PolSAR-Ap: Exploitation of fully polarimetric SAR data for sea oil slick monitoring

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Outline

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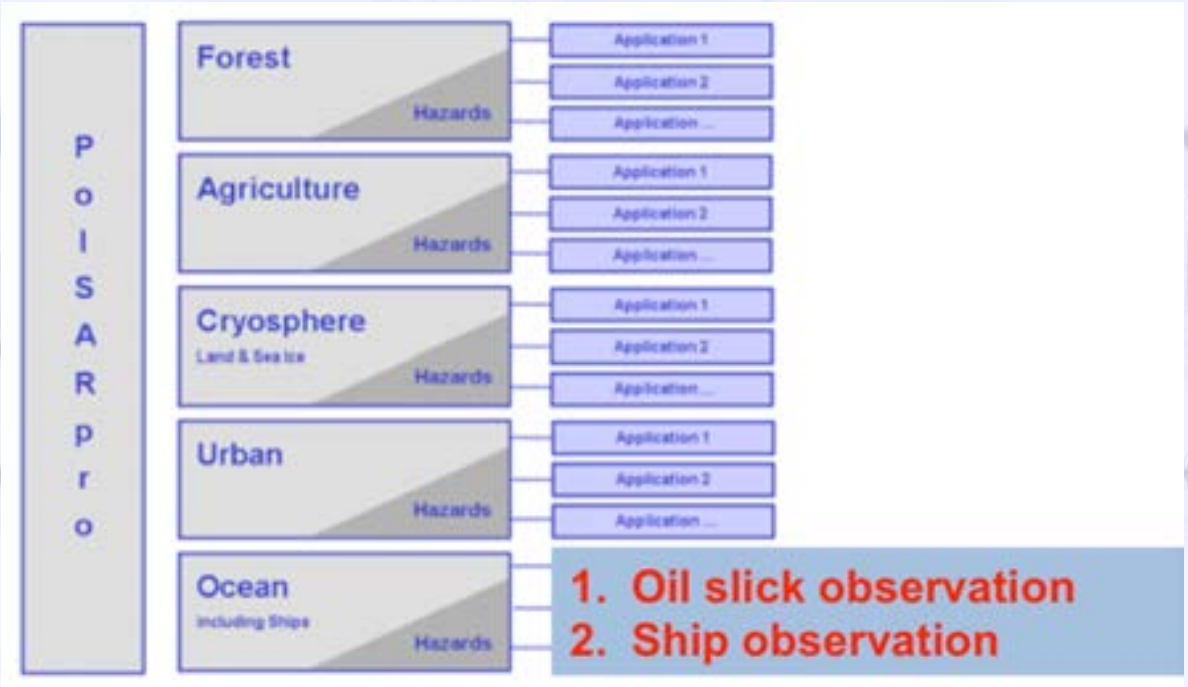
PolSAR-Ap project

The PolSAR-Ap project, supported by ESA and coordinated by DLR, aims at evaluating and demonstrating the importance and the unique benefits of quad-pol SAR data for a wide range of remote sensing applications.



Polarimetric approaches

Polarimetric features

- TD parameters: H, α, A, A_{12}, λ_1.
- HH-VV correlation: CPD, coherence.
- Unpolarized component: DoP, Pedestal.
- Conformity coefficient.

Value-added products

- Oil vs look-alikes
- Surfactant-related properties
- Ongoing investigations: thickness, better discrimination among oil types (Norwegian/Chinese research groups)

Polarimetric scattering & oil at sea observation

Slick-free and oil-covered sea surface can be distinguished using polarimetric features, under low-to-moderate wind conditions ($2 - 15$m/s)

Polarimetric feature	oil-free	oil-covered
HH-VV correlation		
Unpolarized energy		
Polarimetric entropy		
	Bragg	non-Bragg

- Weak-damping surfactants call for Bragg-like scattering.
- Within an oil slick different regions can be distinguished according to the departure from Bragg scattering.
- Polarimetric features may vary according to the oil type and aging

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TD-related features

Polarimetric features

$$H = -\sum_{n=1}^{3} p_n \log_3 p_n \quad p_n = \frac{\lambda_n}{TP}$$

$$A = \frac{\lambda_2 - \lambda_3}{\lambda_2 + \lambda_3}$$

$$A_{12} = \frac{p_1 - p_2}{p_1 + p_2}$$

$$\bar{\alpha} = \sum_{n=1}^{3} p_n \alpha_n$$

Feature	Sea	Oil
0<H<1	low	high
$0<A_{12}<1$	high	low
0°<α<90°	0°	~45°

Normalized pedestal height (NP)

The polarization signature related to distributed targets appears to sit on a “pedestal” that represents unpolarized backscattered energy.

$$\sigma^{o}_{pq} = \frac{1}{2}\frac{4\pi}{k^2}\mathbf{s}^{T}\langle\mathbf{K}\rangle\mathbf{s}$$

$$\mathbf{s} = \begin{bmatrix} 1 \\ \cos 2\chi \cos 2\psi \\ \cos 2\chi \sin 2\psi \\ \sin 2\chi \end{bmatrix}$$

Feature	Sea	Oil
0<NP<1	low	high

Conformity coefficient

It relates co-pol channels to the cross-polarized one

$$\mu \approx \frac{2(Re(C_{13}) - C_{33})}{C_{11} + C_{22} + C_{33}}$$

Feature	Sea	Oil
μ	>0	<0

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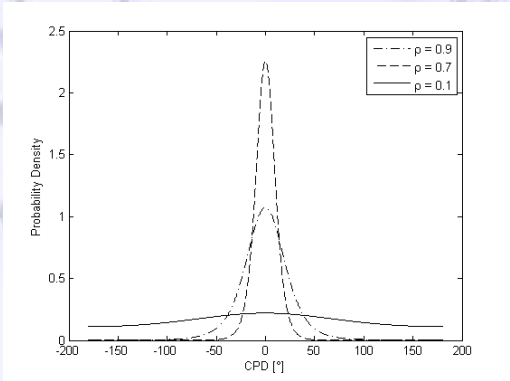
Co-polarized phase difference (CPD)

