Sea Oil Field Satellite Monitoring:

An Operational View

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Outline

- Introduction

- Sea oil fields

- Synthetic Aperture Radar

- SAR sea oil field monitoring

- Conclusions

Introduction

- Petroleum or crude oil is a naturally occurring, toxic, flammable liquid consisting of a complex mixture of hydrocarbons of various molecular weights, and other organic compounds, that are found in geologic formations beneath the Earth's surface.

Introduction

- Petroleum is recovered mostly through oil drilling. It is refined and separated, most easily by boiling point, into a large number of consumer products, from gasoline and kerosene to asphalt and chemicals used to make plastics and pharmaceuticals.


Refinery Gas
Used as a fuel

40°C — Petrol
Used in cars

110°C — Naphtha
Used in chemical production

180°C — Kerosene
Used as jet fuel

260°C — Diesel Oil
Fuel for diesel engines

Heated crude oil — 340°C — Residue
Fuel for ships, lubricating oil, road surface

Introduction

Supply Sources ·····························▶ Demand Sectors

Source: Energy Information Administration, *Annual Energy Review 2009*

Introduction

World's Largest Oil and Gas Companies

Million Oil Equivalent Barrels

Oil reserves

200 billion+
150-199 billion
100-149 billion
50-99 billion
10-49 billion
1-9 billion
100-999 million
10-99 million
9 million-
No information

Sea oil transportation

Kashagan Field

- **Kashagan Field** is an oil field located in Kazakhstan. The field is situated in the northern part of the Caspian Sea close to the Kazakhstan city of Atyrau. The field was discovered in 2000 and was one of the larger discoveries in that decade, it is estimated that the Kashagan Field has commercial reserves from 9 billion barrels (1.4×10^9 m^3) to 16 billion barrels (2.5×10^9 m^3) of oil.
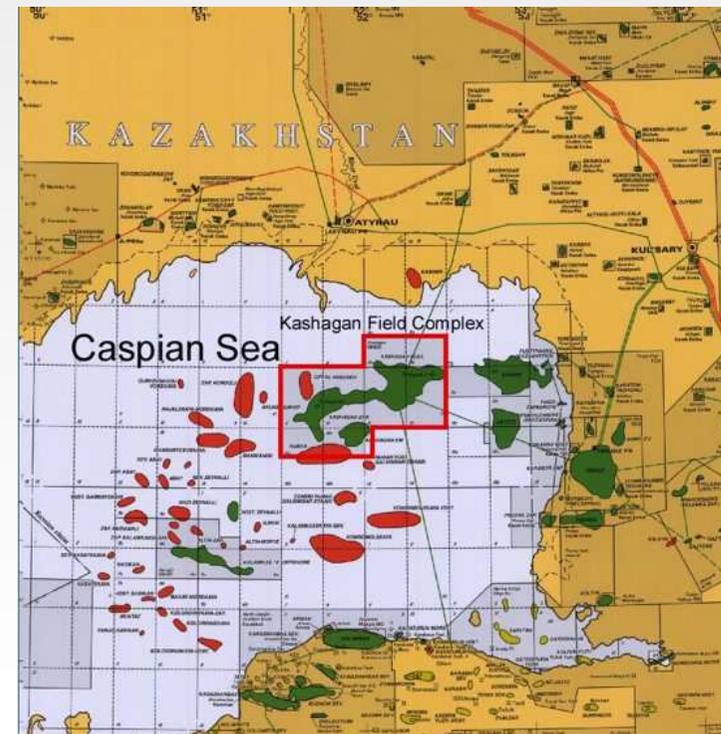
Kashagan Field

Isola A - ENI

Isola D - ENI

Kashagan - Isola Artificiale A in inverno

North sea oil field

- In the oil industry, the term "North Sea" often includes areas such as the Norwegian Sea and the UK "Atlantic Margin" (west of Shetland) that are not geographically part of the North Sea.

- The British and Norwegian sections hold most of the remainder of the large oil reserves. It is estimated that the Norwegian section alone contains 54% of the sea's oil reserves and 45% of its gas reserves.
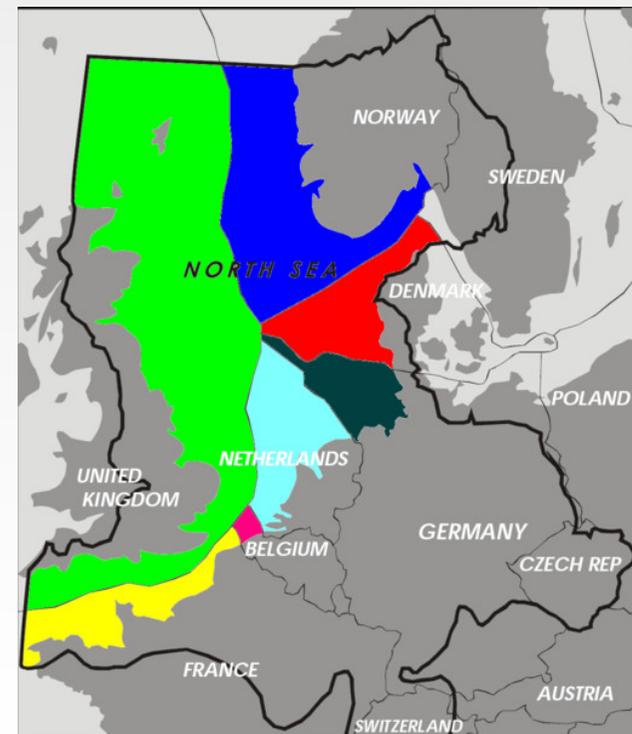
North sea oil field

- For Norway, the Norwegian Petroleum Directorate gives a figure of 4,601 million cubic metres of oil (corresponding to 29 billion barrels) for the Norwegian North Sea alone (excluding smaller reserves in Norwegian Sea and Barents Sea) ultimate of which 2,778 cubic metres (60%) has already been produced prior to January 2007.

- Exact figures are debatable, because methods of estimating reserves vary and it is often difficult to forecast future discoveries.
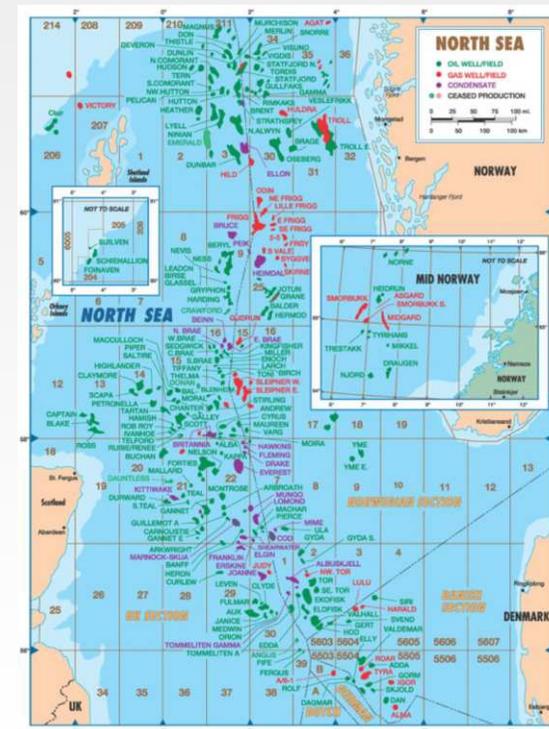
North sea oil field

Ekofisk

The Brent oil field in the North Sea, north west of Shetland

Niger Delta province

- The **Niger Delta province** is a geologic province in the Niger Delta of West Africa also known as the **Niger Delta Basin**. The province contains one petroleum system, the "Tertiary Niger Delta (Akata-Agbada) Petroleum System" (classified as number 701901), the majority of which lies within the borders of Nigeria, with suspected or proven access to Cameroon, Equatorial Guinea and São Tomé and Príncipe.
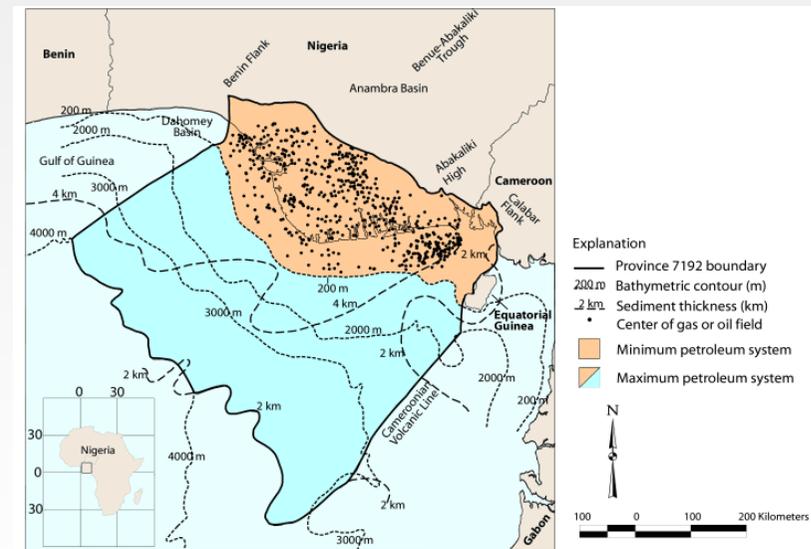
Figure 1 Index map of Nigeria and Cameroon. Map of the Niger Delta showing Province outline (maximum petroleum system); bounding structural features; minimum petroleum system as defined by oil and gas field center points (data from Petroconsultants, 1996a); 200, 2000, 3000, and 4000 m bathymetric contours; and 2 and 4 km sediment thickness.

Niger Delta province

- This petroleum system contains as much as 5.5 10^9m³ (34.5 billion barrels) of recoverable oil and 2.7 10^9m³ (94 trillion cubic feet) of natural gas at the origin. This field is not a single gigantic field but composed of thousands of individual reservoirs, most of which are sandstone pockets, trapped within oil-rich shale strata.

- The total production of the Akata-Agbada system is about 320,000 m³ (2 million barrels) per day.

