



A Comprehensive Analysis of Polarimetric Features for Oil Spill Characterization

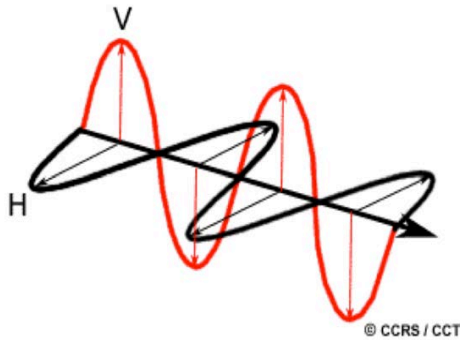
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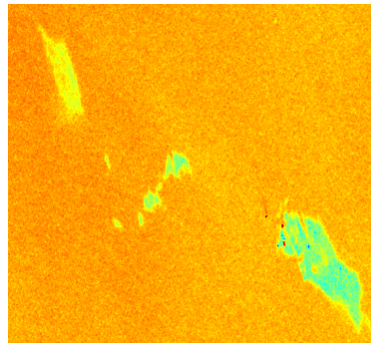
This presentation discusses the use of multi-polarization SAR for oil spill purposes



Data collection



Polarimetry



Multi-polarization analysis

Data was collected at the NOFO oil-on-water exercise, June 2011

Three different slicks were produced:

- Emulsion
- Crude oil
- Plant oil

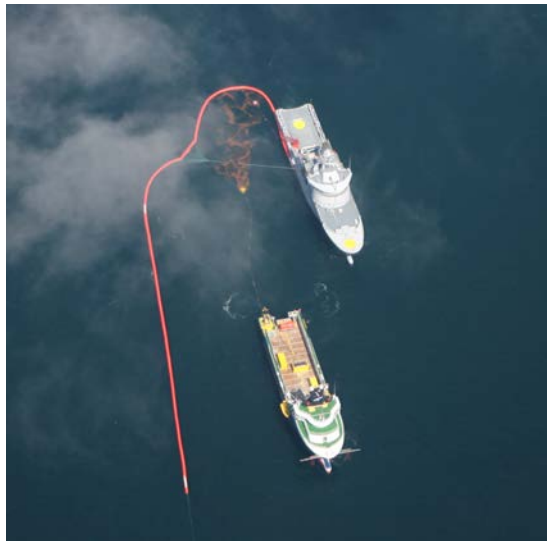
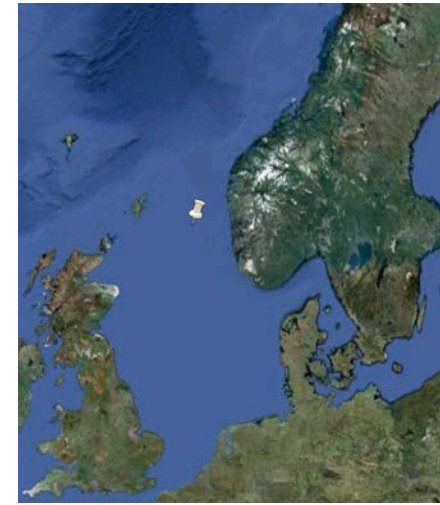