It is the phase difference between the co-polarized complex channels

$$\mathbf{S} = \begin{pmatrix} \dot{S}_{hh} & \dot{S}_{hv} \\ \dot{S}_{vh} & \dot{S}_{vv} \end{pmatrix}$$

$$\text{CPD} = \varphi_{hh} - \varphi_{vv}$$



Feature	Sea	Oil
$0<\sigma<\infty$	low	high

Selected test sites, sensors and data sets

6 full-polarimetric L- and C-band SAR data are processed

Application / Product	Test site - Radar data	Reference data
Oil at sea observation	Gulf of Mexico 3 RadarSAT-2 fine quad-pol ID: PDS_01141700/710/720	Deepwater Horizon oil slick
	Gulf of Mexico 2 RadarSAT-2 fine quad-pol ID: PDS_0200575o/6o	Oil seeps
	Gulf of Mexico 1 UAVSAR MLC quad-pol ID: 14010	Deepwater Horizon oil slick

- Deepwater Horizon oil spill
  - 3 C-band Radarsat-2 SLC SAR scene.
  - 1 L-band UAVSAR (airborne) MLC SAR scene.
- Oil seep
  - 2 C-band Radarsat-2 SLC SAR scene.

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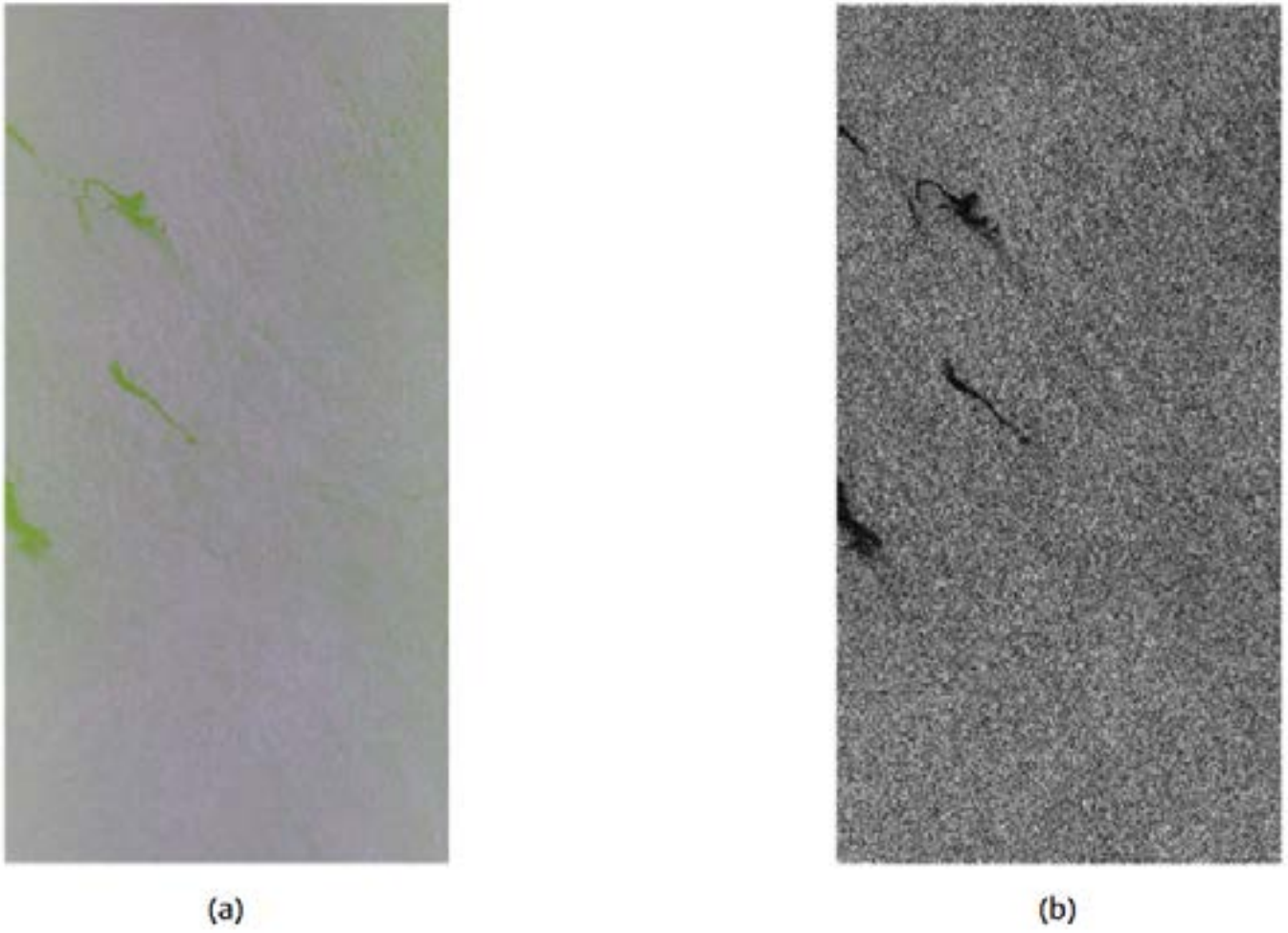
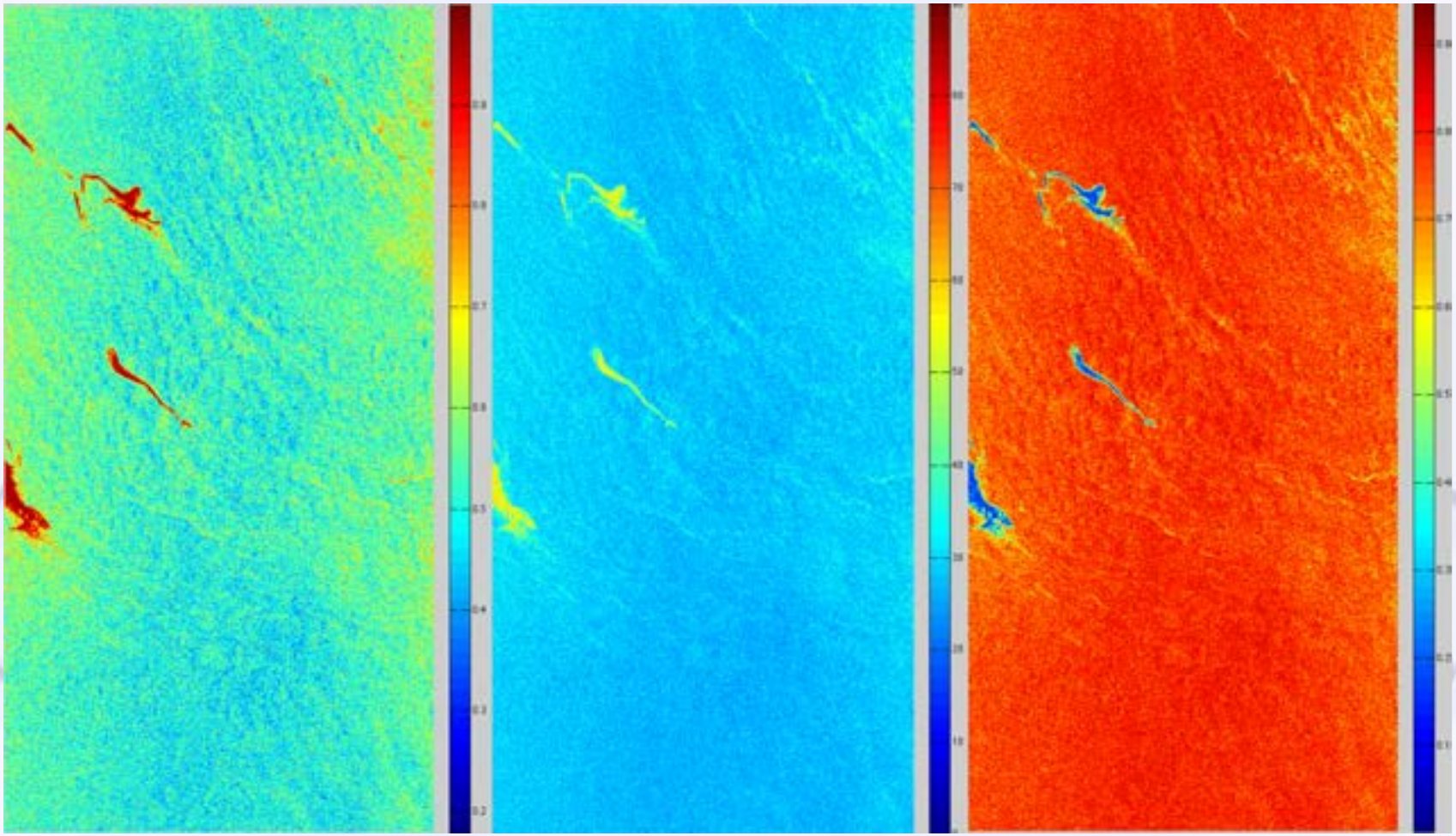
Oil seep: May 8, 2010

