Deteção Remota Multiespetral

Sumário

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- Satélites Meteorológicos
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  - LANSAT, SPOT, IRS, IKONOS, QuickBird, GeoEye-1

Journey to Destination Earth begins

Destination Earth initiative: an ambitious project that involves creating a digital replica of Earth to help us move towards a sustainable future.

Journey to Destination Earth begins

30 abril 2023.

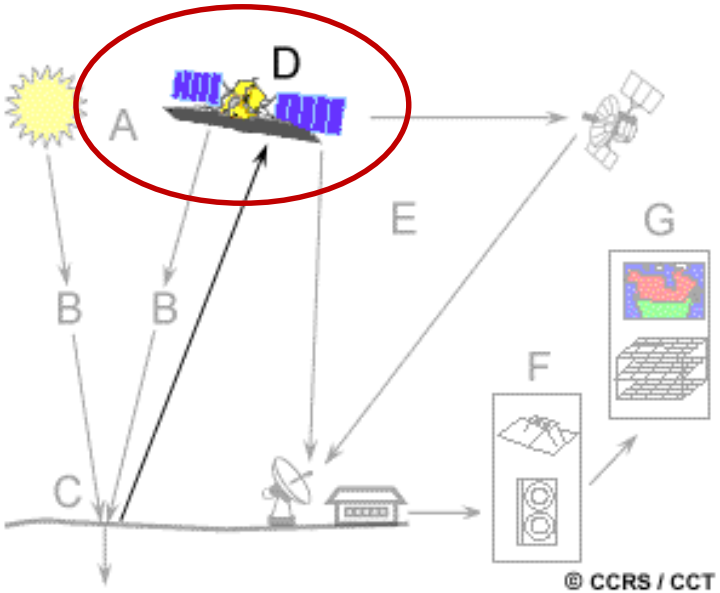
Today,
the European Commission, ESA,
the European Centre for Medium-Range Weather Forecasts (ECMWF) and
the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat)

celebrated the official launch of the **Destination Earth** initiative: an ambitious project that involves creating a digital replica of Earth to help us move towards a sustainable future.

Destination Earth (DestinE), led by the European Commission's DG Connect, aims to develop a highly accurate digital model of Earth that will monitor and predict environmental change and human impact. Using innovative Earth system models, cutting-edge computing, satellite data and machine learning, DestinE will allow its users to explore the effects of climate change on the different components of the Earth system, together with possible adaptation and mitigation strategies.