US imports from south and west Africa 2002

NIGERIA
S AFRICA
ANGOLA
GABON
EQUATORIAL GUINEA

0   1   2   3   4   5   6
$ BILLIONS

Oil reserves, west Africa
(bn barrels/estimated*)

ANGOLA
NIGERIA
GABON
CONGO BRAZZAVILLE
EQUATORIAL GUINEA

0   5   10   15   20   25   30

● Oilfield

SOURCE : US ITA/
USGS/WORLD OIL
VOL. 223 2002
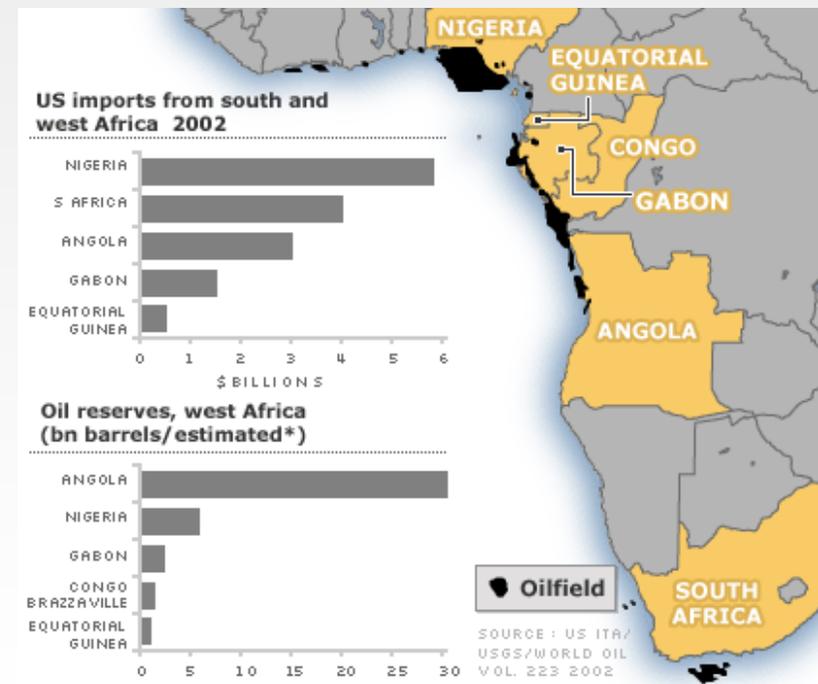
Niger Delta province

Maracaibo

- The **Maracaibo Basin** in Western Venezuela is a prolific, oil-producing sedimentary basin. The basin is bounded on the north by the Oca Fault which separates it from the Caribbean Sea.

Maracaibo

Arctic oil field

The pristine waters off Greenland are targets for a new oil and gas drive

Arctic oil field

- According to the US Geological Survey, almost a quarter of the world's undiscovered but potentially exploitable oil and gas reserves may lie beneath the Arctic seabed.

- Basic science tells you that in colder water, oil products are going to remain intact for much longer before being broken down. Rescue and clean-up operations will be more difficult in the roiling Arctic than in the relative calm of the Gulf.

- The most important governments involved in the new Arctic oil race are Canada, Russia and the US.

Gulf of Mexico

- The **Gulf of Mexico** is a partially landlocked ocean basin largely surrounded by the North American continent and the island of Cuba.

- At its deepest it is 14,383 ft (4,384 m) at the Sigsbee Deep, an irregular trough more than 300 nautical miles (550 km) long. The basin contains a volume of roughly 660 quadrillion gallons (2.5×10^{15} m^3).
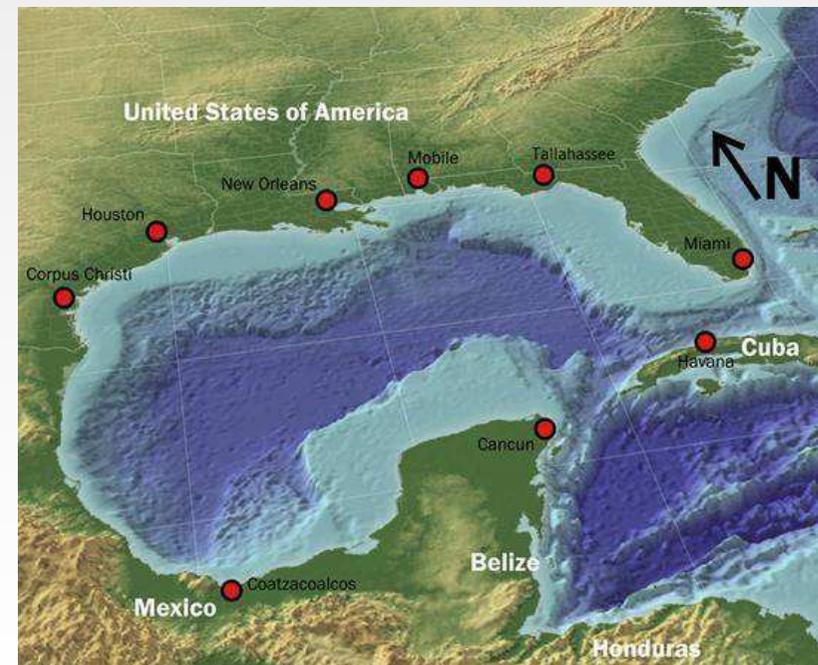
Gulf of Mexico

- One of the largest worldwide sea oil field is in the Gulf of Mexico which can be split into three US areas: the Western Gulf, the Central Gulf and the Eastern Gulf.

- The Central Gulf is the most relevant sea oil field area with 30.3 oil estimated billion of barrels and with 5,001 leases.

- The total number of active offshore leases in the Gulf of Mexico is 6,918 and now accounts for 30% of US production with half of that coming from deep water (>300 m and <1500 m) and a third from ultradeep water (>1500 m).

Gulf of Mexico

Gulf of Mexico

Map 1 – All Pipeline Damages Reported for Hurricanes Katrina and Rita
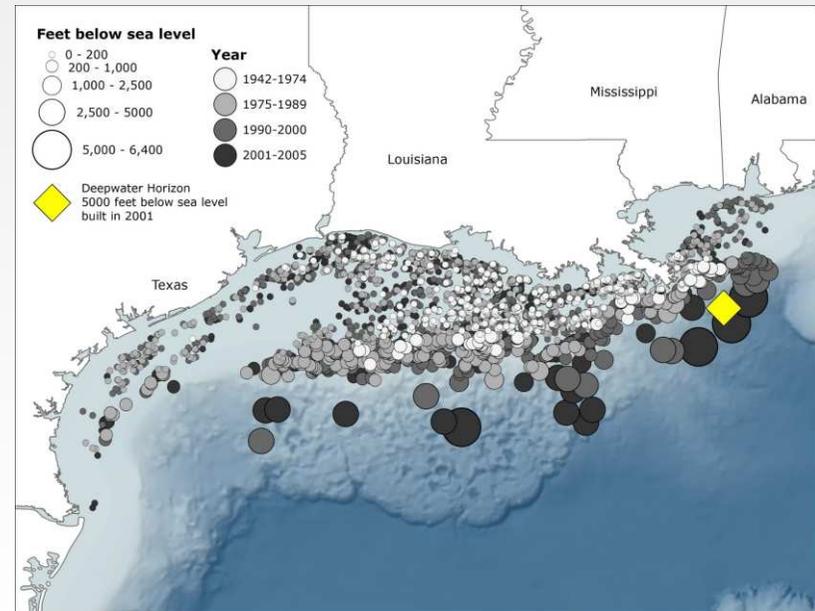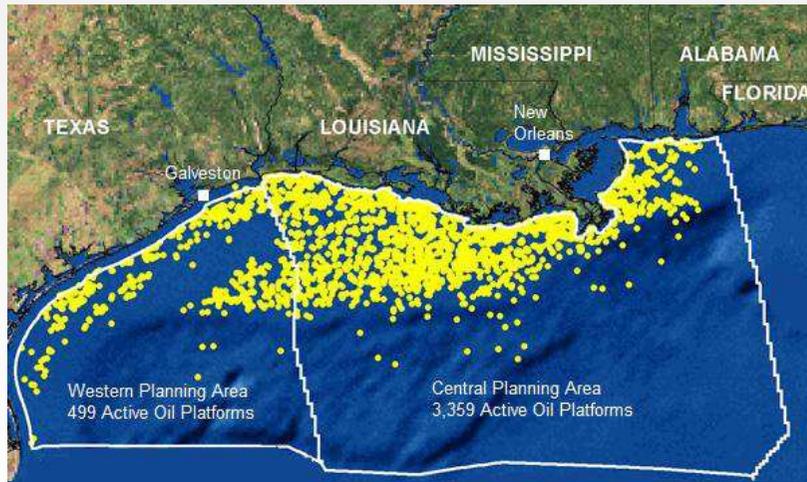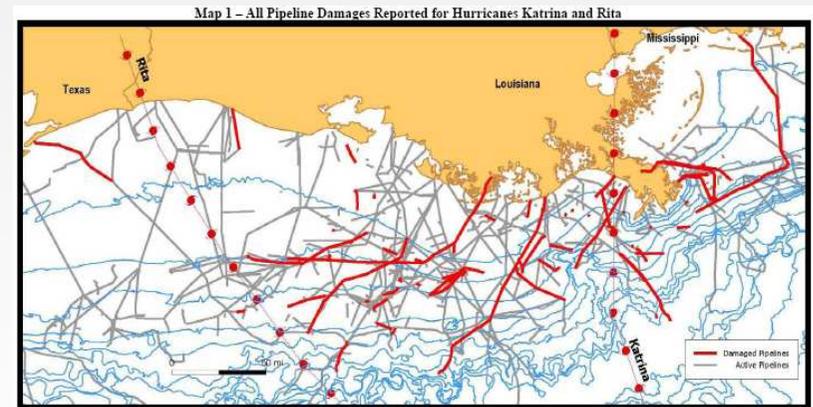
All pipeline damages reported for both Hurricanes Katrina and Rita are mapped over the hurricane routes and seafloor contours. Damaged pipelines are in red and the undamaged active pipeline network is shown in gray. This map represents 542 damage reports; 299 reports for Hurricane Katrina and 243 for Hurricane Rita.