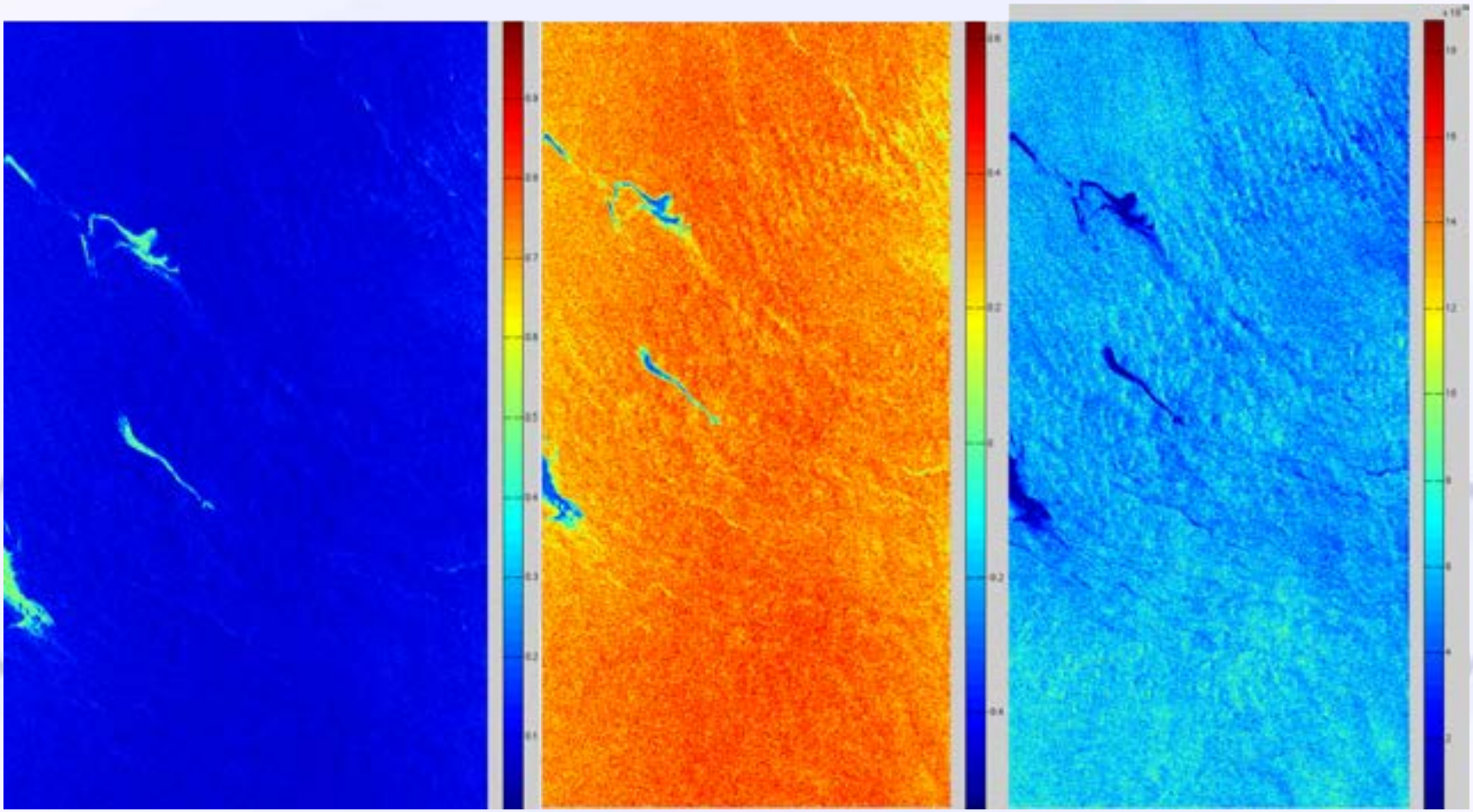


The wind speed is 6 m/s and $41.9 < \vartheta < 43.3$ [deg].

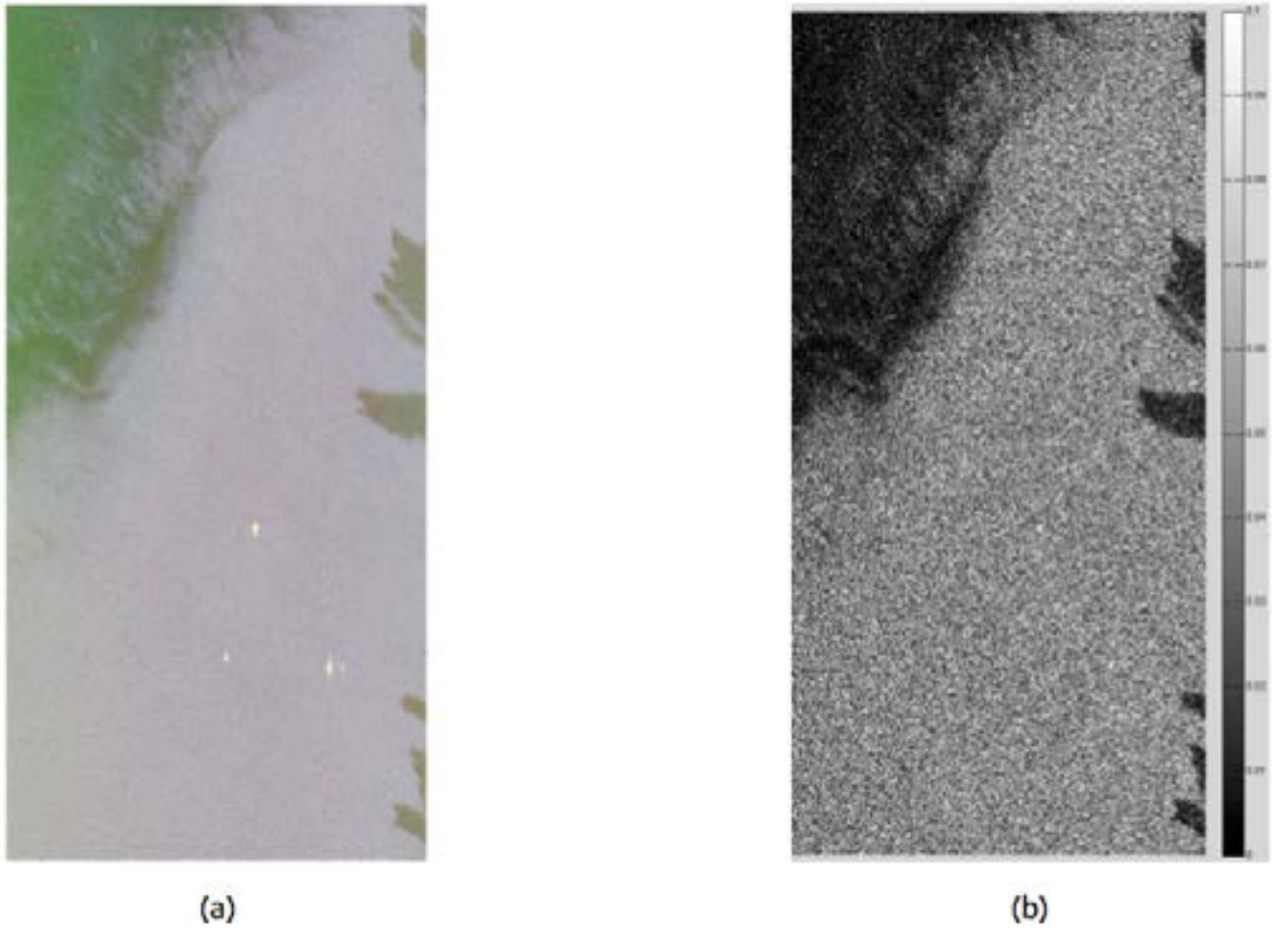
Oil seep May 8, 2010: H, $\bar{\alpha}$ and A_{12}