Photo: Kustbevakningen

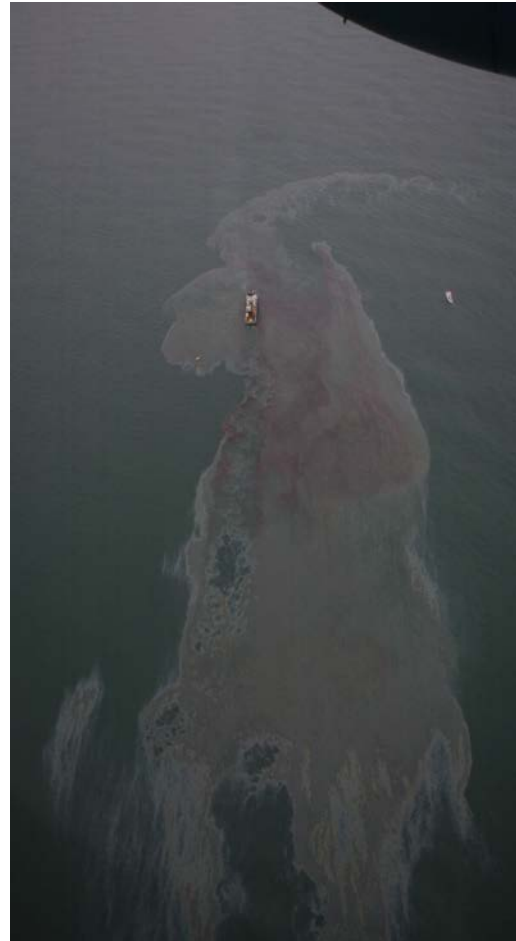


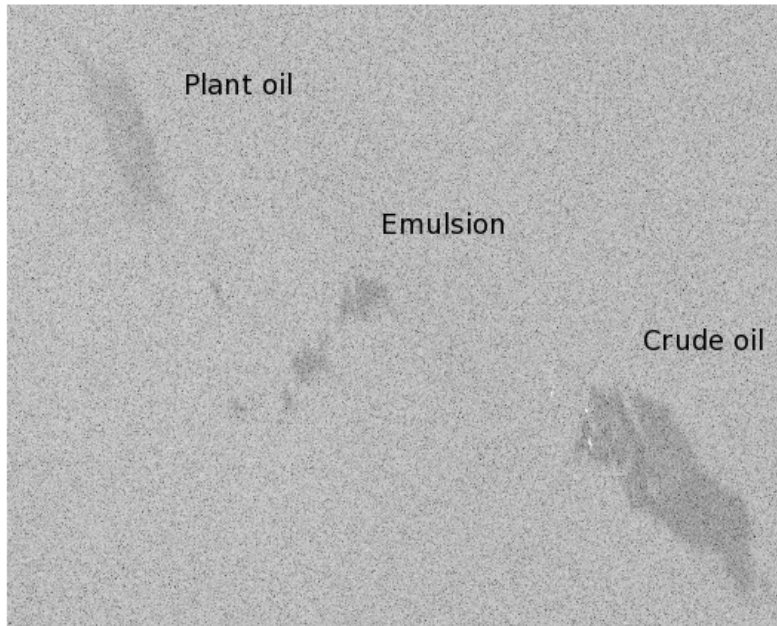
Photo: Kustbevakningen



Photo: Stine Skrunes

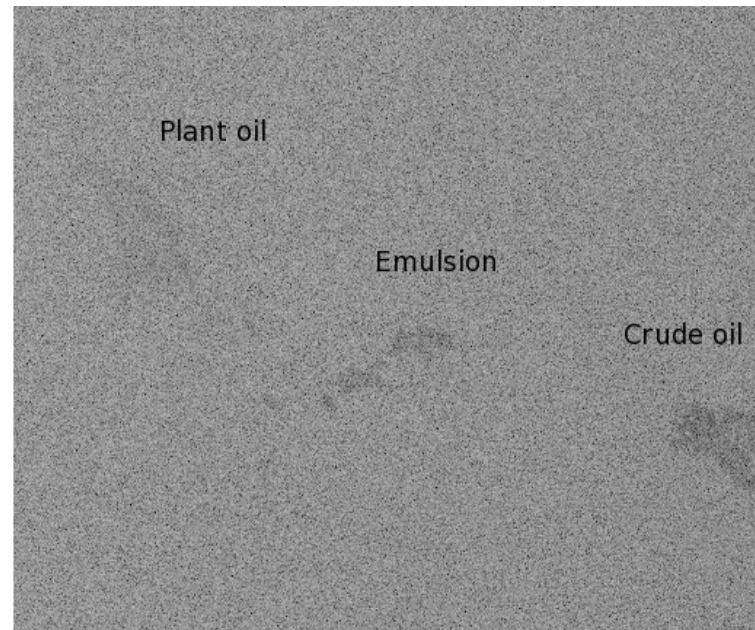
RS-2 and TS-X data with all three slicks were acquired ~16 minutes apart

Radarsat-2



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TerraSAR-X



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Plant oil ~13 hours old
Emulsion ~29 hours old
Crude oil ~9 hours old

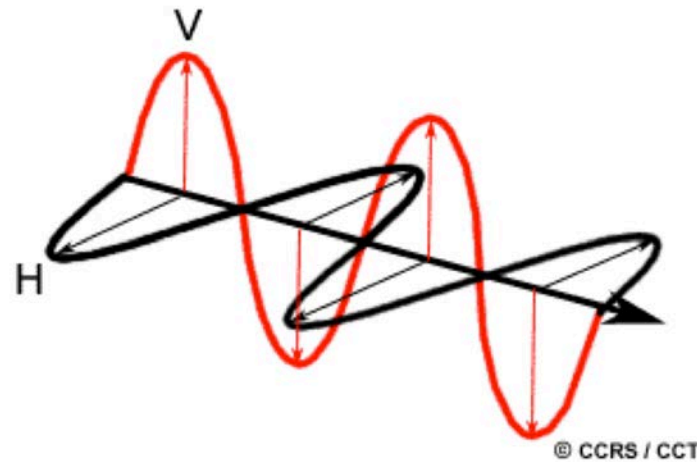


Multi-polarization data may improve the potential for oil spill characterization

$$\mathbf{S} = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{HV} & S_{VV} \end{bmatrix}$$

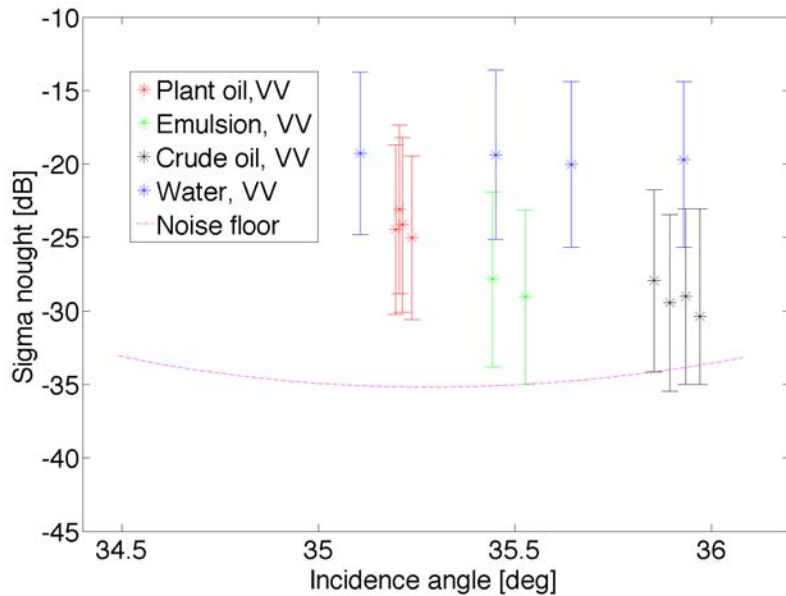
$$\mathbf{l} = [S_{HH} \quad \sqrt{2}S_{HV} \quad S_{VV}]^T$$

$$\mathbf{k} = \frac{1}{\sqrt{2}} [S_{HH} + S_{VV} \quad S_{HH} - S_{VV} \quad 2S_{HV}]^T$$