Deepwater Horizon

- The site of the Transocean Deepwater Horizon was in the Macondo well in the Central Gulf area about 80 km off the Louisiana coast.

- Close enough to the coast and to a coastal area of paramount economical and environmental interest.

Deepwater Horizon

- On 20 April 2010, a fire broke on the Transocean Deepwater Horizon oil rig under lease by BP (British Petroleum), with 126 people on board. After a big explosion, all but 11 of the crew managed to escape as the rig was burnt by fire.

- On 22 April 2010, the rig sank. Safeguards set in place to automatically cap the oil well in case of catastrophe did not work as expected. According to a first conservative MMS (Minerals Management Service) formula the BP estimated at worst a spill of 162,000 barrels per day and a standard technology recovery capacity of about 500,000 barrels per day. Only after 12 weeks the BP succeeded in placing a tight cap on the well.

- A first estimate of about 5 million barrels already makes this accident as the world's largest accidental oil spill. It is surpassed only by the intentional 1991 Gulf war spill in Kuwait.

Deepwater Horizon
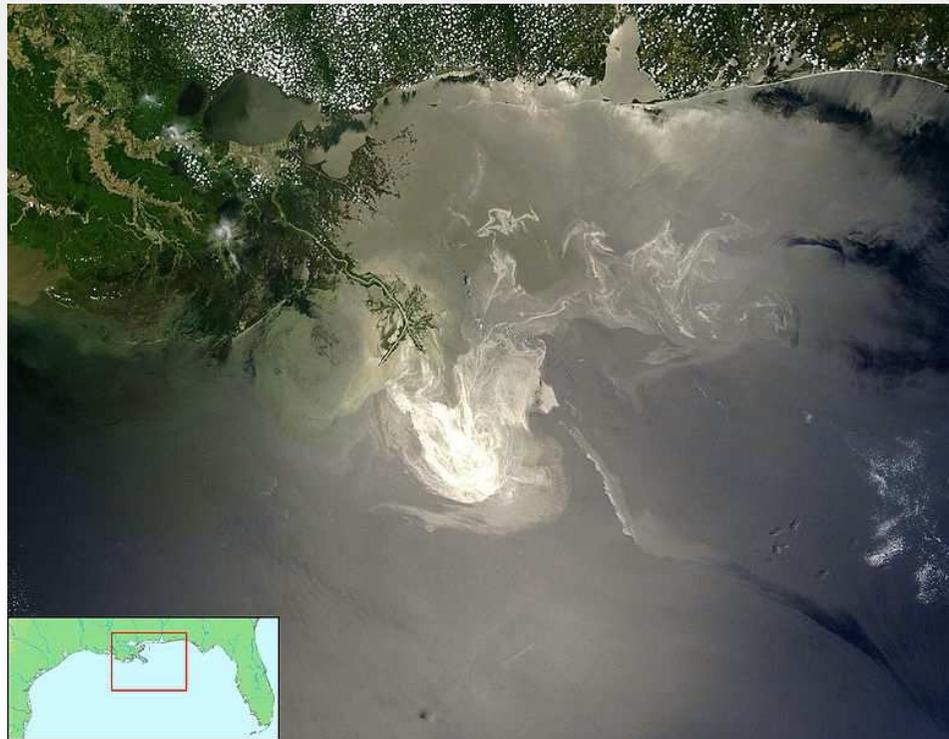
SAR

- The Synthetic Aperture Radar (SAR) is an active coherent band-limited microwave imaging sensor that works exploiting different mechanisms to form the azimuth and the range dimensions of the image.

- SAR can efficiently work day-and-night and almost independently from atmospheric conditions.

- Due to its nature SAR images are affected by speckle that can be reduced at expense of spatial resolution.

- Enhanced SAR sea oil slick observation it has been developed by appropriate physical modelling and use of fully-polarimetric and dual-polarimetric measurements.

SAR

ASAR

RadarSAT-1
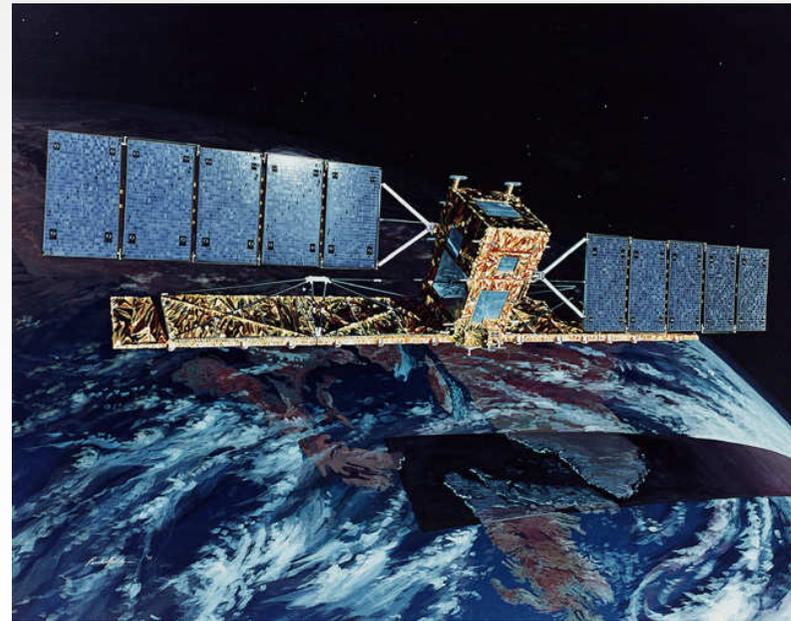
SAR

CosmoSkyMed
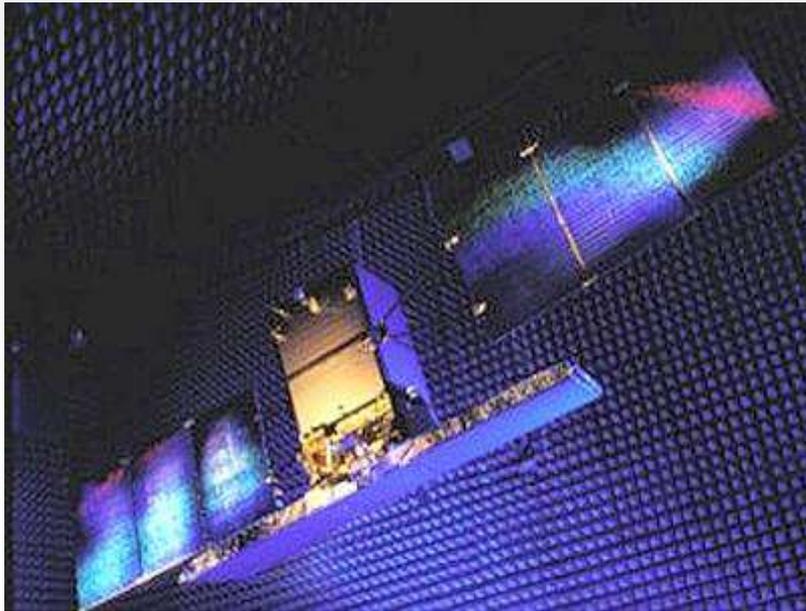
TerraSAR-X

SAR

PALSAR

RadarSAT-2
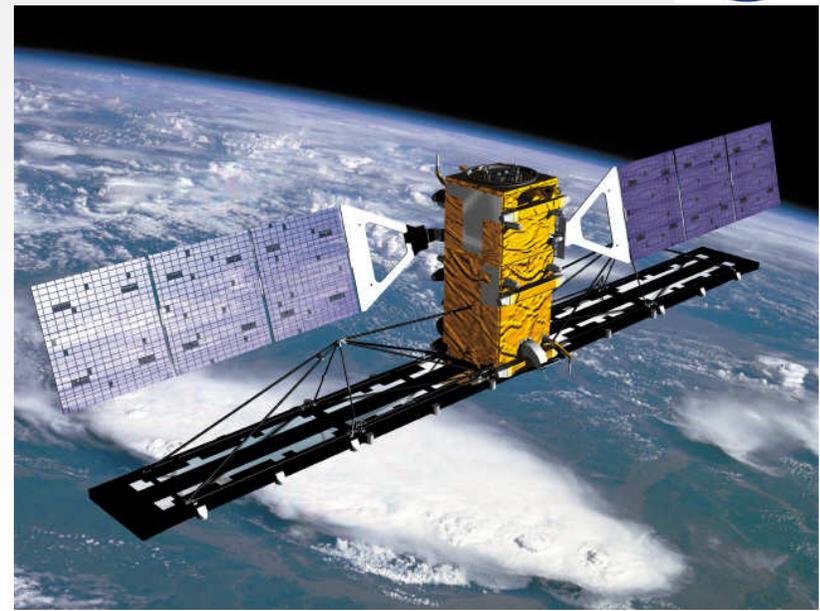
SAR oil field monitoring
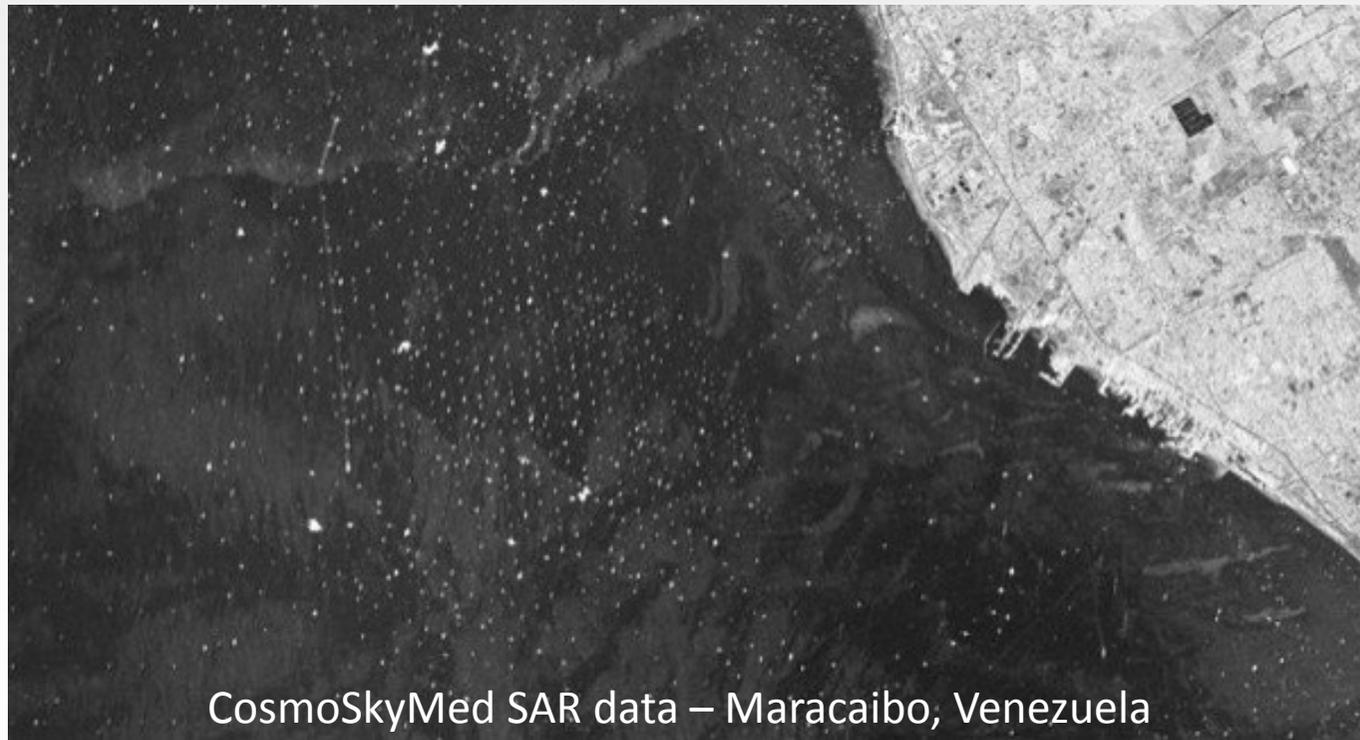
CosmoSkyMed SAR data – Maracaibo, Venezuela