Oil seep May 8, 2010: NP, μ and λ_1

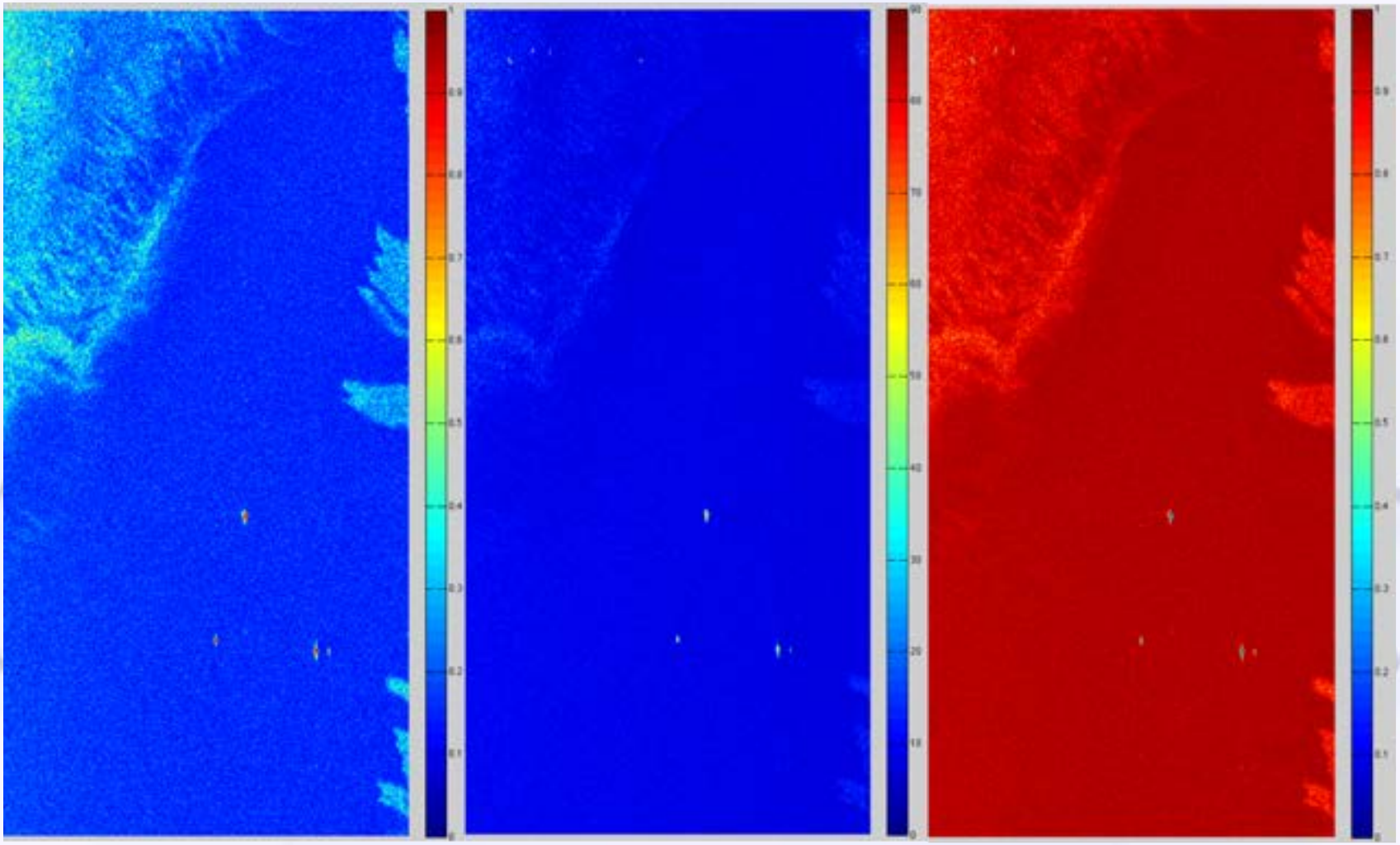


DWH: RadarSAT-2 SAR scene - May 15, 2010

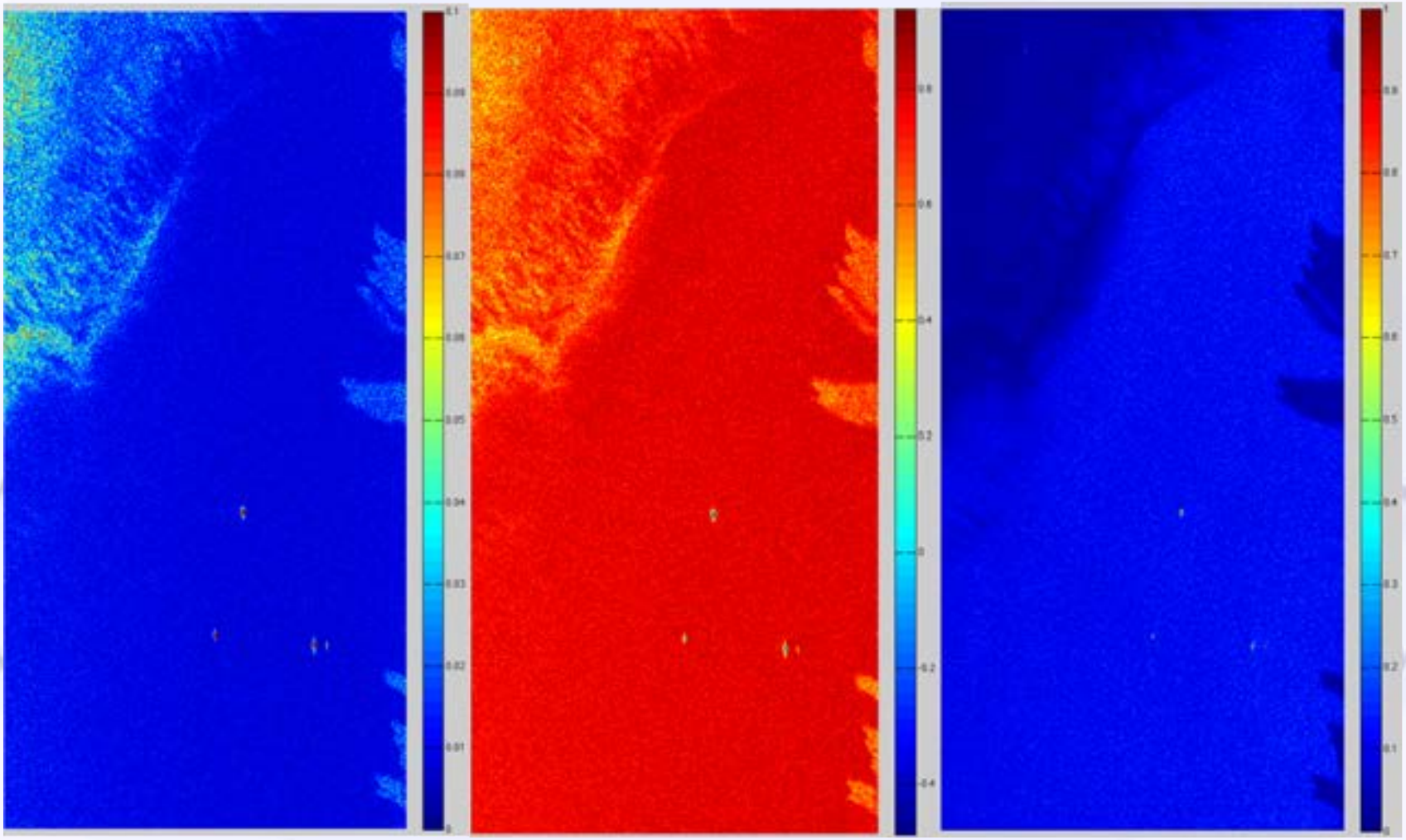


