Deteção Remota Micro-ondas

João Catalão Fernandes, FCUL

When officials at the Federal Communications Commission (FCC) denied launch authorization for four innovative satellites from startup Swarm Technologies last December, the agency was unequivocal as to the reason. “The applicant proposes to deploy and operate four spacecraft that are smaller than 10 centimeters in one of their three dimensions,” read a letter to Swarm’s CEO and founder Sara Spangelo. “These spacecraft are therefore below the size threshold at which detection by the Space Surveillance Network can be considered routine.”

The FCC was worried about collisions in space, where even the smallest objects traveling at orbital velocities can inflict massive damage on satellites or, in a worst-case scenario, manned spacecraft. It thought Swarm’s SpaceBees satellites, measuring 10 by 10 by 2.5 cm, would be just too small to track.

When Swarm launched them anyway, on an Indian rocket in January, the FCC was furious. It rescinded permission for the company’s next satellite launch, due later this month, and questioned whether Swarm was a suitable company to hold a communications license at all. If the FCC comes down hard on Swarm, the company’s ambitious plans for a constellation of Internet of Things communications satellites could be doomed.

So why did Swarm take such a risk in launching its SpaceBees, or even building them in the first place? Perhaps because the FCC’s position on small satellites has been bizarrely inconsistent.

An investigation by *IEEE Spectrum* has revealed that the FCC licensed multiple satellites smaller than 10 cm over the past five years, including some as small as 3.5 by 3.5 by 0.2 cm. But the commission has also changed its mind from one application to the next, refusing launch permission for satellites that were virtually identical to ones previously authorized. This

The Smaller, the Better

Most satellites are essentially smartphones in space. They have sensors such as cameras and magnetometers to gather data, radio transmitters and receivers for communication, processors to crunch the numbers, and batteries to power everything. And like smartphones, satellites have benefited from decades of technological advances such as those whose progress runs on Moore’s Law’s timeclock.

But miniaturization is even more important for satellites than it is for iPhones. Launching a kilogram payload to low earth orbit (LEO) currently costs at least $3000. Multiply that by the 12,000 satellites that SpaceX is planning for its Starlink constellation of communications satellites, and it is clear that lighter and smaller is almost always better.

> **“The idea was to push the limits, to see how small we could really build a satellite. One reason is that they can be extremely cheap. We can now talk about launching a satellite for a couple of hundred bucks.”**
>
> *—Zac Manchester*

When Stanford University astronautics professor Bob Twiggs first came up with the idea of a modular “CubeSat” in 1999, he settled on a small 10-by-10-by-10-cm design. Most CubeSats are multiples of this, but their standard 10-by-10-cm footprint allows them to be launched from the same device, regardless of their length.

By the time Twiggs moved to Kentucky’s Morehead State University in 2009, technological advances had accumulated to the point that he proposed an even smaller building block called “PocketQube,” measuring just 5 by 5 by 5 cm.

SEVENTH SENTINEL SATELLITE LAUNCHED FOR COPERNICUS

25 April 2018 The second Sentinel-3 satellite, Copernicus Sentinel-3B, was launched today, joining its identical twin Sentinel-3A in orbit. This pairing of satellites increases coverage and data delivery for the European Union's Copernicus environment programme.

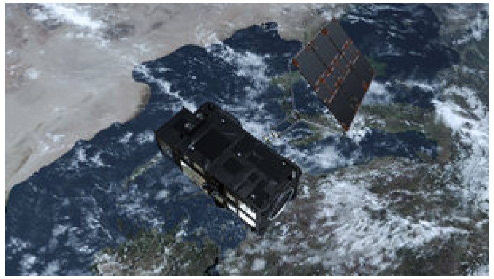
The 1150 kg Sentinel-3B satellite was carried into orbit on a Rockot launcher from Plesetsk, Russia, at 17:57 GMT (19:57 CEST; 21:57 local time) on 25 April.

Rockot's upper stage delivered Sentinel-3B into its planned orbit.

Just 92 minutes after liftoff, Sentinel-3B sent its first signals to the Kiruna station in Sweden. Data links were quickly established by teams at ESA's operations centre in Darmstadt, Germany, allowing them to assume control of the satellite.

During the three-day launch and the early orbit phase, controllers will check that all the satellite's systems are working and begin calibrating the instruments to commission the satellite. The mission is expected to begin routine operations after five months.

"This is the seventh launch of a Sentinel satellite in the last four years. It is a clear demonstration of what European cooperation can achieve and it is another piece to operating the largest Earth observation programme in the world, together with our partners from the European Commission and Eumetsat," said ESA Director General Jan Wörner.



Sentinel-3 in orbit

With this launch, the first set of Sentinel missions for the European Union's Copernicus environmental monitoring network are in orbit, carrying a range of technologies to monitor Earth's land, oceans and atmosphere.

ESA's Director of Earth Observation Programmes, Josef Aschbacher, said, "With Sentinel-3B, Europe has put the first constellation of Sentinel missions into orbit – this is no small job and has required strong support by all involved. It allows us to get a very detailed picture of our planet on a daily basis and provides crucial information for policy makers.

"It also offers lots of opportunities for commercial companies to develop new innovative services. And, the free and open data policy allows every citizen to have updates for their own use.

"When we designed such a satellite constellation 20 years ago not everyone was convinced Europe could do that. I am glad to see this has become reality and that it is now a large European success story."

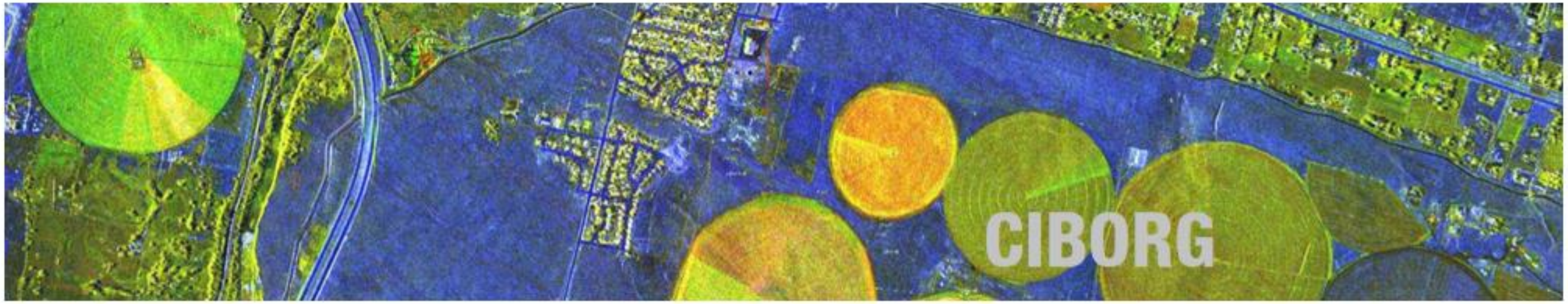
Deimos Imaging Awarded GSA Contract

Published April 23, 2018 | Share

Deimos Imaging and UrtheCast have been awarded a GSA Multiple Award Schedule (MAS) 070 contract by the U.S. General Services Administration (GSA), the procurement arm of the federal government.

This is **the first time that a European company in Earth observation services has been awarded such a contract in the U.S.**, making Deimos Imaging's full portfolio of products and services available to all U.S. government agencies.

CIBORG



LINKS

- Making it Easier — GSA's FASt Lane
- GSA IT Schedule 70
- Geospatial offerings on GSA IT Schedule 70

Commercial Initiative to Buy Operationally Responsive GEOINT

CIBORG will provide centralized, standardized, contractual access to emerging commercially-available imagery, data, analytical capabilities and services.

What CIBORG Will DO

- Provide flexibility to acquire what is required against dynamic GEOINT requirements
- Acquire capabilities that are assessed to be of satisfactory quality and support the GEOINT mission
- Comply with all Intelligence Community, Department of Defense and Federal Acquisition guidance & regulations

Benefits to the IC and DoD

- Leverages NGA expertise/functional management responsibilities and GSA centralized procurement services to expose existing and emerging GEOINT products and services for rapid acquisition.

Opportunities

- Professor in Microwave Remote Sensing Systems at Technical University of Denmark
- Tenured-Track Faculty Positions in Solid Earth Geosciences and Planetary Sciences at Georgia Institute of Technology
- Ph.D Student in Geosensing Systems Engineering and Sciences at University of Houston
- Tenure Track Position in Geoinformatics at Aalto University
- Geospatial Engineer in Satellite Digital Data Processing at DigitalGlobe

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Europe's eyes on Earth

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Copernicus at your fingertips: 20 apps that you can use today!

Copernicus Observer - 04/05/2018

Many developers have taken advantage of full, free and open Copernicus data to create apps for various purposes. From tracking pollen and air quality to real-time information about sea conditions and surfing data maps - we selected 20 applications that you can try out yourself today.

Copernicus Sentinel satellites orbit the Earth high above us, collecting data about our planet day in and day out. But Copernicus can be very close to you, just at the tip of your fingers - on your smartphone or browser.

We selected **20 applications that use Copernicus data** and that you can try out yourself right now.

1. SnapPlanet

SnapPlanet wants to put the Earth in your pocket. Their mobile application, available for iOS and Android, allows anyone to create, browse and share Copernicus Sentinel satellite imagery. You can start by snapping a selfie of your hometown from space.

http://copernicus.eu/news/copernicus-20-apps-you-can-use-today

. Monitor SLG

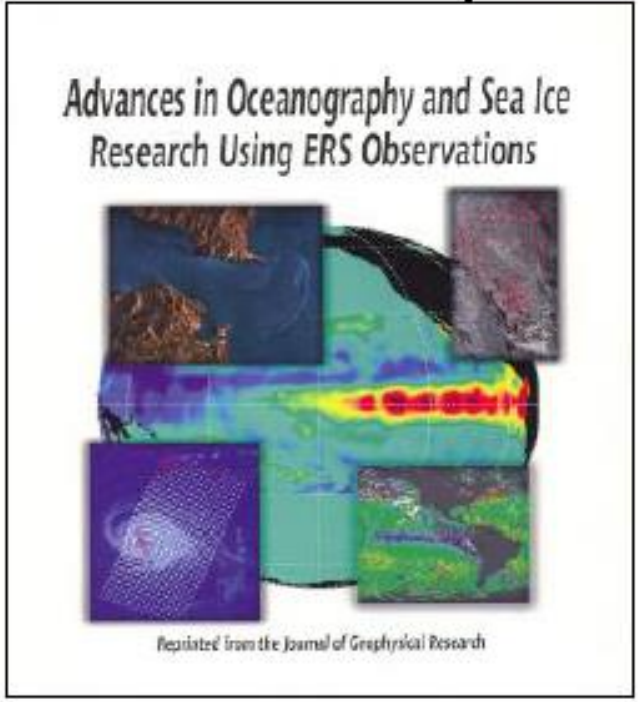
. Temas para Tese, reunião

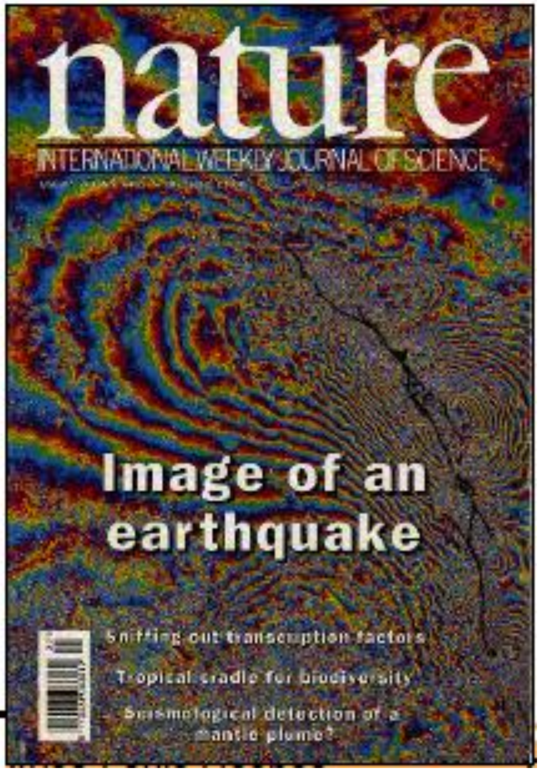
Tópicos

Oceanography and sea Ice

(2000)

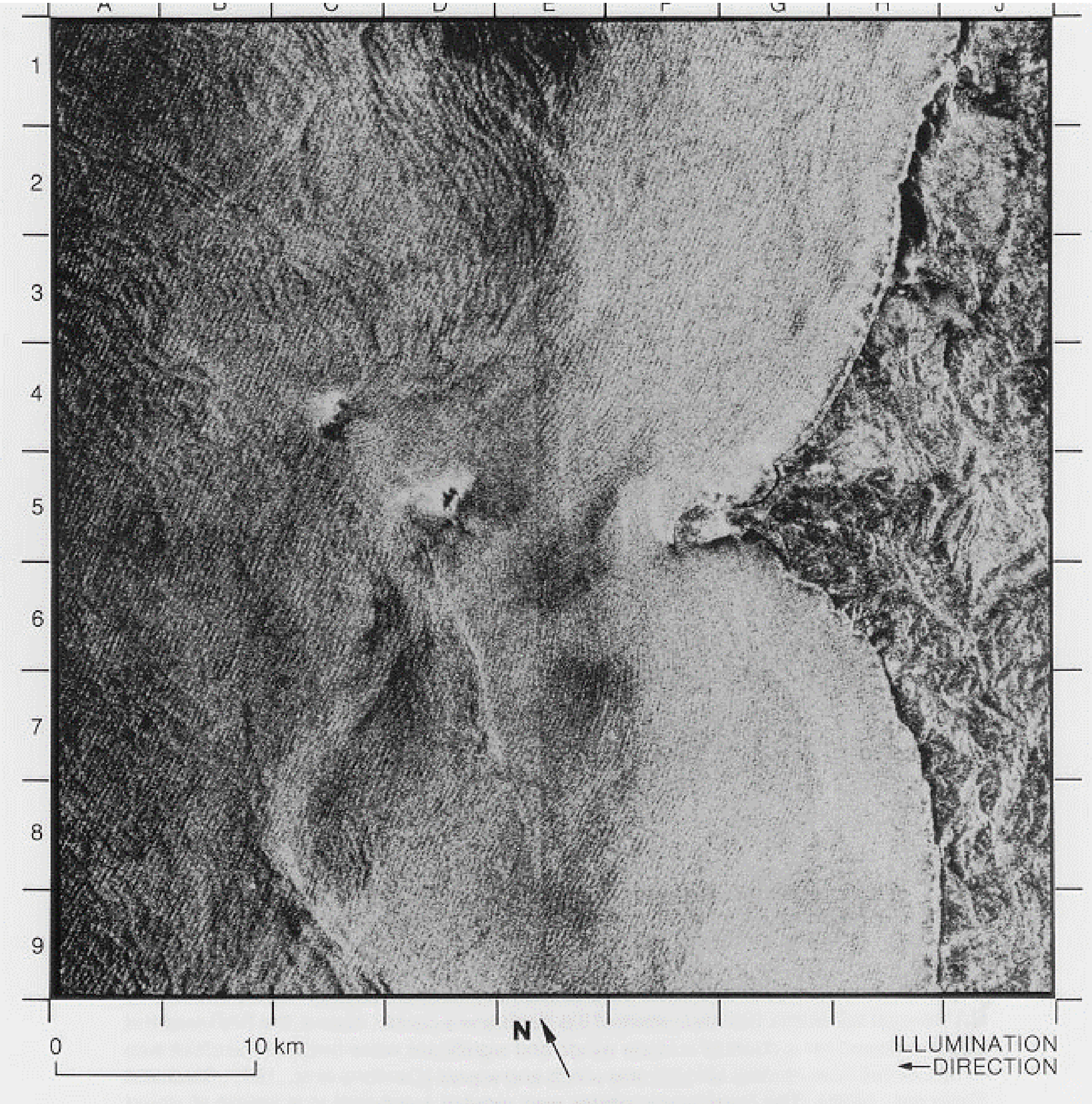
ERS and Volcanic activities





(1993)

ERS and SAR Interferometry



Seasat SAR

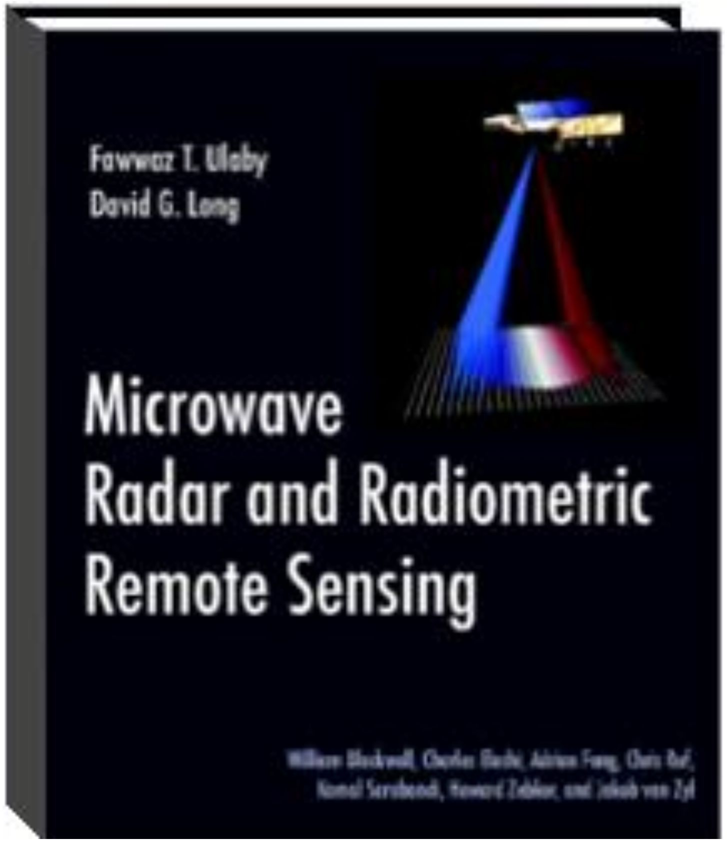
One of the microwave radars on board Seasat was a synthetic-aperture radar (SAR).

(Radar de Abertura Sintética, banda L)

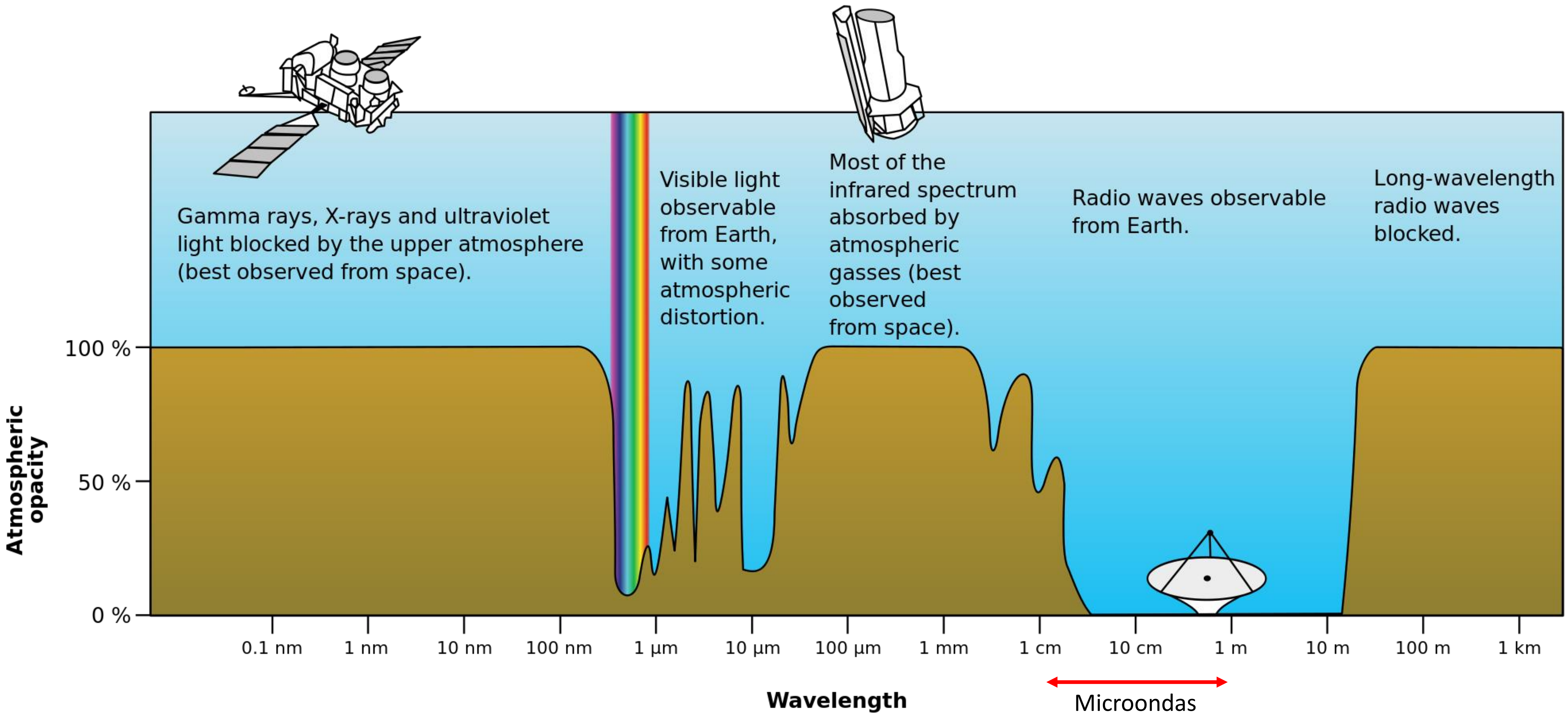
The refraction of impinging deep ocean waves by varying bottom topography in near-shore areas is one of the major concerns of coastal engineers. This image shows how deep ocean waves are refracted by the bottom topography west of Portugal.

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
RADAR micro-ondas



Deteção Remota na banda das microondas

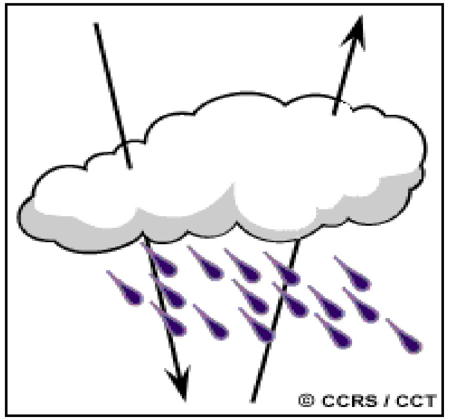


Radio Detection And Raging

Deteção Remota na banda das microondas

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

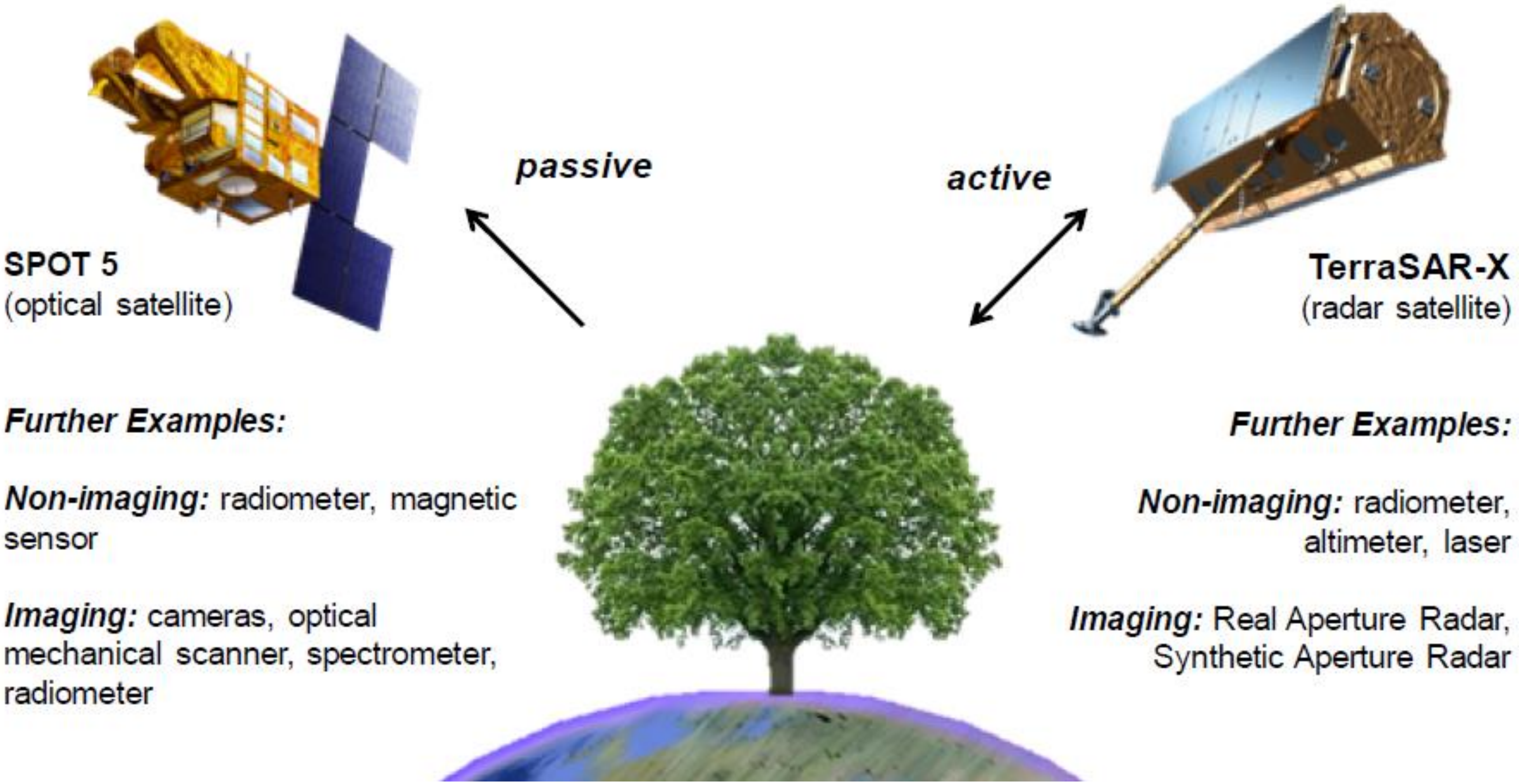
Os maiores comprimentos de onda podem atravessar nuvens, pó, "haze" ou mesmo chuva leve uma vez que os maiores c.o. não são susceptíveis à dispersão atmosférica.



"All-weather"

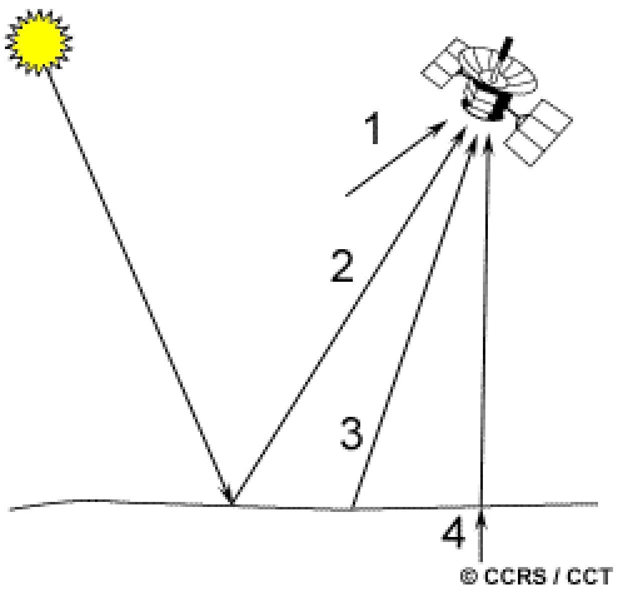
"Day and Night"

Passive and active remote sensing



Malta SAR EDU

Passive Remote Sensing



A energia das microondas registada num **sensor passivo** pode ser:

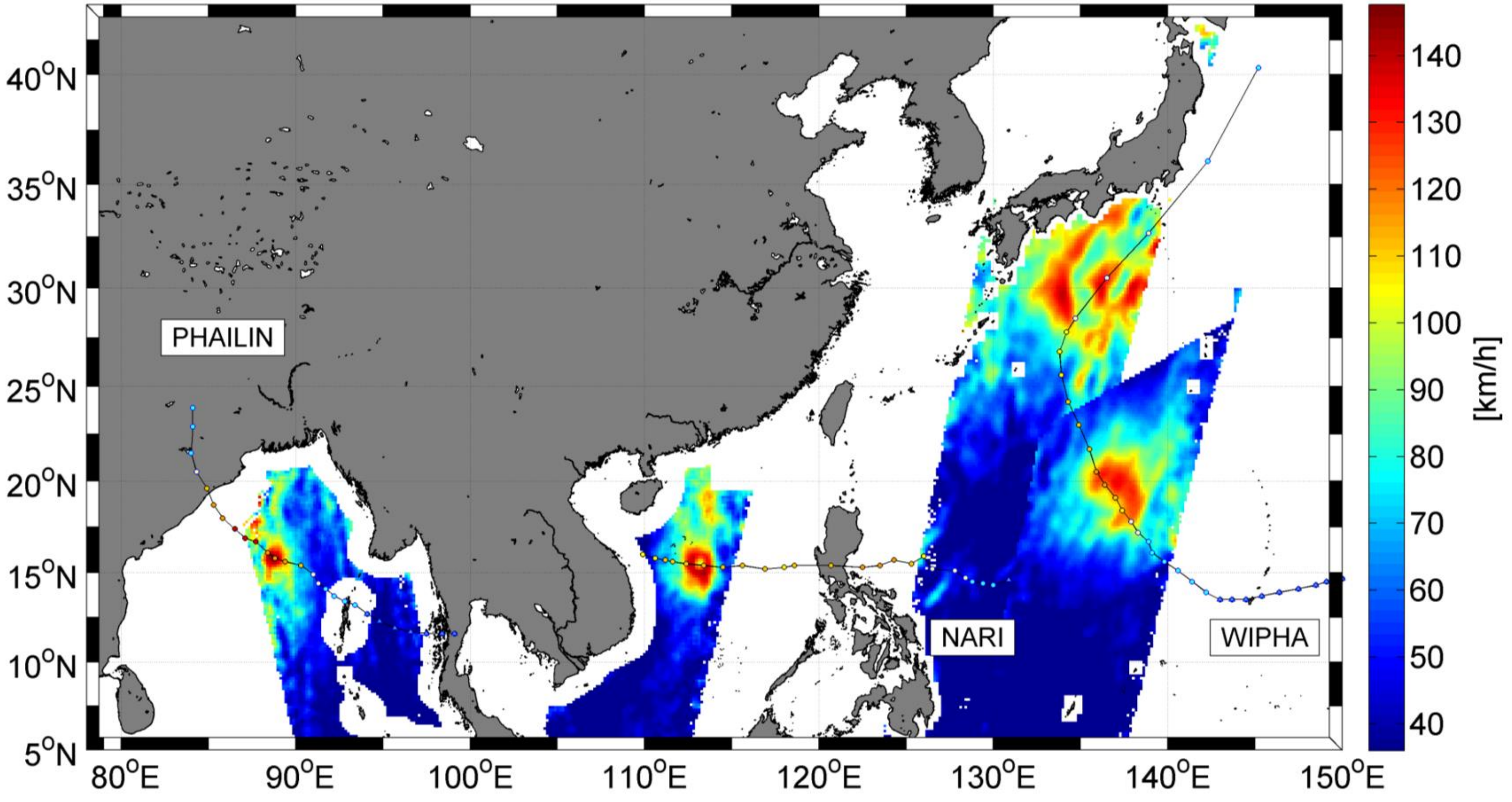
1. Emitida pela atmosfera
2. Reflectida pela superfície
3. Emitida pela superfície
4. Transmitida pela superfície

Como o c.o. é "muito grande", a energia disponível é muito pequena quando comparada com os c.o. ópticos.

Lei de Plank: $Q = h\upsilon$ $c=\lambda\upsilon$

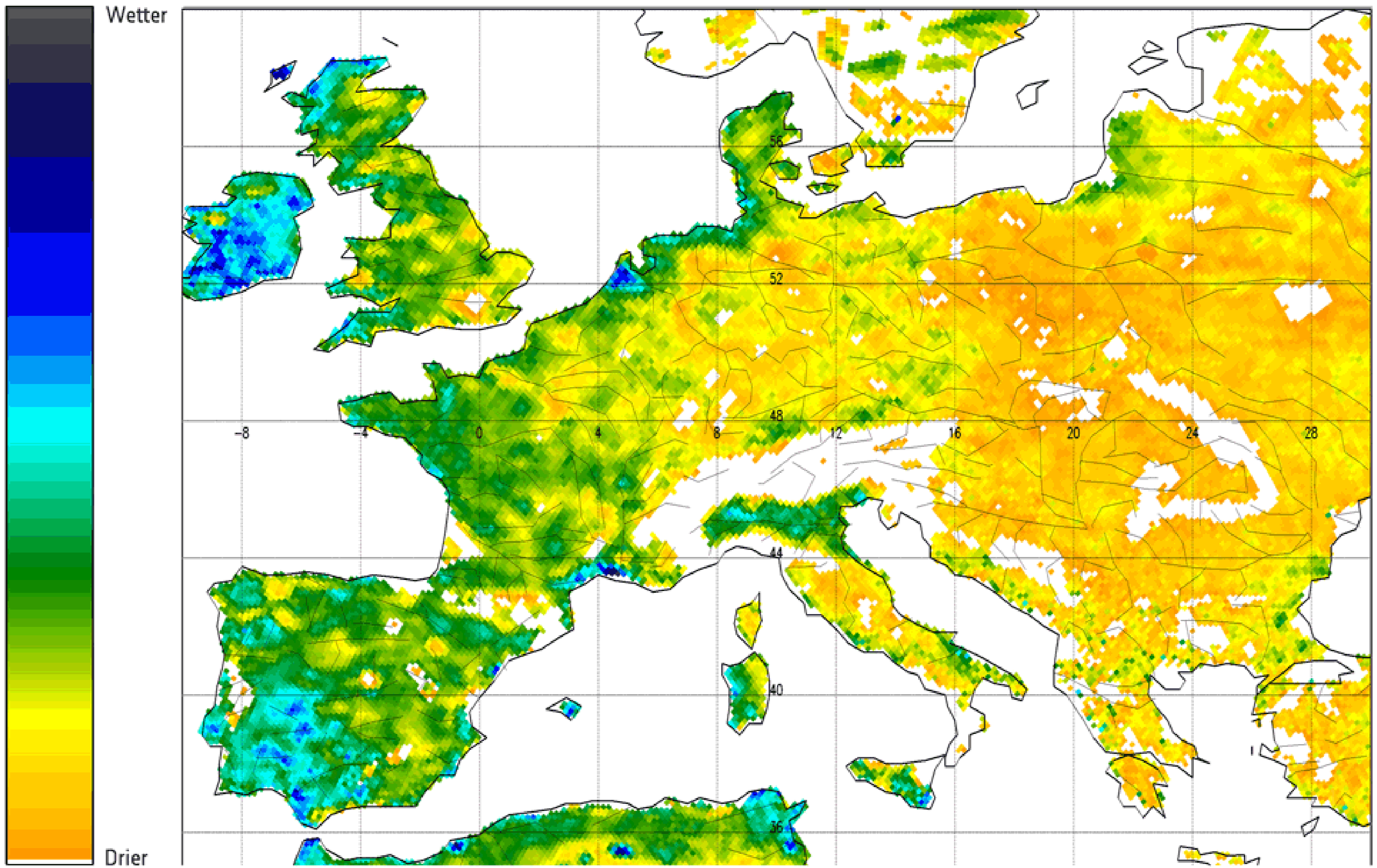
Por isso o elemento resolução no terreno deve ser suficientemente grande para que a energia seja suficiente para ser detetada ao nível do satélite. Os sensores passivos microondas são caracterizados por uma baixa resolução espacial.

Soil Moisture and Ocean Salinity (SMOS)



SMOS's microwave radiometer captured wind speed readings from three different typhoons during 10–15 October 2013. The image shows wind speeds up to 140 km/h (dark red) for Cyclone Phailin (left), Typhoon Nari (middle) and Typhoon Wipha (right). Pixel size 43 km

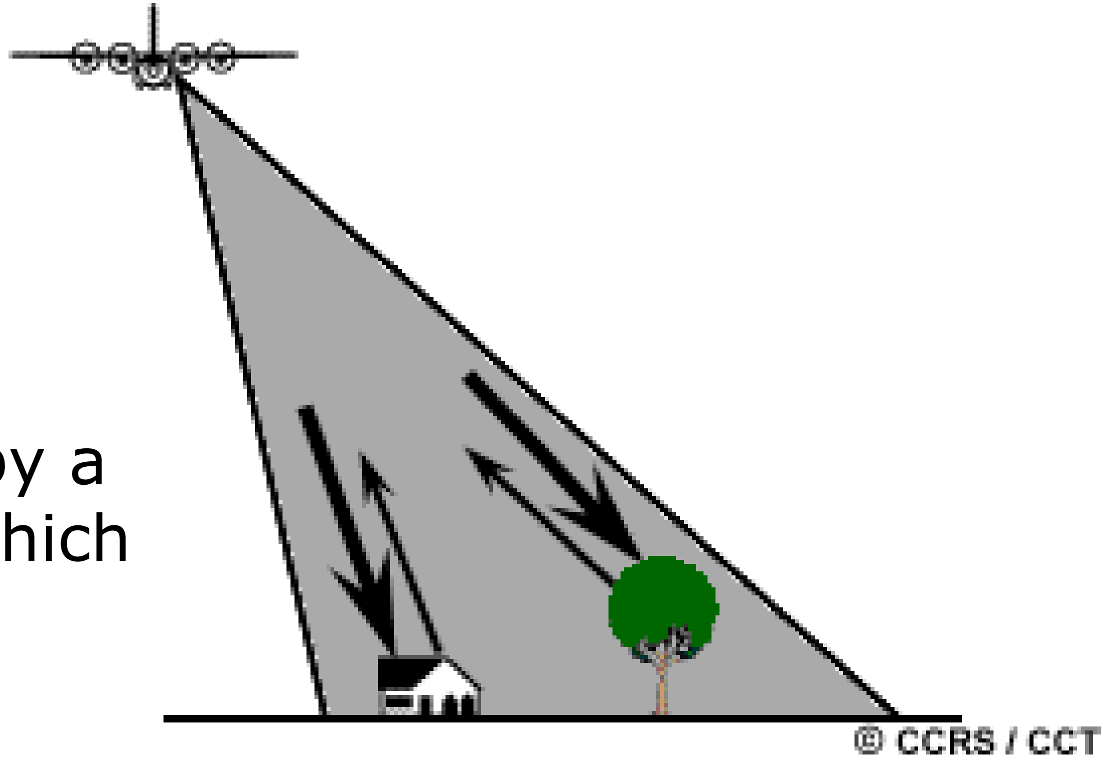
Soil Moisture map of Europe - November 2011



SMOS maps Europe's dry autumn soils / SMOS / Observing the Earth / Our Activities / ESA

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)

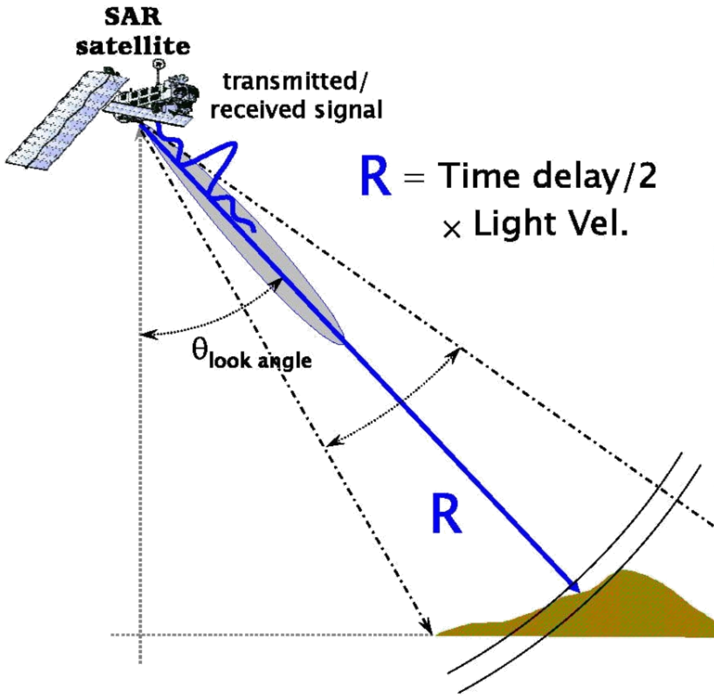
Advantages compared to optical remote sensing

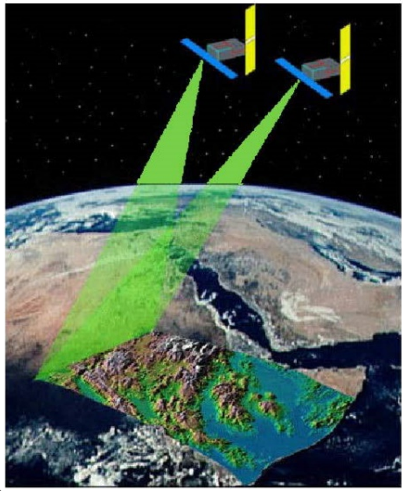
- all weather capability (small sensitivity of clouds, light rain)
- day and night operation (independence of sun illumination)
- no effects of atmospheric constituents (multitemporal analysis)
- sensitivity to dielectric properties (water content , biomass, ice)
- sensitivity to surface roughness (ocean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

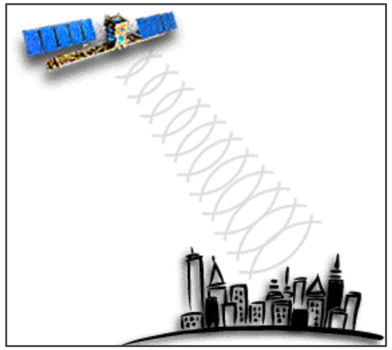
Inconvenients

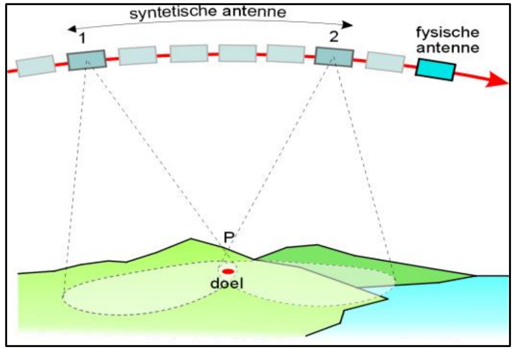
- complex interactions (difficulty in understanding, complex processing)
- speckle effects (difficulty in visual interpretation)
- topograhic effects
- effect of surface roughness