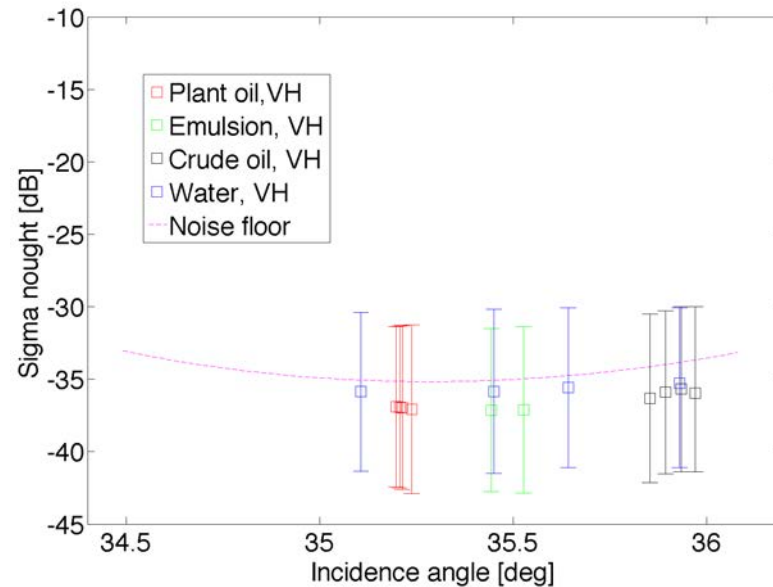


Noise analysis shows that co-polarization signal is more reliable than cross-polarization

Radarsat-2, VV:



Radarsat-2, VH:



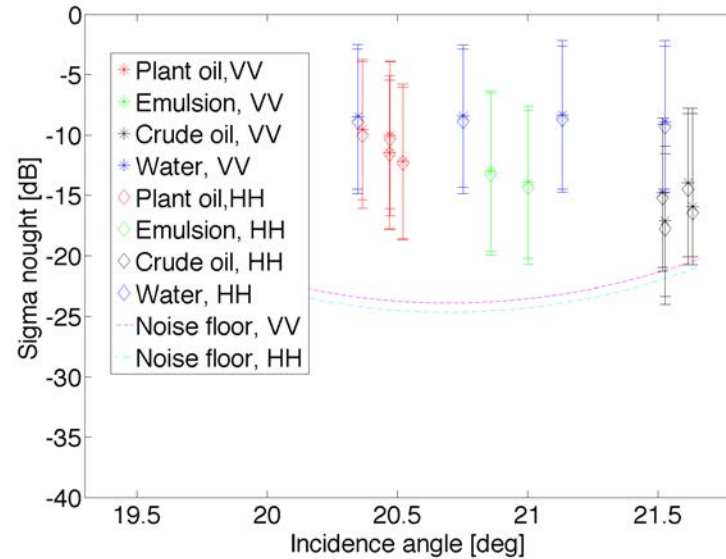
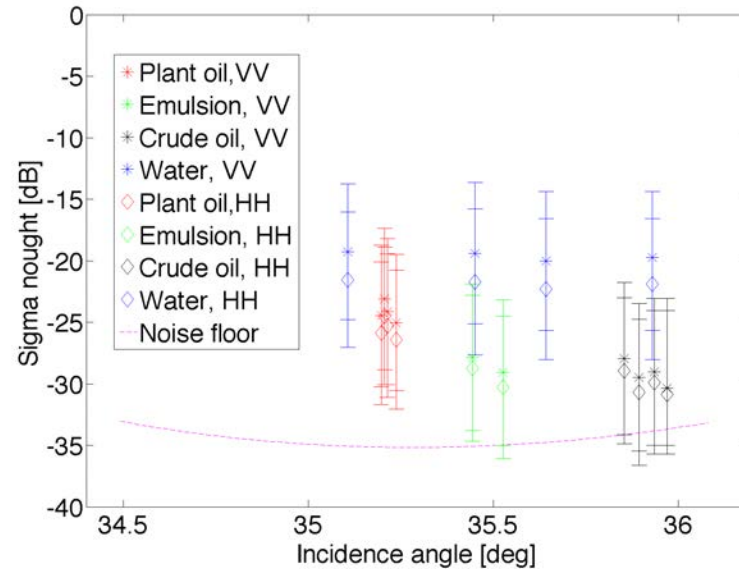
Only co-polarization channels are used in our study

$$\mathbf{l} = [S_{HH} \quad S_{VV}]^T$$

$$\mathbf{k} = \frac{1}{\sqrt{2}} [S_{HH} + S_{VV} \quad S_{HH} - S_{VV}]^T$$

$$\mathbf{C} = \frac{1}{L} \sum_{n=1}^L \mathbf{l}_n \mathbf{l}_n^{*T}$$

$$\mathbf{T} = \frac{1}{L} \sum_{n=1}^L \mathbf{k}_n \mathbf{k}_n^{*T}$$



Multi-polarization features have been extracted from the two scenes



Feature	Definition
Entropy ¹	$H = - \sum_{n=1}^2 p_n \log_2 p_n$
Mean scattering angle ¹	$\bar{\alpha} = p_1 \alpha_1 + p_2 \alpha_2$
Alpha angle of the largest eigenvalue ¹	$\alpha_1 = \arccos(\mathbf{e}_1(1))$
Covariance scaling factor	$\mu = (\det(\mathbf{C}))^{1/d}$
Magnitude of co-polarization correlation coefficient	$\rho_{CO} = \left \frac{\langle S_{HH} S_{VV}^* \rangle}{\sqrt{\langle S_{HH} ^2 \rangle \langle S_{VV} ^2 \rangle}} \right $
Real part of co-polarization correlation ²	$r_{CO} = \Re(\langle S_{HH} S_{VV}^* \rangle)$
Standard deviation of co-polarized phase difference ³	$\sigma_{\phi_{CO}} = \sqrt{(\langle (\phi_{HH} - \phi_{VV})^2 \rangle - (\langle \phi_{HH} - \phi_{VV} \rangle)^2)}$