The wind speed is $4 - 7$ m/s and $29.1 < \vartheta < 30.9$ [deg].

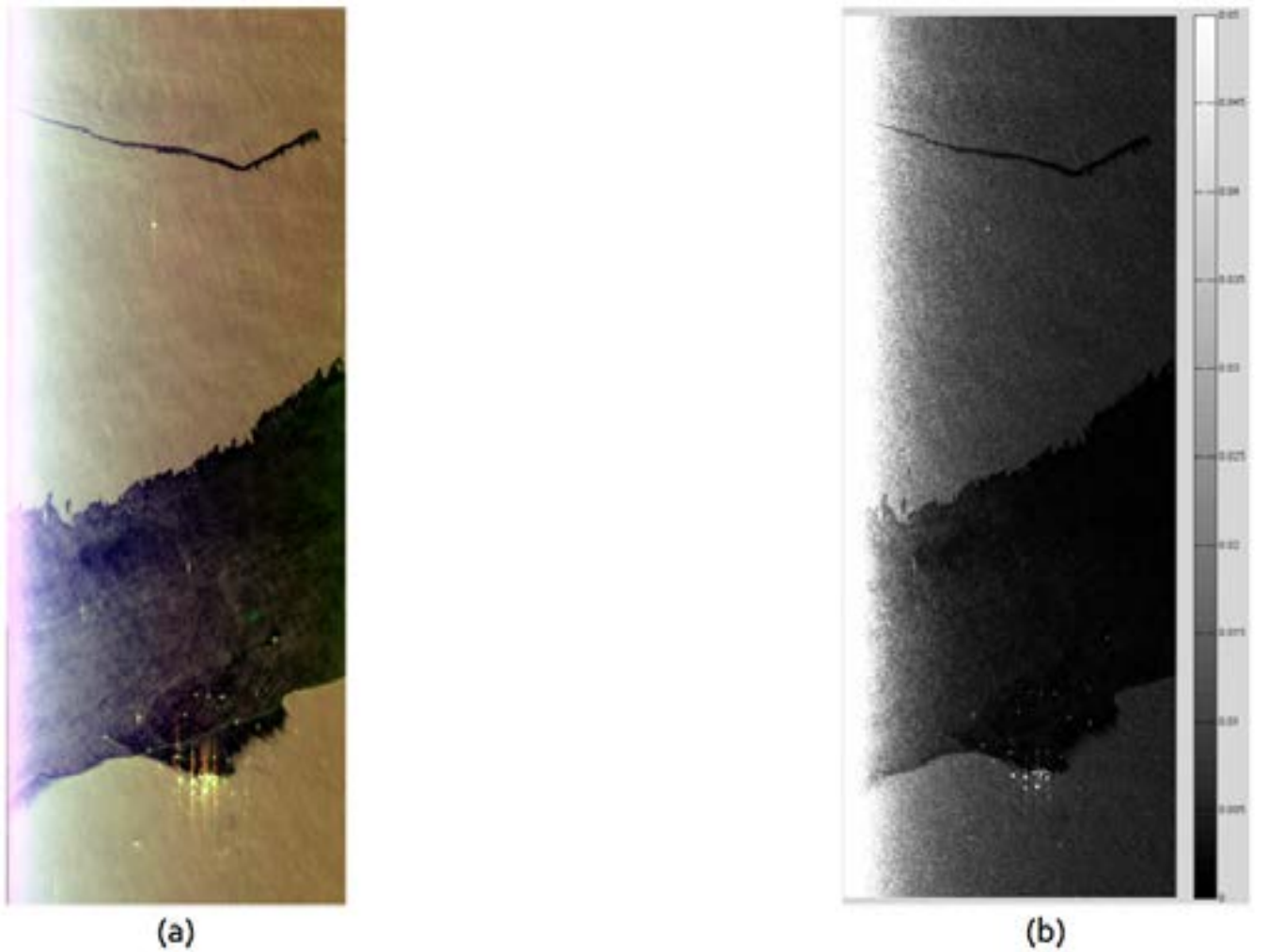
DWH: May 15, 2010: H, $\bar{\alpha}$ and A_{12}



