

Deteção Remota Micro-ondas

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ICEYE



Tópicos

- 10.1 Detecção Remota RADAR
- 10.2 Formação das imagens RADAR
- 10.3 Geometria e Resolução
- 10.4 Interação com a superfície
- 10.5 Radar de Abertura Sintética
- 10.6 Distorção das imagens SAR
- 10.7 Mecanismos de scattering
- 10.8 Missões SAR
- 10.9 Aplicações SAR e INSAR

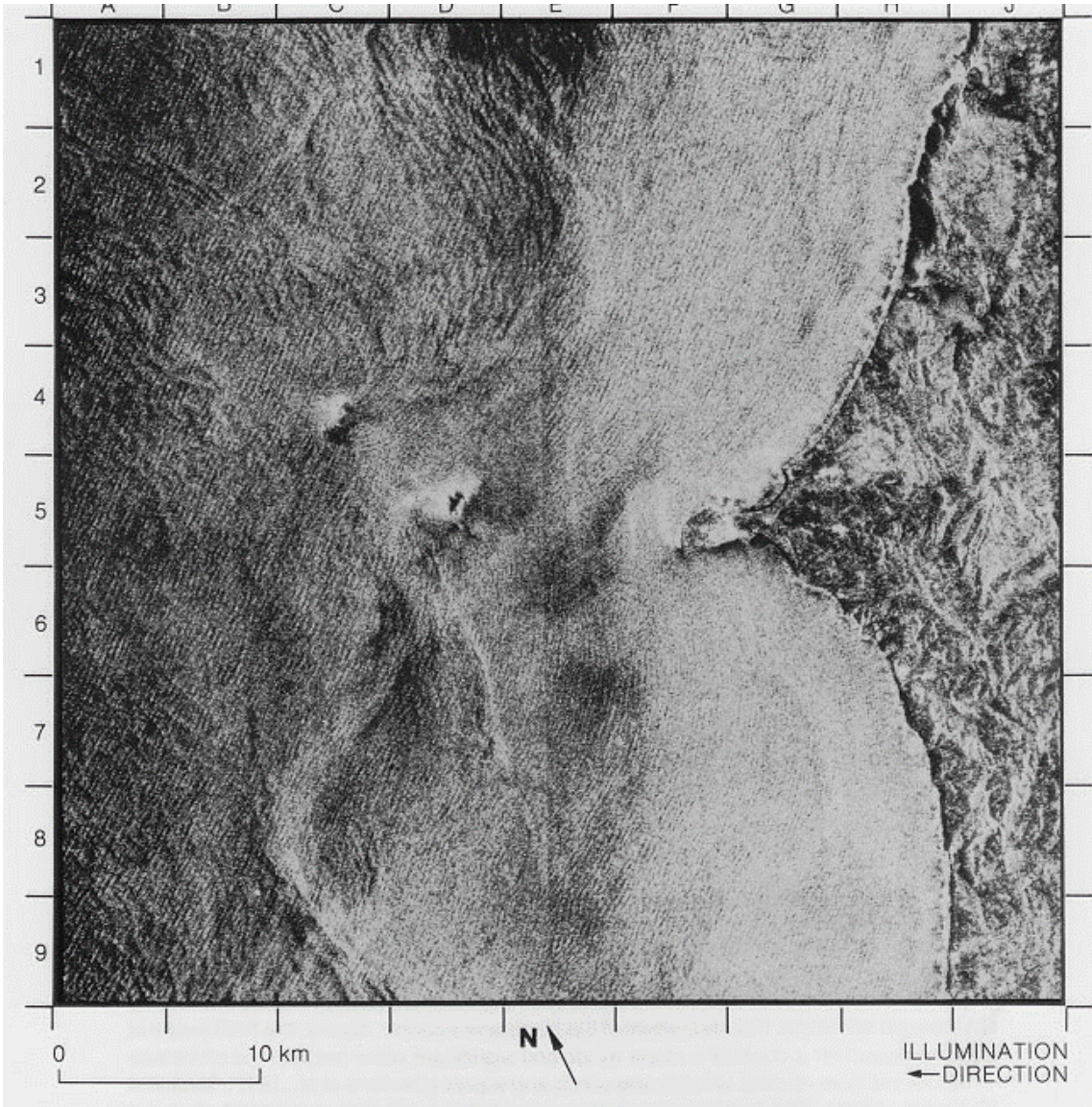
Seasat SAR

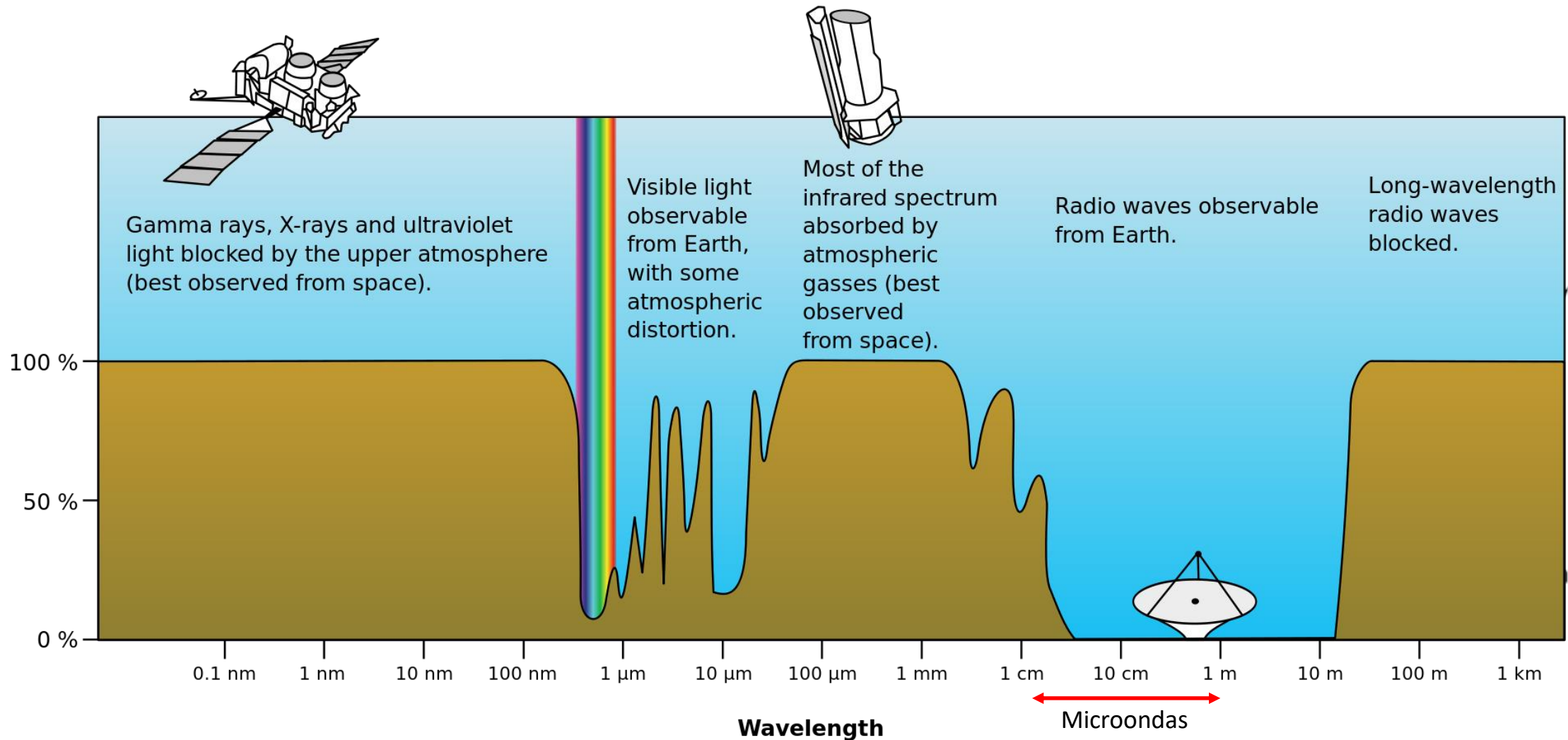
One of the microwave radars on board Seasat was a synthetic-aperture radar (SAR).

(Radar de Abertura Sintética, banda L)

The refraction of impinging deep ocean waves by varying bottom topography in near-shore areas is one of the major concerns of coastal engineers. This image shows how deep ocean waves are refracted by the bottom topography west of Portugal.

Fu, L-L, Holt, B., **1982**. Seasat Views Oceans and Sea Ice with Synthetic-Aperture Radar. JPL Publication 81-120, NASA, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, p. 200.

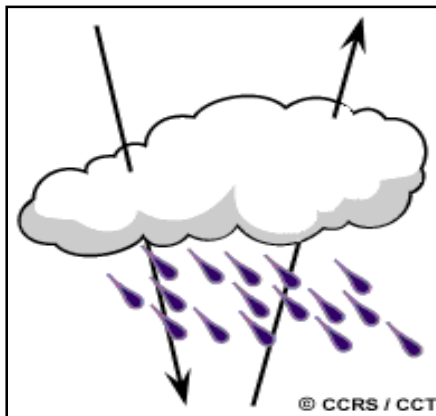




As microondas têm propriedades importantes para a DR devido ao seu grande comprimento de onda (quando comparado com o visível)



Os maiores comprimentos de onda podem atravessar nuvens, pó, "haze" ou mesmo chuva leve uma vez que os maiores c.o. não são susceptíveis à dispersão atmosférica.

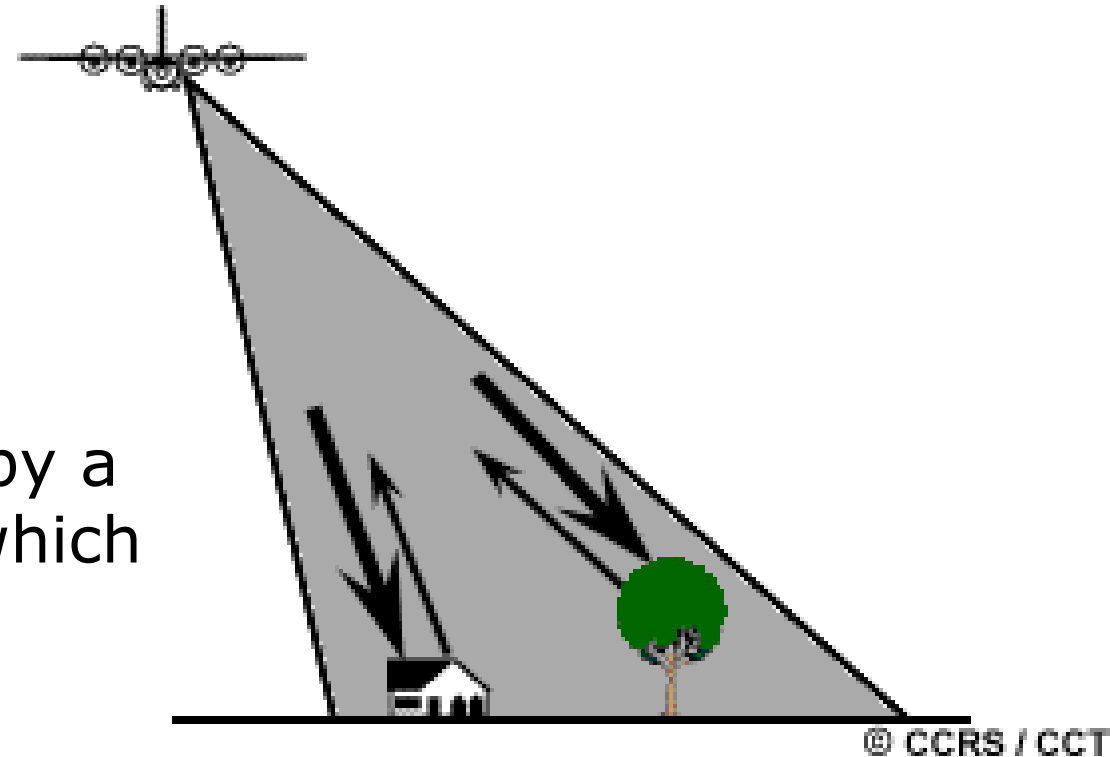


"All-weather"

"Day and Night"

SAR is an active sensor, transmitting its own energy, and then measuring the return scattered by the earth's surface back to the satellite's antenna.

The data for a SAR image is collected by a satellite with a side looking antenna, which transmits a stream of radar pulses and records the backscattered signal corresponding to each pulse.



RADAR (Radio Dectection And Ranging)

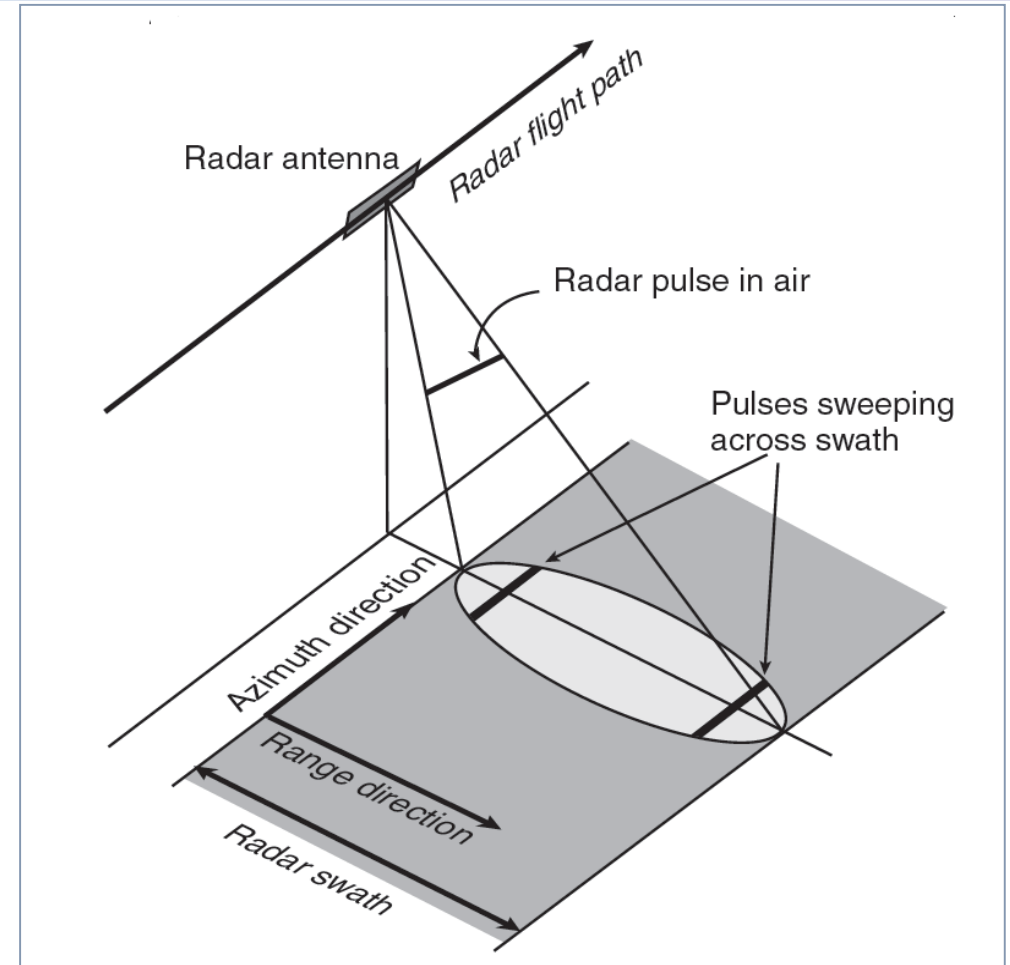
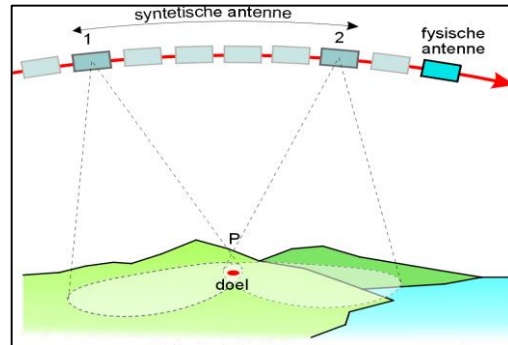
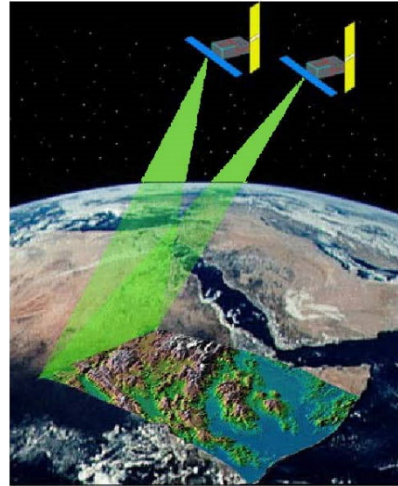
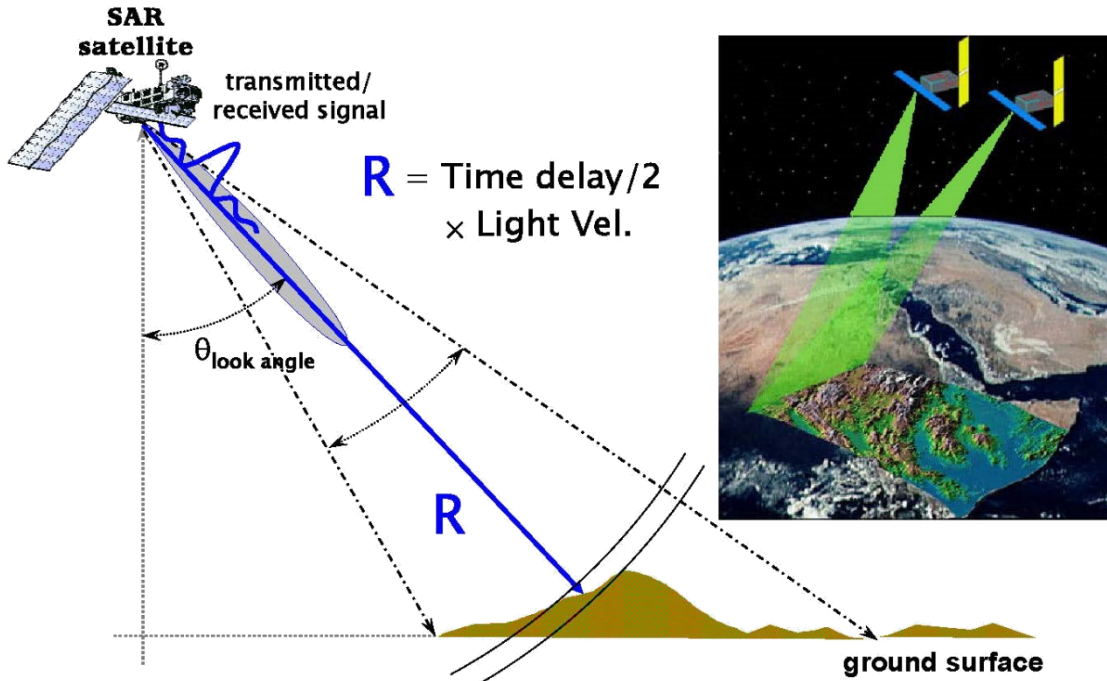