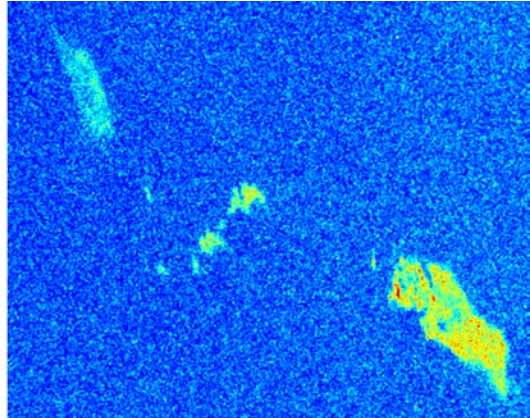
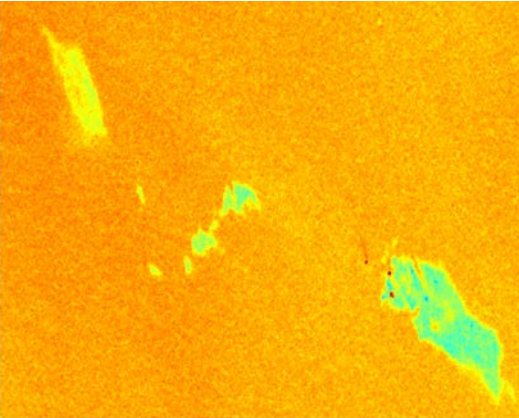
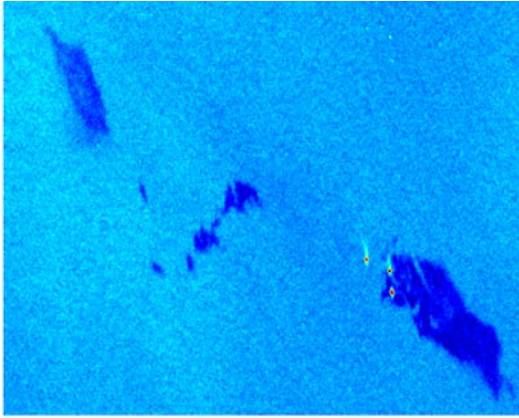
References

- ¹Cloude, S.R.; Pottier, E.: *An Entropy Based Classification Scheme for Land Applications of Polarimetric SAR*, IEEE Trans. on Geosci. and Rem. Sensing, Vol. 35, No. 1, 1997
- ²Nunziata, F., Gambardella, A. and Migliaccio, M., *On the Mueller Scattering Matrix for SAR Sea Oil Slick Observation*, IEEE Geosc. And Rem. Sens. Letters, Vol. 5, No. 4, p. 691-695, 2008
- ³Migliaccio, M; Nunziata, F.; Gambardella, A.: *On the co-polarized phase difference for oil spill observation*, Int. J. of Rem. Sens., Vol. 30, p. 1587-1602, 2009

Interesting variations are seen between and within the slicks



Radarsat-2

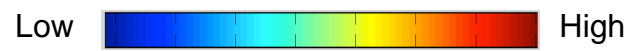
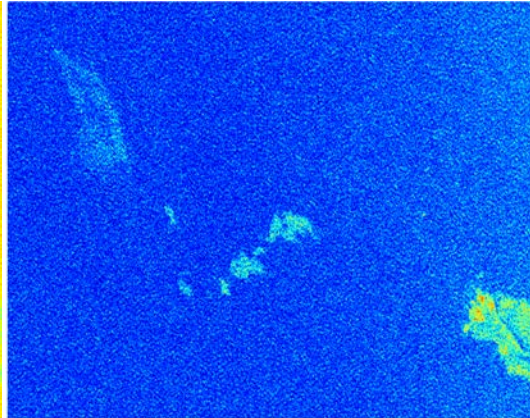
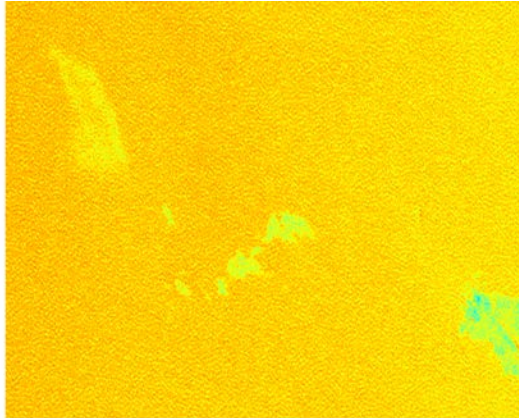
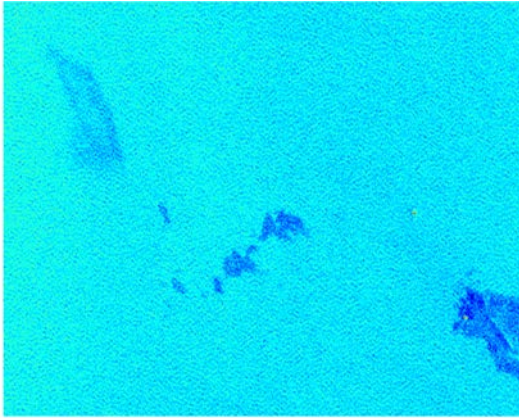