DWH: May 15, 2010: NP, μ and λ_1

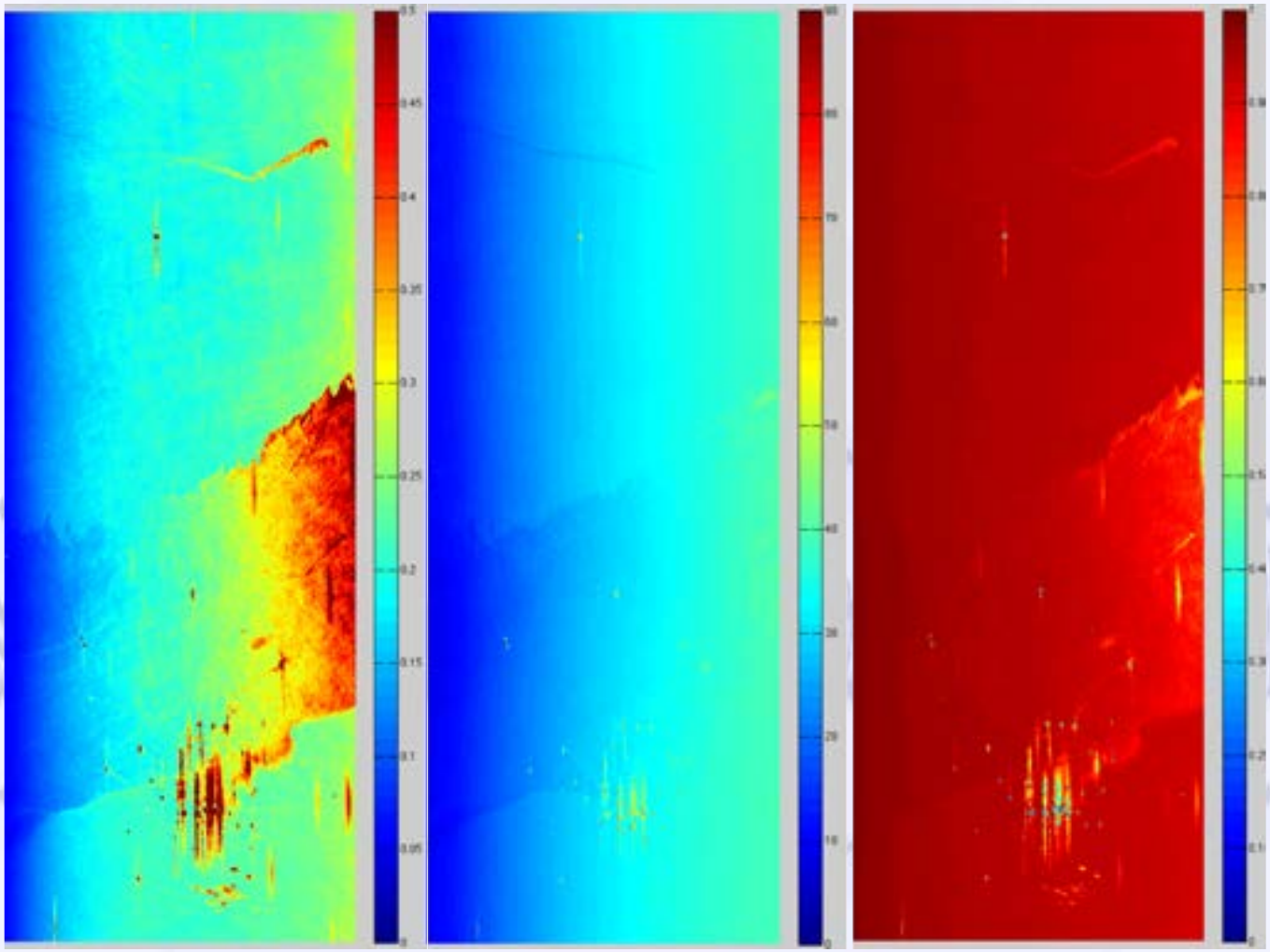


DWH: UAVSAR SAR scene - June 23, 2010

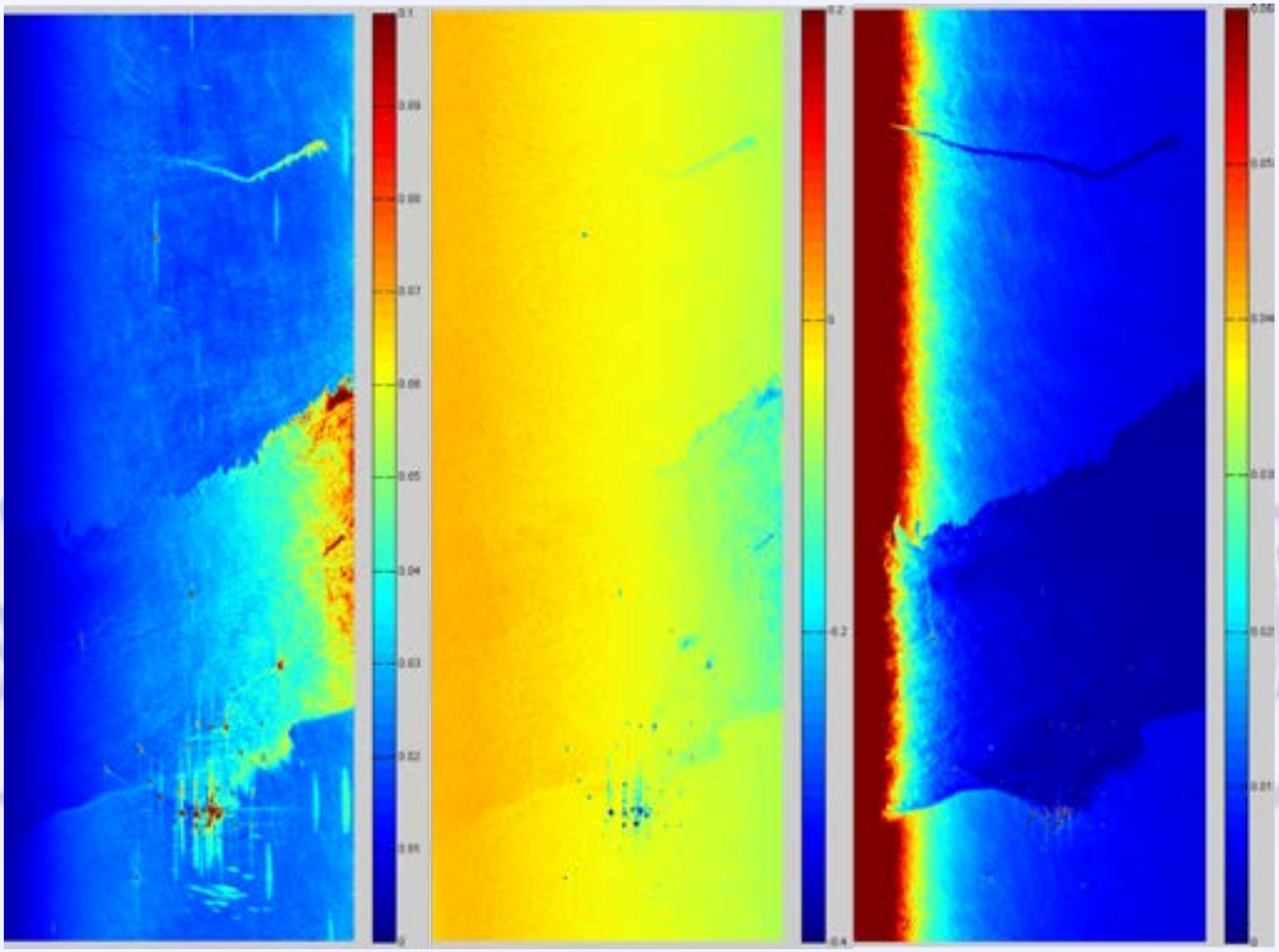


The wind speed is $4 - 7$ m/s and $22 < \vartheta < 65$ [deg].

DWH: June 23, 2010: H, $\bar{\alpha}$ and A_{12}

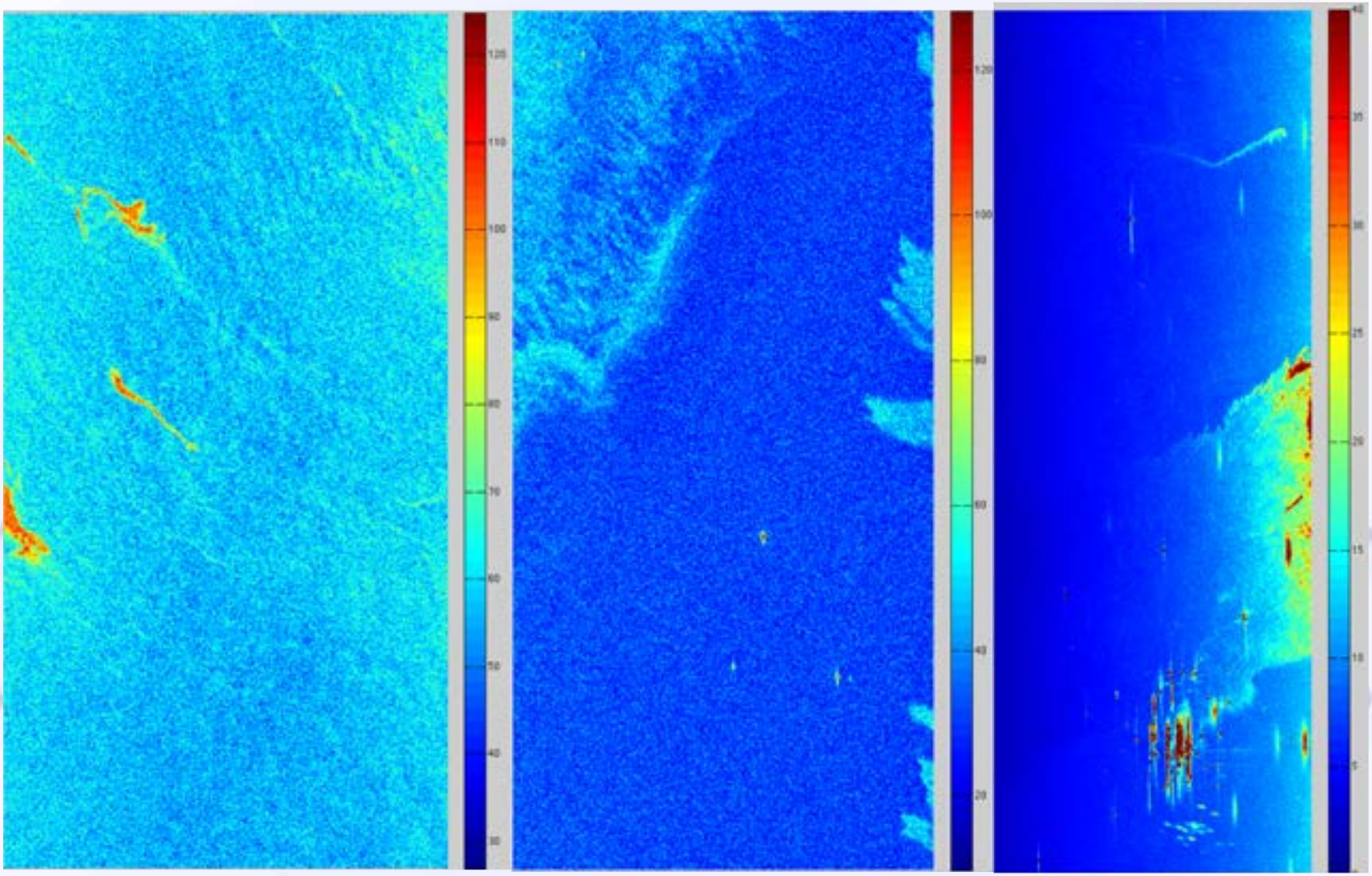


DWH: June 23, 2010: NP, μ and λ_1



Outline

CPD: σ



RS2 - Oil seep

RS2 - DWH

UAVSAR - DWH

Conclusions

Some of the most up-to-dated polarimetric approaches to observe oil at sea are reviewed and their performance is discussed using actual L-band UAVSAR and C-band RadarSAT-2 SAR data where both oil slicks related to the Deepwater Horizon accident and oil seeps are present.

- Oil vs weak-damping look-alikes (not shown).
- The experiments clearly witness that PolSAR data allow: a) detecting oil at sea; b) providing a rough information on the kind of surfactant and on its damping properties.
- PolSAR offers an unprecedented level of scattering details that can be used to assist classical “large swath” single-polarization procedure providing extra-information on the surfactant.