https://youtu.be/FKVHZlGqEyw

Missões de Observação da Terra



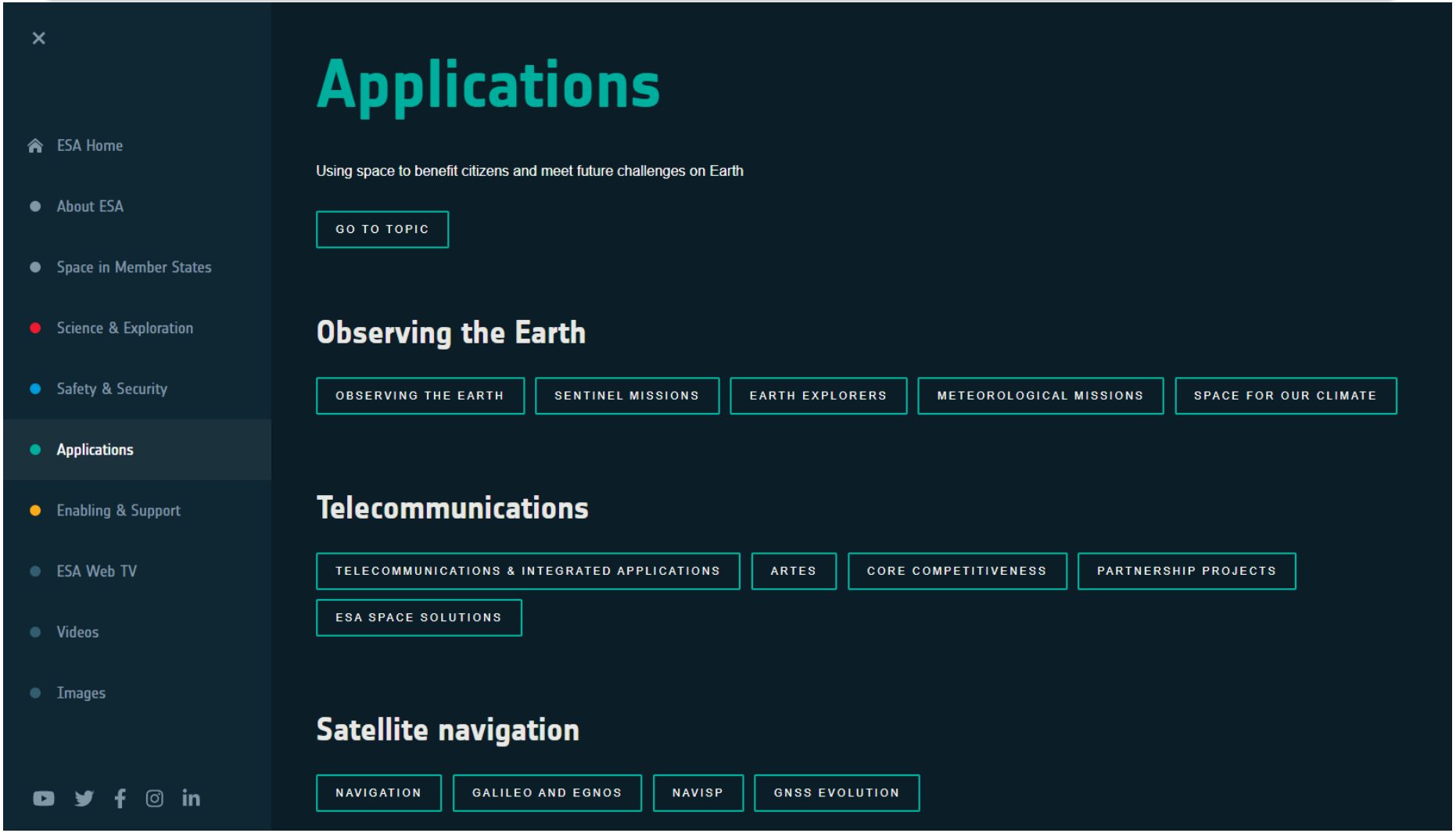
Meteorológicas

Altimetria de Satélite

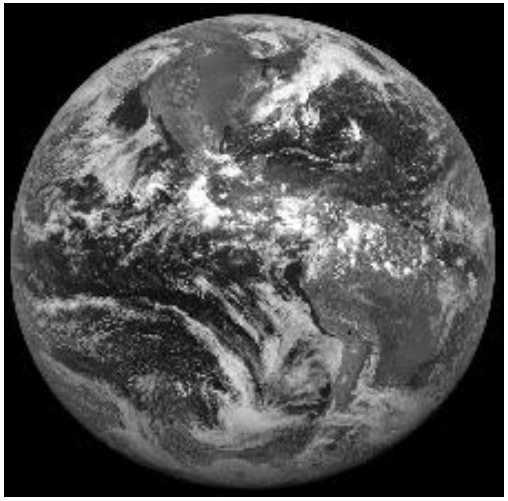
Geopotenciais

Observação da Terra

https://www.esa.int/



Satélites / Sensores Meteorológicos



A monitorização e previsão do tempo foi uma das primeiras aplicações civis da detecção remota com satélites.

TIROS-1 : 1960, EUA.
(Television and Infrared Observation Satellite-1)

ATS-1, 1966, NASA. Satélite geoestacionário que fornecia imagens hemisféricas da superfície da Terra e cobertura de nuvens a cada meia hora.

A resolução temporal dos satélites meteorológicos é bastante elevada e a sua resolução espacial bastante grosseira (comparada com os satélites de Observação da Terra)

GOES (Geostationary Operational Environmental Satellite)