Covariance scaling factor
 $\mu = (\det(\mathbf{C}))^{1/d}$

Real part of co-pol correlation
 $r_{CO} = \Re(\langle S_{HH}S_{VV}^* \rangle)$

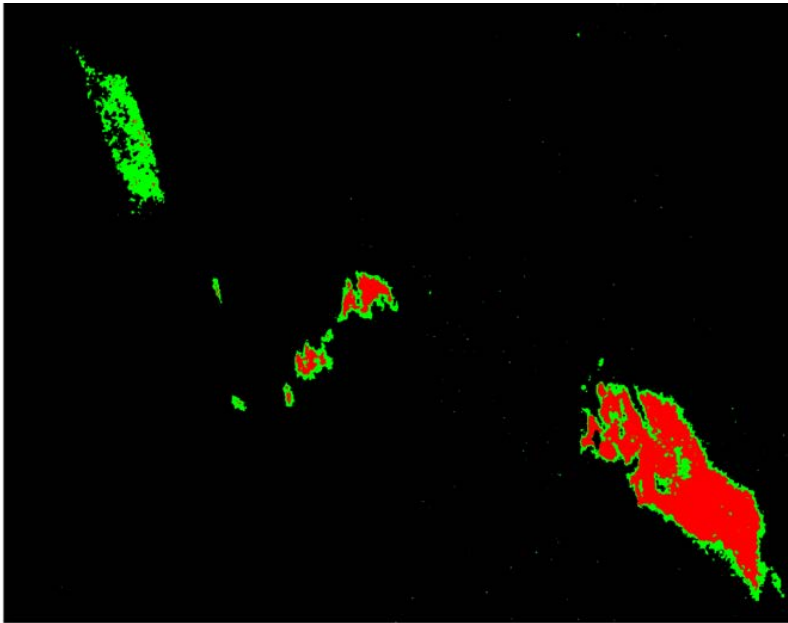
Std of co-polarized phase difference
 $\sigma_{\phi CO} = \sqrt{(\langle (\phi_{HH} - \phi_{VV})^2 \rangle - (\langle \phi_{HH} - \phi_{VV} \rangle)^2)}$

