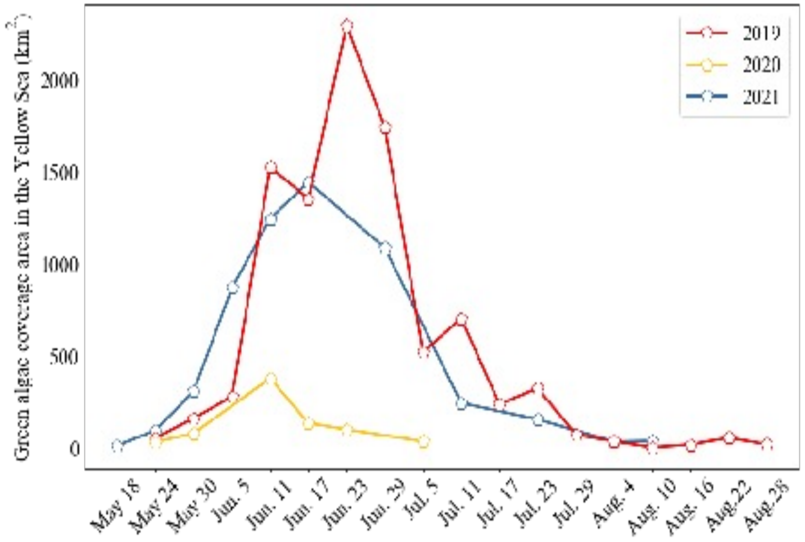
CBAM: convolutional block attention module
GLCM: grey-level co-occurrence matrix



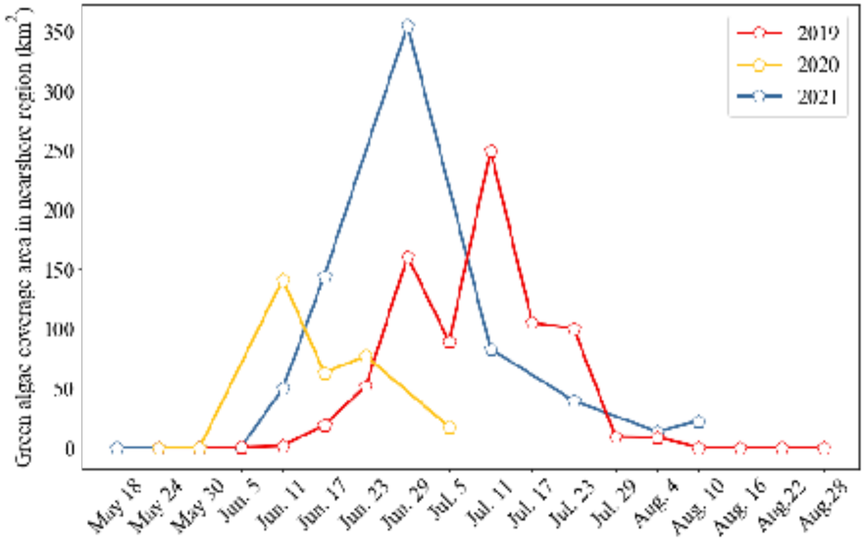
Green Tide Detection from SAR Images



Green tide distribution. Blue shade shows the nearshore area in Shandong Peninsula.



Coverage area in the Yellow Sea



Coverage area in the nearshore (blue shade)

- 2019 (2020) has the longest (shortest) bloom duration and biggest (smallest) coverage area.
- 2021(2020) has the biggest (smallest) nearshore damage to the southern coastlines of the Shandong Peninsula.

EO Data Delivery

ESA Third Party Missions	No. Scenes
1.RadarSAT-2	20
2.Alos-2	10
3.UAVSAR	16
4.CSK	500
5.CSG	6
6.PAZ	4
Total:	556
Issues:	

ESA, Explorers & Sentinels data	No. Scenes
1.Sentinel-1	500
2.	
3.	
4.	
5.	
6.	
Total:	500
Issues:	

Chinese EO data	No. Scenes
1.Gaofen-3	500
2.	
3.	
4.	
5.	
6.	
Total:	500
Issues:	

European Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Anna Verlanti	Università di Napoli Parthenope	A Sensitivity Analysis Of CNNs To Wind-Generated Patters On X-Band Cosmo-SkyMed SAR Scenes	NN method to retrieve wind direction from X-band CSK SAR imagery

Chinese Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Tingyu Meng	AIRCAS	Simulation of X-band Co-polarized backscattering from Oil-covered sea surfaces	Prediction of the X-band signal backscattered off a slick-free and slick-covered sea surface using different scattering and damping models
Yanlei Du	AIRCAS	Numerical Study on Polarimetric SAR Imaging Response to Ocean Current	Numerically investigate the polarimetric SAR imaging responses to two-dimensional ocean surfaces with currents and waves.
Sheng Wang	AIRCAS	A SAR-based Parametric Model for Tropical Cyclone Tangential Wind Speed Estimation	Establishment of a parametric model for tangential wind speed profile of tropical cyclons, committing to achieving smooth transition in the high wind area and high-precision reconstruction
Yuan Guo	IOCAS	A Deep Learning Model for Green Tide Detection Based on SAR Images	Propose a texture-enhanced segmentation model to detect green algae, reveal the green tide interannual variation in the Yellow Sea

