EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

Signature of oil spills from ship discharges

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Satellite Monitoring and Assessment of Sea-based Oil Pollution

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Joint Research Centre

ipsc
Institute for the Protection and Security of the Citizen

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What are we looking for?

- Besides accidental pollution, caused by ships in distress, there are three types of routine ship operations, which pollute the sea:
  - Ballast water.
  - Tank washing residues.
  - Engine room effluent discharges.
- The first two concern mainly tankers, while the third all types of ships.

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What are we looking for?

- In the case of deliberate vessel pollution, monitoring is effective when supported by continuous airborne surveillance.
- However, such surveillance is neither technically nor economically possible over the entire area of the European Seas.
- As an alternative, space-borne surveillance can be considered.
- SAR (Synthetic Aperture Radar) sensors can provide wide-area reconnaissance, and are independent of sunlight or cloud coverage.

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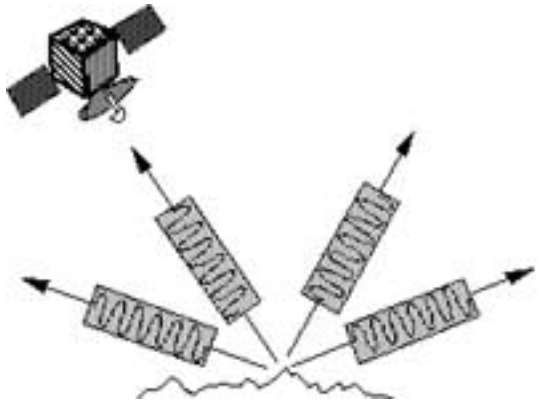
How SAR works?

- A typical SAR sensor measures the strength and round-trip time of the microwave signals that are emitted by the SAR antenna and reflected by a distant surface or object directly to the SAR. This particular signal reflected is called '**backscatter**'.

- The SAR antenna alternately transmits and receives pulses at particular microwave wavelengths (in the range 1 cm to 1 m) and different polarizations (waves polarized in a single vertical or horizontal plane). The different microwave regions considered for SAR sensors are known as 'bands'.



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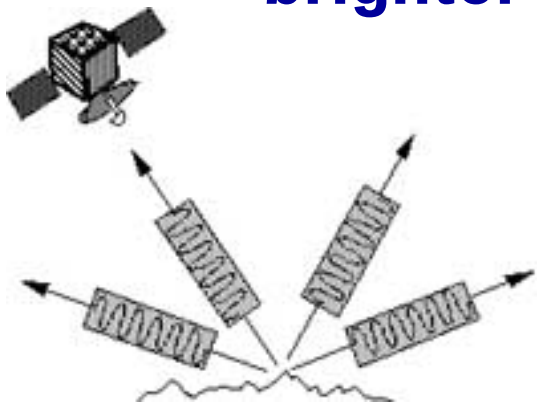
How SAR works?

- Radar images are composed of many pixels, or picture elements.
- Each pixel in the radar image represents the radar-backscattered signal for that area on the ground:
  - **darker areas** in the image indicate **low backscatter**
  - **brighter areas** indicate **high backscatter**.



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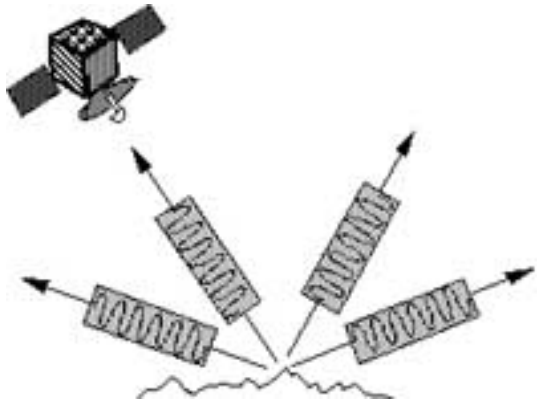
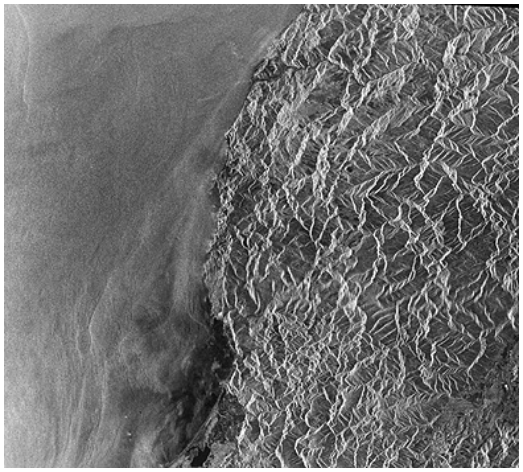
How SAR works?