Advantages compared to optical remote sensing

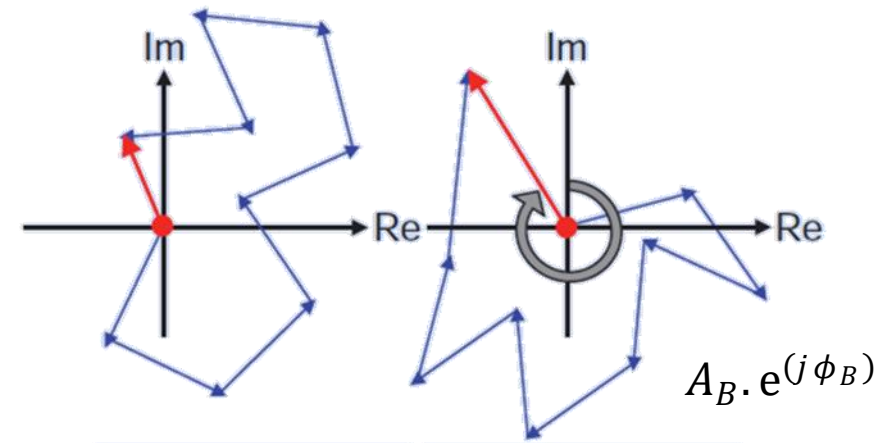
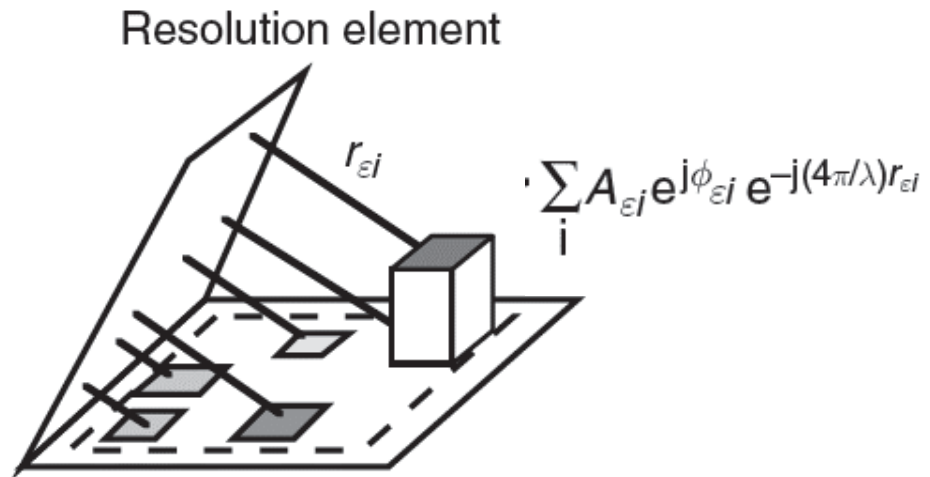
- all weather capability (small sensitivity of clouds, light rain)
- day and night operation (independence of sun illumination)
- no effects of atmospheric constituents (multitemporal analysis)
- sensitivity to dielectric properties (water content , biomass, ice)
- sensitivity to surface roughness (ocean wind speed)
- accurate measurements of distance (interferometry)
- sensitivity to man made objects
- sensitivity to target structure (use of polarimetry)
- subsurface penetration

Inconvenients

- complex interactions (difficulty in understanding, complex processing)
- speckle effects (difficulty in visual interpretation)
- topographic effects
- effect of surface roughness



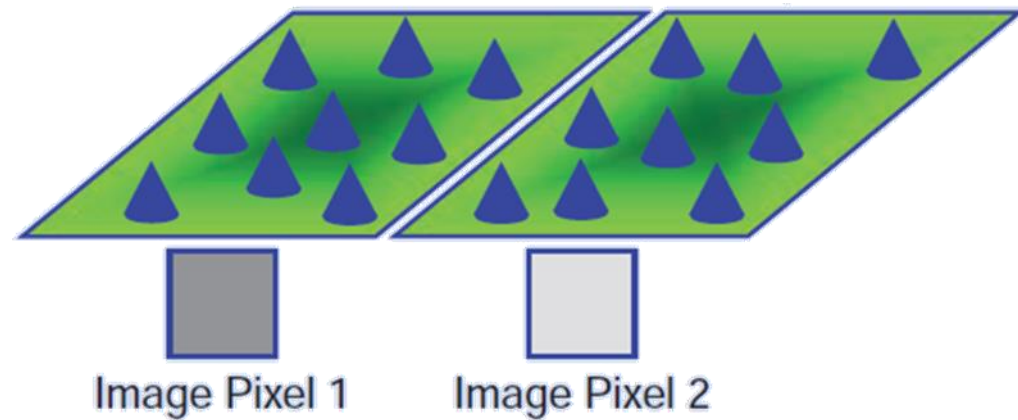
$$s_1 = A \cdot e^{(j\phi_B)} \cdot e^{(-j\left(\frac{4\pi}{\lambda}\right) \cdot r_1)}$$

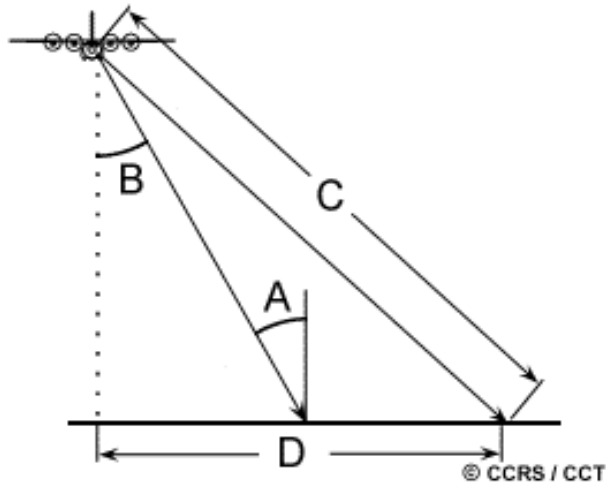


$$s_1 = A_B \cdot e^{(j\phi_B)} \cdot e^{-j\left(\frac{4\pi}{\lambda}\right) \cdot r}$$

Amplitude

Phase





Ângulo Incidente (A)

Ângulo entre o feixe radar e a superfície do terreno. Aumenta com o "range" (incidence angle)

Ângulo de vista (B)

É o ângulo de iluminação da superfície. (view angle)

Slant Range(C)

(distância inclinada)

A distância entre o sensor e o alvo na superfície medida ao longo da linha de vista (Line Of Sight, LOS)

Ground Range(D)

Distância projectada no terreno a partir da "slant" range

Resolução RADAR

ERS-1, Sentinel-1
Azimuth = 5 km; Range = 25 m

TRX
Azimuth = 4.4 km; Range = 3 m

Resolução em Range

Pode ser aumentada usando pulsos com menor comprimento, o que pode ser conseguido dentro de certos limites da engenharia.

Resolução em Azimute

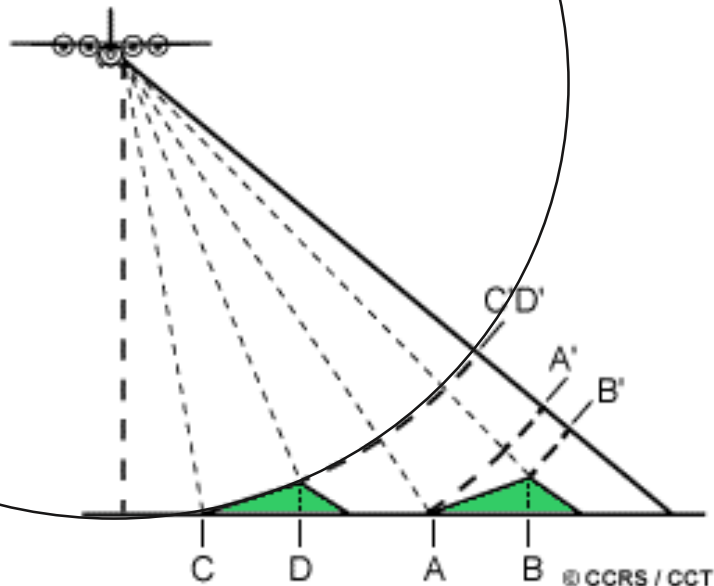
Pode ser conseguida aumentando o tamanho da antena.
Contudo o tamanho das antenas é limitado a 10 ou 15 metros.

Criação de uma antena sintética : Synthetic Aperture Radar (SAR)

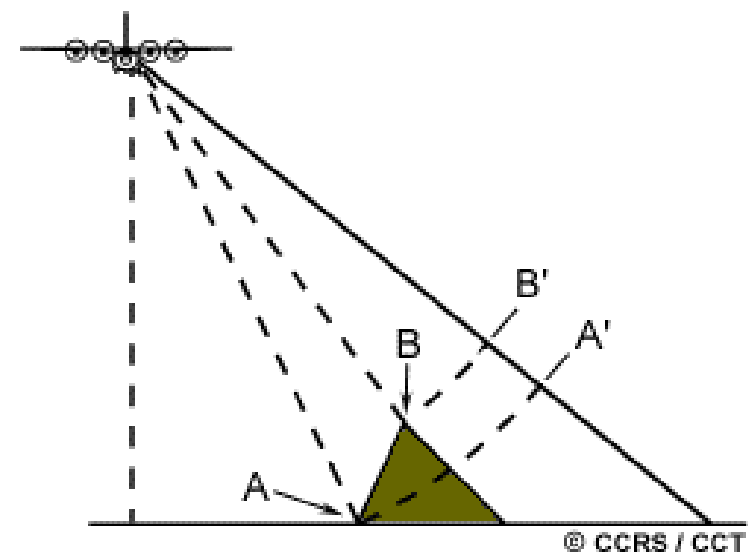
(proposto por Wiley, 1954 e demonstrado por Graham em 1974)

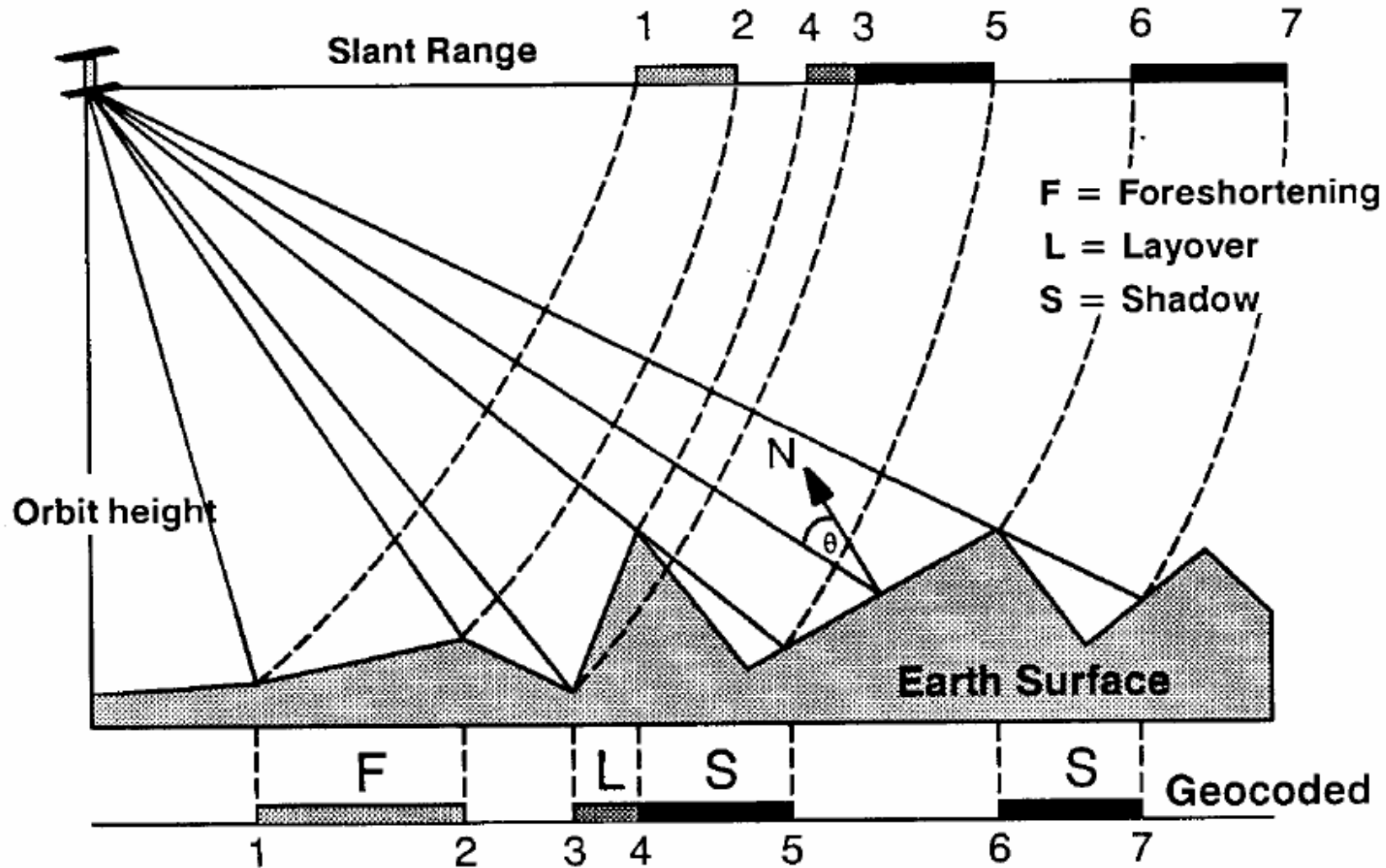
A distorções devidas ao relevo são unidimensionais e ocorrem perpendicularmente à linha de voo.

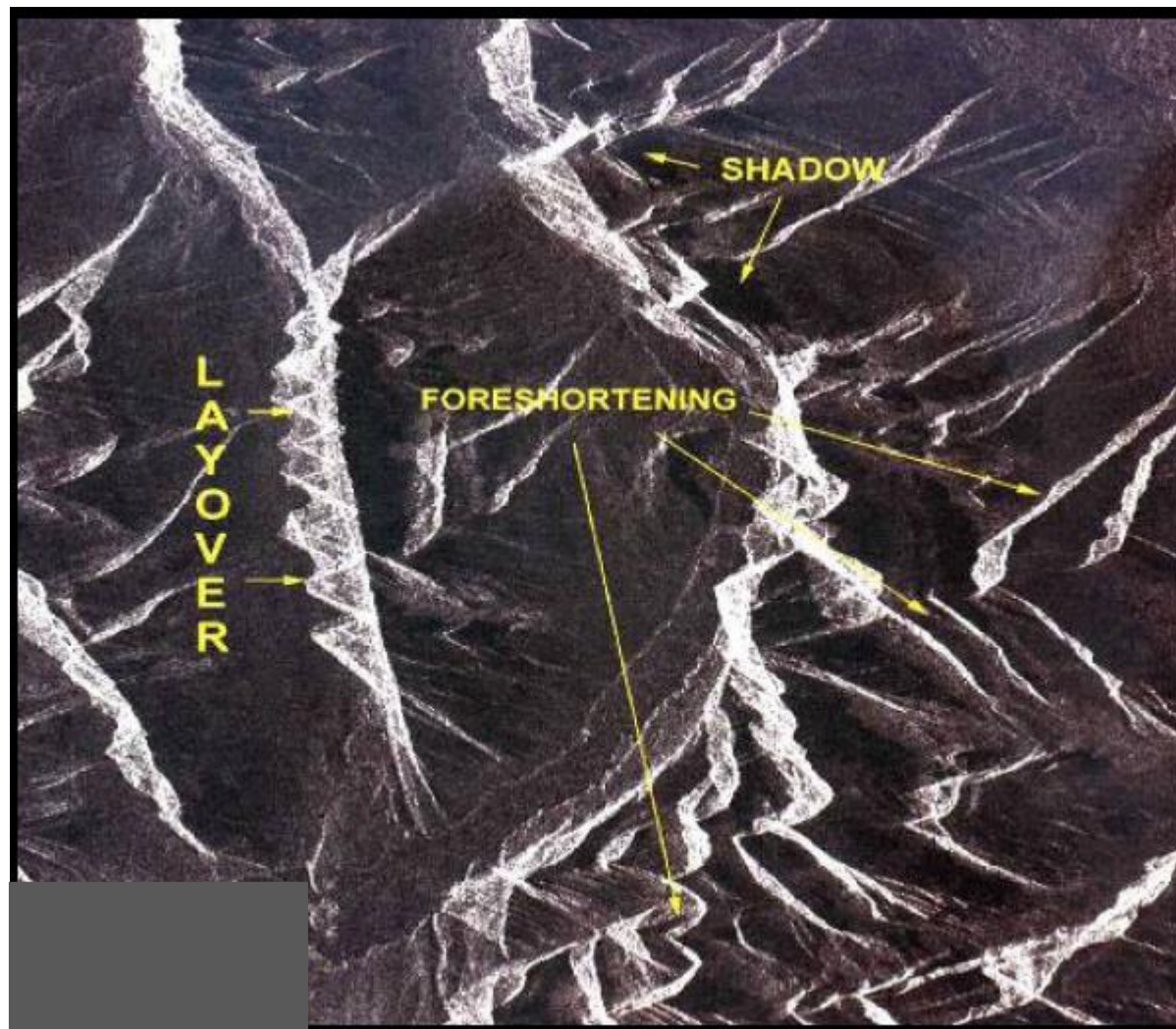
Foreshortening

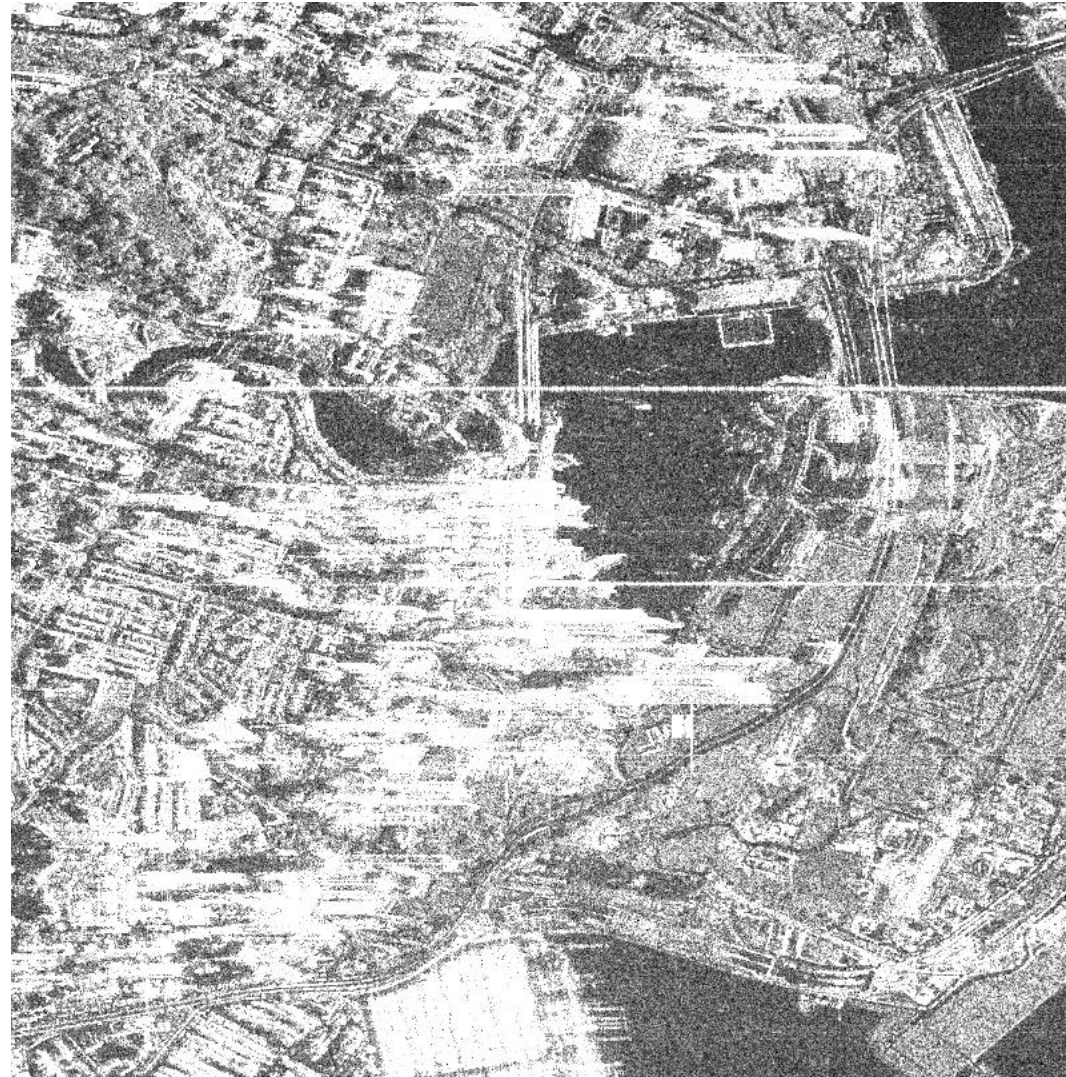
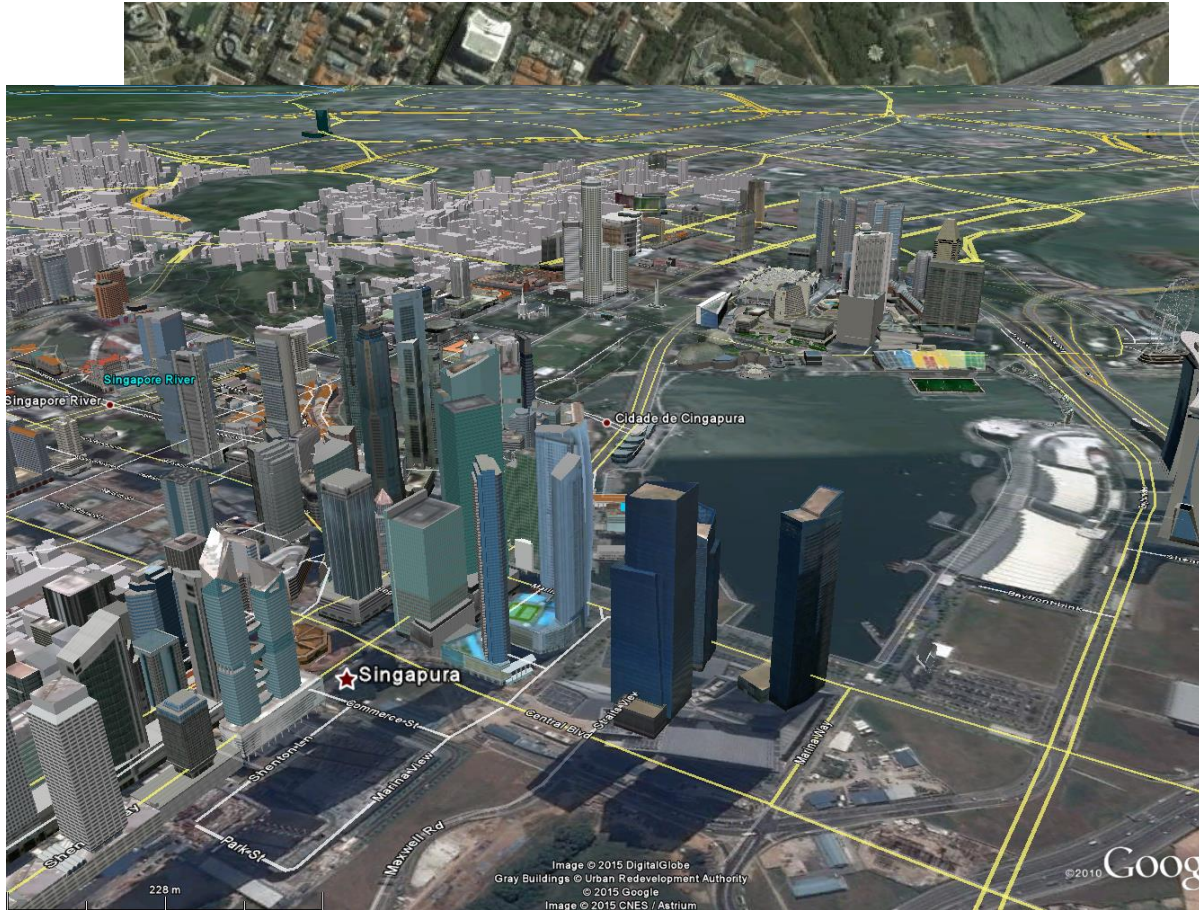


