Deteção Remota Micro-ondas

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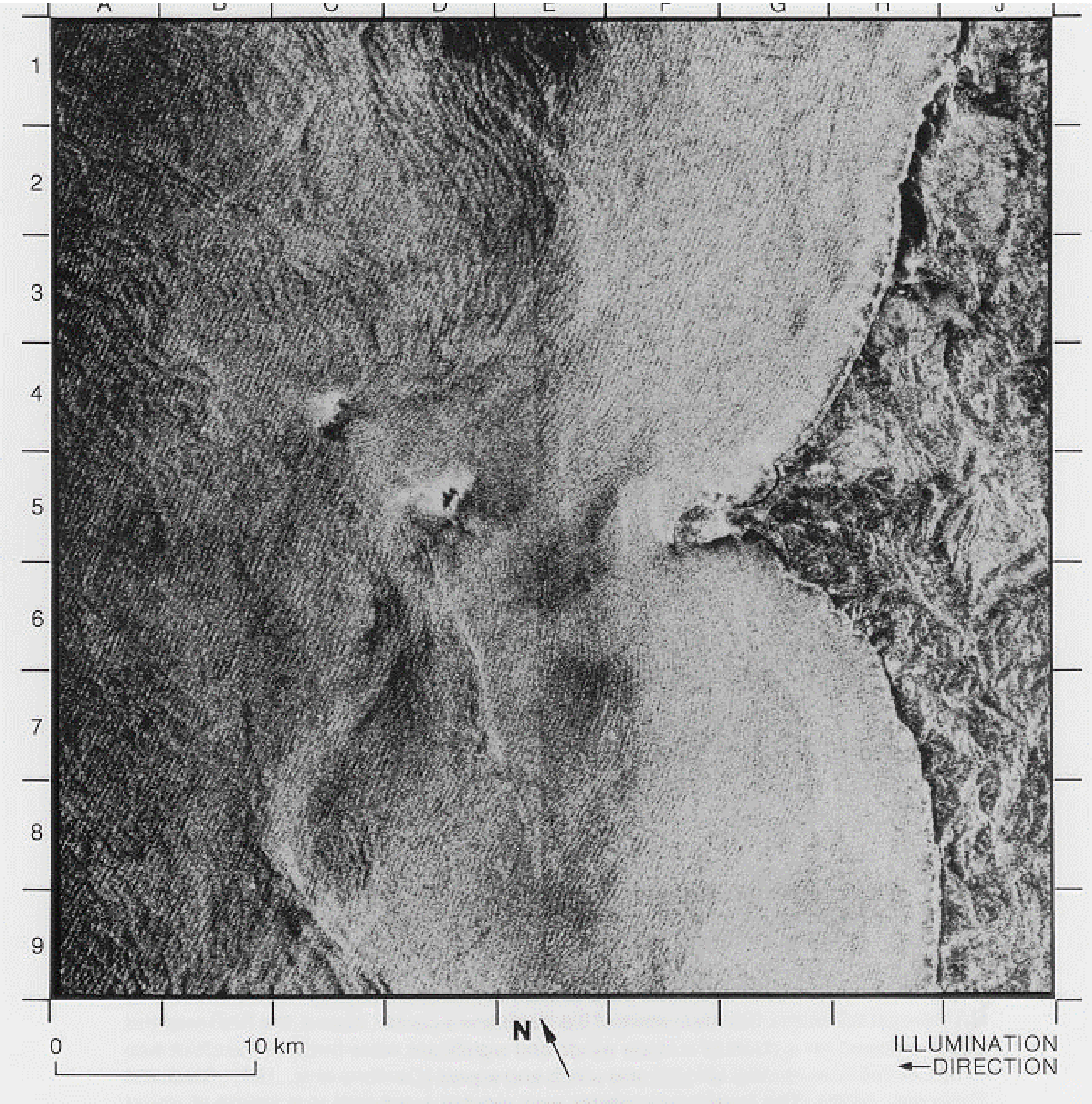
ICEYE

Tópicos

10.1 Deteção 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

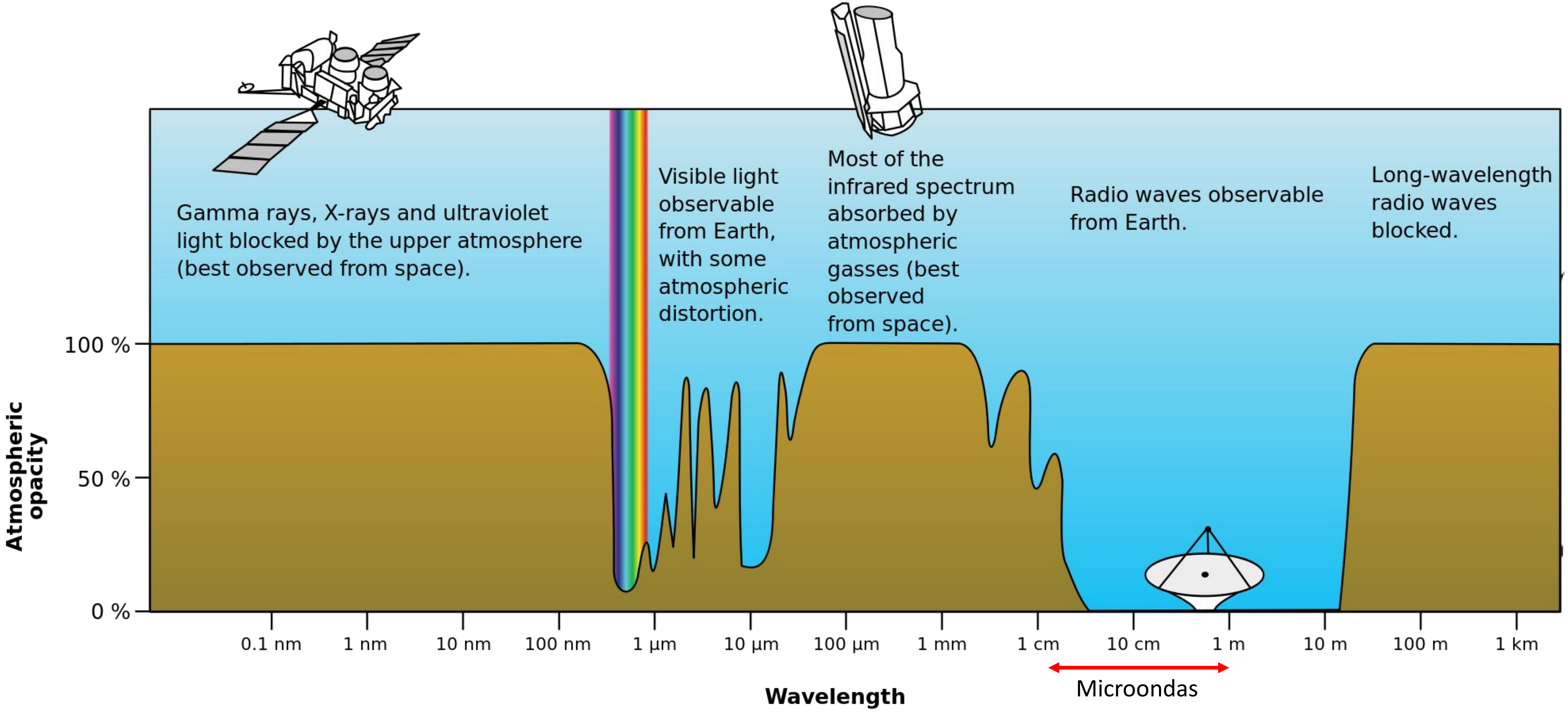
One of the microwave radars on board Seasat was a synthetic-aperture radar (SAR).

(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.

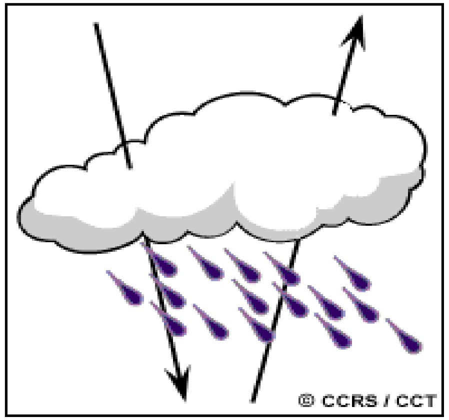
Deteção Remota na banda das microondas



Radio Detection And Raging

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.



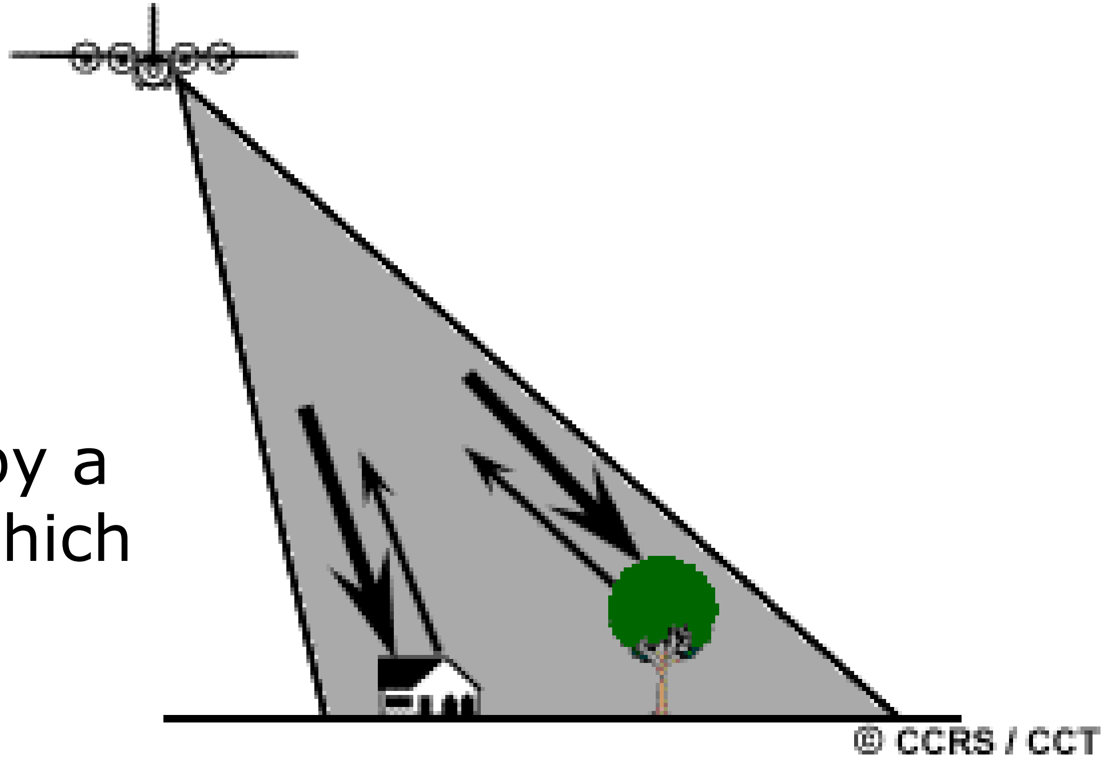
"All-weather"

"Day and Night"

Active Remote Sensing

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)

Deteção Remota Ativa

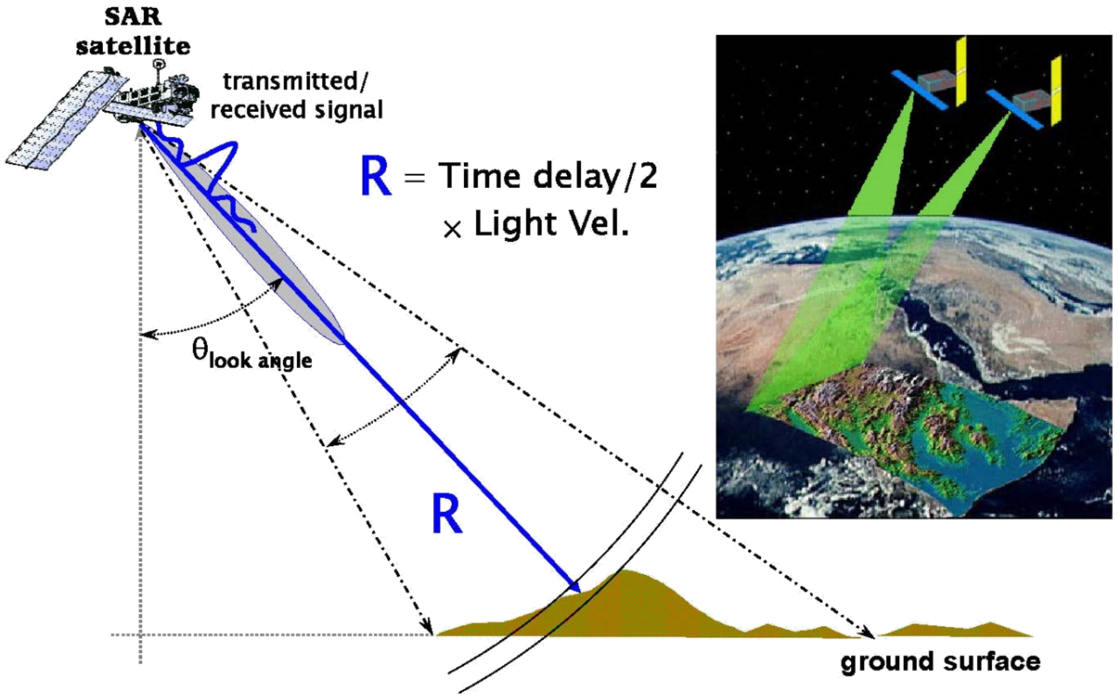
Advantages compared to optical remote sensing

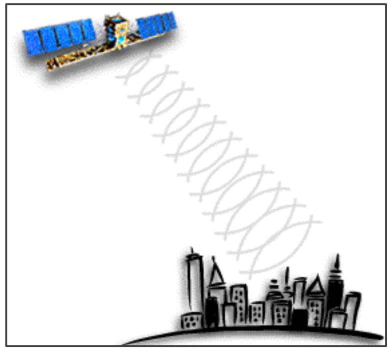
- all weather capability (small sensitivity of clouds, light rain)
- day and night operation (independence of sun illumination)
- no effects of atmospheric constituents (multitemporal analysis)
- sensitivity to dielectric properties (water content , biomass, ice)
- sensitivity to surface roughness (ocean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

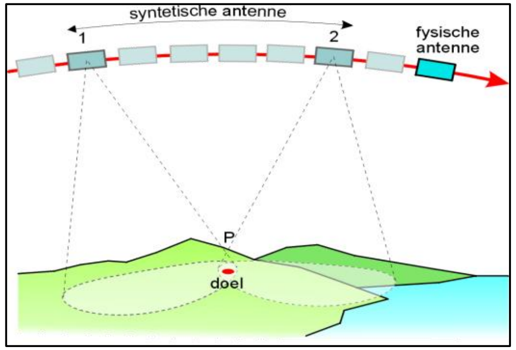
Inconvenients

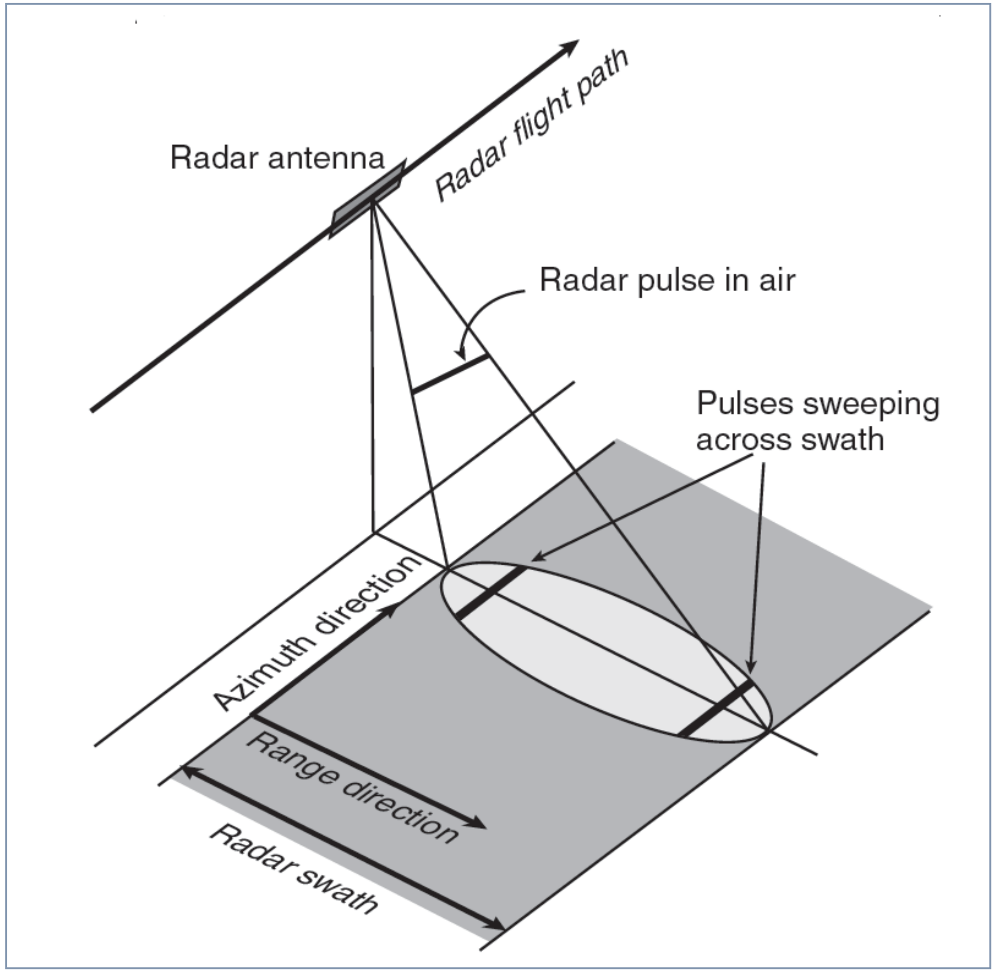
- complex interactions (difficulty in understanding, complex processing)
- speckle effects (difficulty in visual interpretation)
- topograhic effects
- effect of surface roughness

Formação das imagens RADAR



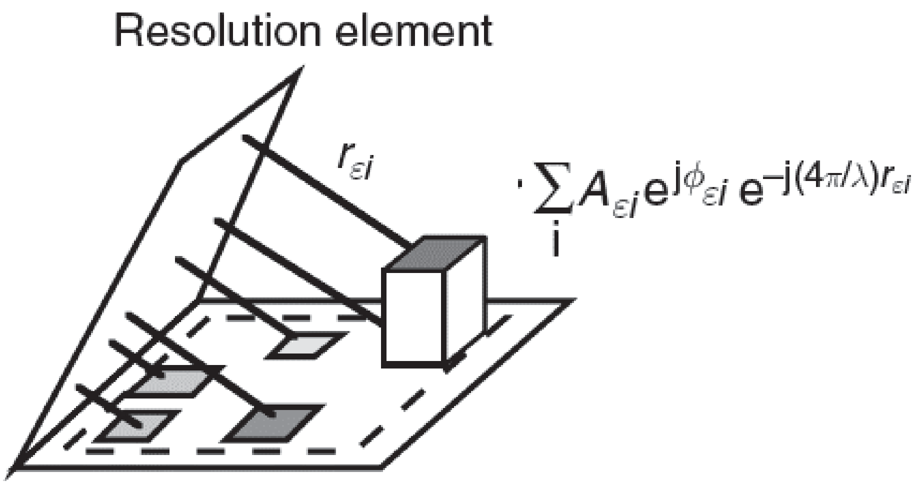


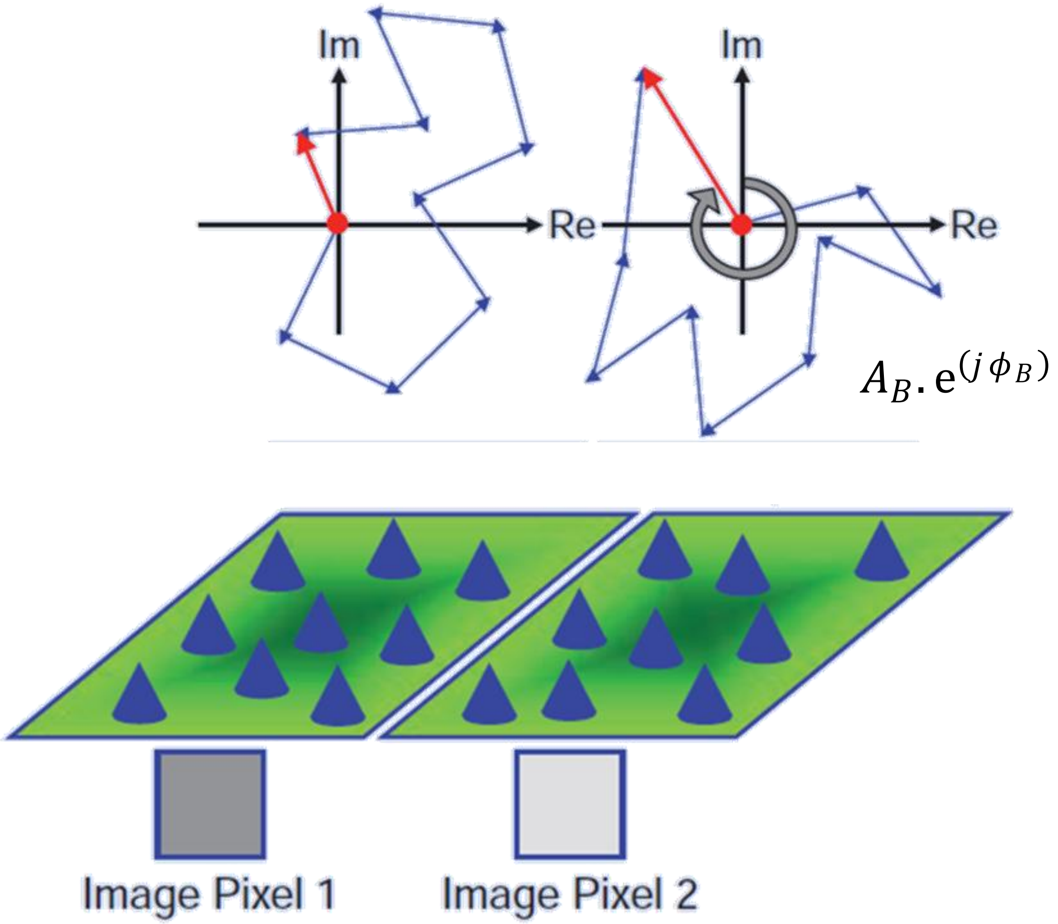




$$s_1 = A.\mathrm{e}^{(j\phi_B)}.e^{\left(-j\left(\frac{4\pi}{\lambda}\right).r_1\right)}$$