- Bright features mean that a large fraction of the radar energy was reflected back to the radar.
- Dark features imply that very little energy was reflected.
- Smooth surfaces that reflect little or no microwave energy back towards the radar will always appear dark in radar images.
- Moderately rough surfaces, on the scale of most radar wavelengths, appear with a grey or light grey color in a radar image.





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Why the SAR can detect an oil spill event?

- Ocean waves are often classified into two types:
  - **capillary waves and**
  - **gravitational waves.**
- The first ones are generated directly from the energy transfer between the wind and the ocean surface. Their small amplitude and wavelengths is small (in the order of a centimeter). The capillary waves are also commonly called Bragg waves.
- Gravitational waves have higher amplitude and wavelengths (in the order of a meter).

Period	Wavelength	Name
0–0.2 s	centimetres	ripples
0.2–9 s	to about 130 m	wind waves
9–15 s	hundreds of metres	swell
15–30 s	many hundreds of metres	long swell or forerunners
0.5 min–hours	to thousands of kilometres	long period waves including tsunamis
12.5, 25 h, etc.	thousands of kilometres	tides

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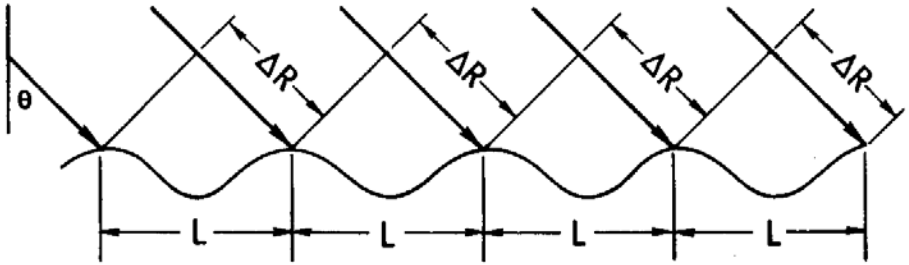
Why the SAR can detect an oil spill event?

- Radar is very sensitive to texture and water content of a surface.

- The backscattered signal from the ocean surface is predominantly due to Bragg scattering from capillary waves and short waves producing a typical "bright" appearance known as a sea clutter.

Bragg Scaterring



$$\lambda_s = \frac{\lambda_r}{2\sin\theta}$$

where:

λ_r *radar wavelength*

λ_s *sea surface wavelenght*

θ *incidence angle*

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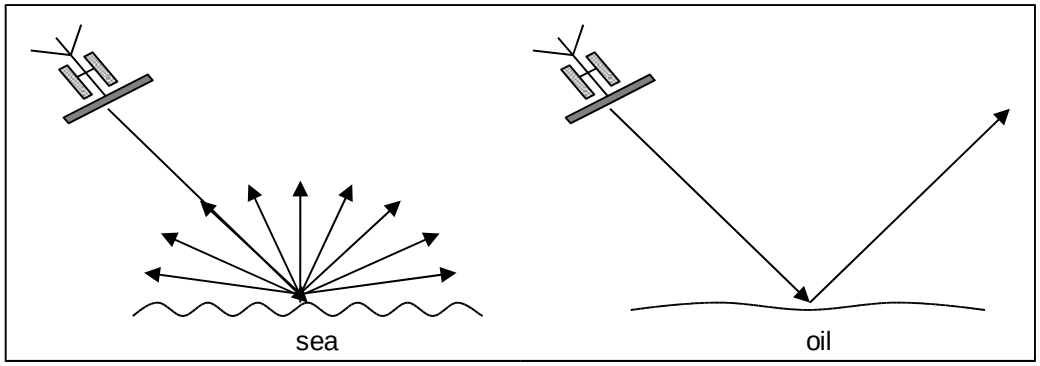
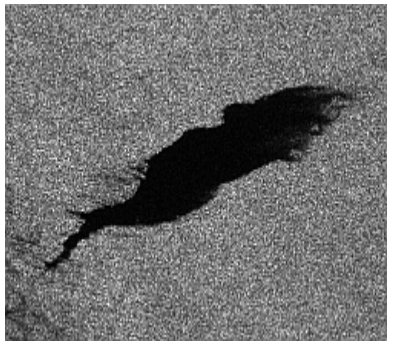
Why the SAR can detect an oil spill event?