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SAR oil field monitoring

- A large emphasis is often posed on data since it is said that satellite data are low cost and support services. Too often is neglected the key fact that in SAR images, conversely to optical ones, data interpretation is not always straightforward.

- Larger data availability *per se* does not ensure an enhancement of the service since added value products generation are often based on *ad hoc* procedures that strongly rely on the operator expertise.

- Semi-automatic image-based procedures are typically adapted to the sensor.

- Automatic and reliable procedures – able to take benefit of all SAR data - are necessary for an effective operational service.

Physical vs Image processing

'The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them.'

— William Bragg

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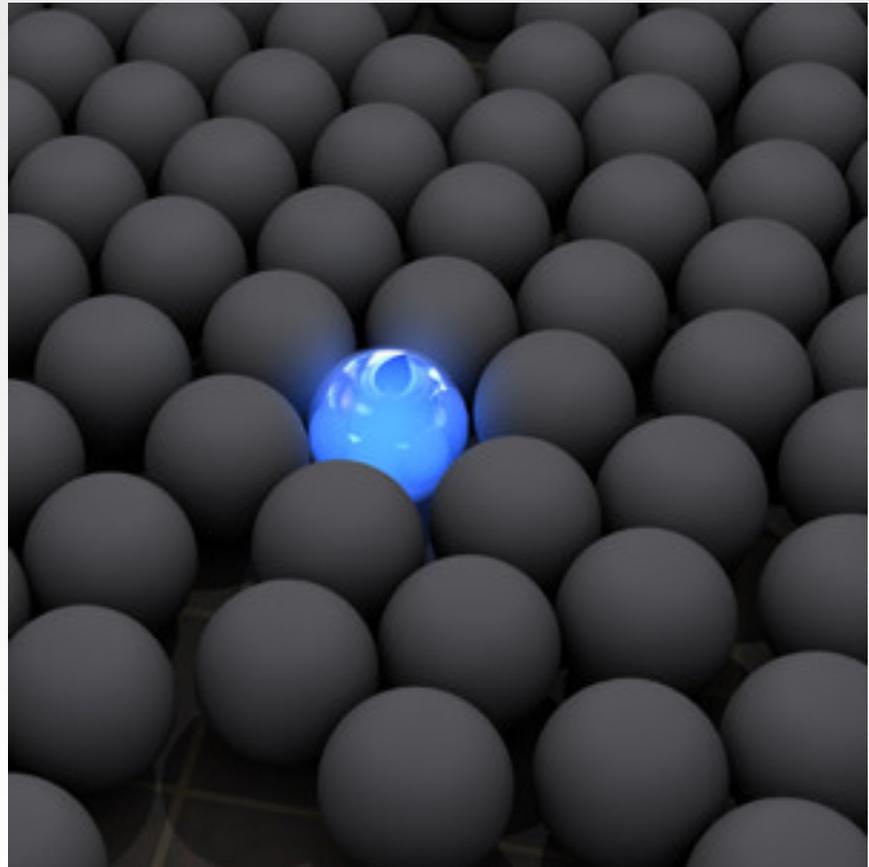
Oil *single-pol* ☹

SIR-C
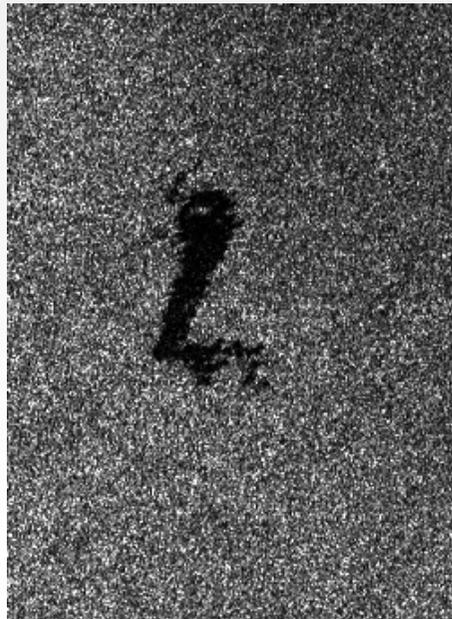
SIR-C

Oil *single-pol* ☹

PalSAR
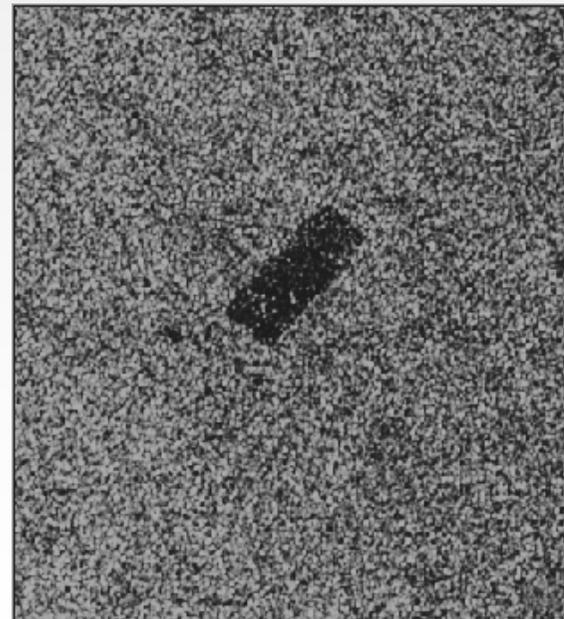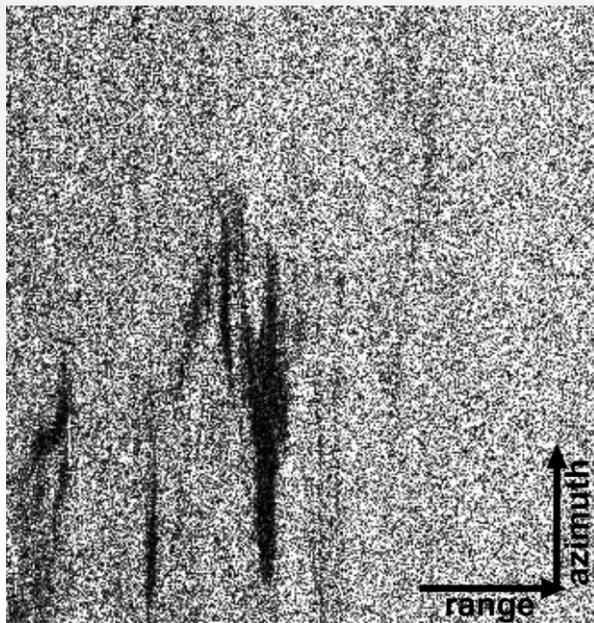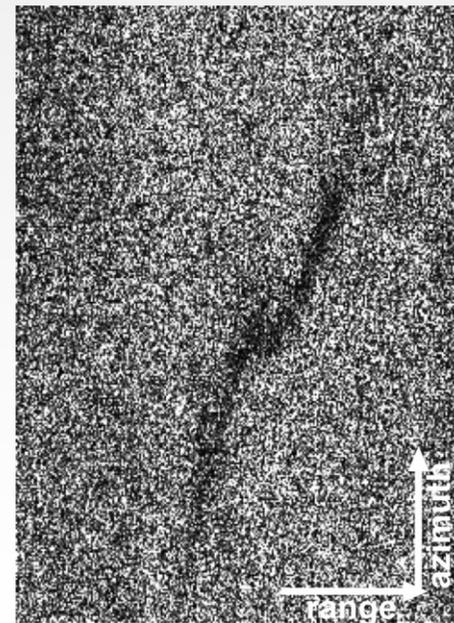
PalSAR