Interação com a superfície



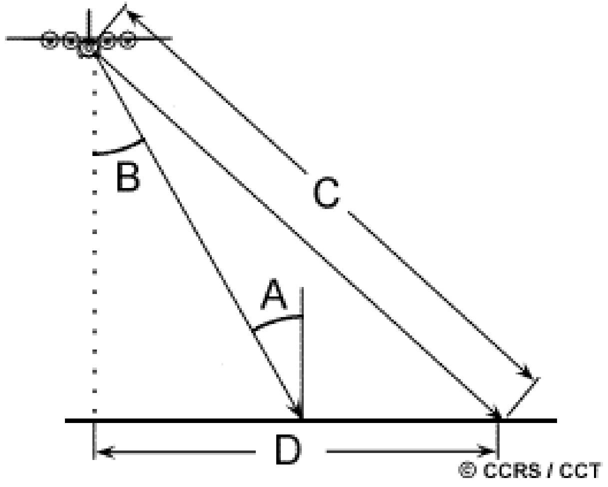


$$s_1 = A_B . e^{(j\,\phi_B)} . e^{\left(-j\left(\frac{4\pi}{\lambda}\right).r\right)}$$

Amplitude

Phase

Geometria e Resolução



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

Aumento da Resolução

Resolução RADAR

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

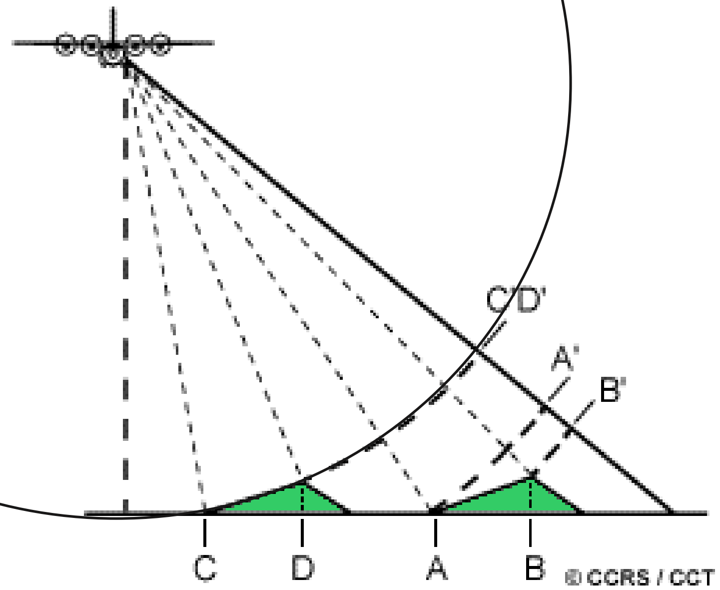
Criação de uma antena sintética : Synthetic Aperture Radar (SAR)

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

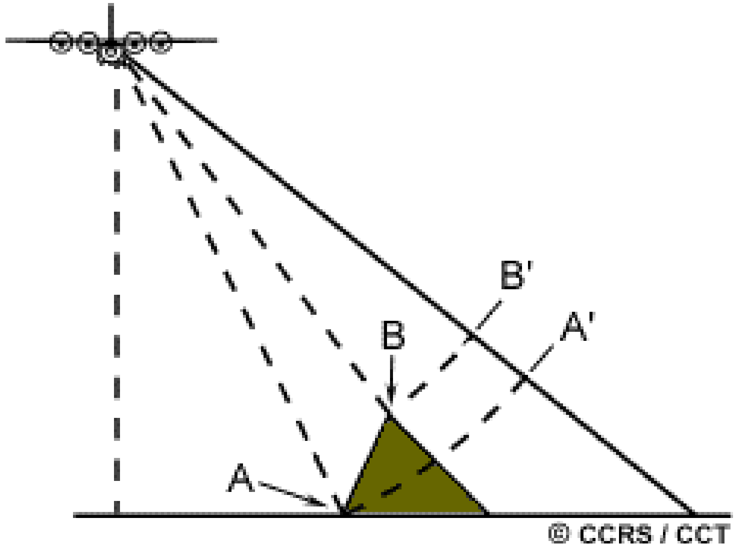
Distorções devidas ao relevo

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

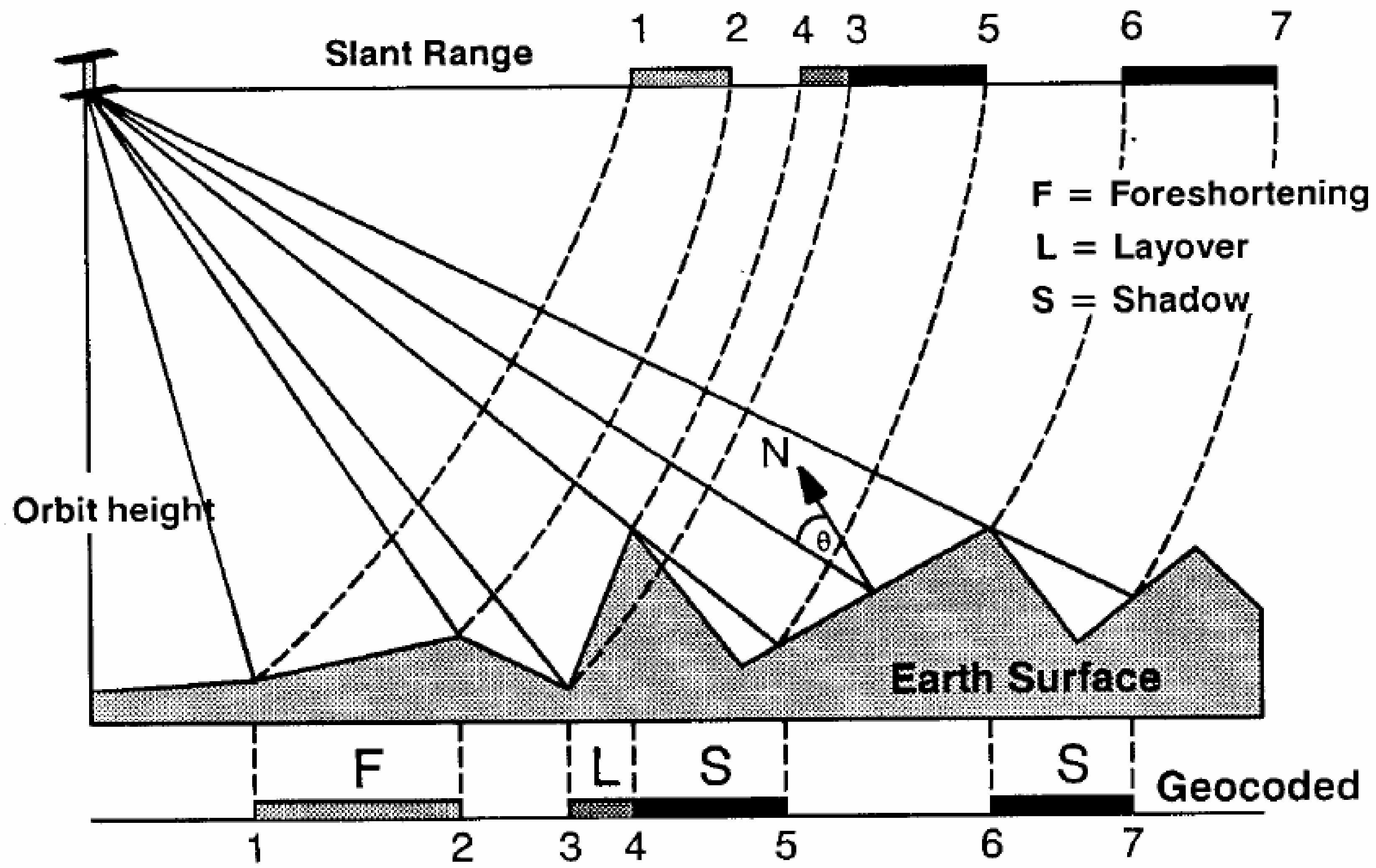
Foreshortening



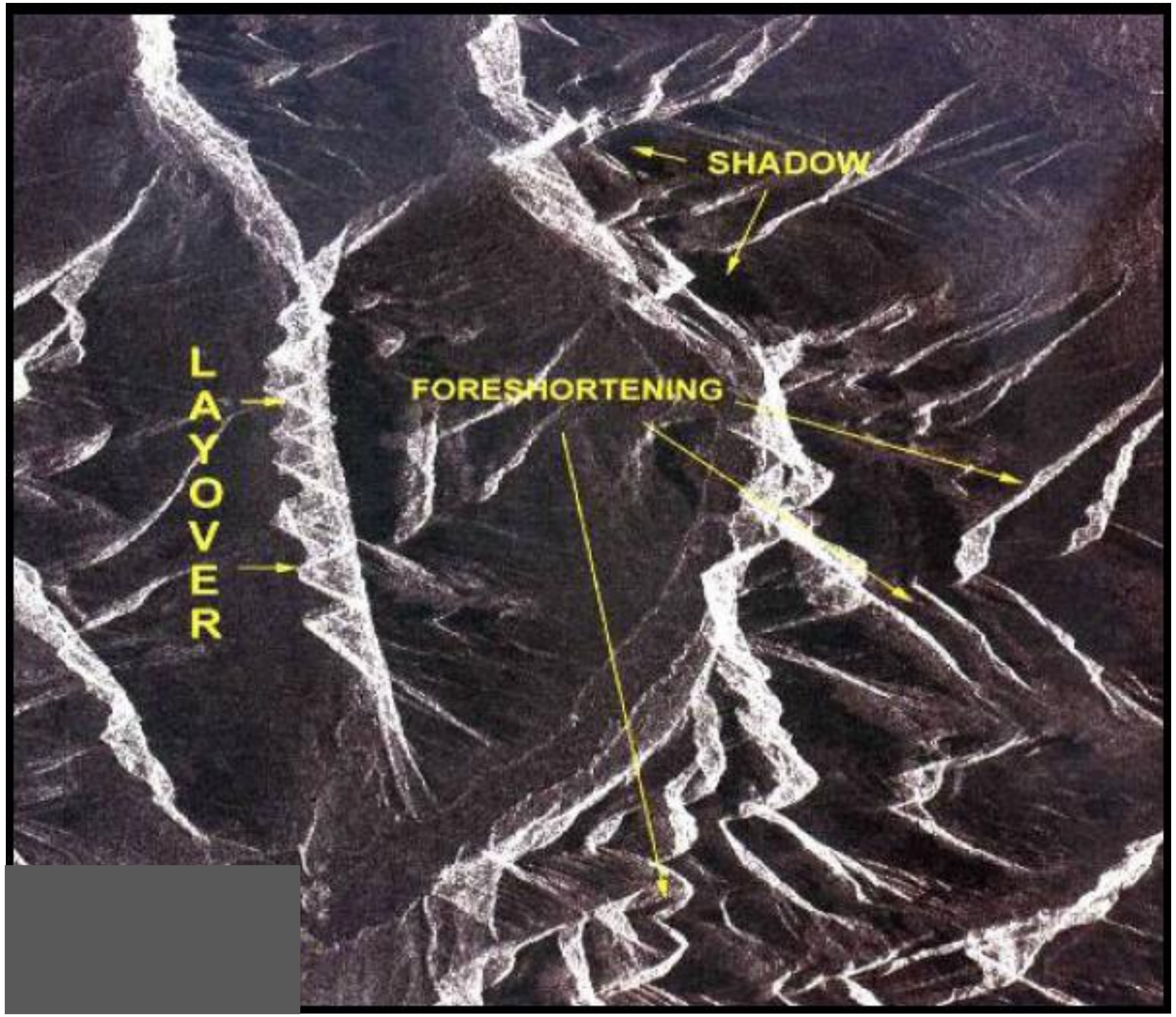
Layover



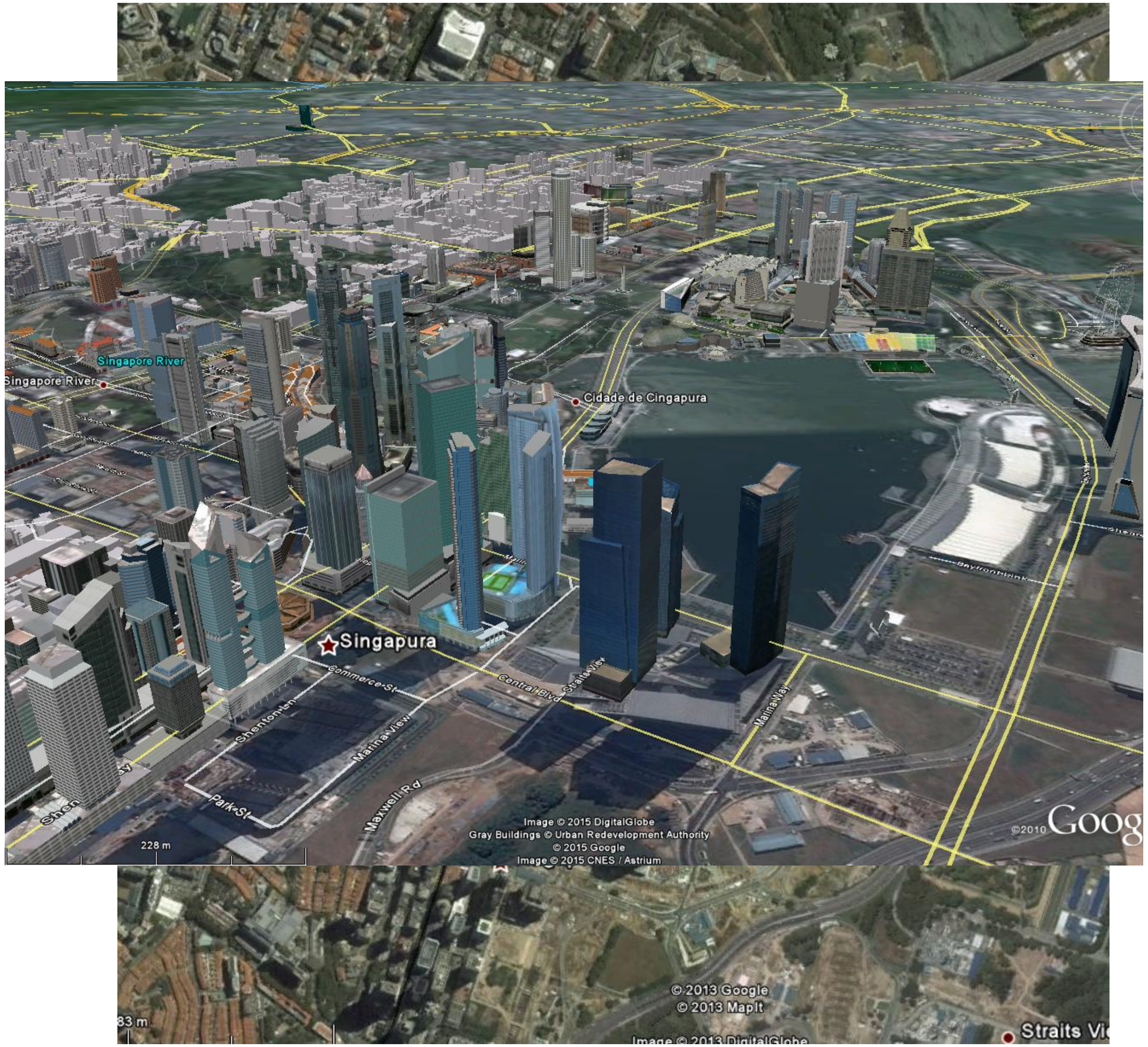
Distorções devidas ao relevo

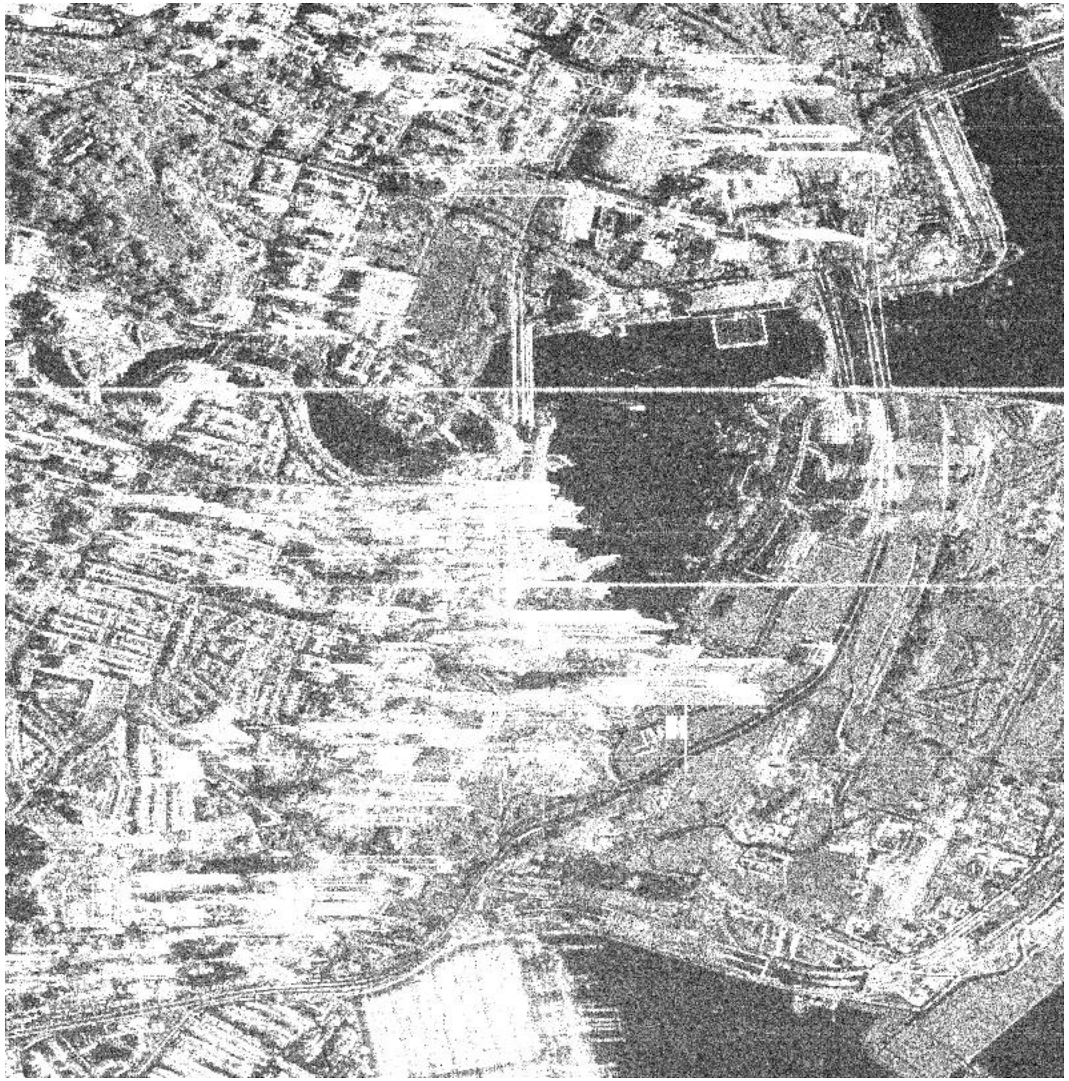


Distorções devidas ao relevo



SAR image


Singapore River
Singapore River
Cidade de Cingapura
Singapura
Commerce St
Central Blvd
Marina View
Park St
Maxwell Rd
228 m
Image © 2015 DigitalGlobe
Gray Buildings © Urban Redevelopment Authority
© 2015 Google
Image © 2015 CNES / Astrium
©2010 Goog
© 2013 Google
© 2013 MapIt
Straits Vi