- An oil spill may cover vast areas of the sea surface and damp some of these capillary waves.
- In this way, the water surface roughness is reduced and can be detected by the Normalized Radar Cross-Section (NRCS) on SAR images, since it appears as a dark area or an area in which there is an absence of sea clutter.





short gravity – capillary waves

Wind speed > 2m/sec…

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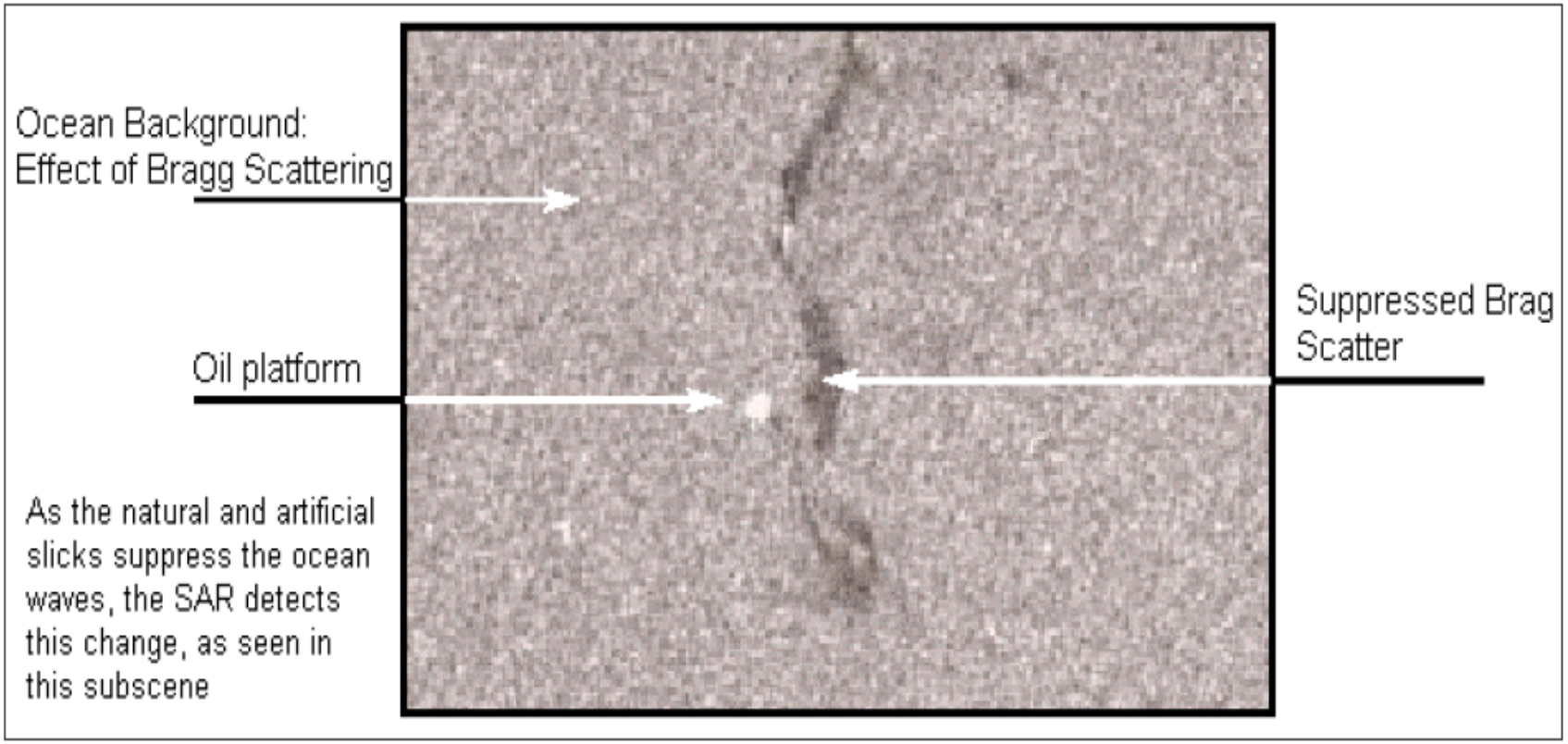