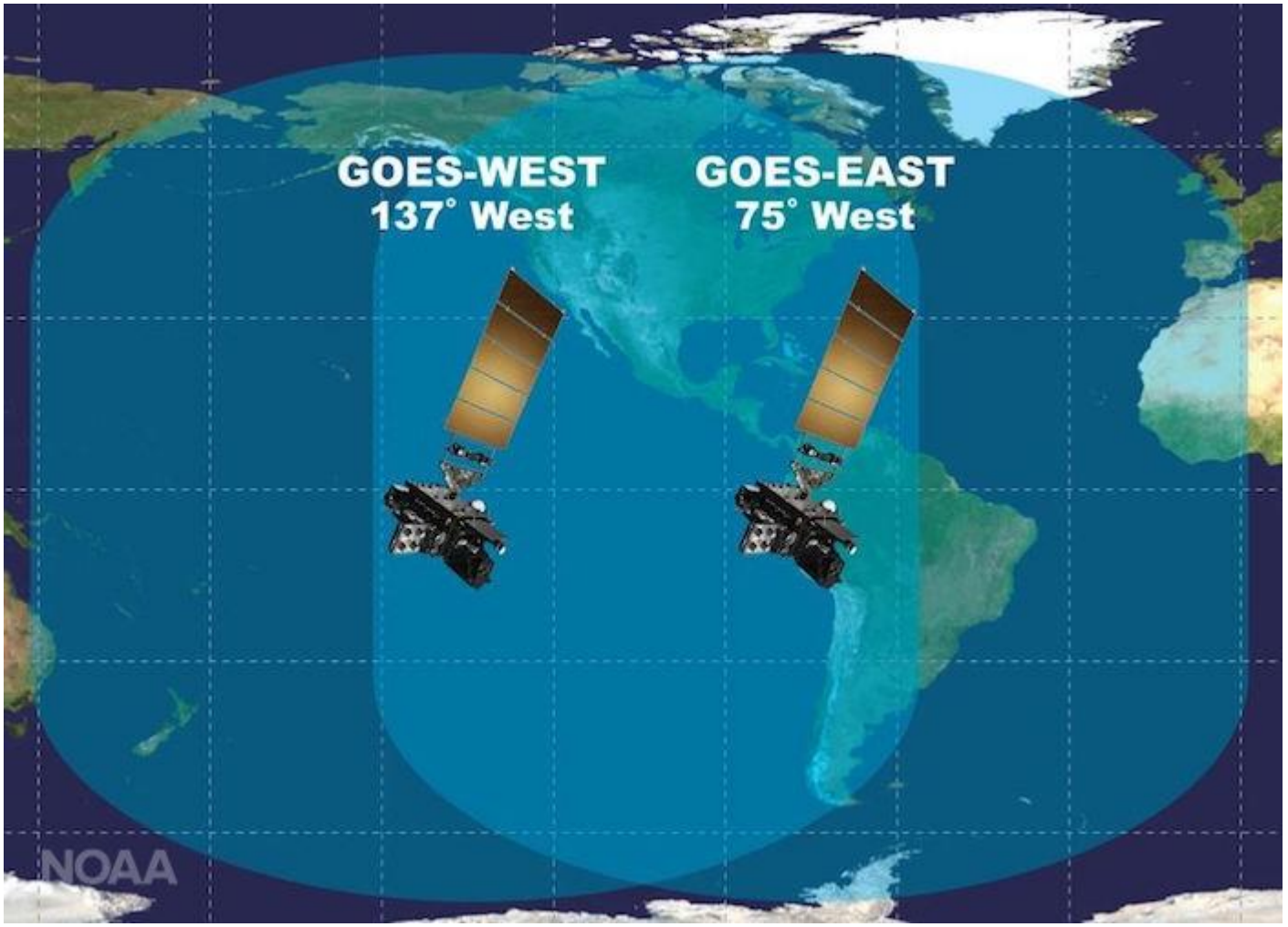
Imagem de um furacão EUA, Setembro de 1996

O sistema GOES é o seguidor da série ATS.

Fornece imagens frequentes de pequena escala da superfície da Terra e da cobertura de nuvens.

Estes satélites fazem parte de uma rede de satélites separados 70º em longitude que fornecem uma cobertura permanente da América.

GOES - Weather Satellites



GOES

Os dois satélites GOES colocados em órbitas geoestacionárias a 36000 km sobre o equador cobrem um terço da Terra.

Um está situado a 75º W e monitoriza o norte e sul da América e parte do Oceano Atlântico. O outro está situado a 135º W e monitoriza o norte da América e o Oceano Pacifico. Em conjunto cobrem a área de 20ºW a 165 E.