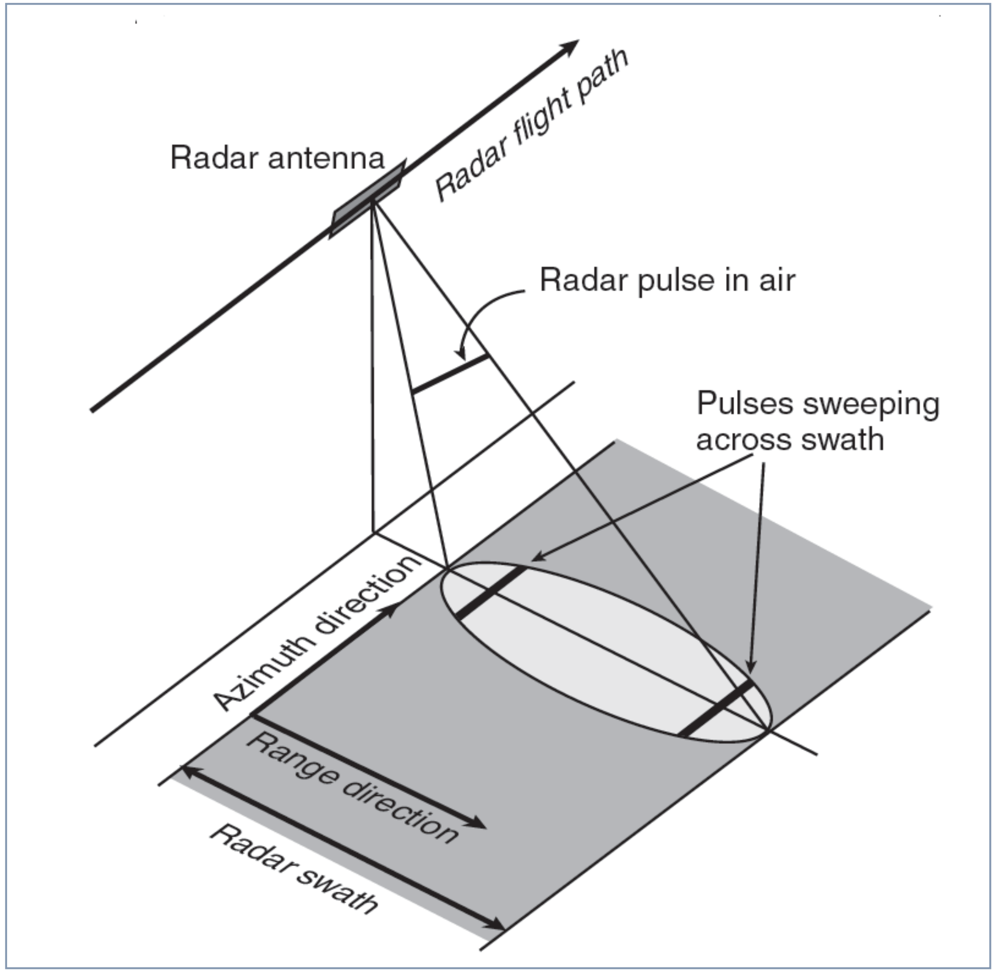
Formação das imagens RADAR





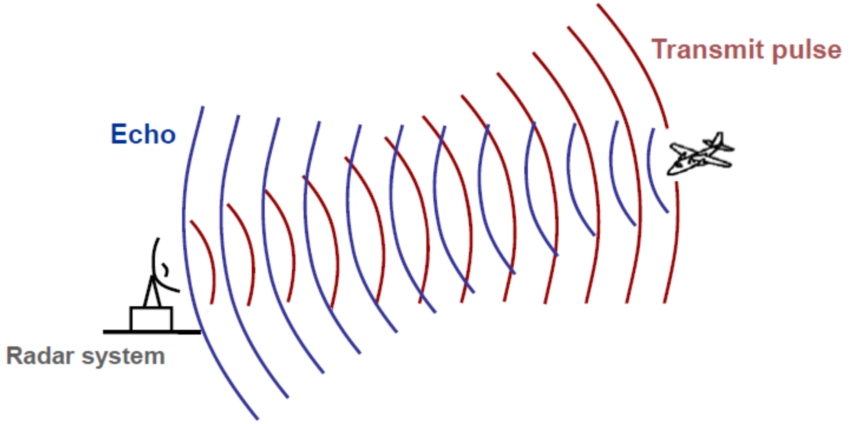




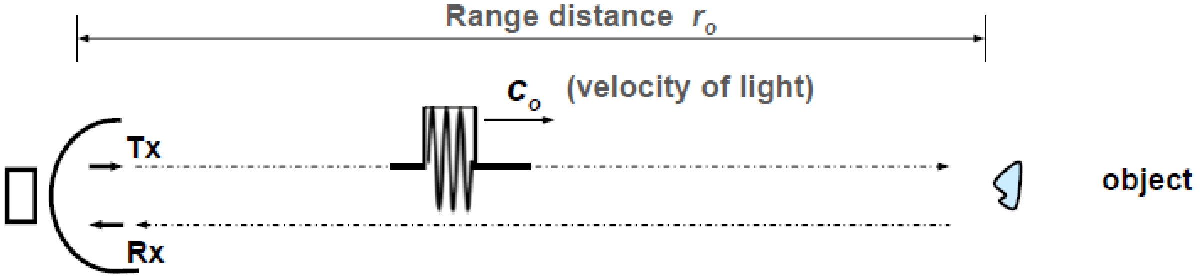


$$s_1 = A.\,e^{(j\phi_B)}.\,e^{\left(-j\left(\frac{4\pi}{\lambda}\right).r_1\right)}$$

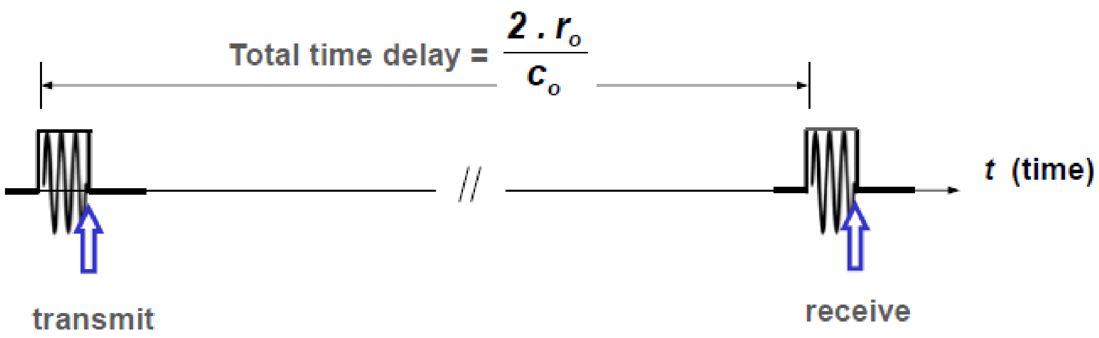
Radar Principle

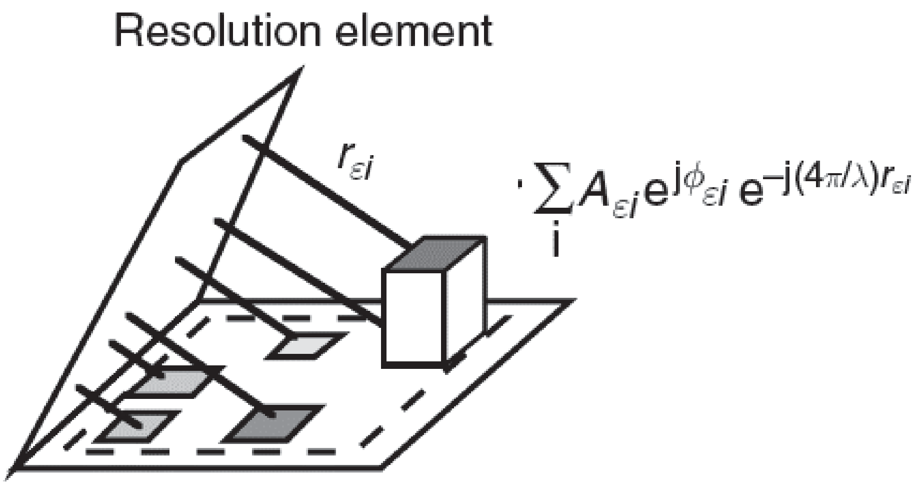


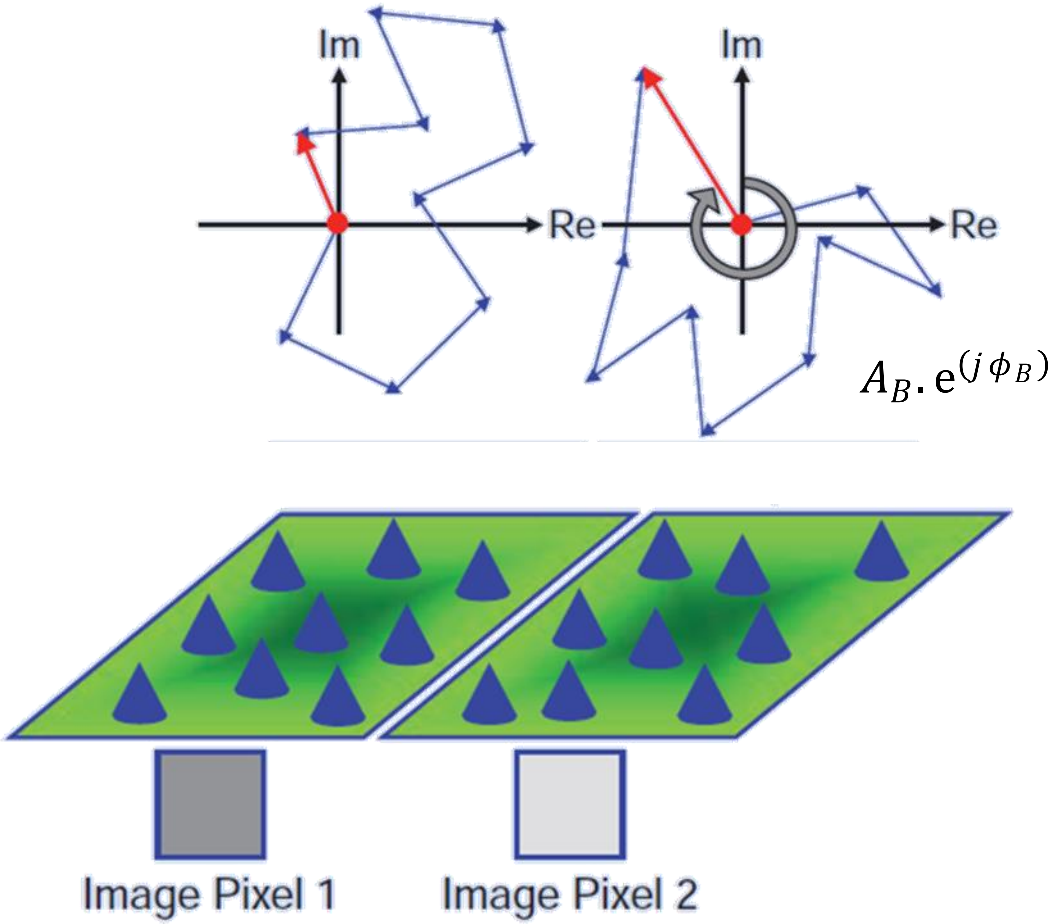
Radar Measurement Principle



- Received echo signal (back-scattered signal of imaged object):



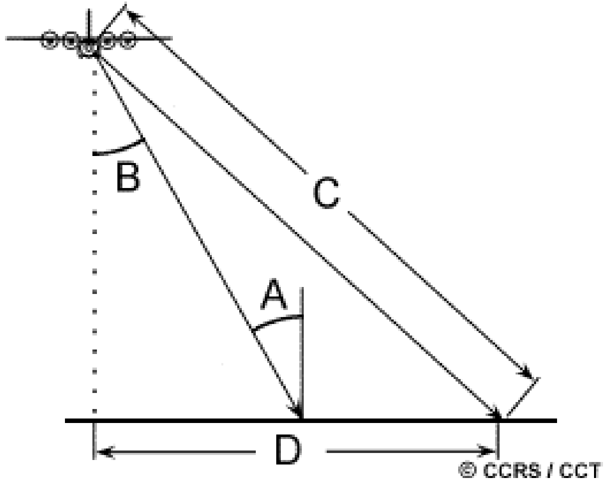




$$s_1 = A_B . \mathrm{e}^{(j\,\phi_B)} . e^{\left(-j\left(\frac{4\pi}{\lambda}\right) . r\right)}$$

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)

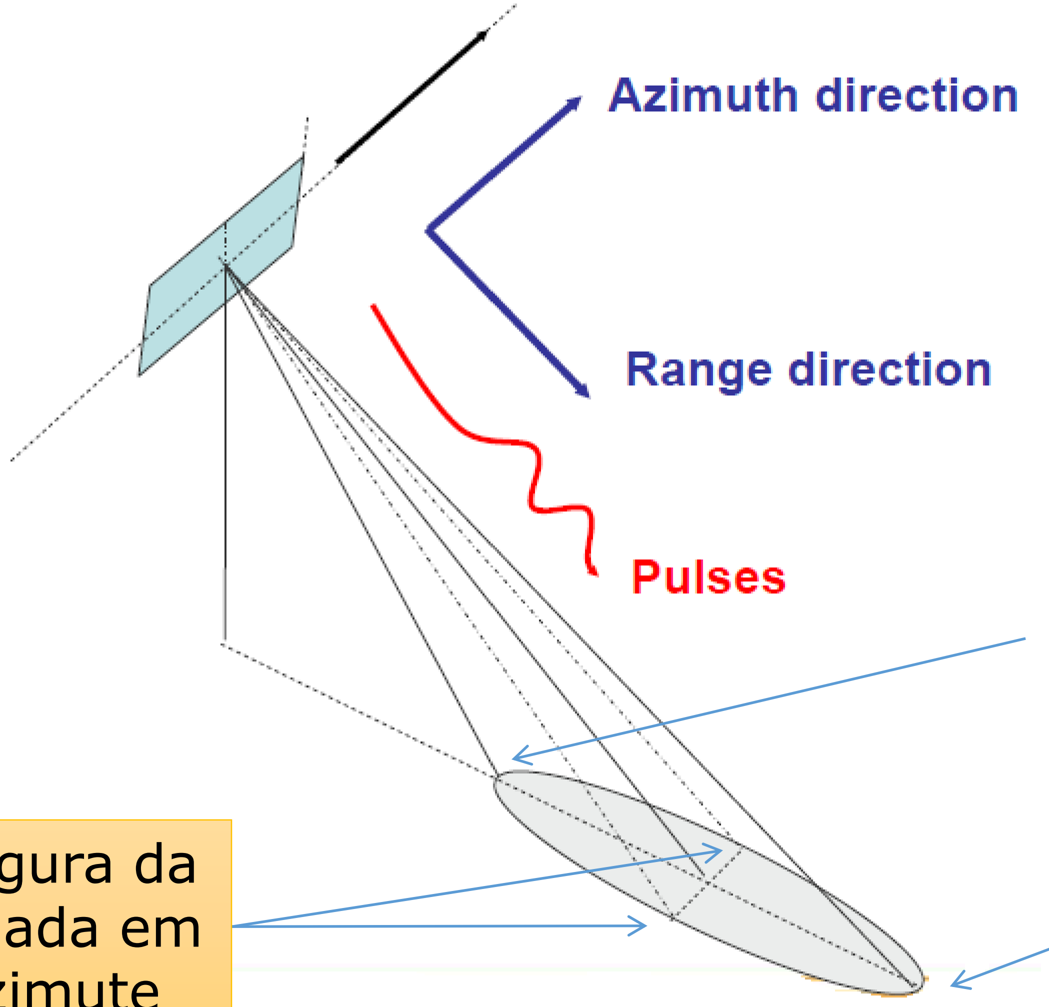
Slant Range(C)

(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



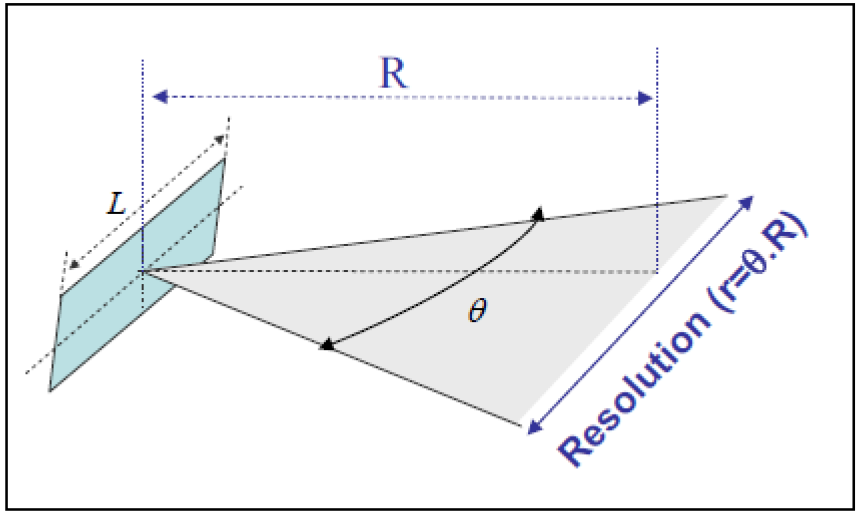
Qual a resolução de um pixel numa imagem radar?

Near range

Far range

Largura da pegada em azimute

Resolução em Azimute



Para uma antena de largura L

Abertura angular

Comprimento de onda

$$\theta = \frac{\lambda}{L}$$

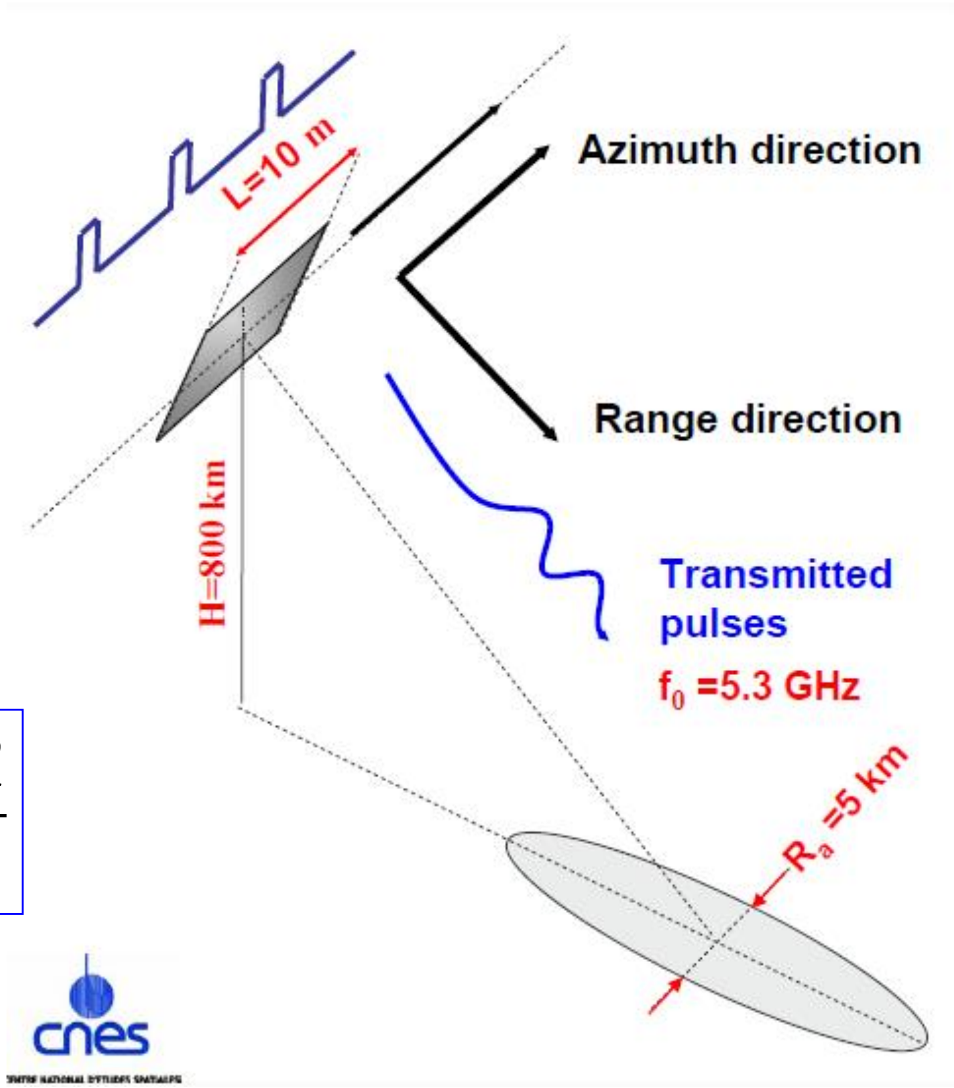
Largura da antena

$$r = \frac{\lambda R}{L}$$

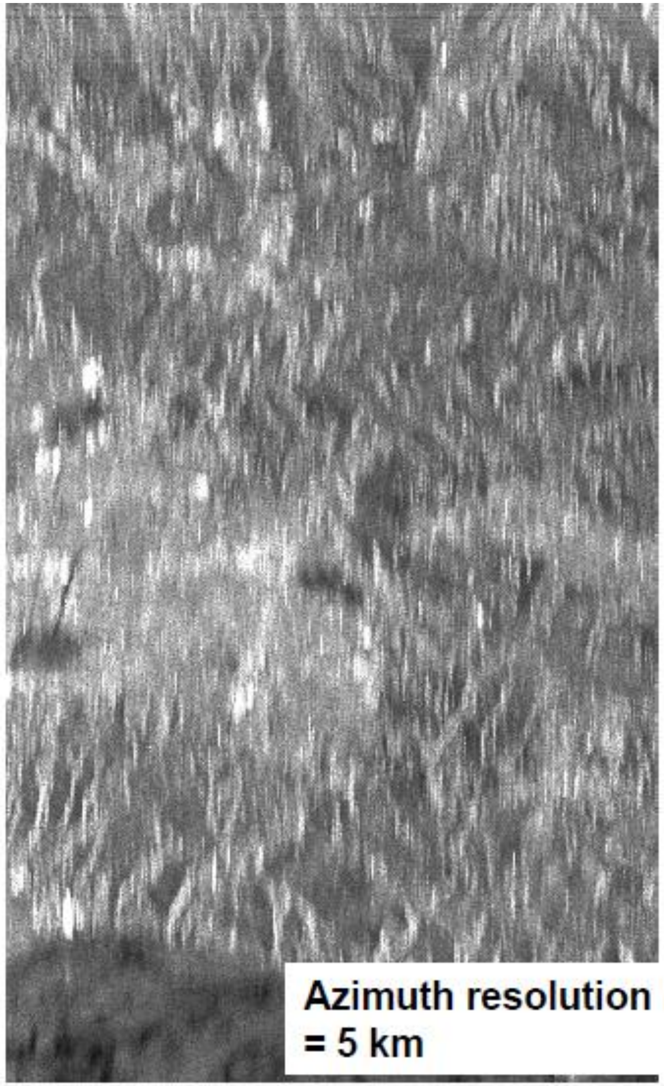
Quanto maior a antena mais fina é a resolução

Exemplo:
Para uma antena de 10m e c.o. de 5 cm (banda C) a resolução em azimute é de **5 km**

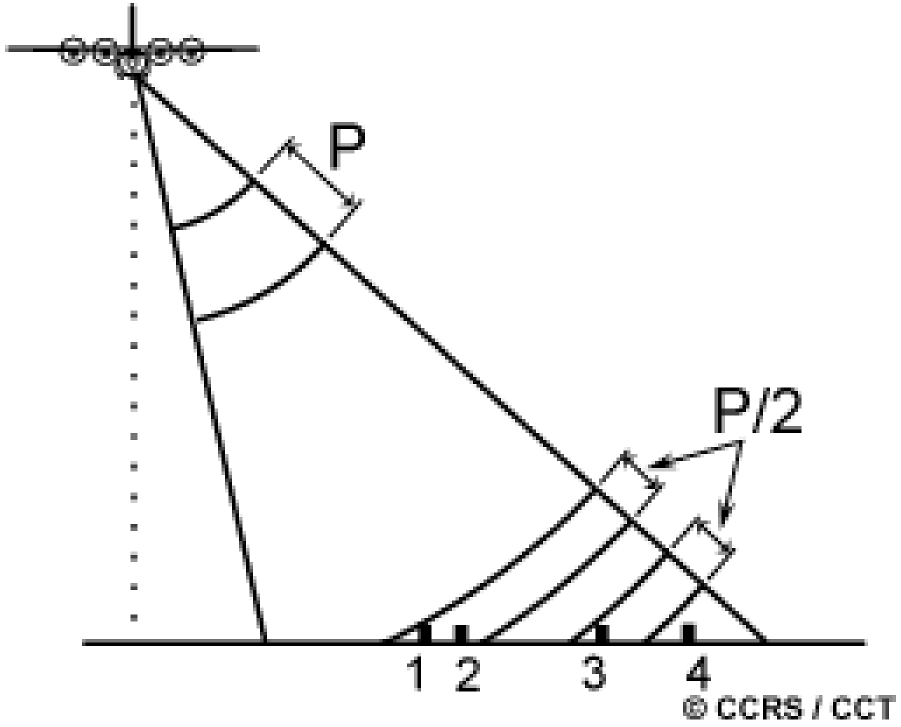
Resolução em Azimute



$$r = \frac{\lambda R}{L}$$



Resolução em Range



A resolução em range é dependente do comprimento do pulso (P) na direção do "slant range".

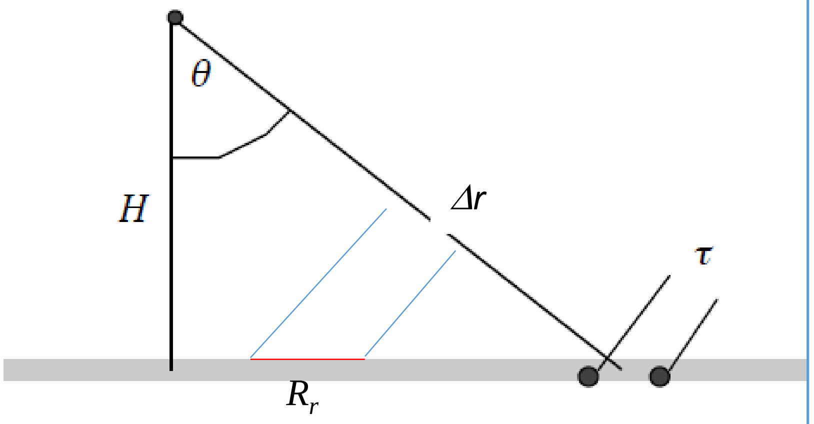
Dois alvos são separáveis se a sua separação é superior metade do comprimento do pulso

$$\Delta r = \frac{c\,P}{2}$$

Resolução slant range

A resolução em "slant range" é constante (e independente da altitude do voo) enquanto que a resolução na "ground range" é variável e dependente do ângulo de incidência.

Resolução em Range



θ	-	look angle
H	-	spacecraft height
B	-	bandwidth of radar
τ	-	pulse length $1/B$
C	-	speed of light

(sar_summary.pdf)

$$\Delta r = \frac{C\tau}{2}$$ - slant range resolution

$$R_r = \frac{C\tau}{2}\frac{1}{\sin\theta}$$ - ground range resolution

ERS: Band width 15.5 MHz
Slant Range resolution = 9.6 m
Ground range resolution = 24. 7 m

TRX: Band width 150 MHz
Slant Range resolution = 1.0 m
Ground range resolution = 2.9m

ERS
Azimuth = 5 km
Range = 25 m

PRF = 1.640 – 1.720 kHz

TRX
Azimuth = 4.4 km
Range = 3 m

PRF = 2.0 – 6.5 kHz

Aumento da Resolução

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

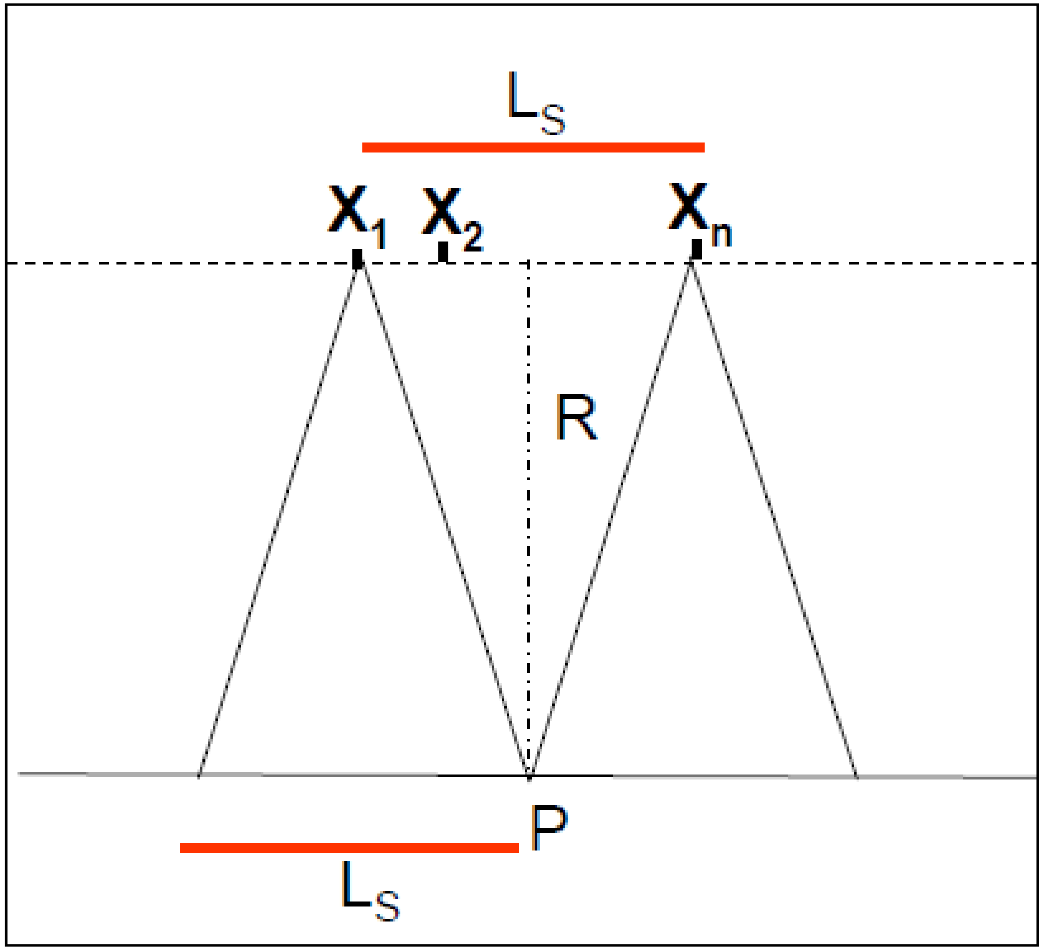
Pode ser conseguida aumentando o tamanho da antena.

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)

Radar de Abertura Sintética



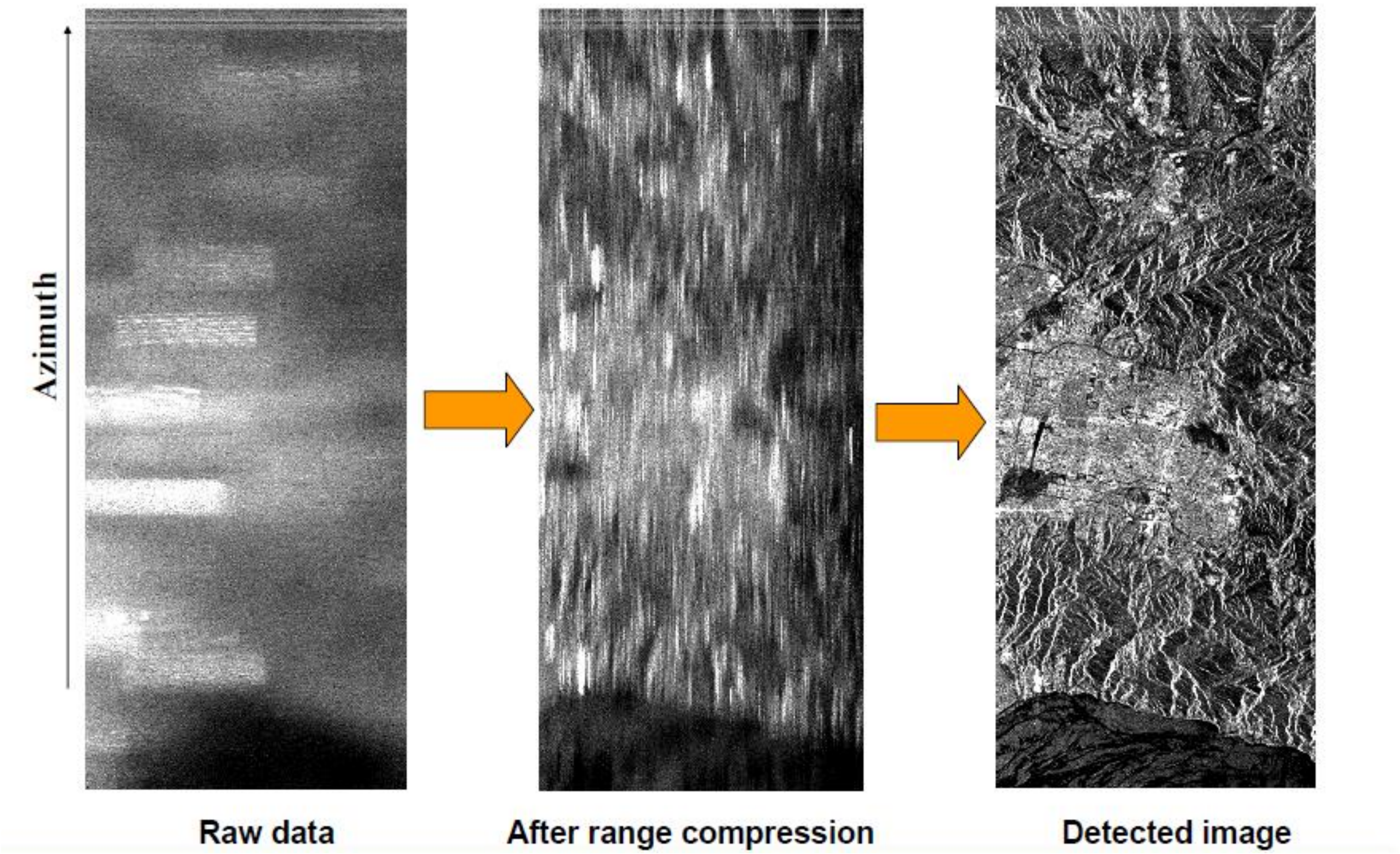
Os ecos obtidos das posições X_1, X_2 .. X_n são registados coerentemente (amplitude e fase) em função do tempo.

A distância entre a primeira posição registada e a ultima determina a abertura sintética da antena L_S.

Este método é designado por:

Synthetic Aperture Radar

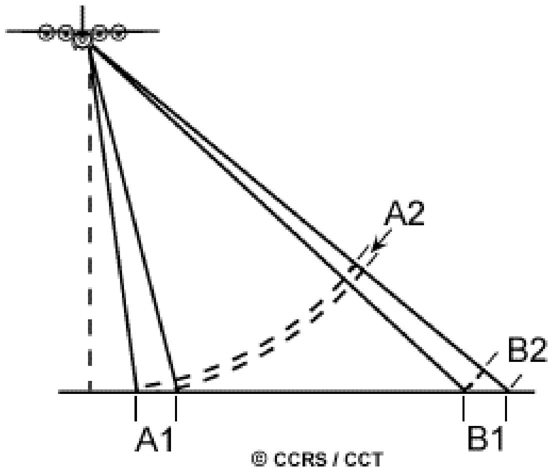
Radar de Abertura Sintética

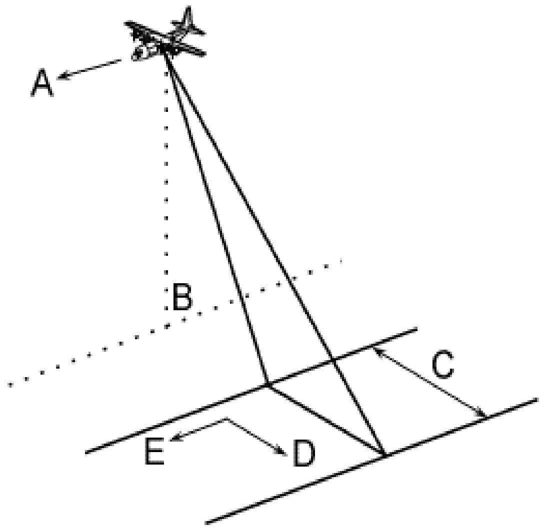


Distorção nas imagens SAR:

facto de haver apenas a medição de uma distância

à geometria de aquisição com uma visada lateral,

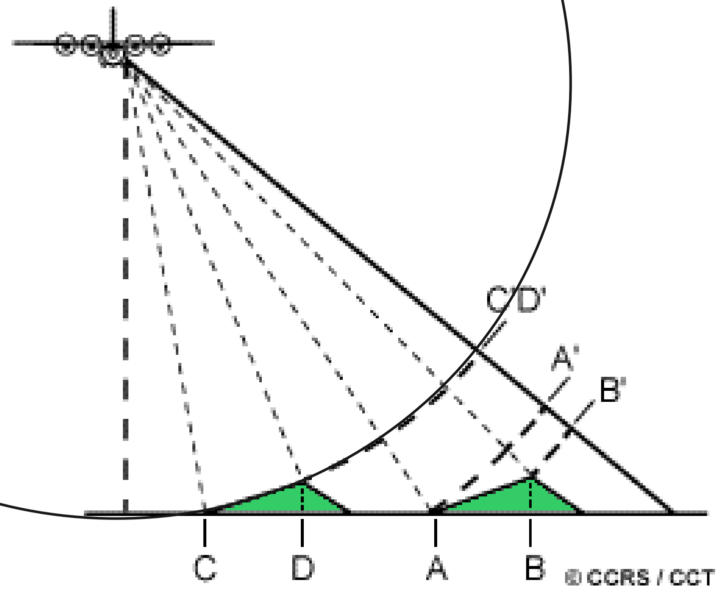




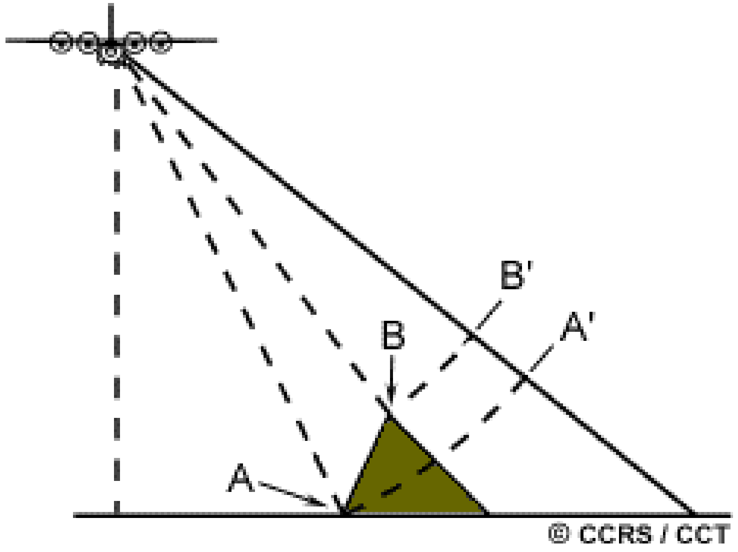
Distorções devidas ao relevo

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

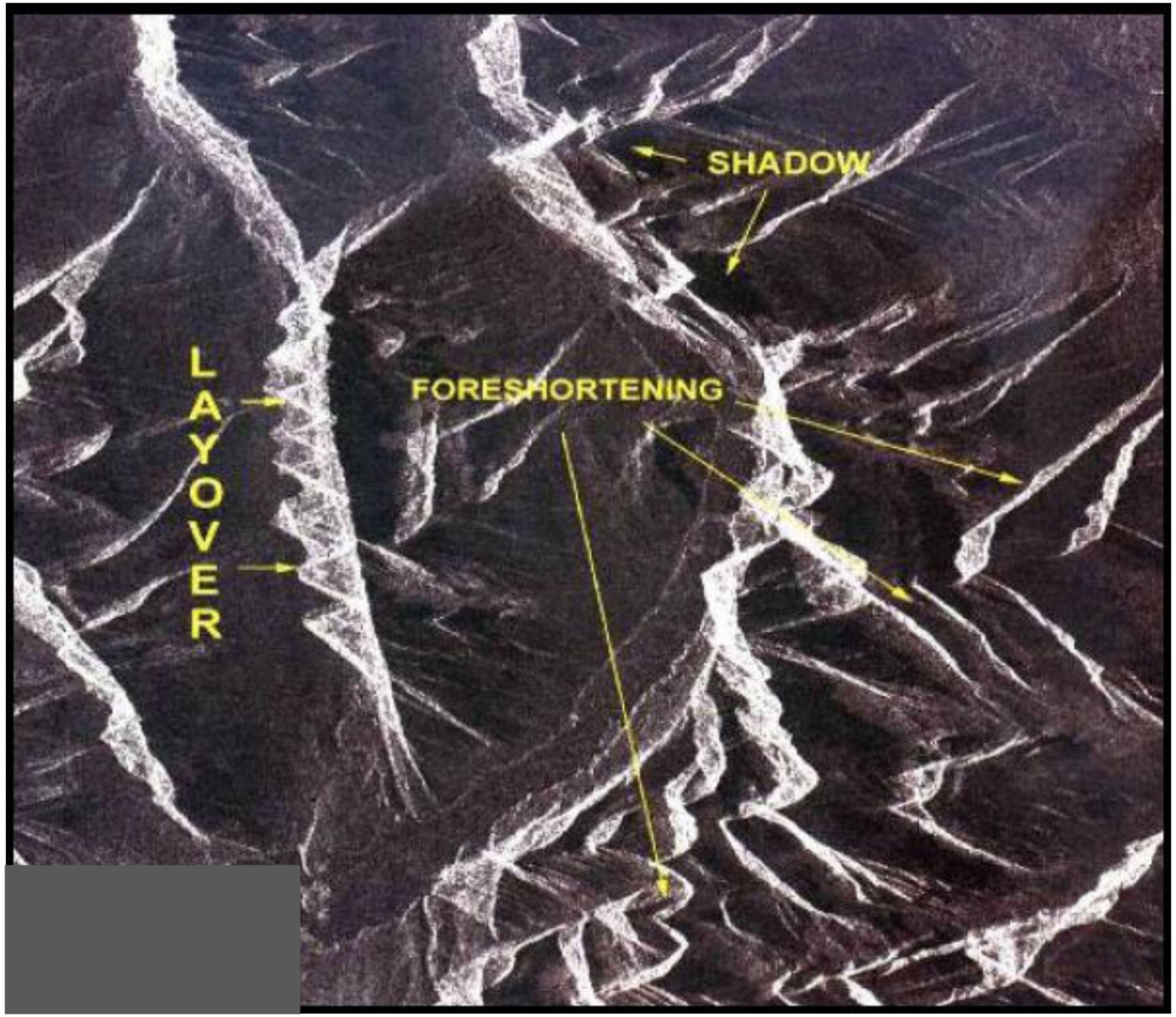
Foreshortening



Layover

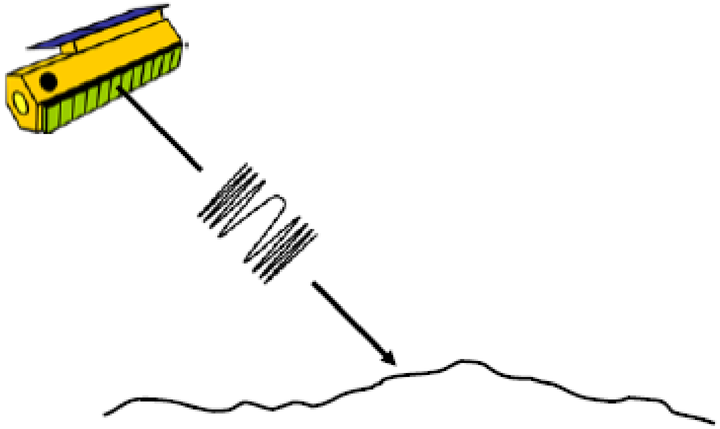


Distorções devidas ao relevo

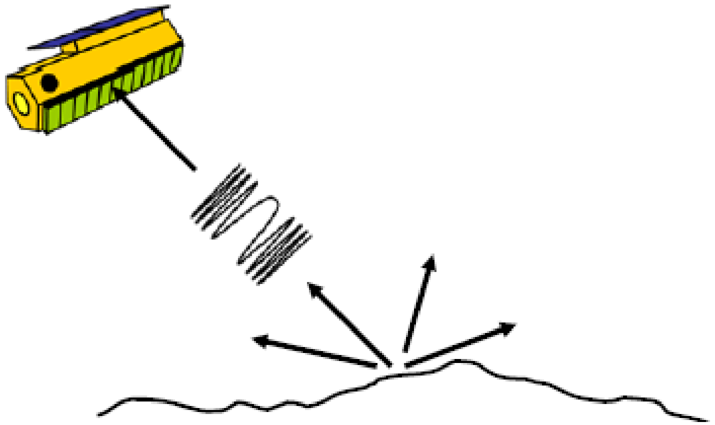


What does the Radar measure ?