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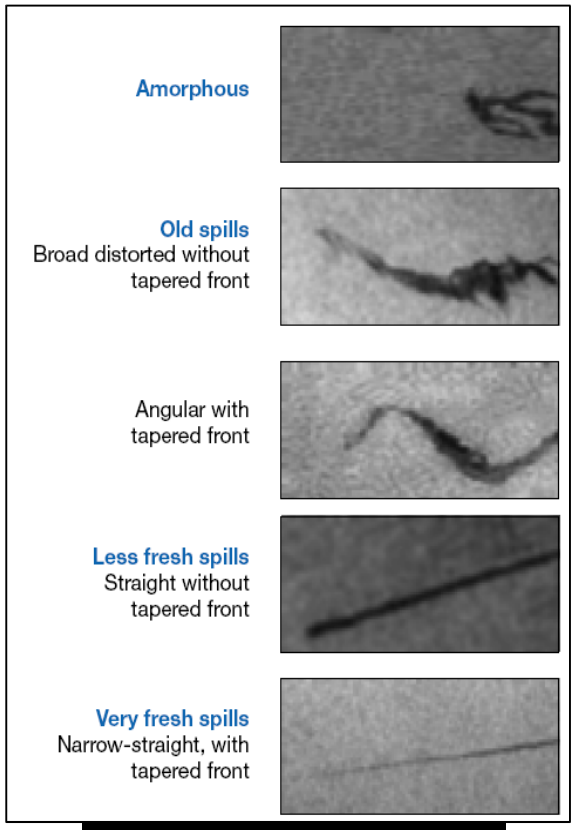
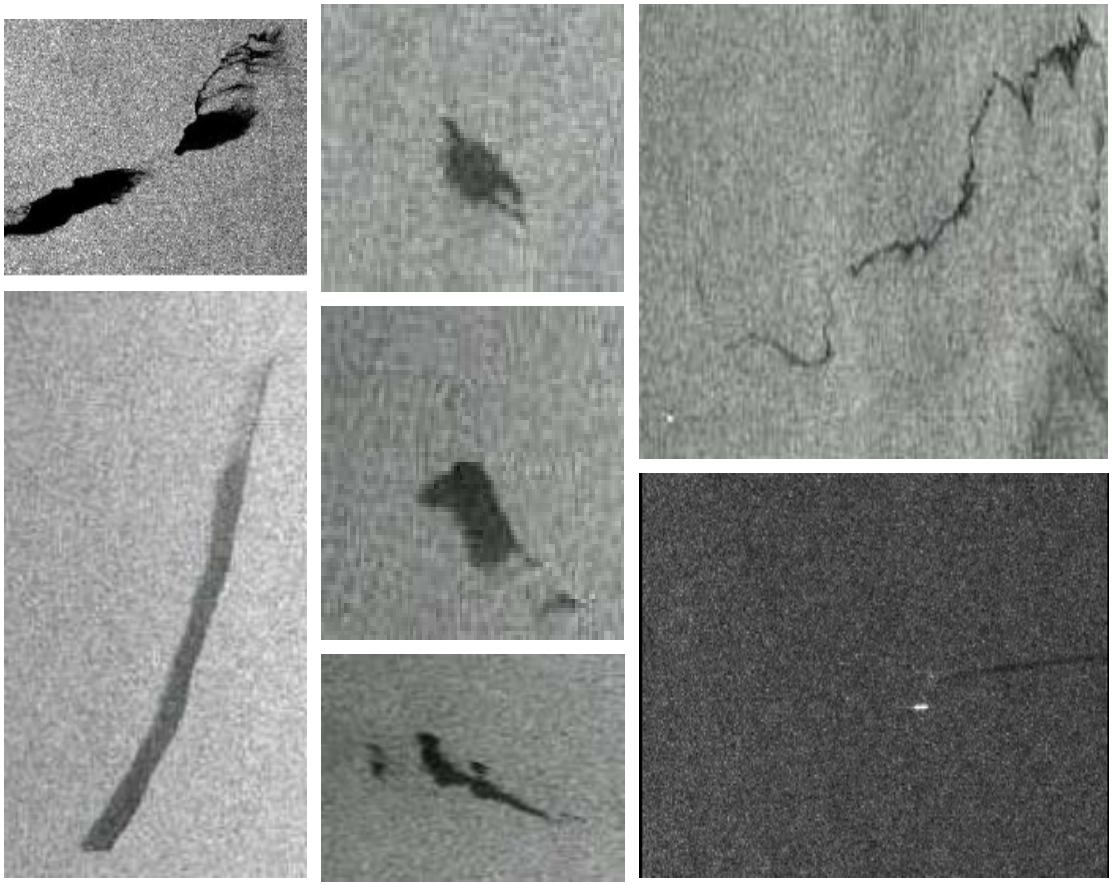
How man made oil spills looks like?