Scattering Mechanisms

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

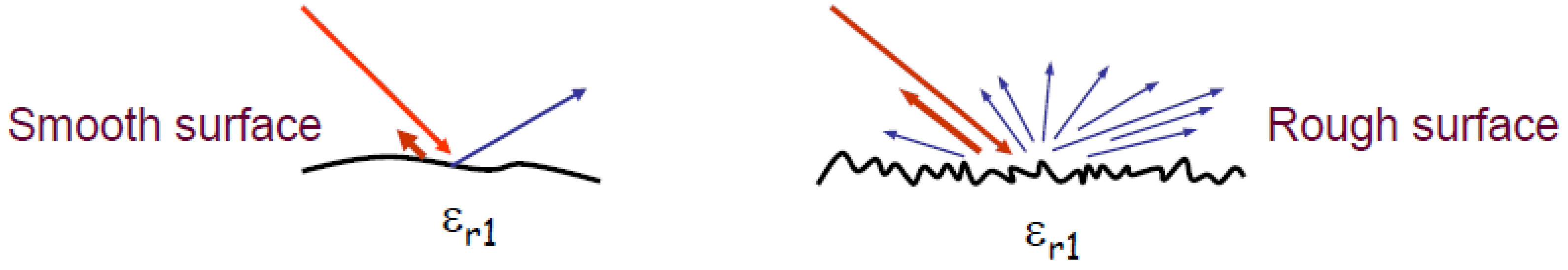
Todos estes factores dependem de:

Frequência do radar

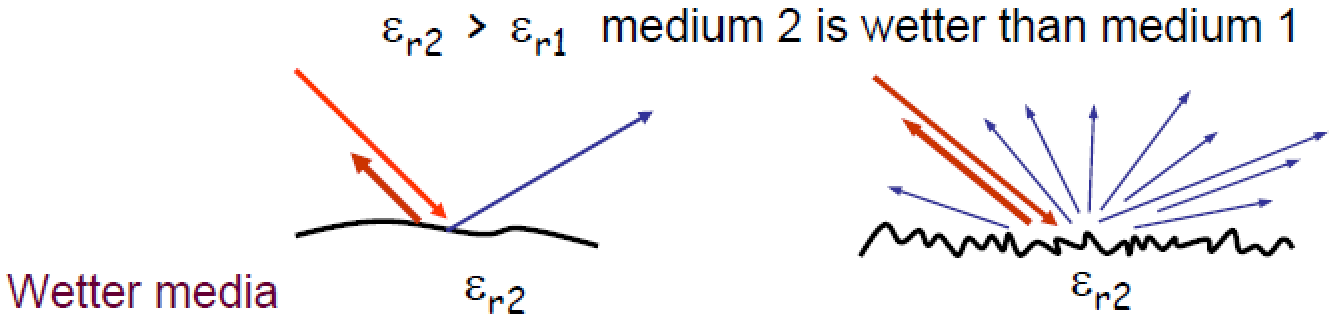
Ângulo de incidência

Polarização

Efeito da rugosidade e humidade

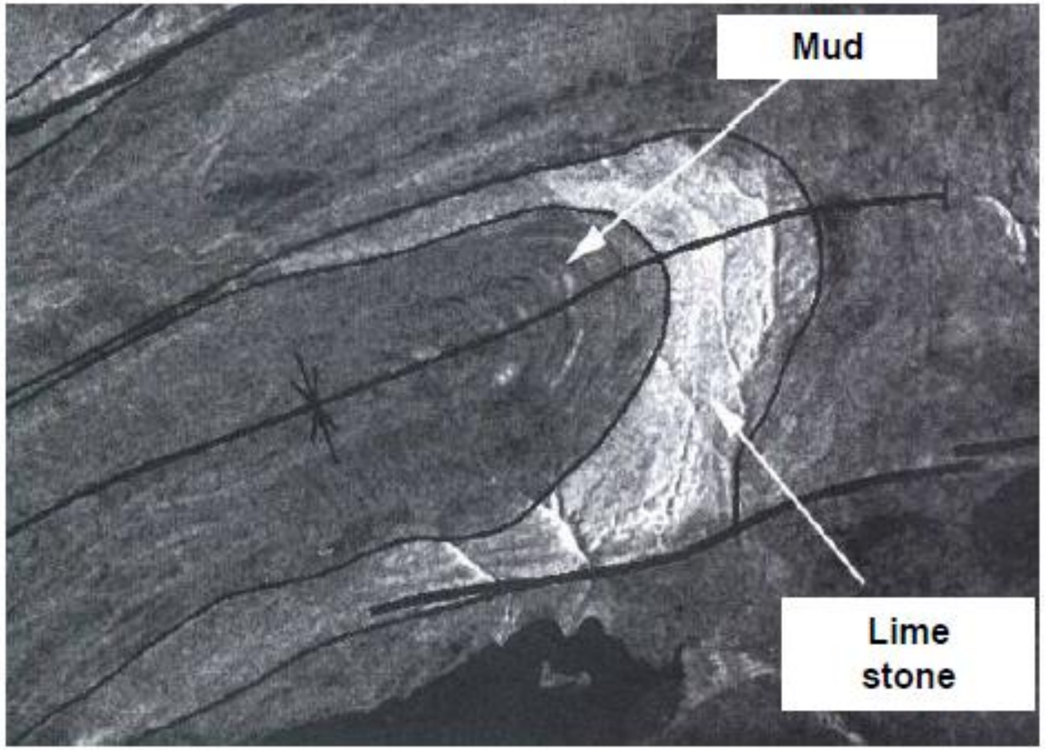


A rugosidade da superfície (relativamente ao comprimento de onda) condiciona o padrão da dispersão.



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

Efeito da rugosidade e humidade



RADARSAT
(C band, HH, 45°)

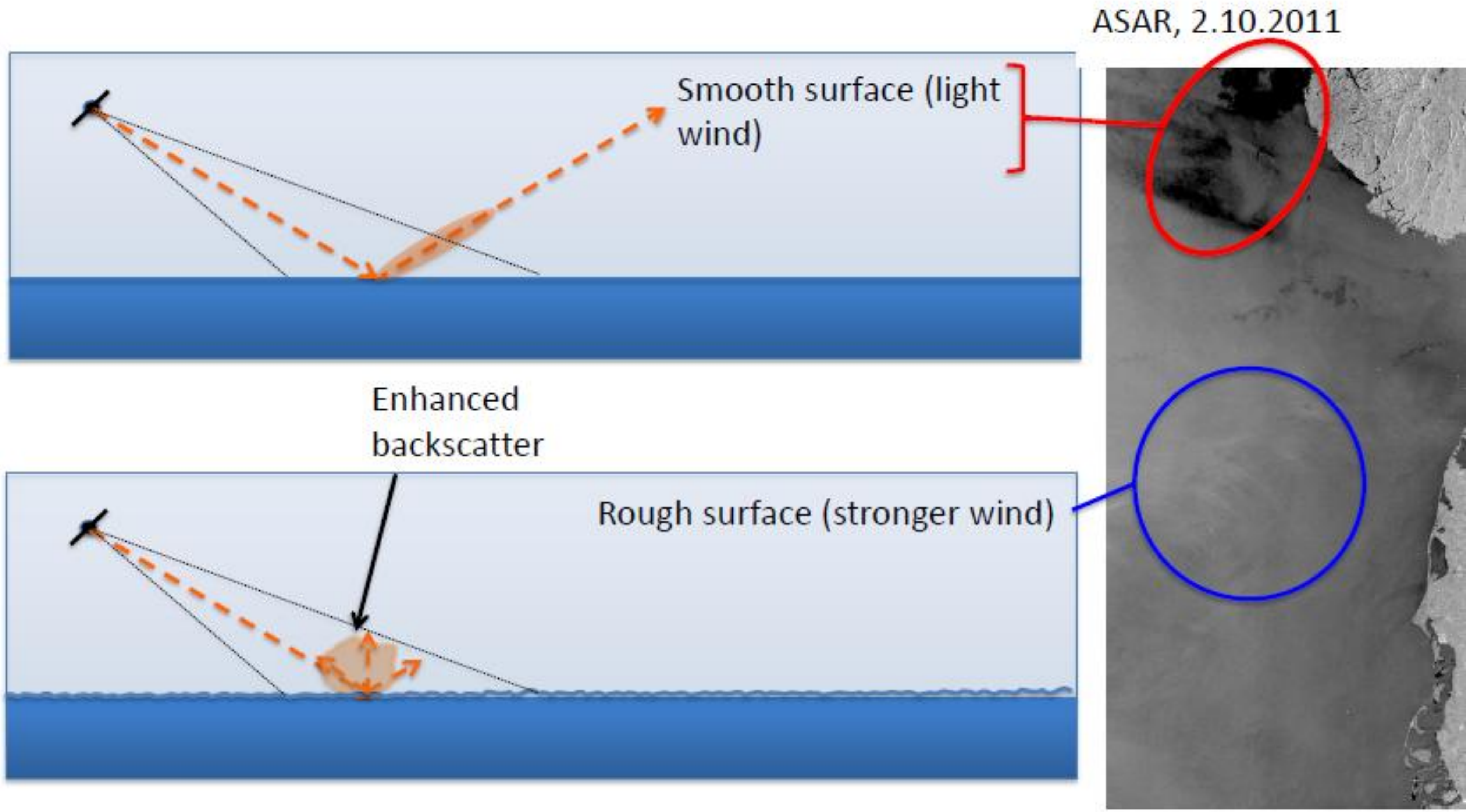
Quaternary lithology:
Bathurst Island, Canada

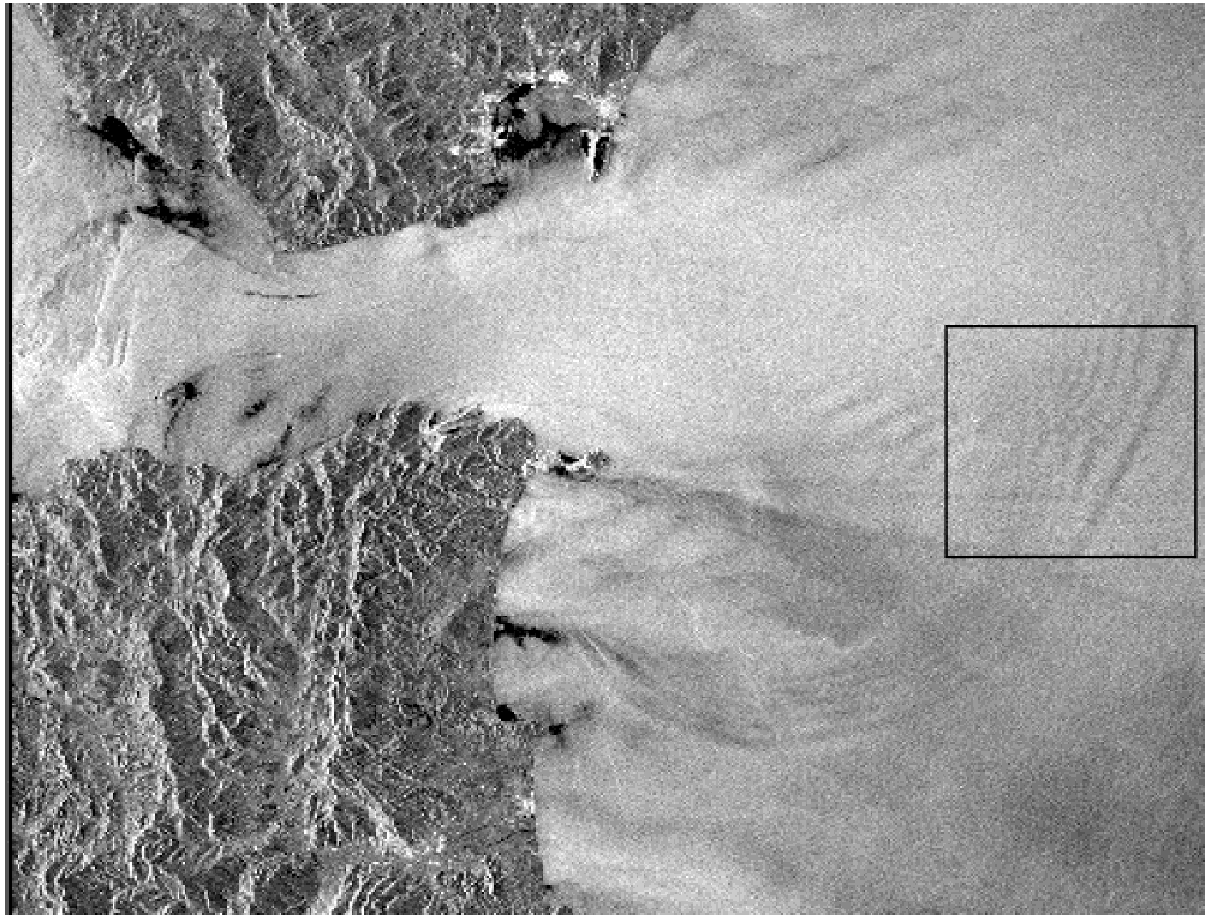
From : RADARSAT Geology Handbook

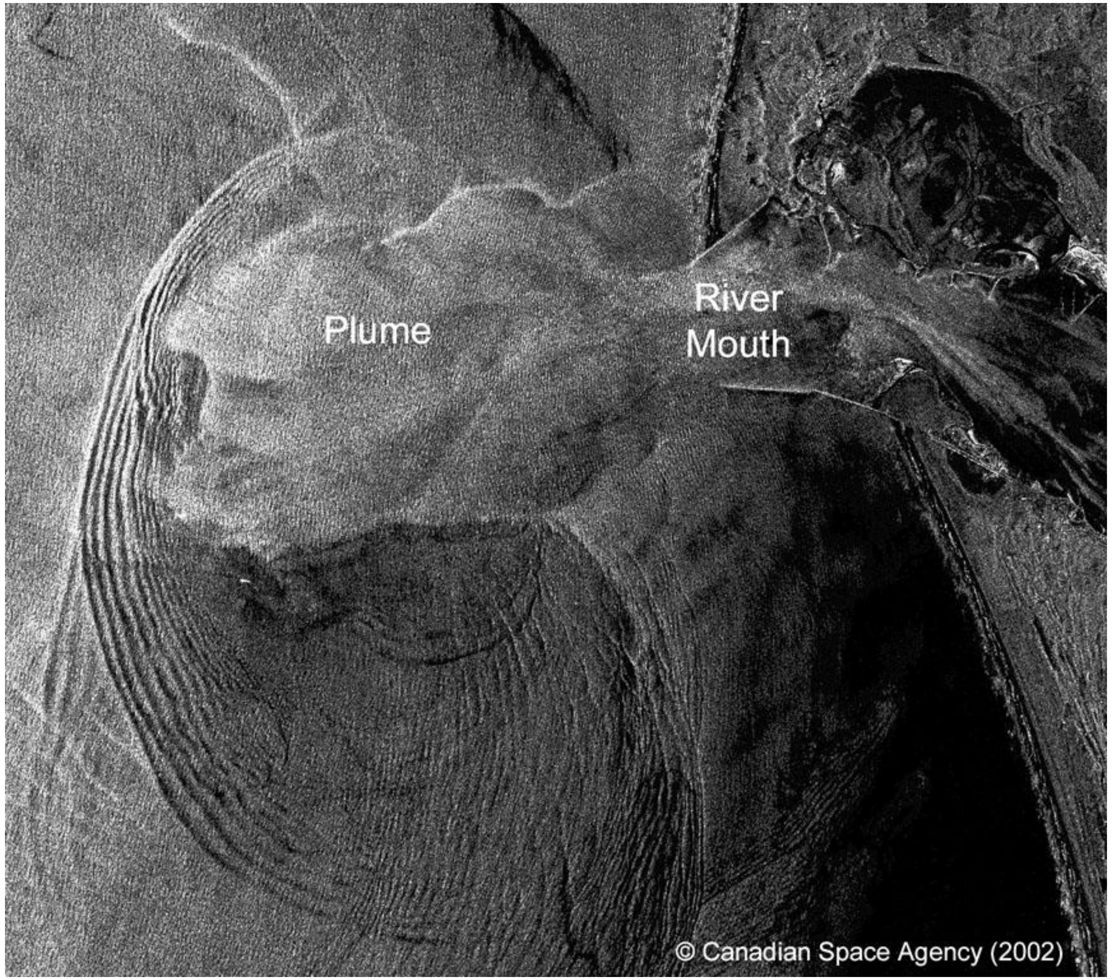
Mud fragments (smooth surface)
➡ low radar backscatter
(marga/argila)

Limestone ➡ **Higher backscatter**
because of rougher surface
(calcário)

Surface roughness and scattering

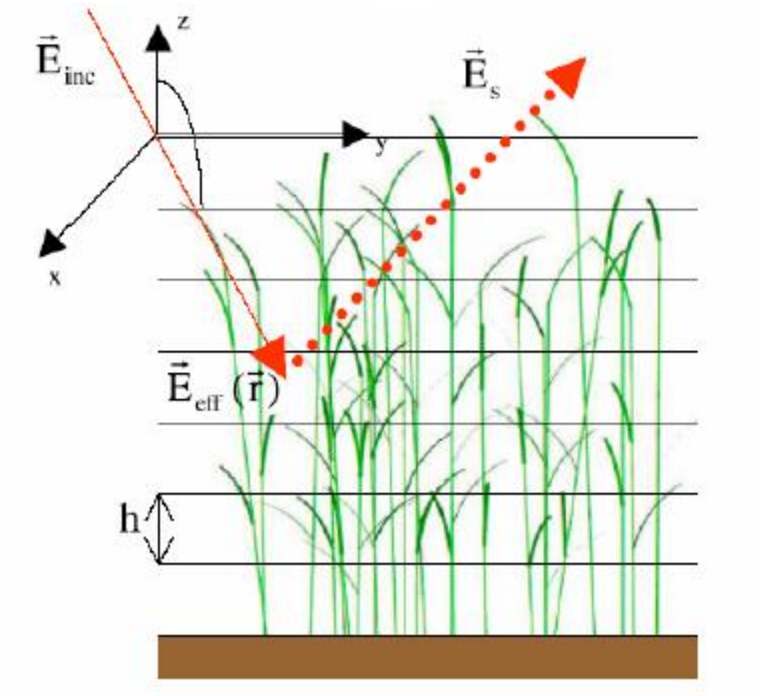


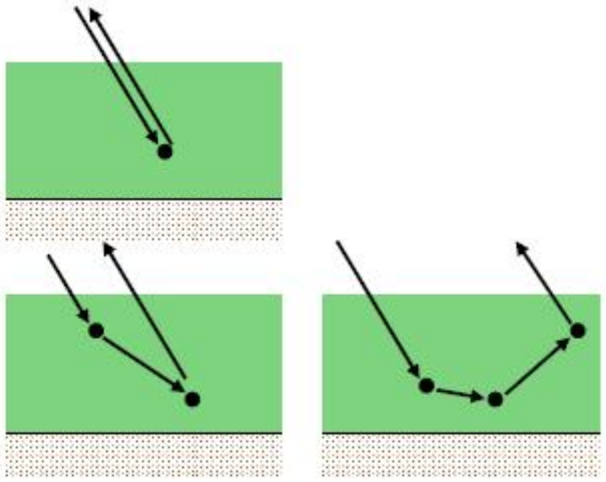



Plume
River
Mouth
© Canadian Space Agency (2002)