- *Radar reflectivity (backscattered signal) of targets as a function of their position*



- radar transmits a pulse (travelling velocity is equal to velocity of light)



- some of the energy in the radar pulse is reflected back towards the radar. This is what the radar measures.

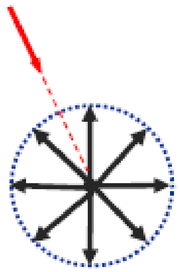
It is known as radar backscatter σ_o

(sigma nought or sigma zero).

What does the Radar measure ?

- Normalized radar cross-section (backscattering coefficient) is given by:

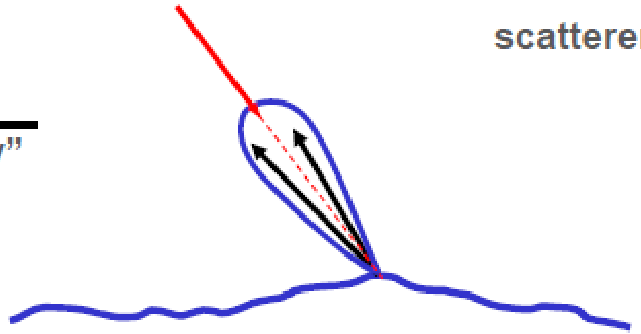
$$\sigma_o\ (dB) = 10.\ Log_{10}\ (energy\ ratio)$$



Isotropic scatterer

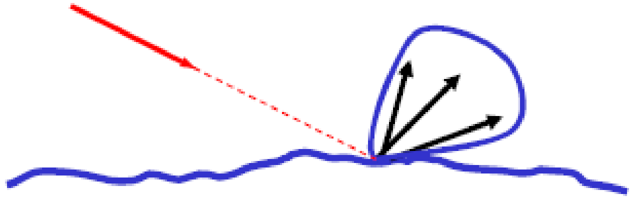
whereby

$$\text{energy ratio} = \frac{\text{received energy by the sensor}}{\text{“energy reflected in an isotropic way”}}$$



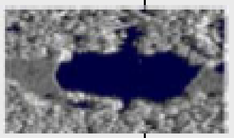
The backscattered coefficient can be a positive number if there is a focusing of backscattered energy towards the radar

or

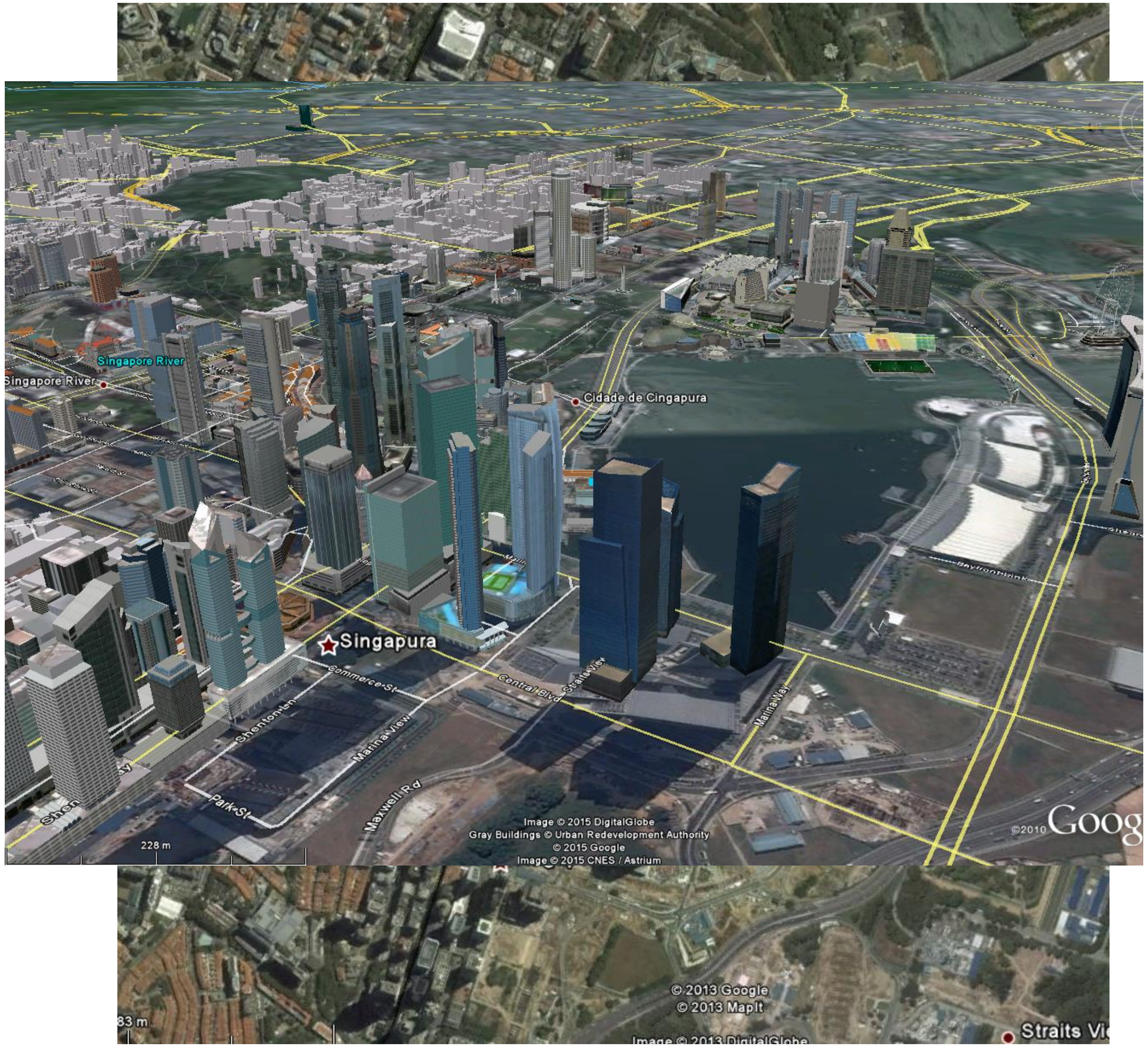


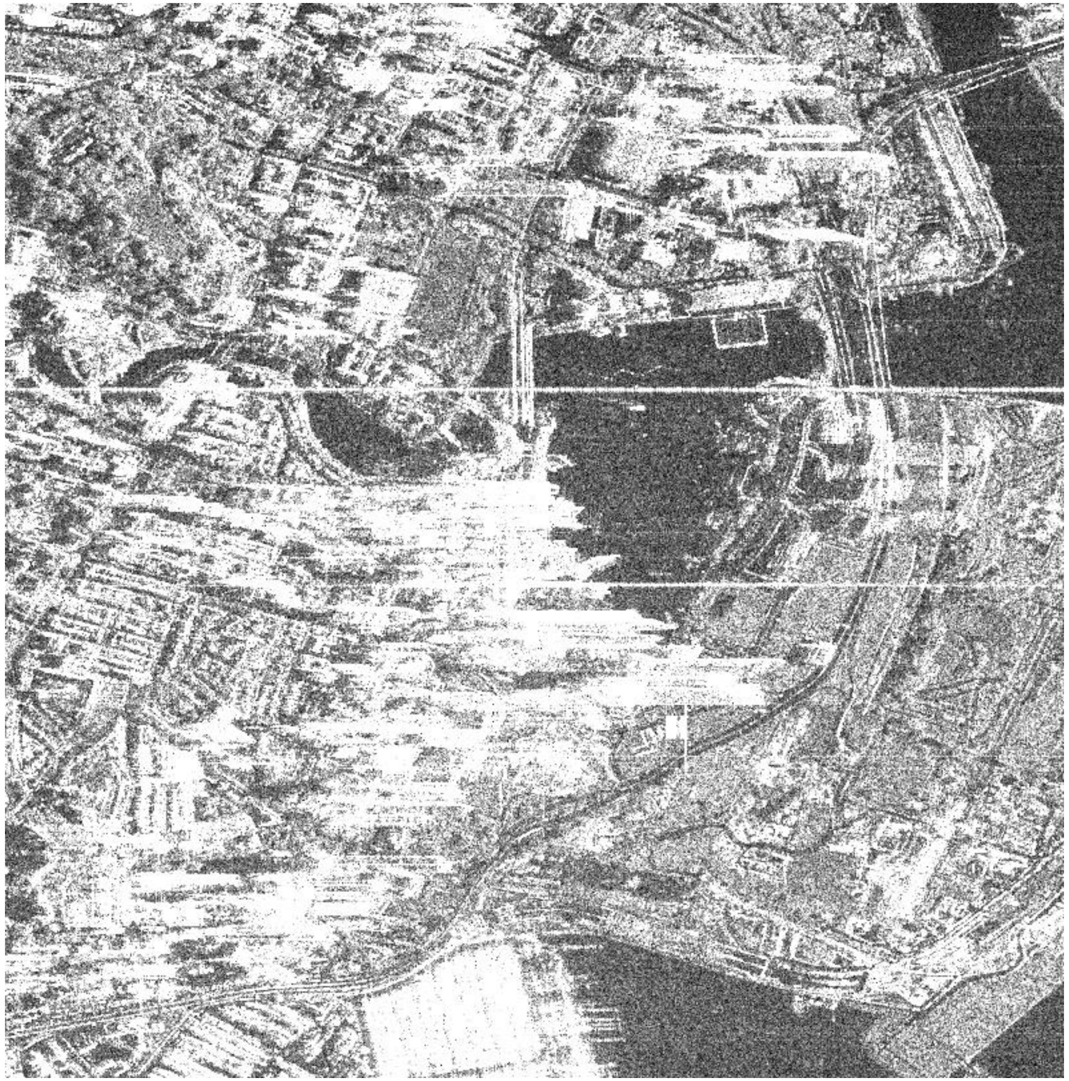
The backscattered coefficient can be a negative number if there is a focusing of backscattered energy way from the radar (e.g. smooth surface)

Backscattering Coefficient σ_o

Levels of Radar backscatter		*Typical scenario*
• *Very high backscatter (above -5 dB)*		*Man-Made objects (urban)* *Terrain Slopes towards radar* *very rough surface* *radar looking very steep*
• *High backscatter (-10 dB to 0 dB)*		*rough surface* *dense vegetation (forest)*
• *Moderate backscatter (-20 to -10 dB)*		*medium level of vegetation* *agricultural crops* *moderately rough surfaces*
• *Low backscatter (below -20 dB)*		*smooth surface* *calm water, road* *very dry terrain (sand)*

SAR image

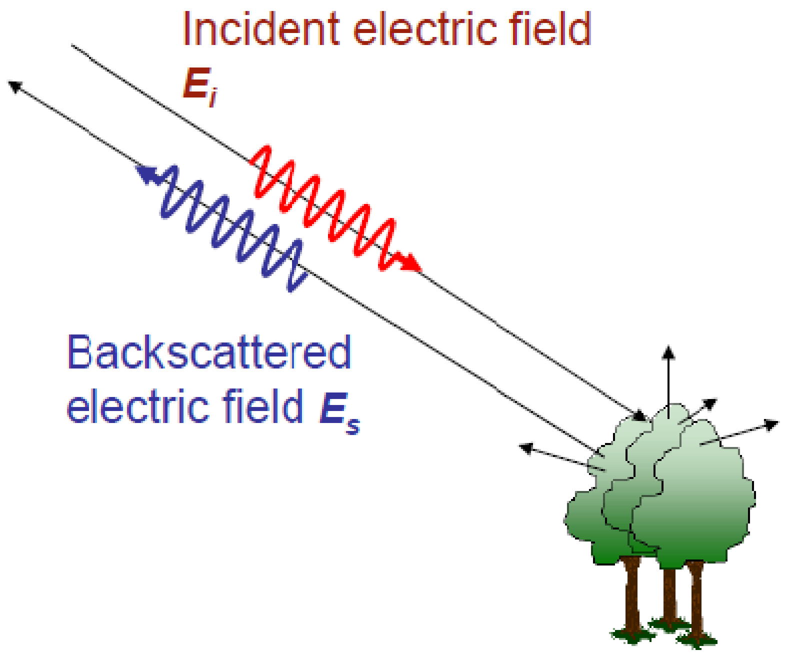

Singapore River
Singapore River
Cidade de Cingapura
Singapura
Commerce St
Central Blvd
Straits View
Shenton Ln
Marina View
Park St
Maxwell Rd
Bayfront Link
Image © 2015 DigitalGlobe
Gray Buildings © Urban Redevelopment Authority
© 2015 Google
Image © 2015 CNES / Astrium
228 m
©2013 Google
©2013 MapIt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



Que informação extraímos da imagem SAR

O sinal transmitido tem as seguintes caraterísticas:

- **Amplitude**
- **Fase e referencia temporal**
- **Polarização**
- **Comprimento de onda ou frequência**



A comparação das caraterísticas do sinal recebido com sinal transmitido permite determinar as propriedades dos objetos.

Scattering Mechanisms

O sinal retro-disperso resulta de:

Surface scattering

Volume scattering

A importância relativa destas contribuições depende da:

Rugosidade da superfície

Propriedades dieléctricas do meio

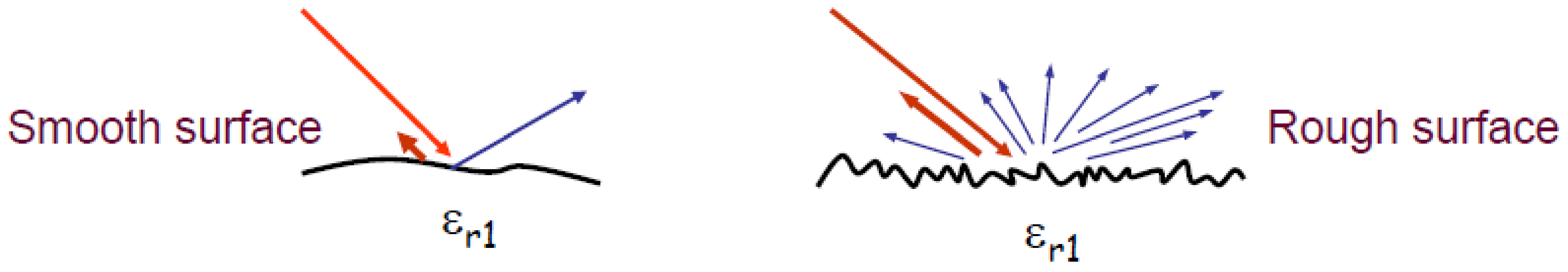
Todos estes factores dependem de:

Frequência do radar

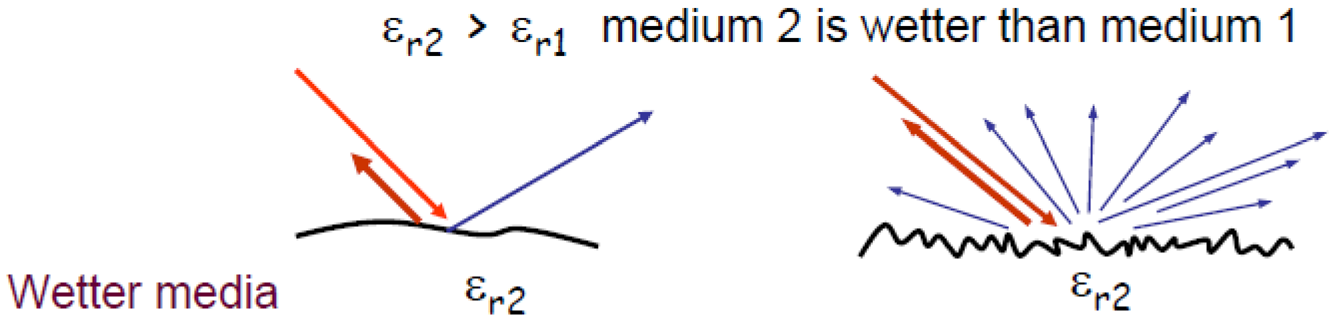
Ângulo de incidência

Polarização

Efeito da rugosidade e humidade

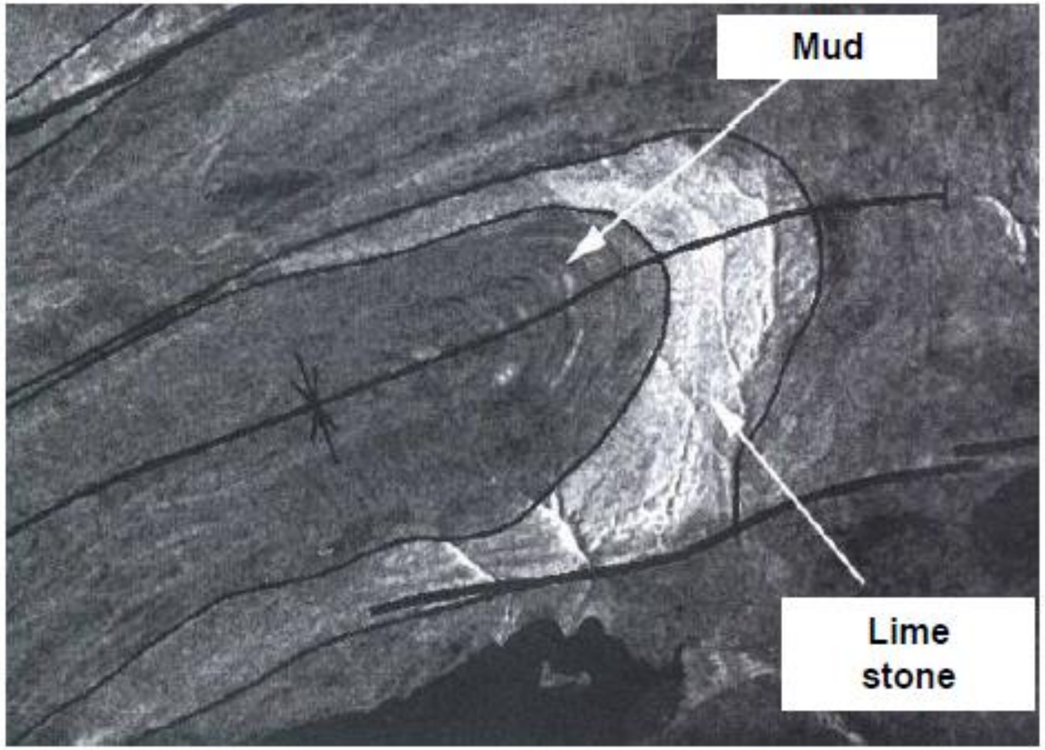


A rugosidade da superfície (relativamente ao comprimento de onda) condiciona o padrão da dispersão.



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

Efeito da rugosidade e humidade



RADARSAT
(C band, HH, 45°)

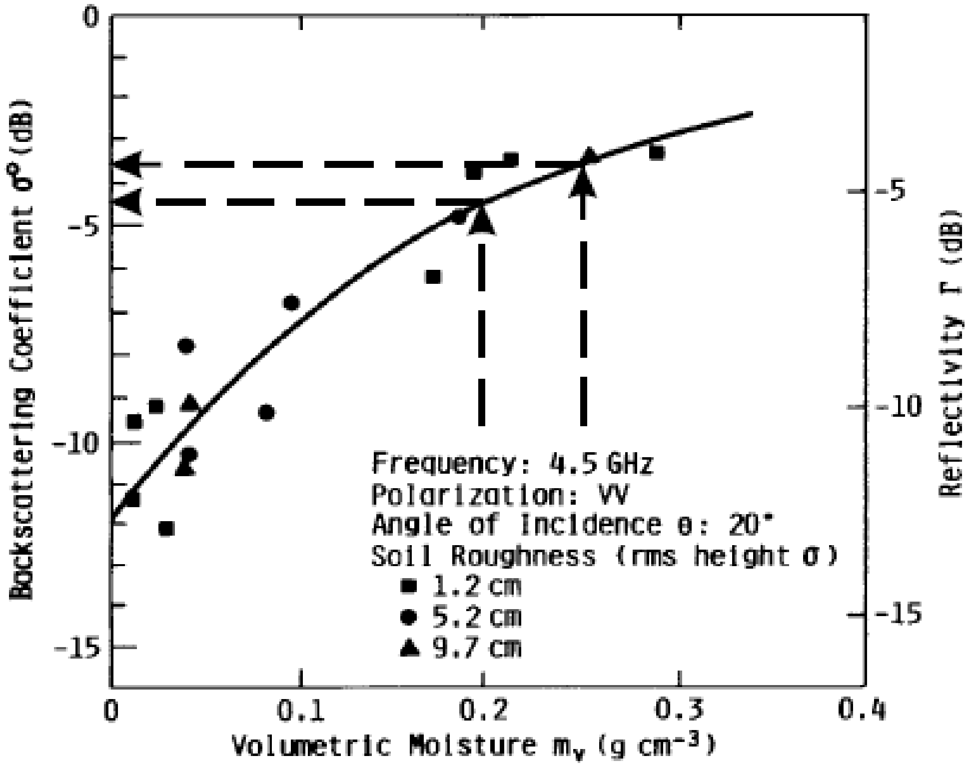
Quaternary lithology:
Bathurst Island, Canada

From : RADARSAT Geology Handbook

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

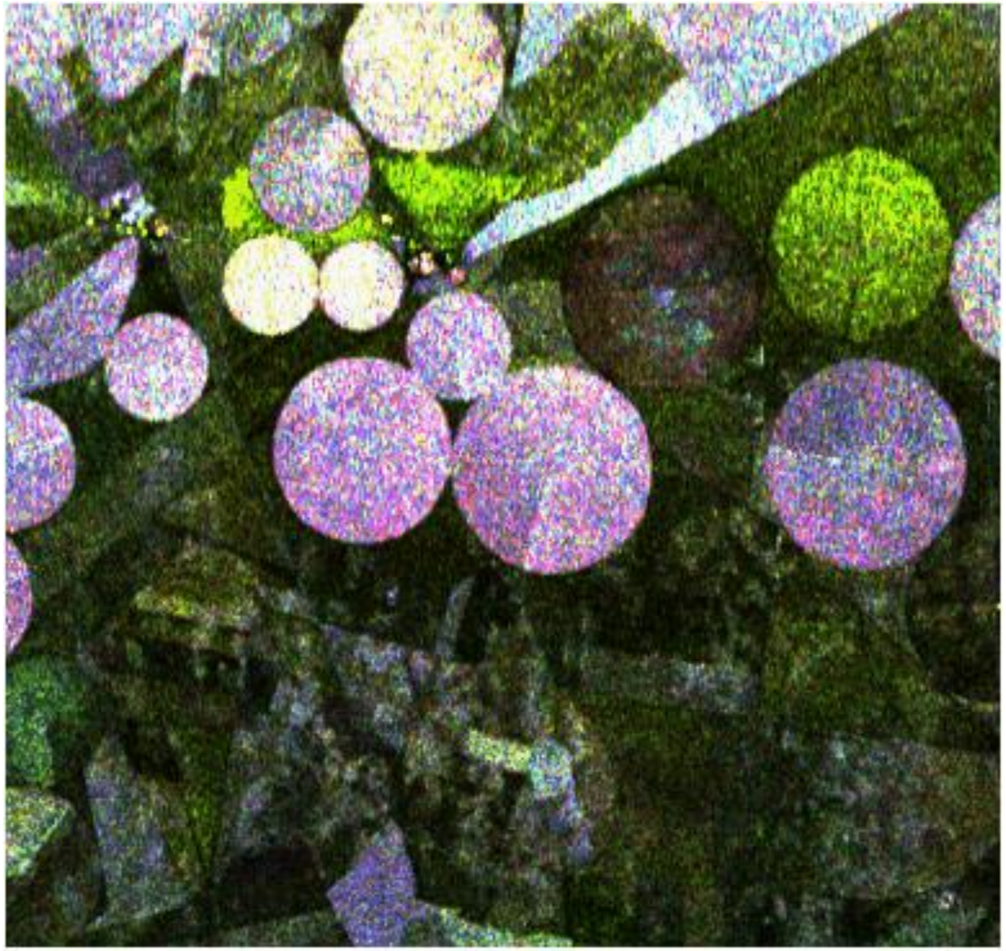
Limestone ➡ **Higher backscatter**
because of rougher surface
(calcário)

Efeito da rugosidade e humidade



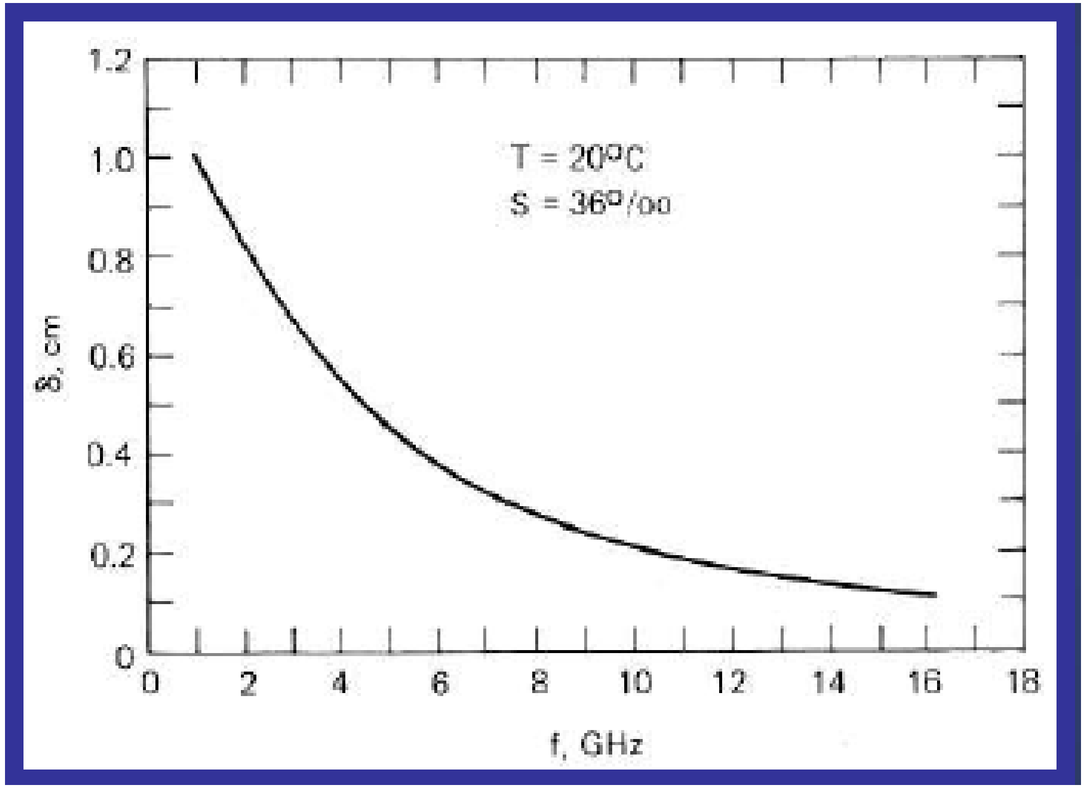
(Humidade)

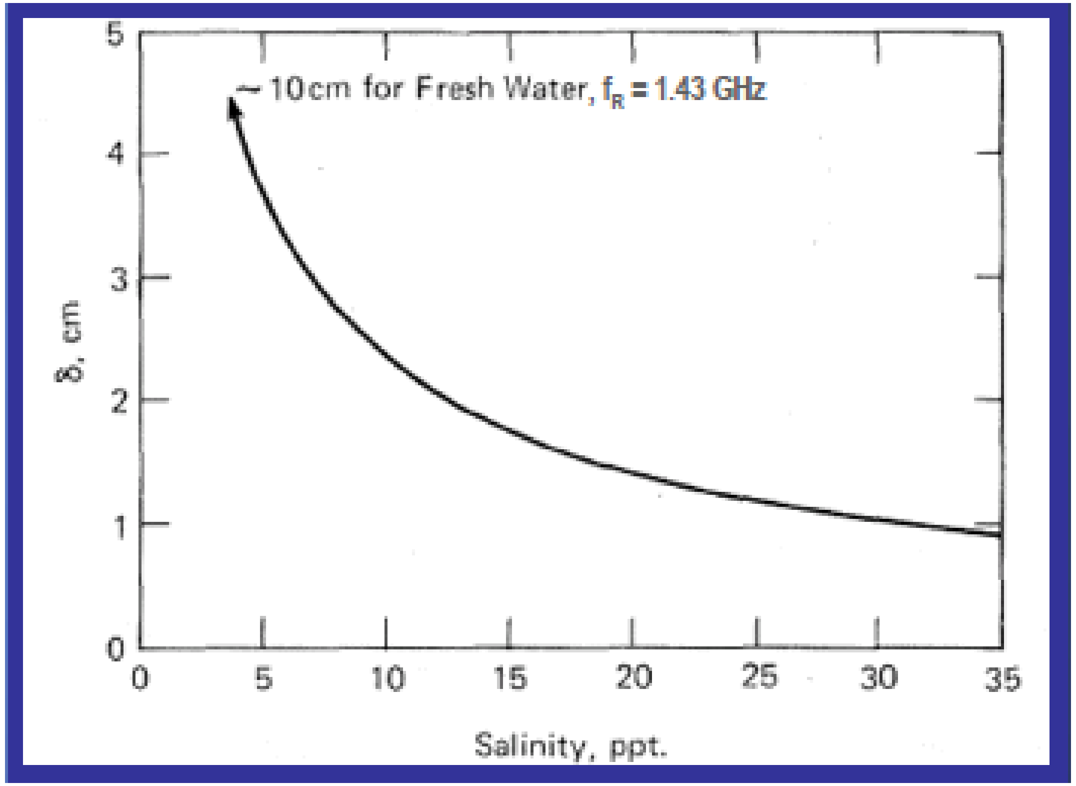
Resultado experimental realizado com um "scatererometer"



Campos irrigados têm maior backscatterer

Propriedades dielétricas da água



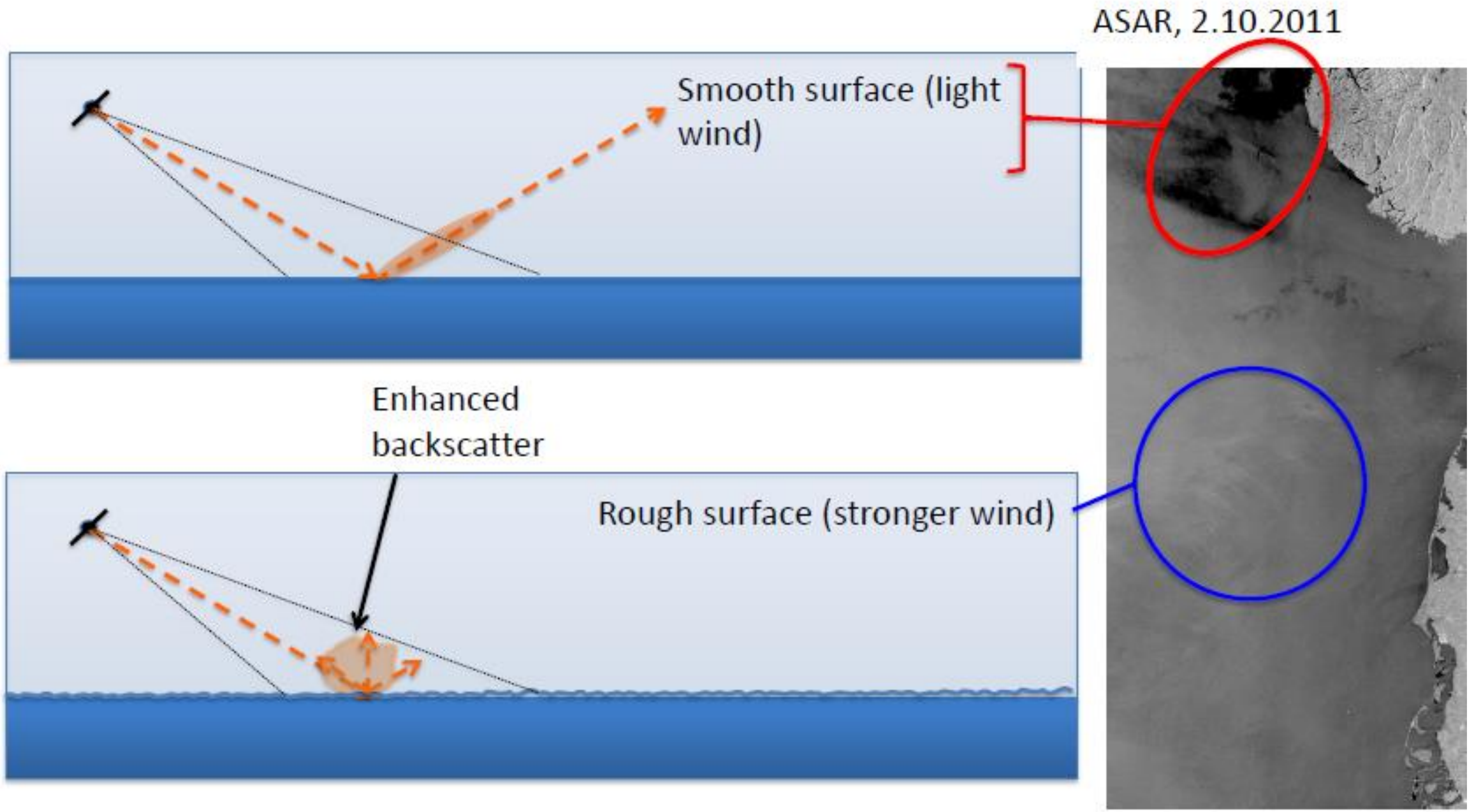


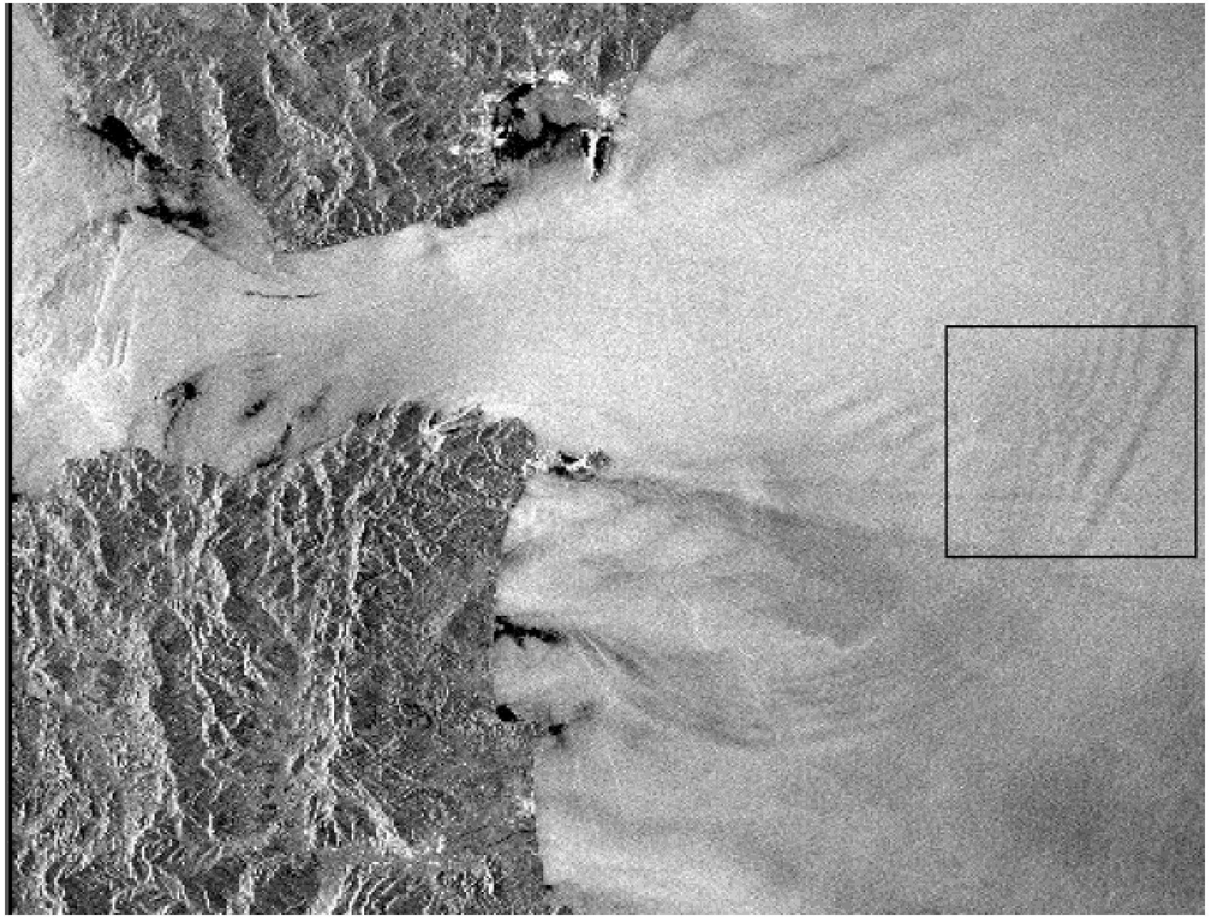
A profundidade de penetração do sinal na água depende das propriedades dielétricas da água e do comprimento de onda do sinal Radar.

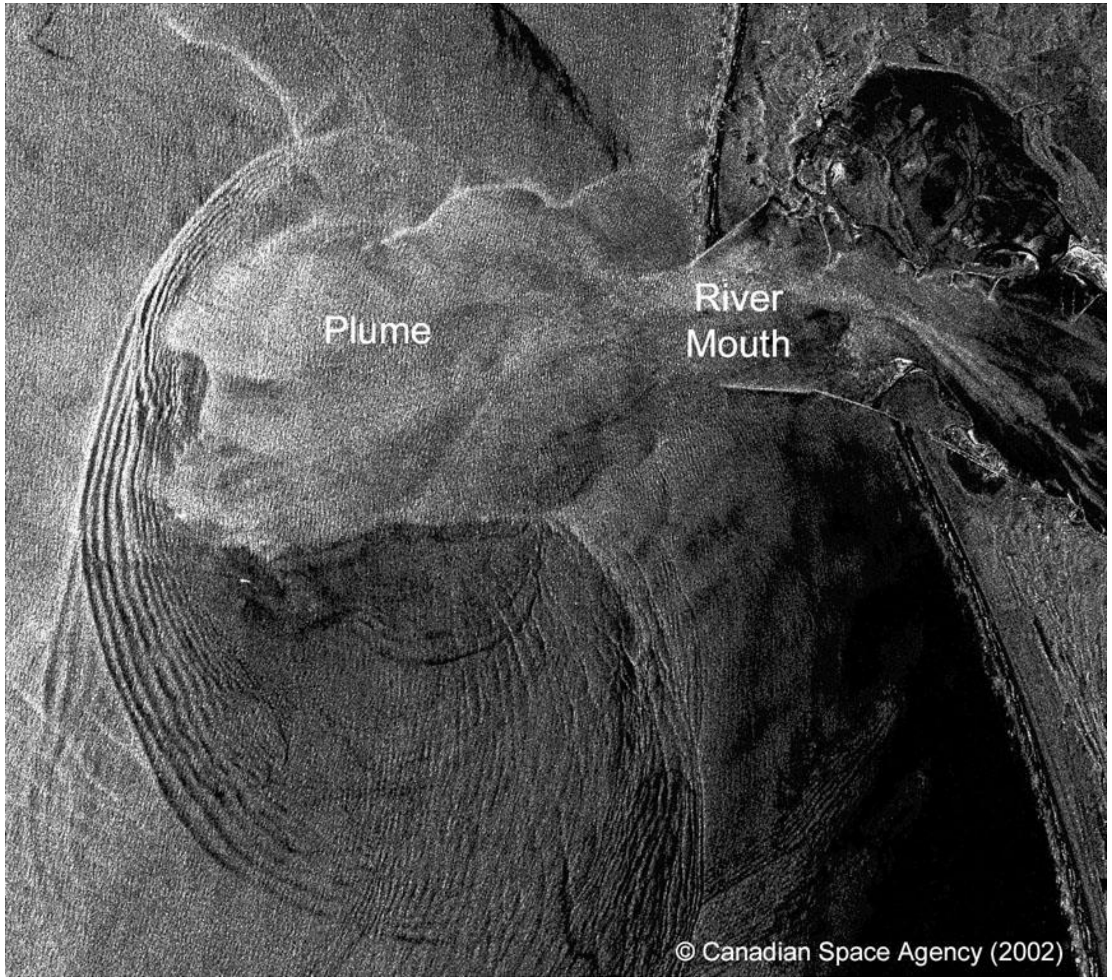
As propriedades dielétricas dependem da salinidade e da temperatura.