Source Pavlakis et al, 2001



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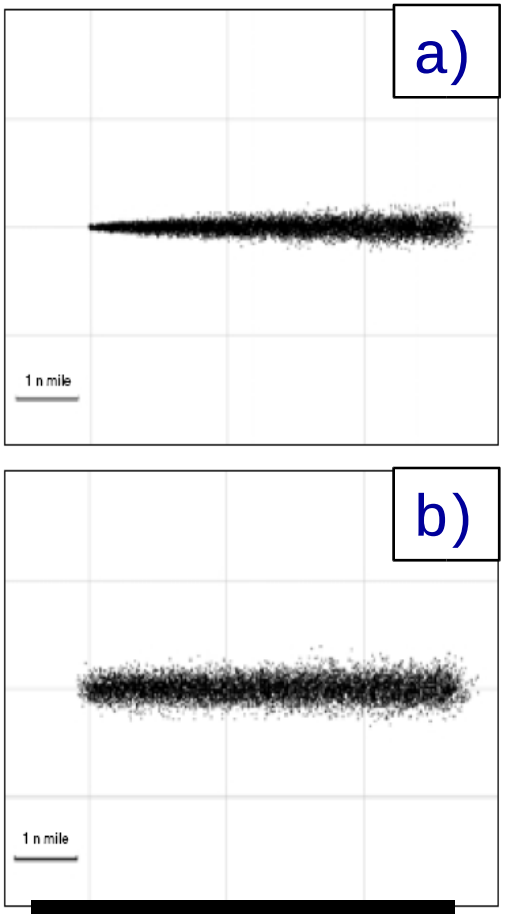

Source Pavlakis et al, 2001

Simulations of spills from a ship discharging on a 15knots straight course, an amount of 7 tons of fuel oil:

a) Just at the end of discharging,

b) 2 hours after discharging.

The sea is assumed calm and current free, while the oil is assumed to spread at 0.6 m/sec.