Volume scattering

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



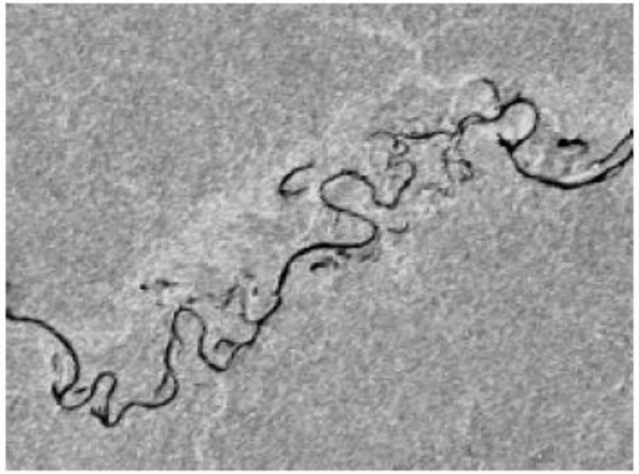


Single and multiple scattering

Penetração através das árvores

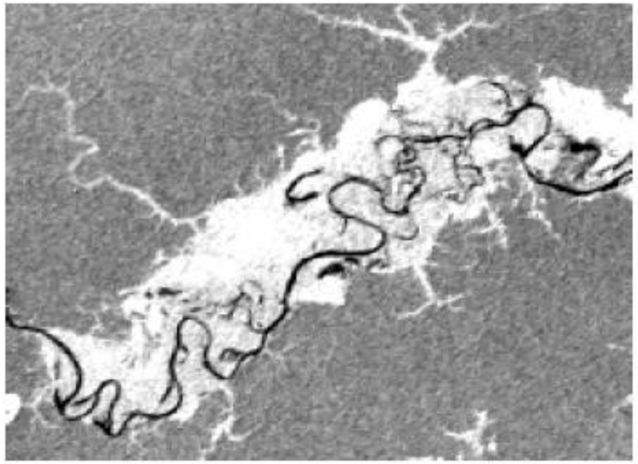
Varzea Dry Season

Varzea Wet Season



P-band image

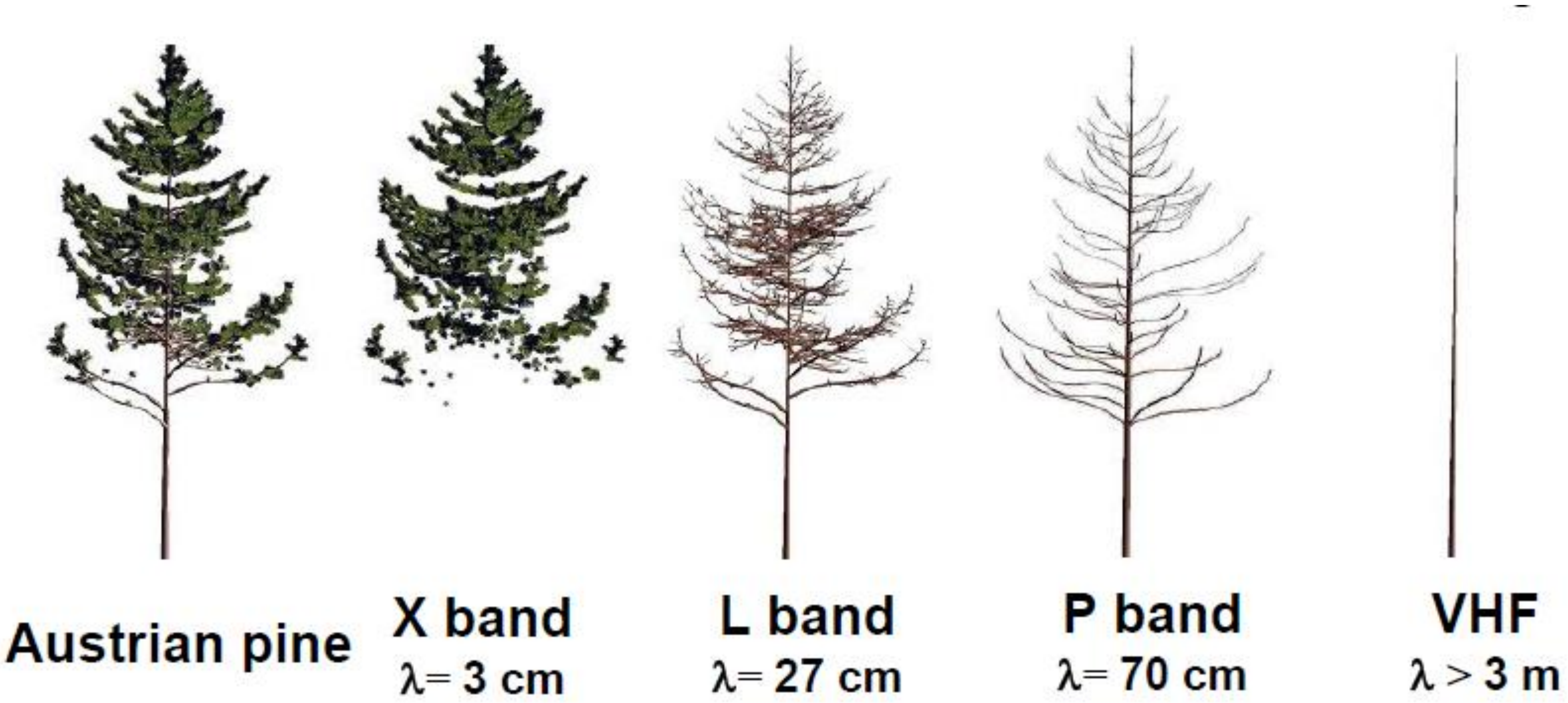
Document S.Saatchi, JPL



P-band image

Volume scattering

Quem são os scatterers numa dispersão volúmica.



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

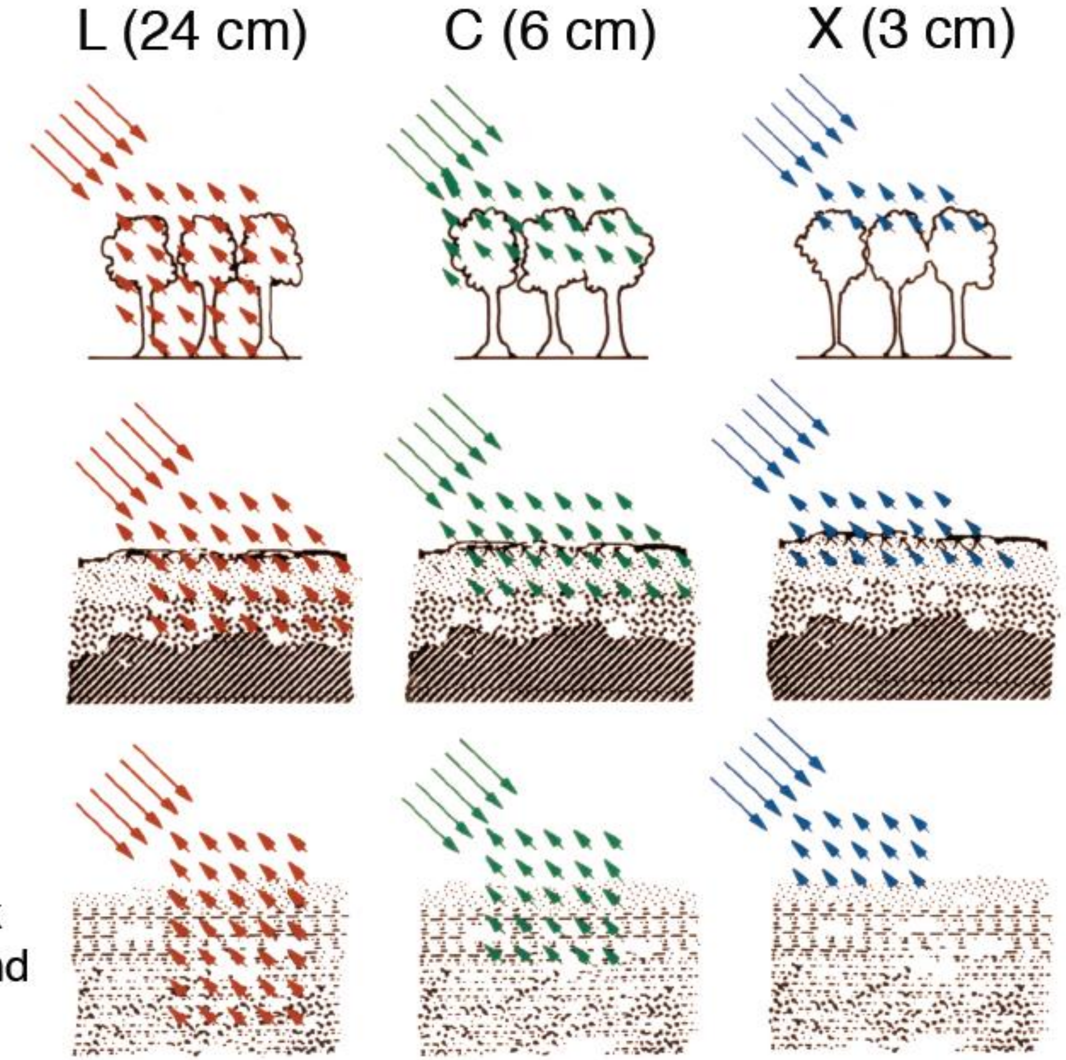
Scaterring / wavelenght

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

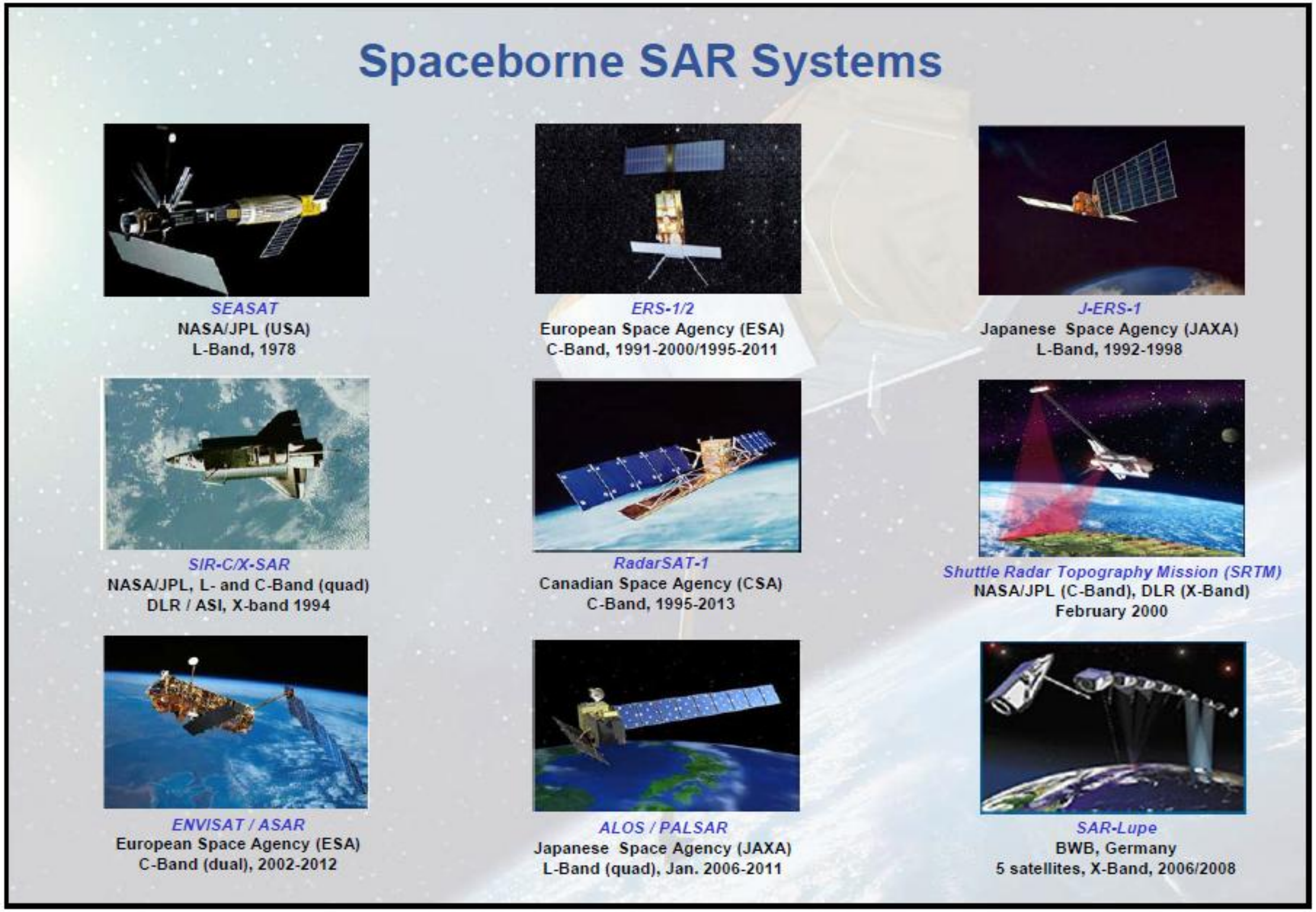
Forest: Leaves reflect X-band wavelengths but not L-band

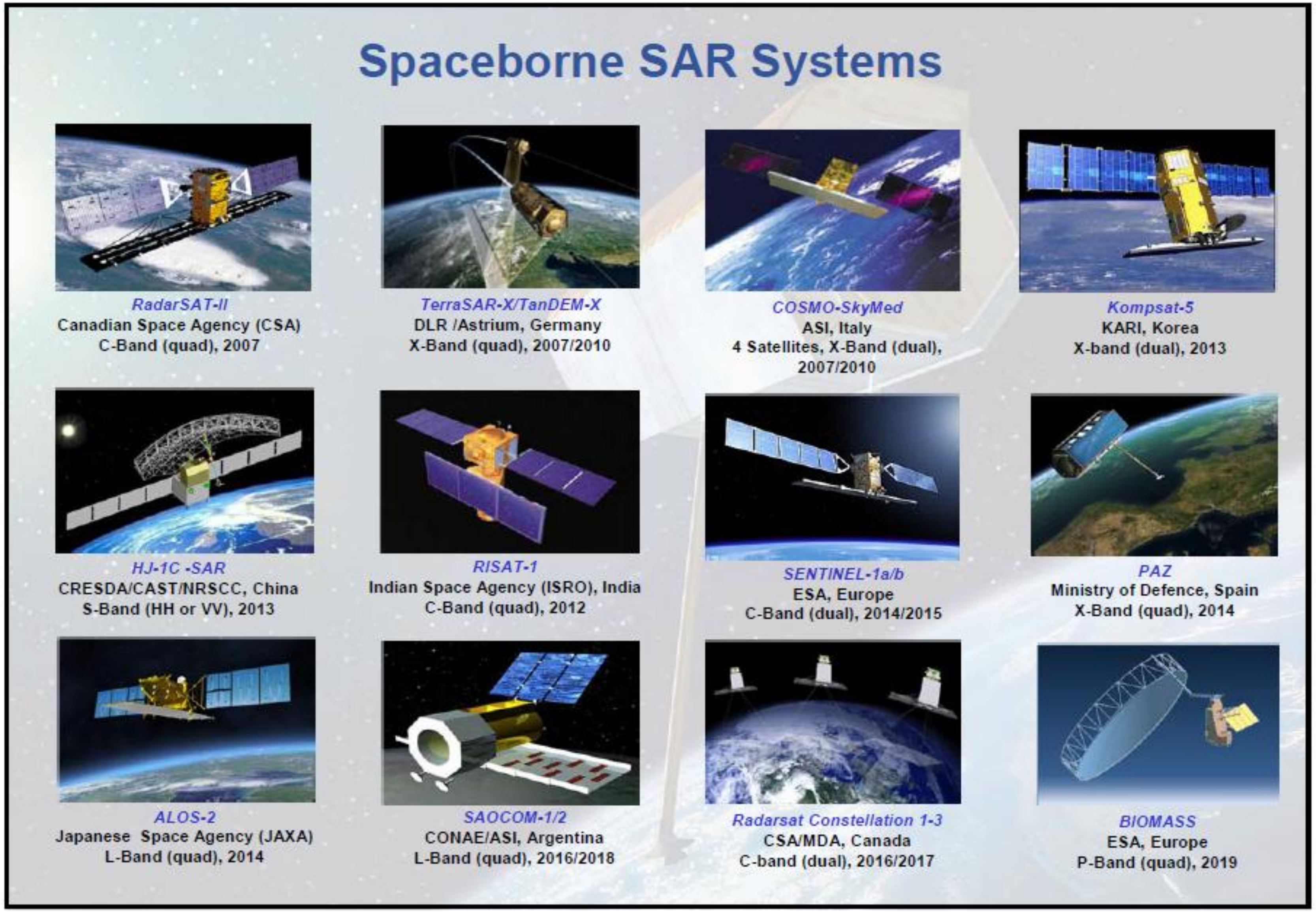
Dry soils: Surface looks rough to X-band but not L-band

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

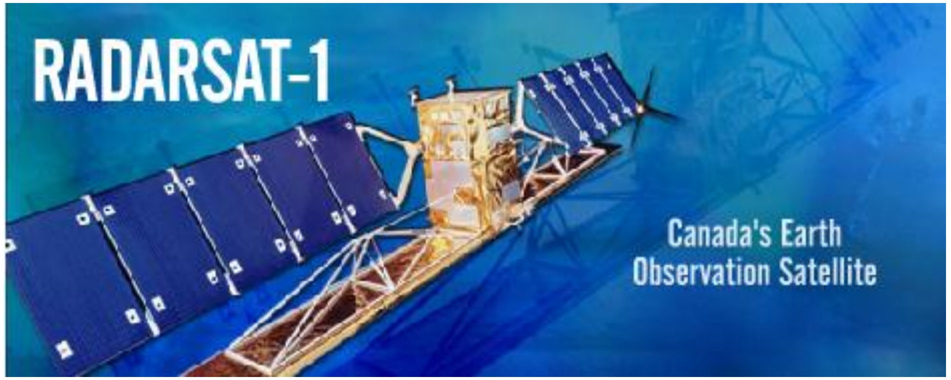


(adapted JPL, 2010)


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
Kompsat-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

RADARSAT

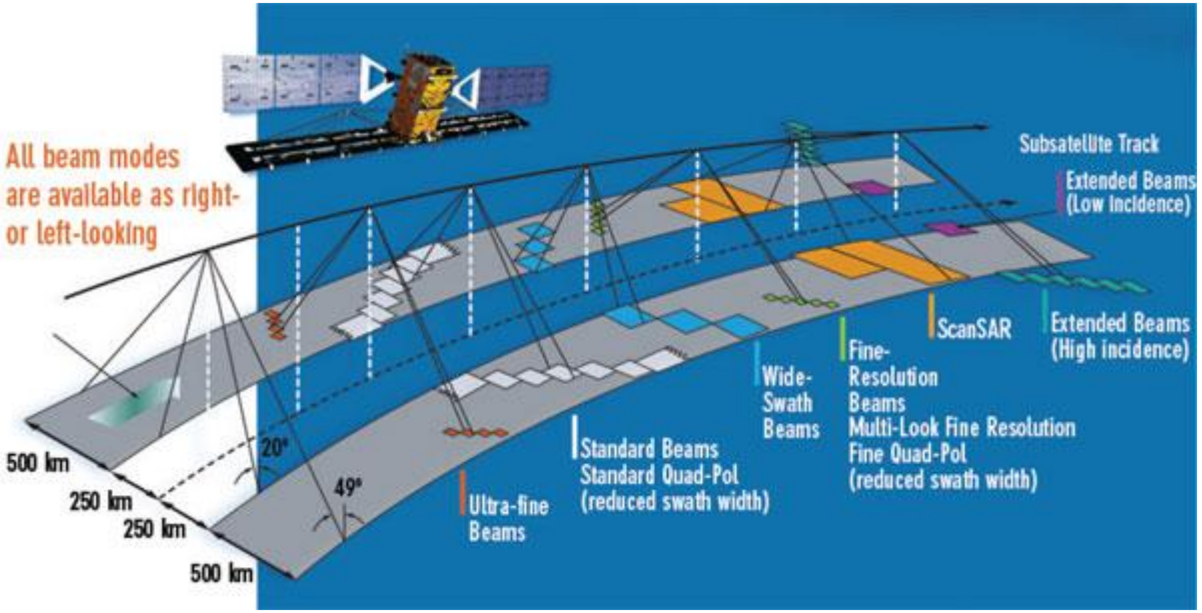


Launched in November 1995, **RADARSAT-1** provides Canada and the world with an operational radar satellite system capable of timely delivery of large amounts of data. Equipped with a powerful synthetic aperture radar (SAR) instrument, it acquires images of the Earth day or night, in all weather and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