L : 1.25 GHz
C : 5.30 GHz
X : 10.0 GHz

Rugosidade da superfície e scattering

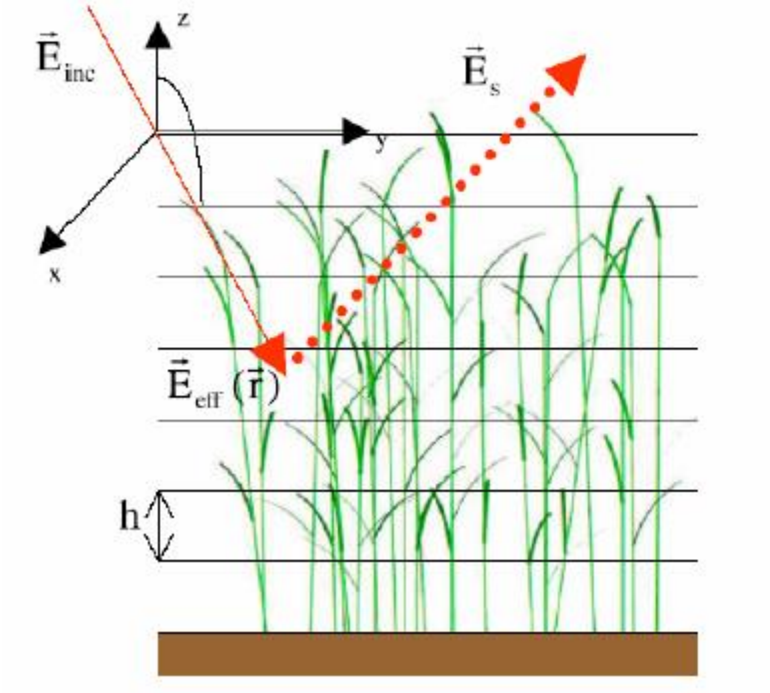


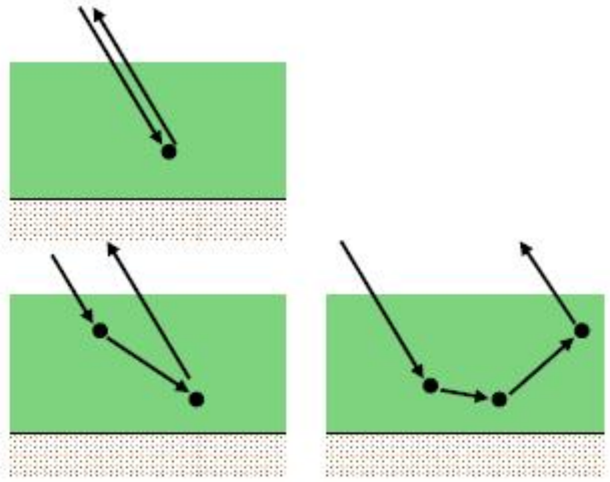



Plume
River Mouth
© Canadian Space Agency (2002)

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



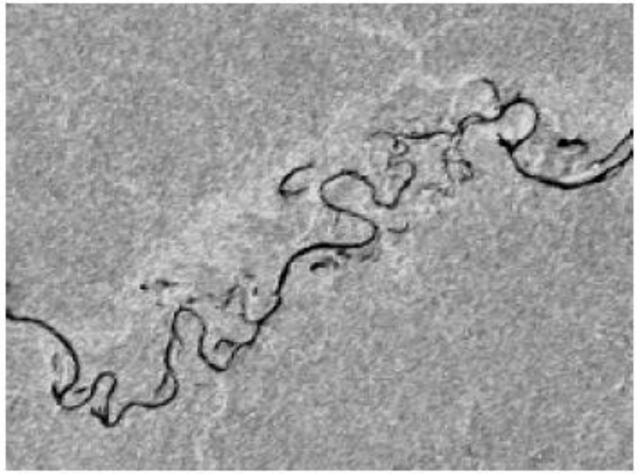


Single and multiple scattering

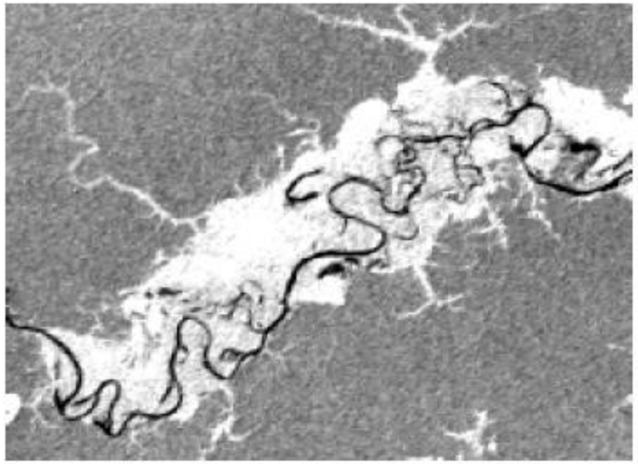
Penetração através das árvores

Varzea Dry Season

Varzea Wet Season



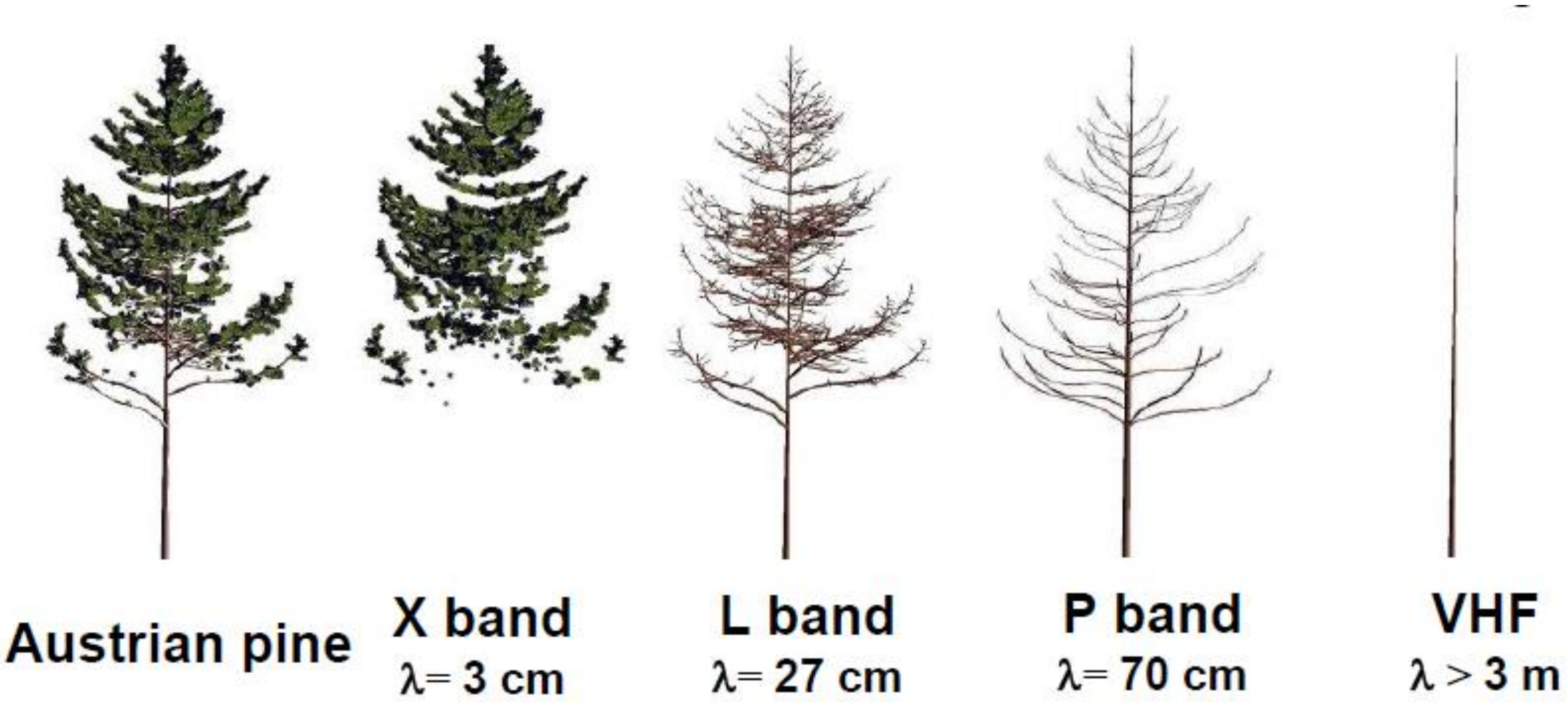
P-band image



P-band image

Document S.Saatchi, JPL

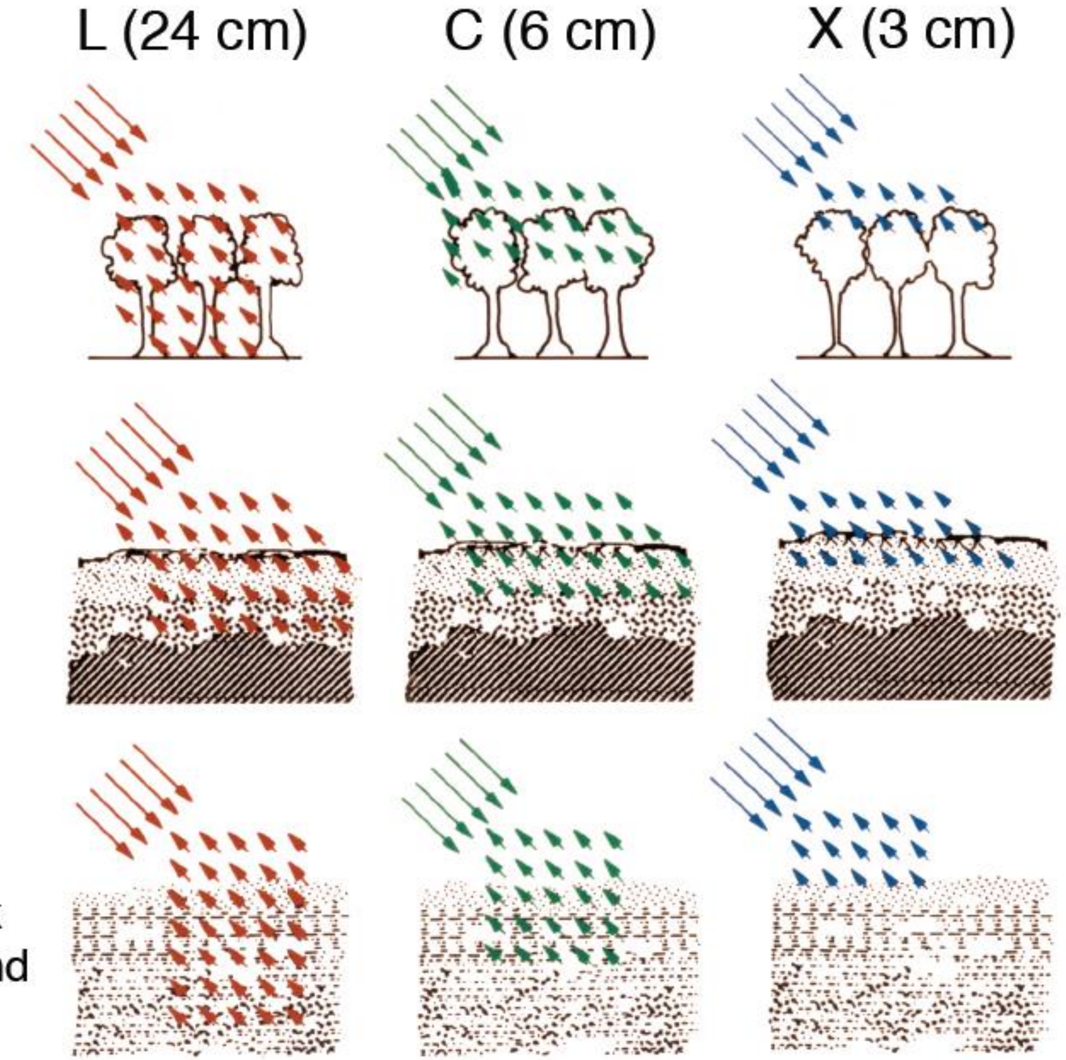
Quem são os scatterers numa dispersão volúmica.



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

Scaterring / comprimento de onda

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



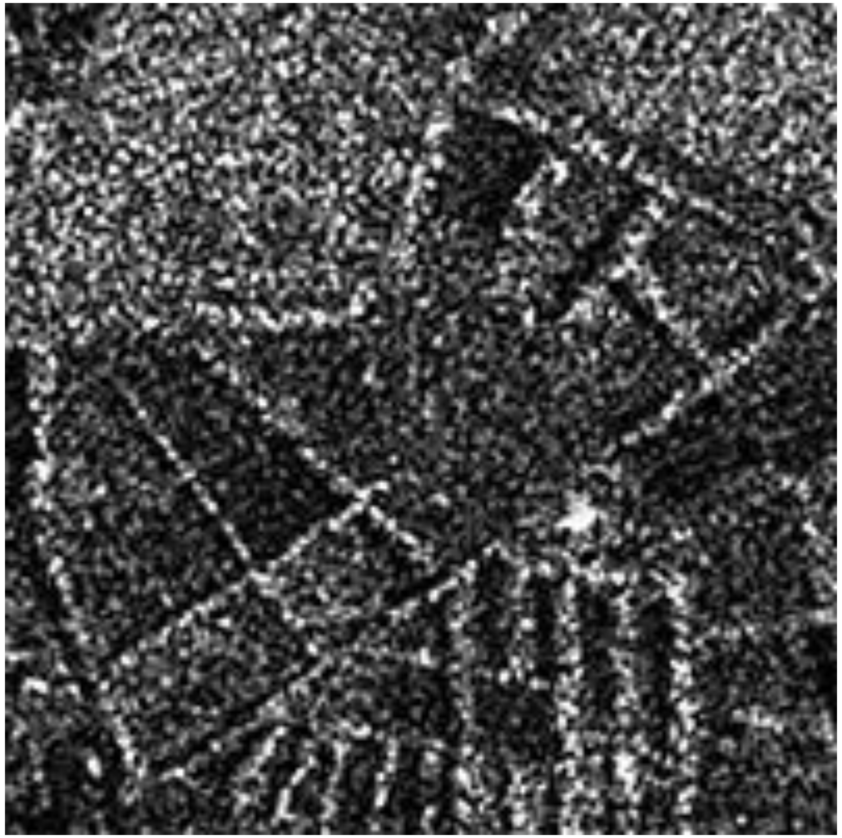
Forest: Leaves reflect X-band wavelengths but not L-band

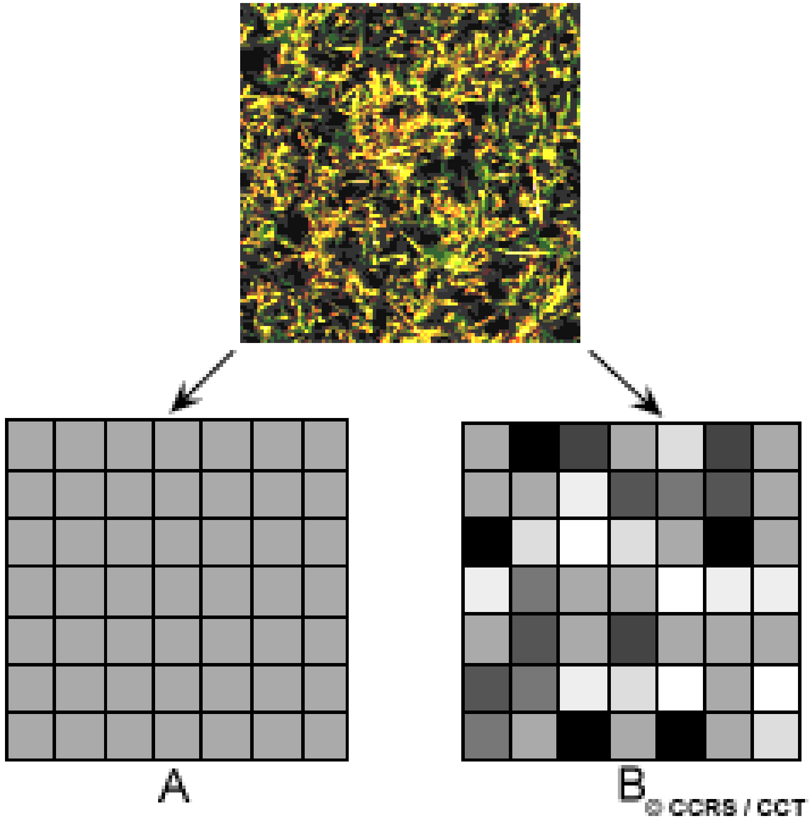
Dry soils: Surface looks rough to X-band but not L-band

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

(adapted JPL, 2010)

Speckle





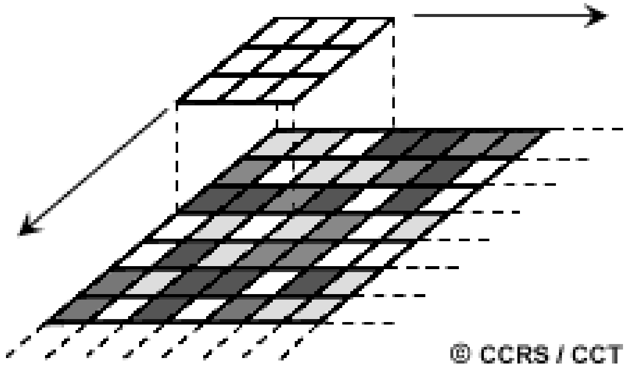
O *speckle* é causado pela interferência destrutiva e construtiva de muitos ecos de dispersão que ocorrem numa única célula.

Mitigação do Speckle

O speckle é uma forma de ruído que degrada a qualidade de uma imagem poderá tornar a interpretação (visual ou digital) mais difícil.

A redução do speckle pode ser conseguida de duas formas:

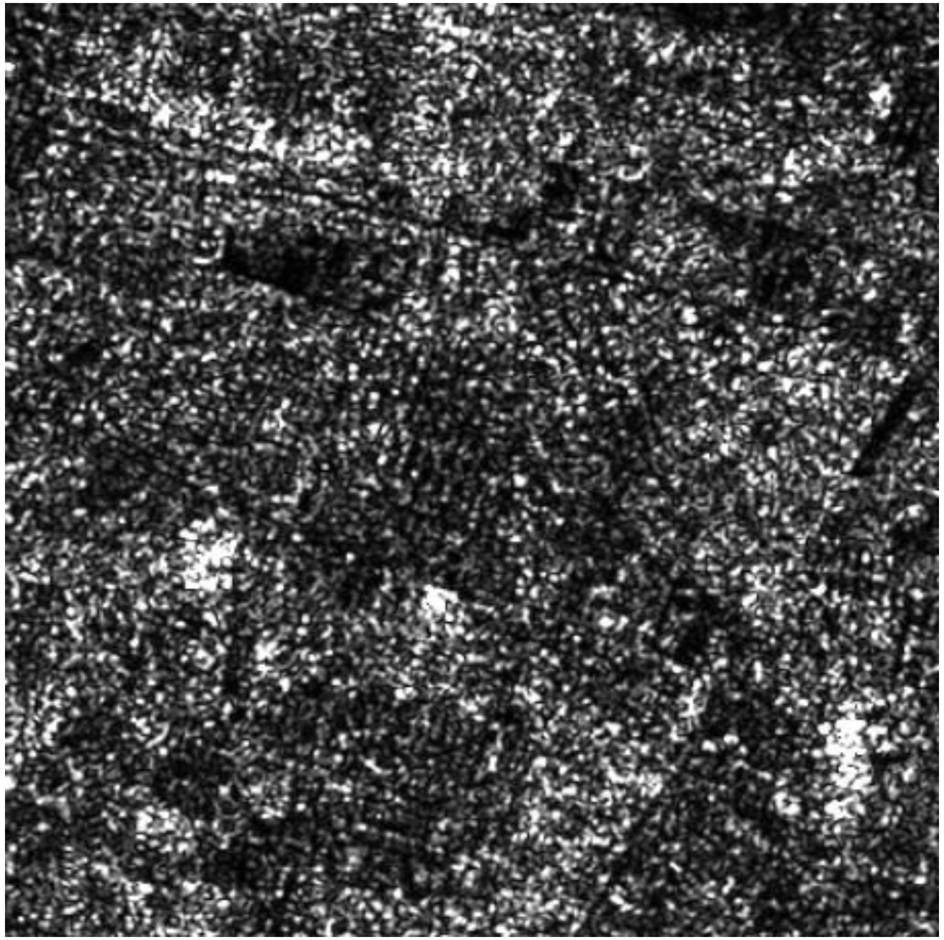
Processamento Multi-look

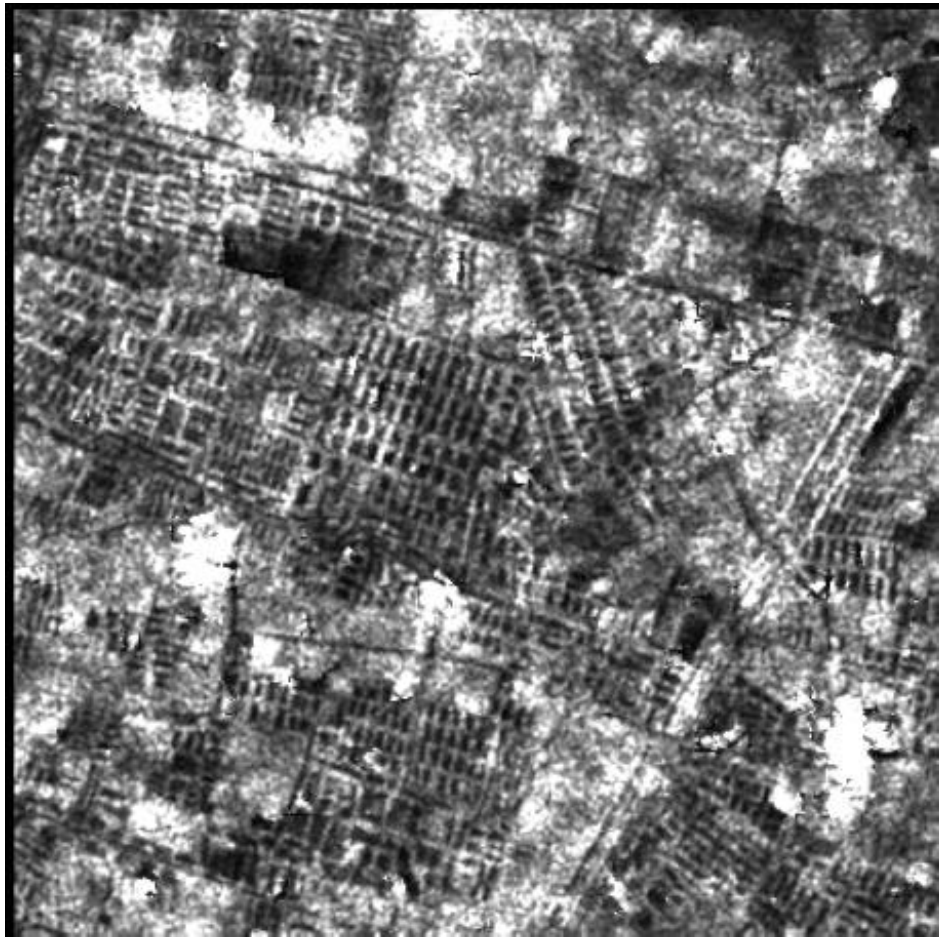


Filtro Espacial

O filtro espacial consiste numa pequena janela de alguns pixéis (ex. 3x3, 5x5) sobre cada pixel na imagem, calculando a média ou qualquer outro valor (filtro) e substituindo o pixel central por este novo valor.

Filtro Espacial





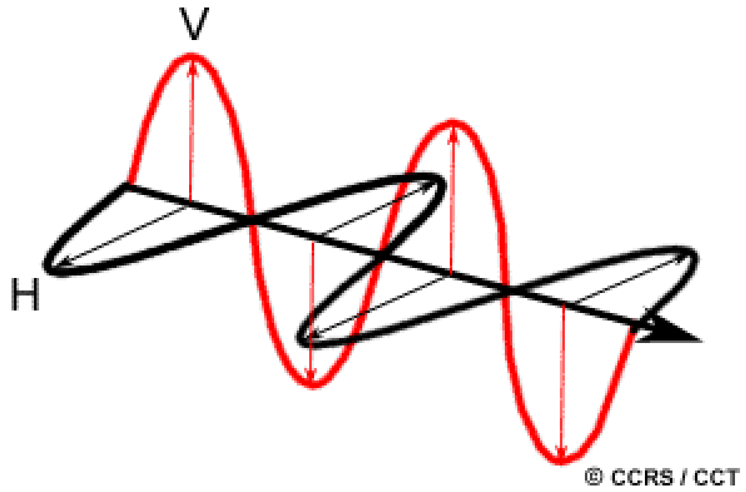
Na imagem da esquerda foi aplicado um filtro da mediana, obtendo-se a imagem da direita.

HH image 400 x 400 pixels (of 12.5m)

Polarização

A polarização de uma onda refere-se à orientação do campo eléctrico.

Os radares são construídos para **transmitir** radiação microondas com polarização Horizontal (H) ou Vertical (V).

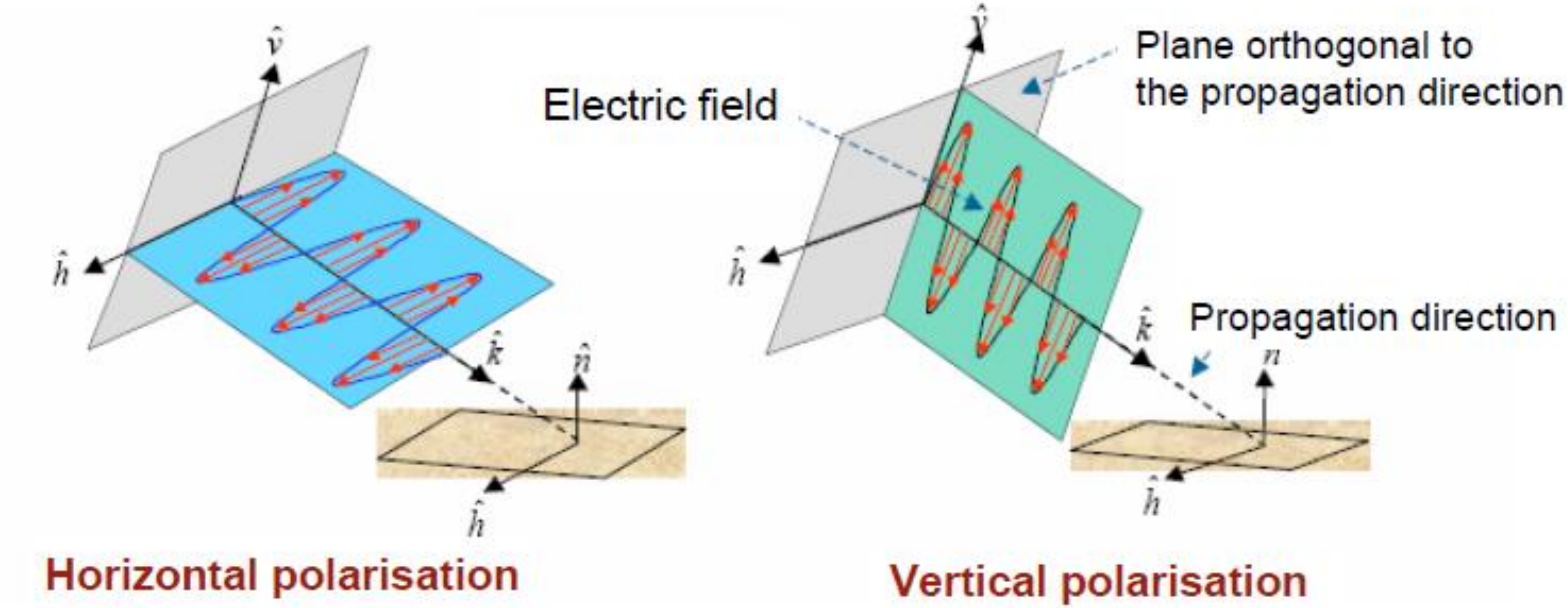


As antenas recebem a energia backscattered com polarização horizontal ou vertical e alguns sensores recebem ambas. Podemos assim ter as combinações:

- HH – Transmissão e recepção Horizontal,
- VV – Transmissão e recepção Vertical,
- HV – Transmissão Horizontal e recepção Vertical
- VH - Transmissão Vertical e recepção Horizontal

Polarização cruzada

Polarização



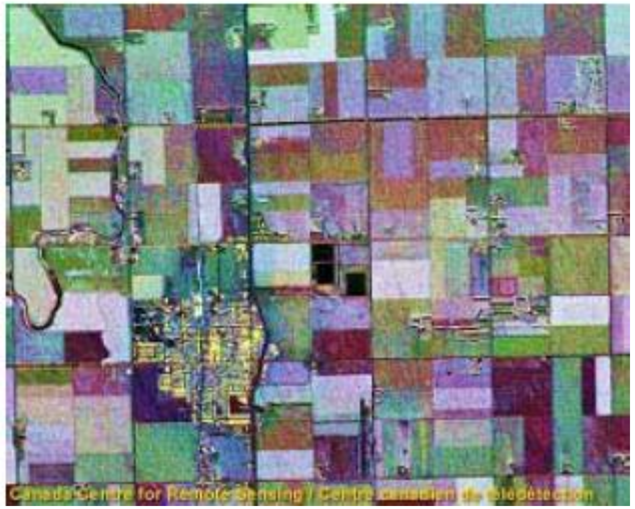
Polarização

Banda C

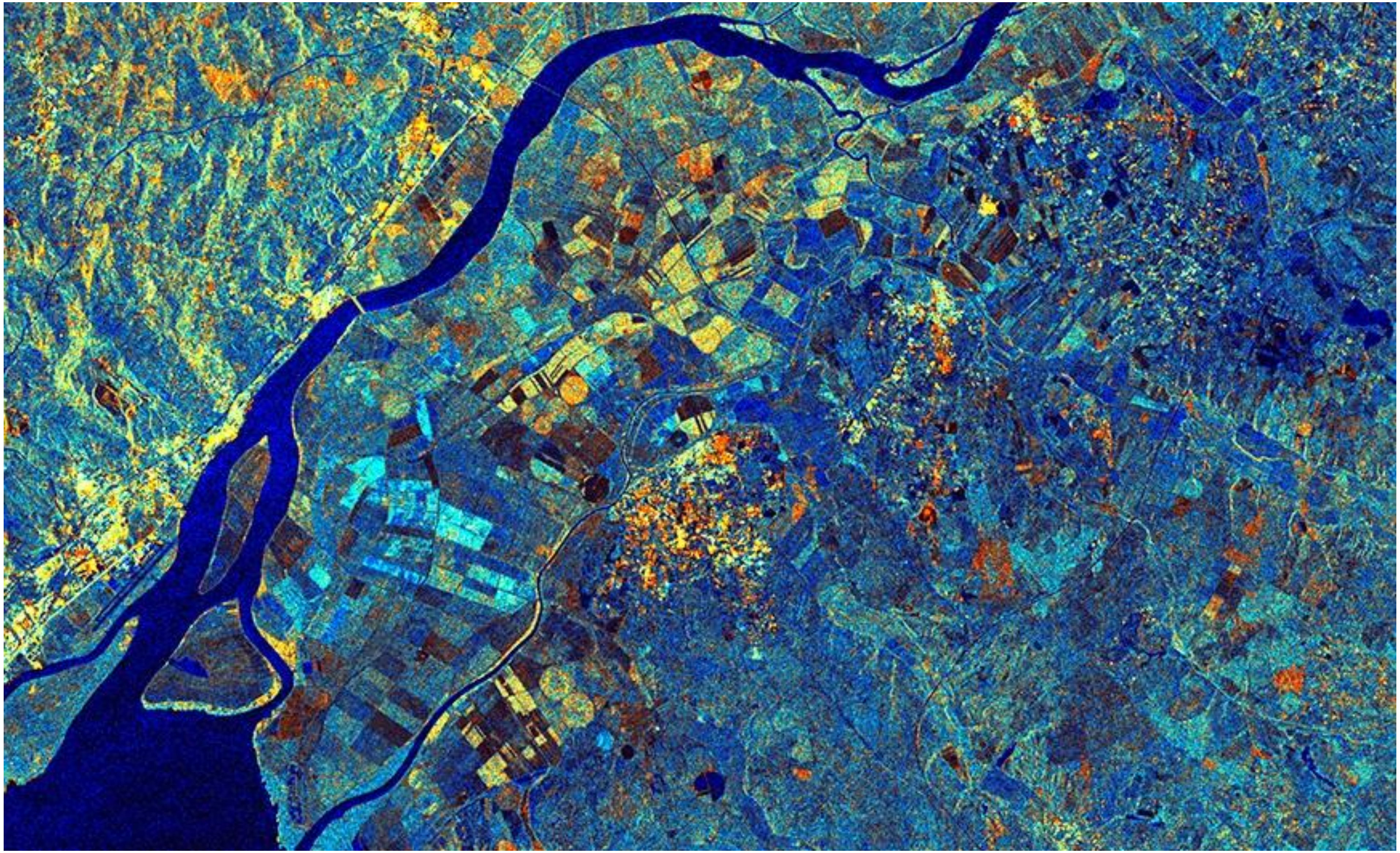
Polarização HH (esquerda) e VV (direita)

Polarização HV

Composição colorida
HH - Red,
VV - Green,
HV - Blue



Polarização



Aplicações da Polarimetria

As aplicações da polarimetria são:

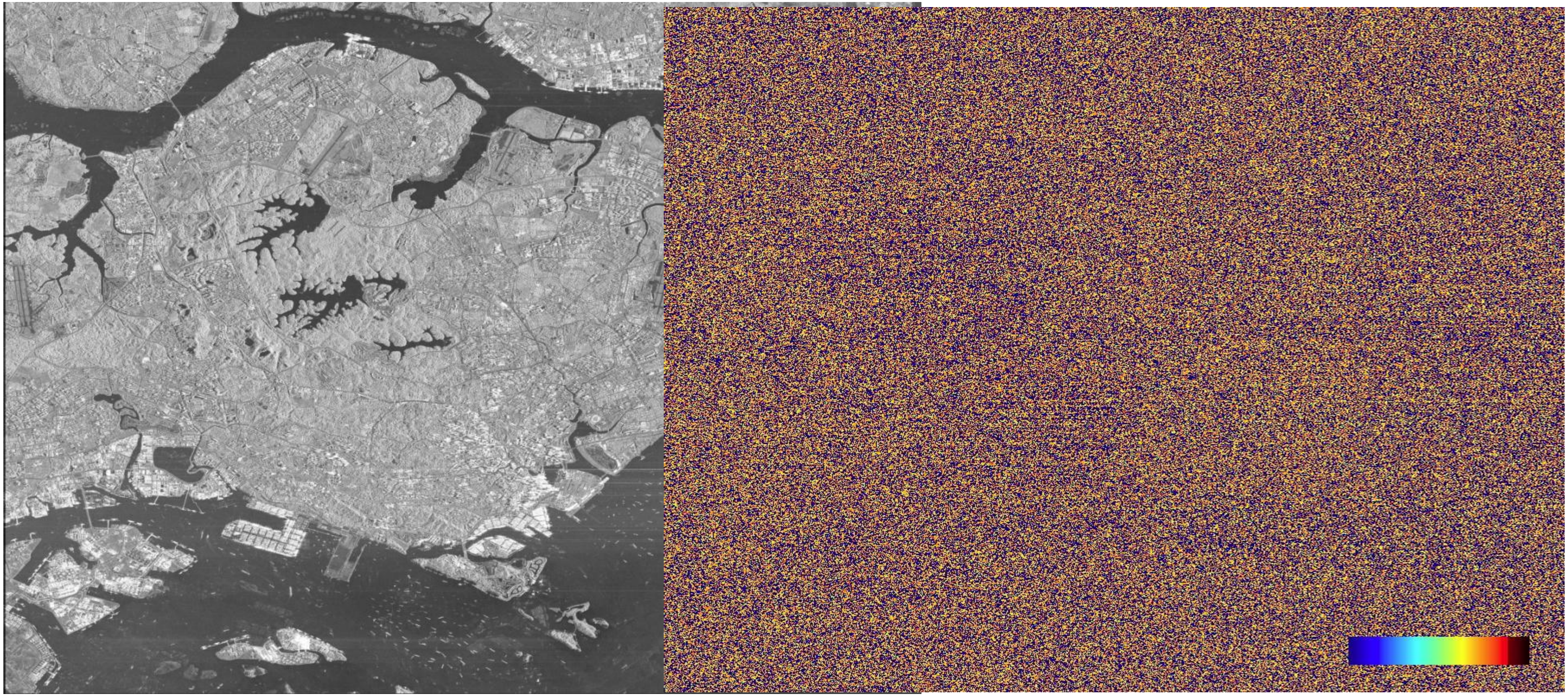
Agriculture: for crop type identification, crop condition monitoring, soil moisture measurement, and soil tillage and crop residue identification;

Hydrology: for monitoring wetlands and snow cover;

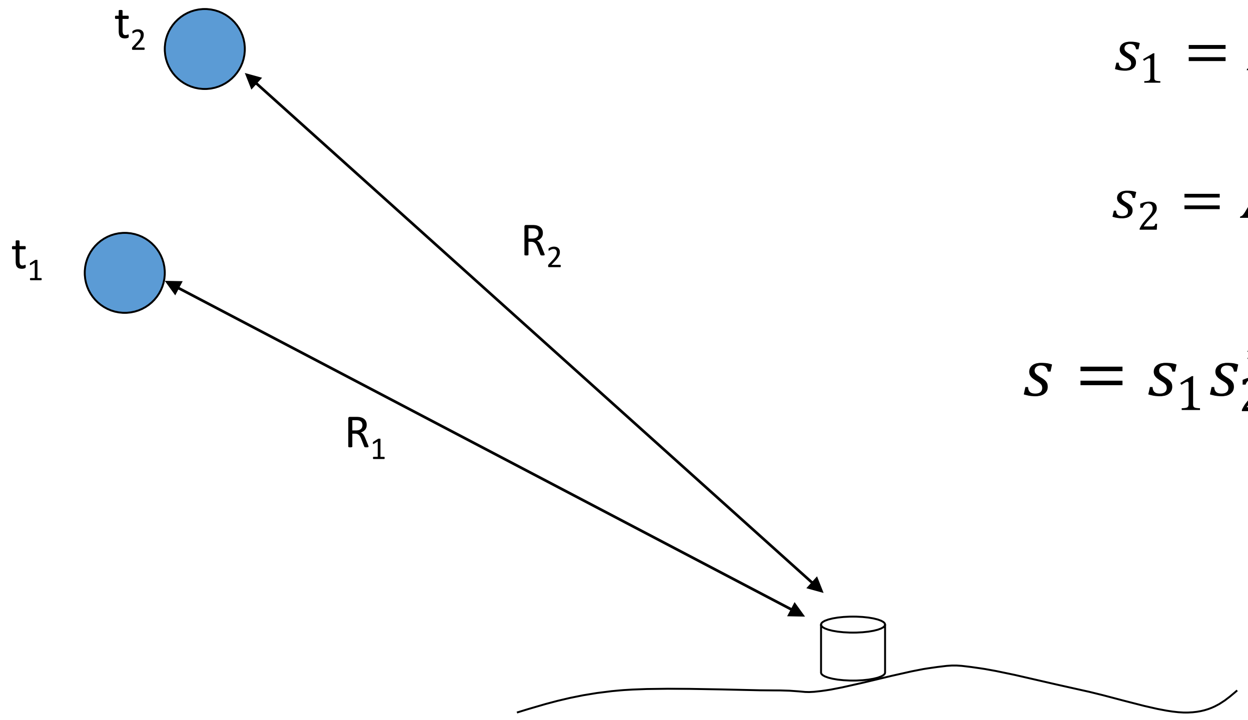
Forestry: for clearcuts and linear features mapping, biomass estimation, species identification and fire scar mapping;

Coastal Zone: for shoreline detection, substrate mapping, slick detection and general vegetation mapping.

Imagem SAR SLC



Interferometria SAR



$$s_1 = A.\mathrm{e}^{(j\phi_B)}.e^{\left(-j\left(\frac{4\pi}{\lambda}\right).R_1\right)}$$

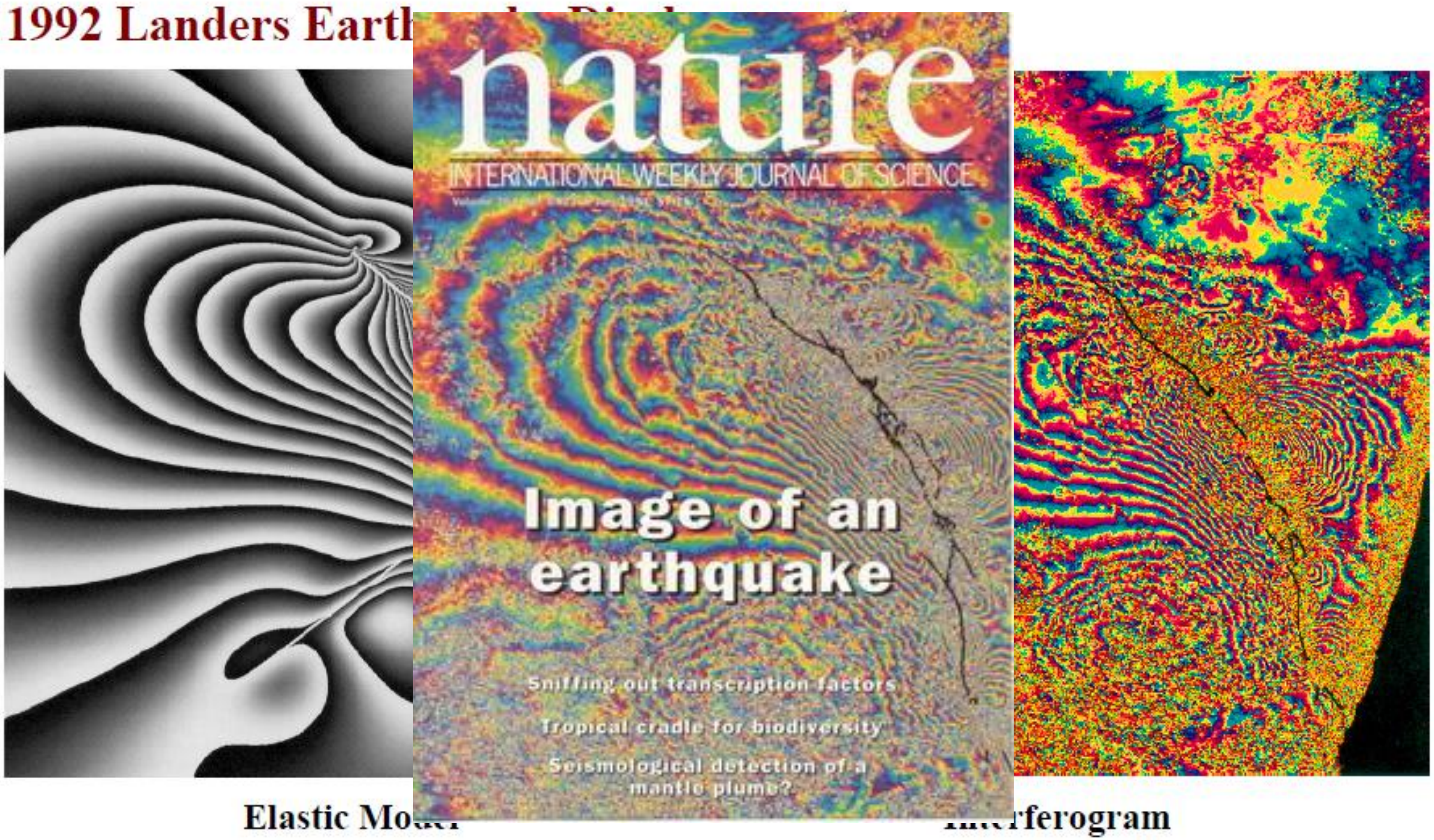
$$s_2 = A'.\mathrm{e}^{(j\phi'_B)}.e^{\left(-j\left(\frac{4\pi}{\lambda}\right).R_2\right)}$$

$$s = s_1 s_2^* = |s_1||s_2|\, e^{-j\left(\frac{4\pi}{\lambda}\right).R_1 + j\left(\frac{4\pi}{\lambda}\right).R_2}$$

Interferograma

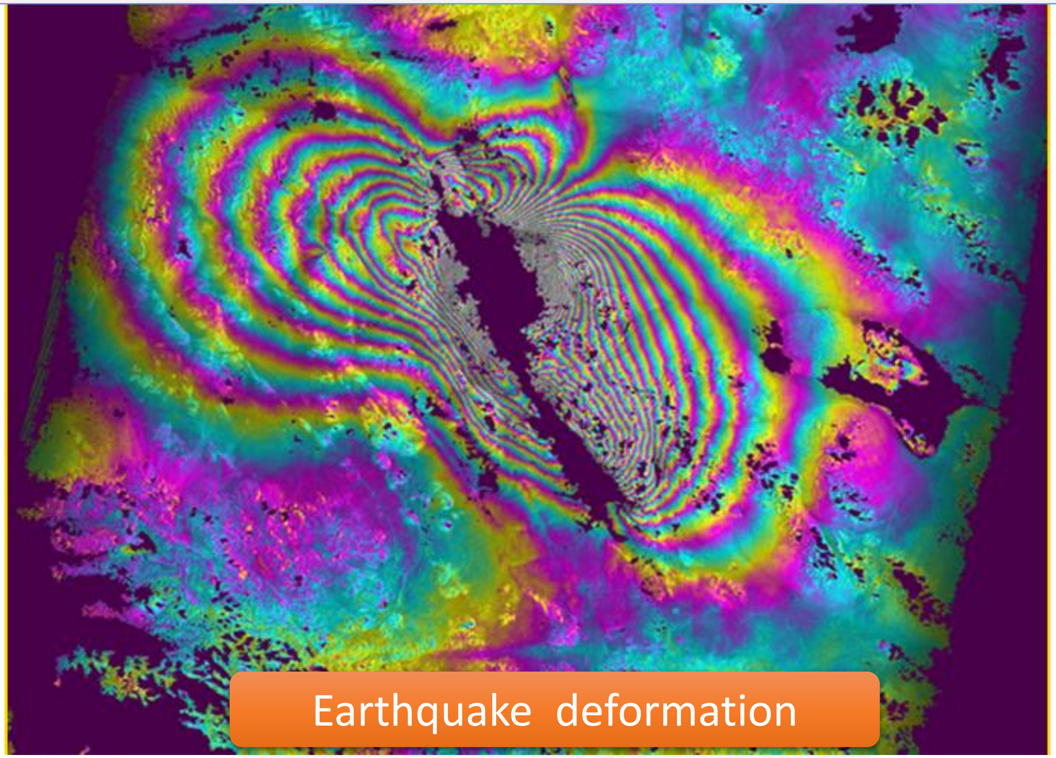
$$\phi_I = -\frac{4\pi}{\lambda}(R_1 - R_2)$$

Se $\phi_B = \phi'_B$, ou seja se não houver alteração do mecanismo de scattering da célula de resolução.

