Multifrequency radar imagery and characterization of Hazardous and Noxious Substances at sea

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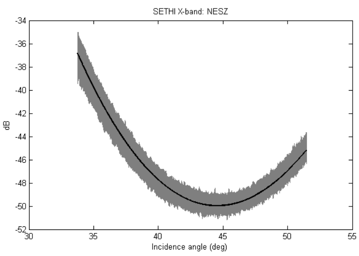
Maritime pollution by chemical products occurs at much lower frequency than spills of oil, however the consequences of a chemical spill can be more wide-reaching than those of oil. While detection and characterization of hydrocarbons have been the subject of numerous studies, detection of other chemical products at sea using remote sensing has been little studied and is still an open subject of research. To address this knowledge gap, an experiment was conducted in May 2015 over the Mediterranean Sea during which controlled releases of Hazardous and Noxious Substances were imaged by remote sensing systems.

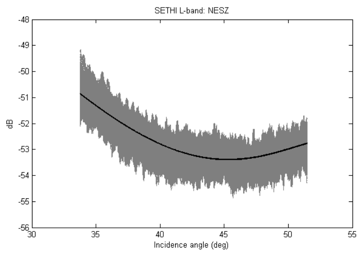
In this paper we discuss the experimental procedure and report the main results from the airborne radar imaging campaign. We develop an accurate method for using multifrequency radar sensors to detect and quantify impact of chemical products at sea. We conclude by demonstrating the capability of radar imagery to distinguish two different substances within the same spill.

Experimentation at sea

Airborne SAR remote sensing

Frequency	Bandwith	Polarization	Incidence angle	Swath
X	300 MHz (9.6-9.9 GHz)	Quad-pol (HH, HV, VH, VV)	45° (34-52°)	1500m (slant range)
L	150 MHz (1.25-1.4 GHz)	Quad-pol (HH, HV, VH, VV)	45° (34-52°)	1500m (slant range)





Chemical products (1 m^3 each)

Category I : vegetal oil and fatty acid esters

- Rapeseed oil
- Fatty Acid Methyl Esters (FAME)

Category II : petrochemical products

- Toluene
- Heptane
- Xylene

Category III : alcohols and derivatives

- Methanol

Methodology

Detection and relative quantification:

PD=VV-HH (in linear units) ⇔ sensitive to small scale features of the ocean surface (damped by the slick)

$$NPD = \frac{PD_{\max} - PD}{PD_{\max}} \qquad 0 < NPD < 1$$

PD_{max} = PD value in the case of a clean sea surface

NPD goes to 1 as the impact of the HNS increases

Characterization: Oil / Water mixing index

$$\sigma^0_{pp} = 4\pi k^4_{EM} \cos^4 \theta_i \Gamma_{pp} W$$

W : spectral density of the ocean surface roughness
Γ_{pp} : reflectivity

Normalized damping factor: $M_W = \frac{W^{water} - W^{oil}}{W^{water}}$

Normalized power attenuation factor: $M_\alpha = \frac{|\alpha^{water}_{VV}|^2 - |\alpha^{oil}_{VV}|^2}{|\alpha^{water}_{VV}|^2}$

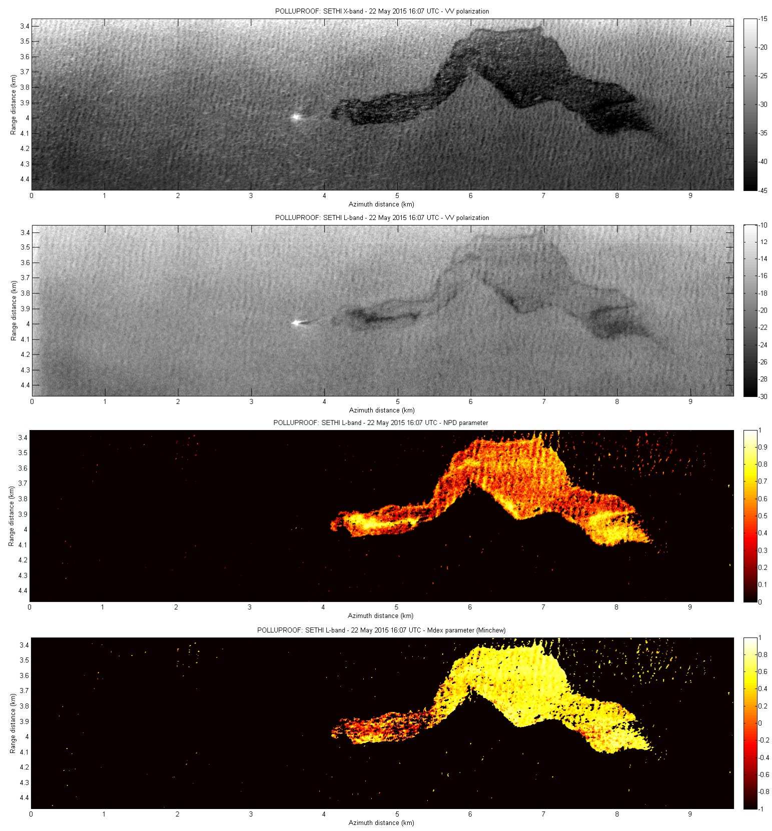
Oil / Water mixing index(*): $M_{dex} = M_W - M_\alpha$

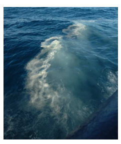
M_{dex} < 0 : HNS is mixing with sea water
M_{dex} > 0 : film on the top of the surface

POLLUPROOF [ANR-13-ECOT-007]

(*) Minchew, B., Determining the mixing of oil and sea water using polarimetric synthetic aperture radar, Geophys. Res. Lett., 39, 2012.

Results





FAME: 3D plume / mix between HNS and water

Rapeseed oil: discontinuous film on the surface