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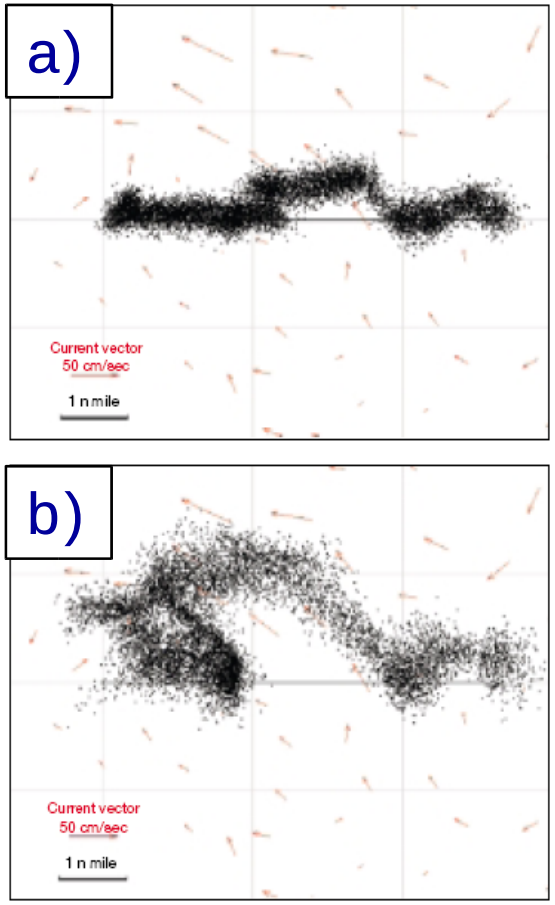
How man made oil spills looks like?

Simulations of spill shape distortion by an arbitrary current field:

a) 1 hour after discharging,

b) 3 hours after discharging.

The amount of oil, its spreading rate and the speed of the ship during the discharge are the same as in previous case.



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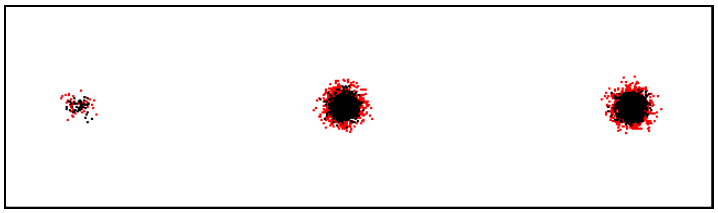