TerraSAR-X

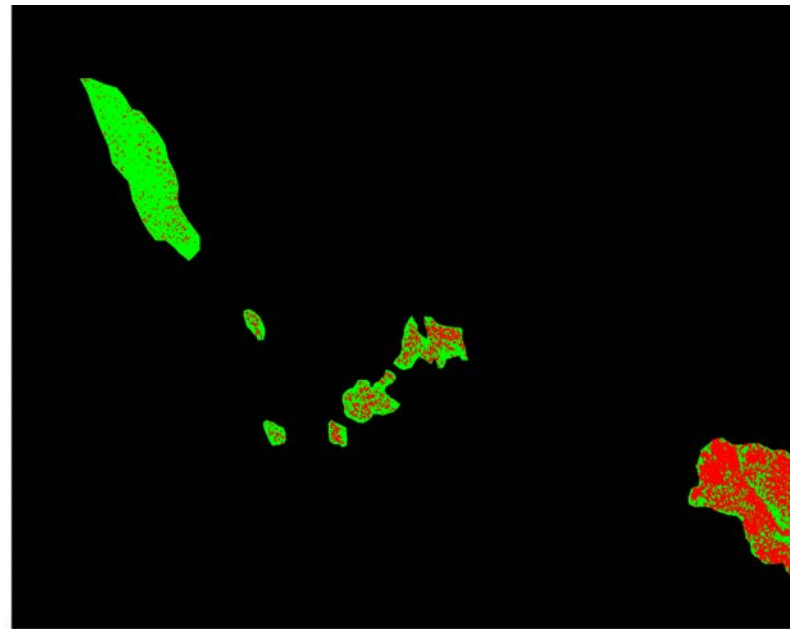


A potential for discrimination between mineral oil and biogenic slick is found

Radarsat-2

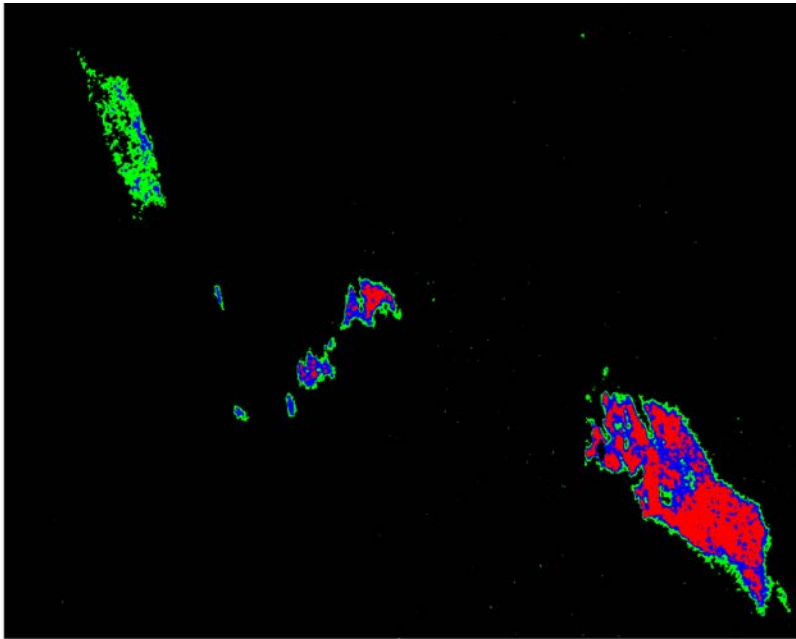


TerraSAR-X

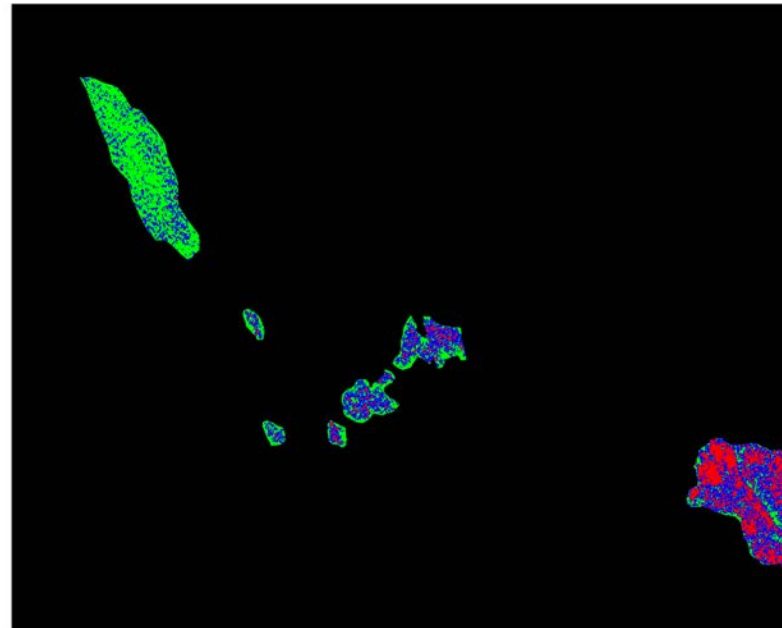


Classifications show interesting zoning along the edge of mineral oil spills

Radarsat-2



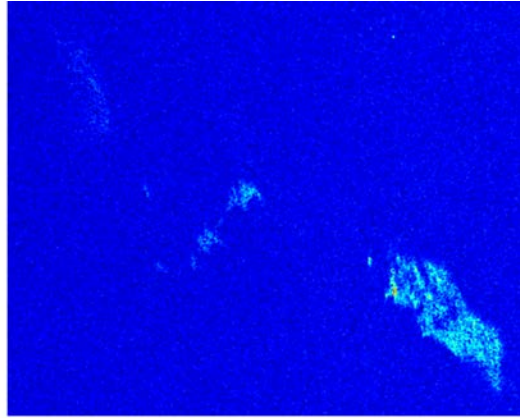
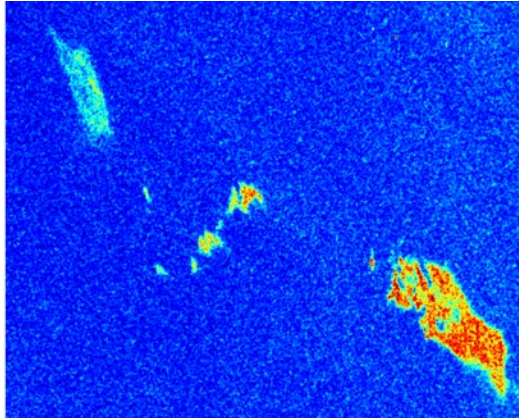
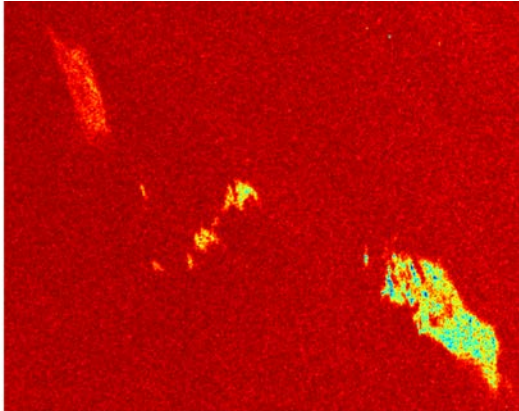
TerraSAR-X



Interesting variations are seen between and within the slicks



Radarsat-2



Mag. of co-pol correlation coefficient

$$\rho_{CO} = \left| \frac{\langle S_{HH} S_{VV}^* \rangle}{\sqrt{\langle |S_{HH}|^2 \rangle \langle |S_{VV}|^2 \rangle}} \right|$$

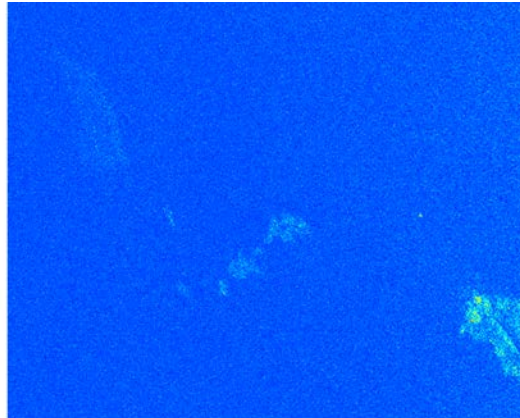
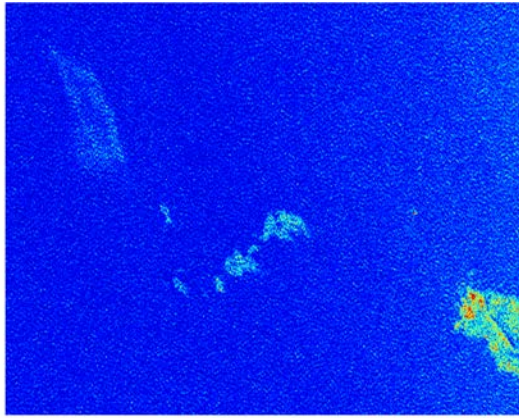
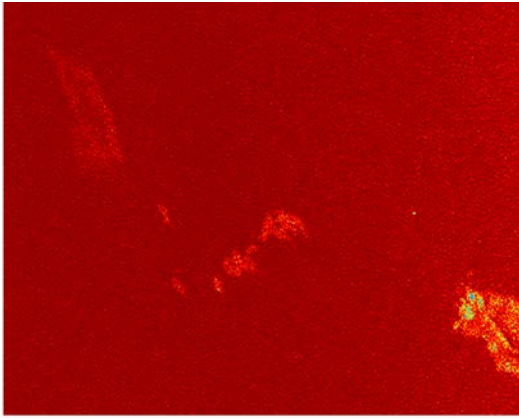
Entropy

$$H = - \sum_{i=1}^2 p_i \log_2 p_i$$

Mean scattering angle

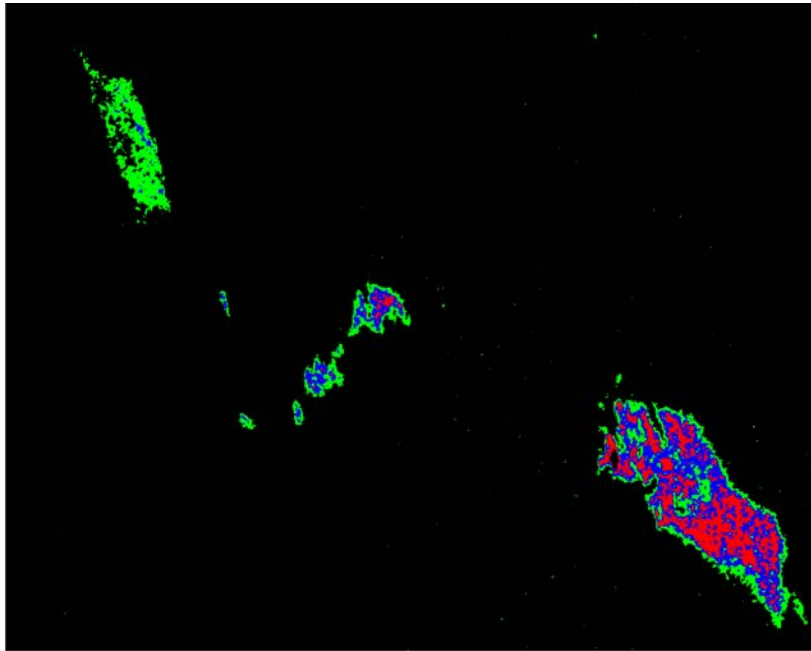
$$\bar{\alpha} = p_1 \alpha_1 + p_2 \alpha_2$$