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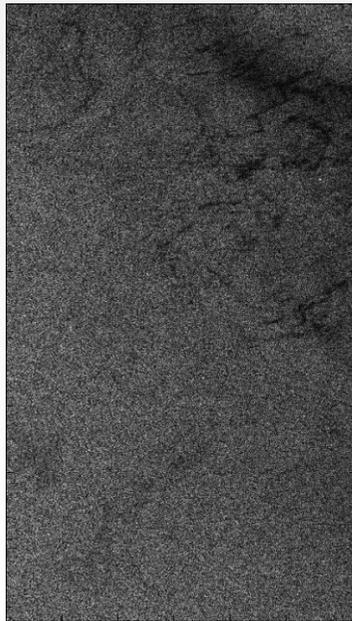
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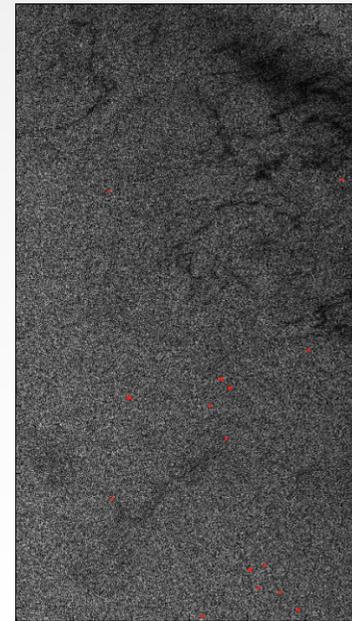
PalSAR output

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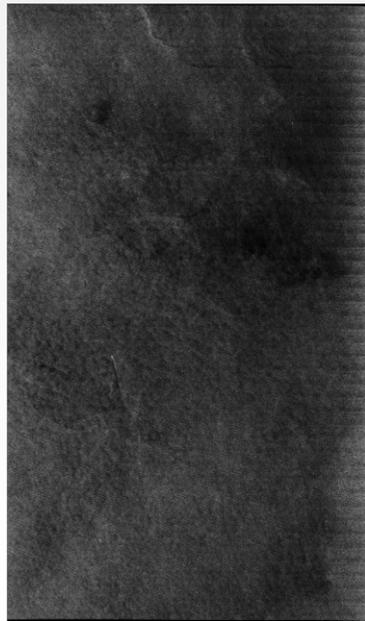
CosmoSkyMed input

CosmoSkyMed output
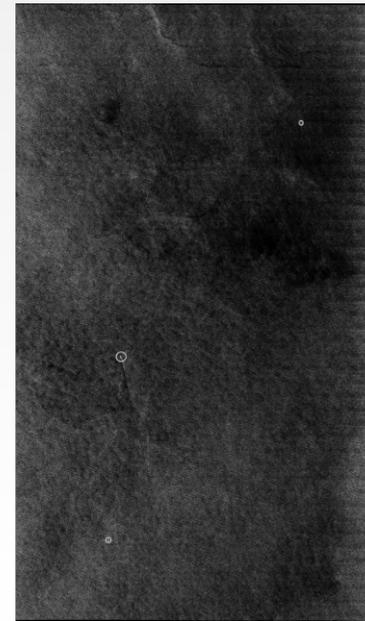
Target *single-pol*

- Based on the same physical rationale one can develop an appropiately tailored filter related to the cross-pol channel.
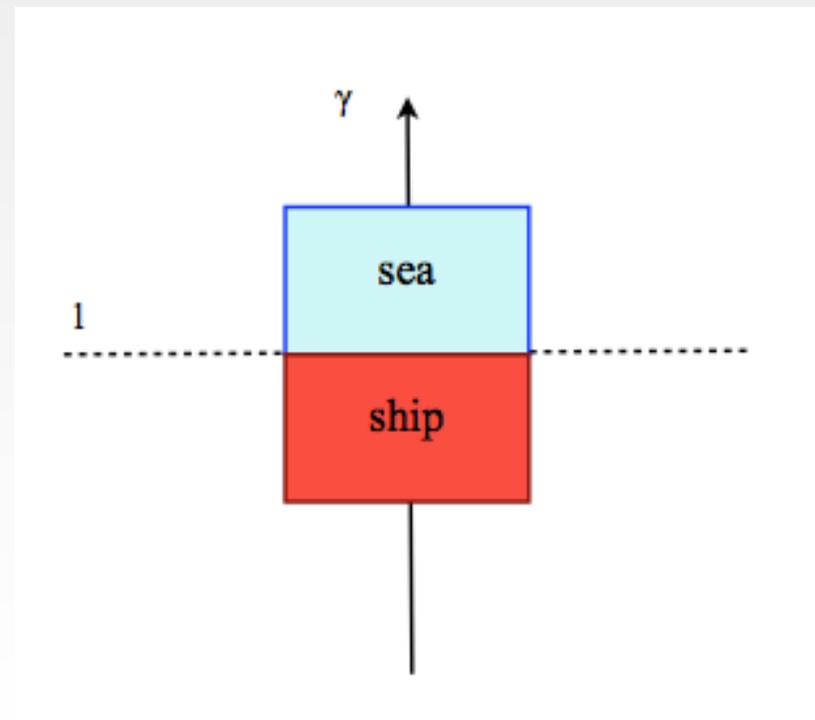
Target *single-pol*
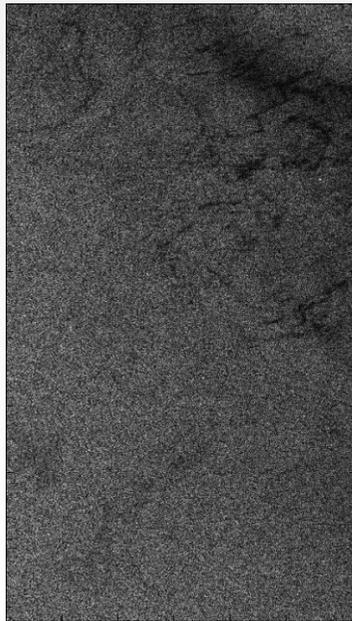
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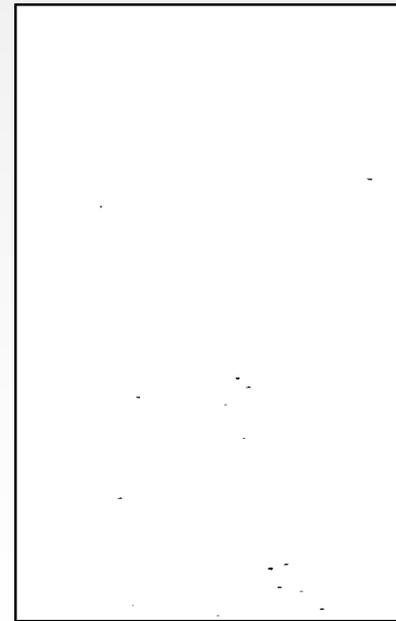
PalSAR output

Target *single-pol*

CosmoSkyMed input

CosmoSkyMed output
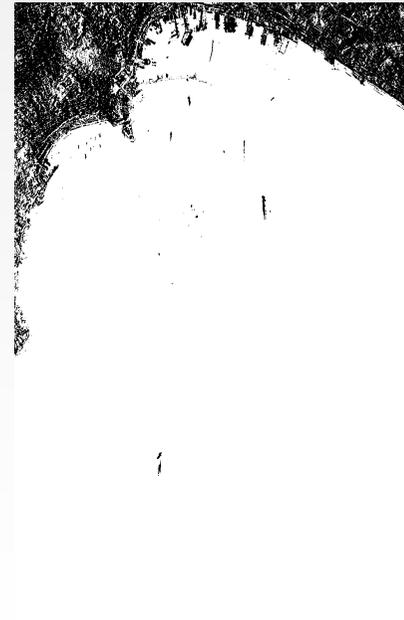
Oil *dual-pol*
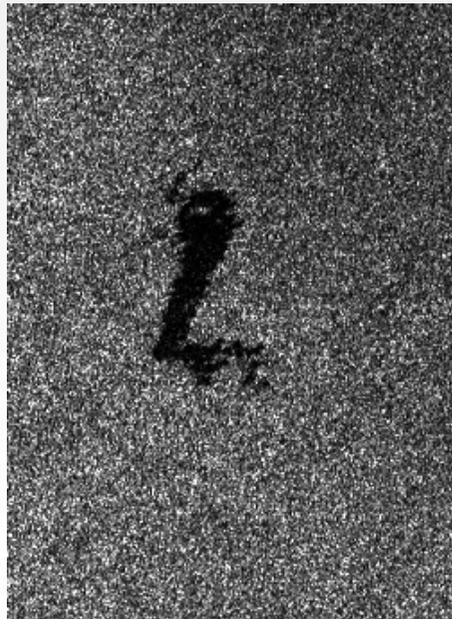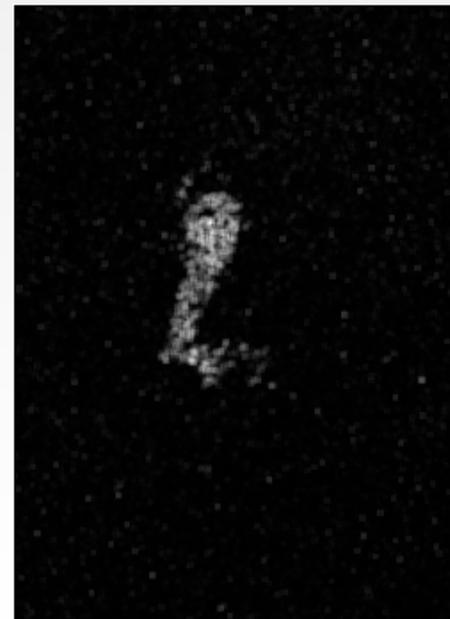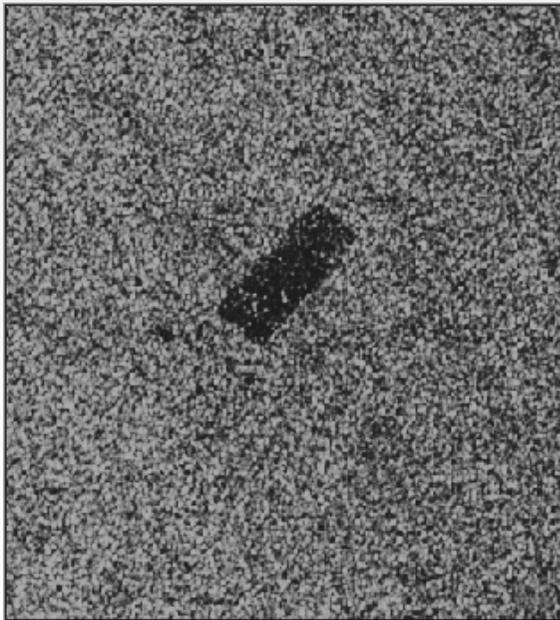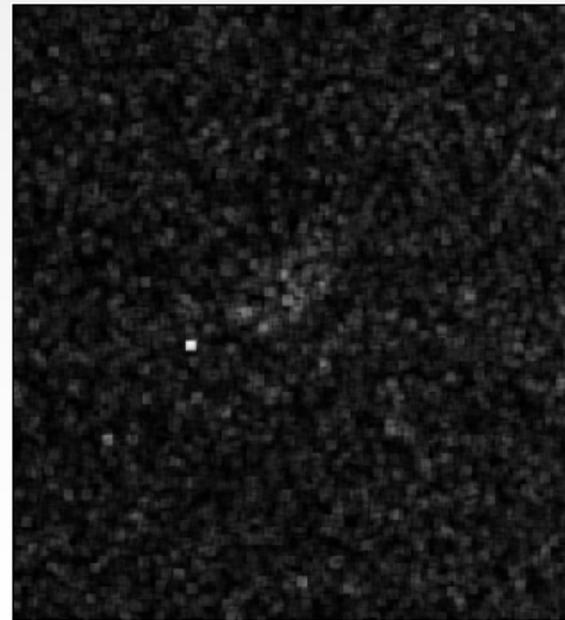
SIR-C input