Layover









O sinal retro-disperso resulta de:

Surface scattering

Volume scattering

A importância relativa destas contribuições depende da:

(Surface
Roughness)

**Rugosidade da
superfície**

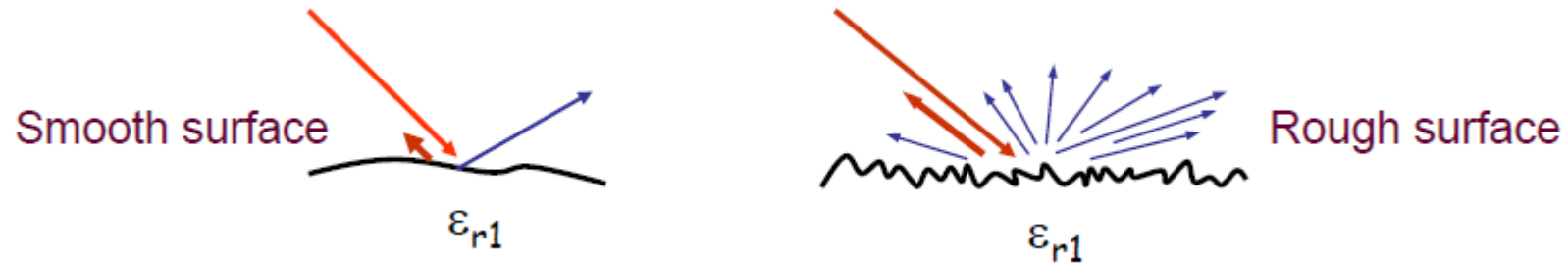
**Propriedades dieléctricas
do meio**

Todos estes factores dependem de:

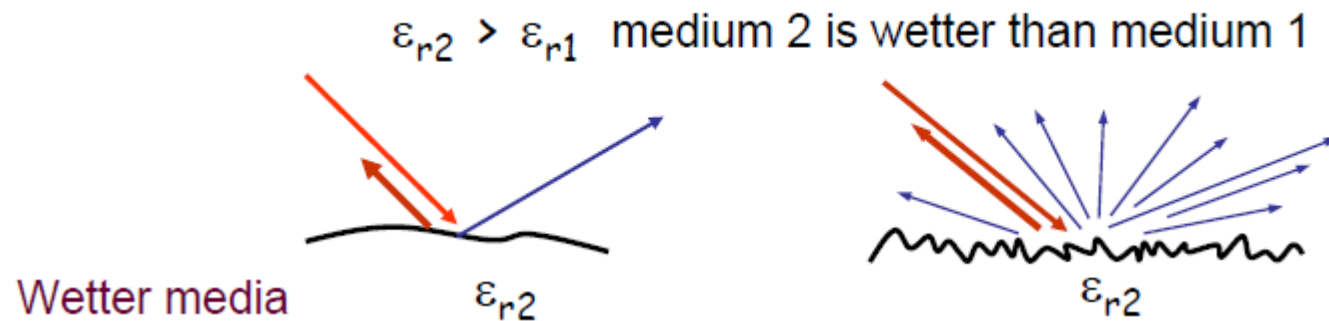
Frequência do radar

Ângulo de incidência

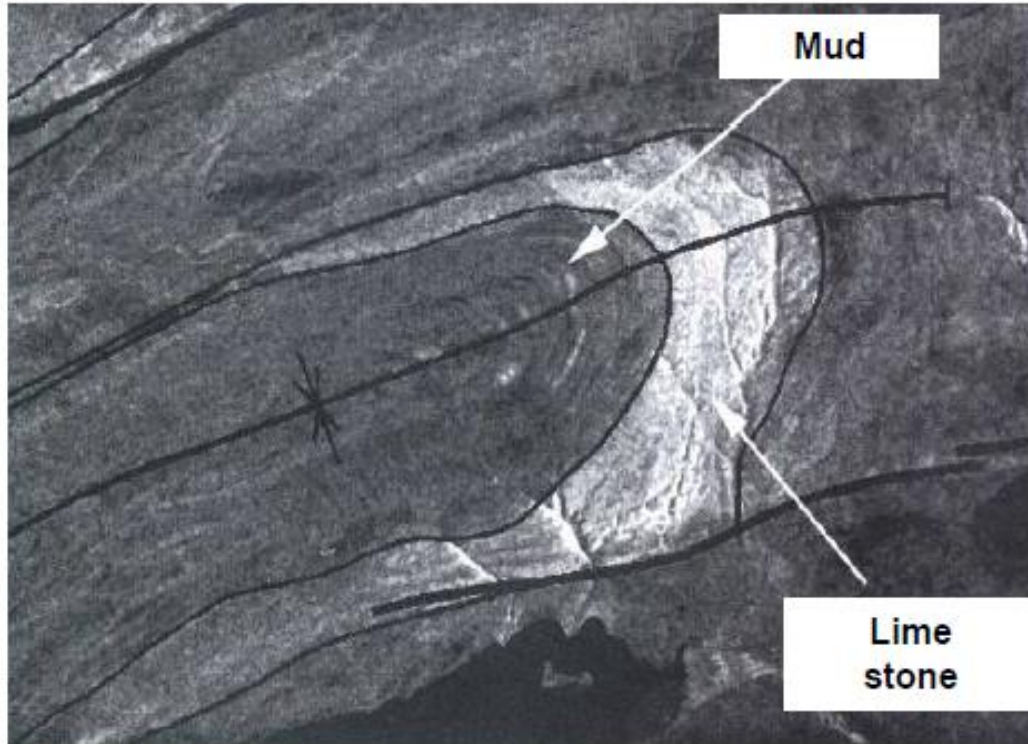
Polarização



A rugosidade da superfície (relativamente ao comprimento de onda) condiciona o padrão da dispersão.



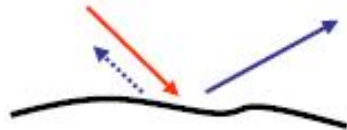
A constante dielétrica (humidade do solo) condiciona a força do sinal retro-disperso.



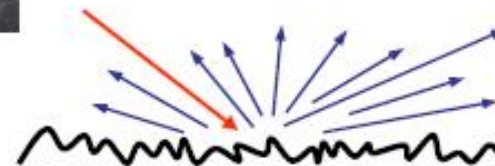
RADARSAT
(C band, HH, 45°)

Quaternary lithology:
Bathurst Island, Canada

From : RADARSAT Geology Handbook

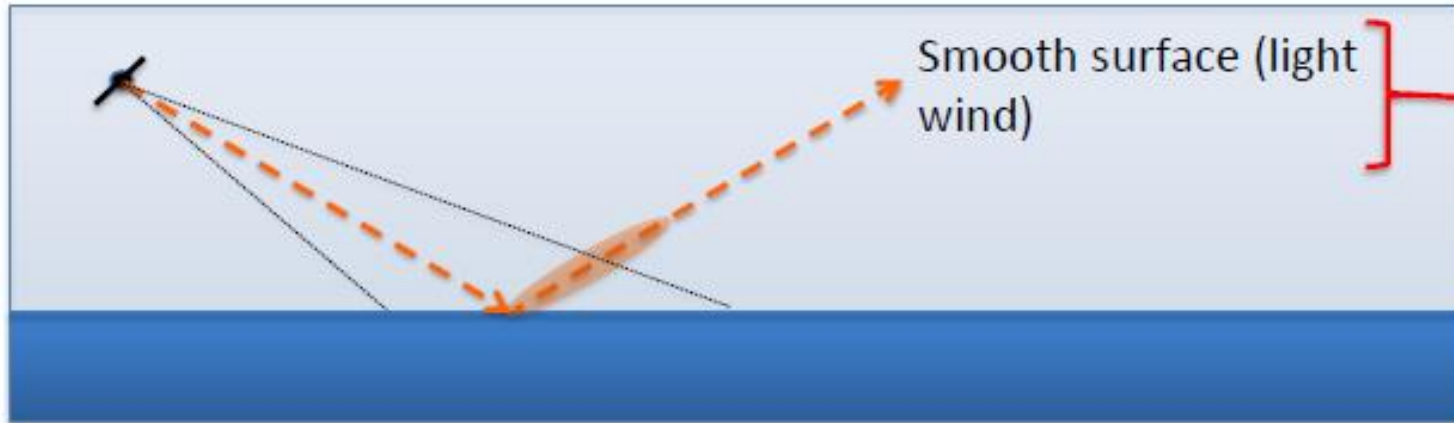


Mud fragments (smooth surface)
 → low radar backscatter
 (marga/argila)

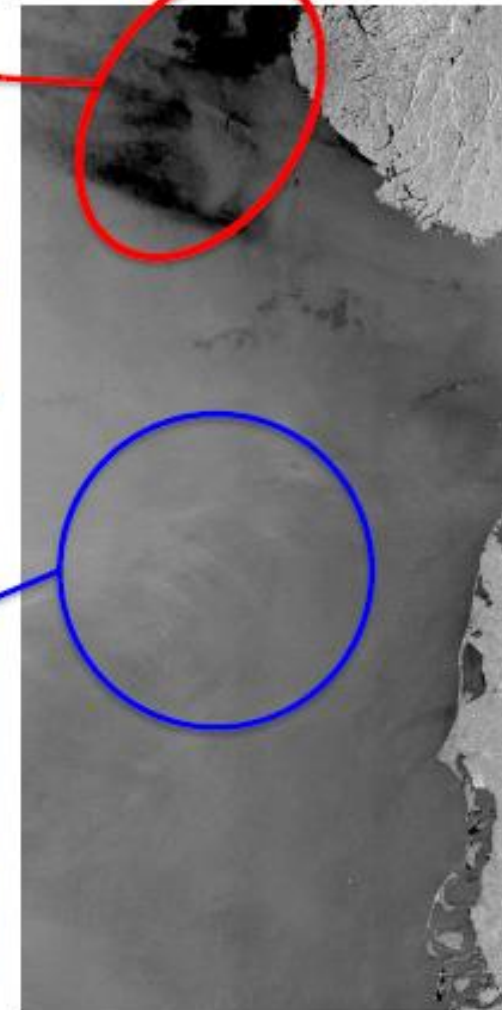
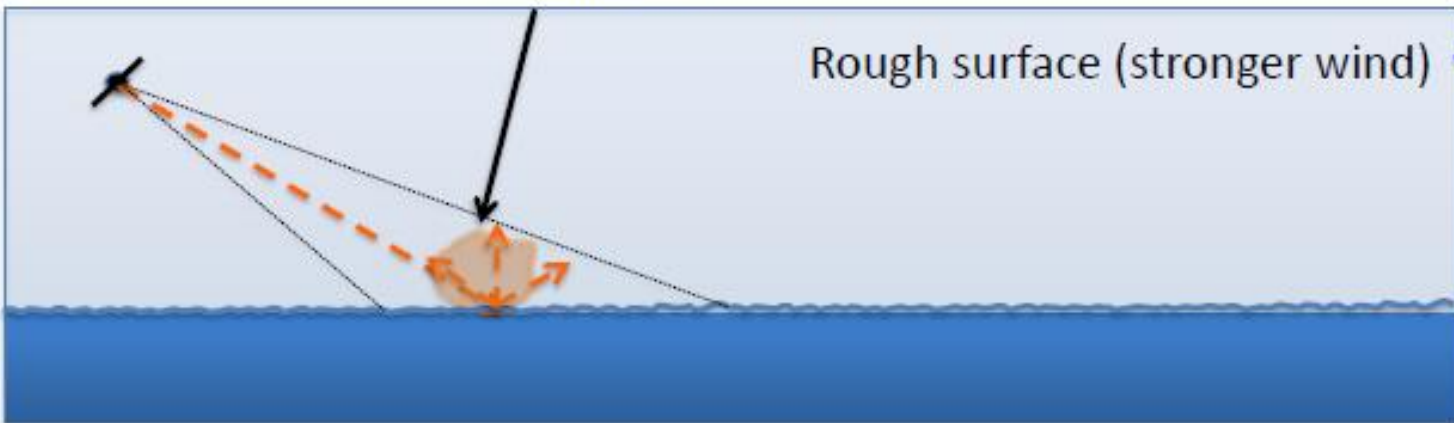


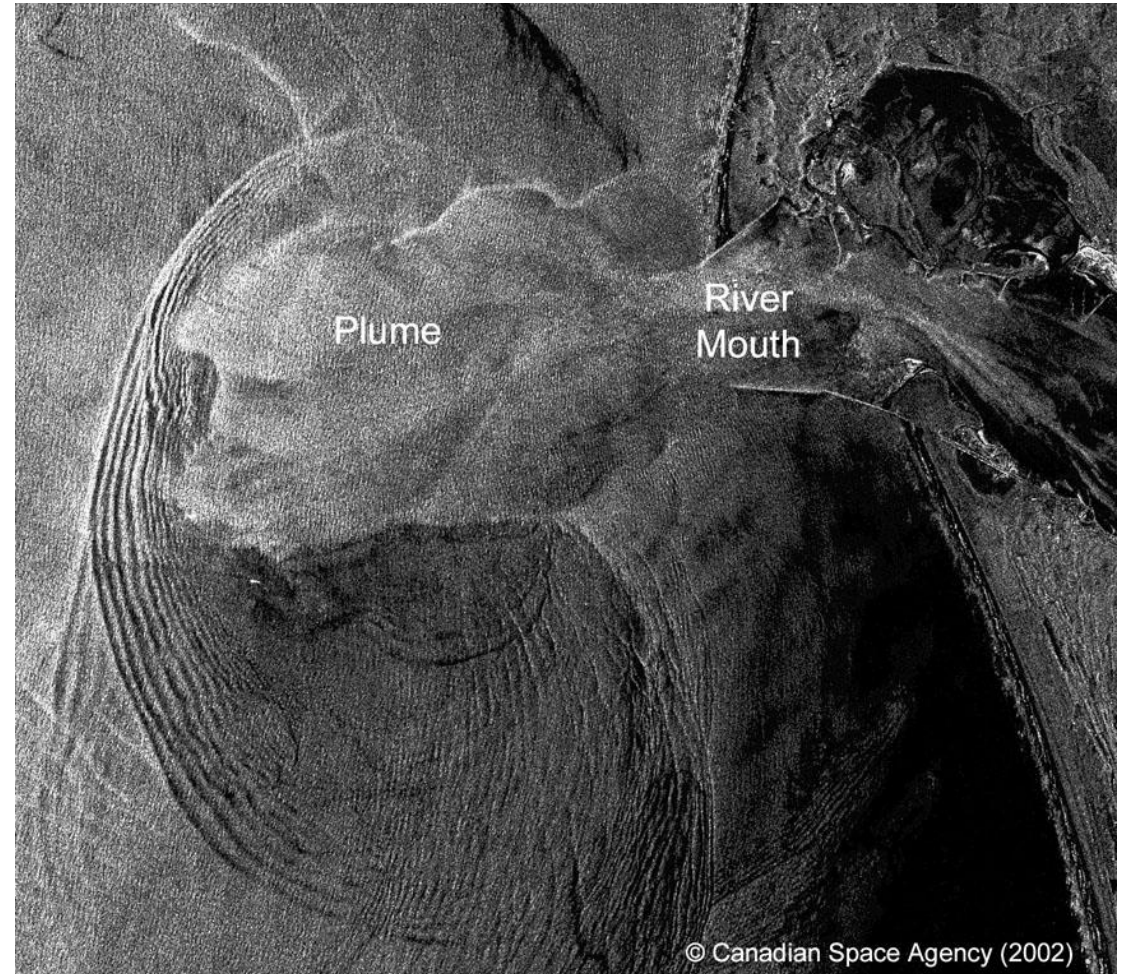
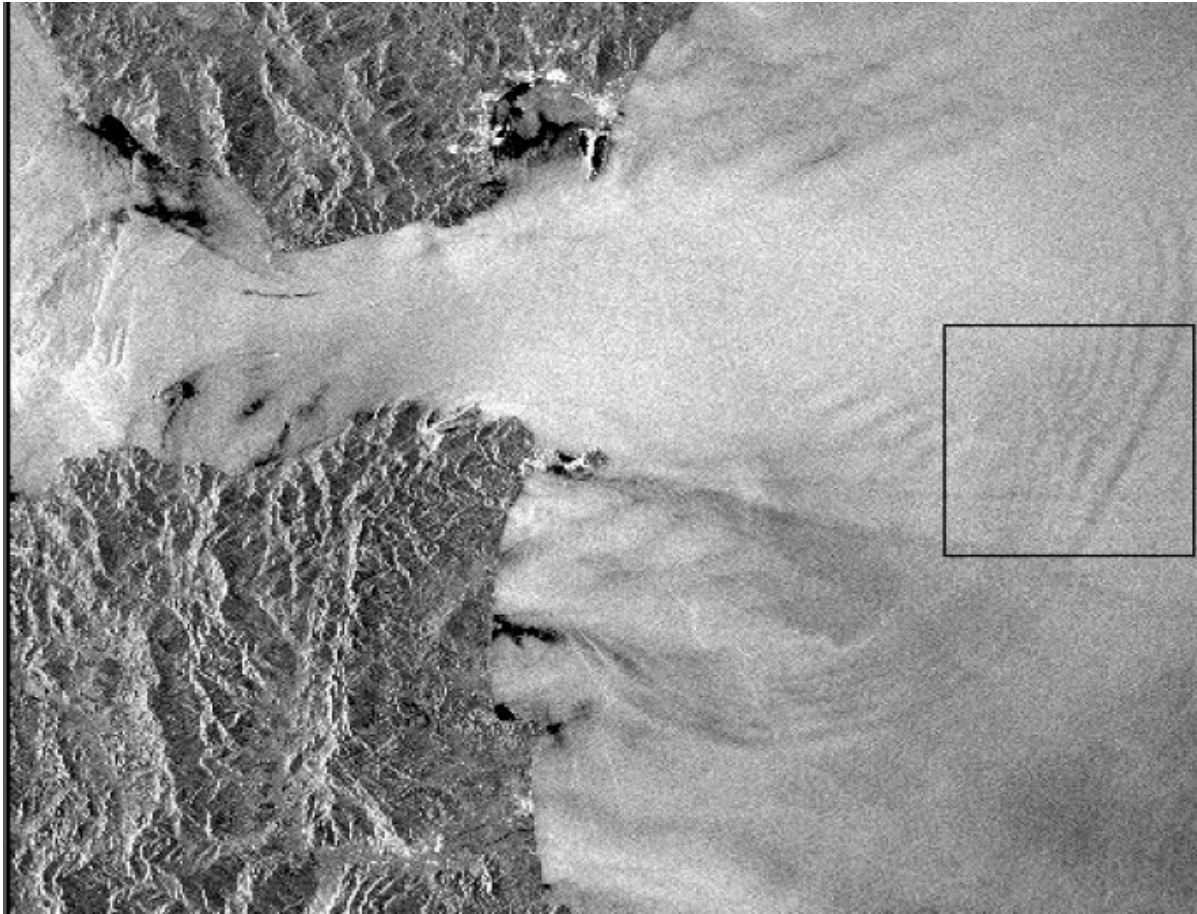
Limestone → Higher backscatter
 because of rougher surface
 (calcário)