Foram lançadas duas gerações dos satélites GOES ambas medindo a radiação emitida e reflectida a partir da qual se pode determinar:

- a temperatura da atmosfera,
- ventos e
- cobertura de nuvens.

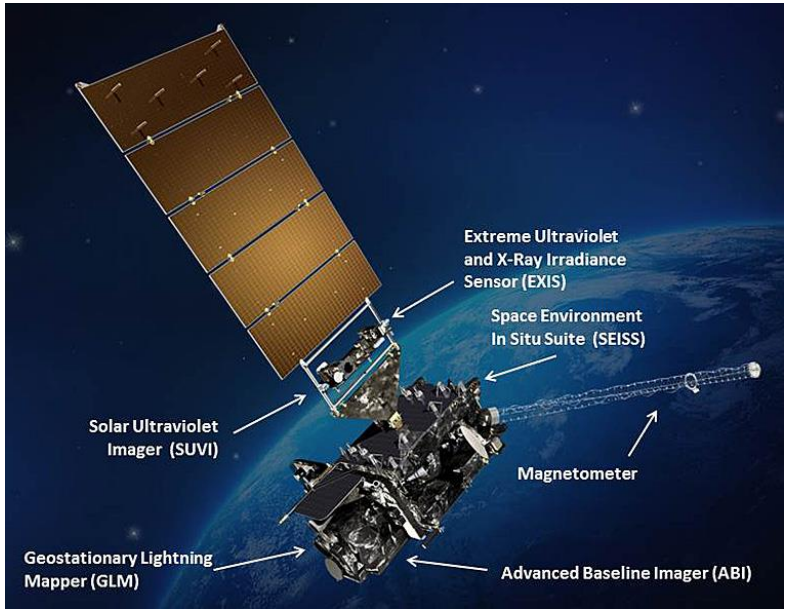
GOES - Bandas

Band	Wavelength Range (>μm)	Spatial Resolution	Application
1	0.52 - 0.72 (visible)	1 km	cloud, pollution, and haze detection; severe storm identification
2	3.78 - 4.03 (shortwave IR)	4 km	identification of fog at night; discriminating water clouds and snow or ice clouds during daytime; detecting fires and volcanoes; night time determination of sea surface temperatures
3	6.47 - 7.02 (upper level water vapour)	4 km	estimating regions of mid-level moisture content and advection; tracking mid-level atmospheric motion
4	10.2 - 11.2 (longwave IR)	4 km	identifying cloud-drift winds, severe storms, and heavy rainfall
5	11.5 - 12.5 (IR window sensitive to water vapour)	4 km	identification of low-level moisture; determination of sea surface temperature; detection of airborne dust and volcanic ash

GOES-R (S/T/U)