SIR-C output

Oil *dual-pol* ;)

SIR-C input

SIR-C output

Oil *dual-pol*
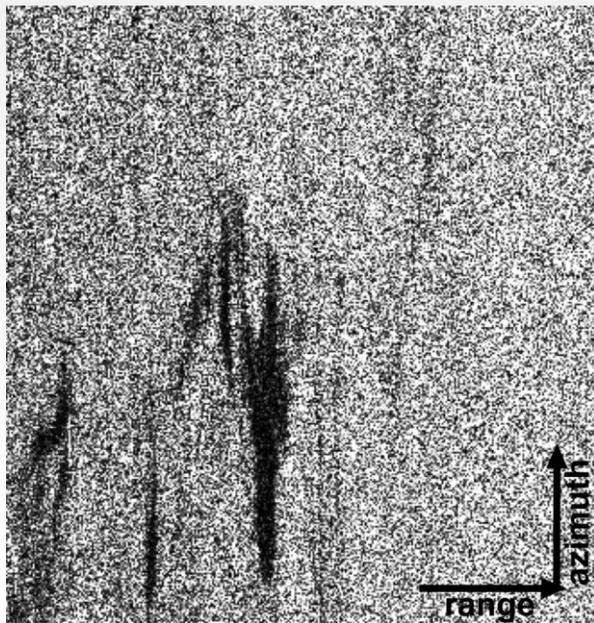
PALSAR input

PALSAR output

Oil *dual-pol*
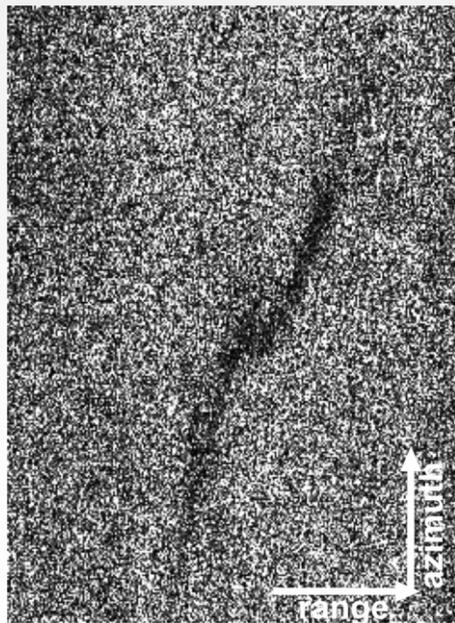
PALSAR input

PALSAR output
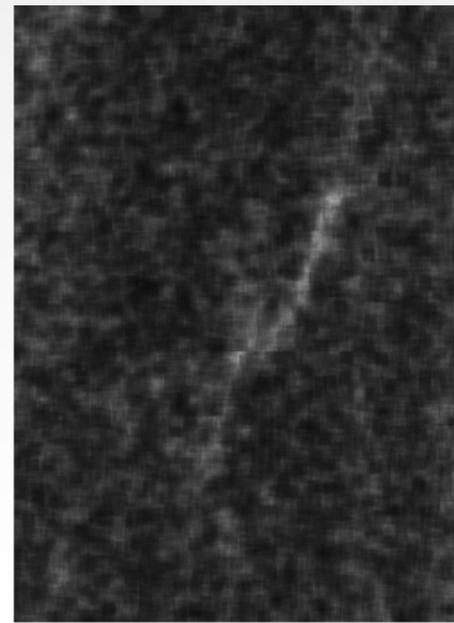
Oil *dual-pol* ;)

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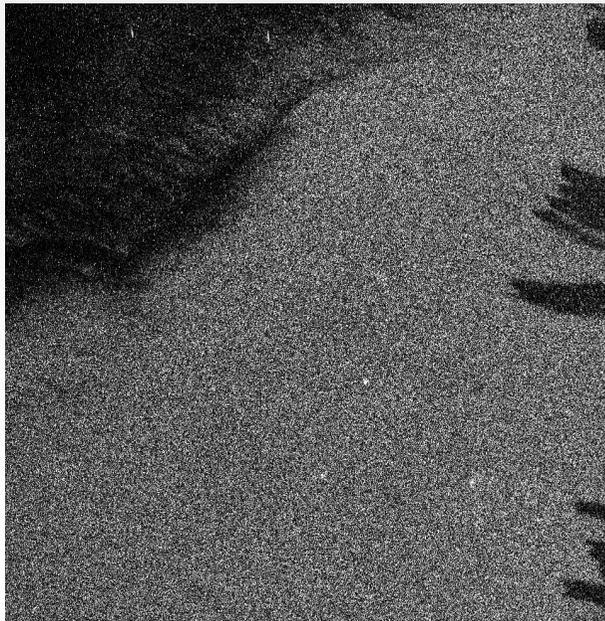
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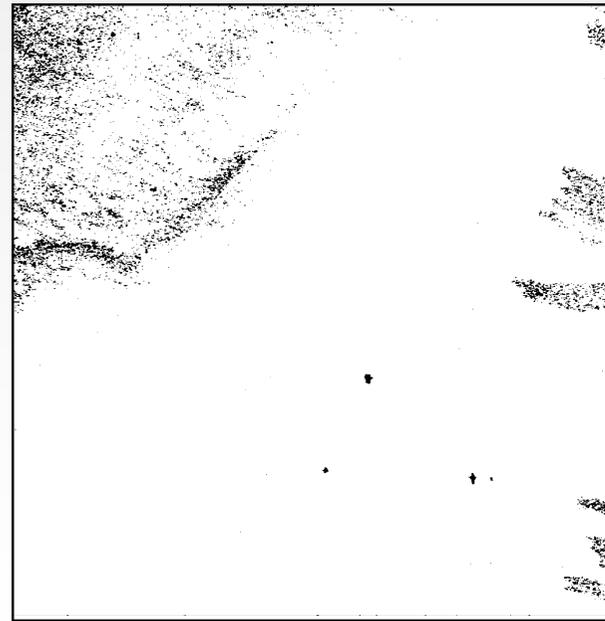
Physical vs Image processing
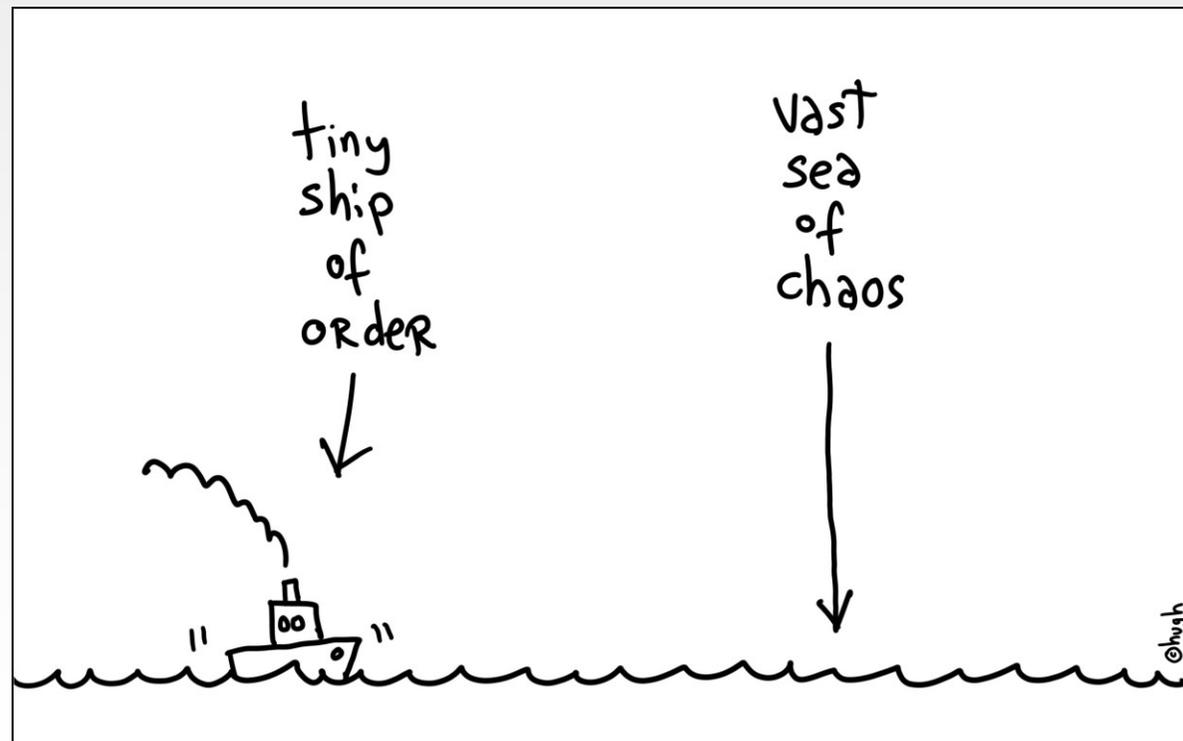
Oil *full-pol*