TerraSAR-X

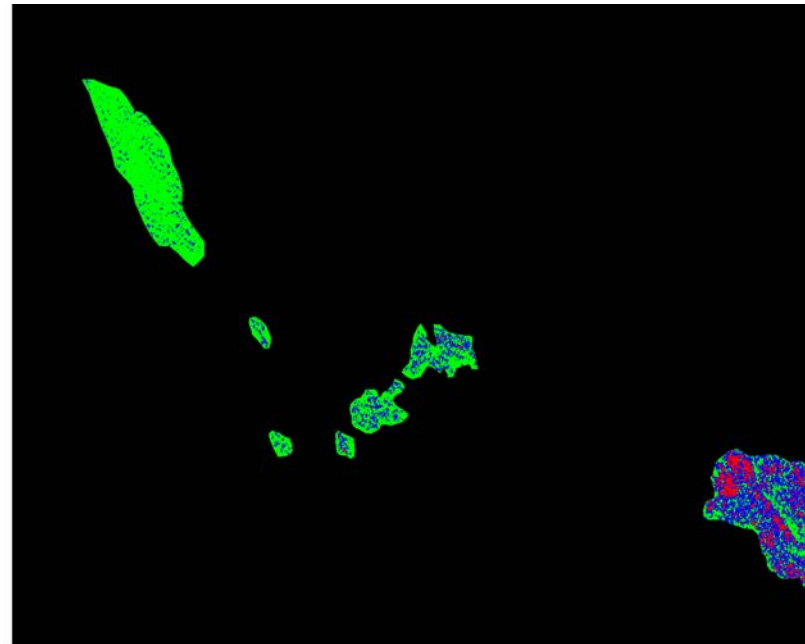


Zones along the edges and internal zoning could be related to thickness variations

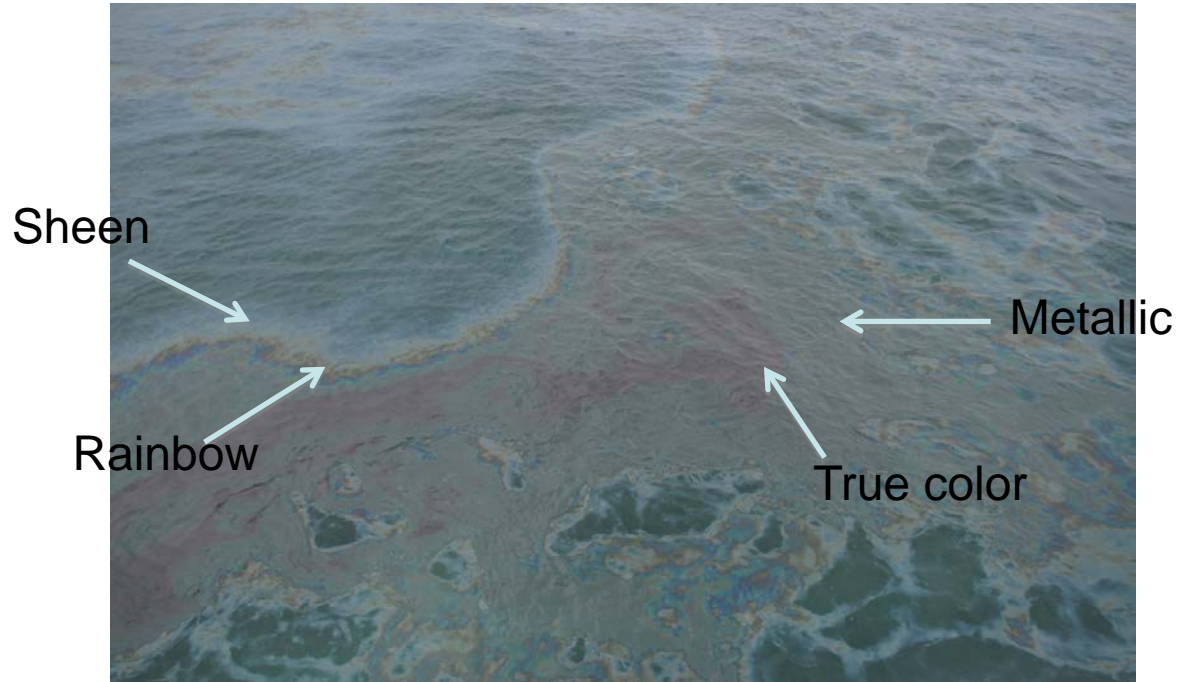
Radarsat-2



TerraSAR-X



Internal oil spill variations are classified into thickness zones according to the BAOAC



Appearance	Thickness (μm)
Sheen	0,04 – 0,3
Rainbow	0,3 – 5,0
Metallic	5,0 - 50
Discontinuous True Colour	50 - 200
Continuous True Colour	>200