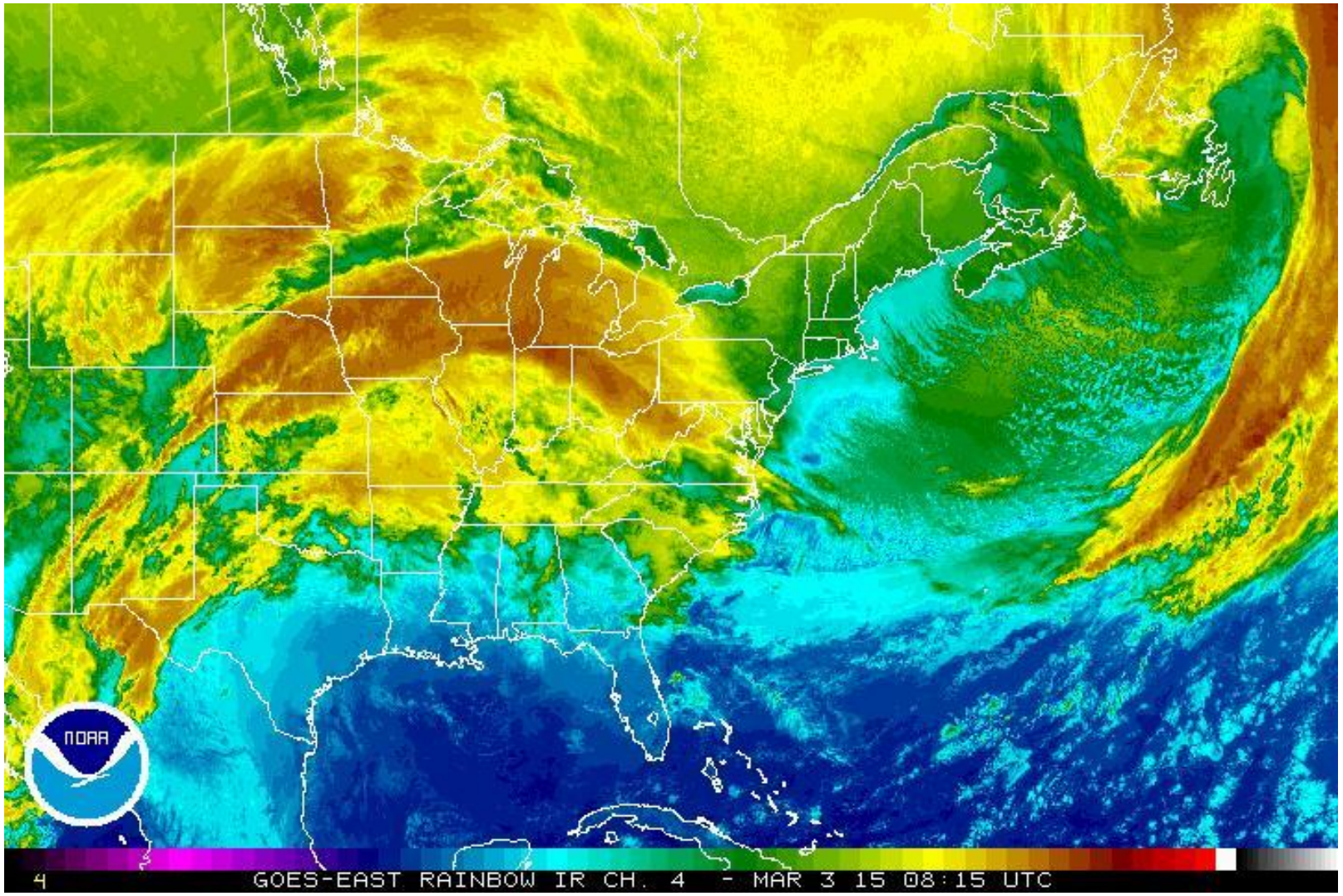
The **Advanced Baseline Imager (ABI)** is the primary instrument on the GOES–R Series spacecraft for imaging Earth's weather, oceans and environment.

ABI views Earth with **16 spectral bands** (compared to five on previous GOES), including two visible channels, four near-infrared channels, and ten infrared channels. It provides three times more spectral information, four times the spatial resolution (1km), and five times faster coverage than previous GOES.