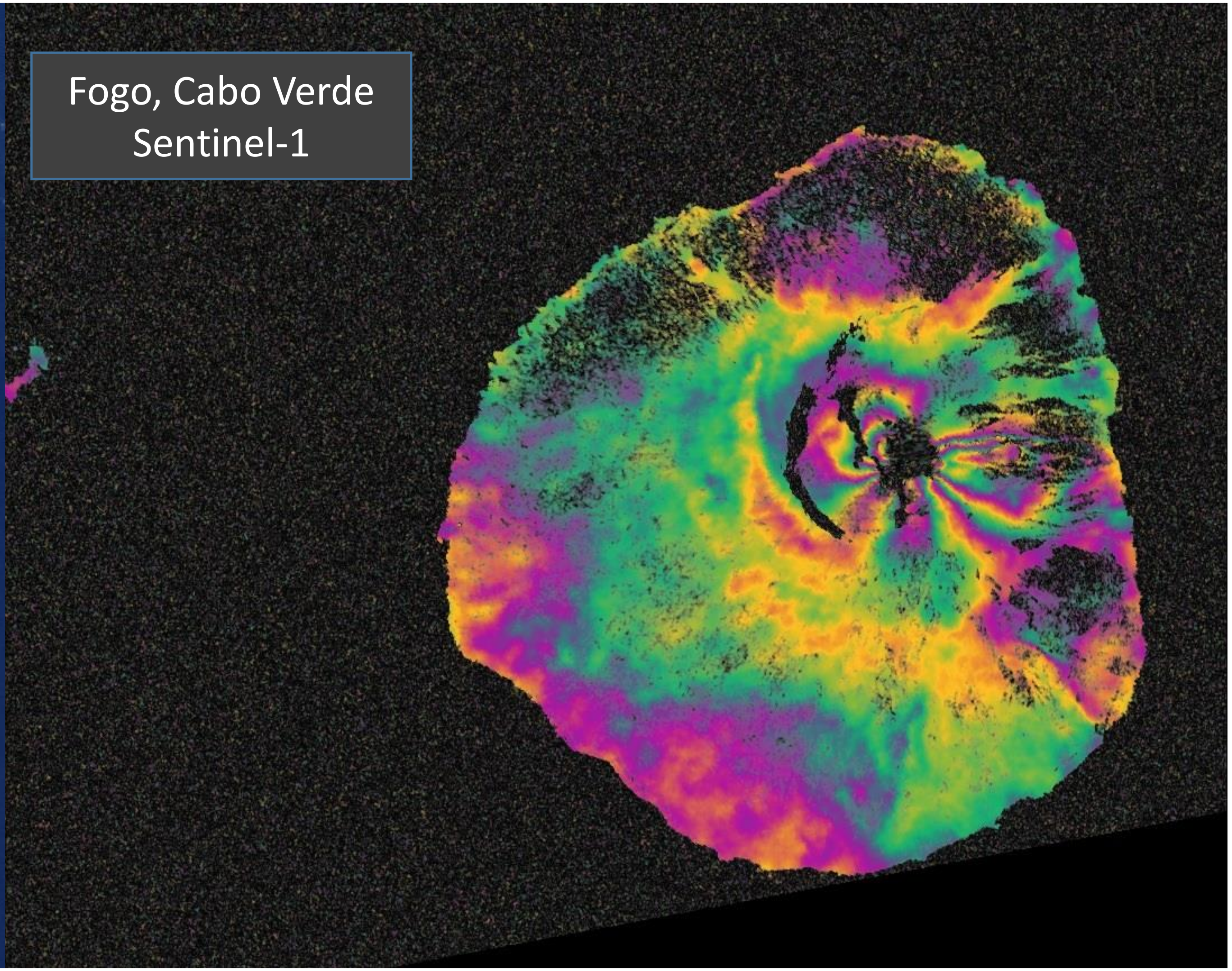

1992 Landers Earth
nature
INTERNATIONAL WEEKLY JOURNAL OF SCIENCE
Image of an earthquake
Sniffing out transcription factors
Tropical cradle for biodiversity
Seismological detection of a mantle plume?
Elastic Mo
rferogram

- Volcano deformation
- Earthquake deformation
- Permafrost and Glaciar displacement

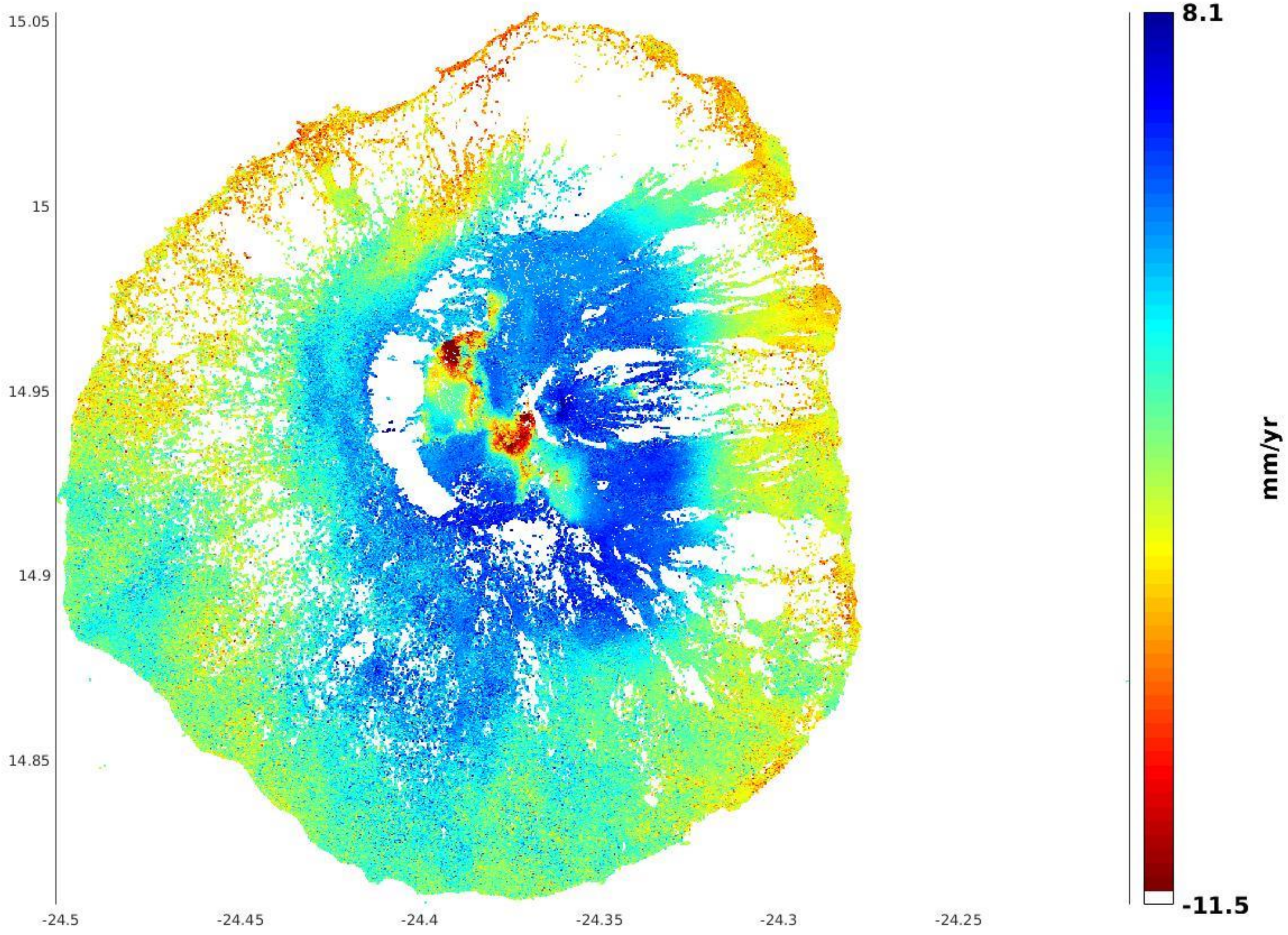
Volcanic Hazards



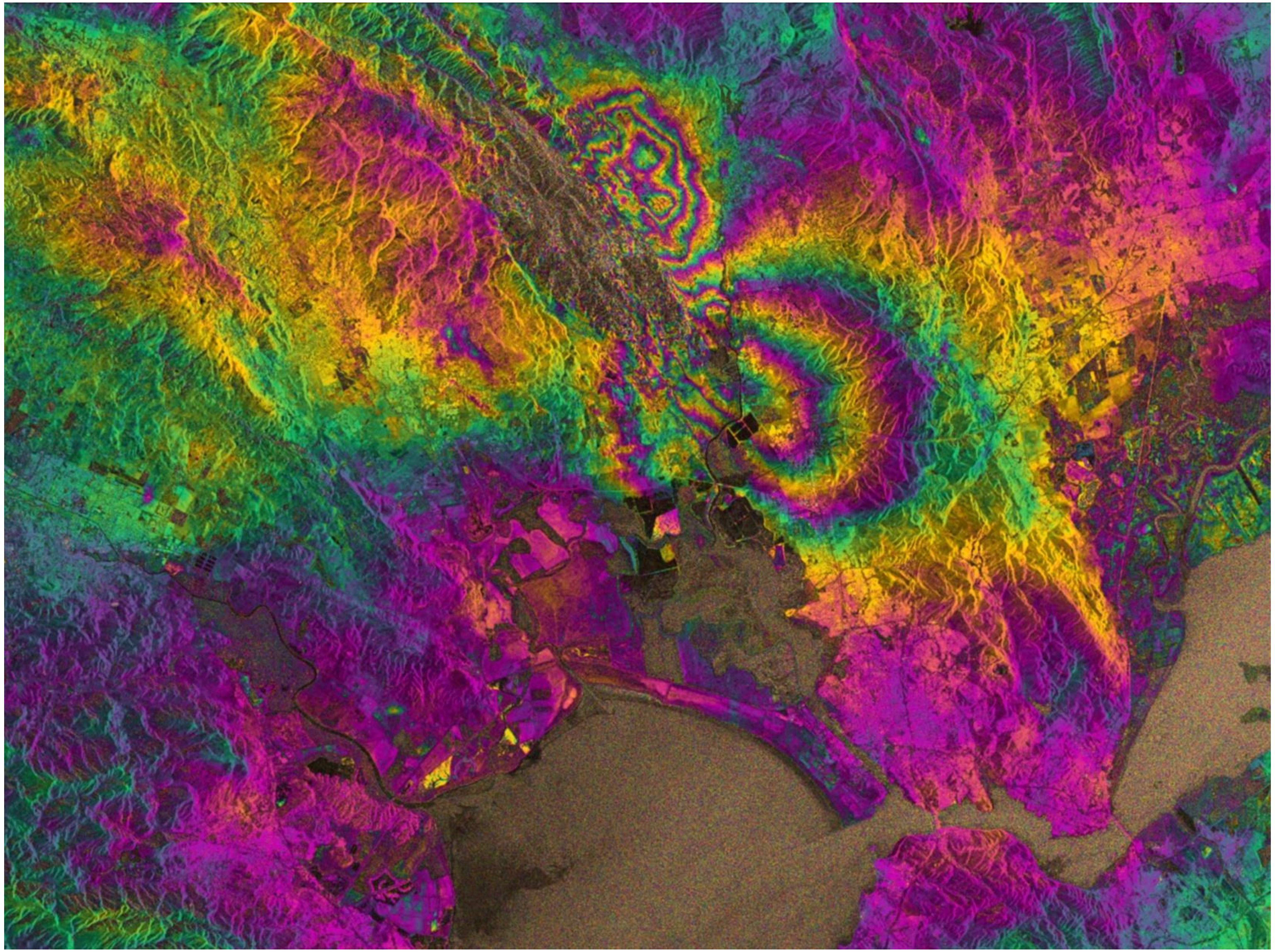
Deformação vulcanica



2015-2017



Deformação causada por um sismo

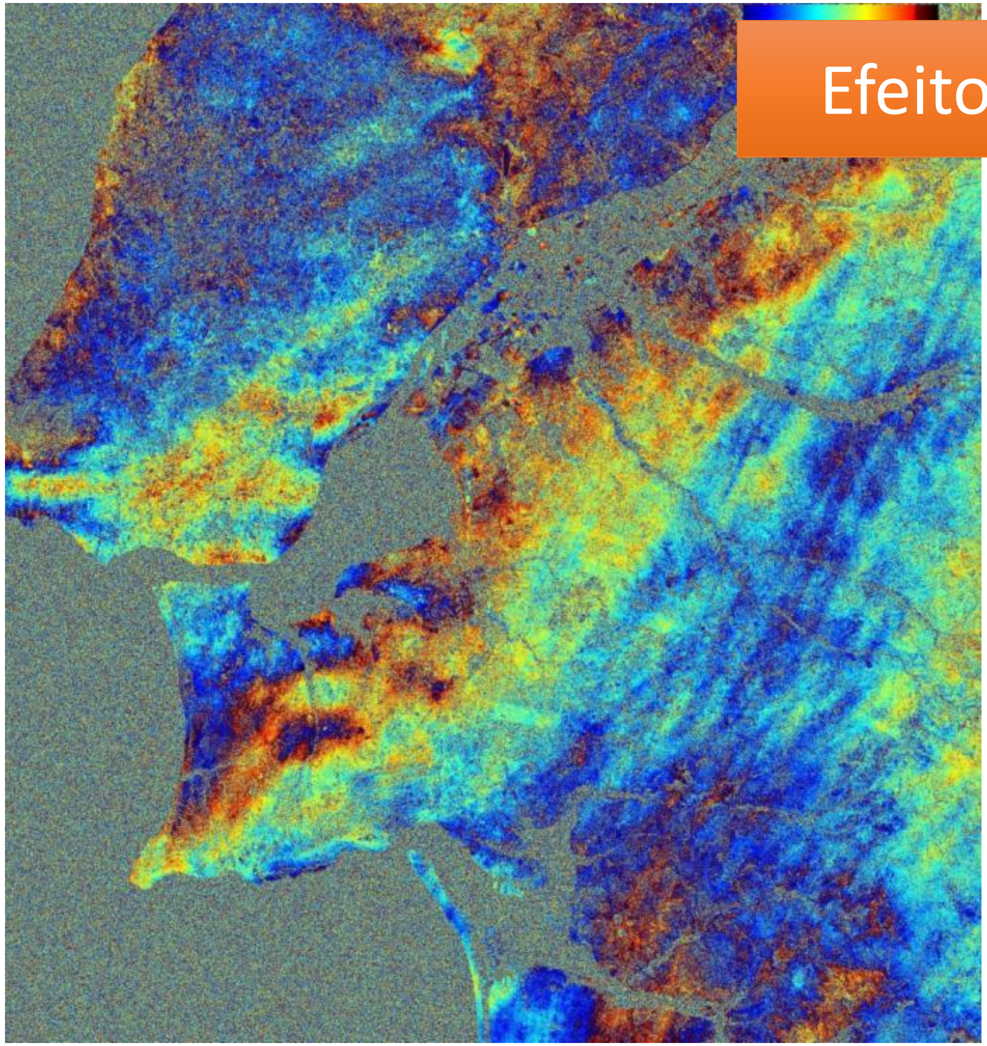


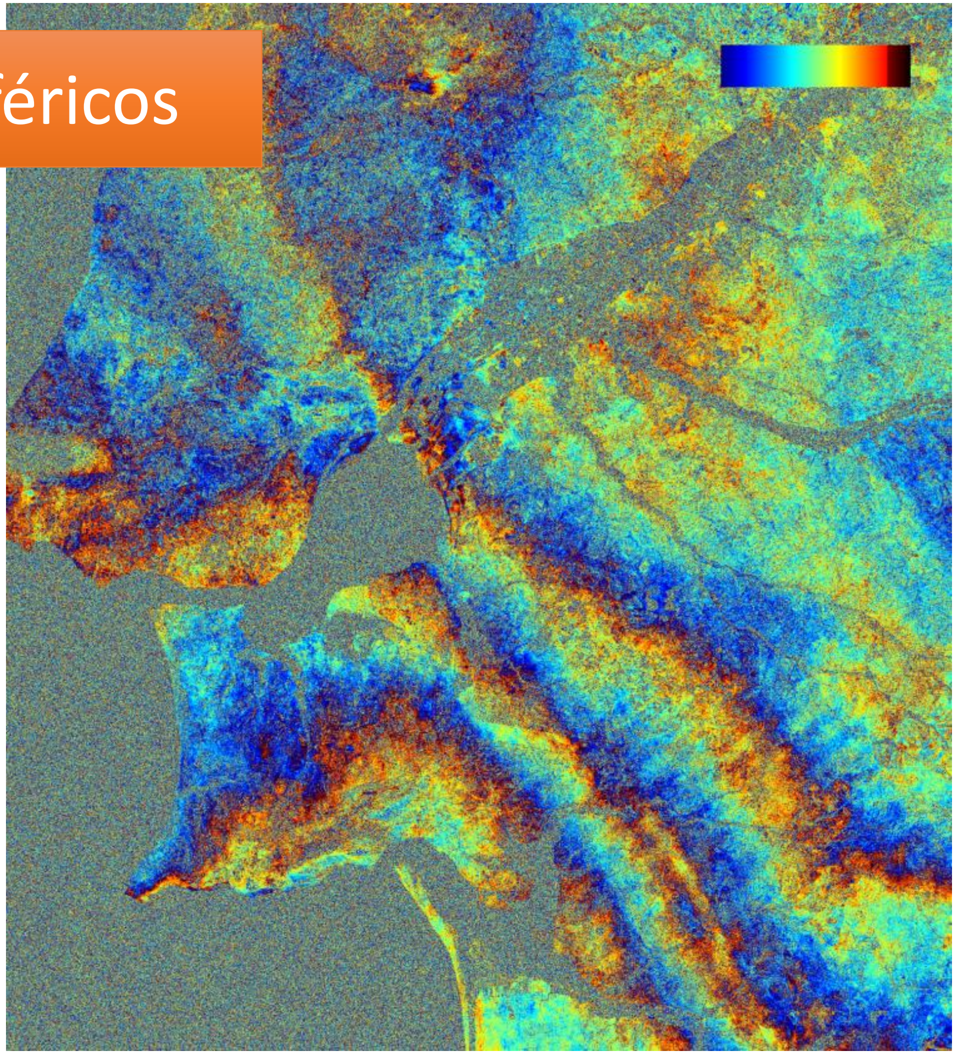
Sentinel -1

Napa Valey earthquake, 24 Agosto 2014

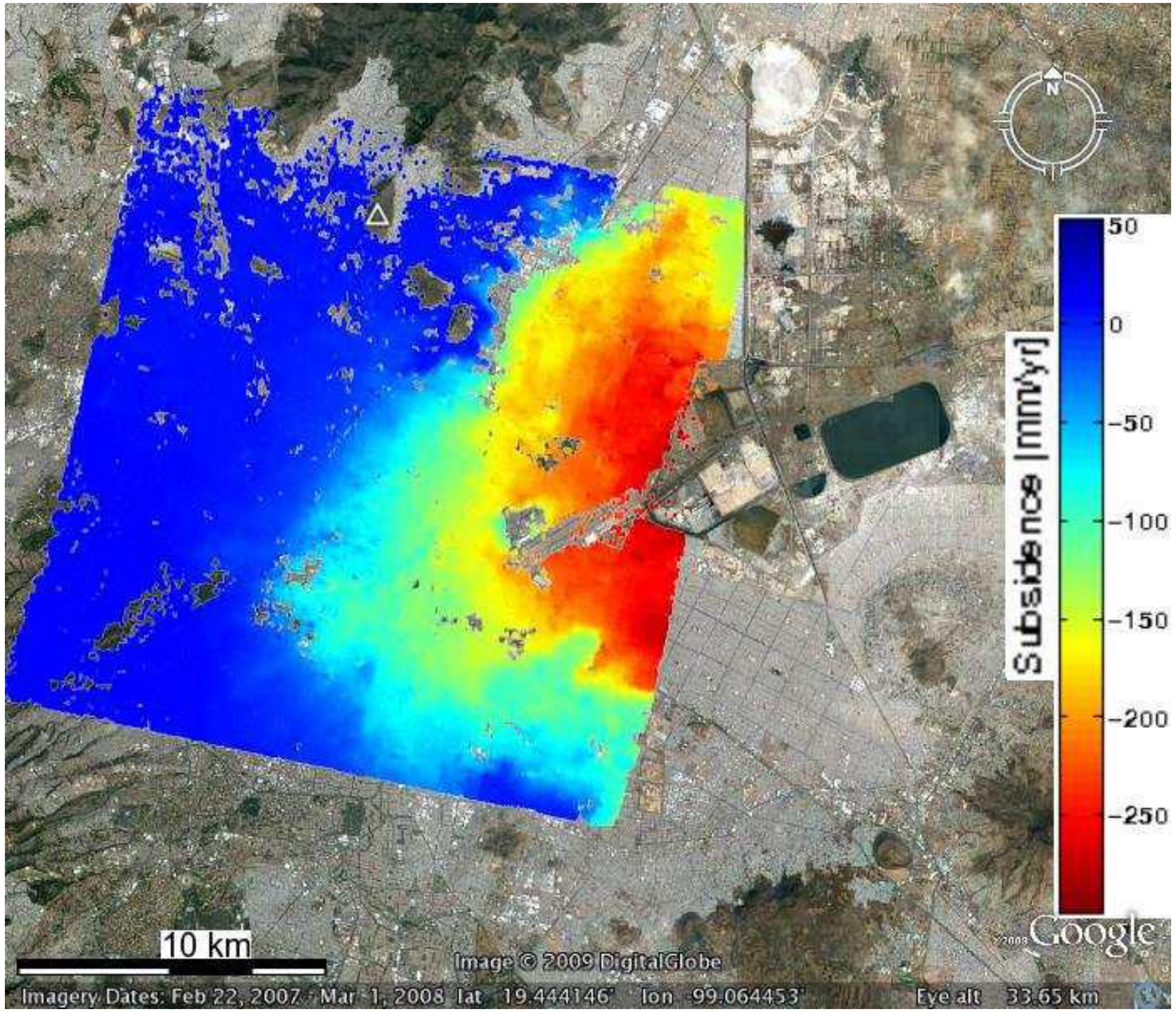
Atraso atmosférico / vapor de água

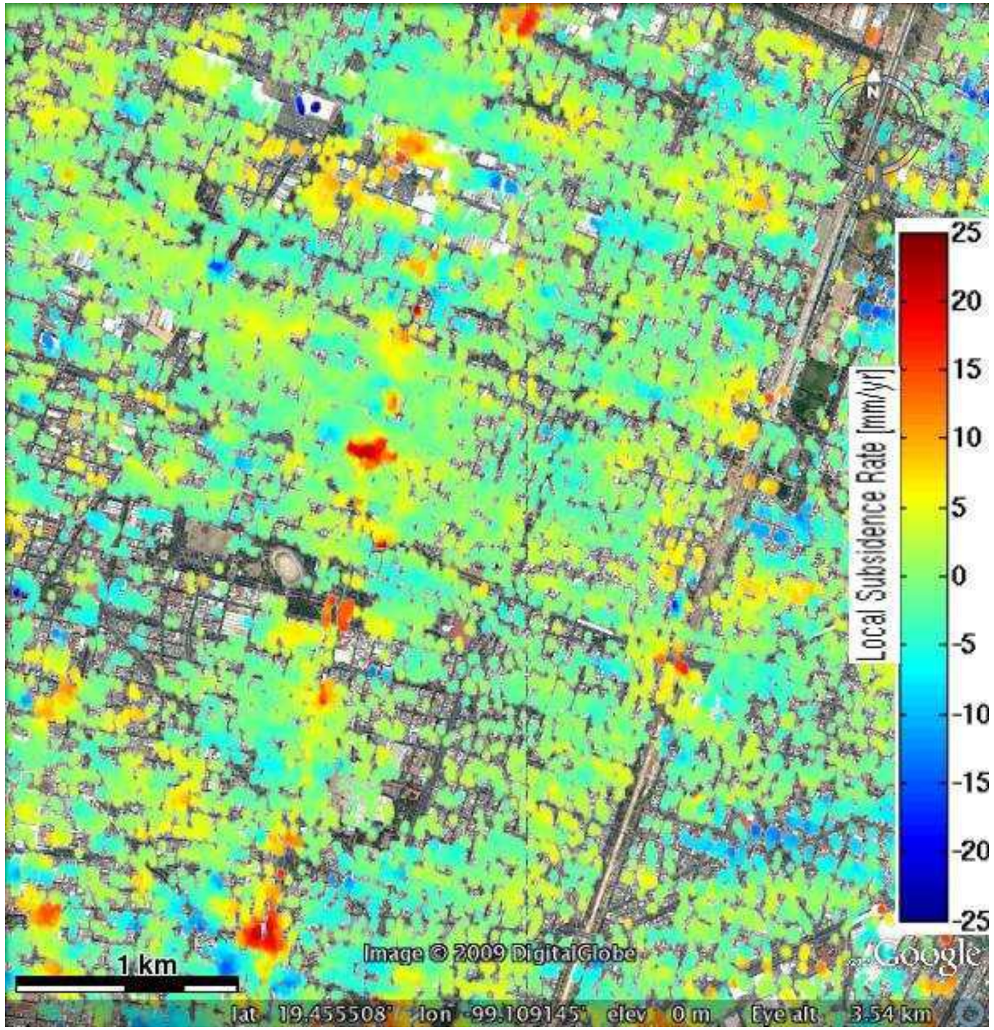
Efeitos atmosféricos





Subsidência

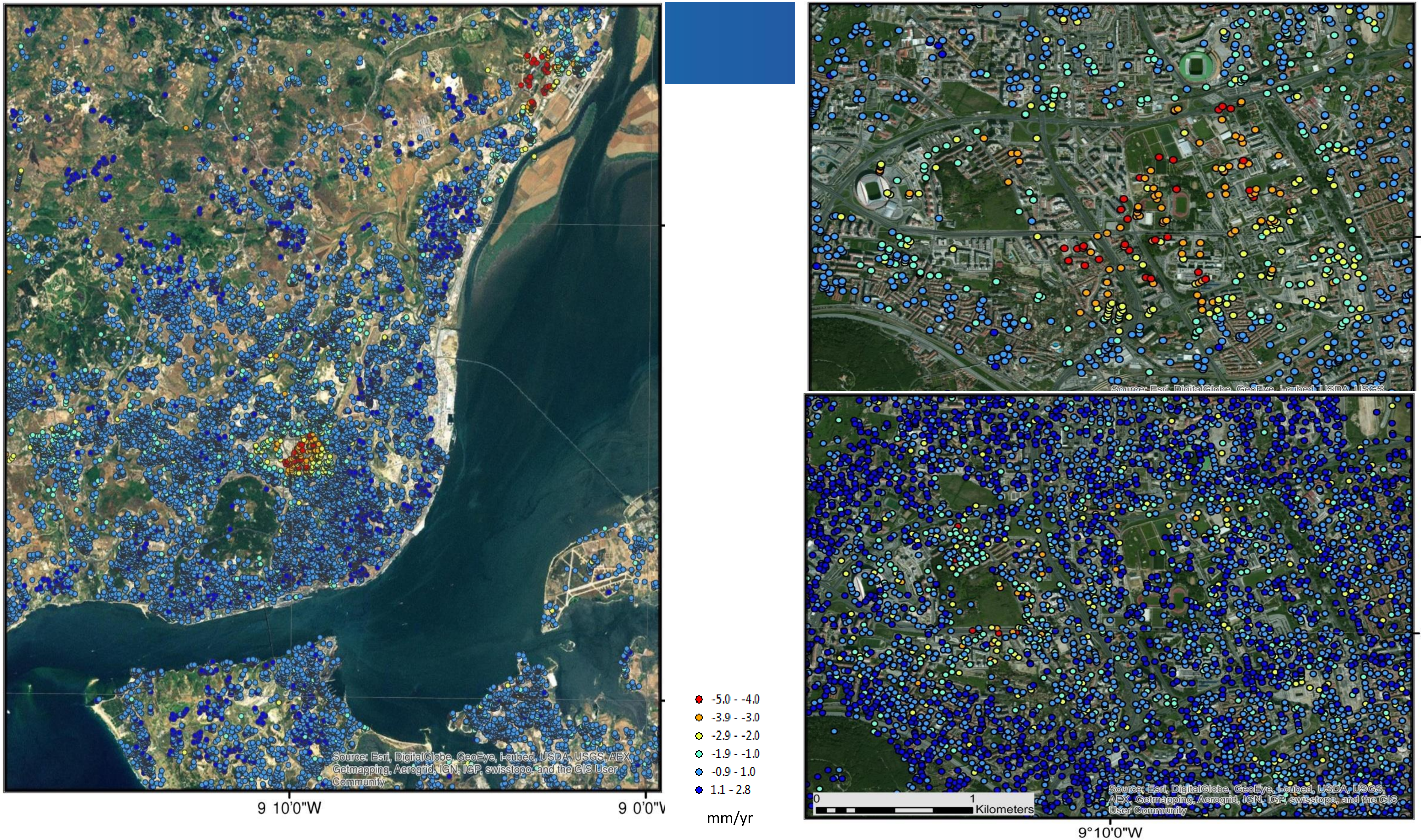




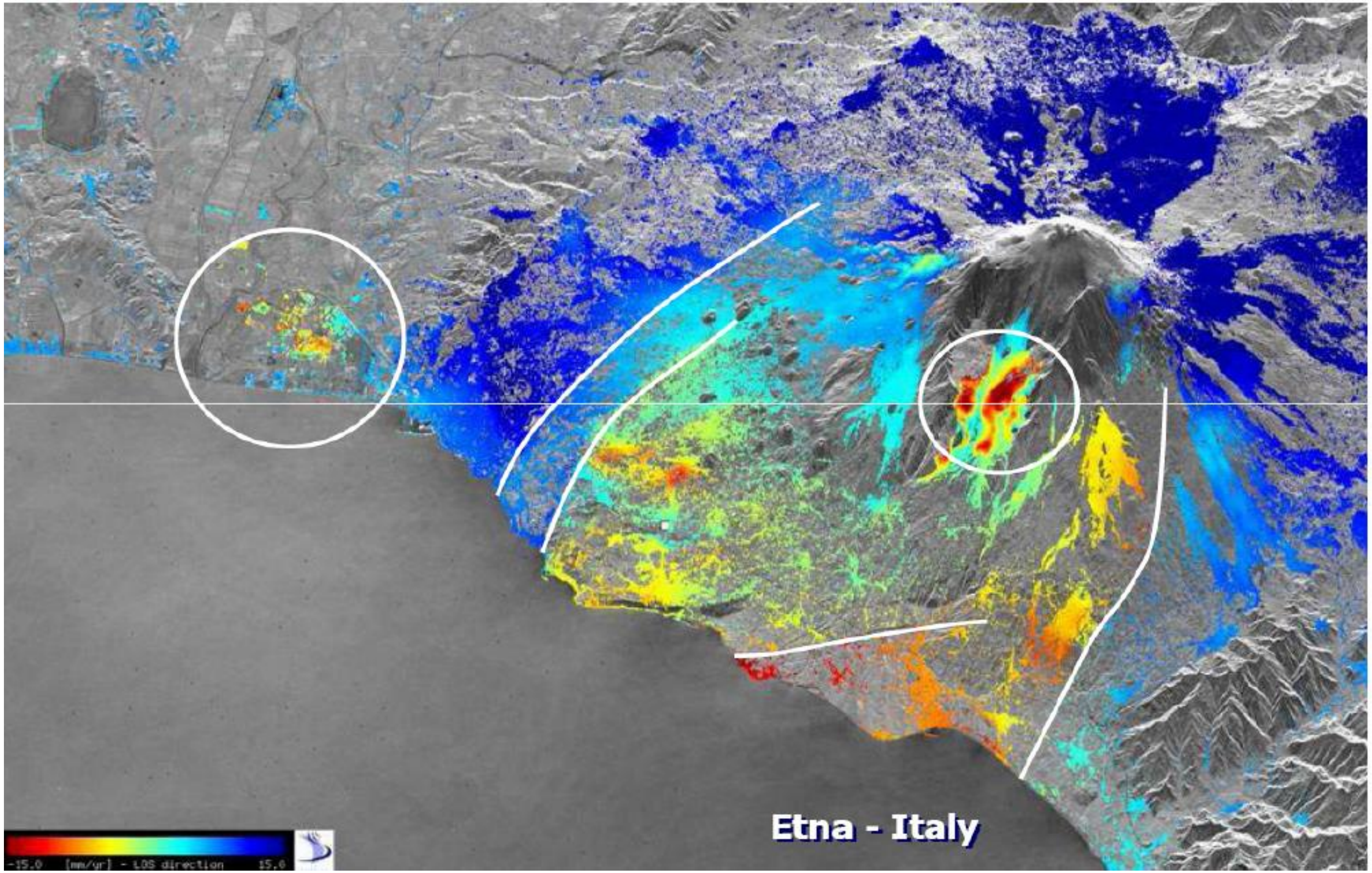
Cidade do México

Osmanoglu et al., 2011

Subsidence rates for the period 16 January 2004 to 14 July 2006 using Envisat ASAR


Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
9 10'0"W
9 0'0"W
-5.0 - -4.0
-3.9 - -3.0
-2.9 - -2.0
-1.9 - -1.0
-0.9 - 1.0
1.1 - 2.8
mm/yr
0
1
Kilometers
9°10'0"W

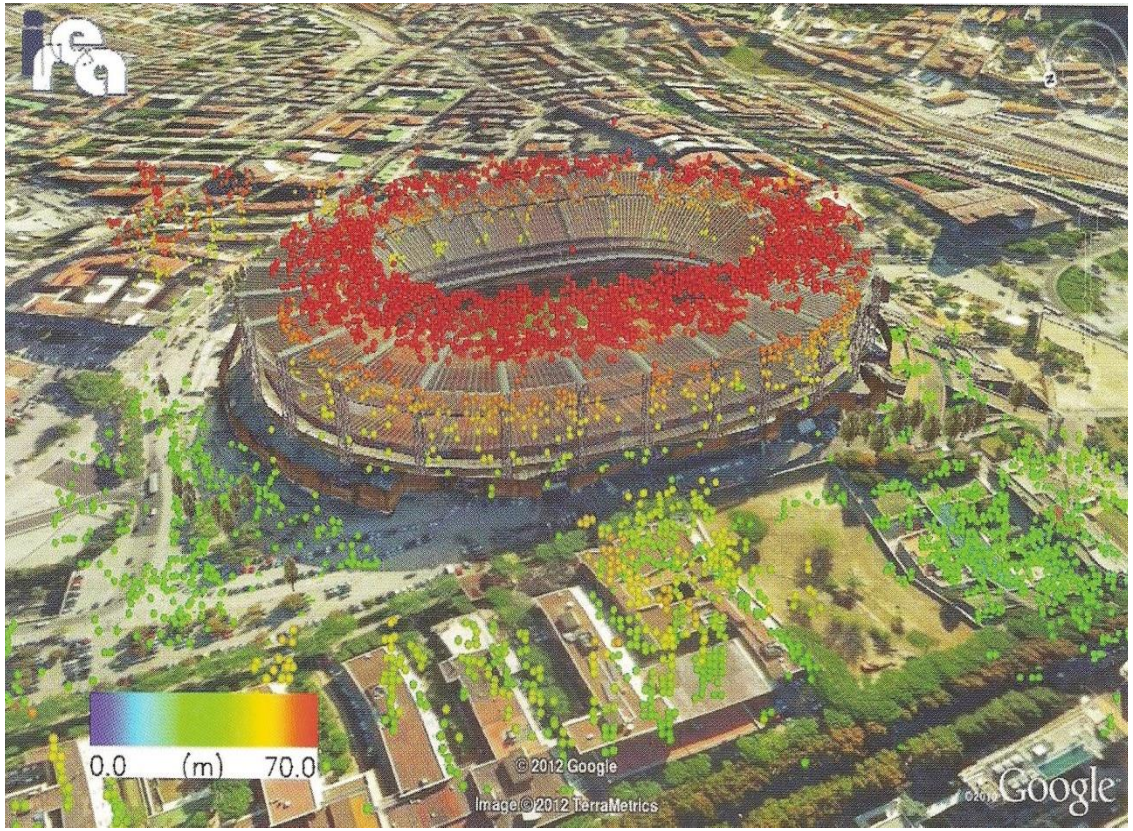
Movimentos de massa



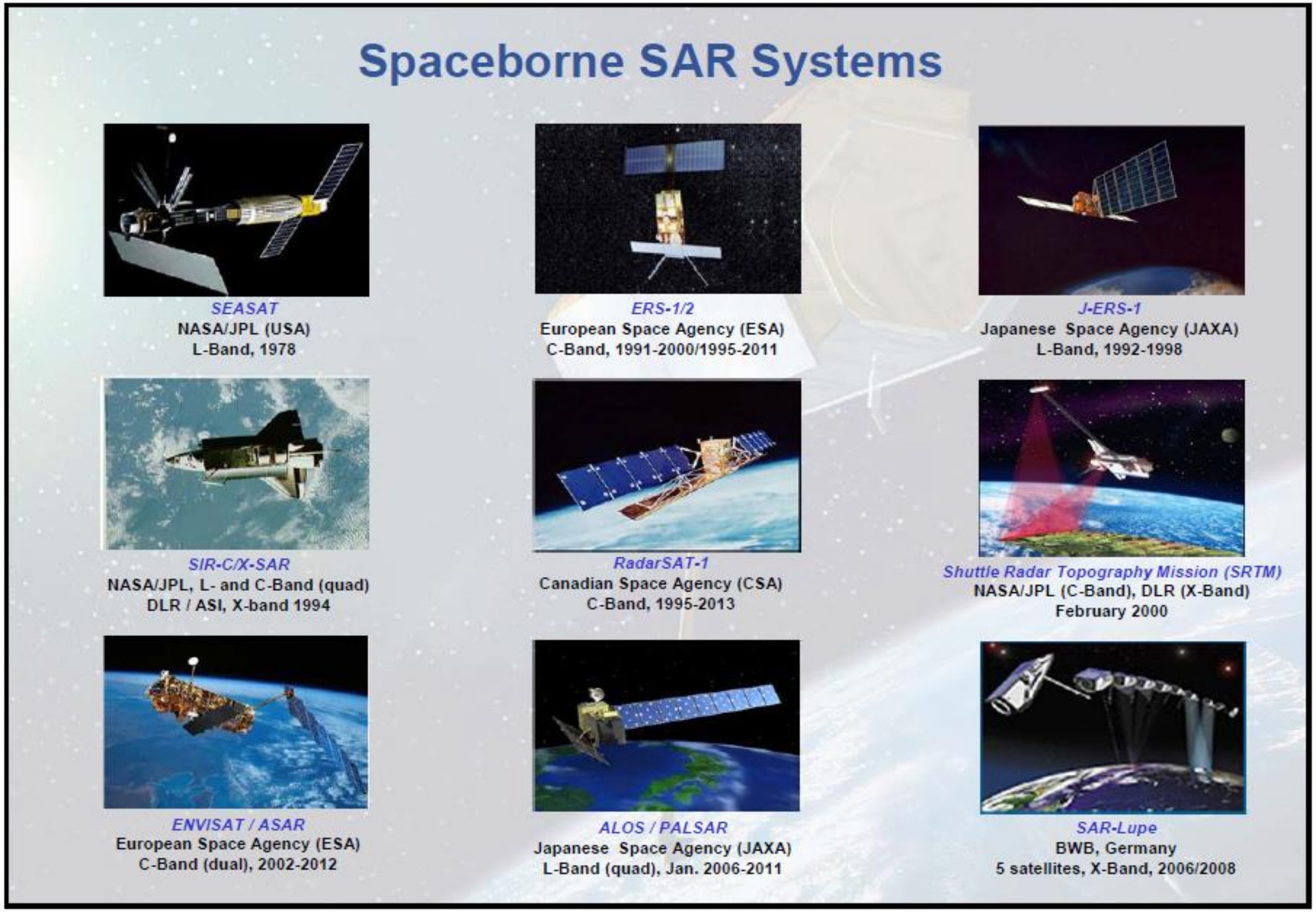
TRE, ESA

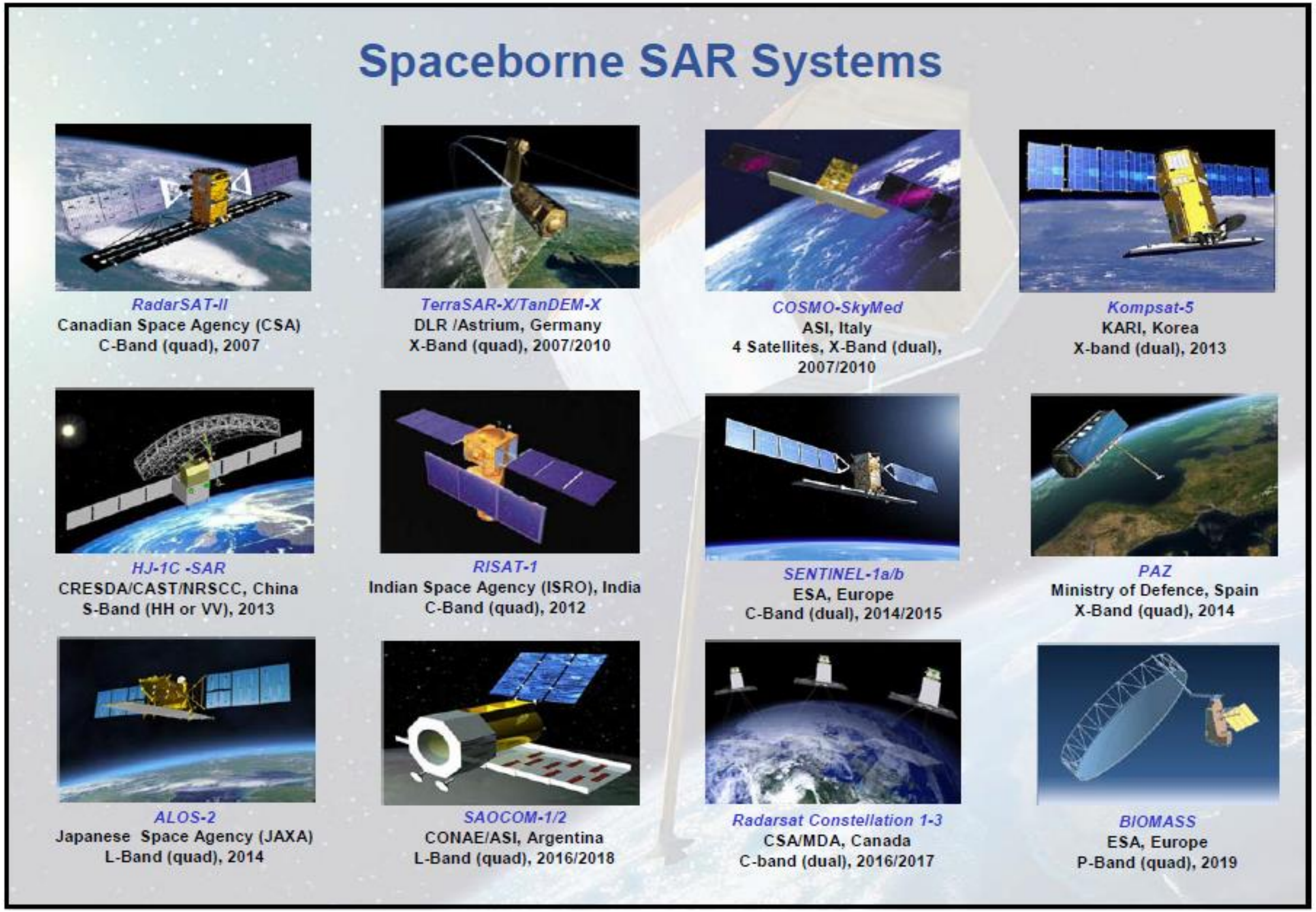
Modelos de elevação

Crosetto, M., Monserrat, O., Iglesias, R. and Crippa, B., 2010.