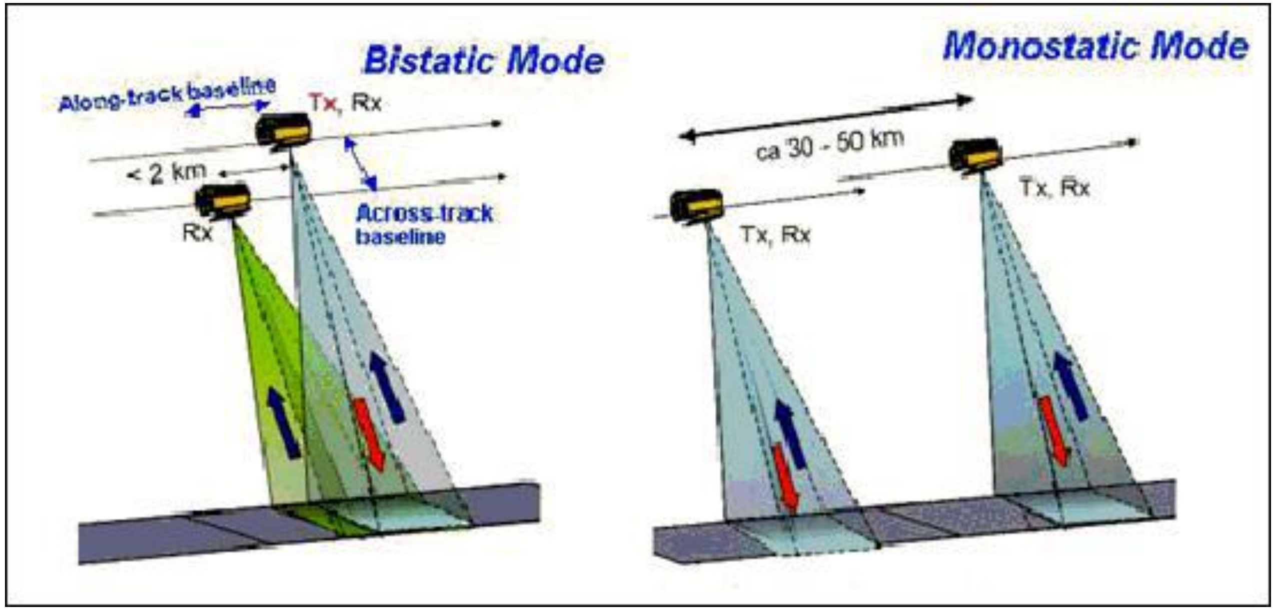
RADARSAT-2

Lançado em 2007

Resolução 3m



TERRASAR-x


Bistatic Mode
Along-track baseline
Tx, Rx
< 2 km
Rx
Across-track baseline
Monostatic Mode
ca 30 - 50 km
Tx, Rx
Tx, Rx

COSMO-SkyMed

COSMO-SkyMed (COnstellation 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.

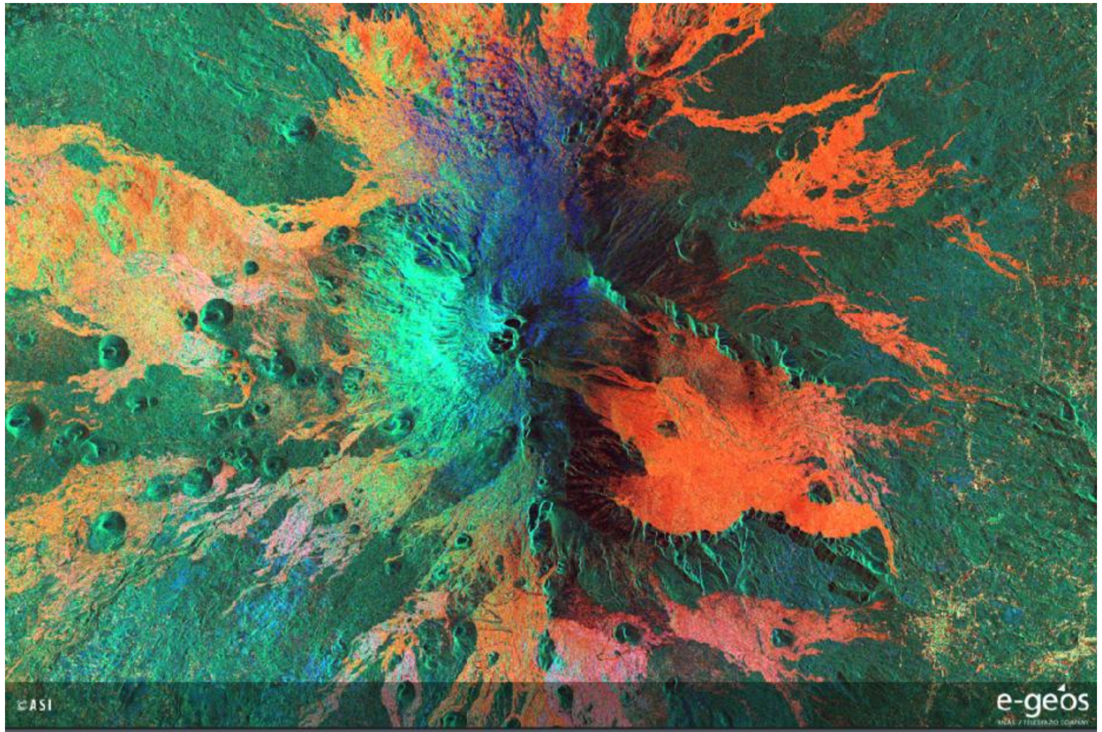
With 4 satellites up to 1800 images per day

Daily scenario example:

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

And

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

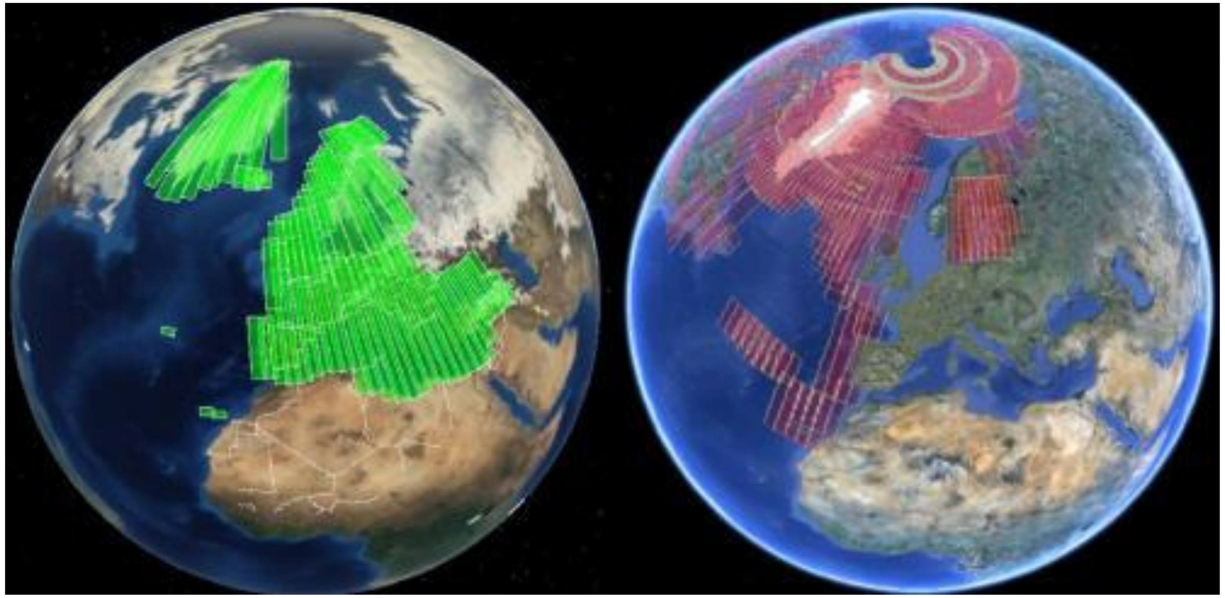


COSMO-SkyMed coherence image Mount Etna

Sentinel-1

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.

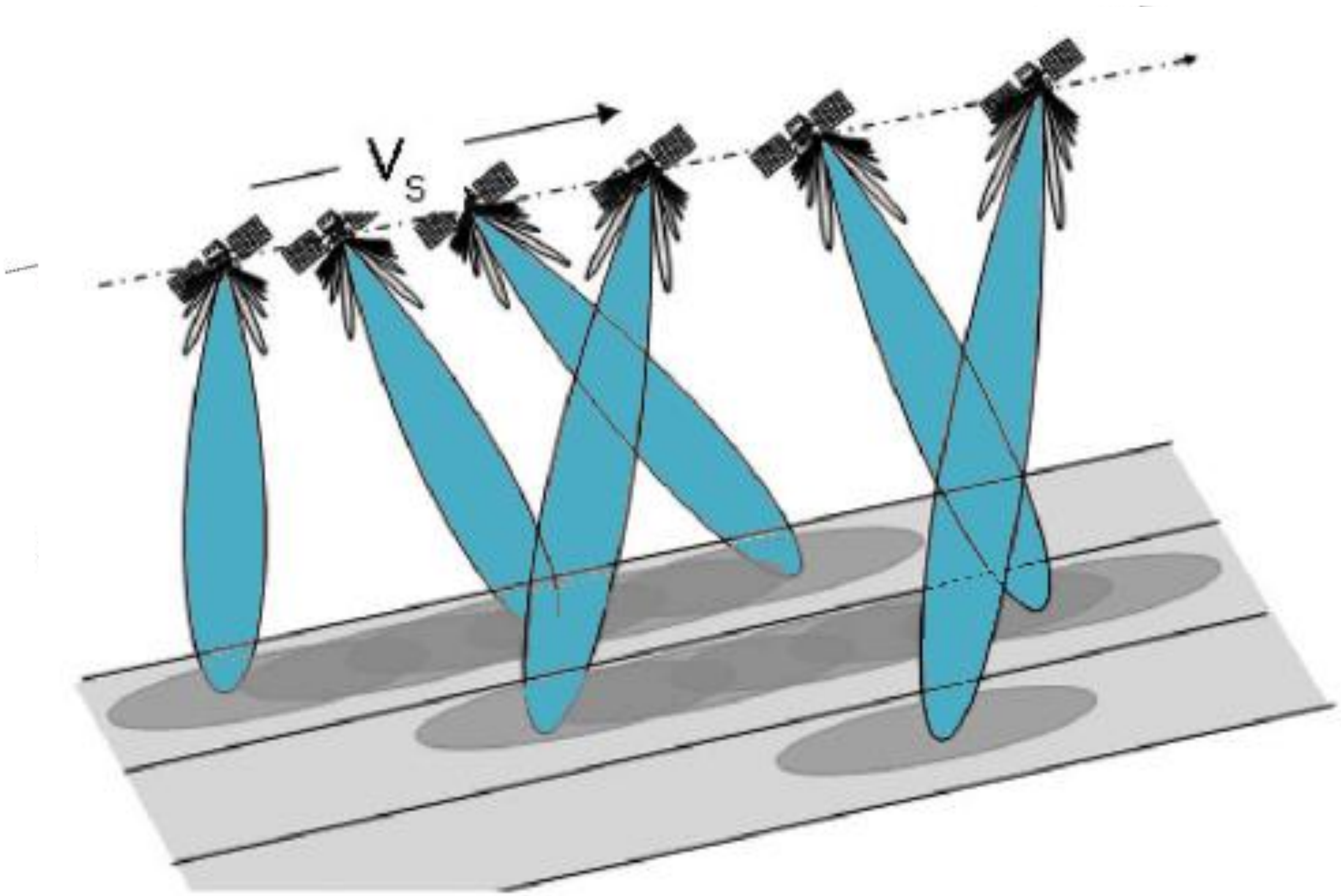
At the equator, however, the repeat frequency is just three days and less than one day over the Arctic. Europe, Canada and main shipping routes are covered in less than three days.



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)

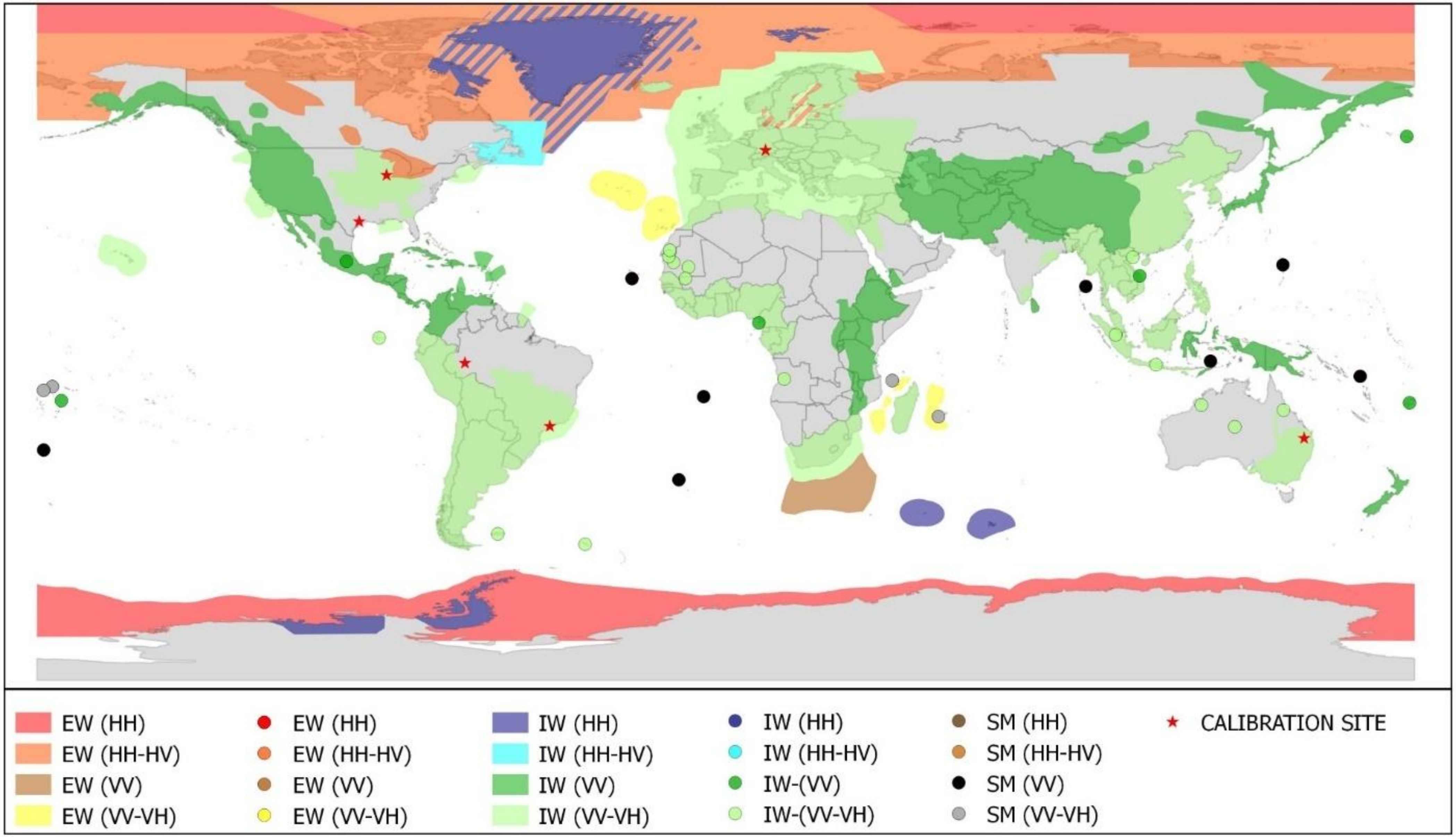
Wave mode acquisitions – which can help to determine the direction, wavelength and heights of waves on the open oceans – are 20 x 20 km, acquired alternately on two different incidence angles every 100 km.

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 × 40 m on the ground). (TOPSAR)