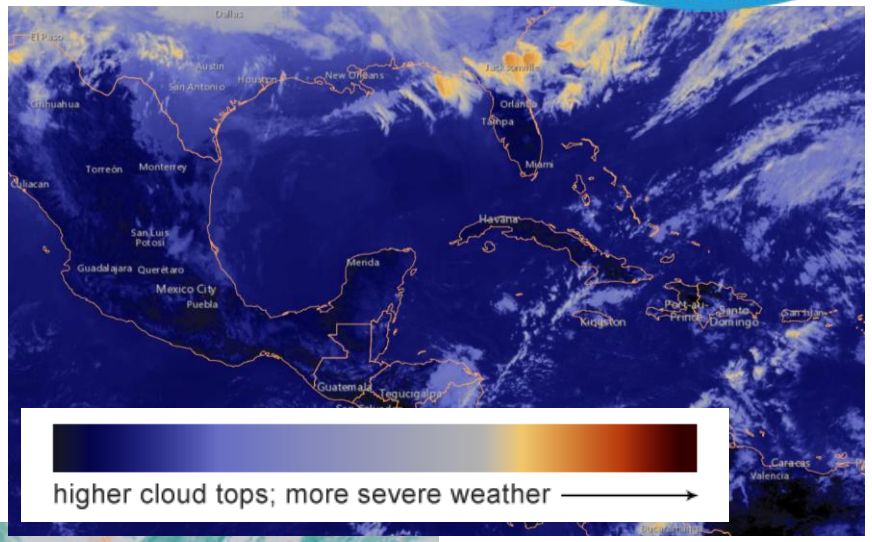
Ciências ULisboa

GOES

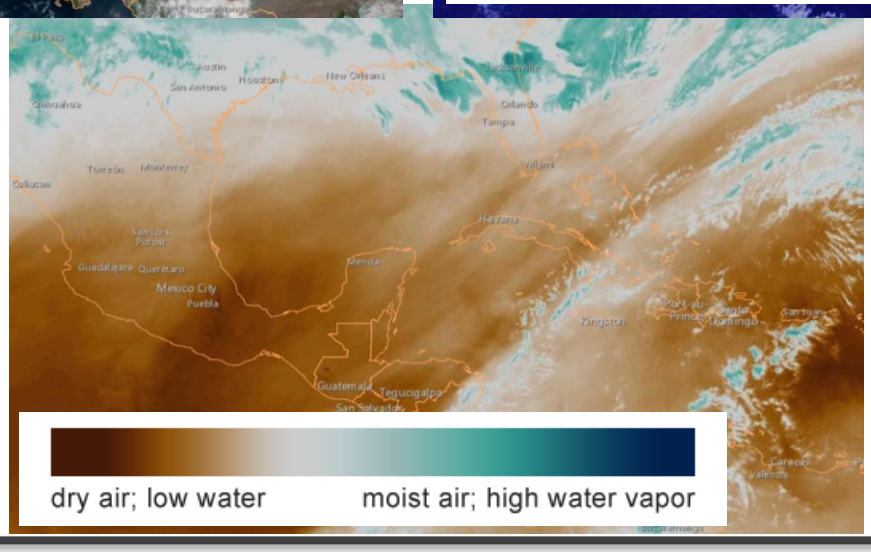


Weather Satellites

Geocolor Map



Infrared Map



Water vapor Map

NOAA (National Oceanic and Atmospheric Administration)

A **NOAA** é responsável por outra série de satélites usados em aplicações meteorológicas, os NOAA-1..-15.

Estes satélites têm órbitas heliosincronas, quase polares a cerca de 830-870 km sobre a superfície e são a continuação da série TIROS e fornecem informação complementar ao sistema GOES.

Dois satélites cada um com cobertura global garantem que qualquer região da Terra é observada no máximo cada 6 horas. Um satélite cruza o equador no final da manhã de norte para sul e o outro cruza o equador no final da tarde.

O sensor a bordo deste satélite é o:

AVHRR (Advanced Very High Resolution Radiometer)