Zhu and Bamler, 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

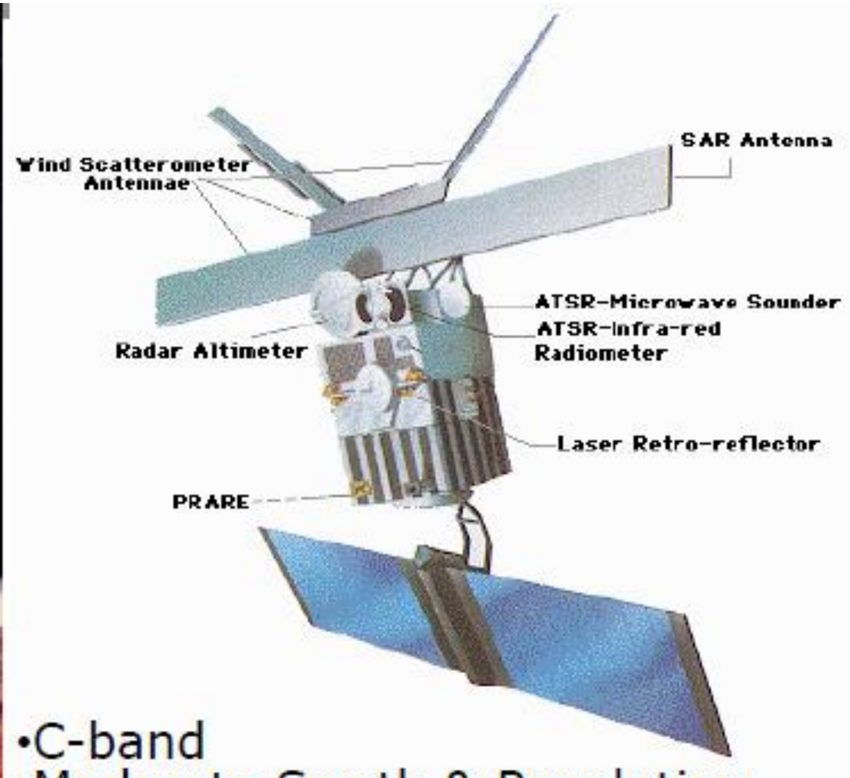

Spaceborne SAR Systems
RadarSAT-II
Canadian Space Agency (CSA)
C-Band (quad), 2007
TerraSAR-X/TanDEM-X
DLR /Astrium, Germany
X-Band (quad), 2007/2010
COSMO-SkyMed
ASI, Italy
4 Satellites, X-Band (dual), 2007/2010
Kompsat-5
KARI, Korea
X-band (dual), 2013
HJ-1C -SAR
CRESDA/CAST/NRSCC, China
S-Band (HH 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

Satellite		*Agency*	*Frequency - Polarisation*	*Resolution - Swath*	*Special*
JERS	1992-1998	JAXA	L-HH	25m 100 km	35° incidence
ERS -1 ERS -2	1991-2000 1995→ 2012	ESA	C - VV	25 m 100 km	Interferometry (ERS -1/2)
RADARSAT -1	1995→ 2013	CSA	C - HH	10 -100 m 45 - 500 km	Multi-incidence
ENVISAT - ASAR	2002→ 2012	ESA	C - HH/VV/HV	25 - 1000 m 50 - 500 km	Multi-incidence
ALOS - PALSAR	2006→ 2011	JAXA	L - Polarimetric	10 - 100 m 100 - 350 km	Multi-incidence
TerraSAR -X	2006 ->	DLR	X - Polarimetric	1 – 16 m 5 – 100 km	Multi-incidence

… and SRTM/X-SAR, RADARSAT-2 (CSA), COSMO-Skymed (ASI Italy), Tandem-X, Sentinel-1

European Space Agency

ERS-1,2



- C-band
- Moderate Swath & Resolution
- Single Polarisation (VV)
- Successful Operations
- Excellent Data Quality
- Application Development
- Emerging Market

European Space Agency

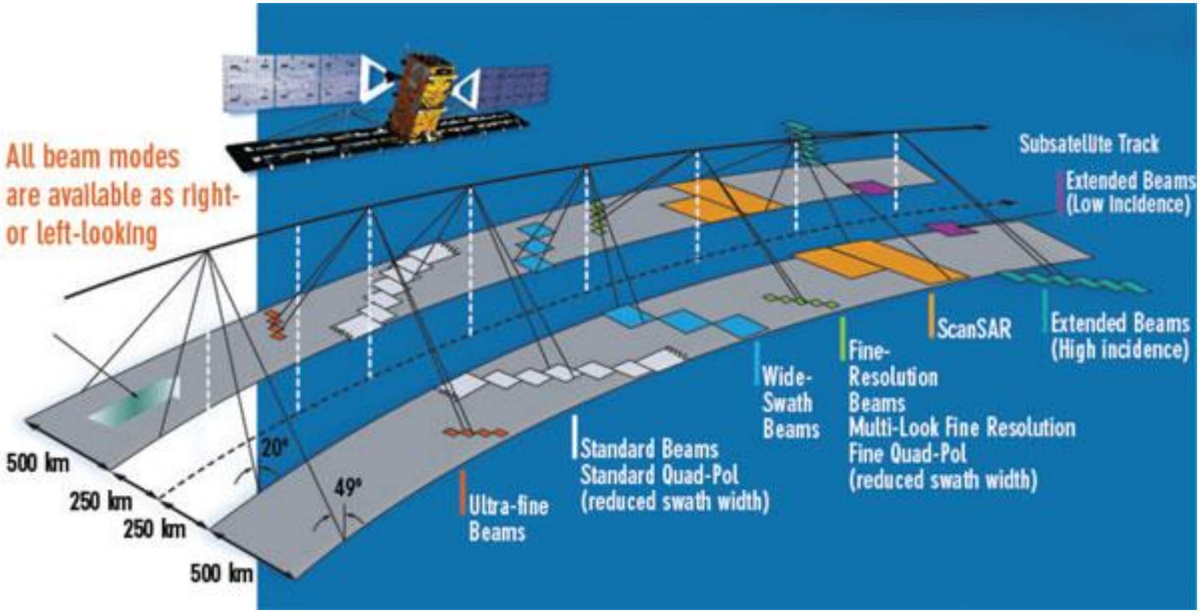
RADARSAT

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.

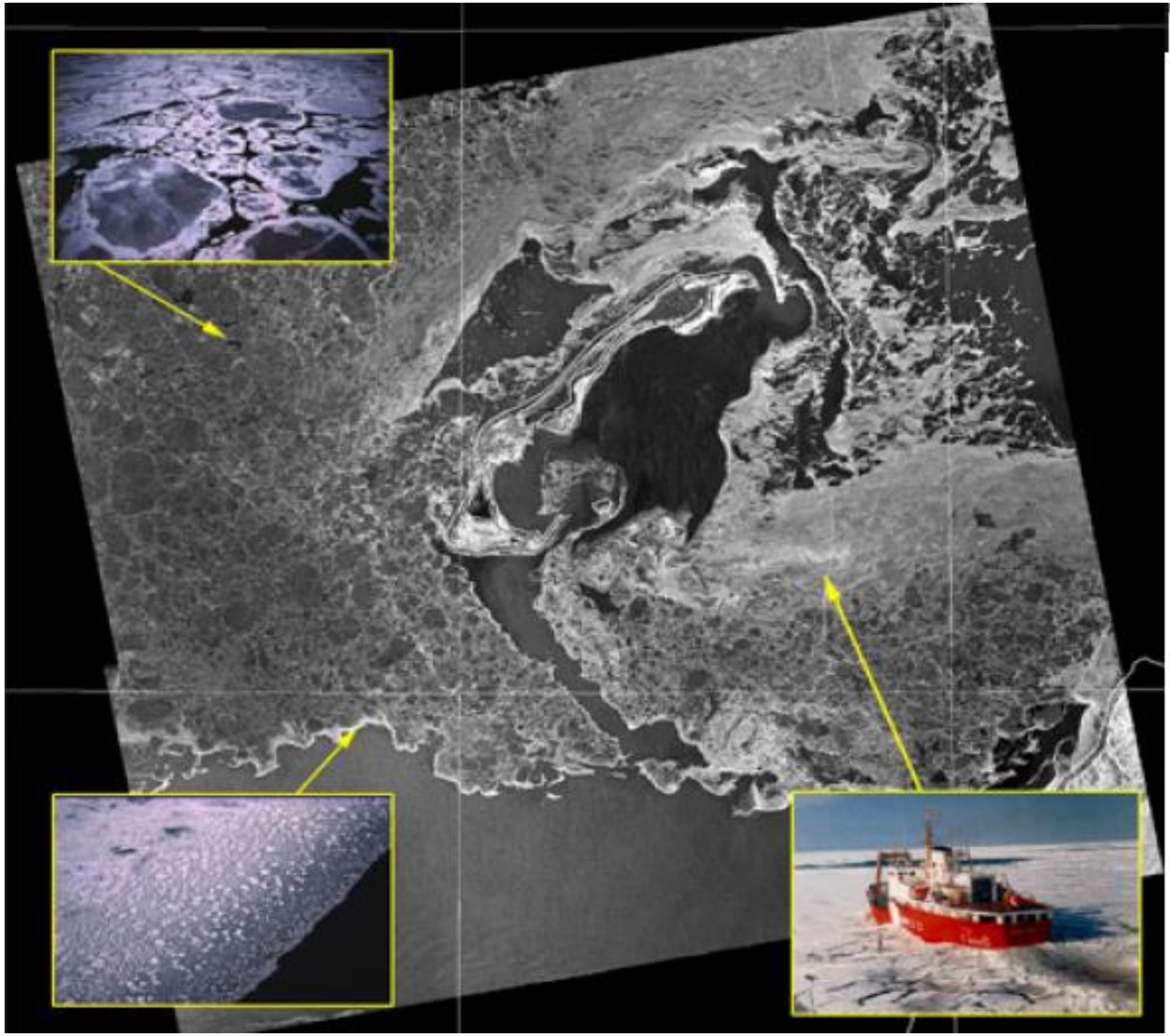
RADARSAT-2

Lançado em 2007

Resolução 3m



RADARSAT



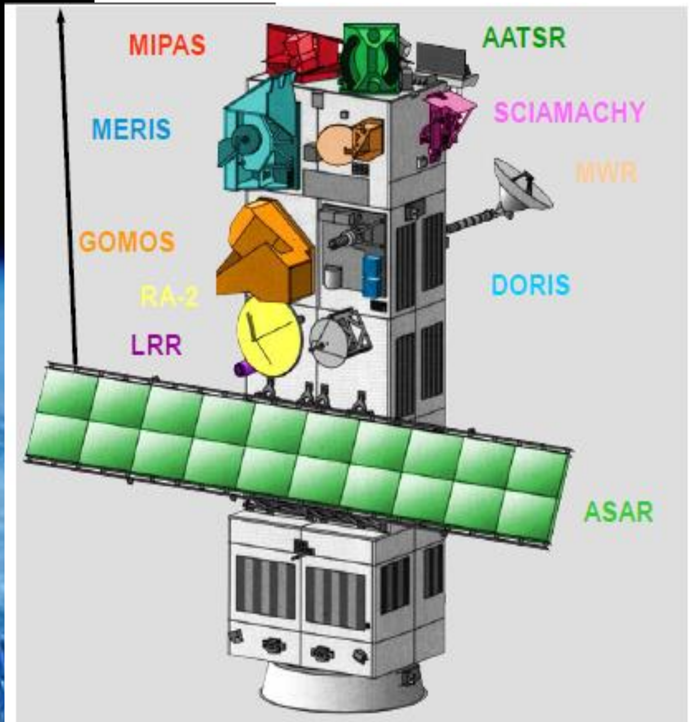
RADARSAT provides routine surveillance of the entire Arctic region.

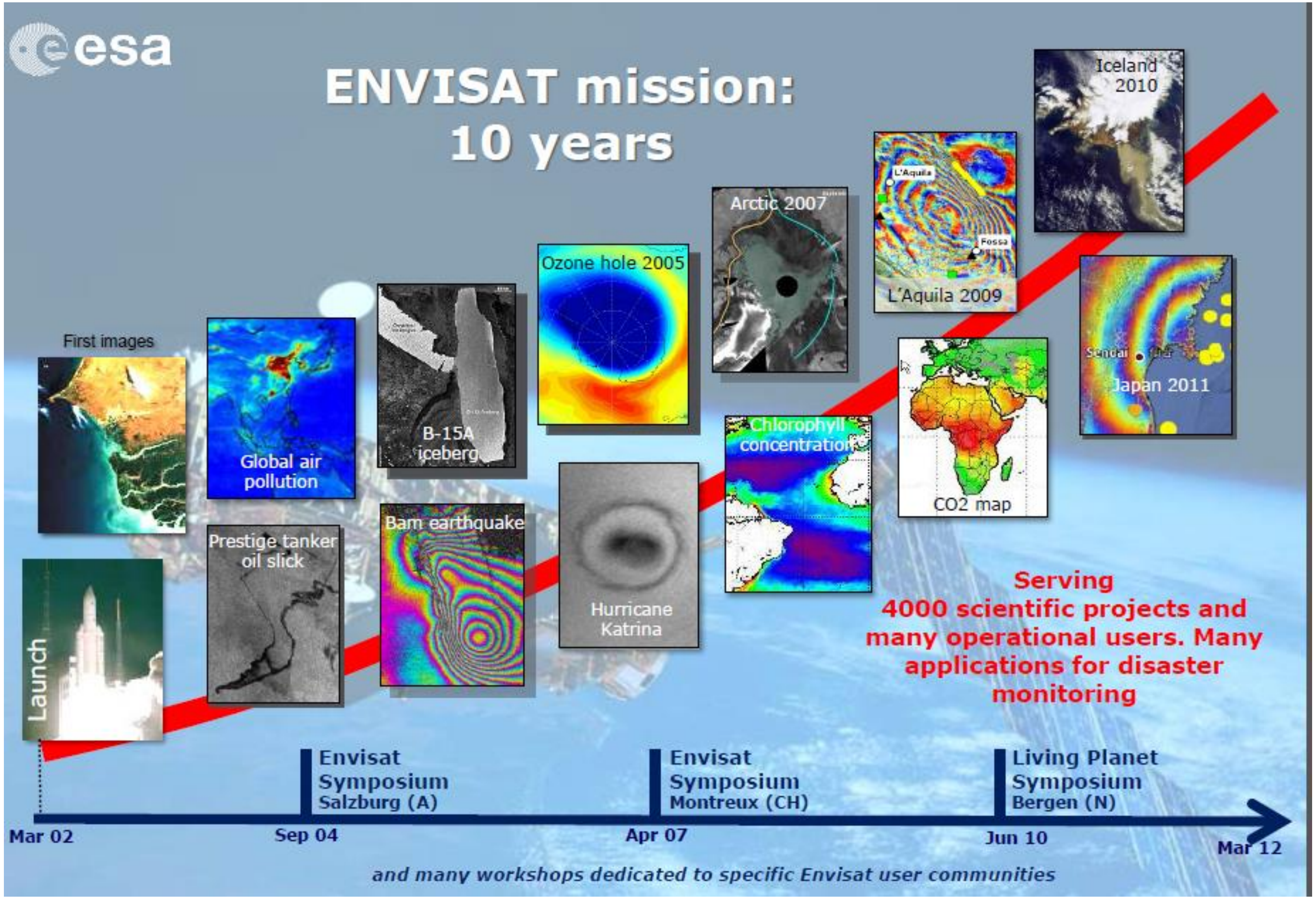
This helps track sea ice distribution, identify various types of ice, and produce daily ice charts.

The information is used for planning safe shipping routes and supply operations for offshore exploration platforms or ocean research stations.

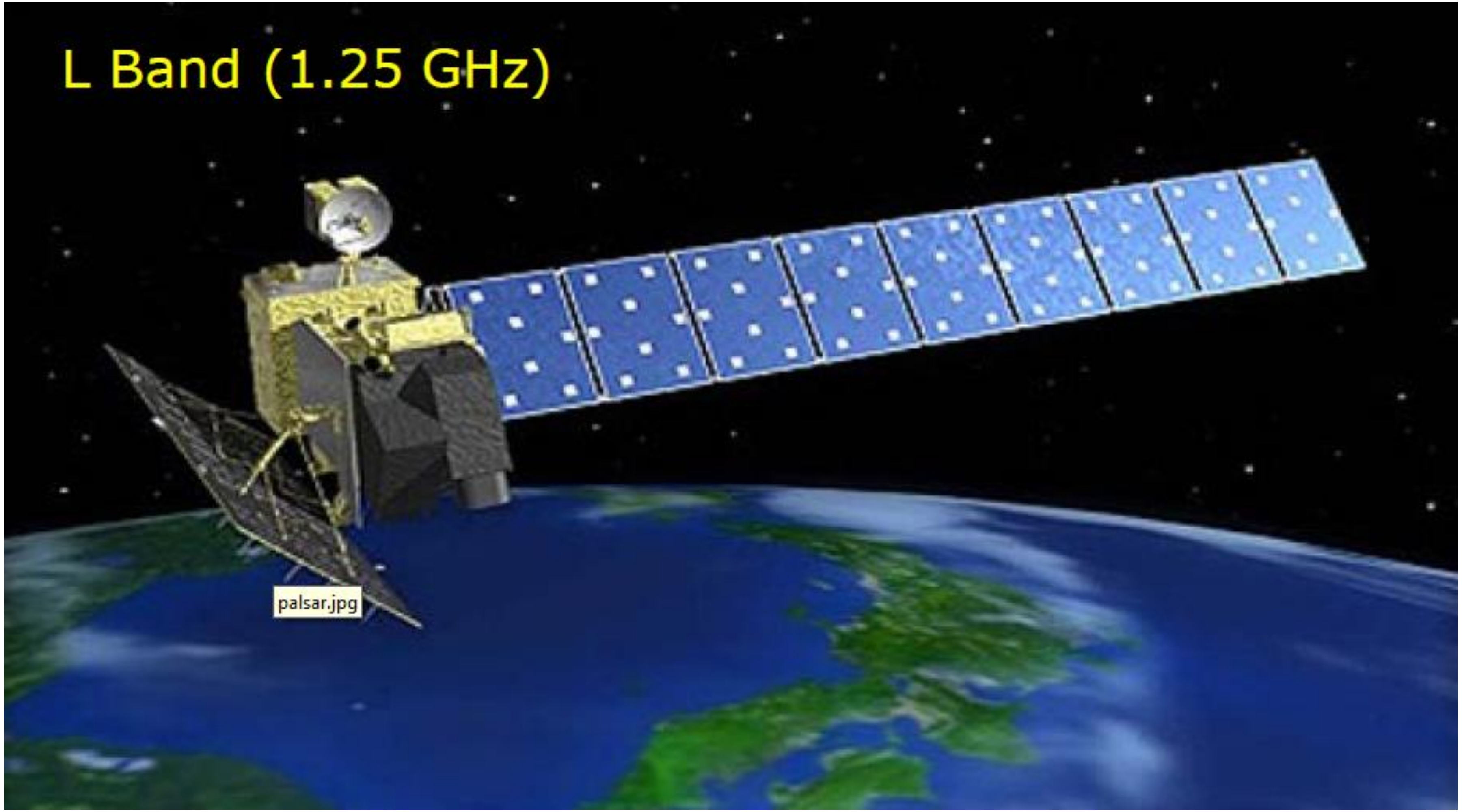
ENVISAT


❑ Largest European satellite & largest worldwide EO satellite:
- unique combination of 10 instruments addressing land, ocean, ice and atmosphere studies,
- instruments working nominally, except MIPAS instrument
❑ Satellite OK with long-term operations capabilities:
- 65 % of fuel available (about 5 years)
❑ 78 different types of data products
- but many more geophysical parameters
❑ 250 Gigabytes of data products generated per day
❑ Nominal lifetime (5 years) ends in March 2007
- but operations funding until end 2010


MIPAS
AATSR
MERIS
SCIAMACHY
MWR
GOMOS
DORIS
RA-2
LRR
ASAR

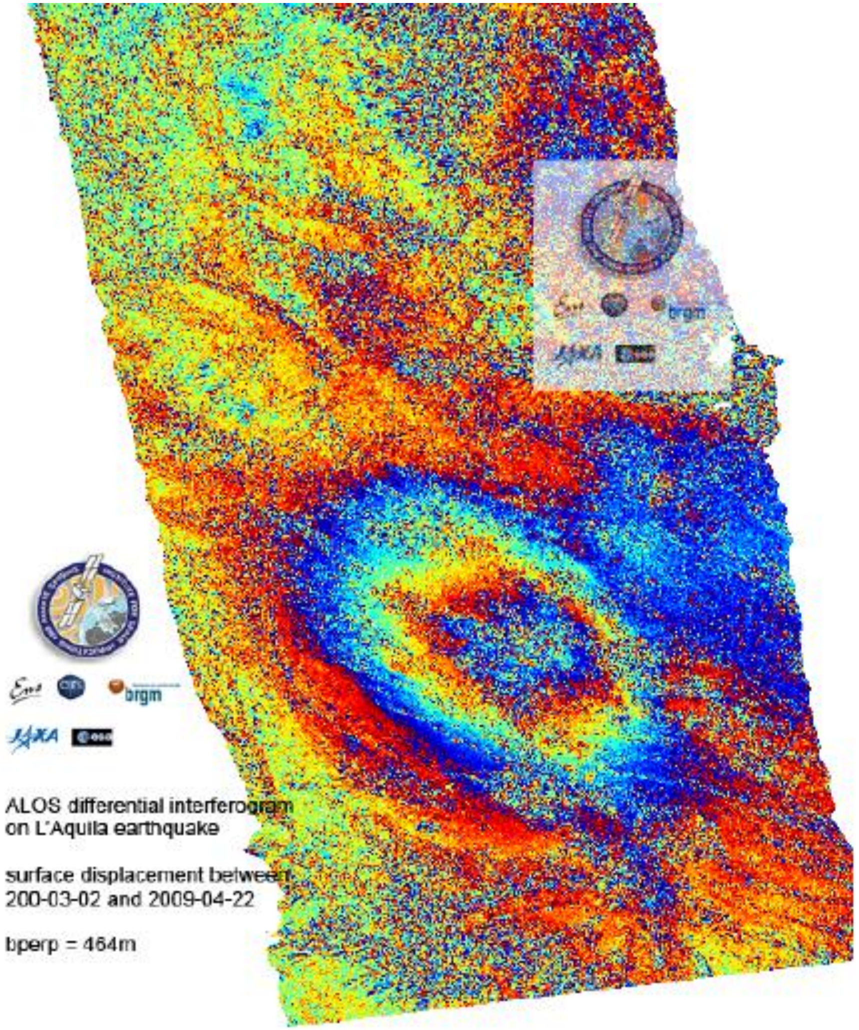

esa
ENVISAT mission:
10 years
First images
Global air pollution
B-15A iceberg
Ozone hole 2005
Arctic 2007
L'Aquila 2009
Iceland 2010
Japan 2011
Launch
Prestige tanker oil slick
Bam earthquake
Hurricane Katrina
Chlorophyll concentration
CO2 map
Serving
4000 scientific projects and many operational users. Many applications for disaster monitoring
Envisat Symposium Salzburg (A)
Envisat Symposium Montreux (CH)
Living Planet Symposium Bergen (N)
Mar 02
Sep 04
Apr 07
Jun 10
Mar 12
and many workshops dedicated to specific Envisat user communities

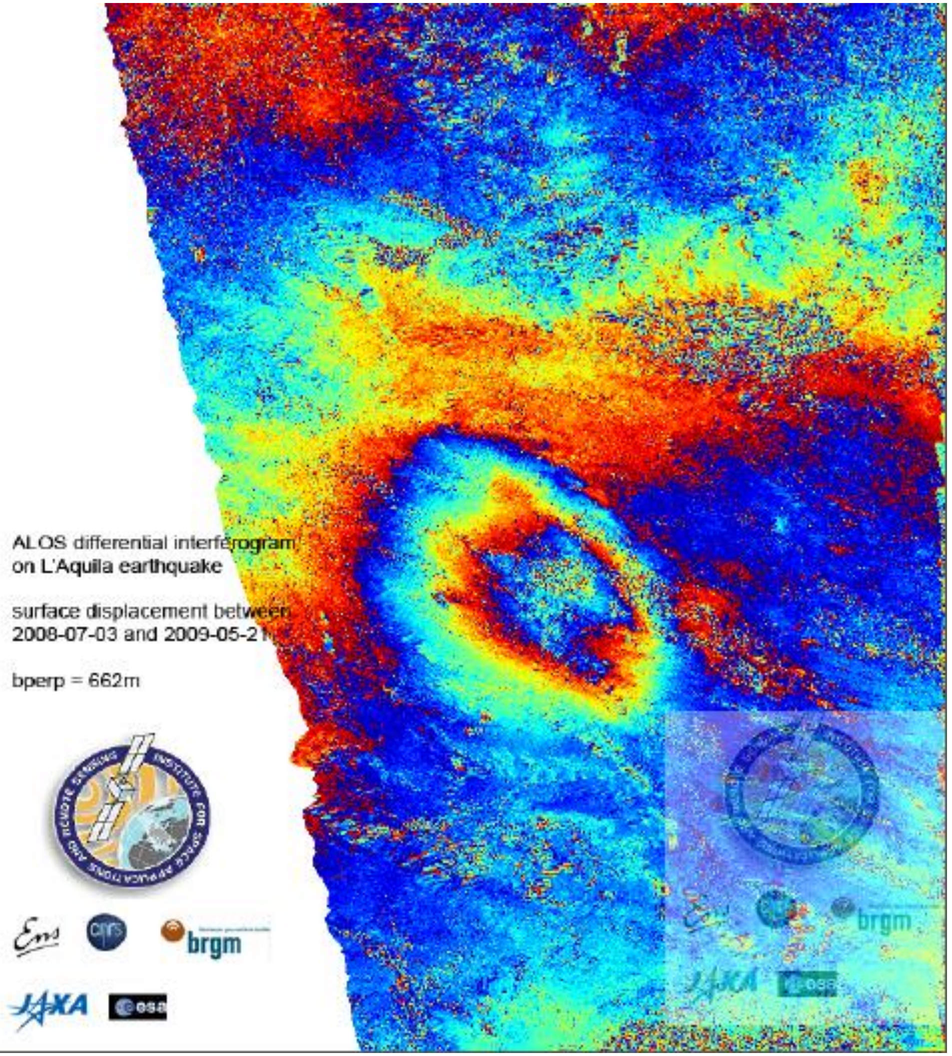
PALSAR on ALOS



Lançado em 2006

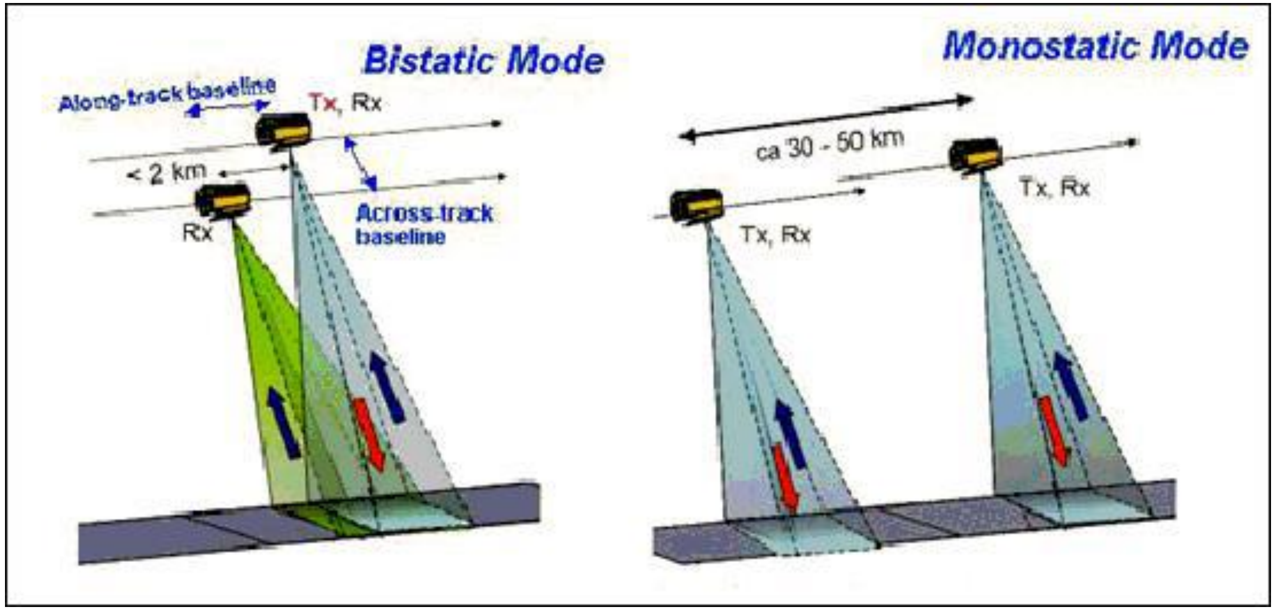
PALSAR on ALOS





L'Aquila, 2009

TERRASAR-x


Bistatic Mode
Monostatic Mode
Along-track baseline
Tx, Rx
< 2 km
Rx
Across-track baseline
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.

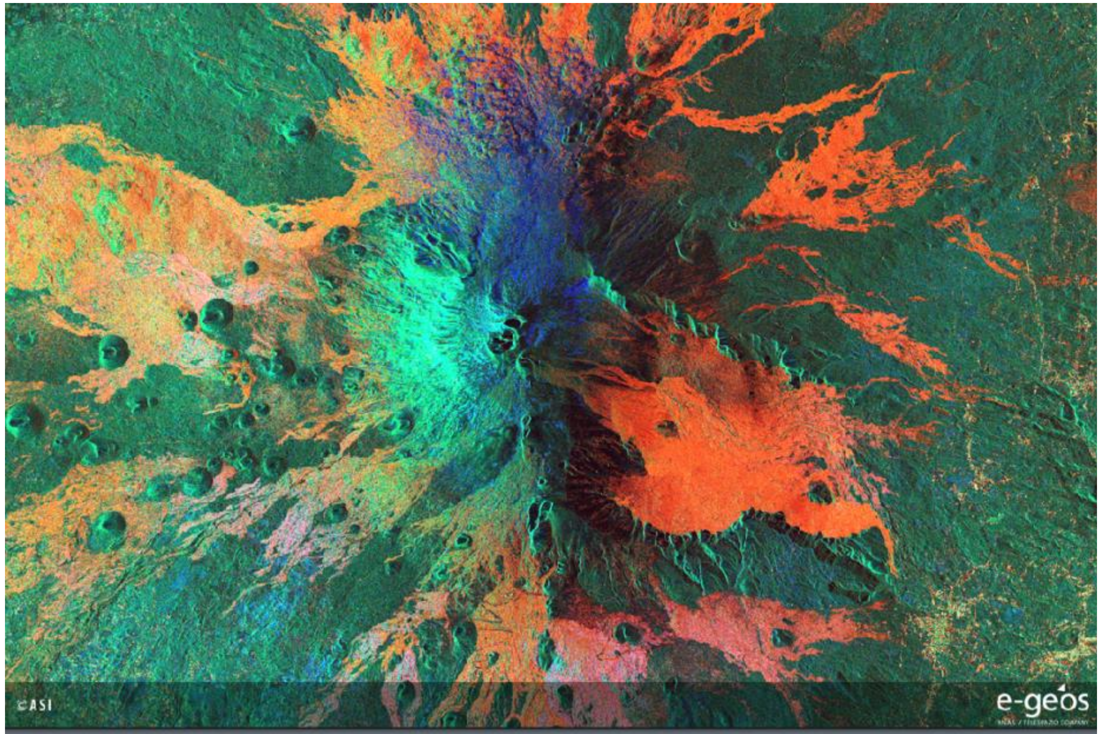
With 4 satellites up to 1800 images per day

Daily scenario example:

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

And

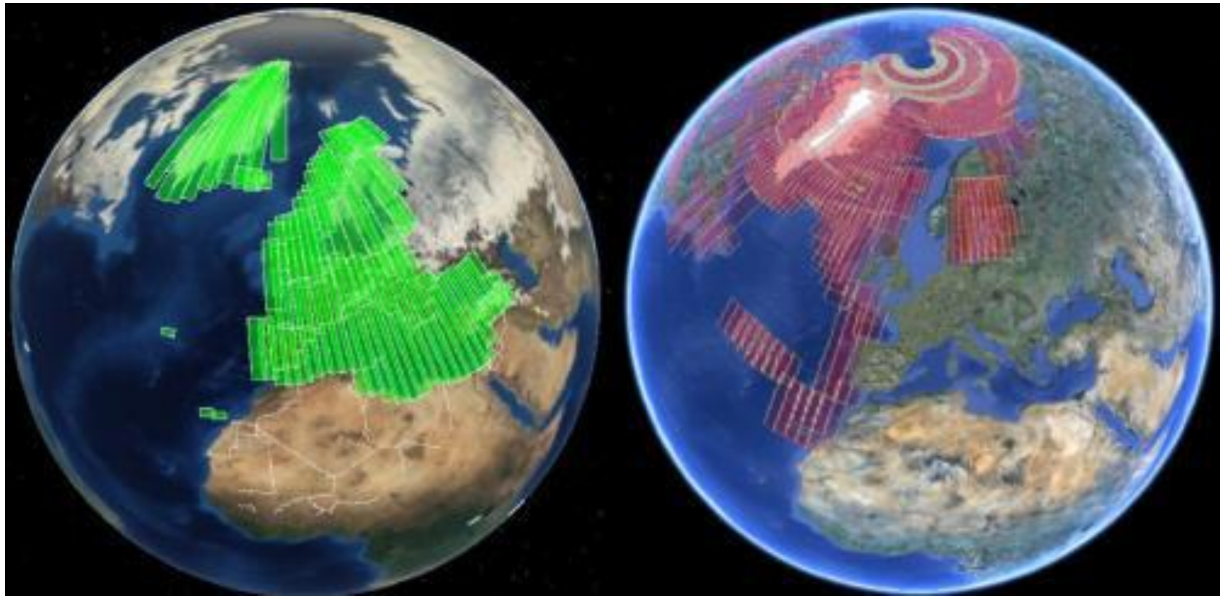
- 1,500 Stripmap = 2,400,000 km² at 3m resolution



COSMO-SkyMed coherence image Mount Etna

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 <u>just six days</u>.

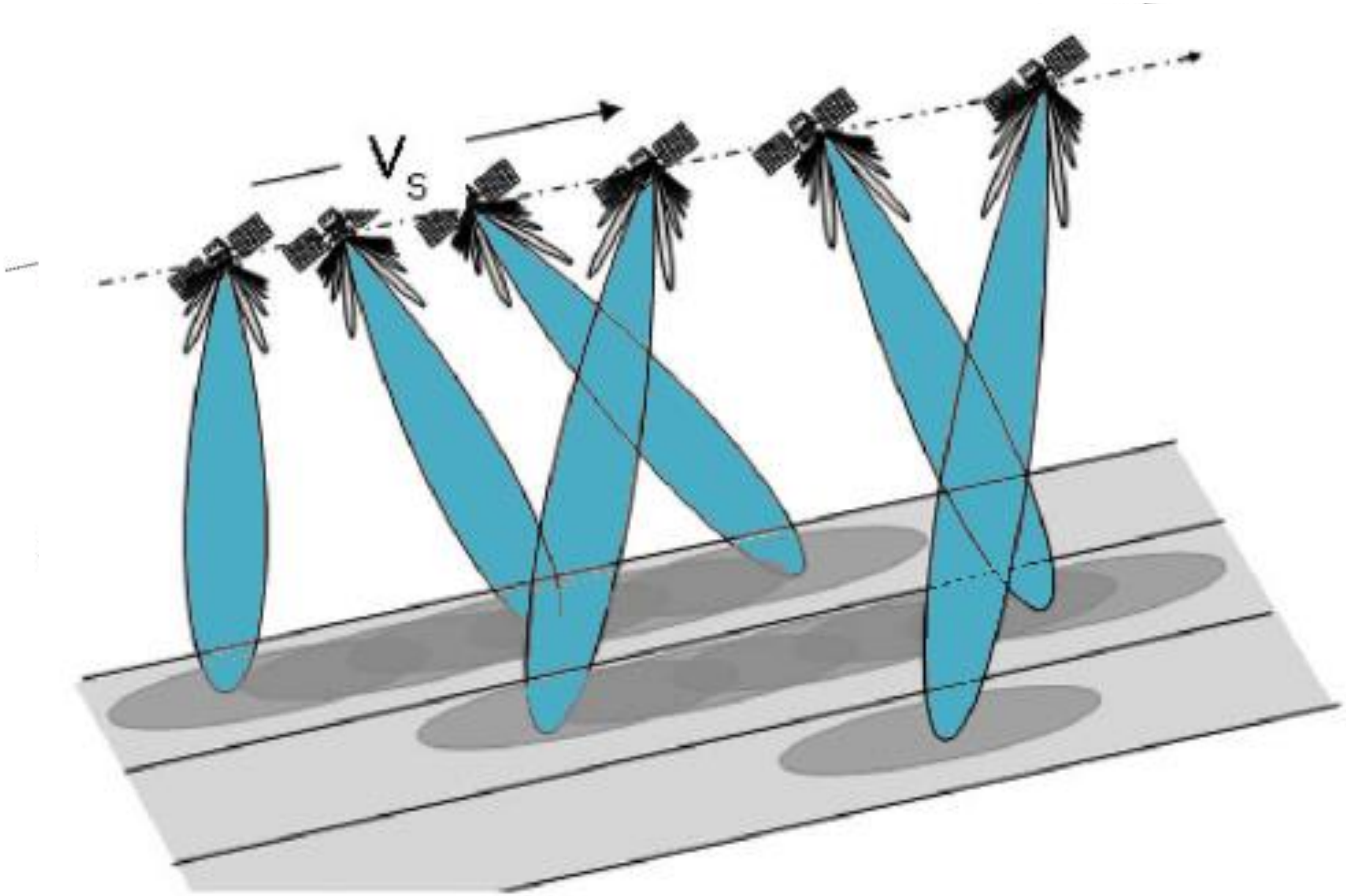
At the equator, however, the repeat frequency is <u>just three days</u> <u>and less than one day over the Arctic</u>. Europe, Canada and main shipping routes are covered in less than three days.



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.

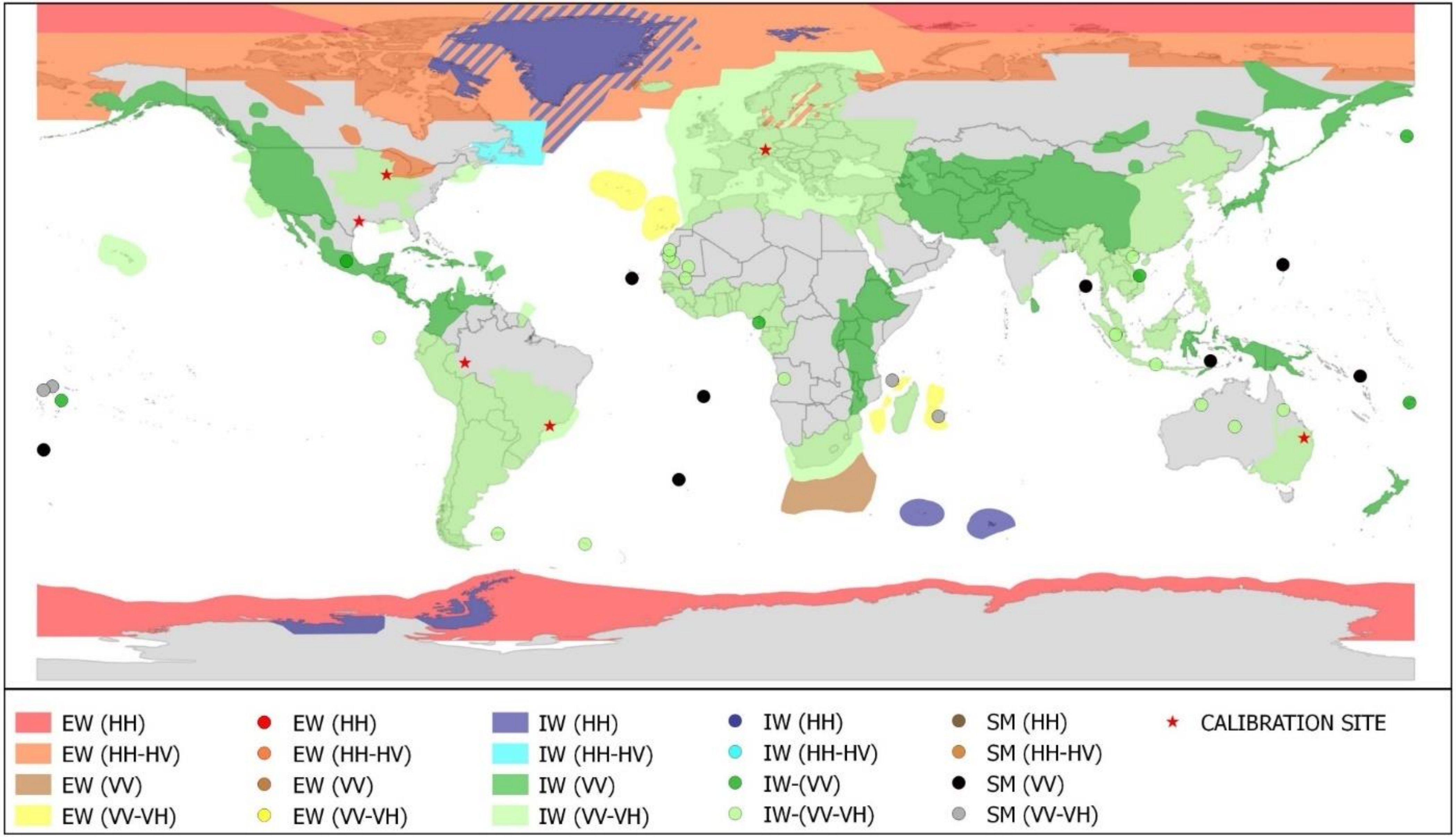
There's also the potential for operating it in two additional modes: Stripmap (5m x 5m) and Extra Wide Swath (20m x 40m).