ASAR, 2.10.2011



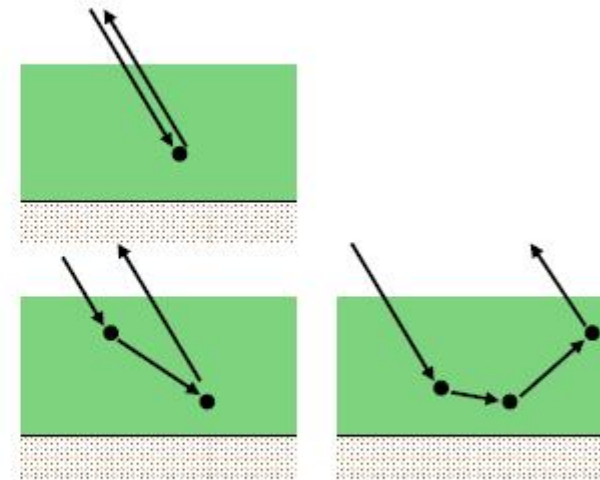
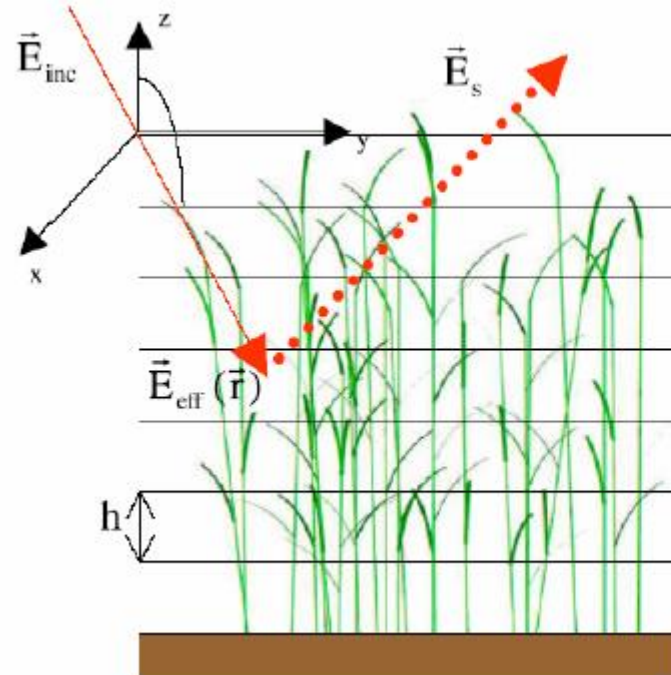
Enhanced backscatter





© Canadian Space Agency (2002)

Designamos por volume scattering quando o feixe radar penetra o topo de uma superfície e ocorre a dispersão por múltiplas reflexões entre os elementos no interior do volume



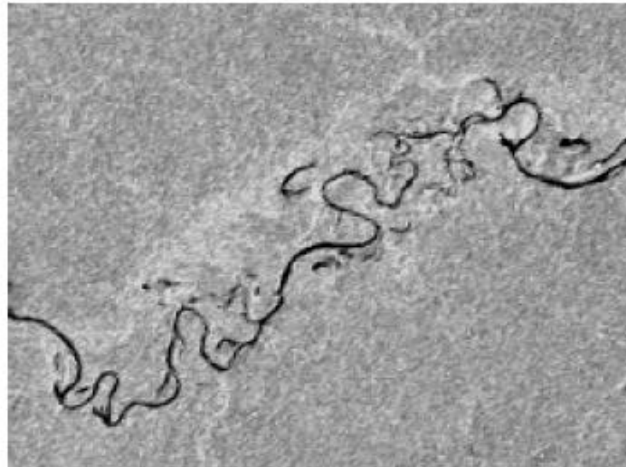
Single and multiple scattering



Varzea Dry Season

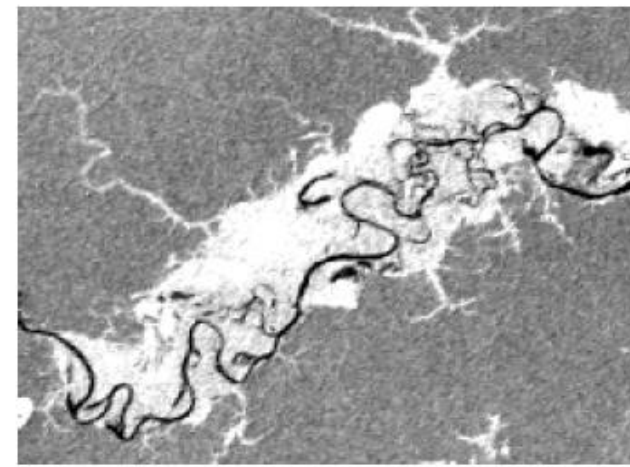


Varzea Wet Season



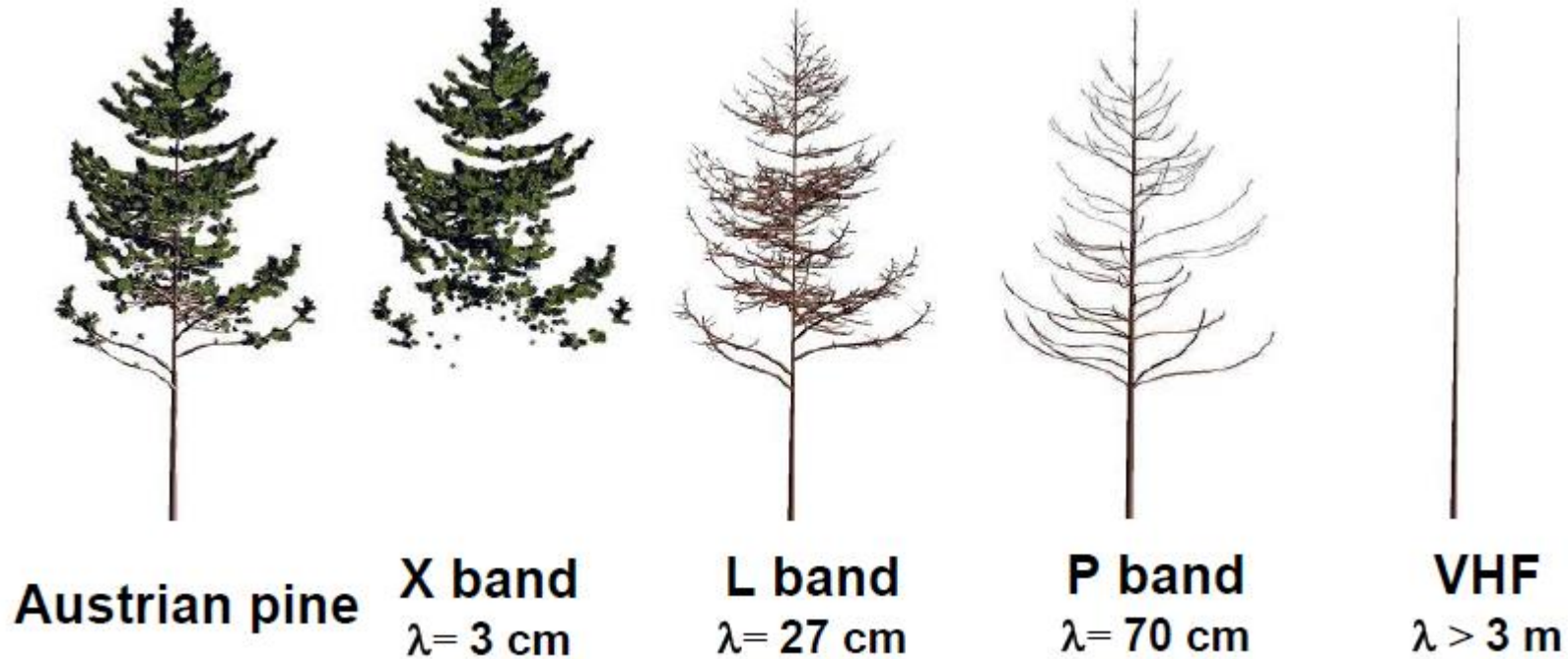
P-band image

Document S.Saatchi, JPL



P-band image

Quem são os scatterers numa dispersão volúmica.



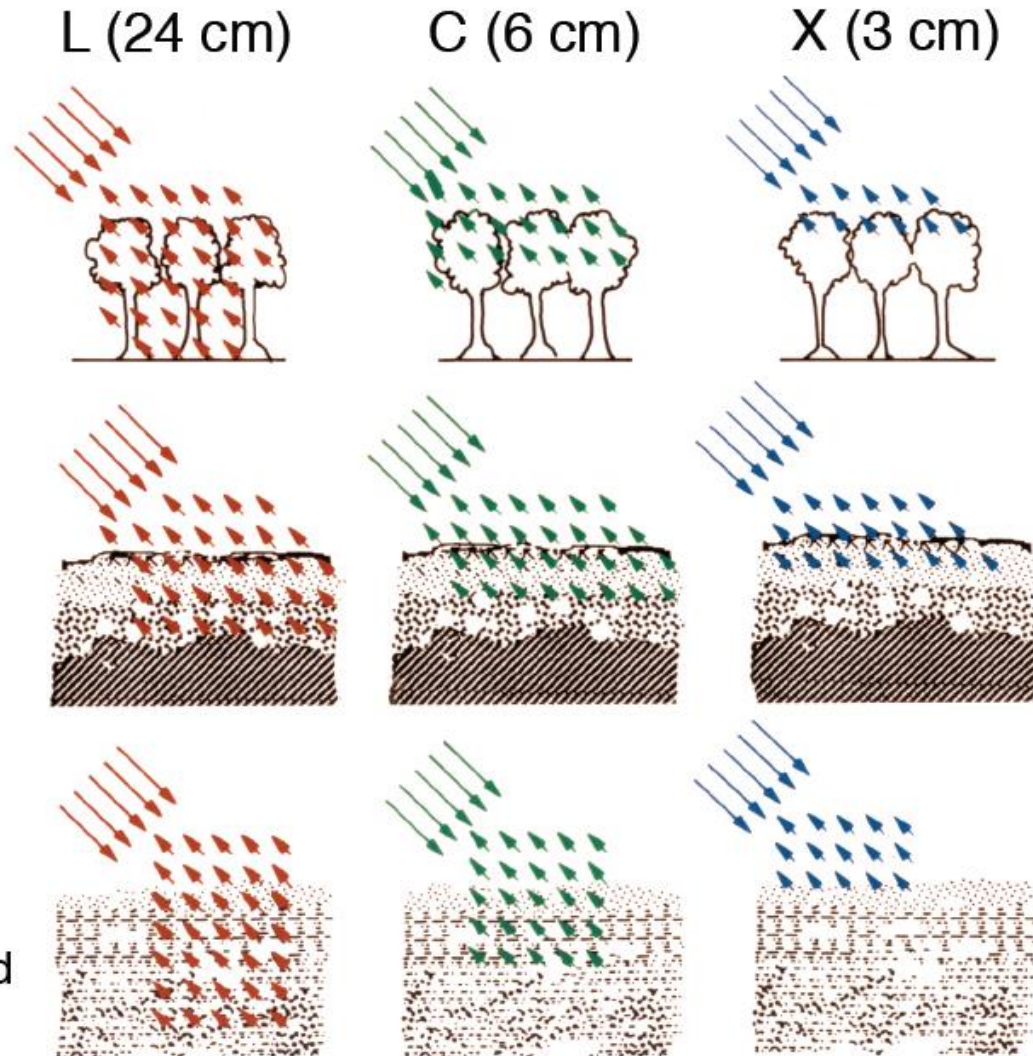
Os principais scatterers são os elementos com dimensão idêntica ao comprimento de onda.

Light interacts most strongly with objects on the size of the wavelength

Forest: Leaves reflect X-band wavelengths but not L-band

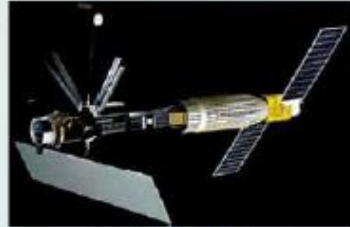
Dry soils: Surface looks rough to X-band but not L-band

Ice: Surface and layering look rough to X-band but not L-band

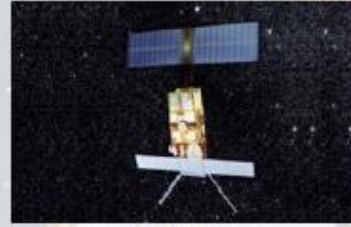


(adapted JPL, 2010)

Spaceborne SAR Systems



SEASAT
NASA/JPL (USA)
L-Band, 1978



ERS-1/2
European Space Agency (ESA)
C-Band, 1991-2000/1995-2011



J-ERS-1
Japanese Space Agency (JAXA)
L-Band, 1992-1998



SIR-C/X-SAR
NASA/JPL, L- and C-Band (quad)
DLR / ASI, X-band 1994



RadarSAT-1
Canadian Space Agency (CSA)
C-Band, 1995-2013



Shuttle Radar Topography Mission (SRTM)
NASA/JPL (C-Band), DLR (X-Band)
February 2000



ENVISAT / ASAR
European Space Agency (ESA)
C-Band (dual), 2002-2012



ALOS / PALSAR
Japanese Space Agency (JAXA)
L-Band (quad), Jan. 2006-2011

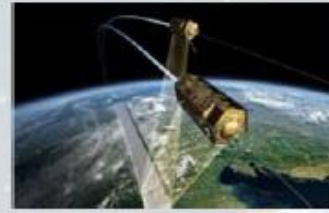


SAR-Lupe
BWB, Germany
5 satellites, X-Band, 2006/2008

Spaceborne SAR Systems



RadarSAT-II
Canadian Space Agency (CSA)
C-Band (quad), 2007



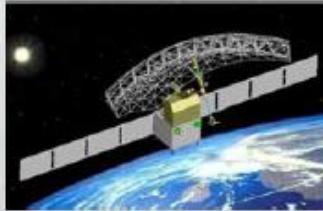
TerraSAR-X/TanDEM-X
DLR /Astrium, Germany
X-Band (quad), 2007/2010



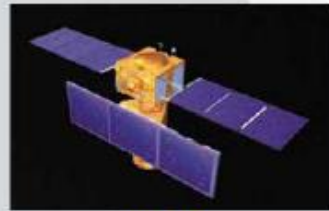
COSMO-SkyMed
ASI, Italy
4 Satellites, X-Band (dual),
2007/2010



Komsat-5
KARI, Korea
X-band (dual), 2013



HJ-1C-SAR
CRESDA/CAST/NRSCC, China
S-Band (HH or VV), 2013



RISAT-1
Indian Space Agency (ISRO), India
C-Band (quad), 2012



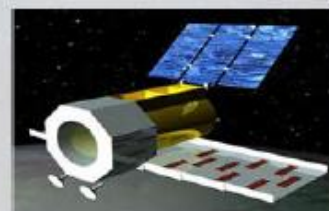
SENTINEL-1a/b
ESA, Europe
C-Band (dual), 2014/2015



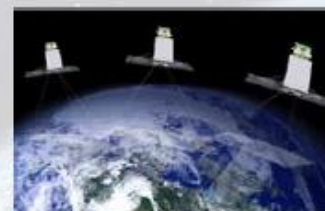
PAZ
Ministry of Defence, Spain
X-Band (quad), 2014



ALOS-2
Japanese Space Agency (JAXA)
L-Band (quad), 2014



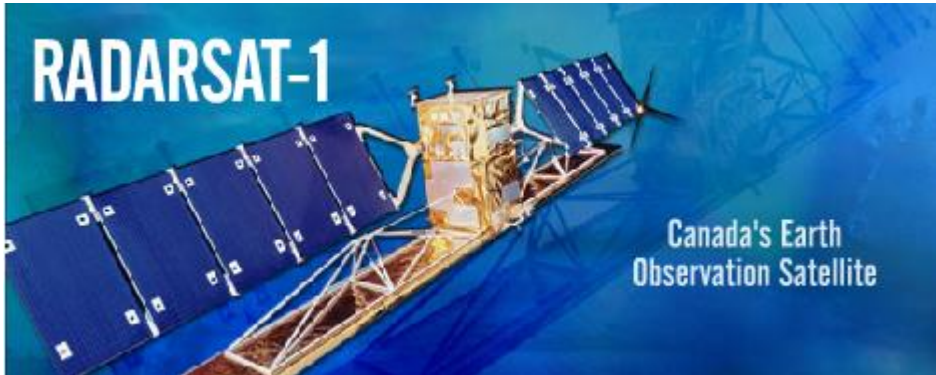
SAOCOM-1/2
CONAE/ASI, Argentina
L-Band (quad), 2016/2018



RadarSat Constellation 1-3
CSA/MDA, Canada
C-band (dual), 2016/2017



BIOMASS
ESA, Europe
P-Band (quad), 2019

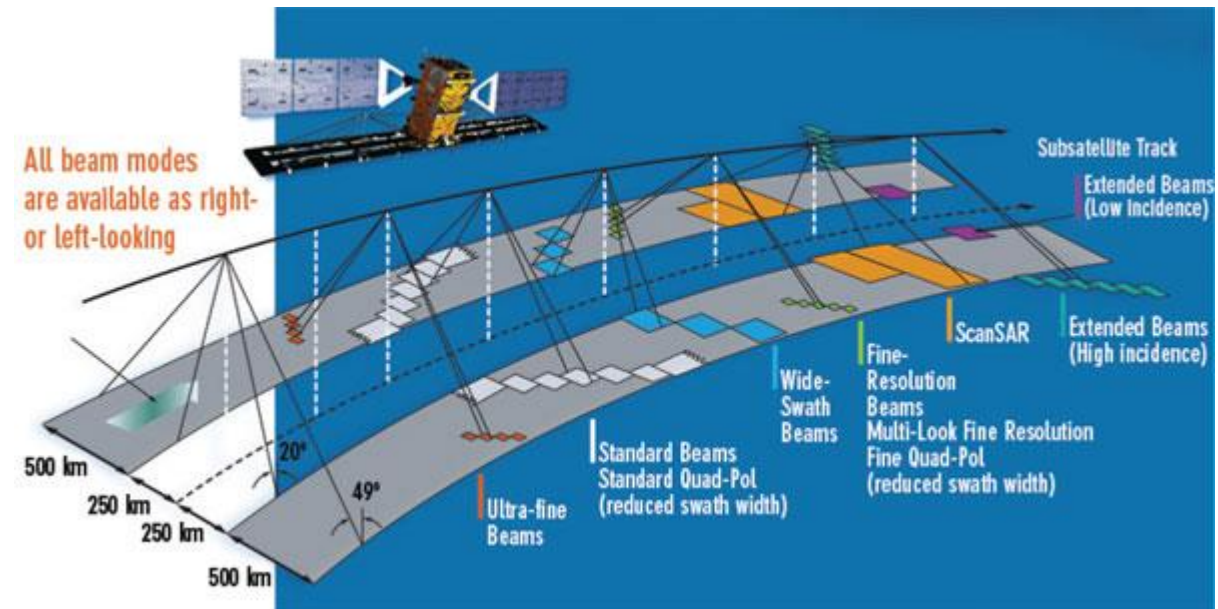


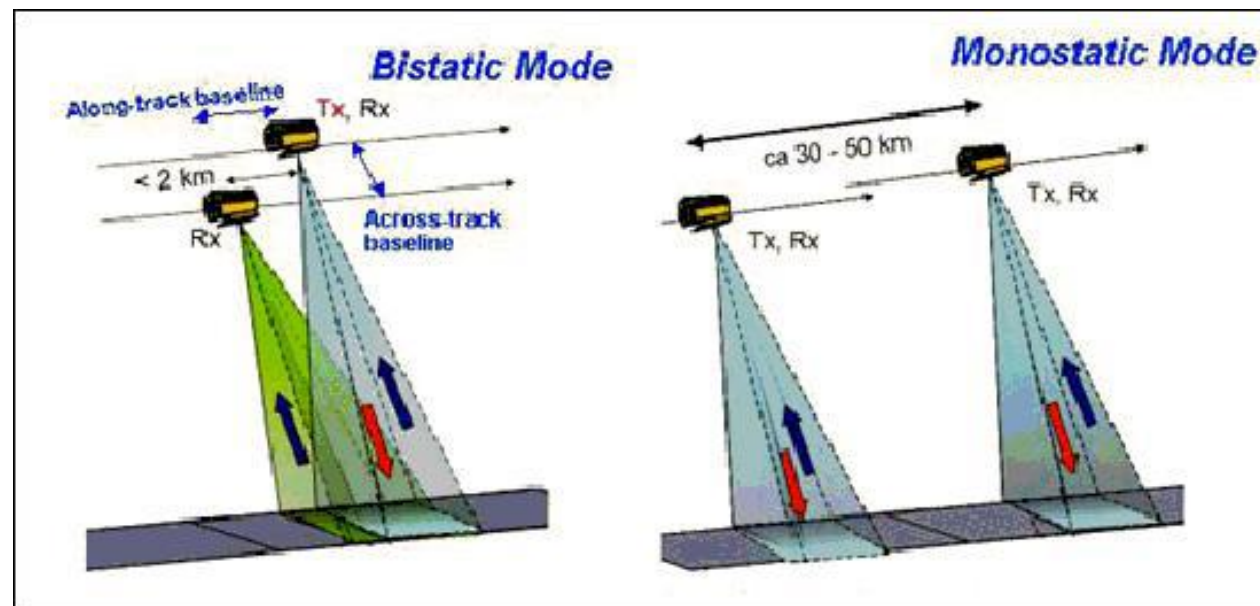
Launched in November 1995, **RADARSAT-1** provides Canada and the world with an operational radar satellite system capable of timely delivery of large amounts of data. Equipped with a powerful synthetic aperture radar (SAR) instrument, it acquires images of the Earth day or night, in all weather and through cloud cover, smoke and haze.