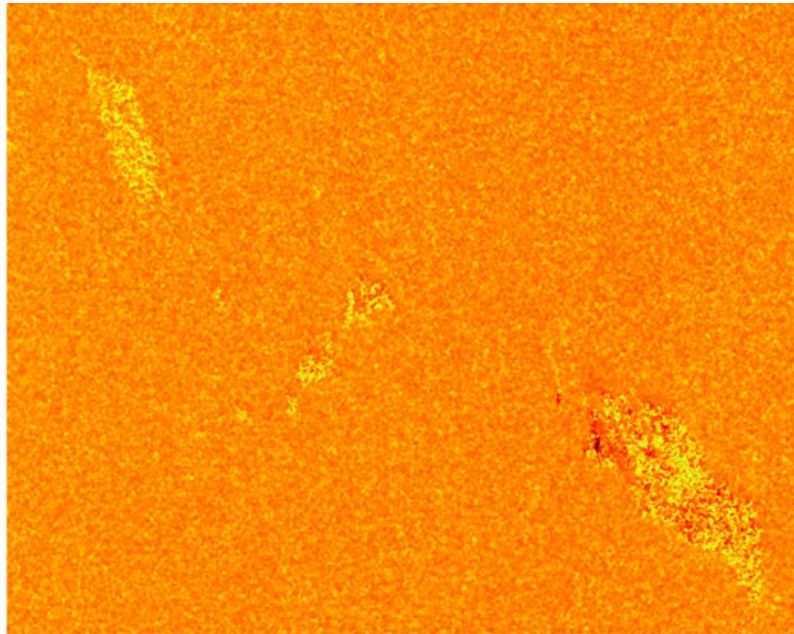
Aerial photos can be used to interpret the results



Photo: Kystverket/NOFO/Sundt Air

α_1 may be used to detect variations in dielectric constant, ϵ

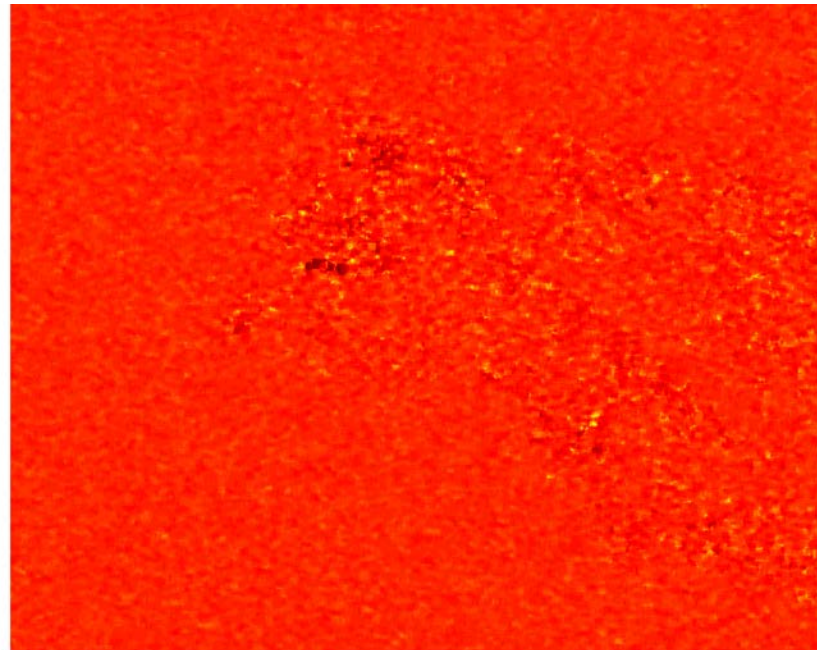
Radarsat-2



Low  High

- Sea water: $\epsilon \sim 80$
- Oil: $\epsilon \sim 3$

TerraSAR-X



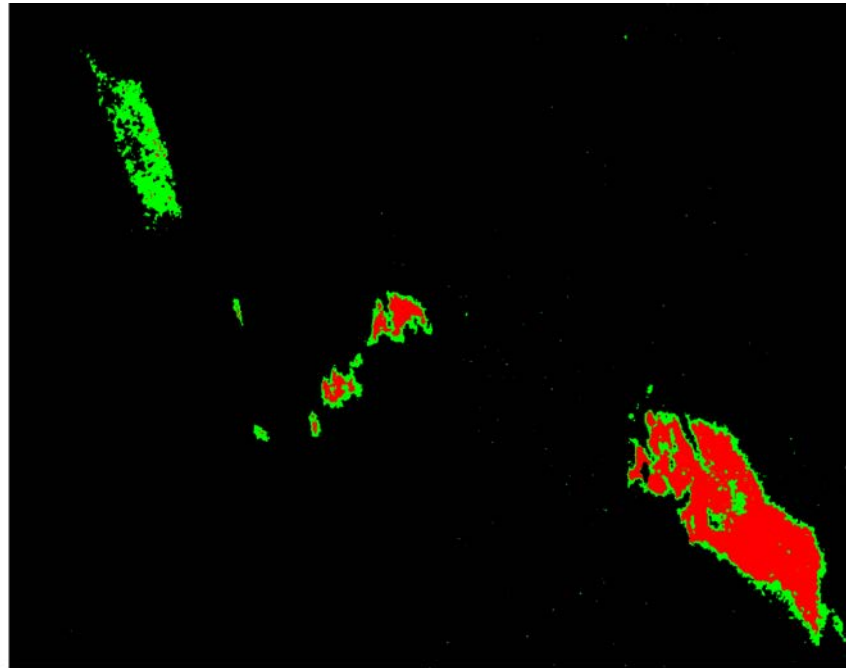
References

- Allain, S., Ferro-Famil, L. & Pottier, E. (2003). Surface parameters retrieval from polarimetric and multi-frequency SAR data. Proc. of IEEE Int. Geosc. and Rem. Sens. Symp., 2003

Conclusion:

Multi-polarization features show potential for oil spill characterization

- Mineral oil vs biogenic film discrimination
- Internal variations possibly related to physical parameters
- Co-polarization channels most reliable for characterization
- Better results with Radarsat-2 compared to TerraSAR-X



Further work: OPV-2012 (June 11-15)



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Questions?

Thanks to:



Meteorologisk
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