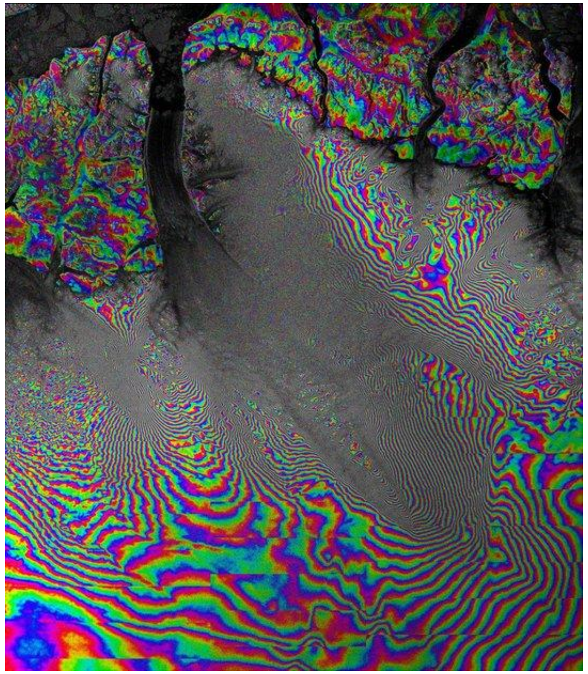
D

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

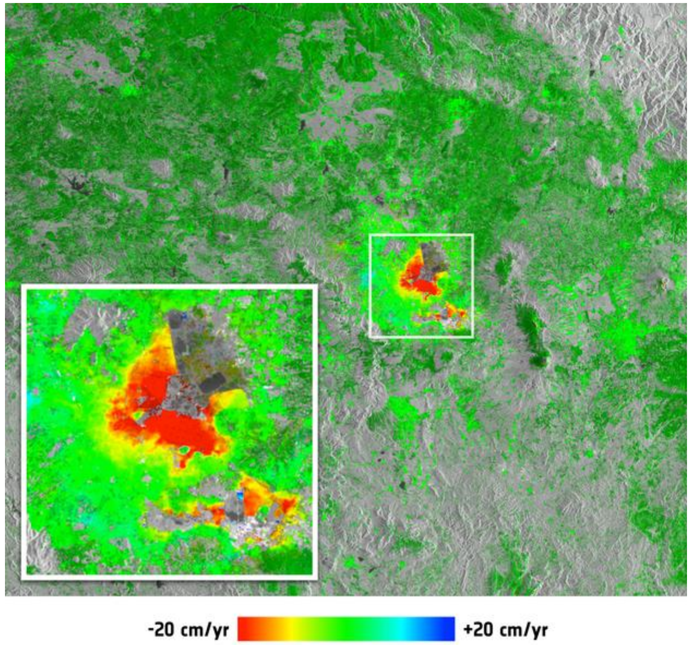


Aplicações

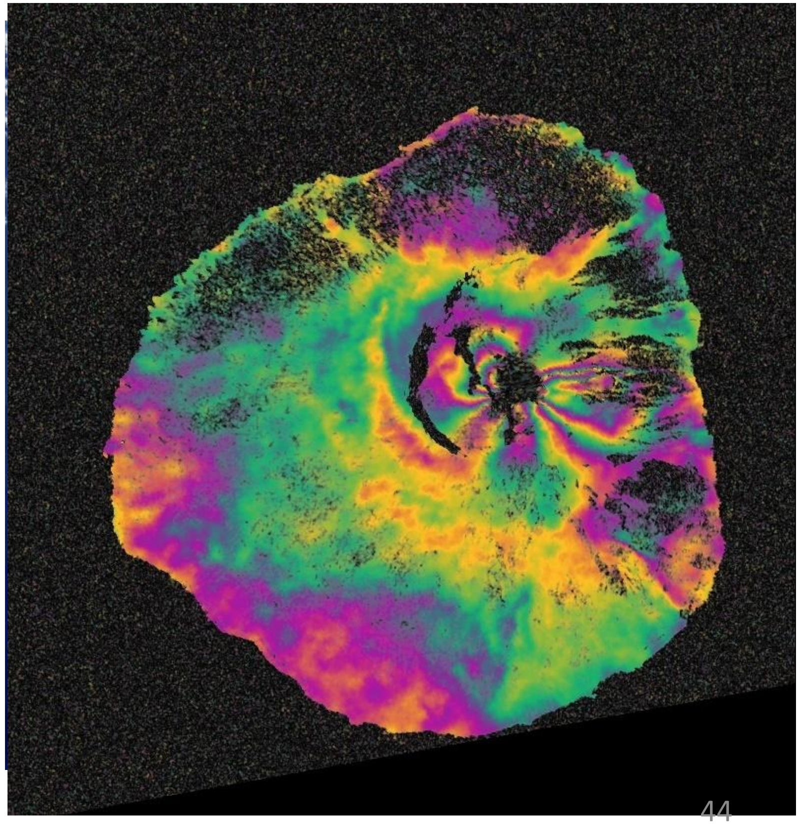
Oceano e Gelo



Changing lands

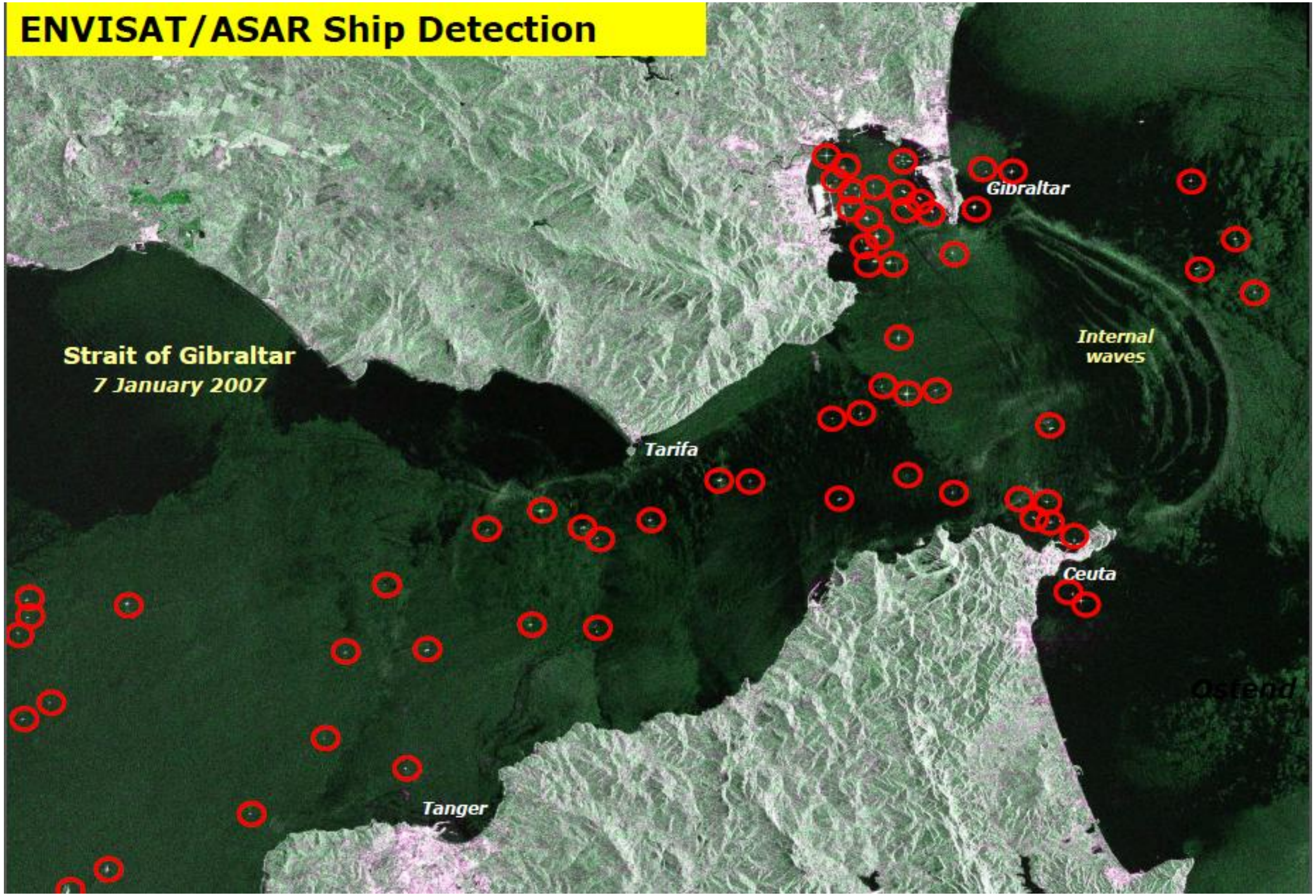


Emergency response

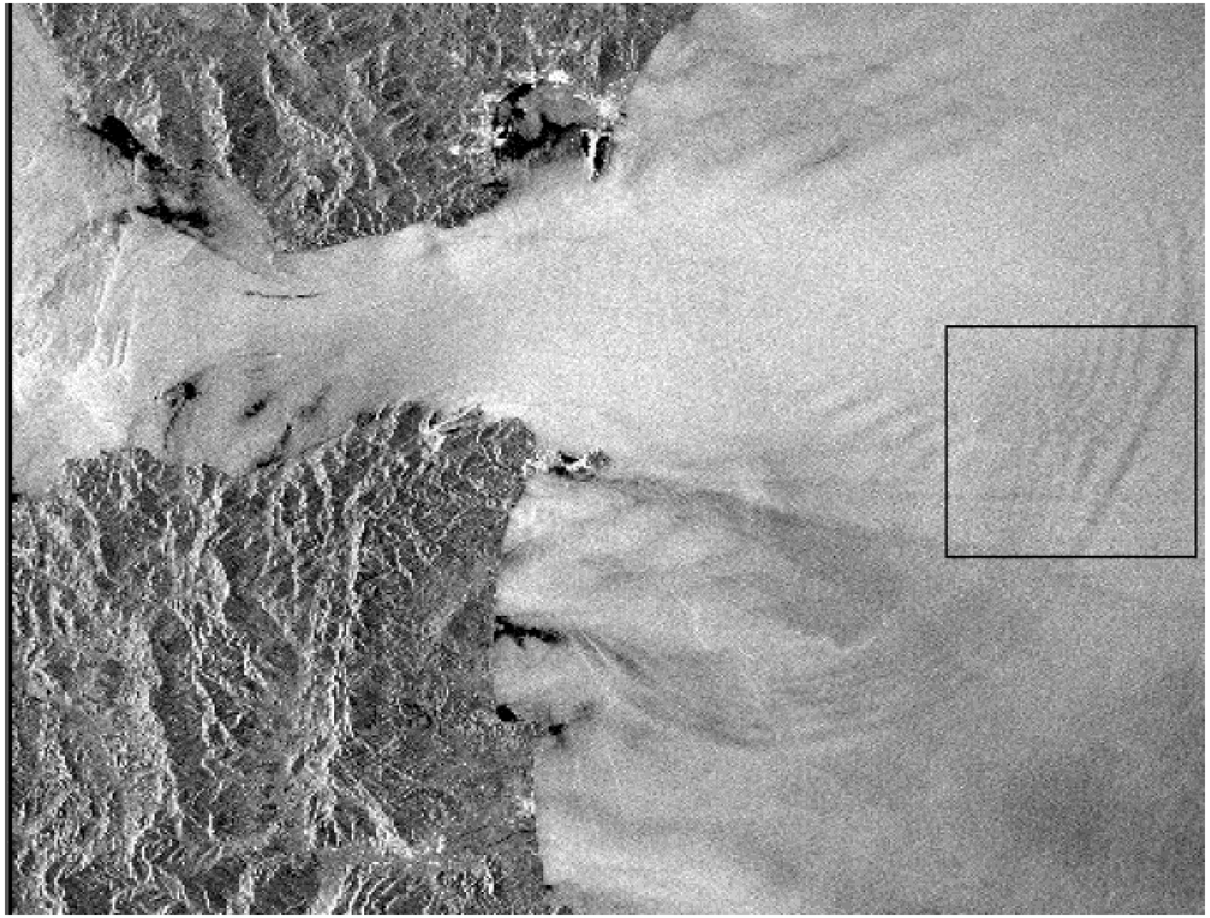


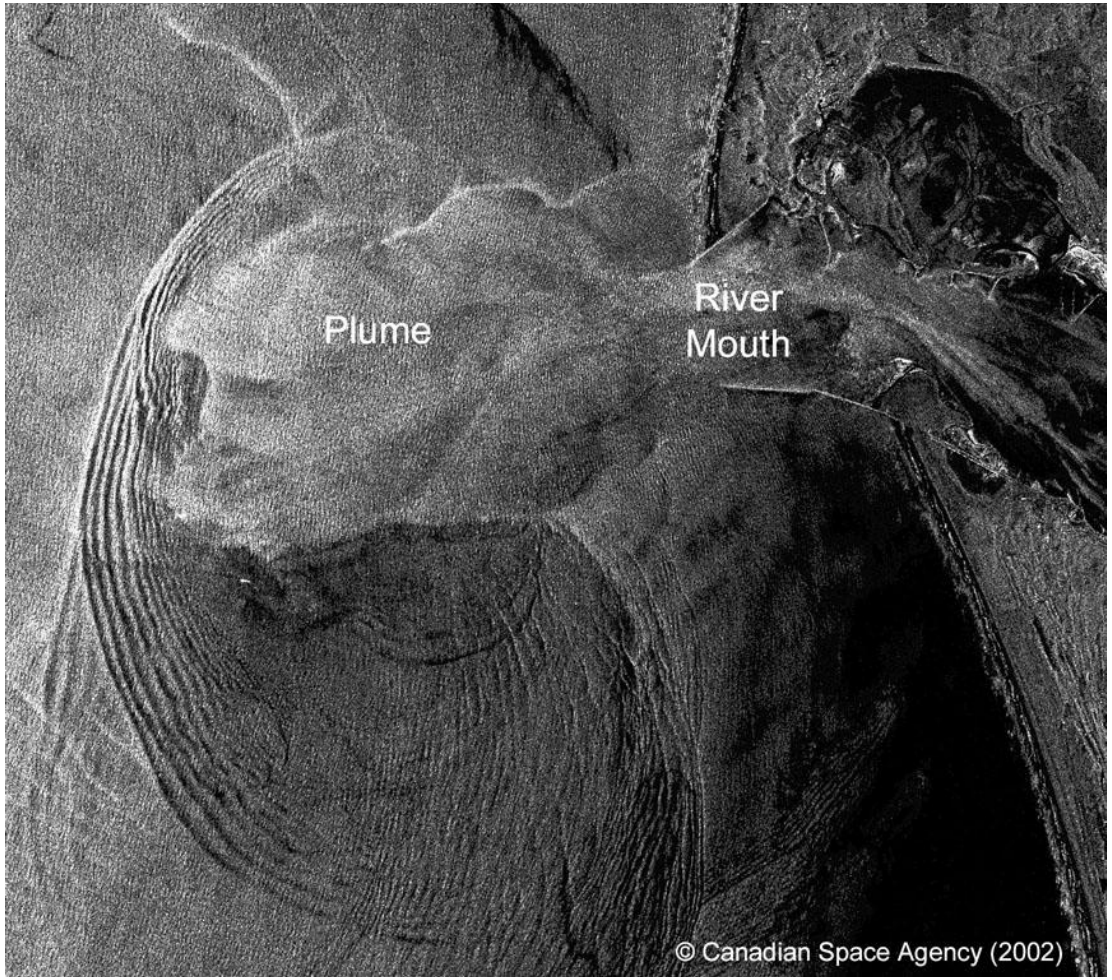
Aplicações
SAR e INSAR

Aplicações Oceano

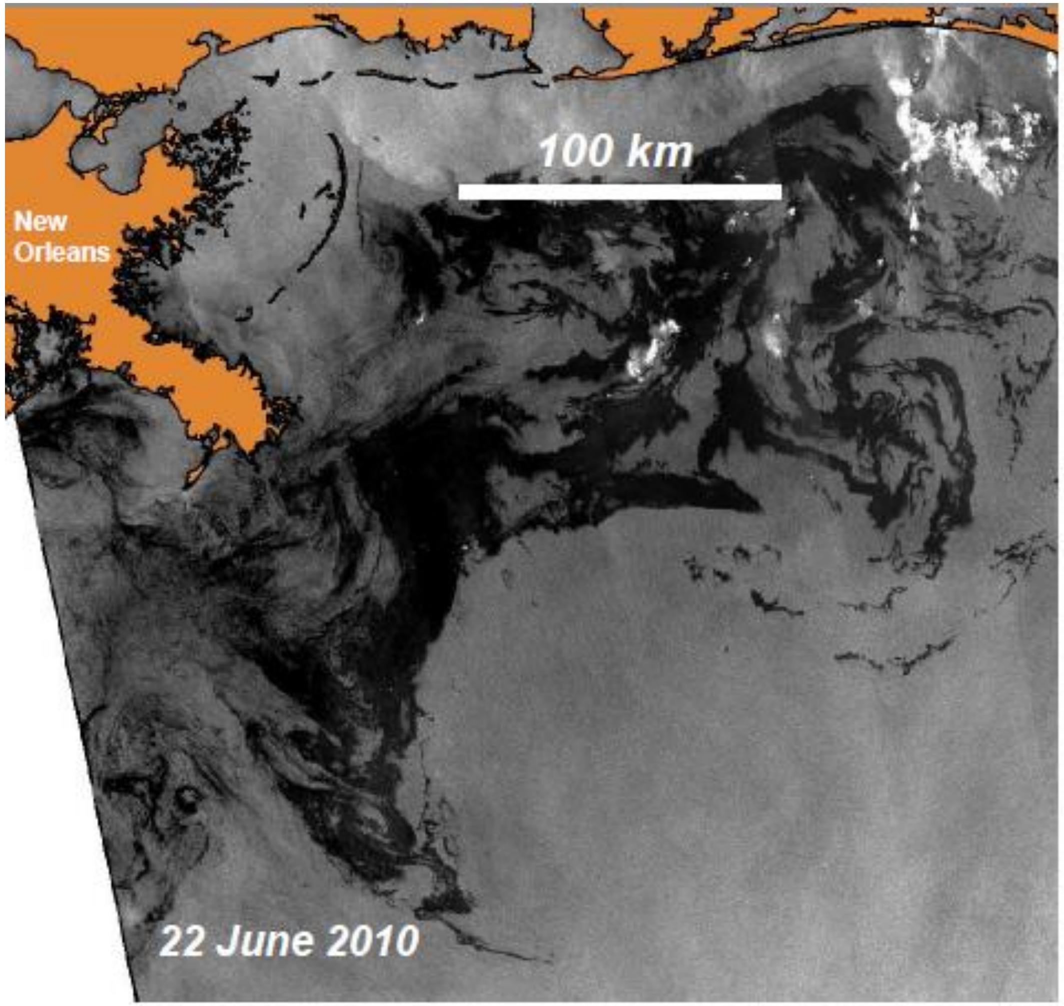