RADARSAT-2

Lançado em 2007

Resolução 3m





COSMO-SkyMed (COntellation of small Satellites for the Mediterranean basin Observation) is an Earth observation satellite system funded by the Italian Ministry of Research and Ministry of Defense and conducted by the Italian Space Agency(ASI), intended for both military and civilian use.



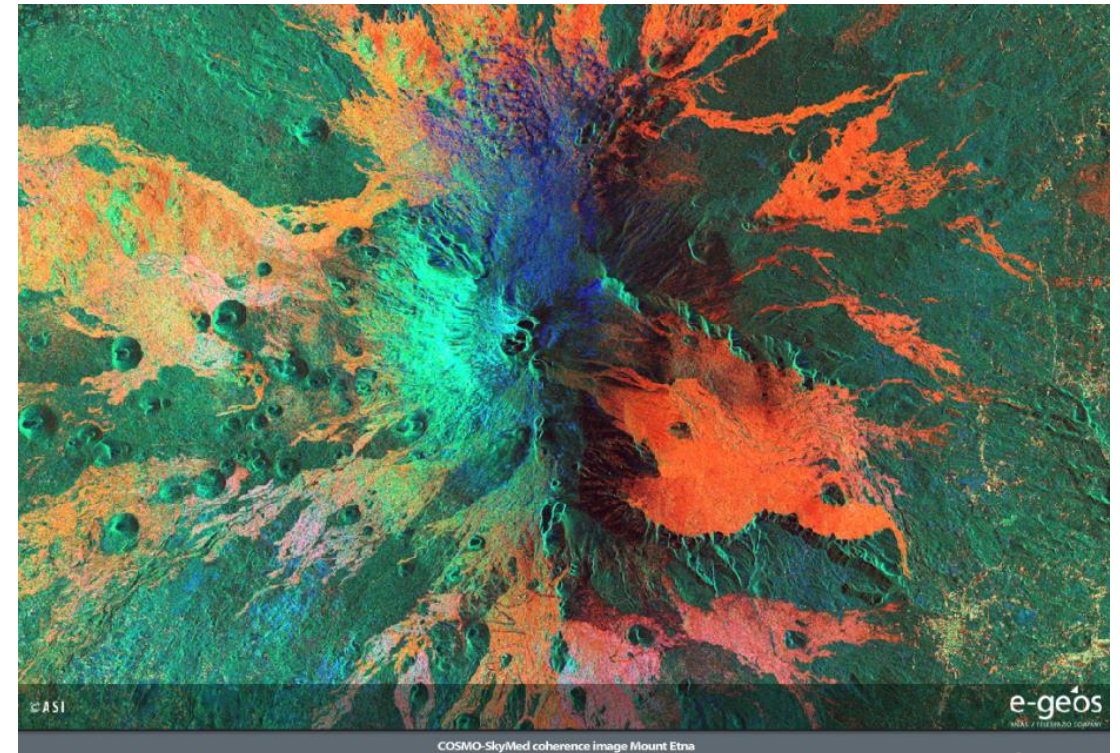
With 4 satellites up to 1800 Images per day

Daily scenario example:

- 300 Spotlight-2 = 30,000 km² at 1m resolution

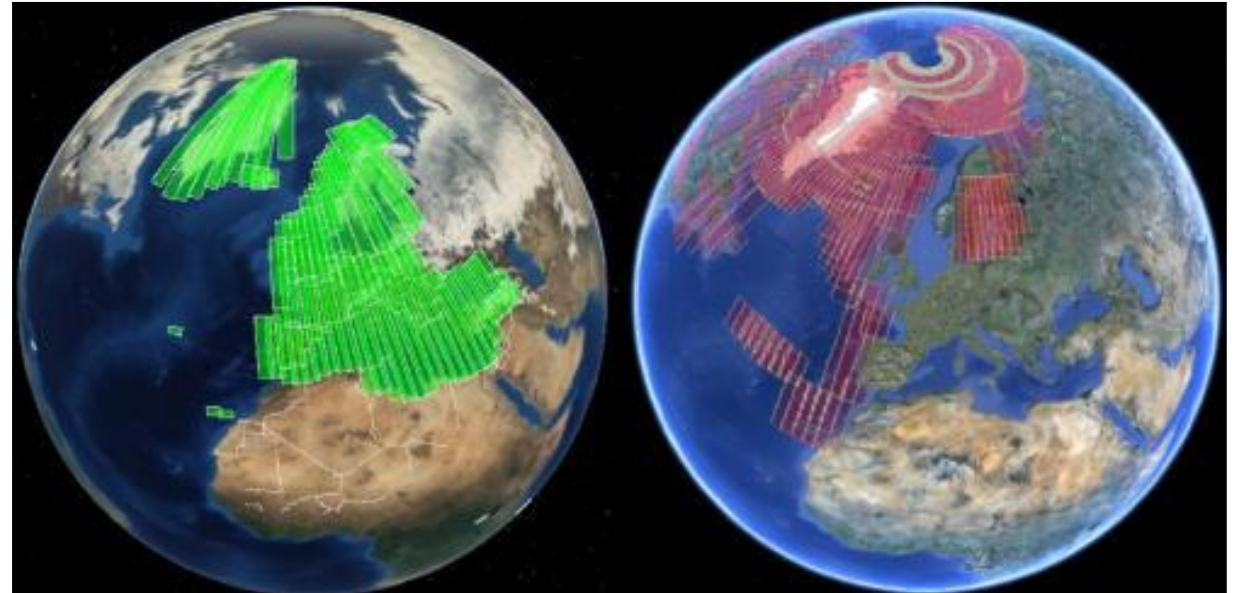
And

- 1,500 Stripmap = 2,400,000 km² at 3m resolution



The Sentinel-1 mission is designed as a two-satellite constellation. The identical satellites orbit Earth 180° apart and at an altitude of almost 700 km. This configuration optimises coverage, offering a global revisit time of just six days.

At the equator, however, the repeat frequency is just three days and less than one day over the Arctic. Europe, Canada and main shipping routes are covered in less than three days.

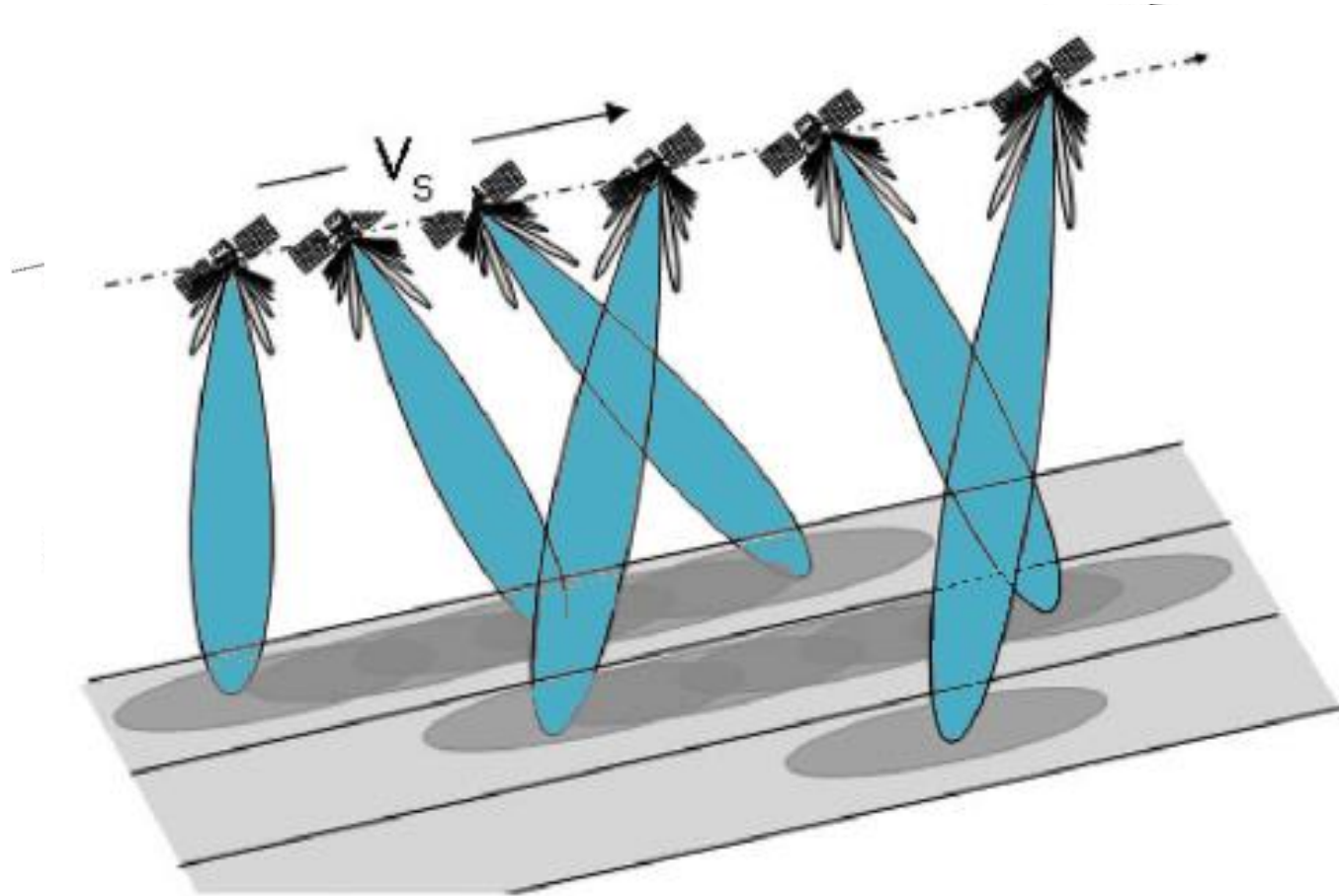


Left: Europe and European waters – IW mode, ascending orbits over a 12-day repeat cycle (January)

Right: Europe and European waters – EW mode, descending orbits over a 12-day repeat cycle (January)

Interferometric Wide swath (IW) and Extra Wide swath (EW) modes (400 km swath)

Visão Radar



Interferometric Wide swath mode, the default mode over land, has a swath width of 250 km and a ground resolution of 5 x 20 m. (TOPSAR, burst)

Wave mode acquisitions – which can help to determine the direction, wavelength and heights of waves on the open oceans – are 20 x 20 km, acquired alternately on two different incidence angles every 100 km.

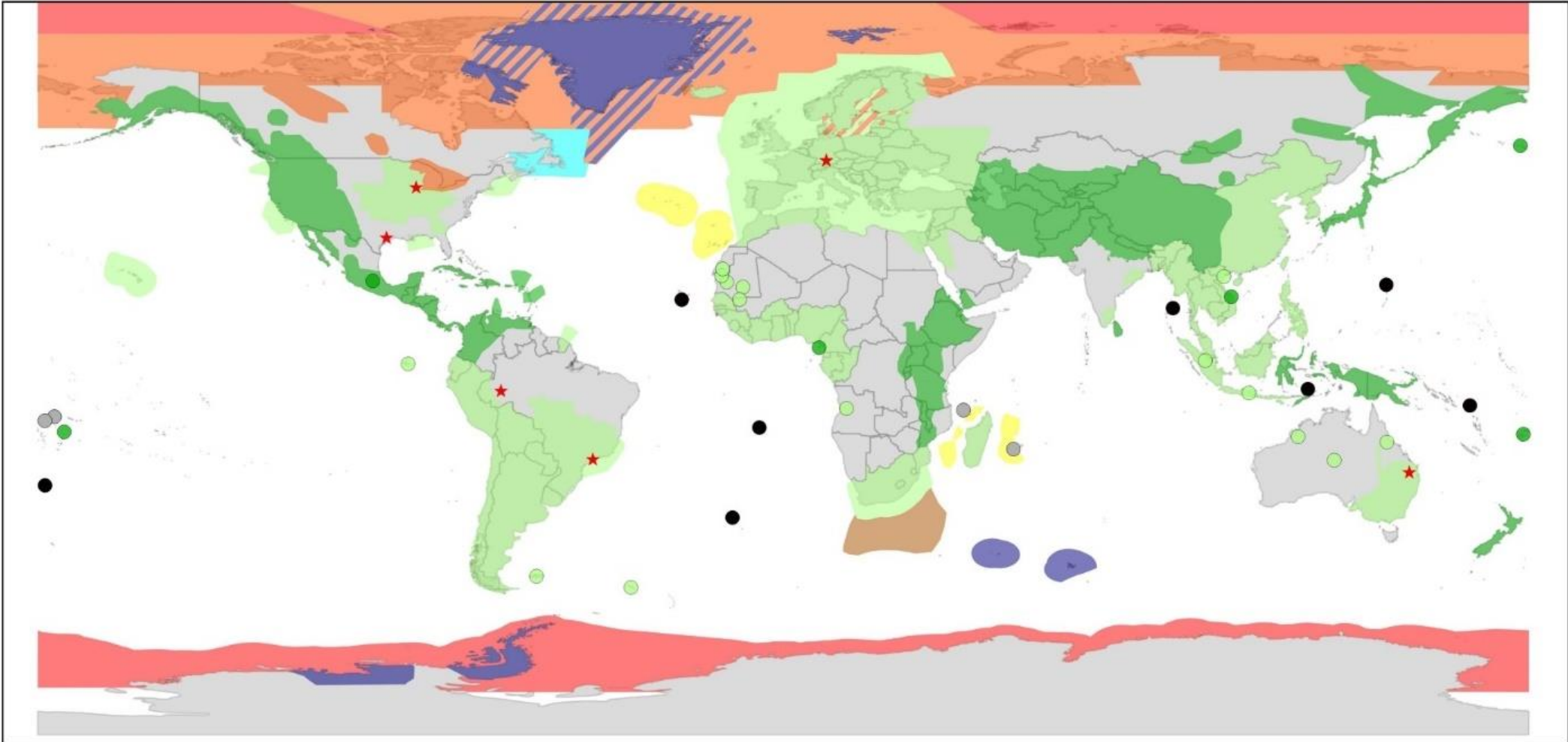
There's also the potential for operating it in two additional modes: Stripmap (5m x 5m) and Extra Wide Swath (20m x 40m).

Extra Wide-swath mode covers an ultra-wide-swath width of more than 400 km at medium resolution (20 x 40 m on the ground). (TOPSAR)



SENTINEL-1A - OBSERVATION SCENARIO 28.01.2015 - 09.02.2016 (CYCLE 70)

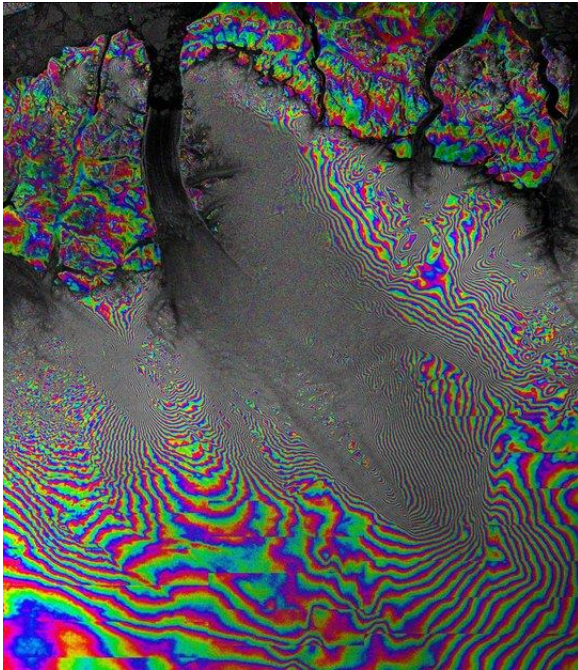
D



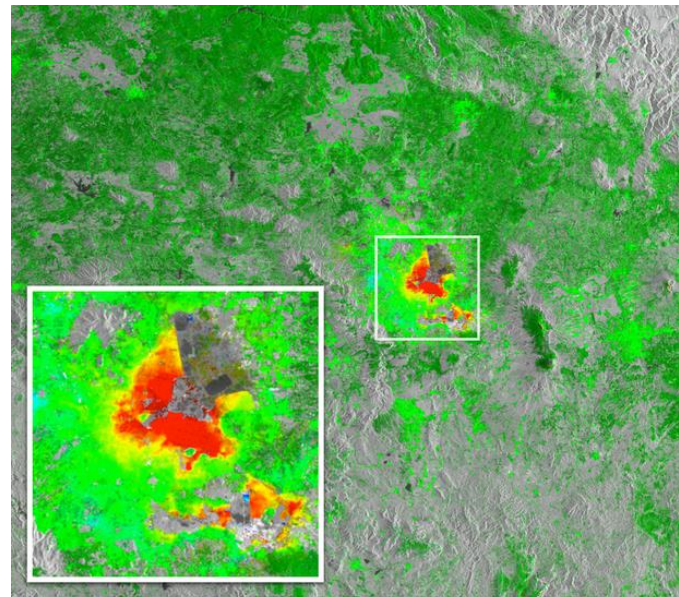
EW (HH)	EW (HH)	IW (HH)	IW (HH)	SM (HH)	★ CALIBRATION SITE
EW (HH-HV)	EW (HH-HV)	IW (HH-HV)	IW (HH-HV)	SM (HH-HV)	
EW (VV)	EW (VV)	IW (VV)	IW-(VV)	SM (VV)	
EW (VV-VH)	EW (VV-VH)	IW (VV-VH)	IW-(VV-VH)	SM (VV-VH)	