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

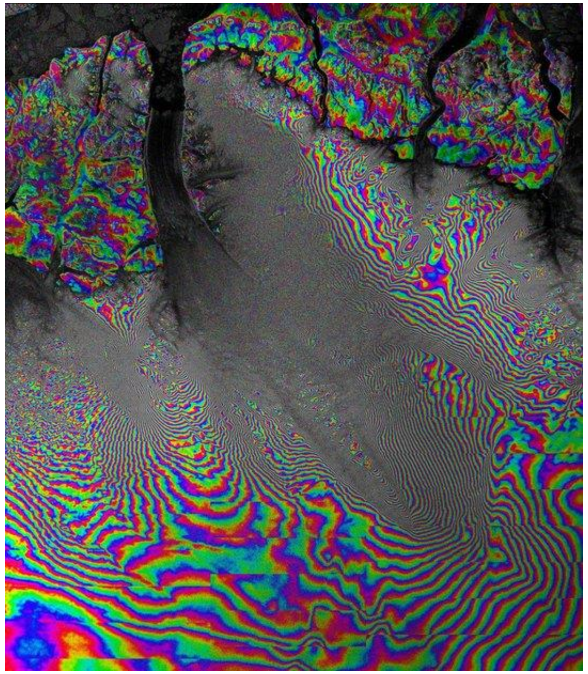
D

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

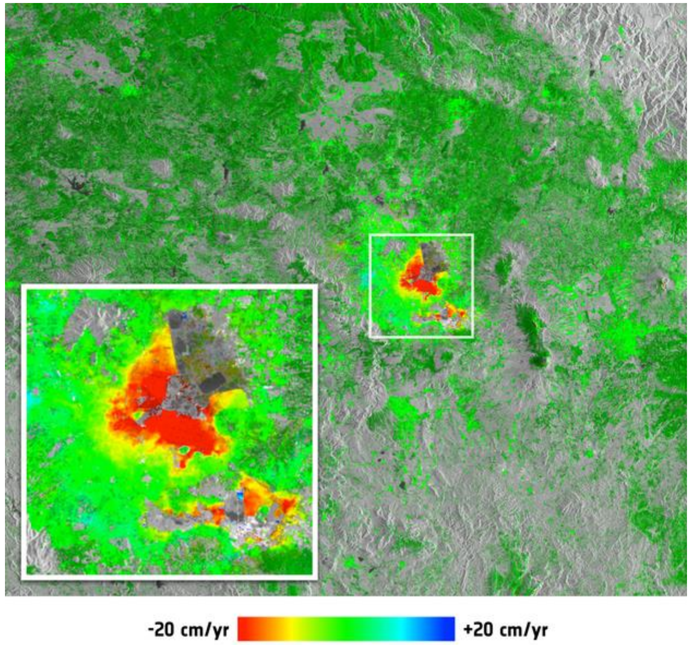


Aplicações

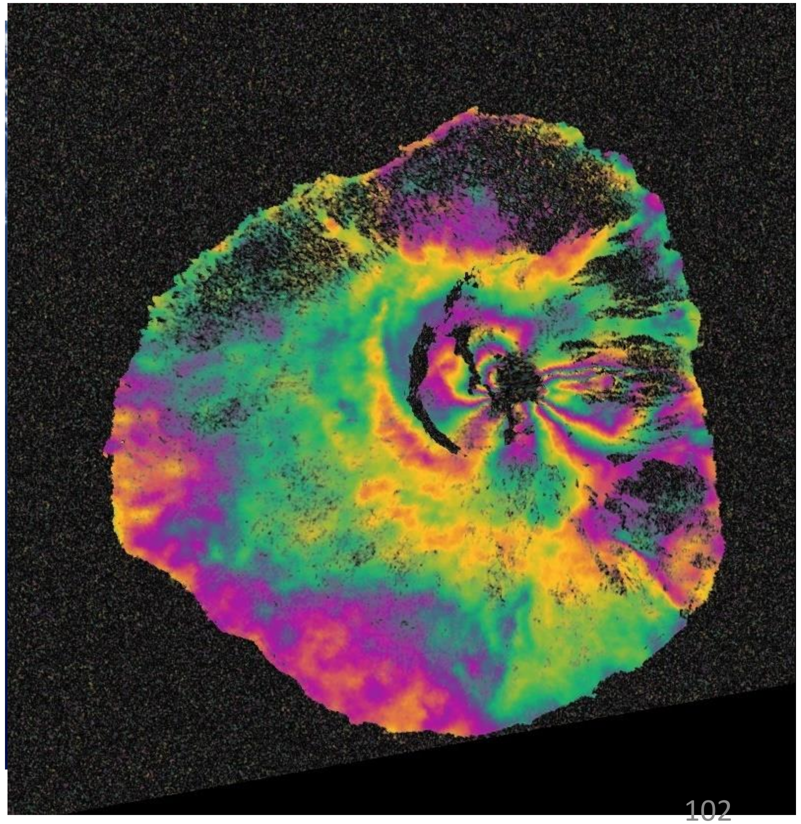
Oceano e Gelo



Changing lands

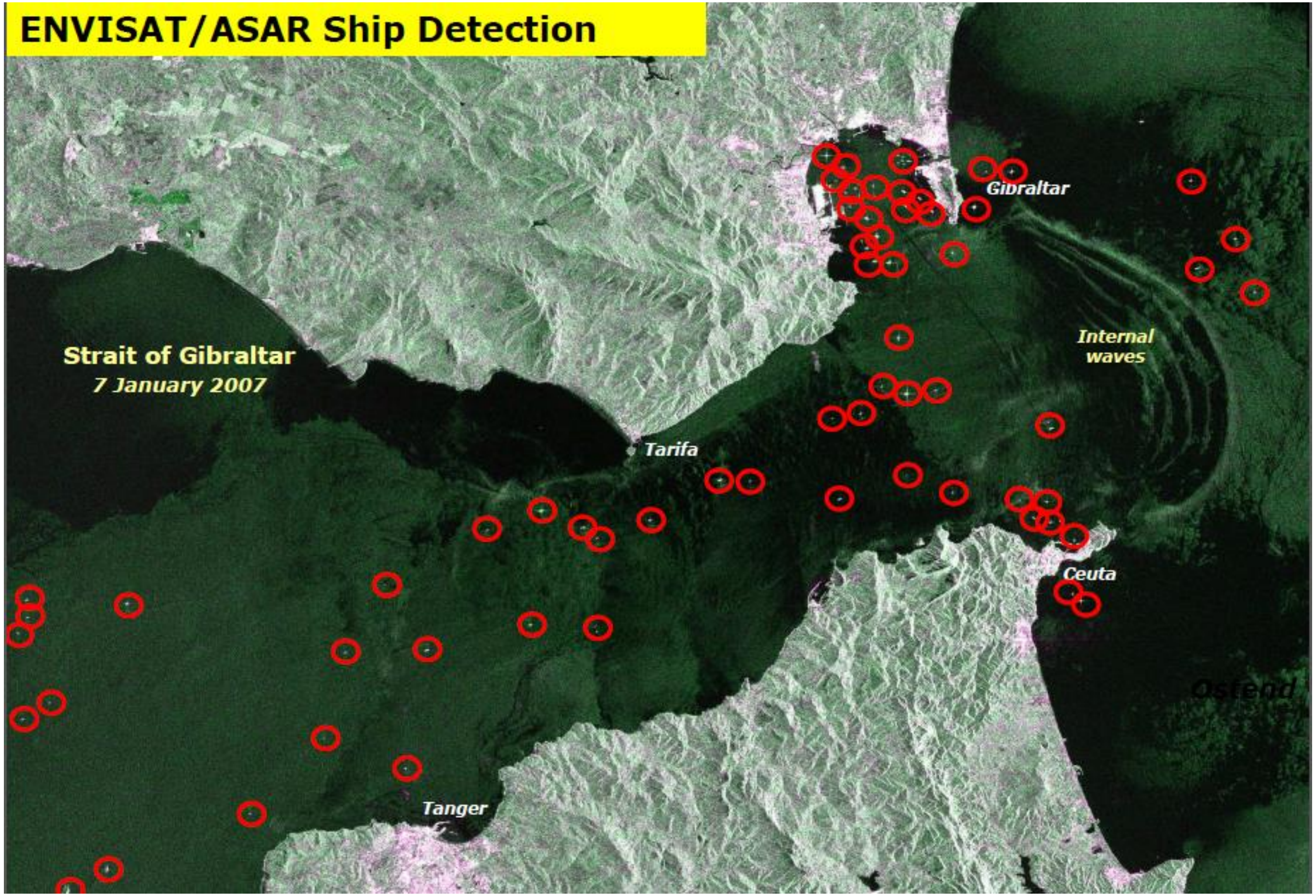


Emergency response

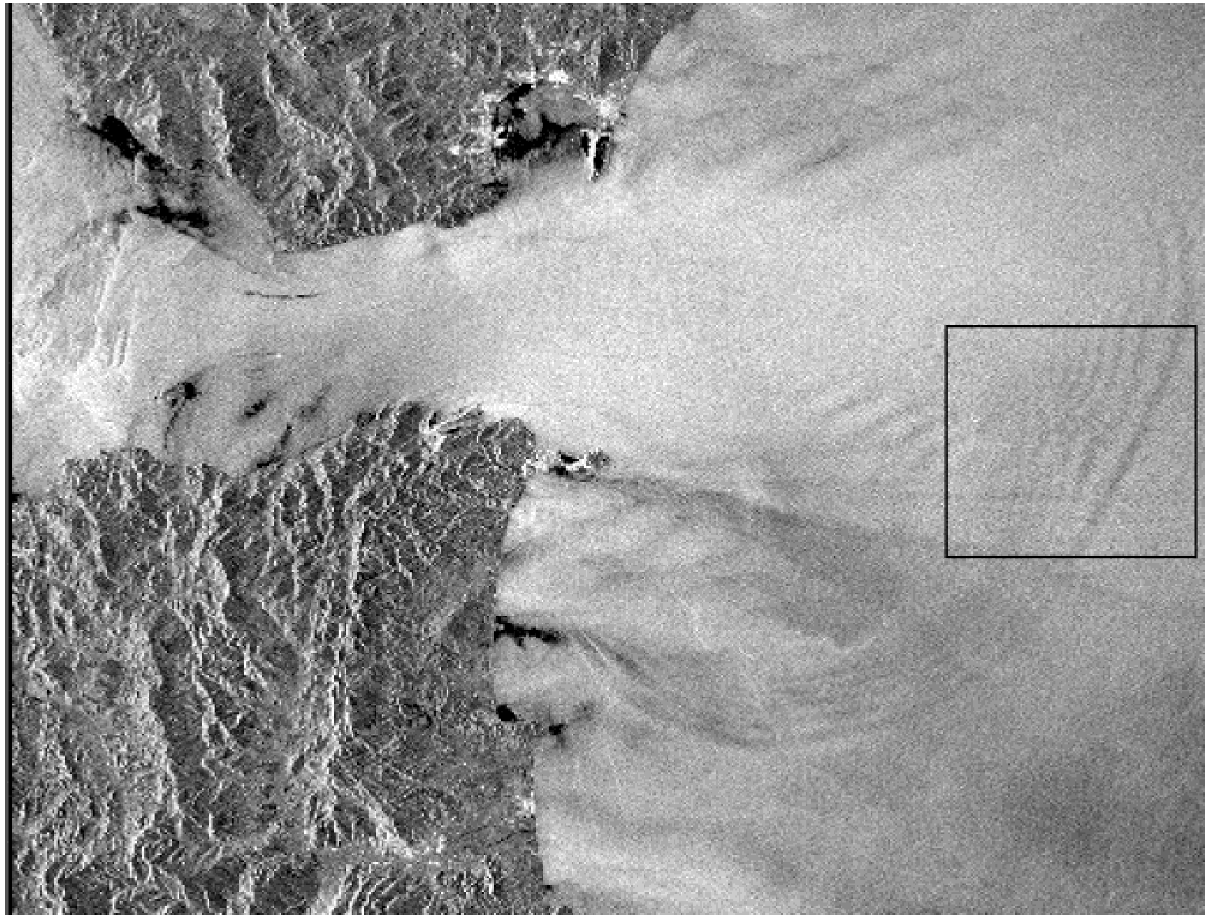


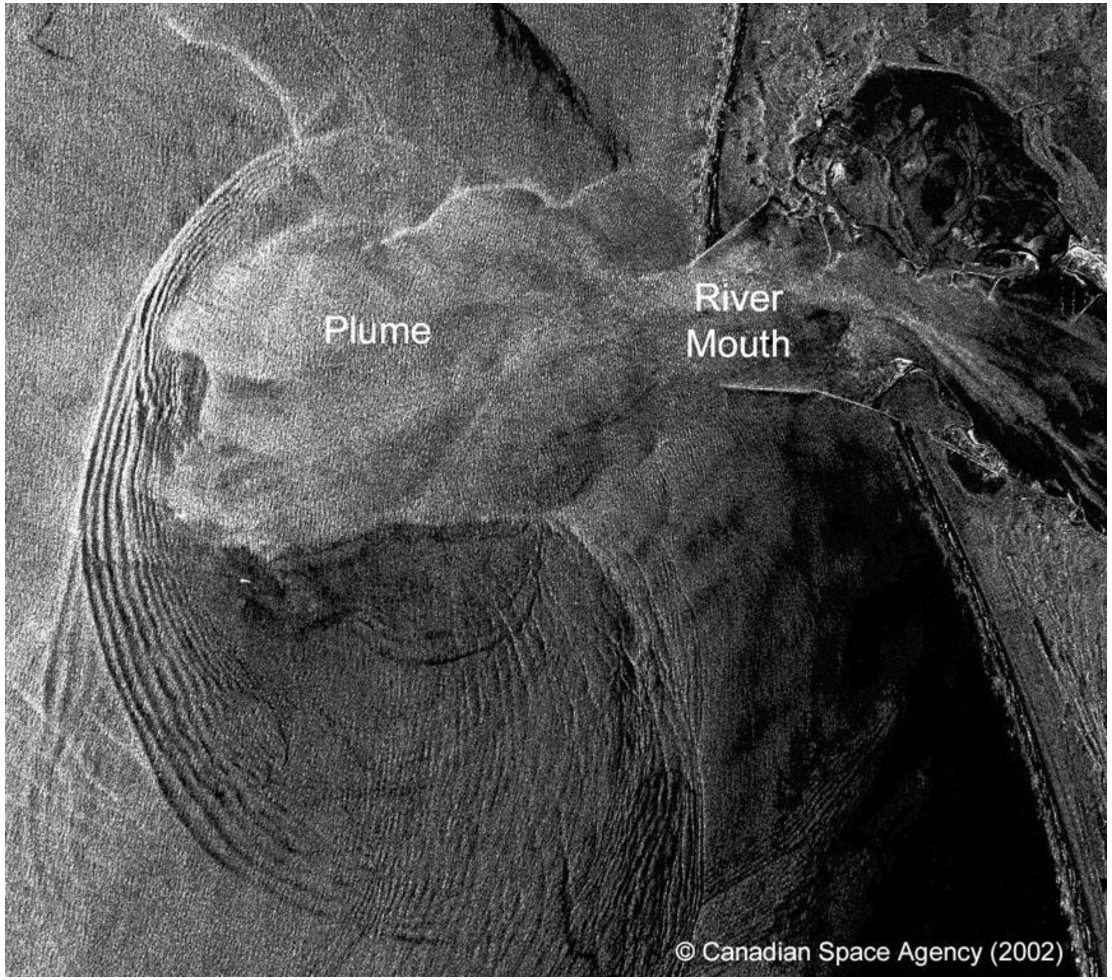
Aplicações
SAR e INSAR

Aplicações Oceano

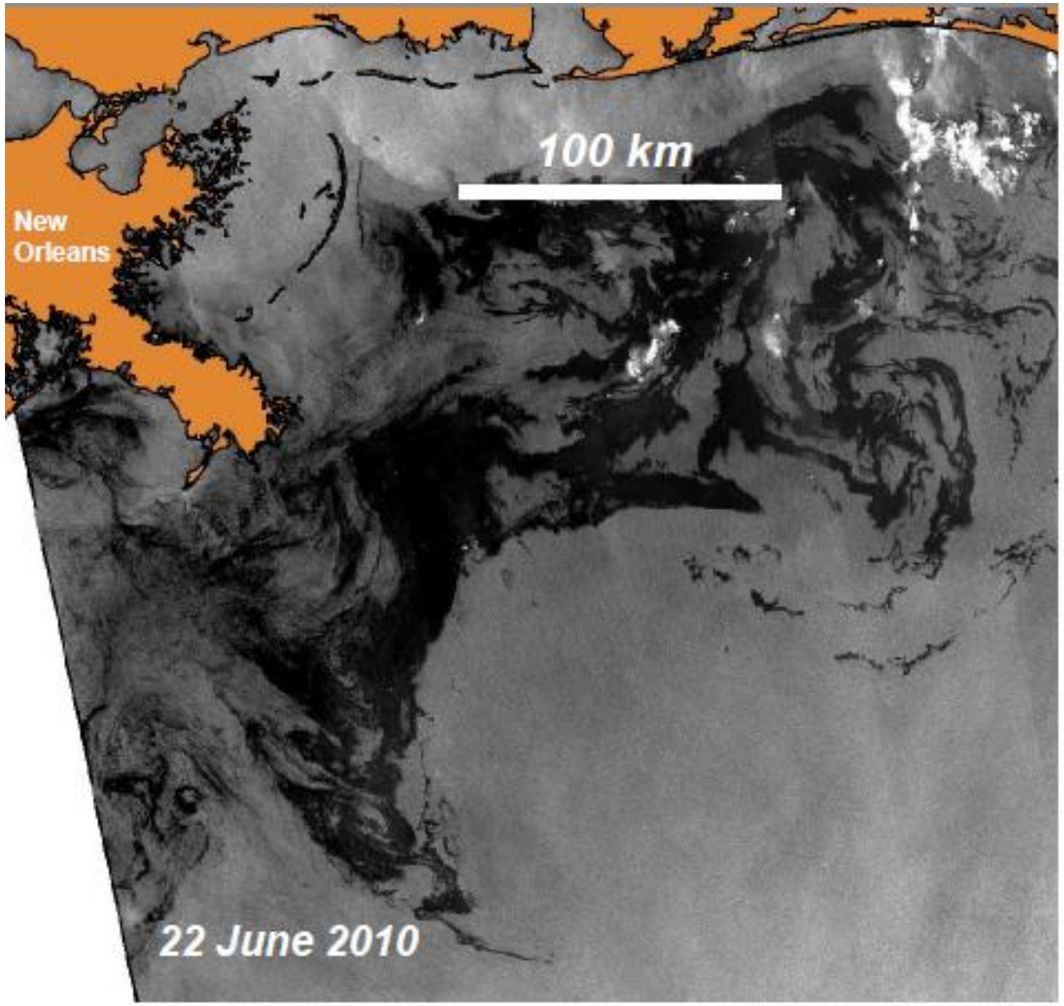


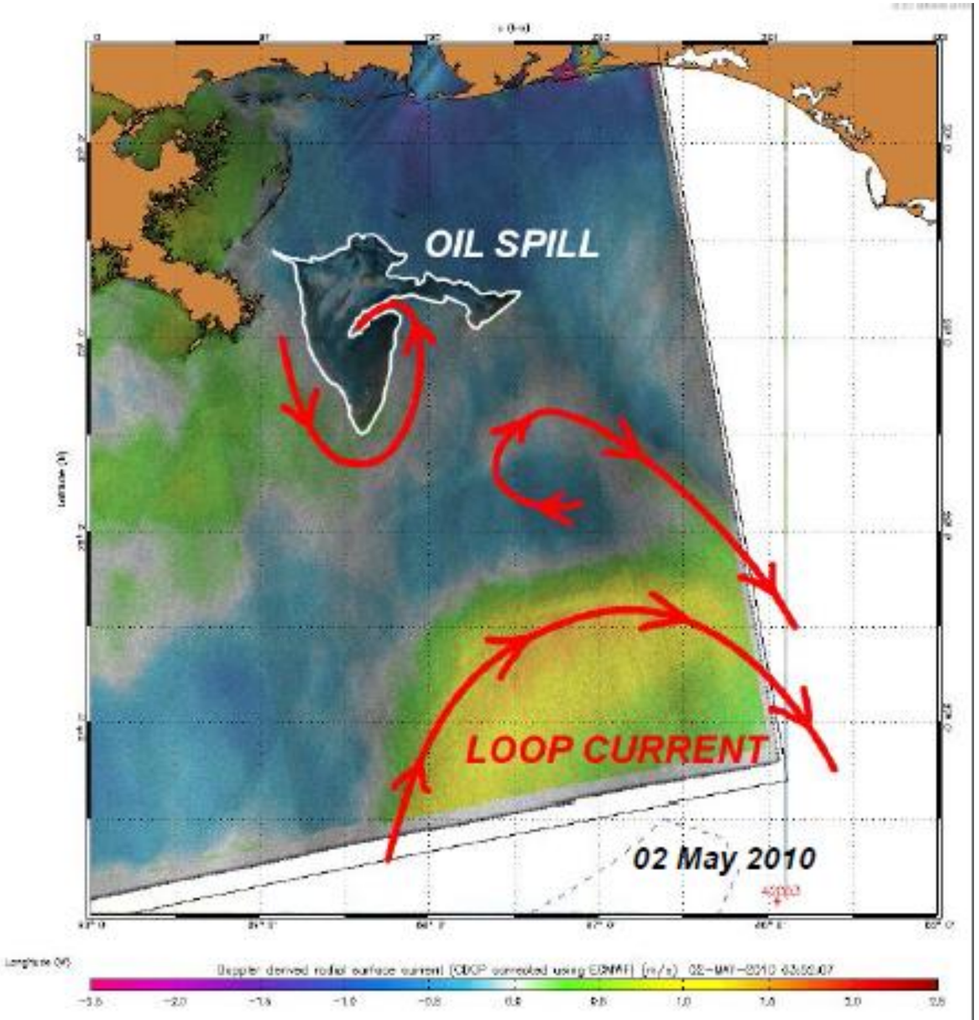
Aplicações Oceano





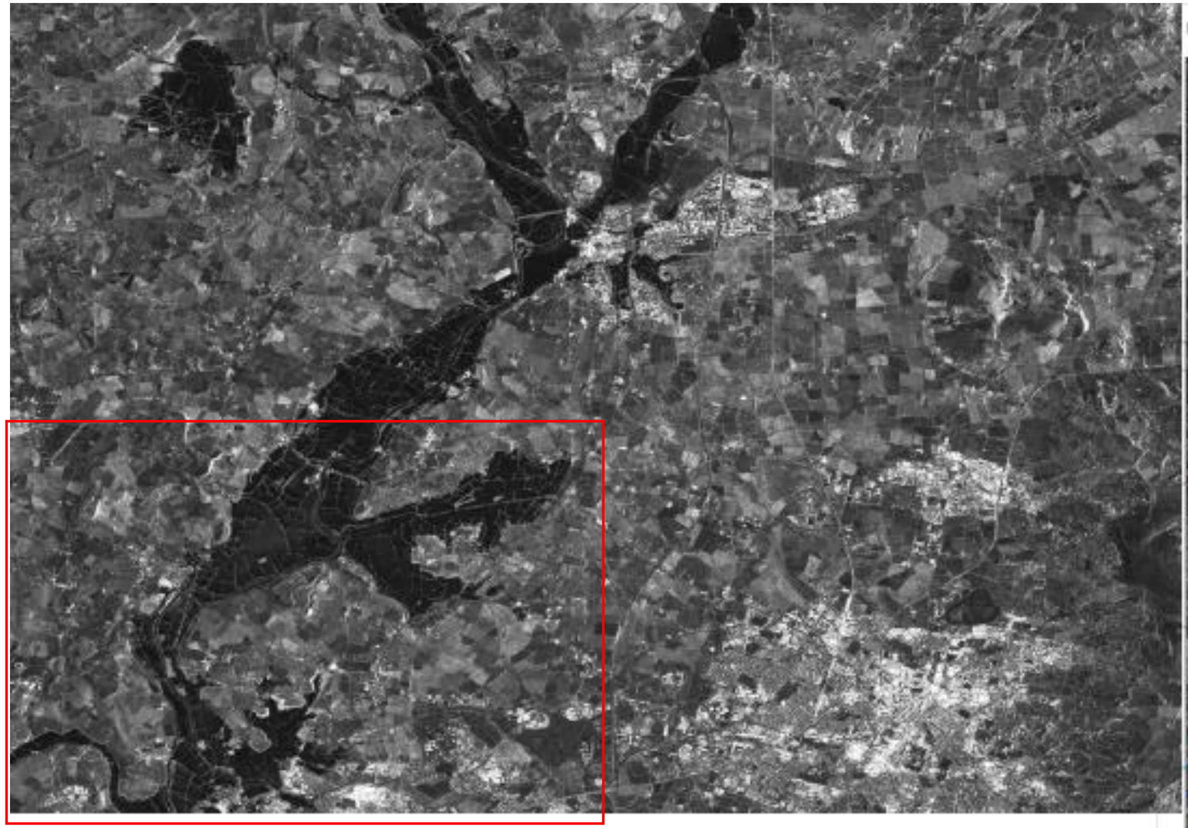
Aplicações Oceano



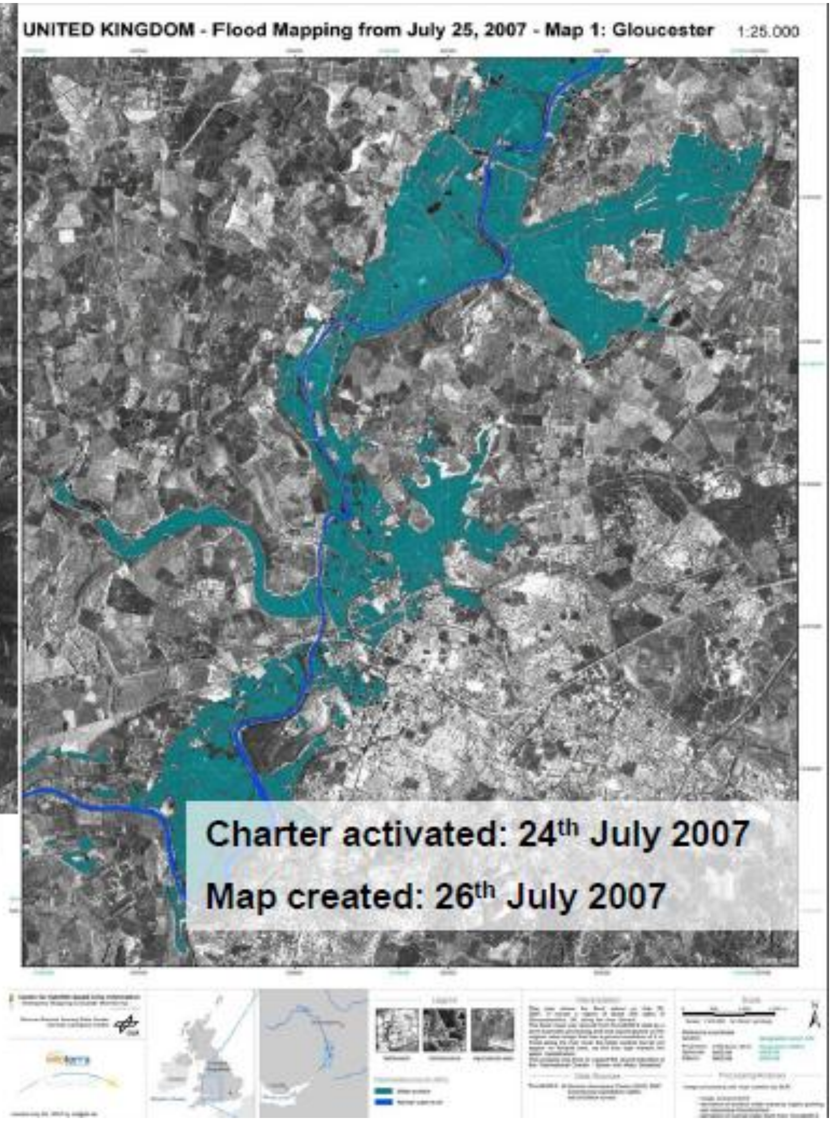


European Space Agency

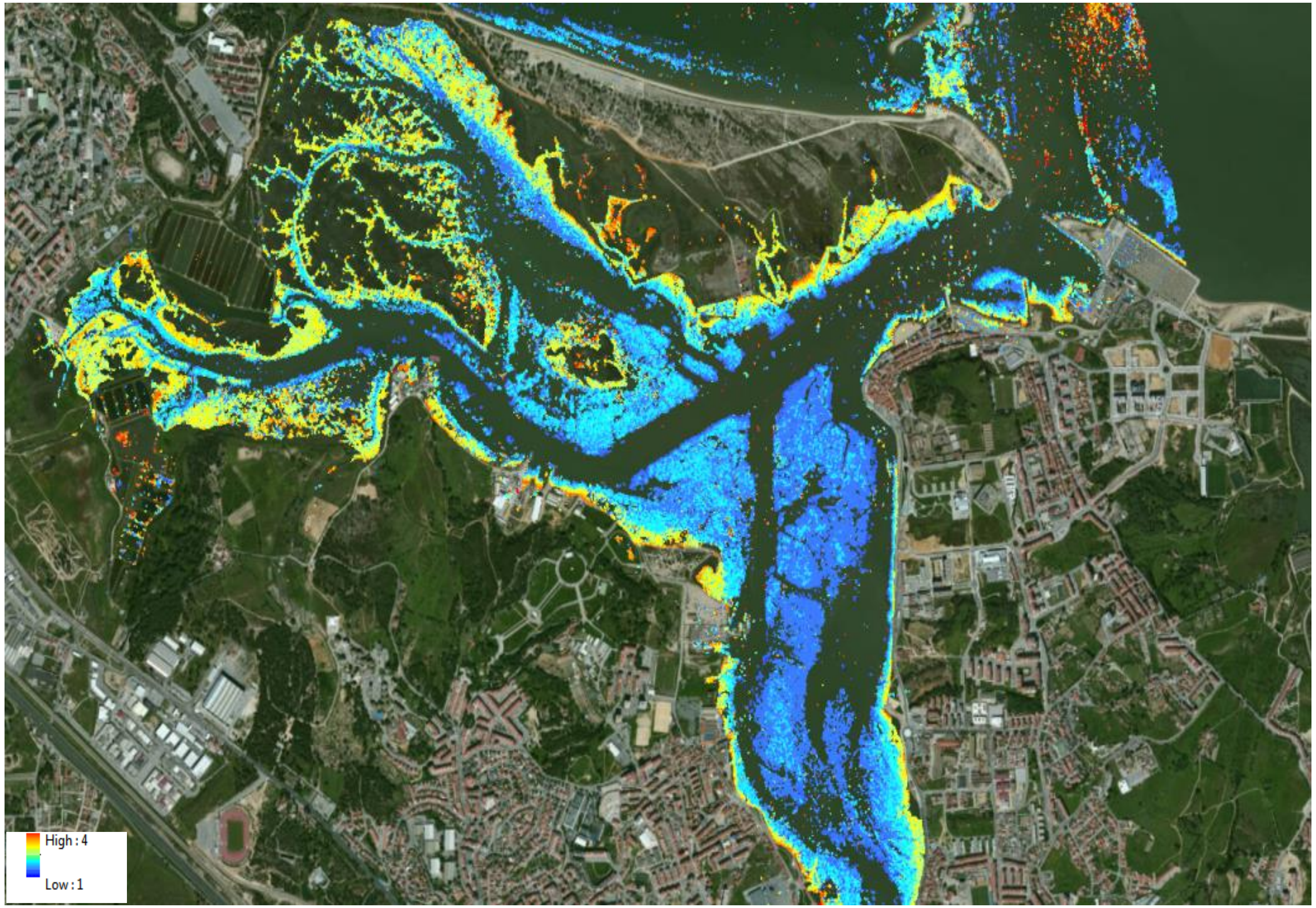
Monitorização de Cheias

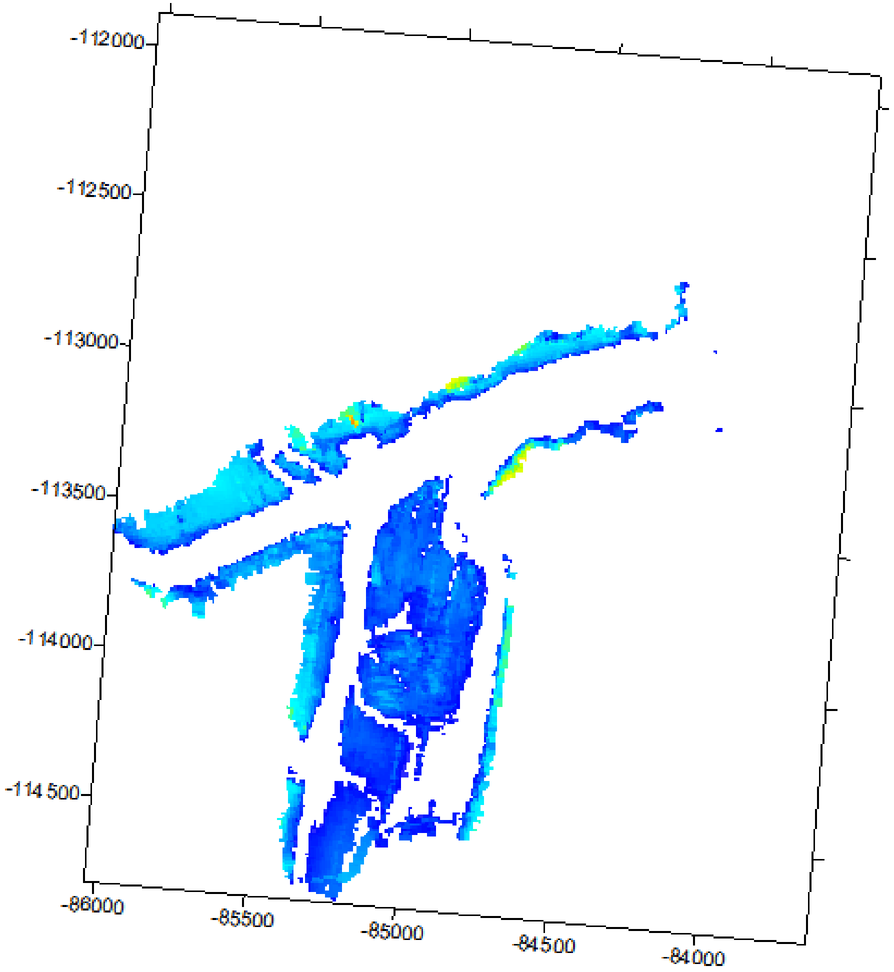


TerraSAR-X data (3m resolution) used in Charter Call



Inter-tidal

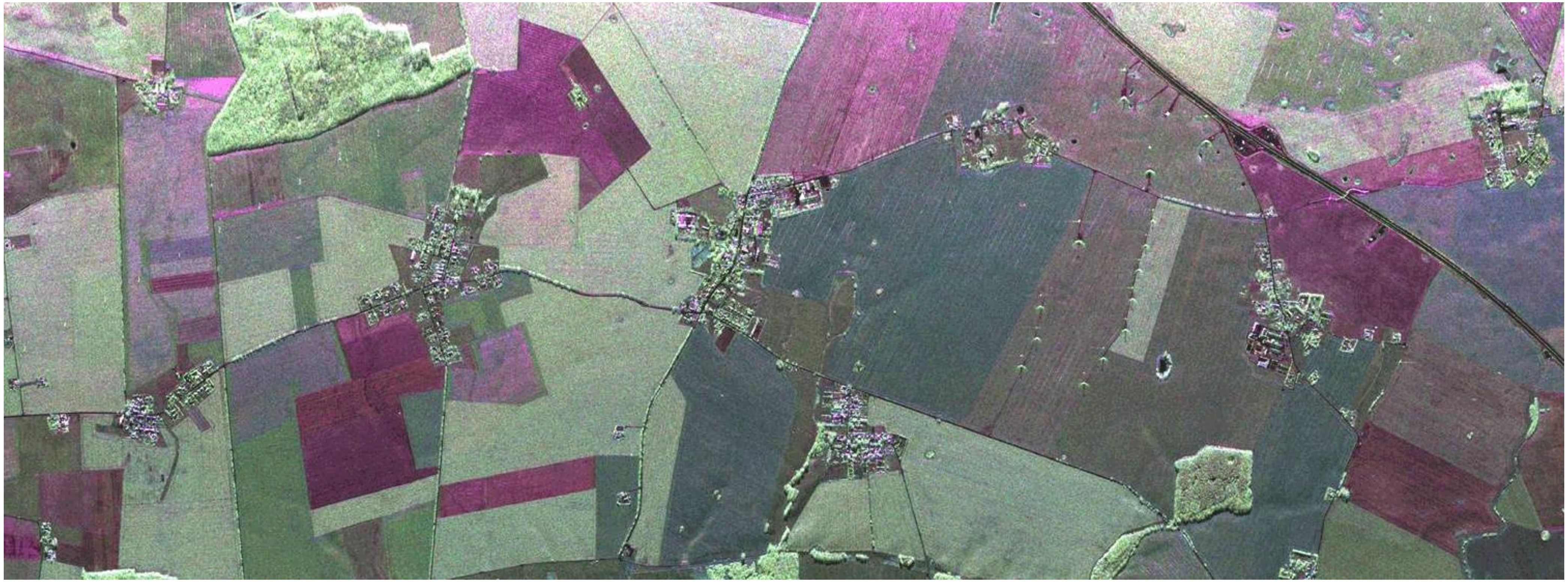




Levantamento CM Seixal (realizado pelo IH)

Monitorização da Vegetação

(Polarimetria SAR)

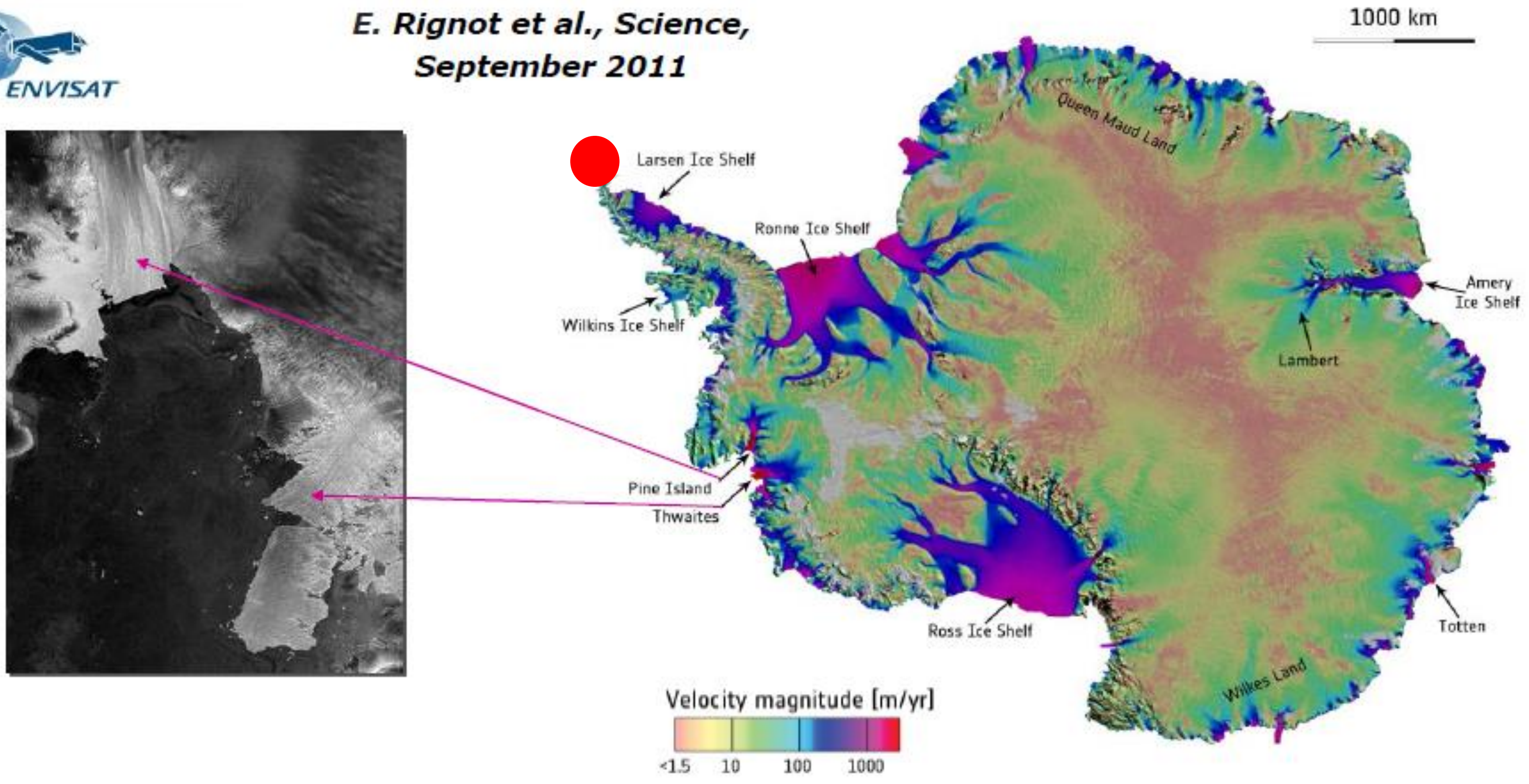


Movimento de glaciares

(InSAR)

ENVISAT

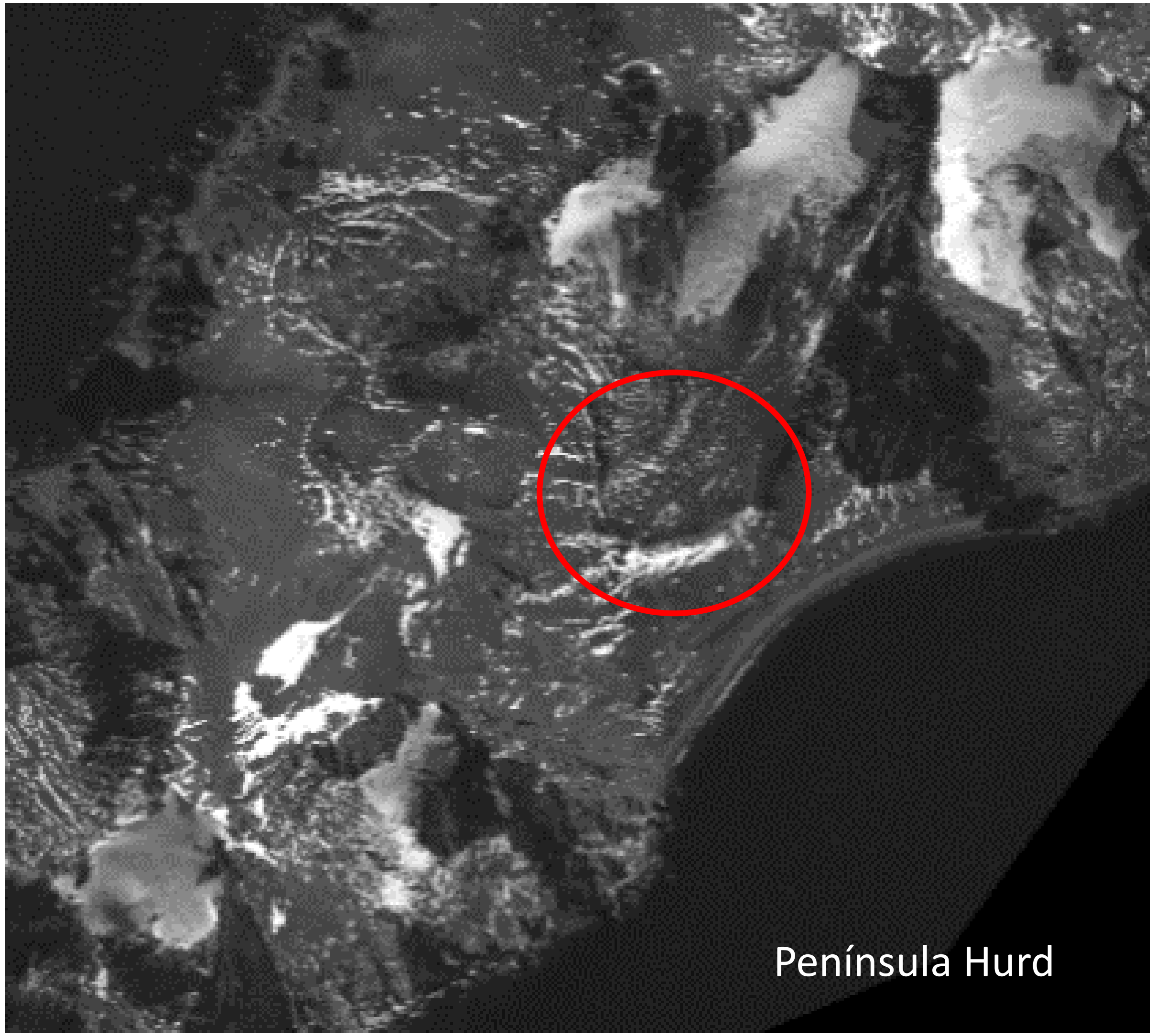
E. Rignot et al., Science, September 2011