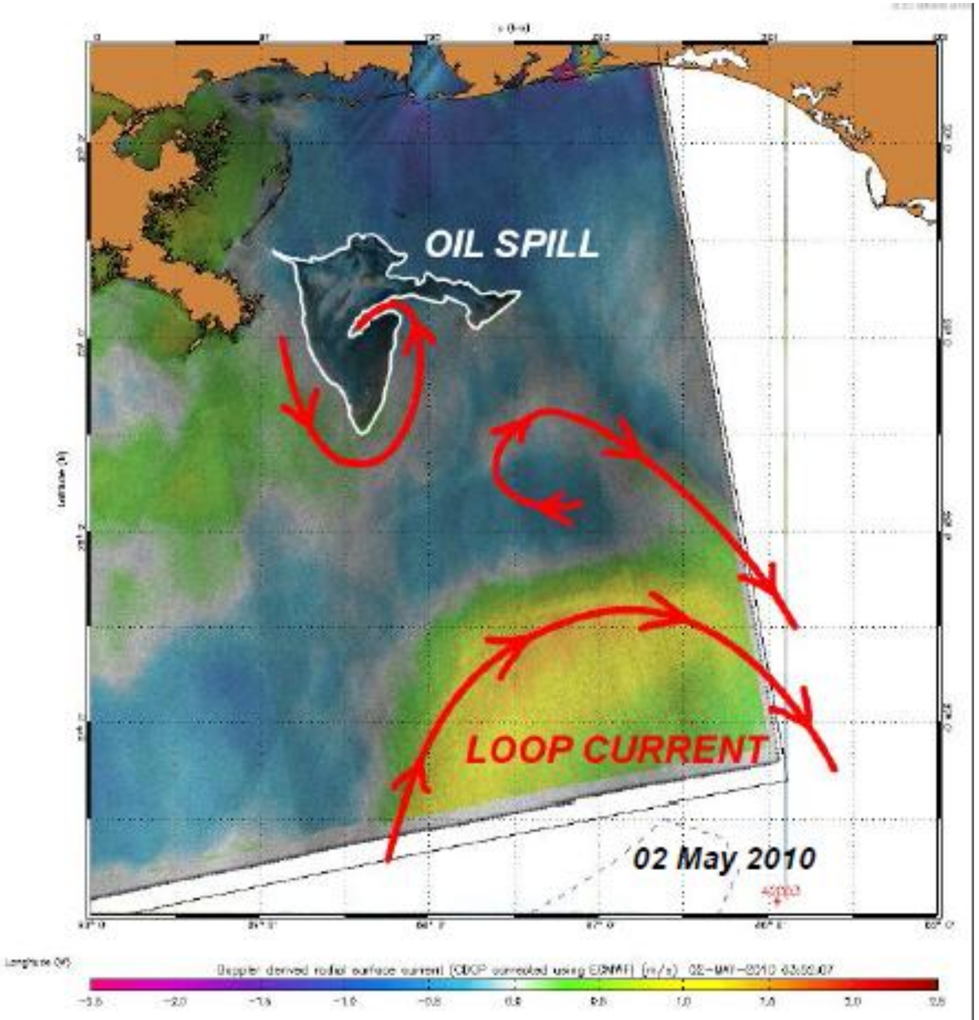
Aplicações Oceano





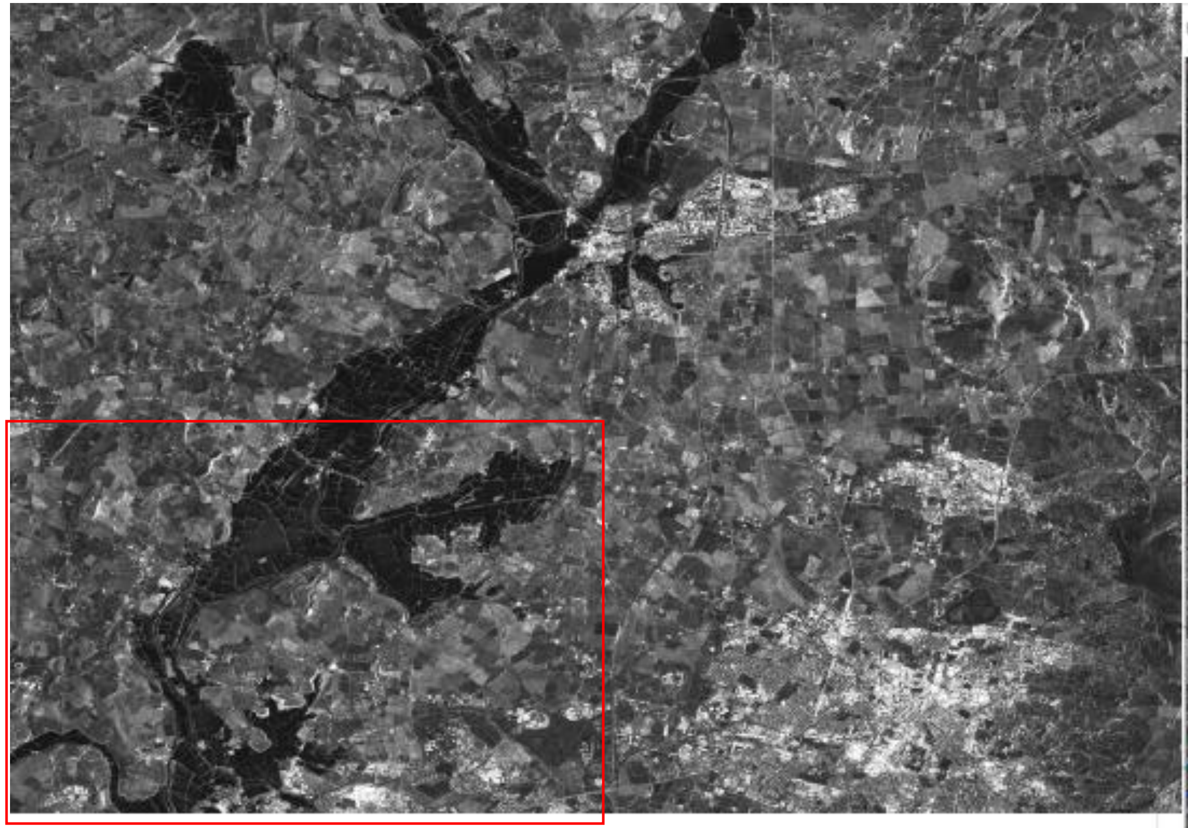
Aplicações Oceano



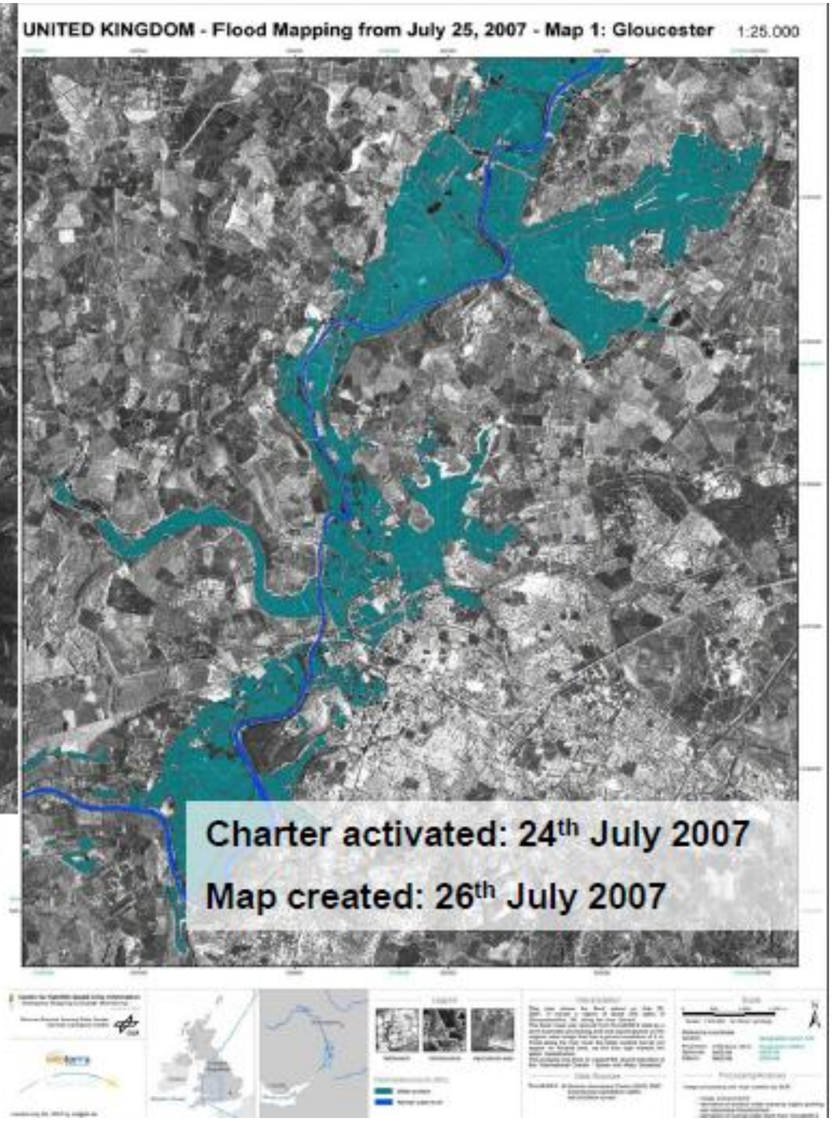


European Space Agency

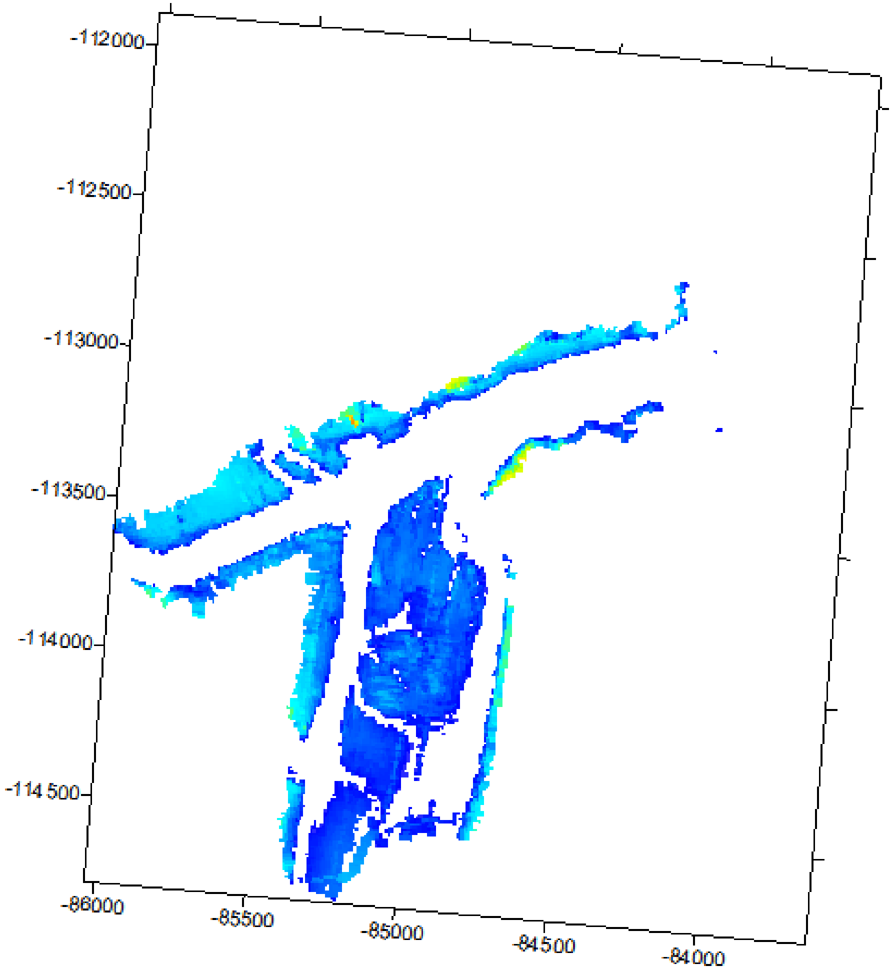
Monitorização de Cheias



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



Inter-tidal

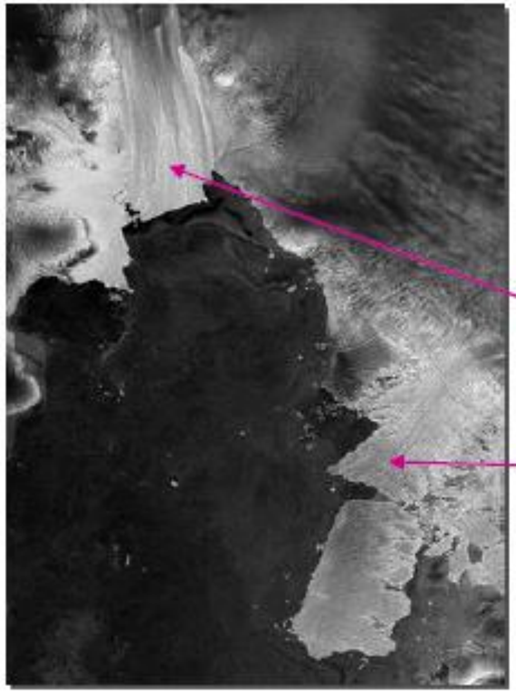


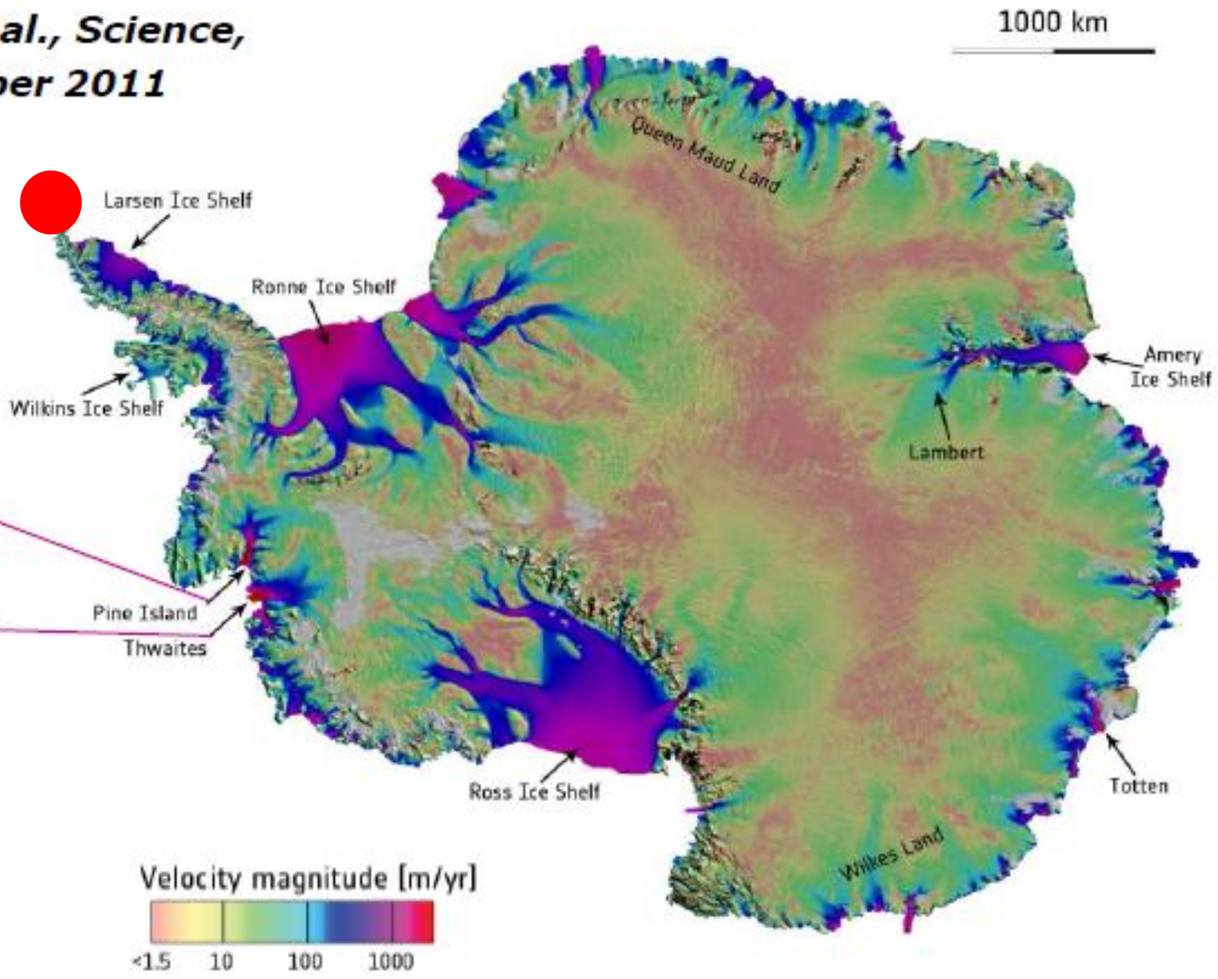
Levantamento CM Seixal (realizado pelo IH)

Movimento de glaciares

(InSAR)