Aplicações

Oceano e Gelo

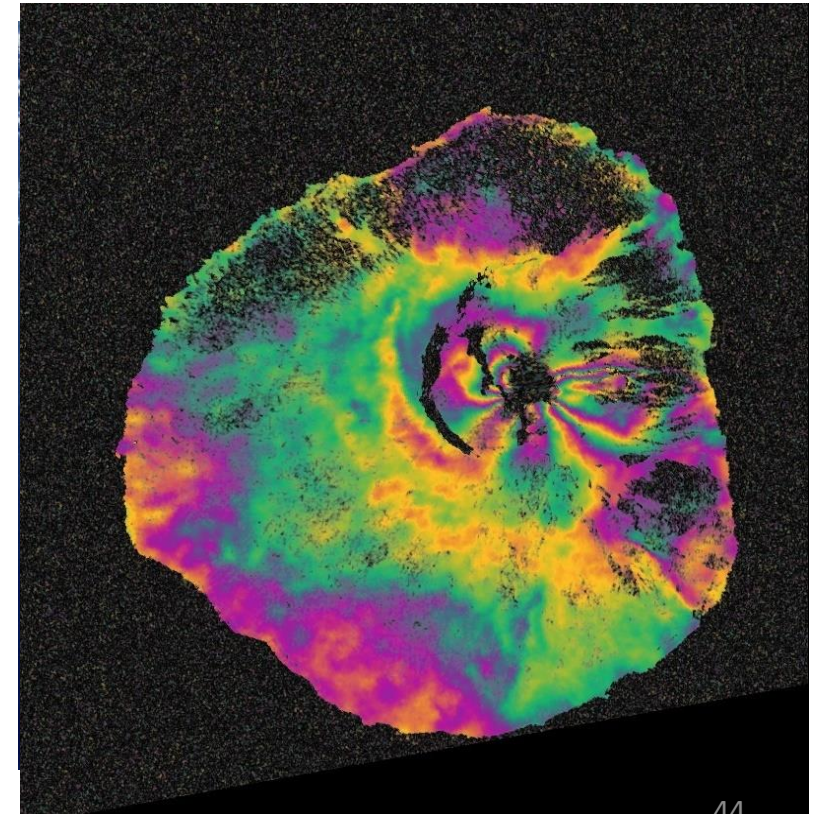


Changing lands

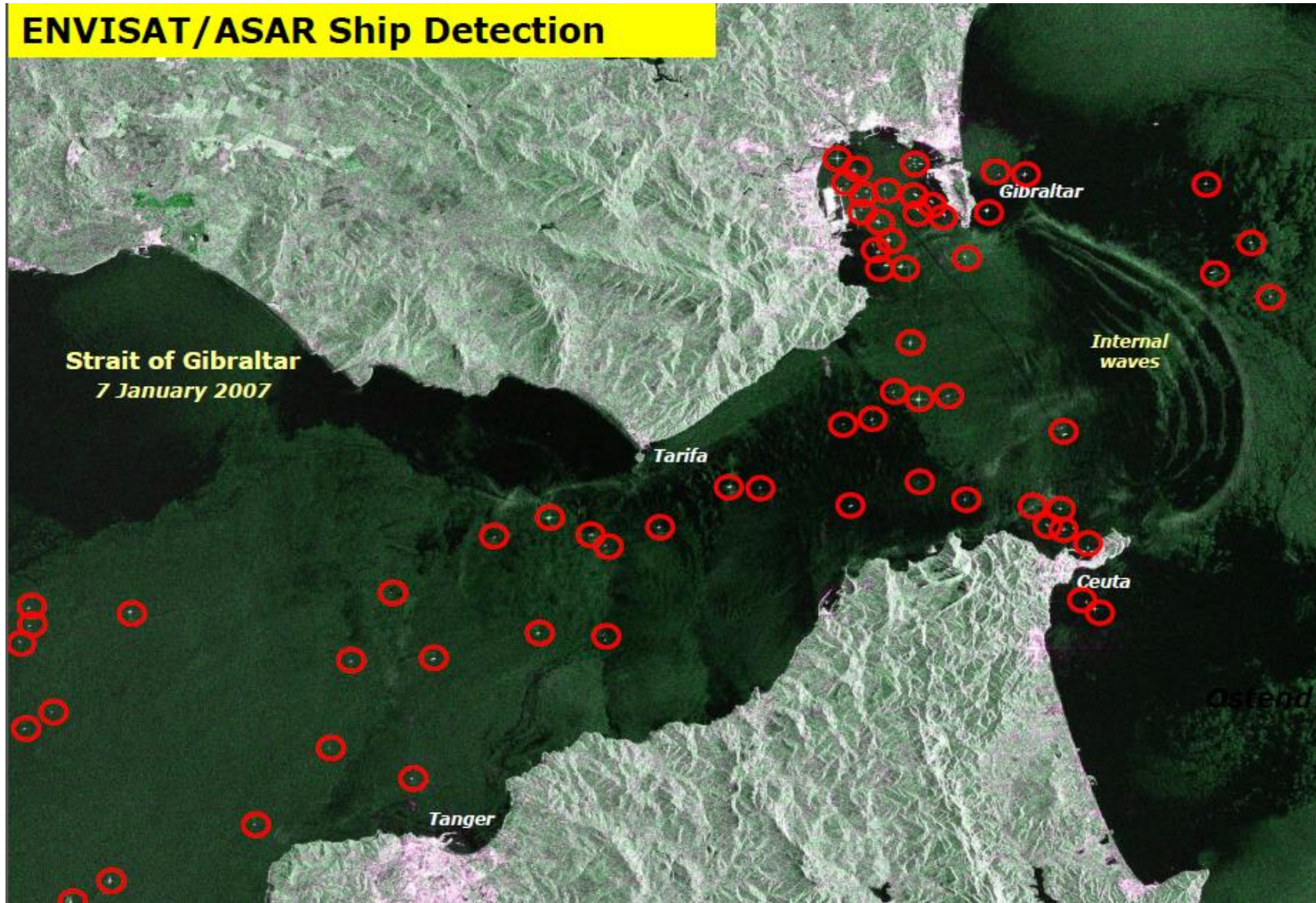


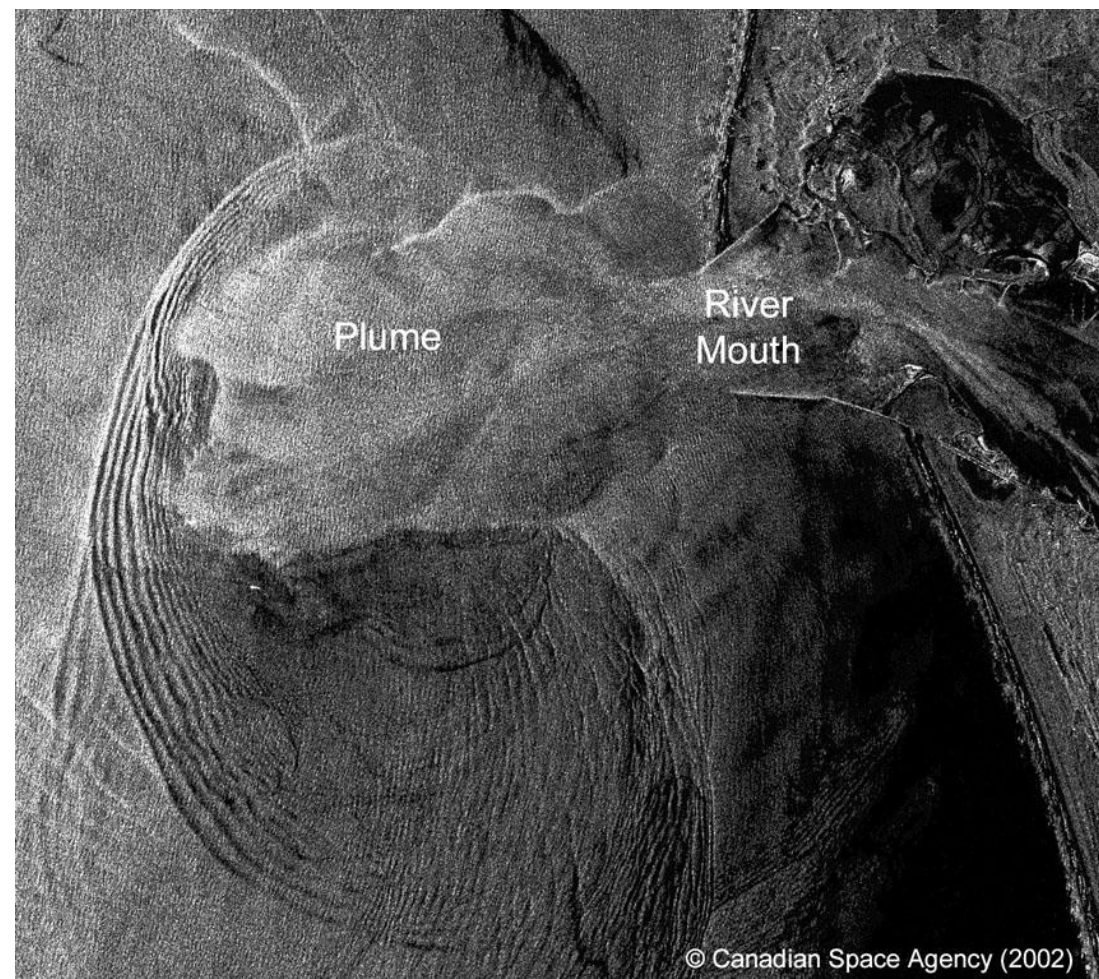
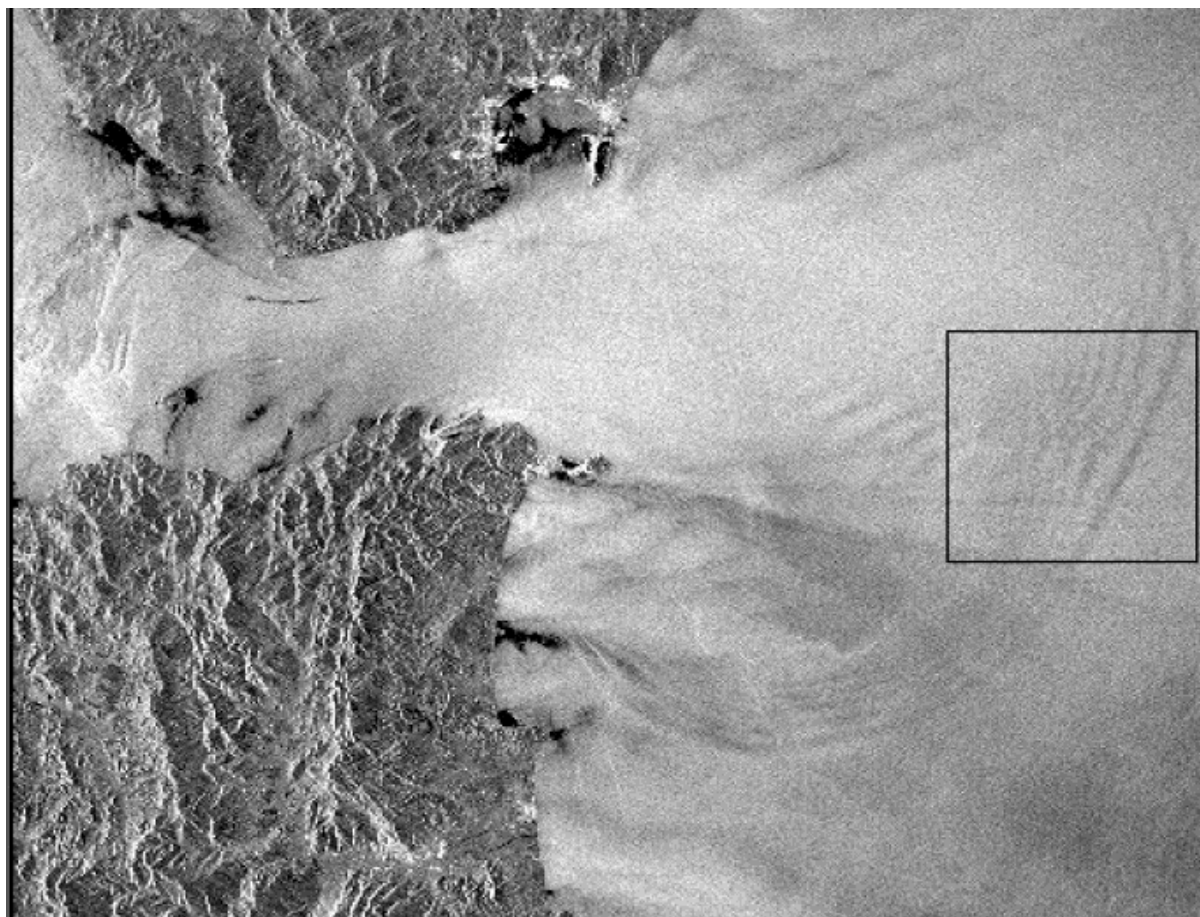
-20 cm/yr  +20 cm/yr

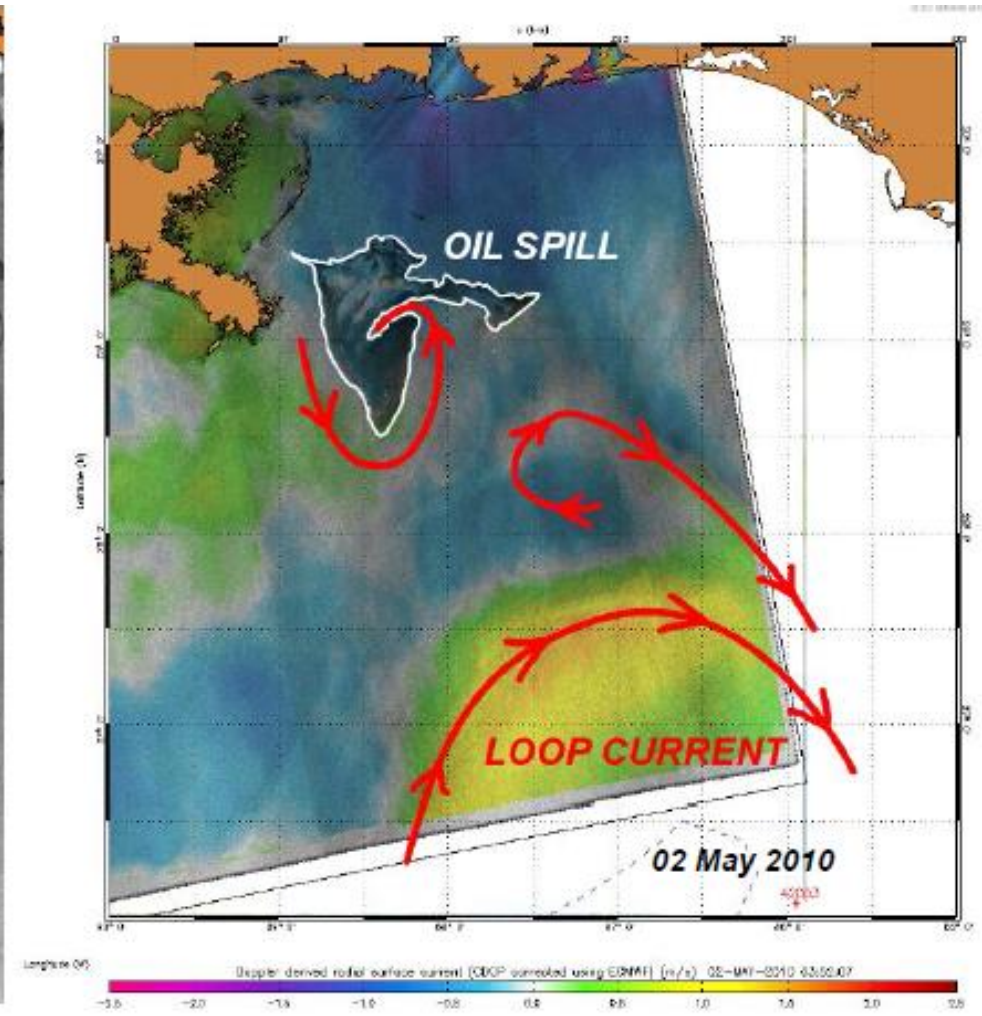
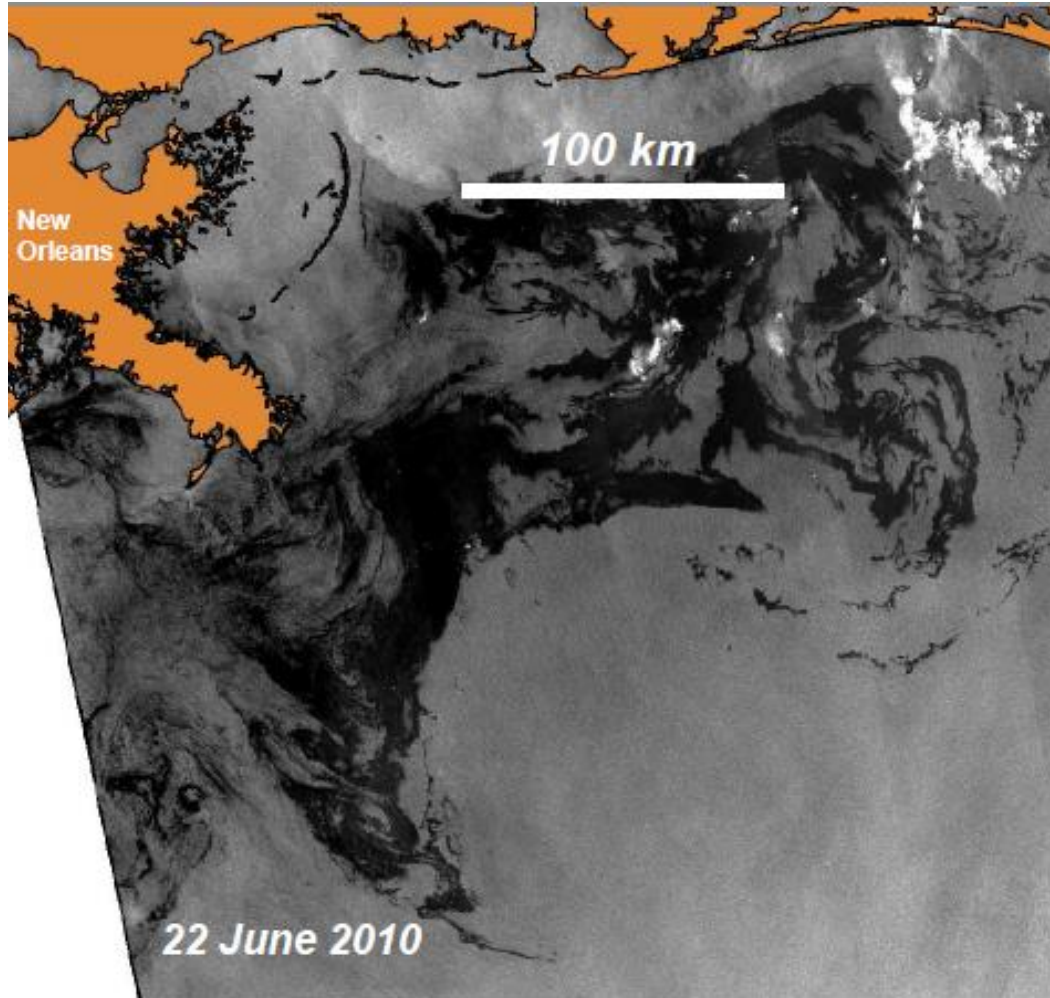
Emergency response