PalSAR l_band
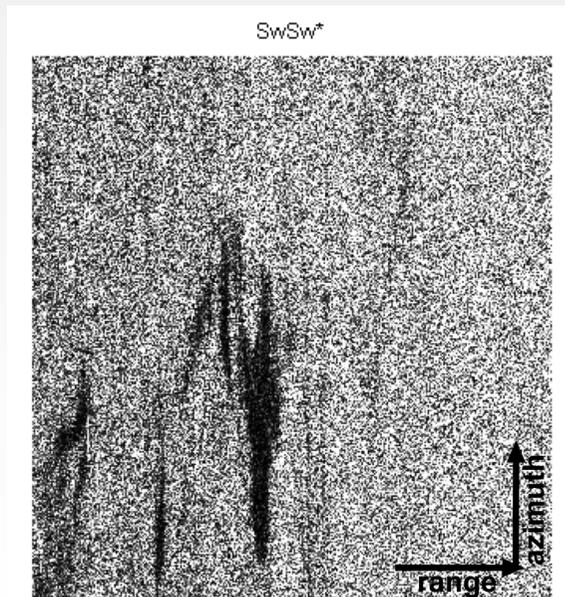
entropy

Oil *full-pol*
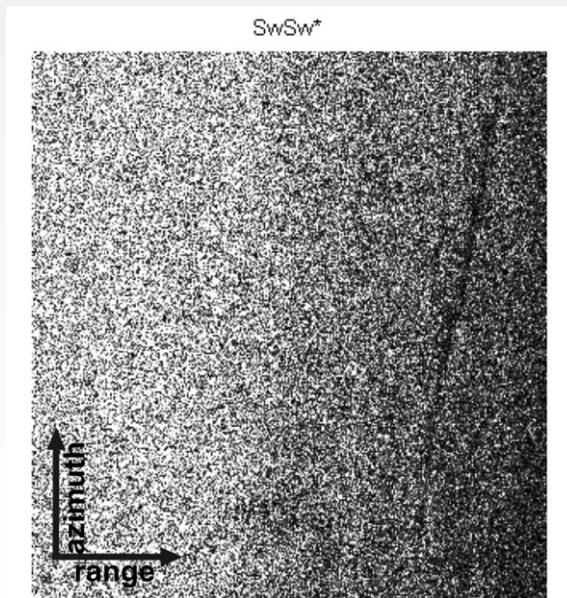
PalSAR l_band

SwSw*

entropy

Entropy

Oil *full-pol*

PalSAR l_band

SwSw*

Mueller

Mueller filtering

Oil *full-pol*

PalSAR l_band

SwSw*

Mueller

Mueller filtering
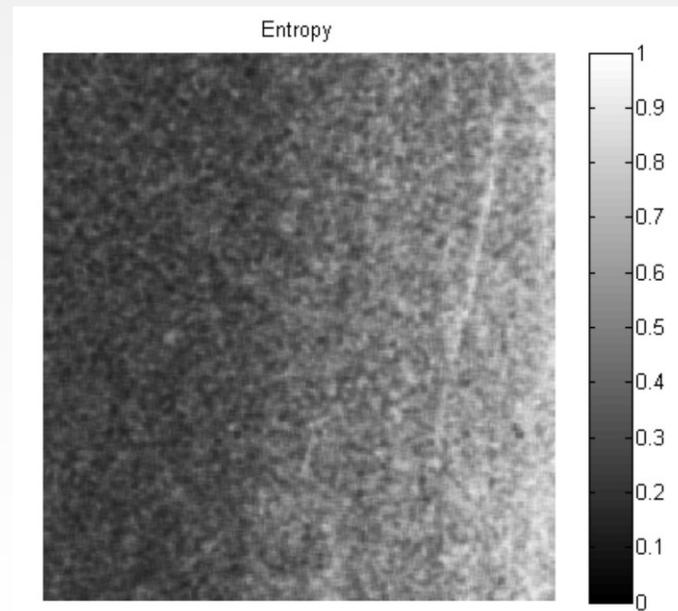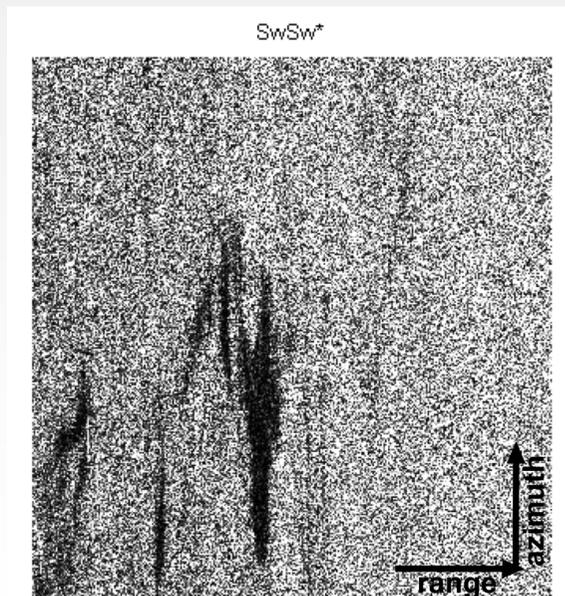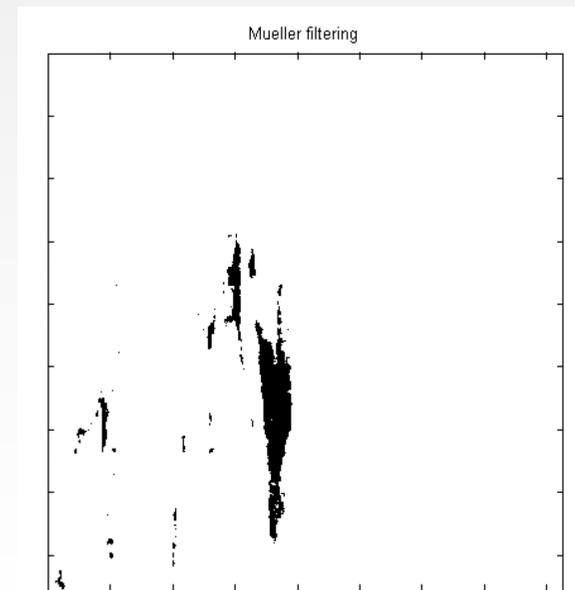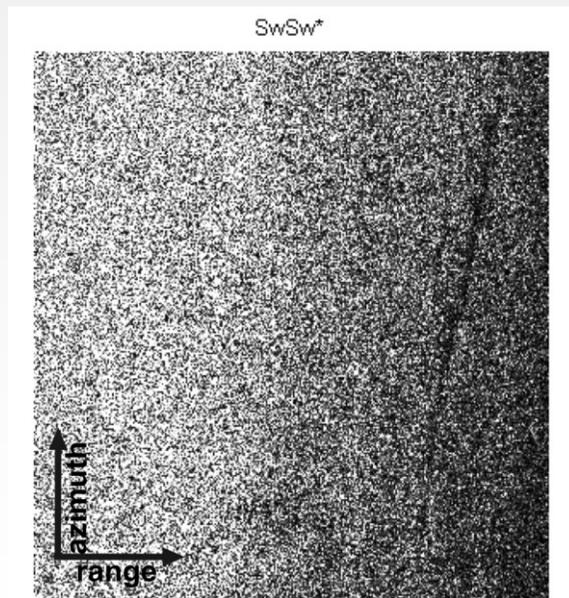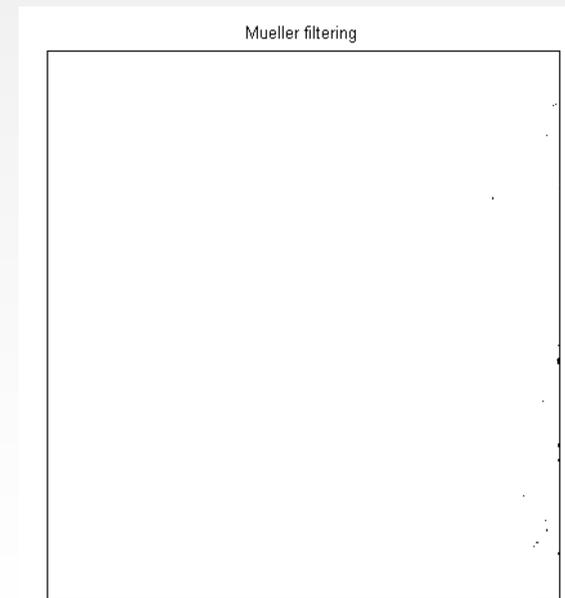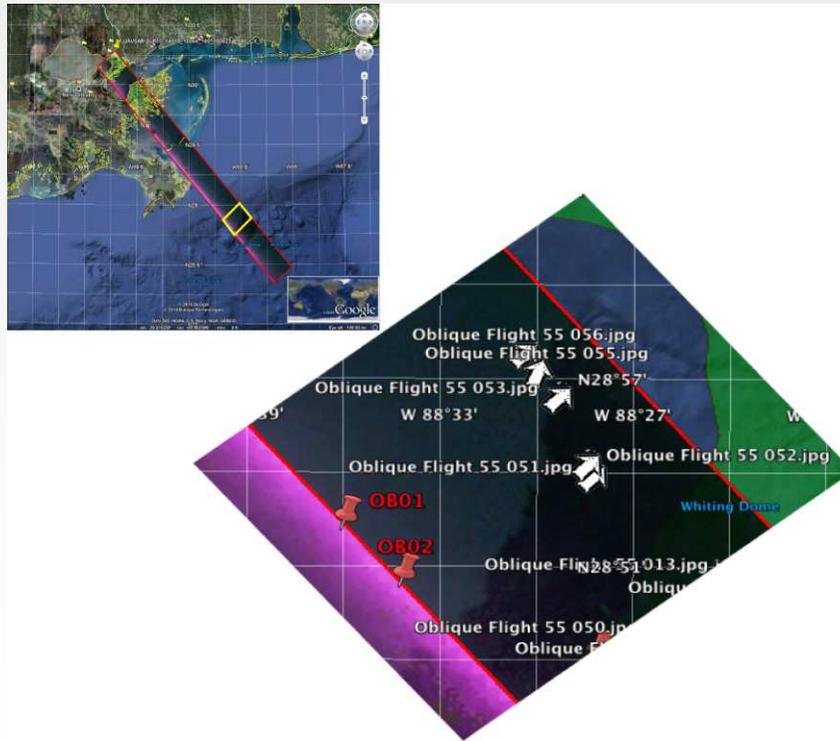
# Oil *full-pol*