E. Rignot et al., Science, September 2011

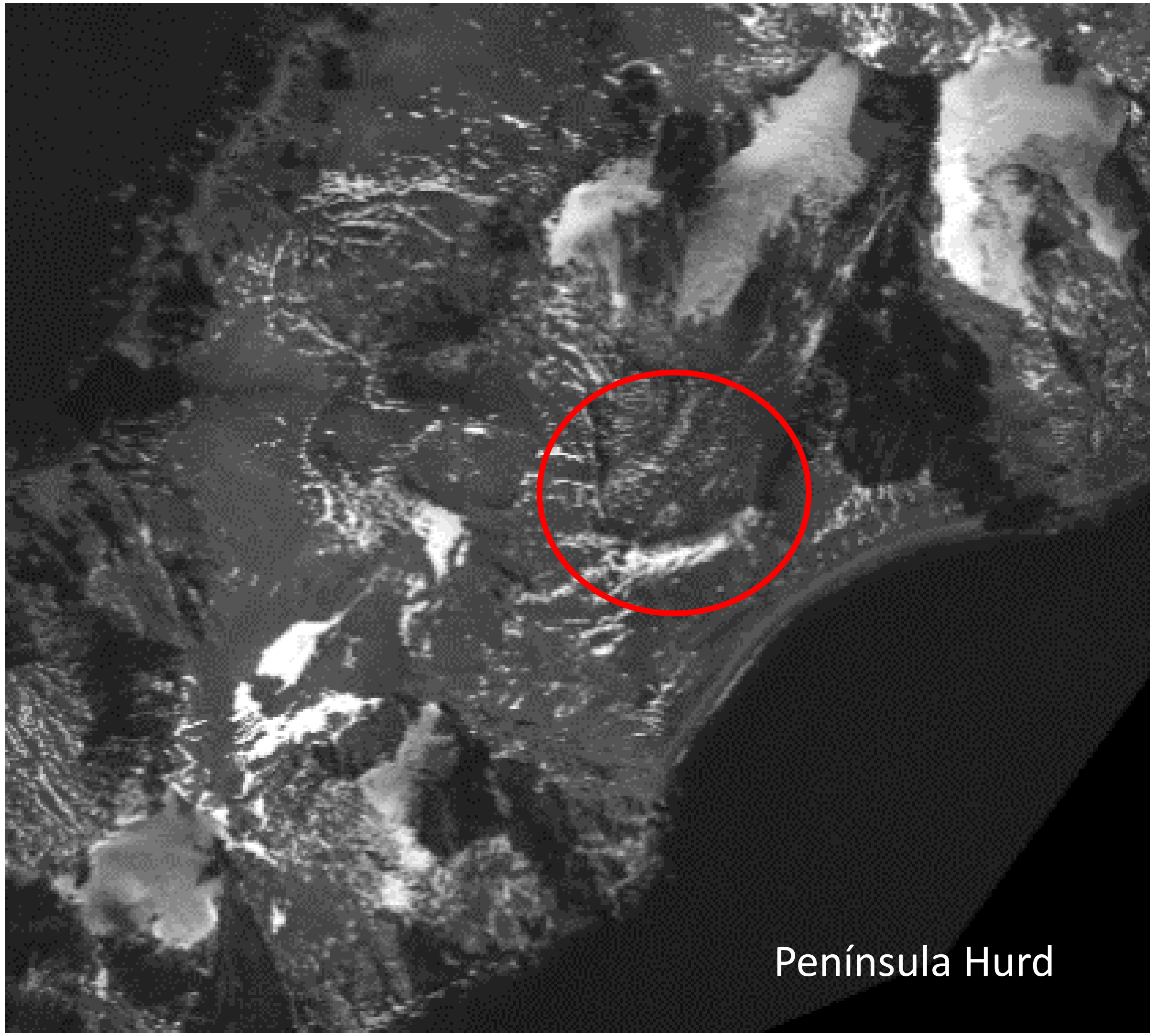


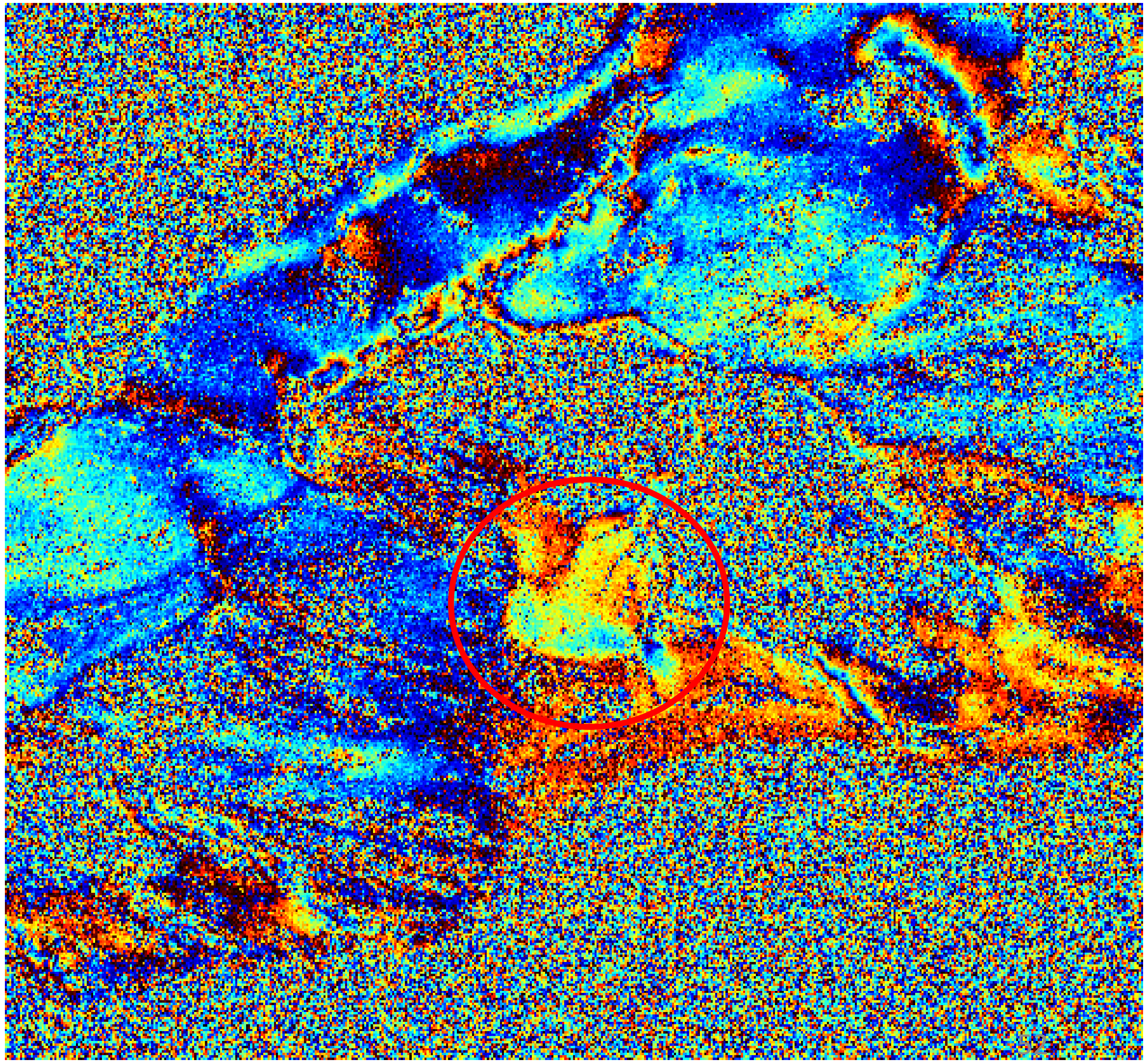


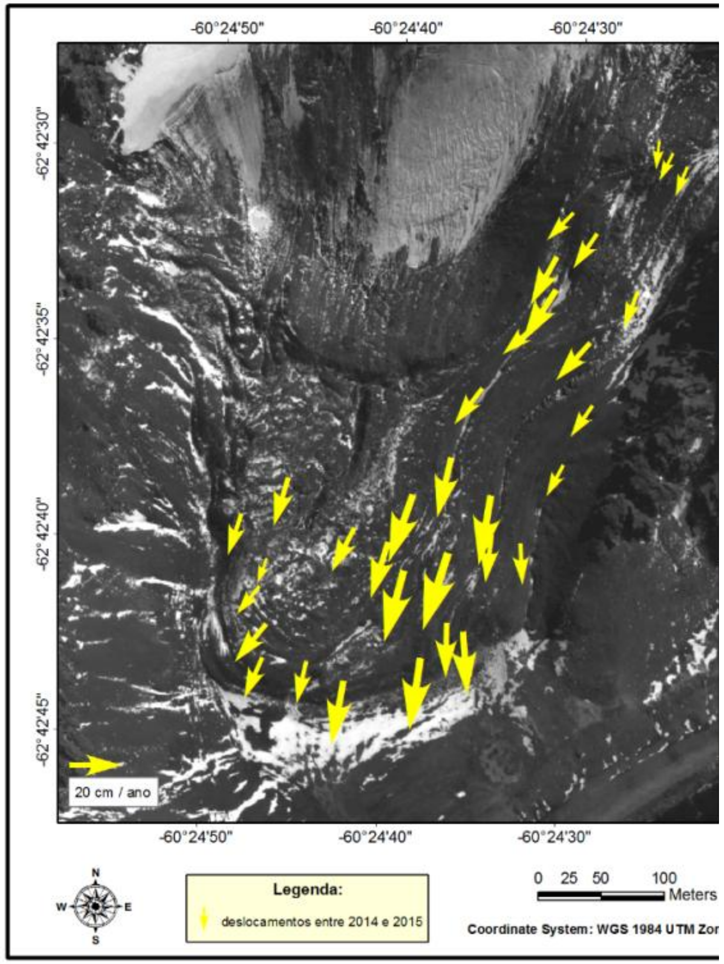
European Space Agency

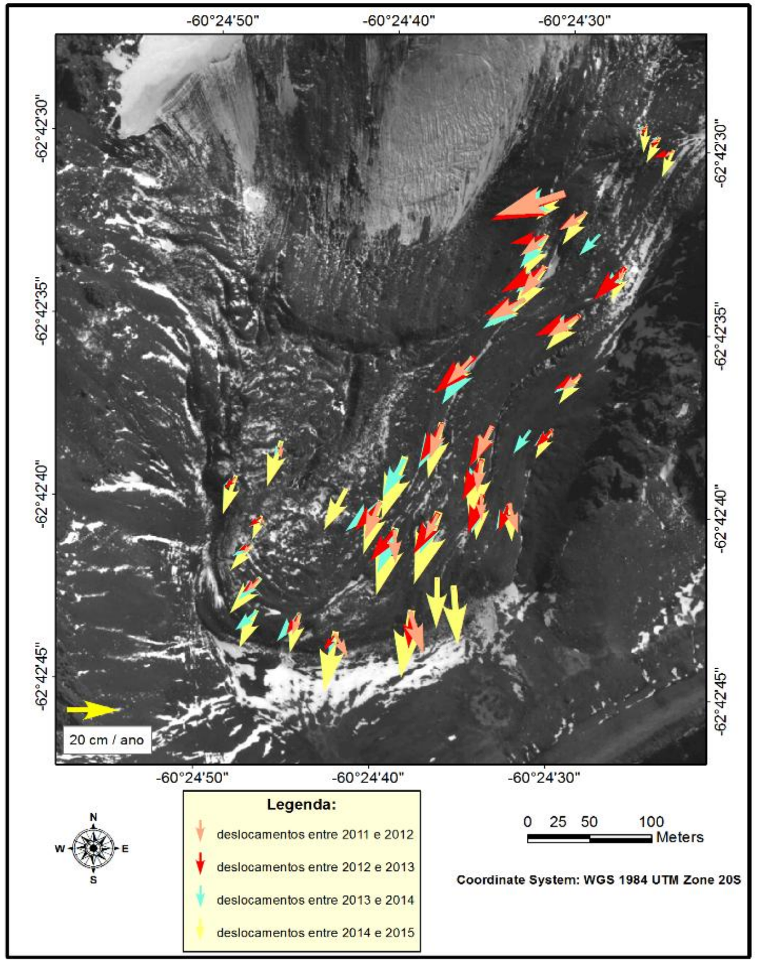
Monitorização do Permafrost

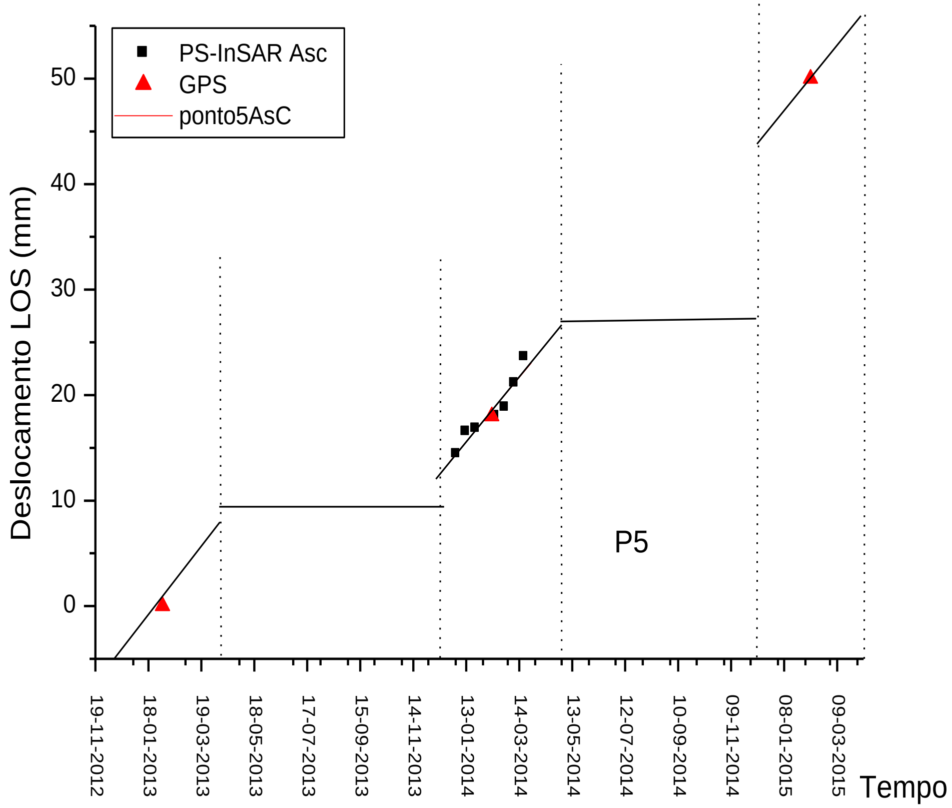
(InSAR)





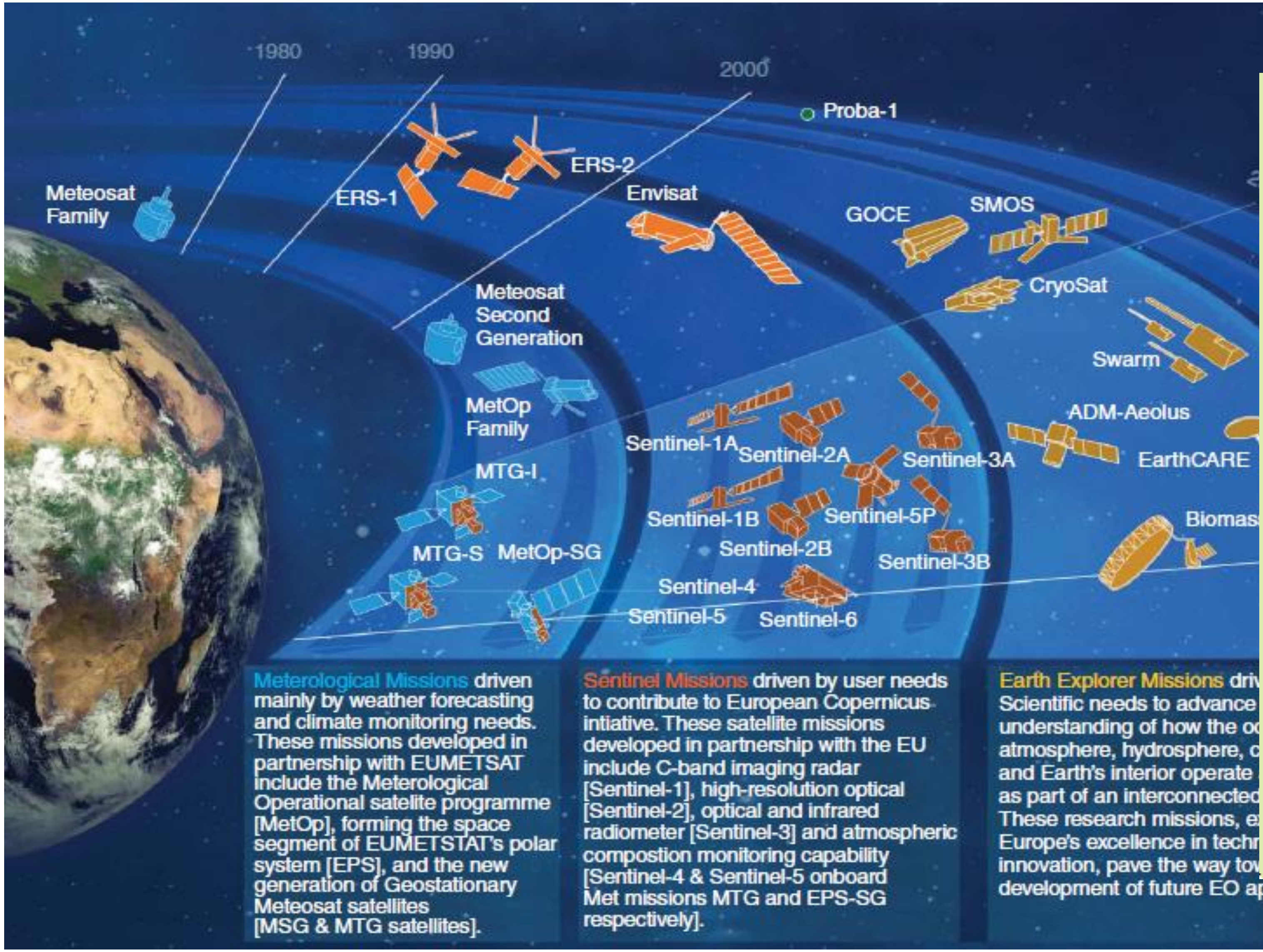

-60°24'50"
-60°24'40"
-60°24'30"
-62°42'30"
-62°42'35"
-62°42'40"
-62°42'45"
20 cm / ano
Legenda:
deslocamentos entre 2014 e 2015
0 25 50 100
Meters
Coordinate System: WGS 1984 UTM Zor


-60°24'50"
-60°24'40"
-60°24'30"
-62°42'30"
-62°42'35"
-62°42'40"
-62°42'45"
20 cm / ano
Legenda:
deslocamentos entre 2011 e 2012
deslocamentos entre 2012 e 2013
deslocamentos entre 2013 e 2014
deslocamentos entre 2014 e 2015
0 25 50 100
Meters
Coordinate System: WGS 1984 UTM Zone 20S


PS-InSAR Asc
GPS
ponto5AsC
Deslocamento LOS (mm)
50
40
30
20
10
0
P5
19-11-2012
18-01-2013
19-03-2013
18-05-2013
17-07-2013
15-09-2013
14-11-2013
13-01-2014
14-03-2014
13-05-2014
12-07-2014
10-09-2014
09-11-2014
08-01-2015
09-03-2015
Tempo

O programa de Observação da ESA

Missões ESA



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 Constella-tion-1/2/3	Launch scheduled in 2017	C (quad)
SAOCOM-1/2	Launch scheduled in 2014/2015	L (quad)

O programa Copernicus

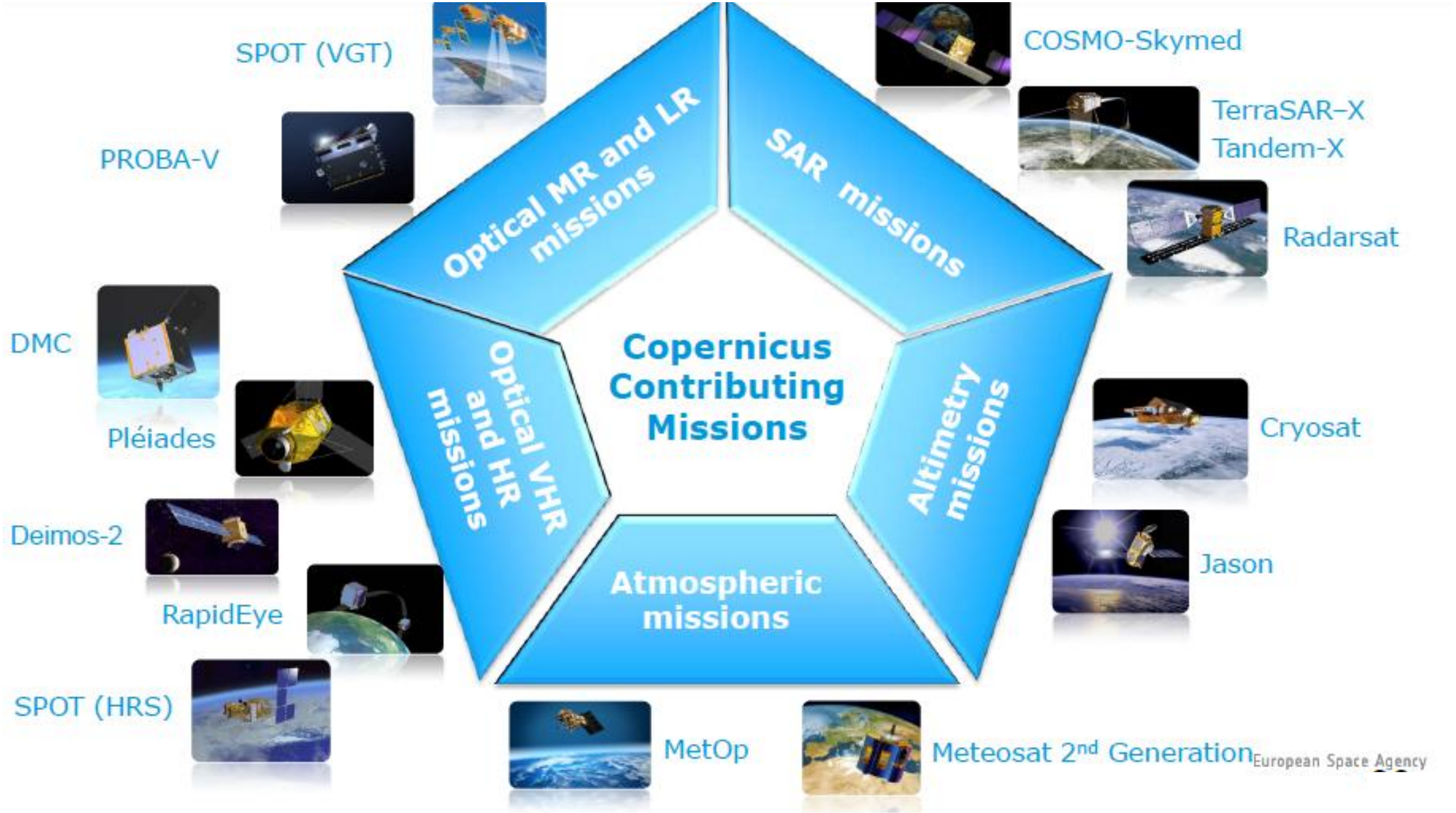
- Copernicus is a European space flagship programme led by the European Union
- Copernicus provides the necessary data for operational monitoring of the environment and for civil security
- ESA coordinates the space component

Copernicus

Os Sentinel

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

Copernicus contributing missions

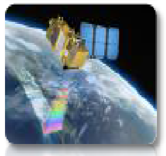


Copernicus componente Serviços

Sentinel Scientific Toolboxes

esa

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.

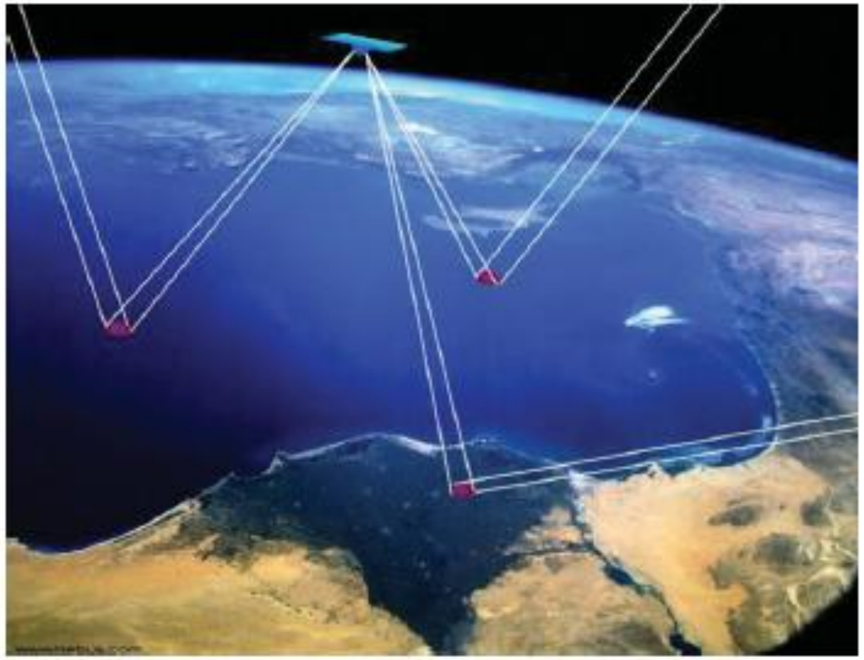
SNAP SNAP 2.0-beta-07

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.



Perspetivas para o radar de abertura sintética

SAR

SAR Polarimetry

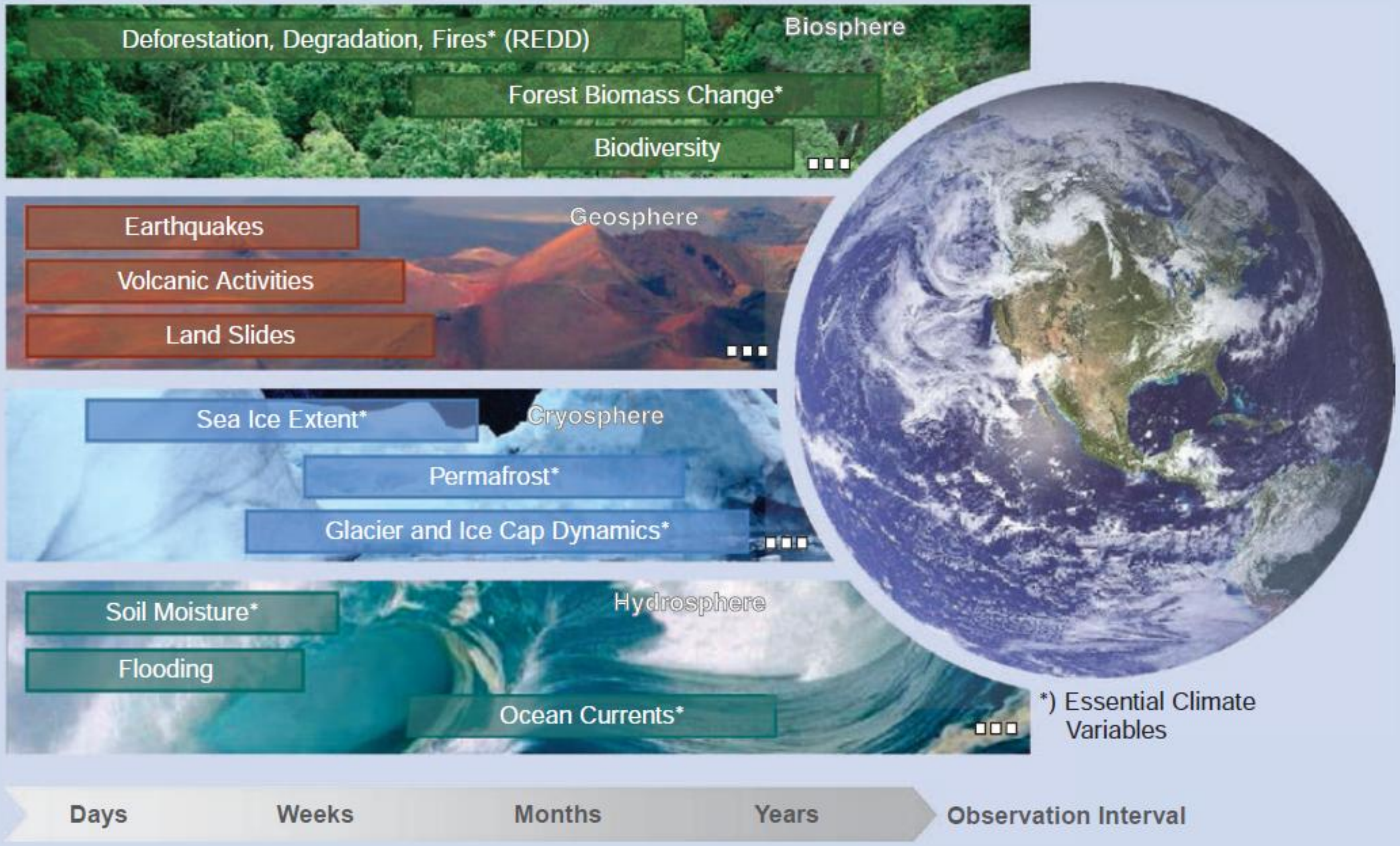
InSAR

SAR

InSAR

SAR InSAR

SAR Polarimetry



(Moreira et al, 2013)

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