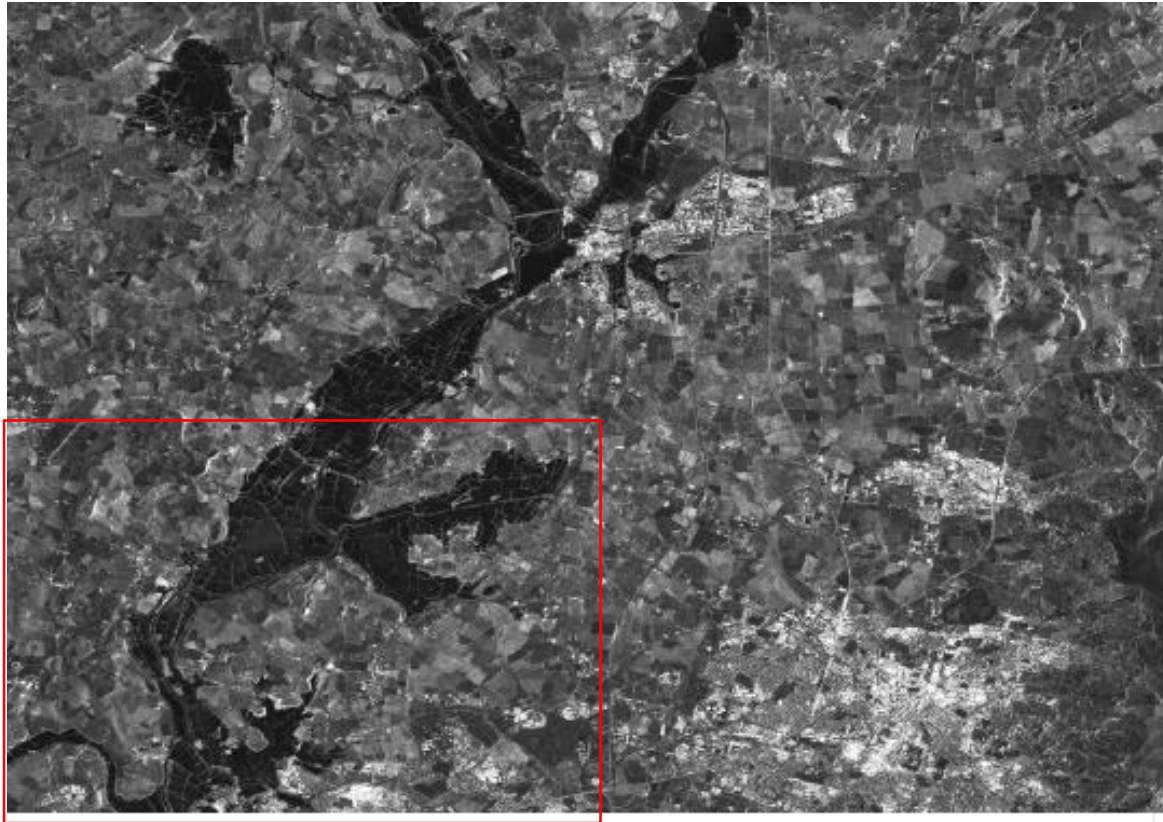


Aplicações SAR e INSAR

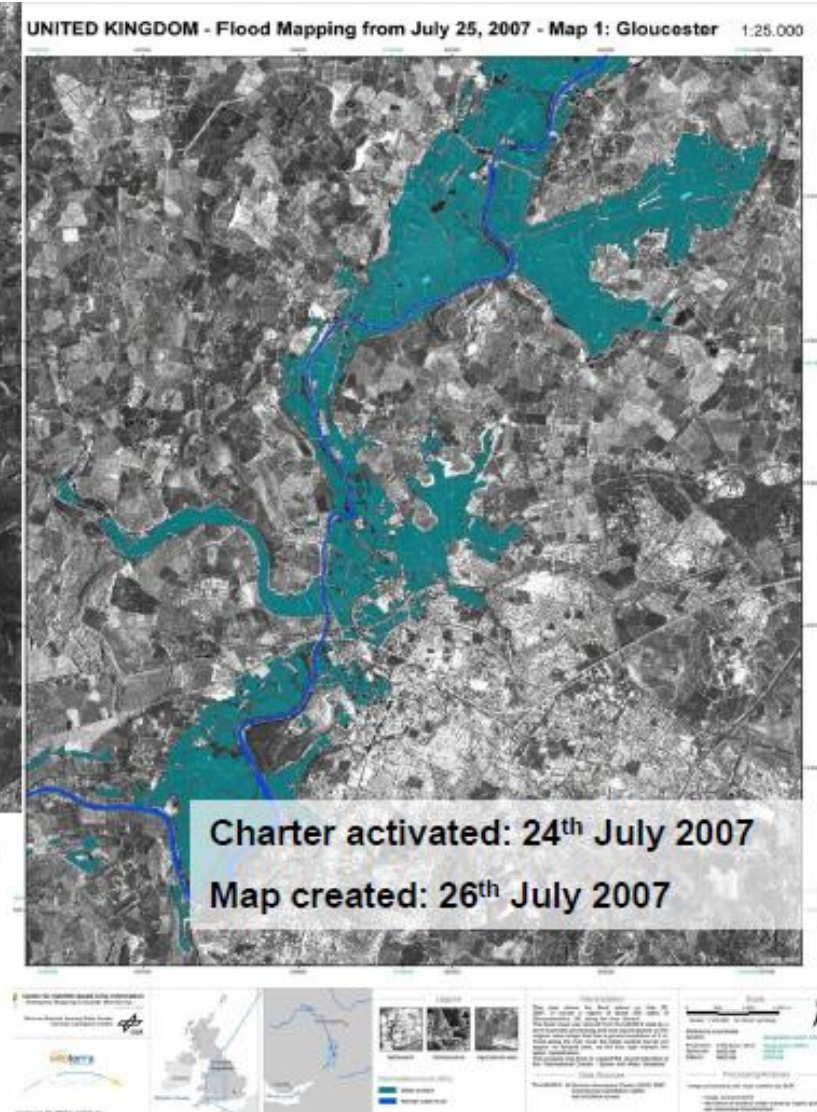


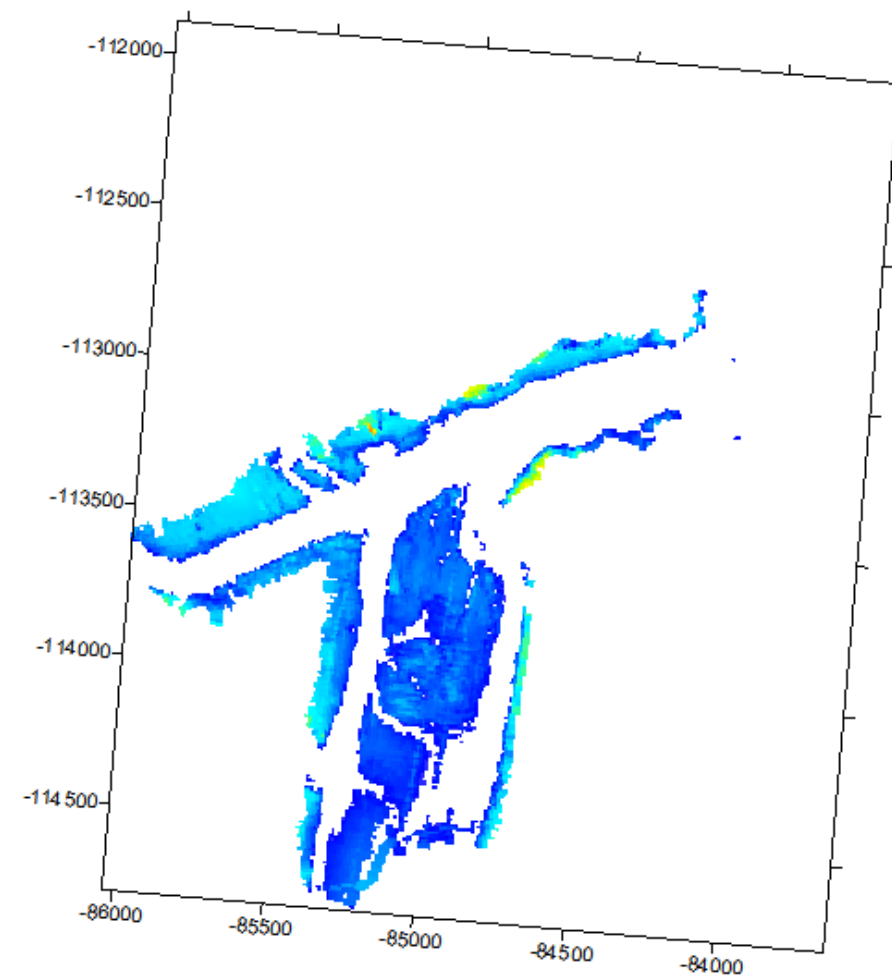






TerraSAR-X data (3m resolution) used in Charter Call





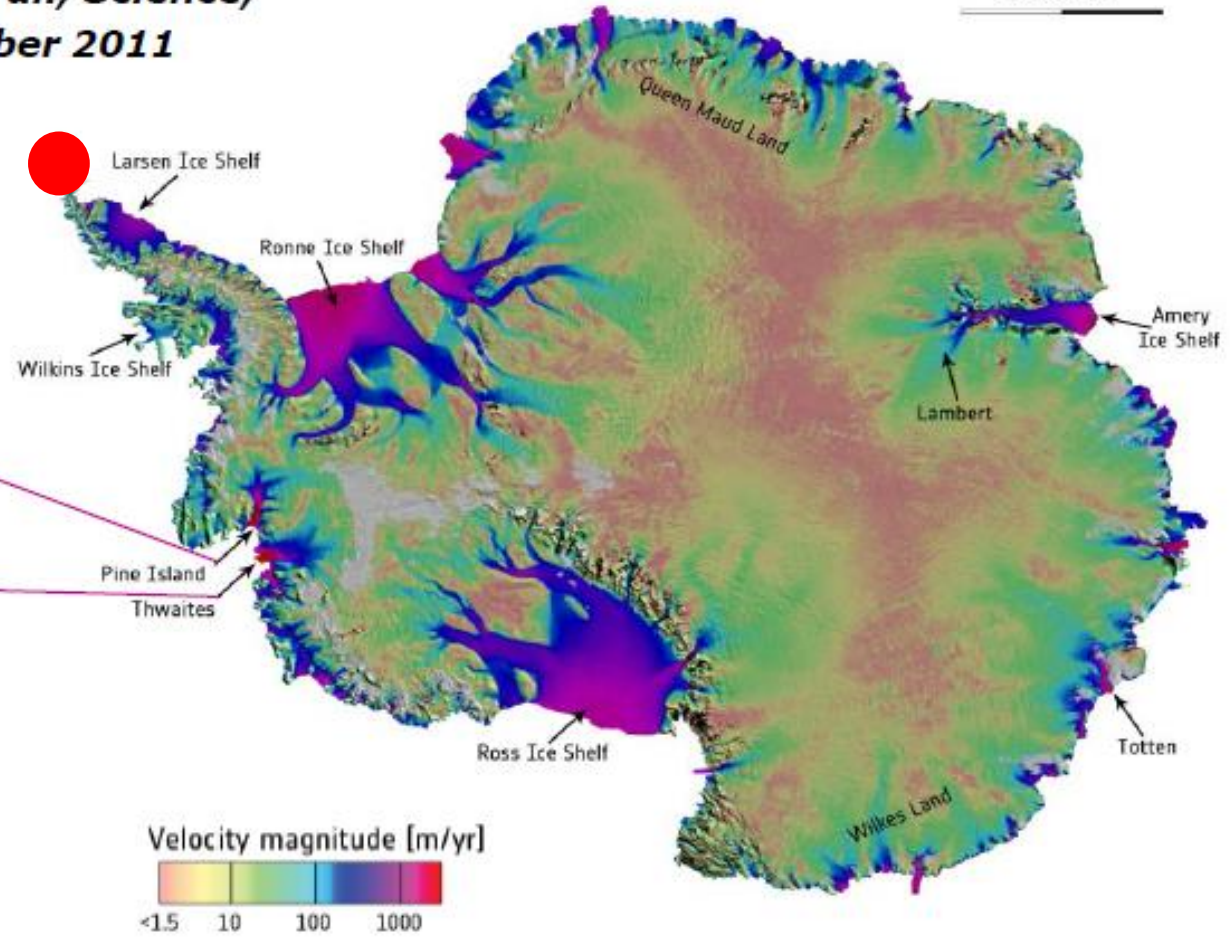
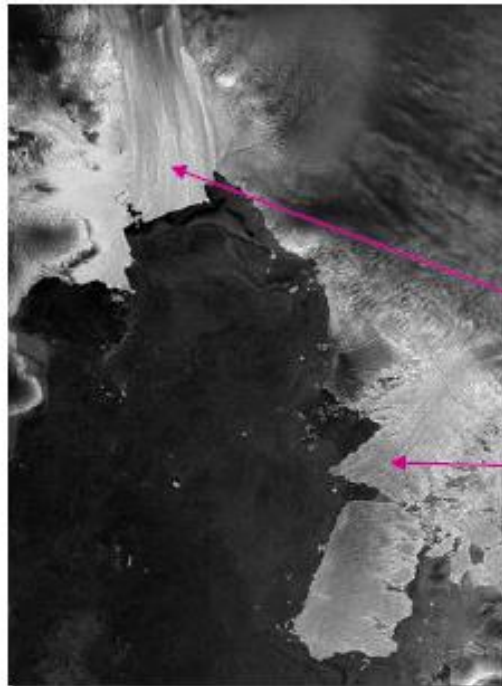
Levantamento CM Seixal (realizado pelo IH)

(InSAR)

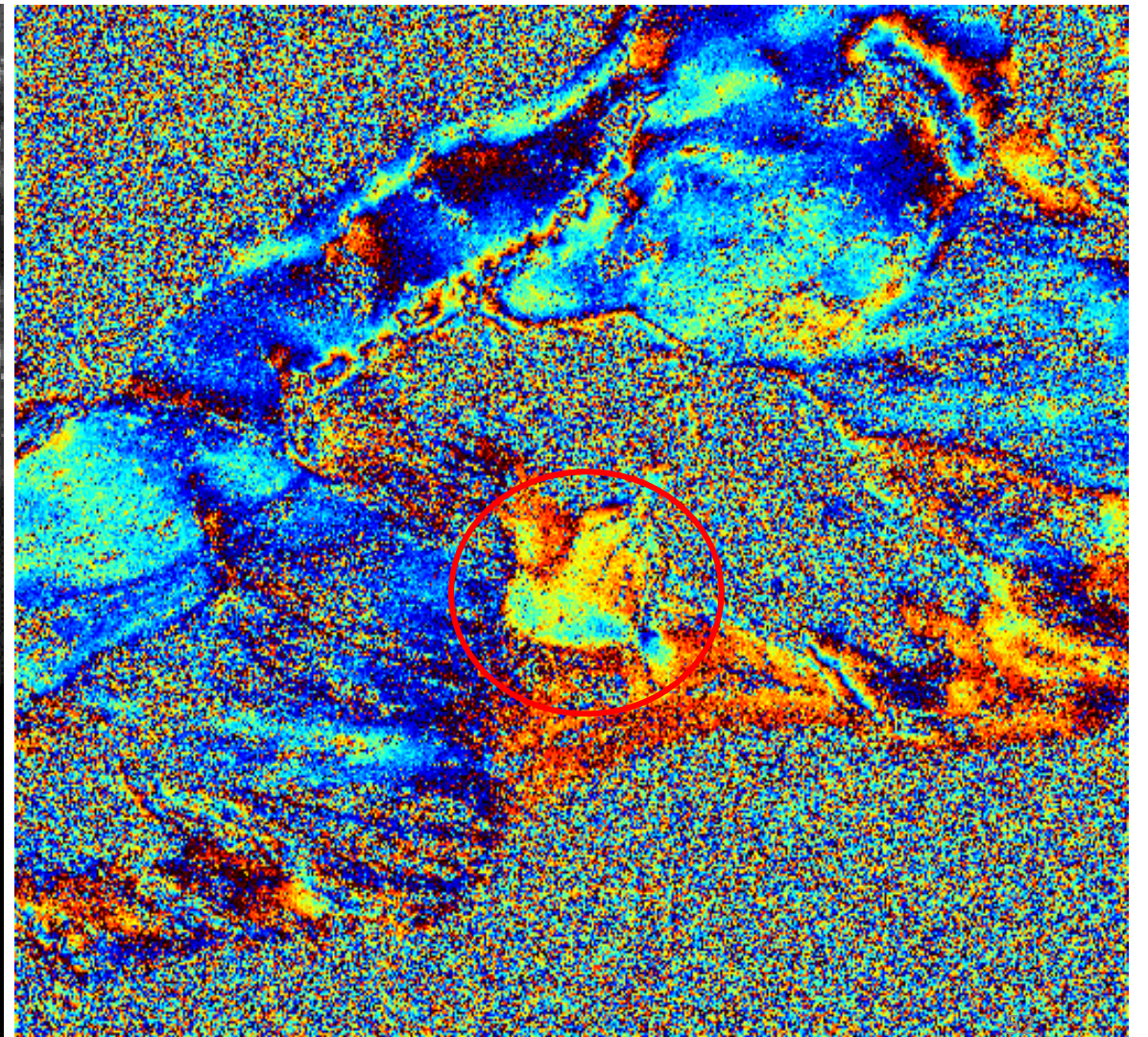
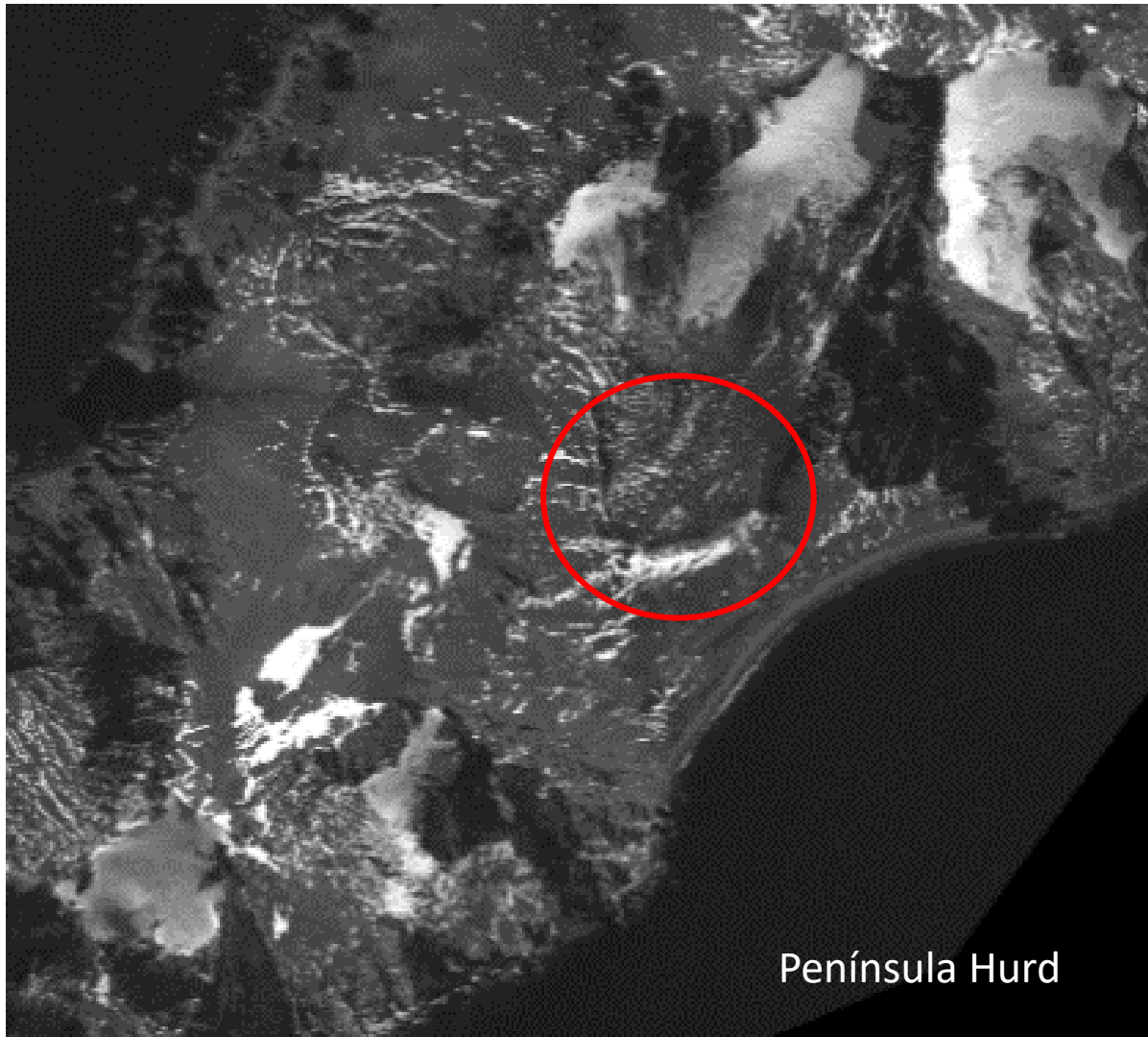