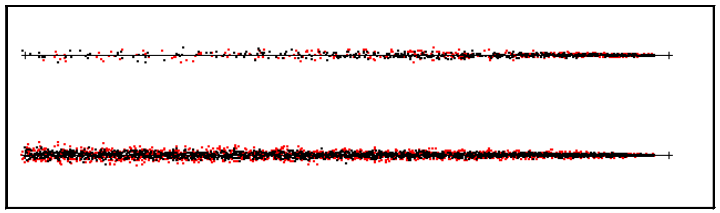

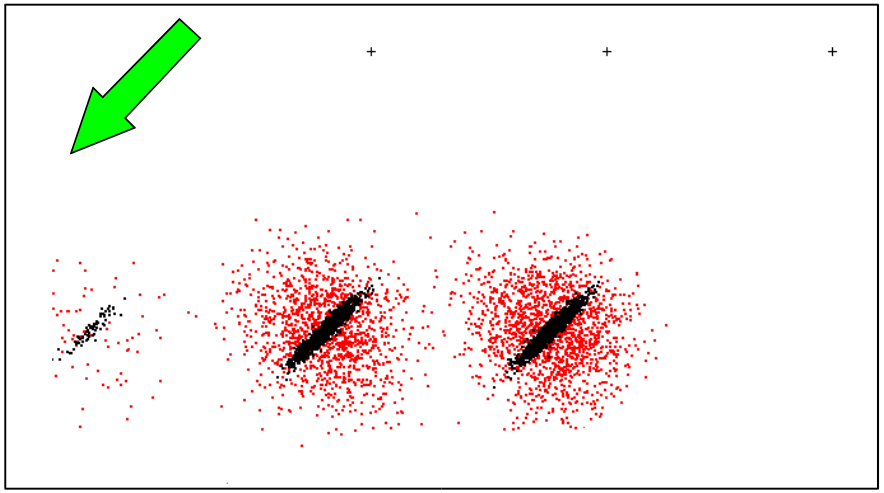

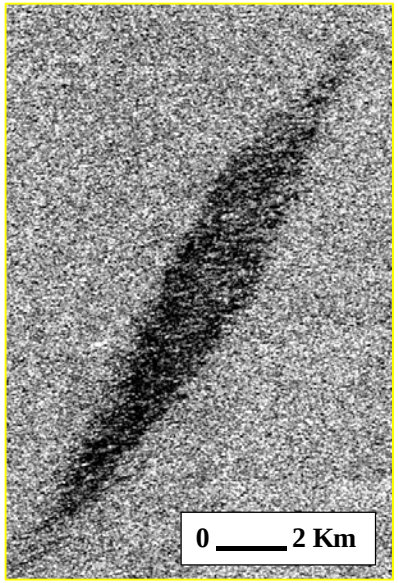

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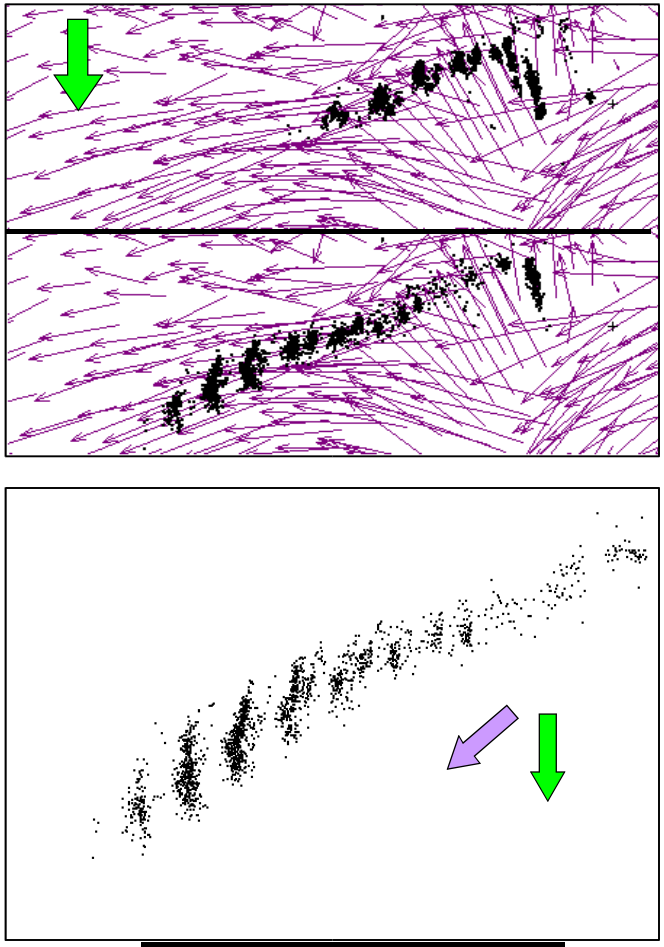

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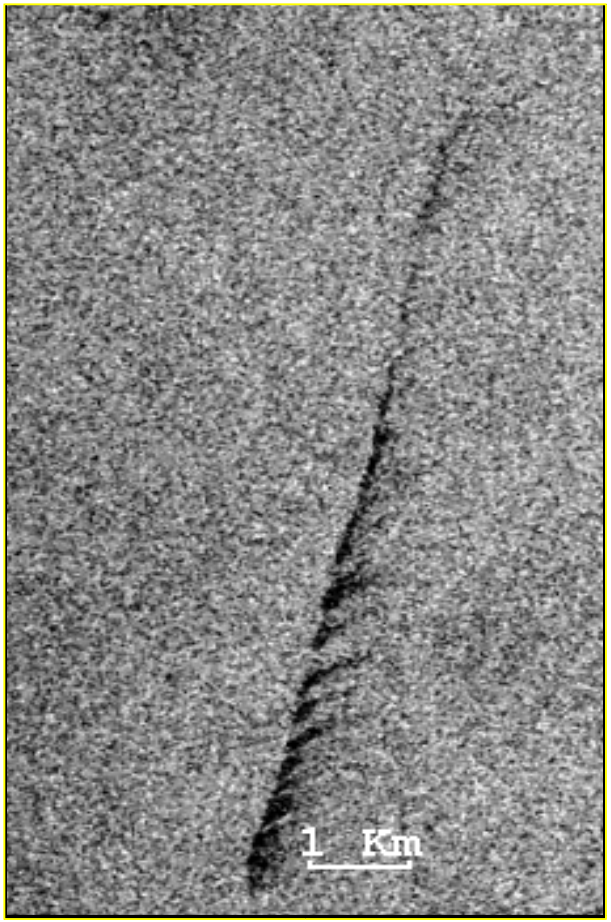

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