Oil *full-pol*

UAVSAR
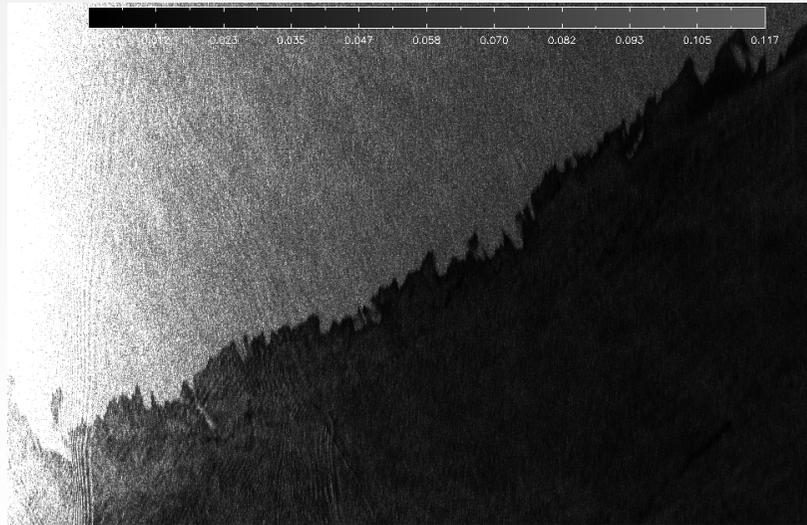
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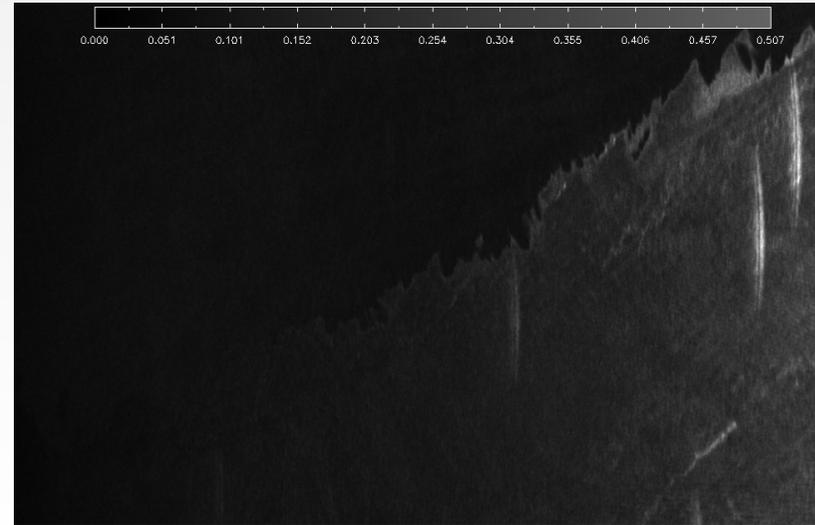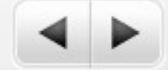
Oil & Target *full-pol*
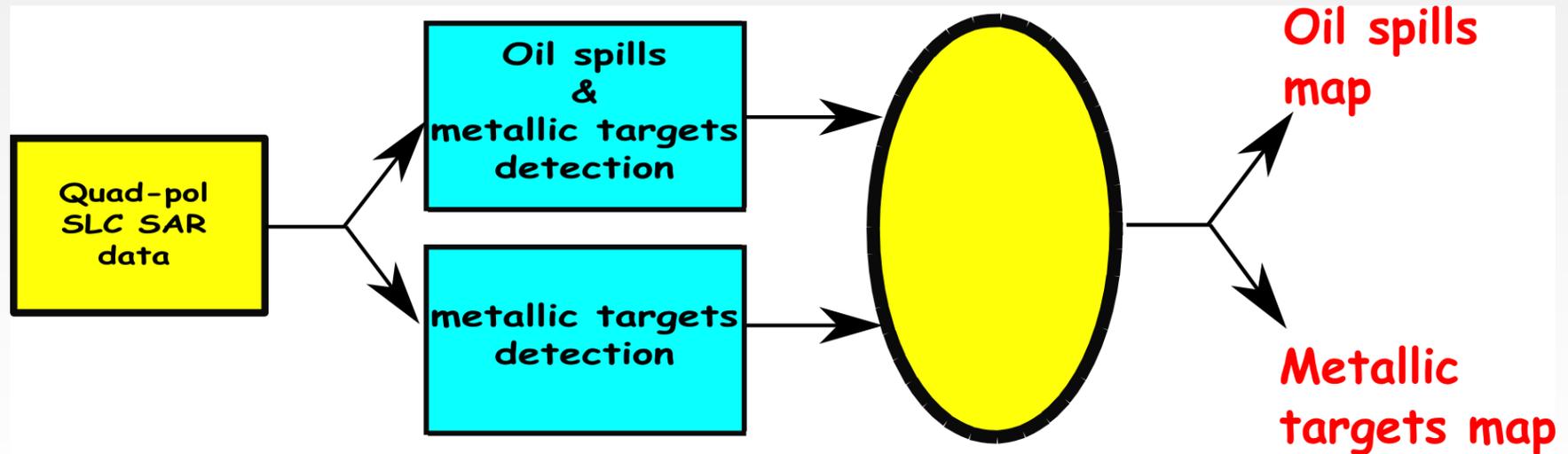
# Oil & Target *full-pol*

PalSAR

oil
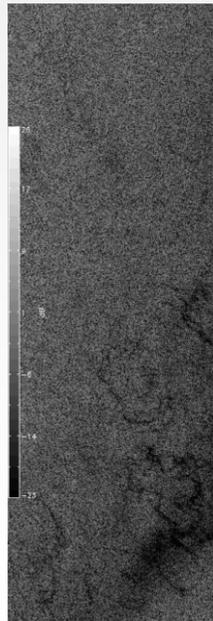
Oil & Target *full-pol*

PalSAR
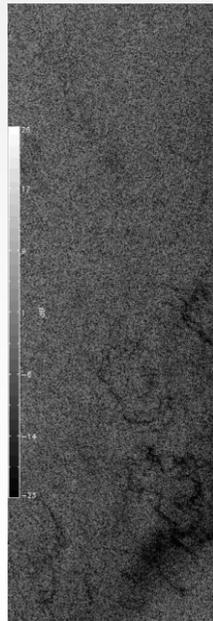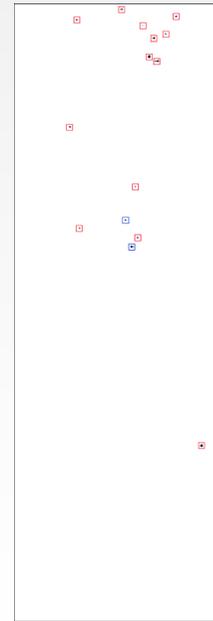
target

# Oil & Target *full-pol*
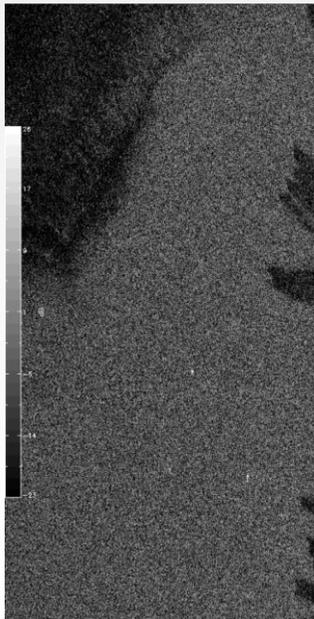
RadarSAT-2   oil

Oil & Target *full-pol*

RadarSAT-2
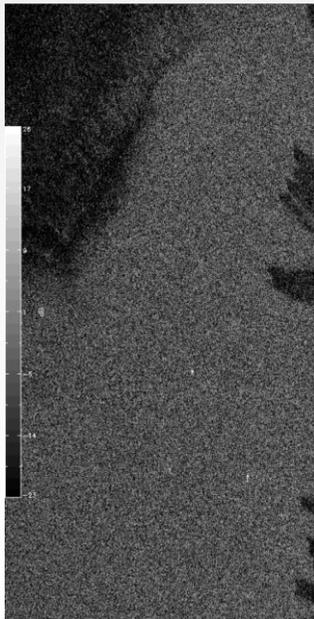
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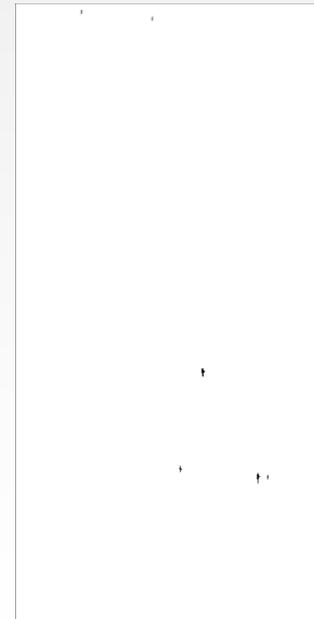
Conclusions

- An operational service for sea oil field monitoring can be effectively conceived by exploiting a SAR constellation of constellations, i.e. a virtual (but real !) constellation.

- Physical-processing is robust respect to change of SAR frequency.

- Full-pol procedures do not require an external threshold.

- Procedures are very fast and effective.

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