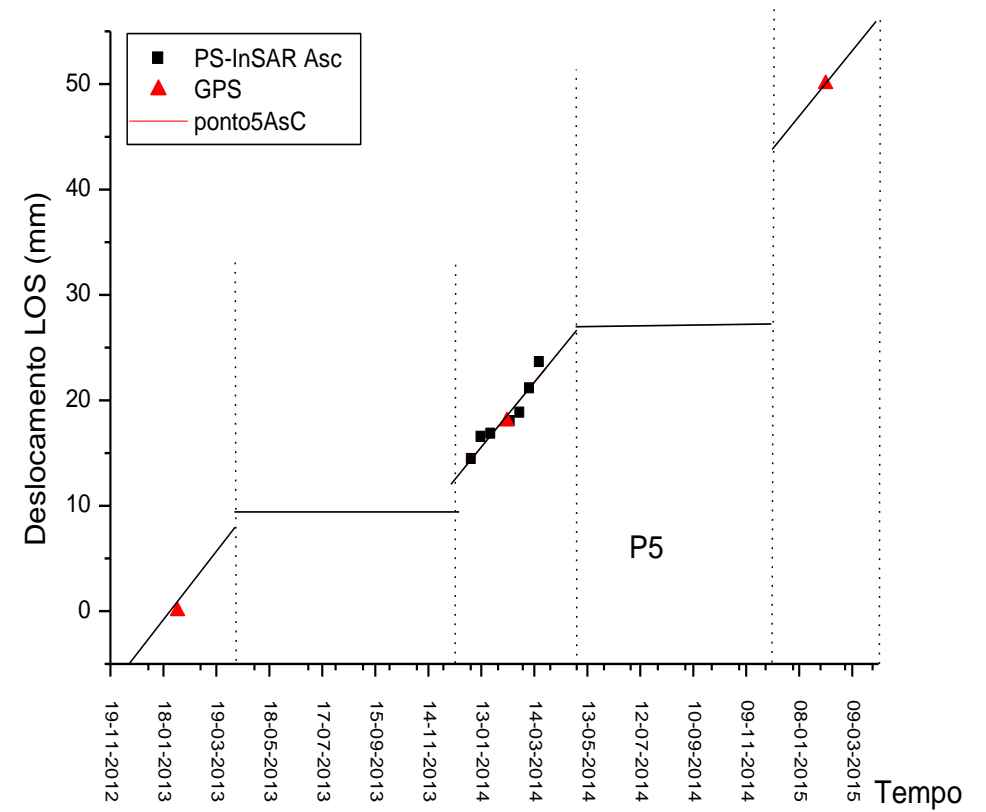
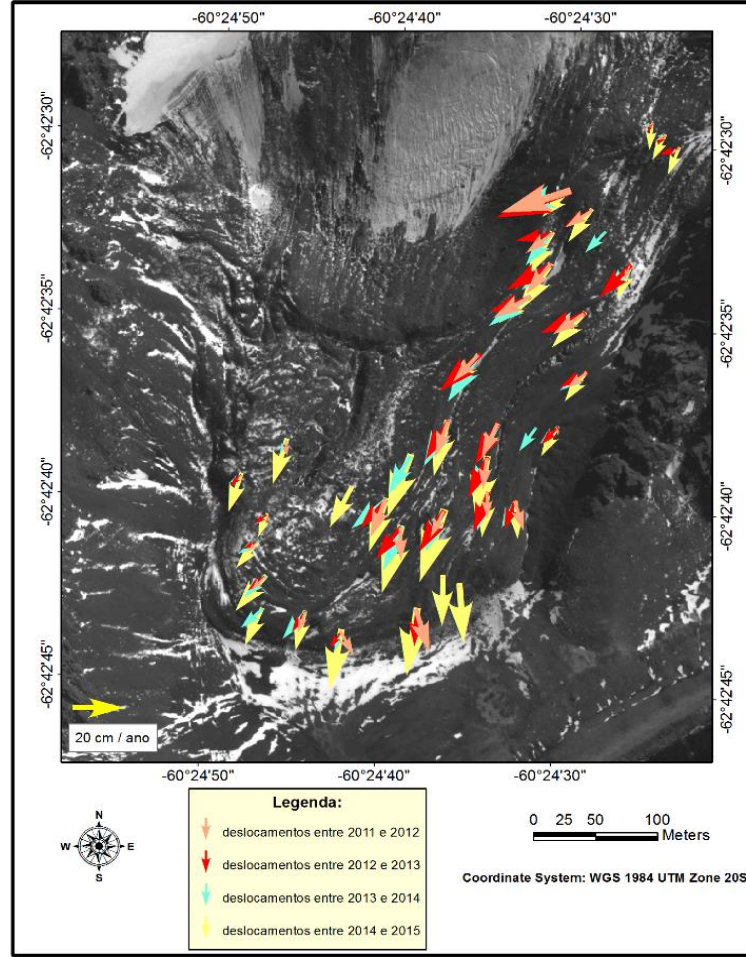
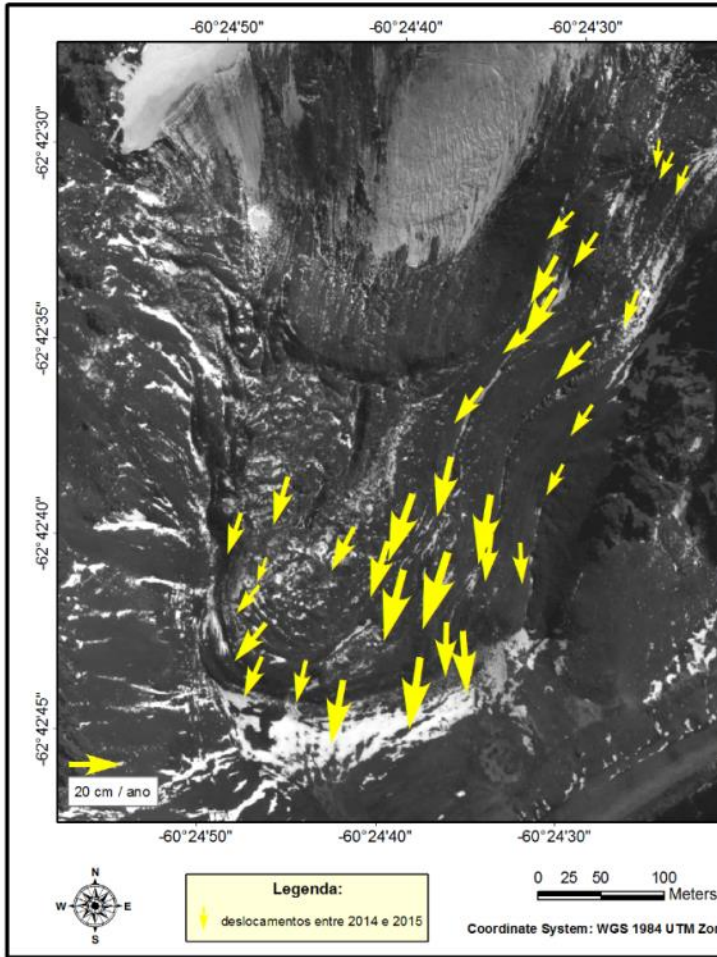
E. Rignot et al., Science, September 2011

1000 km

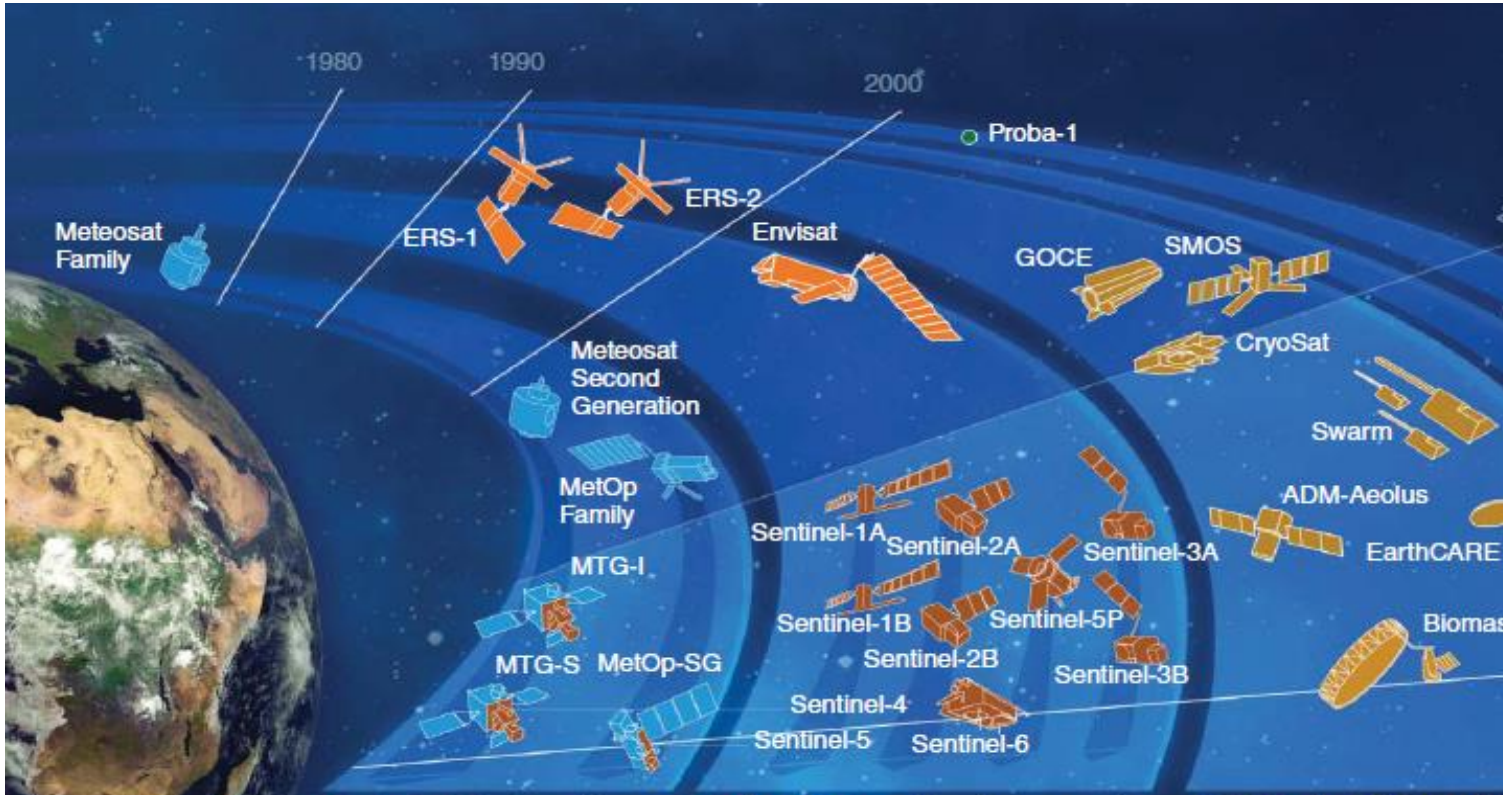


(InSAR)





Missões ESA



Meteorological Missions driven mainly by weather forecasting and climate monitoring needs. These missions developed in partnership with EUMETSAT include the Meteorological Operational satellite programme [MetOp], forming the space segment of EUMETSAT's polar system [EPS], and the new generation of Geostationary Meteorological satellites [MSG & MTG satellites].

Sentinel Missions driven by user needs to contribute to European Copernicus initiative. These satellite missions developed in partnership with the EU include C-band imaging radar [Sentinel-1], high-resolution optical [Sentinel-2], optical and infrared radiometer [Sentinel-3] and atmospheric composition monitoring capability [Sentinel-4 & Sentinel-5 onboard Met missions MTG and EPS-SG respectively].

Earth Explorer Missions driven by Scientific needs to advance understanding of how the ocean, atmosphere, hydrosphere, and Earth's interior operate as part of an interconnected system. These research missions, exemplifying Europe's excellence in technological innovation, pave the way towards development of future EO applications.

ENVISAT/ ASAR	2002–2012	C (dual)
ALOS/PalsAR	2006–2011	L (quad)
TerraSAR-X/ TanDEM-X	2007–today 2010–today	X (quad)
Radarsat-2	2007–today	C (quad)
COSMO-SkyMed-1/4	2007 ... 2010–today	X (dual)
RISAT-1	2012–today	C (quad)
HJ-1C	2012–today	S (VV)
Kompsat-5	Launch scheduled in 2013	X (dual)
PAZ	Launch scheduled in 2013	X (quad)
ALOS-2	Launch scheduled in 2013	L (quad)
Sentinel-1a/1b	Launch scheduled in 2013/2015	C (dual)
Radarsat Constellation-1/2/3	Launch scheduled in 2017	C (quad)
SAOCOM-1/2	Launch scheduled in 2014/2015	L (quad)

Sent-1A/B



Sentinel-2A/B



Sentinel-3A/B



Sentinel-4A/B



Sentinel-5/5P











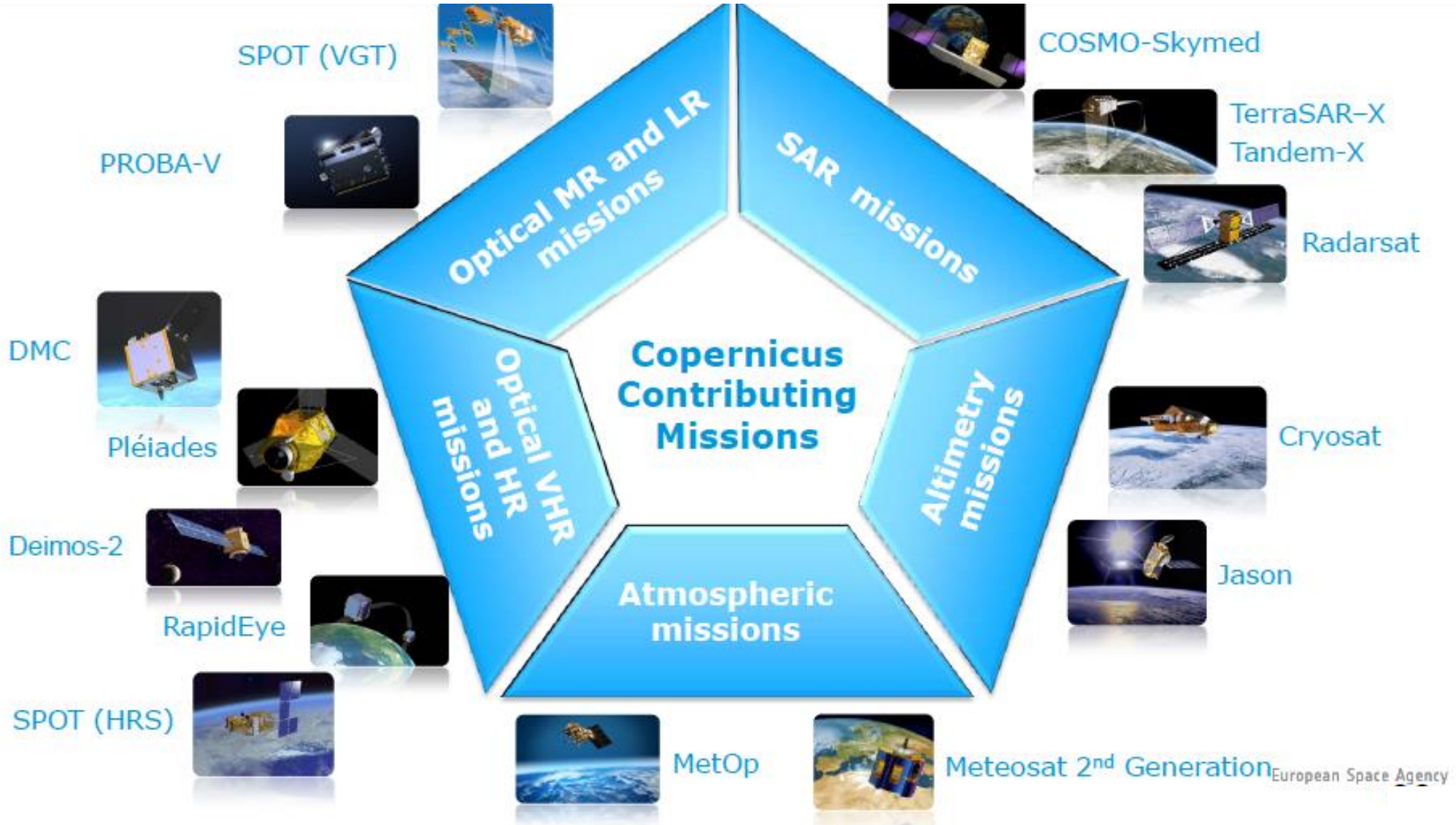
Sentinel-6A/B



- Copernicus is a European space flagship programme led by the European Union
- Copernicus provides the necessary data for operational monitoring of the environment and for civil security
- ESA coordinates the space component



 S1A/B: Radar Mission	 2014/2016
 S2A/B: High Resolution Optical Mission	2015/2016
 S3A/B: Medium Resolution Imaging and Altimetry Mission	2015/2017
 S4A/B: Geostationary Atmospheric Chemistry Mission	2019/2027
 S5P: Low Earth Orbit Atmospheric Chemistry Mission	2016
 S5A/B/C: Low Earth Orbit Atmospheric Chemistry Mission	2020/2027
 S6-(Jason-CS) A/B: Altimetry Mission	2019/2025





Sentinel Scientific Toolboxes



Sentinel-1 (A/B/C/D) – SAR Imaging

All weather, day/night applications, interferometry



Sentinel-2 (A/B/C/D) – Multi-Spectral Imaging

Land applications: urban, forest, agriculture, ...
Continuity of Landsat, SPOT



Sentinel-3 (A/B/C/D) – Ocean & Land Monitoring

Wide-swath ocean color, vegetation, sea/land surface temperature and altimetry

- ❑ The Toolboxes are based on sound heritage but also offer innovative technologies for analysing, processing and visualizing EO data.
- ❑ The Toolboxes are implemented incrementally in several releases with additional functionality to the public.
- ❑ Available free of charge, in line with the Sentinel free and open data policy.

→ SNAP

SNAP 2.0-beta-07



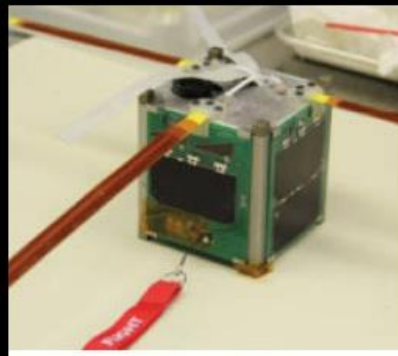
Technology

NASA Small Satellites to Demonstrate Swarm Communications and



Robotics

First CubeSat Built by an Elementary School Deployed into Space

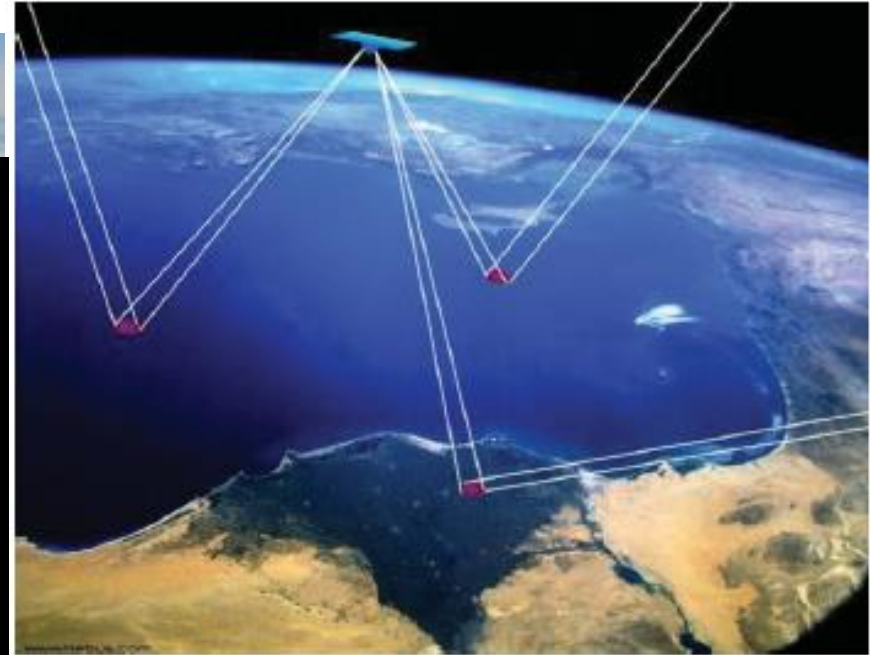
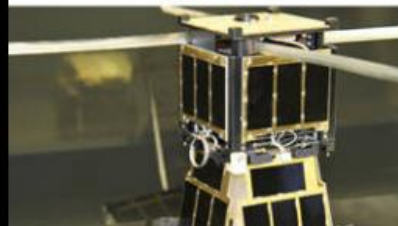


The CubeSat Launch Initiative

NASA's CubeSat Launch initiative (CSLI) provides opportunities for small satellite payloads to fly on rockets planned for upcoming launches. These CubeSats are flown as auxiliary payloads on previously planned missions.

To participate in the CSLI program, CubeSat investigations should address research in science, exploration, technology, or education consistent with NASA's Strategic Plan and the Education Strategic Coordination Framework.

CSLI provides educational opportunities that attract and retain students, teachers, and faculty in STEM disciplines. This strengthens the nation's future workforce and promotes and innovative partnerships among NASA, U.S. industry, and other sectors for the benefit of agency programs and projects.



SAR

SAR Polarimetry

InSAR

SAR

InSAR

SAR InSAR

SAR Polarimetry

Biosphere

Deforestation, Degradation, Fires* (REDD)

Forest Biomass Change*

Biodiversity

Geosphere

Earthquakes

Volcanic Activities

Land Slides

Cryosphere

Sea Ice Extent*

Permafrost*

Glacier and Ice Cap Dynamics*

Hydrosphere

Soil Moisture*

Flooding

Ocean Currents*



*) Essential Climate Variables



Síntese

- > Missões SAR + Programa Copernicus
- > Formação imagem Radar
- > Interação com a superfície
- > Distorção das imagens SAR
- > Mecanismos Scattering
- > Polarização
- > Interferometria SAR

> ESA / COPERNICUS, Global Monitoring for Environment and Security