Future activities

- Backscattering from offshore wind farms
- Comparison of microwave backscattering from slick-covered sea surface predicted using different scattering and damping models
- Retrieval of oil thickness & fraction of water into the oil
- Classification of harsh coastal environments using polSAR multi-frequency measurements

Academic exchanges, cooperation, contribution to Dragon 5 training

- Zoom meetings on a regular basis

- Visiting scientist exchanges: we hosted a Chinese PhD student – Tingyu Meng - working on **scattering from oil-covered sea surface** for 1y

- Visiting scientist exchanges: we finalized the procedure to host a Chinese PhD student - Yuan Guo - working on **AI for coastal area classification** for 2y

- Visiting scientist exchanges: we plan to have an EU YS to be hosted in China

Peer-reviewed journal publications

[IJ-1] W. Shao, Z. Lai, F. Nunziata, A. Buono, X. Jiang and J. Zuo, Wind Field Retrieval with Rain Correction from Dual-polarized 2 Sentinel-1 SAR Imagery Collected During Tropical Cyclones, *MDPI Remote Sensing*, in print.

[IJ-2] S. Wang, X. Yang, M. Portabella, K. -V. Yuen, M. Zhang and Y. Du, "A SAR-Based Parametric Model for Tropical Cyclone Tangential Wind Speed Estimation," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 15, pp. 8806-8818, 2022, doi: 10.1109/JSTARS.2022.3213822.

[IJ-3] Meng T, Nunziata F, Buono A, Yang X and Migliaccio M (2022) On the joint use of scattering and damping models to predict X-band co_x0002_polarized backscattering from a slick-covered sea surface. Front. Mar. Sci. doi: 10.3389/fmars.2022.1113068

[IJ-4] T. Meng, F. Nunziata, A. Buono, X. Yang, M. Migliaccio, "On the joint use of scattering and damping models to predict X-band co-polarized backscattering from a slick-covered sea surface," Front. Mar. Sci., vol. 9, n.23, 2022.

[IJ-5] M. Zahriban Hesari, A. Buono, F. Nunziata, G. Aulicino, M. Migliaccio, "Multi-Polarisation C-Band SAR Imagery to Estimate the Recent Dynamics of the d'Iberville Glacier," Remote Sensing, vol. 14, n. 22, pp.5758, 2022.

[IJ-6] W. Shao, Z. Lai, F. Nunziata, A. Buono, X. Jiang, J. Zuo, "Wind Field Retrieval with Rain Correction from Dual-Polarized Sentinel-1 SAR Imagery Collected during Tropical Cyclones," Remote Sensing, vol.14 n.19, 2022.

[IJ-7] M. Adil, A. Buono, F. Nunziata, E. Ferrentino, D. Velotto, M. Migliaccio, "On the Effects of the Incidence Angle on the L-Band Multi-Polarisation Scattering of a Small Ship", Remote Sensing, 14, n.22, 2022.

[IJ-8] T. Meng, X. Yang, K.-S. Chen, F. Nunziata, D. Xie and A. Buono, "Radar Backscattering Over Sea Surface Oil Emulsions: Simulation and Observation," IEEE Transactions on Geoscience and Remote Sensing, vol. 60, pp. 1-14, 2022.

[IJ-9] E. Ferrentino, A. Buono, F. Nunziata, A. Marino and M. Migliaccio, "On the Use of Multi-polarization Satellite SAR Data for Coastline Extraction in Harsh Coastal Environments: The Case of Solway Firth," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 14, pp. 249-257, 2021.

[IJ-10] F. Nunziata, X. Li, A. Marino, W. Shao, M. Portabella, X. Yang, A. Buono, "Microwave Satellite Measurements for Coastal Area and Extreme Weather Monitoring", Remote Sens. 2021, 13, 3126. https://doi.org/10.3390/rs13163126

[IJ-11] W. Shao, F. Nunziata, Y. Zhang, V. Corcione and M. Migliaccio, "Wind speed retrieval from the Gaofen-3 synthetic aperture radar for VV- and HH-polarization using a re-tuned algorithm," European Journal of Remote Sensing, vol. 54, no. 1, pp. 318-337, 2021.

[IJ-12] A. Buono, C. R. de Macedo, F. Nunziata, D. Velotto and X. Li, "The Taylor Energy Oil Spill: Time-series of PolSAR Data to Support Continuous and Effective Observation," Journal of Geodesy and Geoinformation Science, vol. 4, no. 1, pp. 24-29, 2021.

[IJ-13] V. Corcione, A. Buono, F. Nunziata and M. Migliaccio, "A Sensitivity Analysis on the Spectral Signatures of Low-Backscattering Sea Areas in Sentinel-1 SAR Images," Remote Sens., vol. 13, pp. 1183-1200, 2021.

Conclusions

The project aims at demonstrating the benefits of radar products for coastal area monitoring and, therefore, it is framed into the “Ocean & coastal zone” Dragon-5 thematic area.

- The co-operation was successful in all the topics
- A Chinese PhD student spent a 1y period @ Uniparthenope
- A Chinese PhD student is going to spend 2y in Italy working on AI for coastal area applications
- An Italian PhD student will spend a visiting period in China
- The activities scheduled for the next year are already ongoing

Greetings from Hohhot,
Inner Mongolia, China