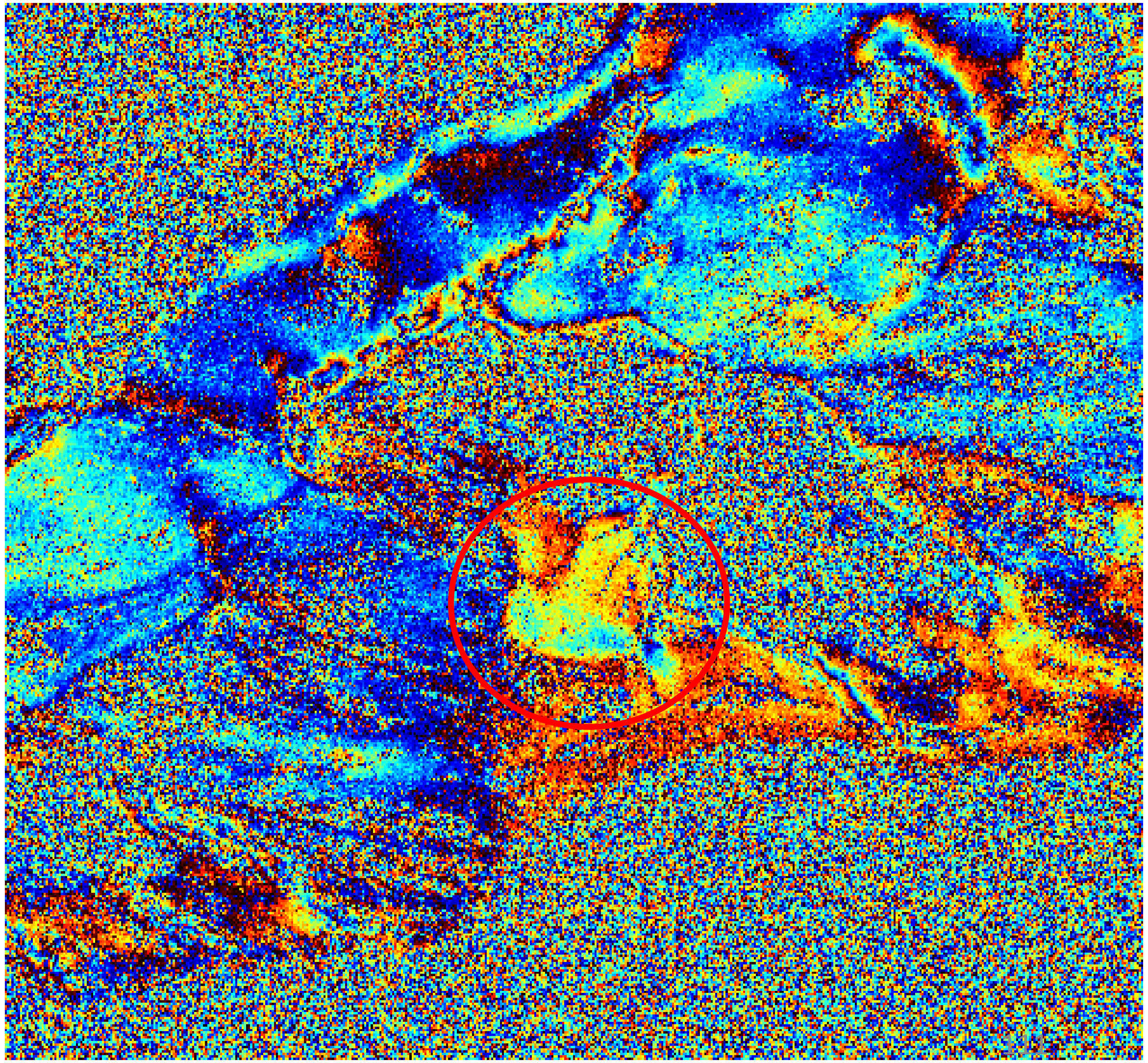


European Space Agency

Monitorização do Permafrost

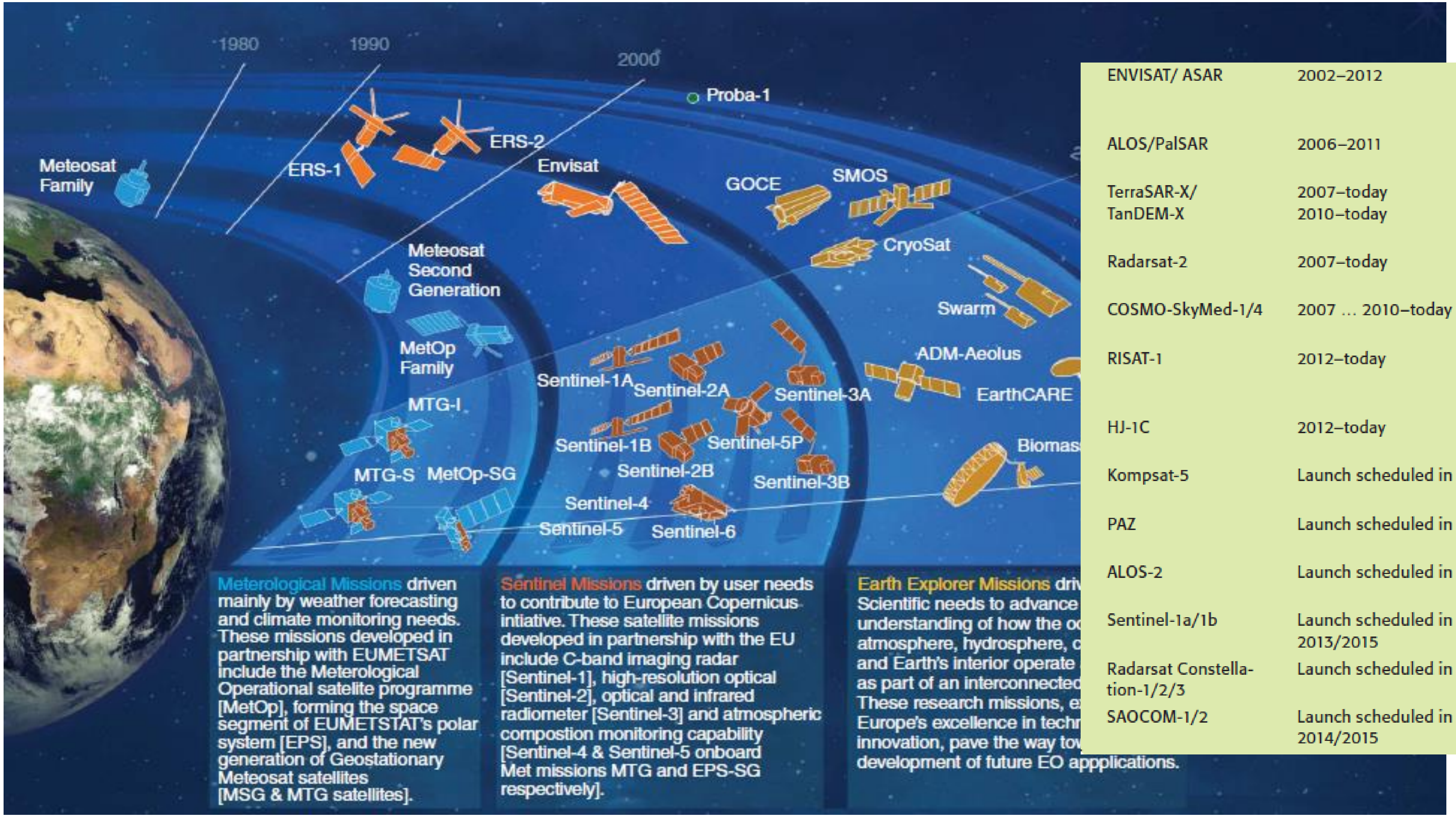
(InSAR)





O programa de Observação da ESA

Missões ESA



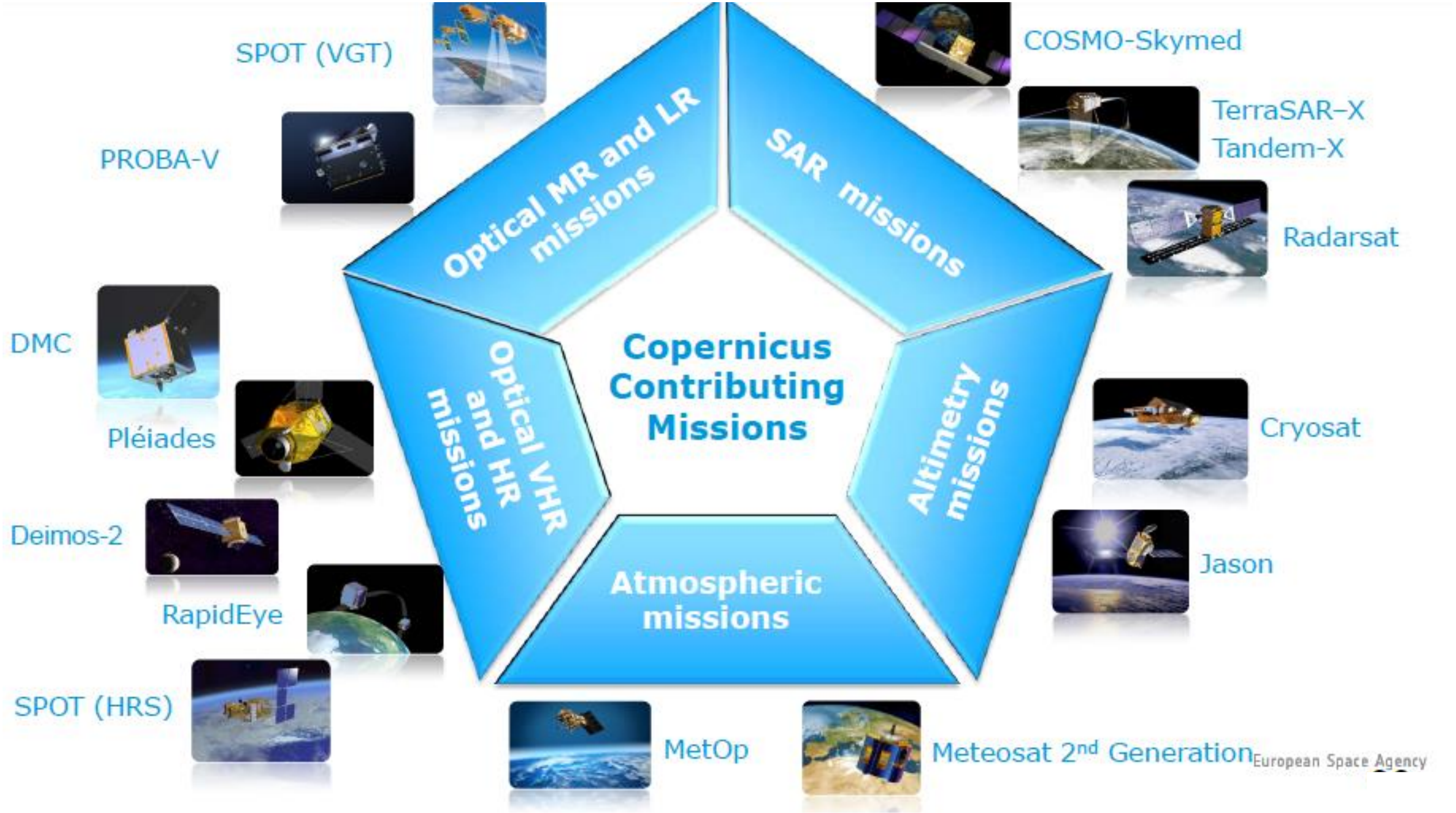
ENVISAT/ ASAR	2002–2012	C (dual)
ALOS/PalSAR	2006–2011	L (quad)
TerraSAR-X/ TanDEM-X	2007–today 2010–today	X (quad)
Radarsat-2	2007–today	C (quad)
COSMO-SkyMed-1/4	2007 … 2010–today	X (dual)
RISAT-1	2012–today	C (quad)
HJ-1C	2012–today	S (VV)
Kompsat-5	Launch scheduled in 2013	X (dual)
PAZ	Launch scheduled 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

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

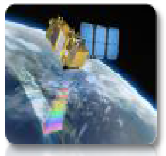
Copernicus contributing missions



Copernicus componente Serviços

Sentinel Scientific Toolboxes

Sentinel-1 (A/B/C/D) – SAR Imaging
All weather, day/night applications, interferometry

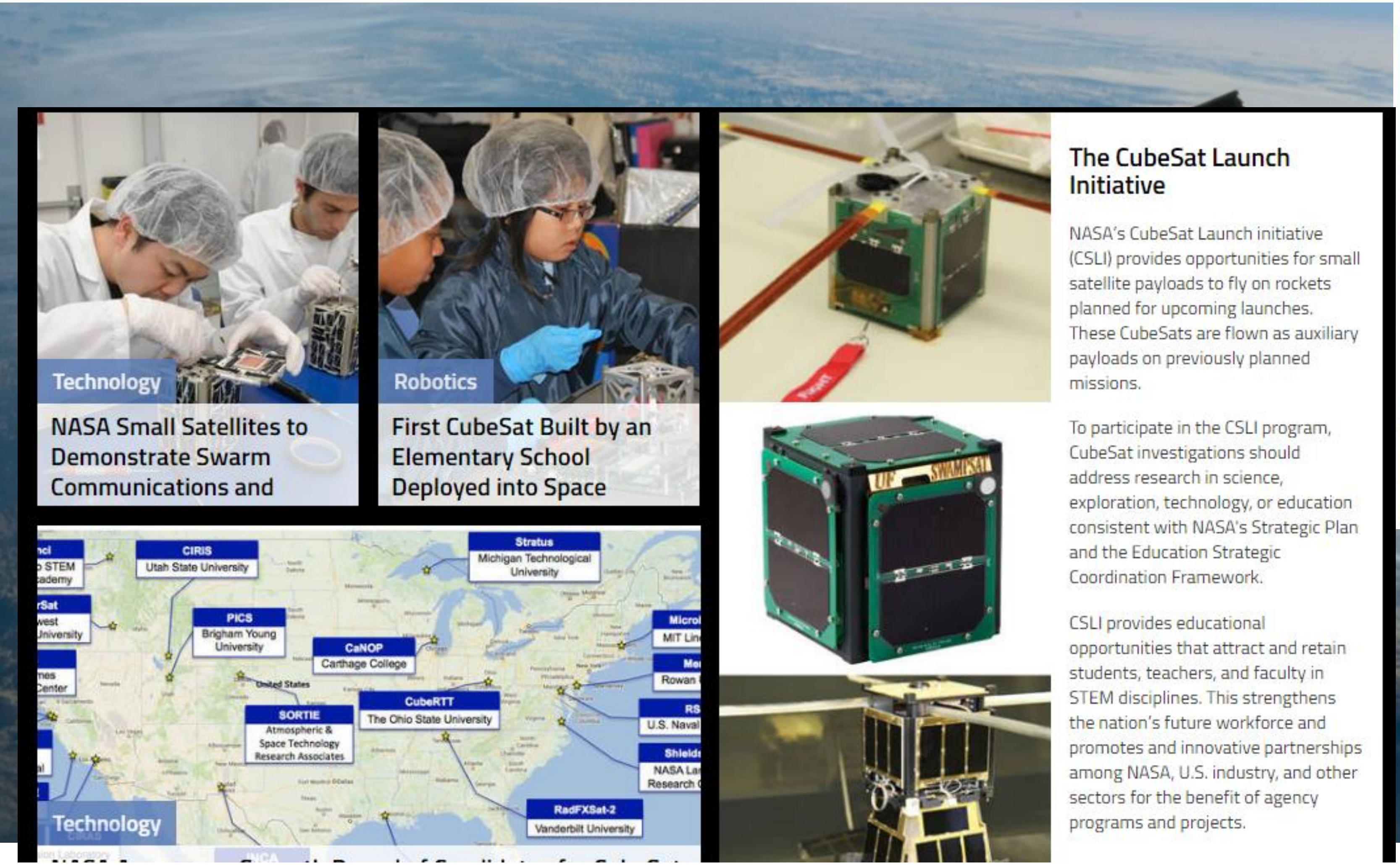


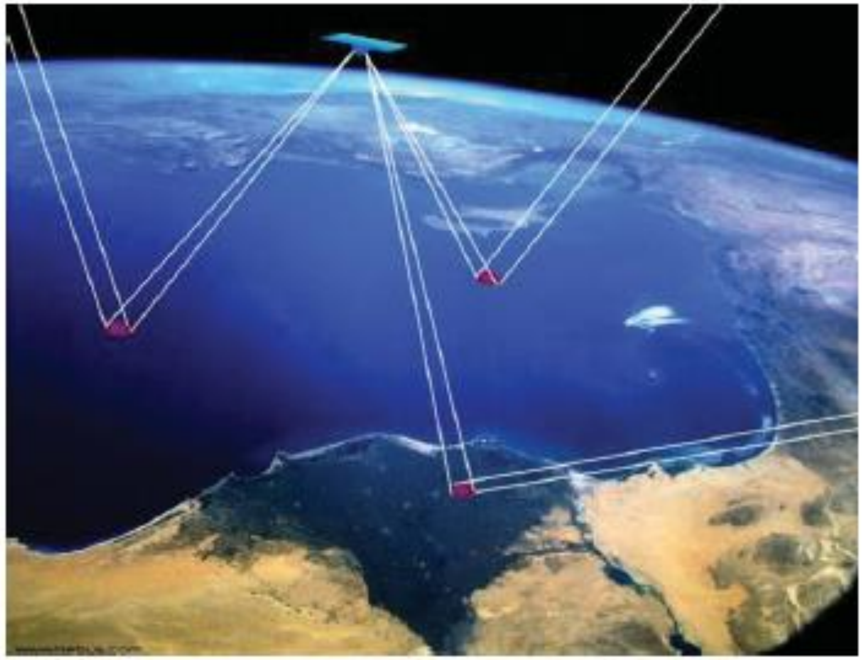
Sentinel-2 (A/B/C/D) – Multi-Spectral Imaging
Land applications: urban, forest, agriculture,…
Continuity of Landsat, SPOT

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
CIRIS
Utah State University
Stratus
Michigan Technological University
PICS
Brigham Young University
CaNOP
Carthage College
CubeRTT
The Ohio State University
SORTIE
Atmospheric & Space Technology Research Associates
RadFXSat-2
Vanderbilt University
Technology
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.



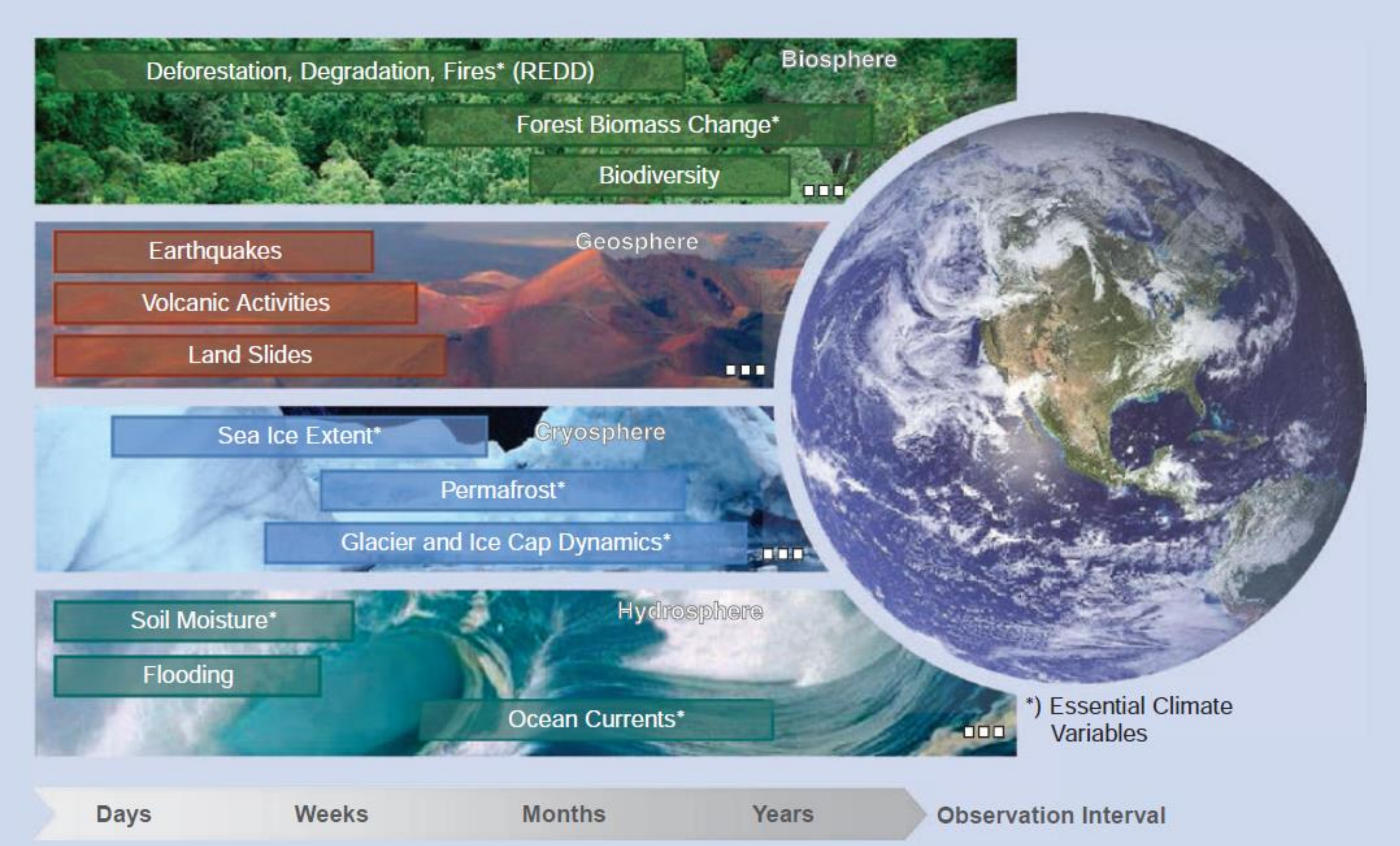
Perspetivas para o radar de abertura sintética

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

ERS-1,2

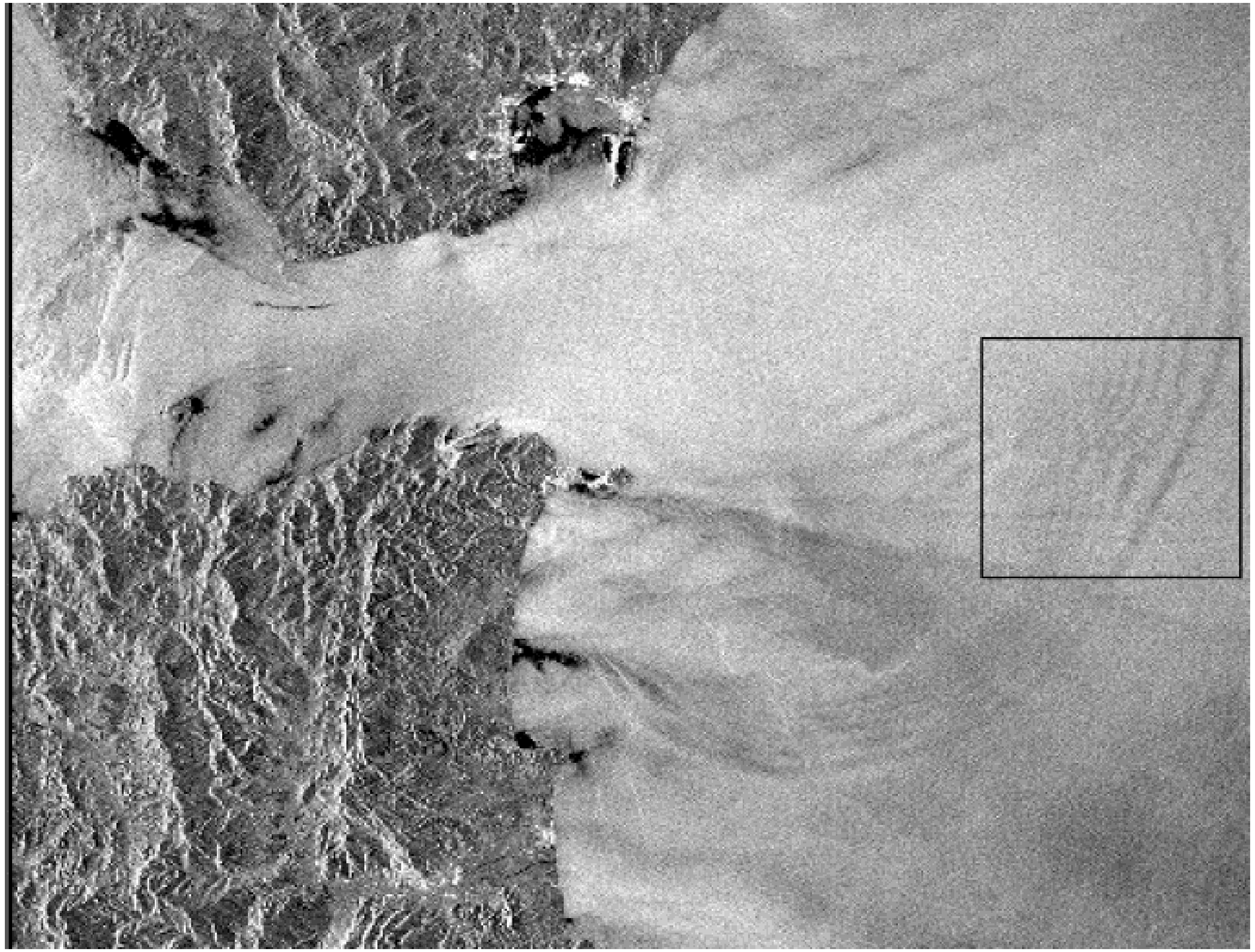
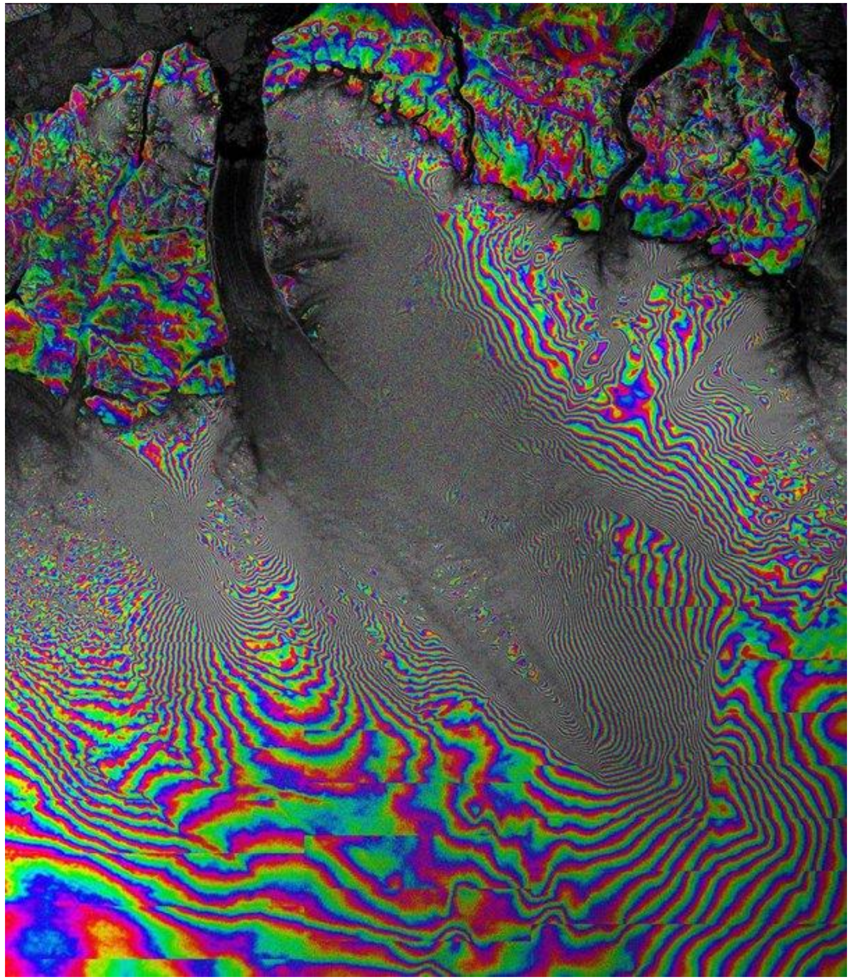


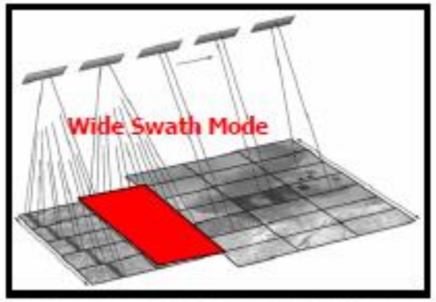
Imagem do estreito de Gibraltar, Outubro de 1993

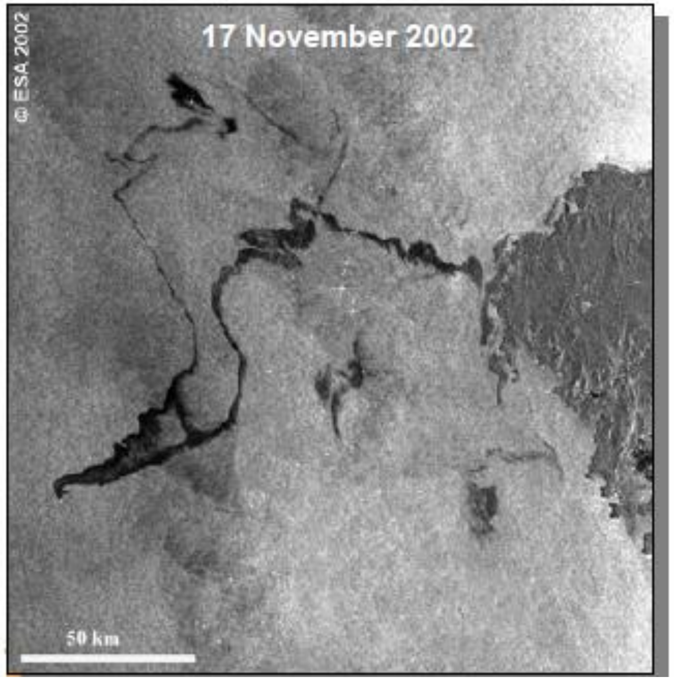


Glaciar em movimento

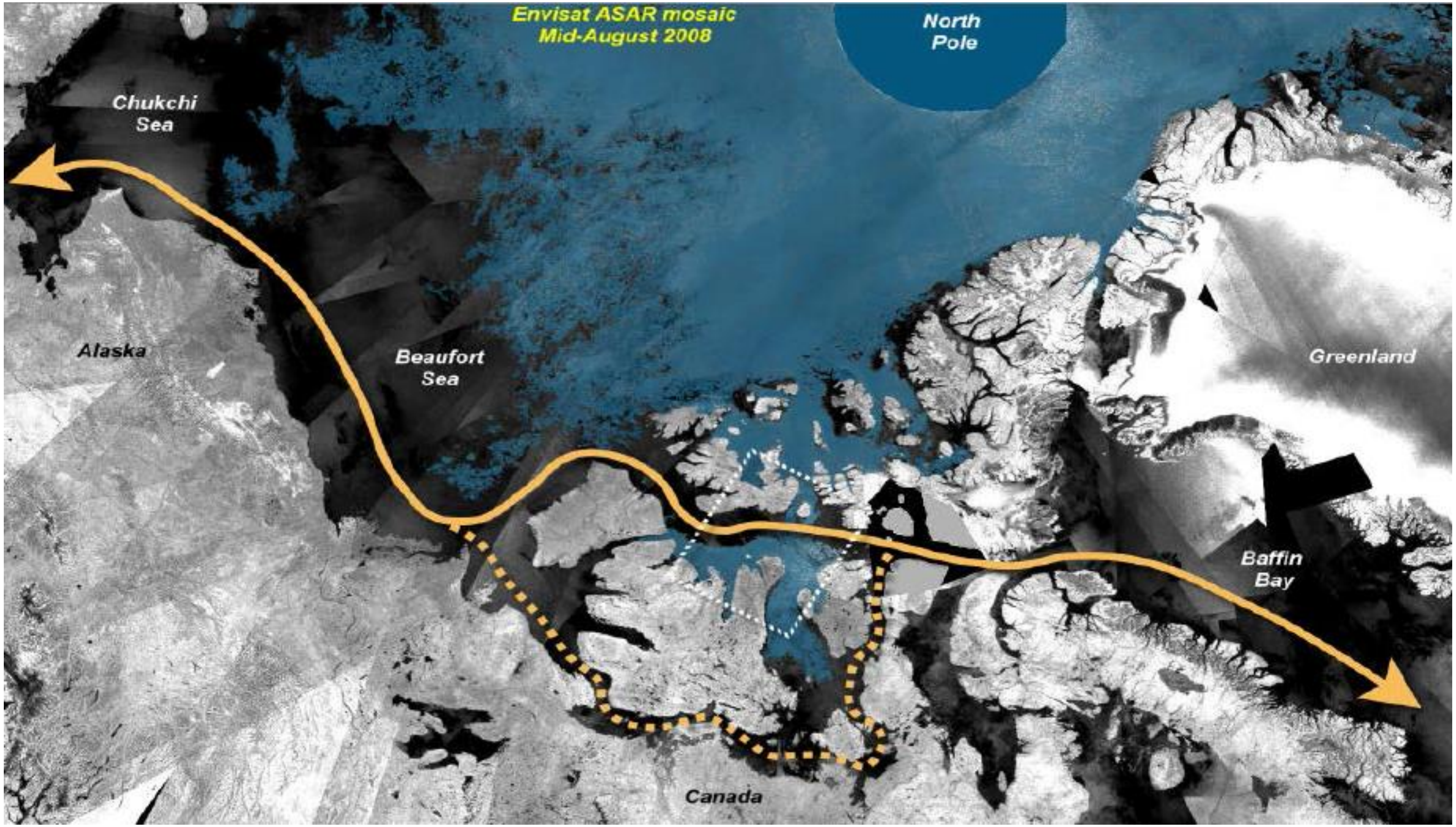
ENVISAT

ENVISAT Imaging Radar



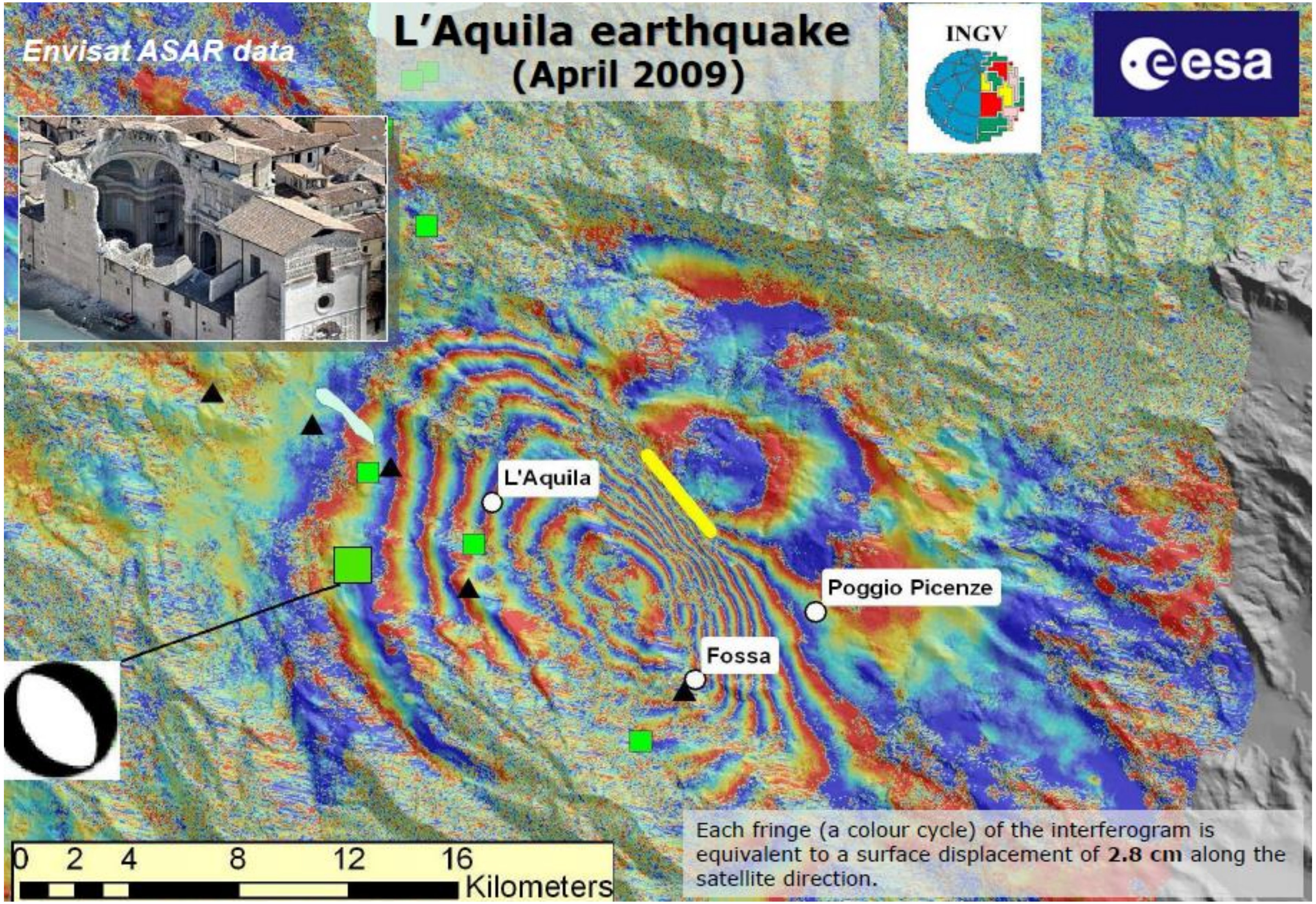


Monitorização do Gelo



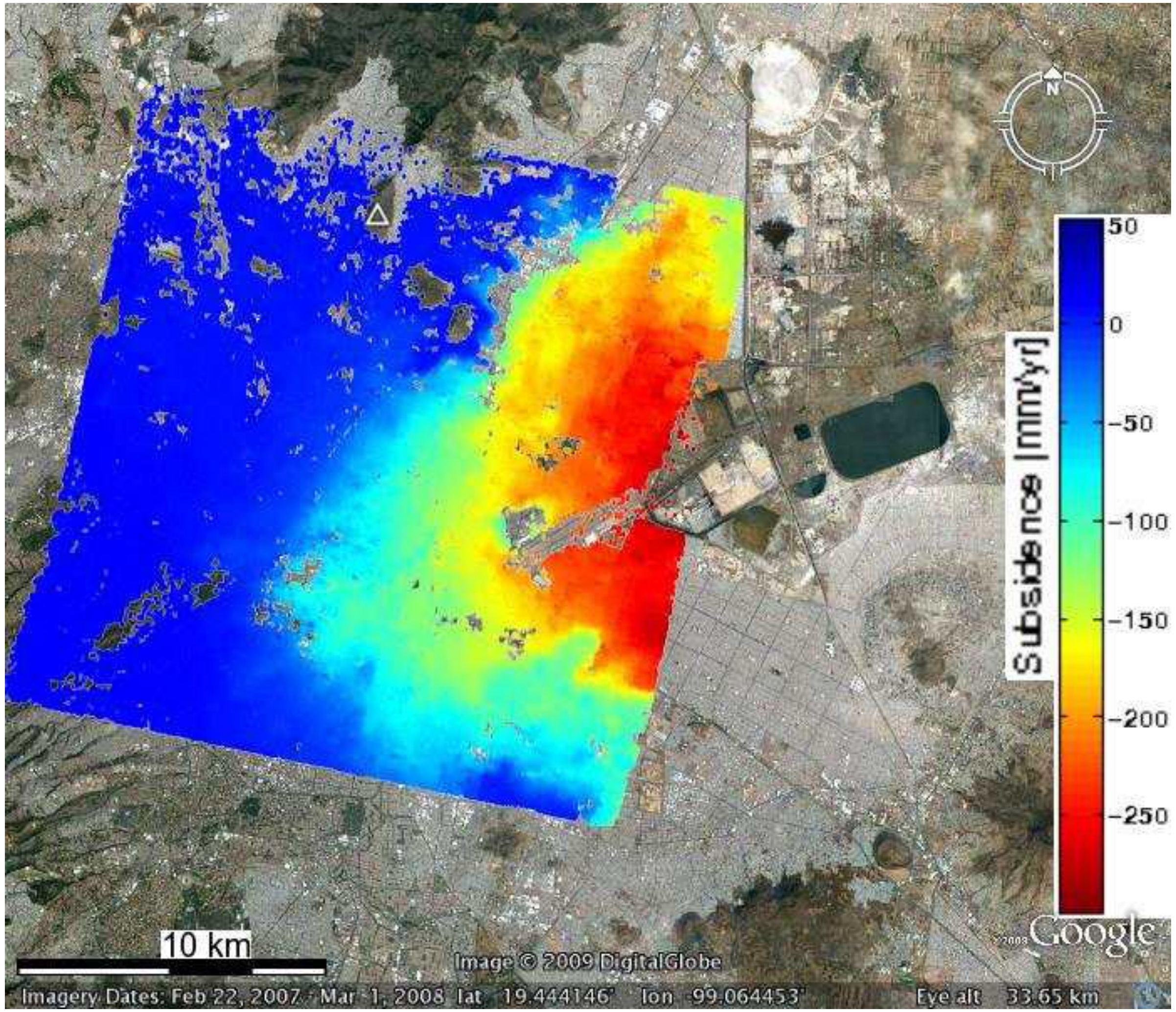
Medição da deformação da superfície

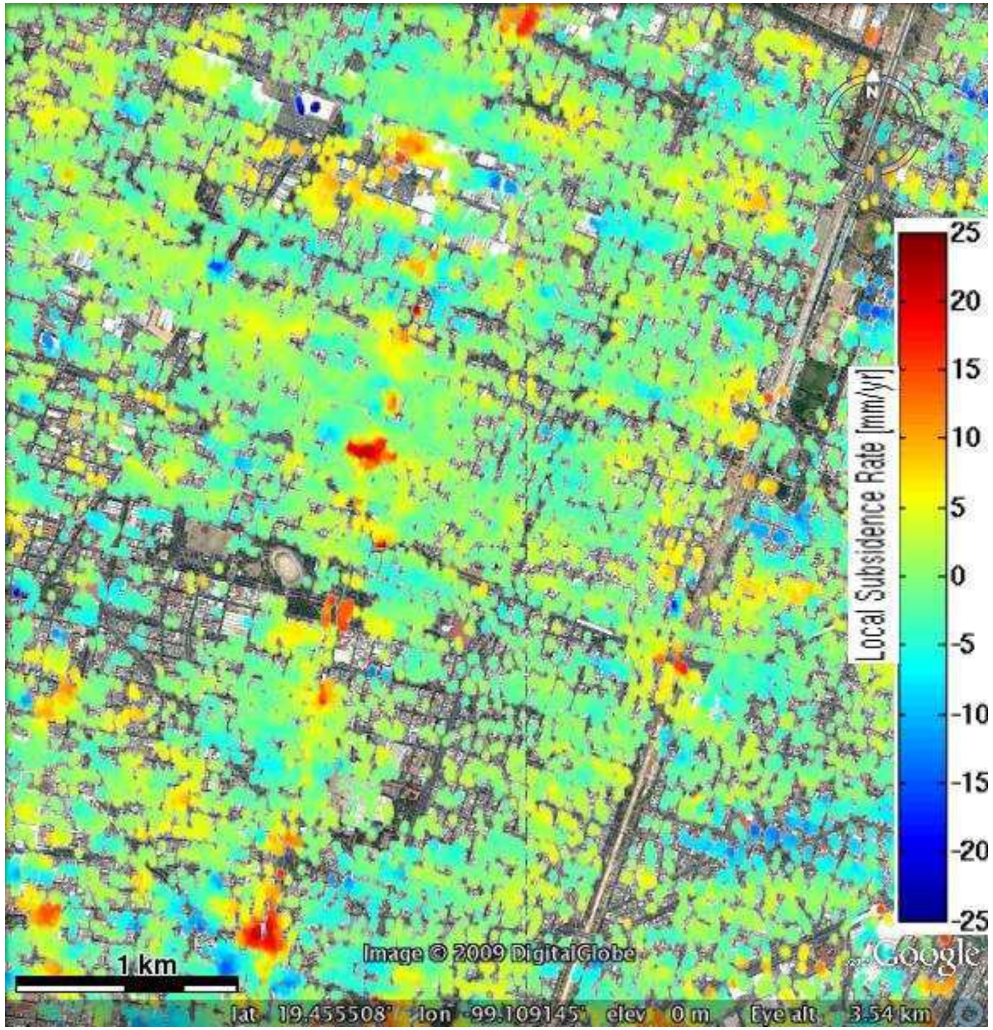
(InSAR)



Subsidência

(InSAR)





Cidade do México

Osmanoglu et al., 2011

Subsidence rates for the period 16 January 2004 to 14 July 2006 using Envisat ASAR

Topografia (Altitude)

(InSAR)