NOAA AVHRR

BANDAS

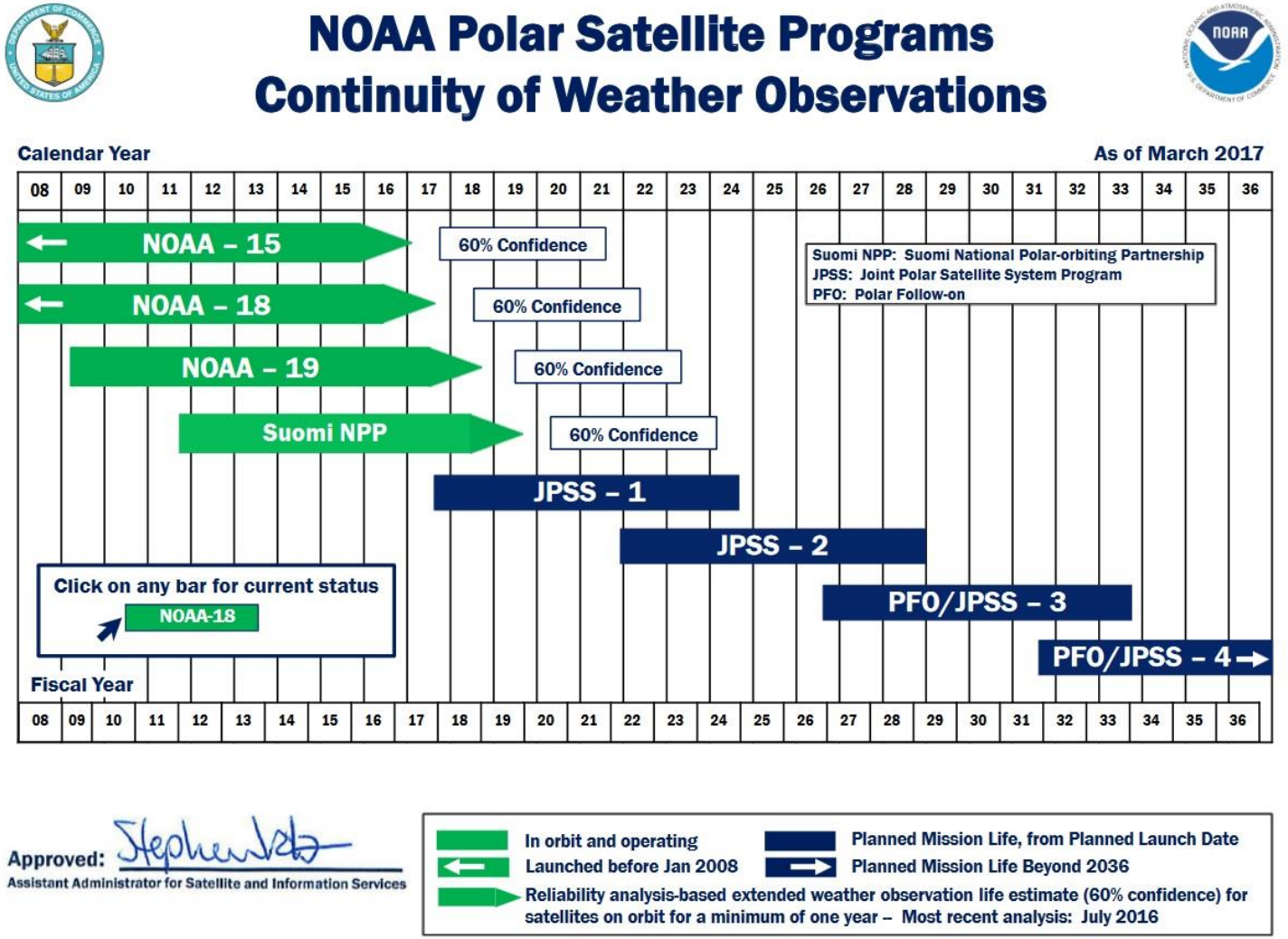
Table 3.1.2.1-1. Summary of AVHRR/3

Parameter	Ch. 1	Ch. 2	
Spectral Range (μm)	0.58-0.68	.725-1.0	
Detector type	Silicon	Silicon	
Resolution (km)	1.09	1.09	
IFOV (see Note 1) (milliradian)	1.3 sq.	1.3 sq.	
S/N @ 0.5% albedo	≥9:1	≥9:1	
NEdT @ 300K	-	-	
MTF @ 1.09 km	>.30	>.30	
Temperature Range (K)	-	-	

Note:
1. Tolerance on IFOV values are ±0.2 mr with a ±0.1 mr design goal.

GIFOV = 2* H * tan (IFOV/2)

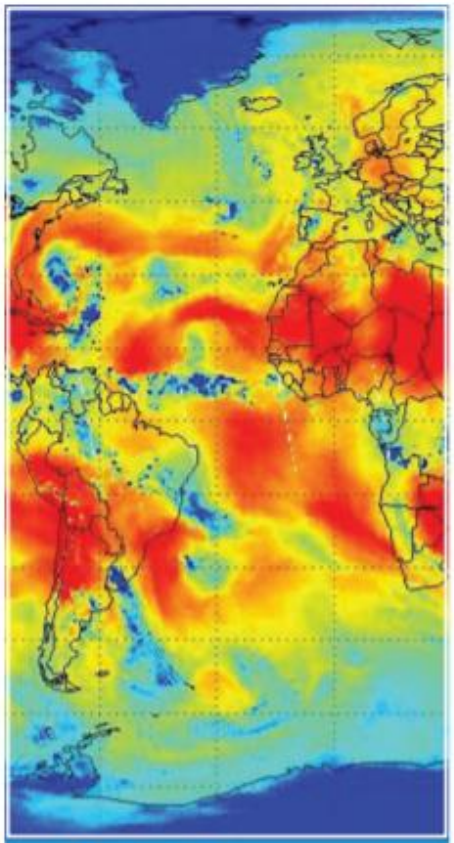
Weather Satellites



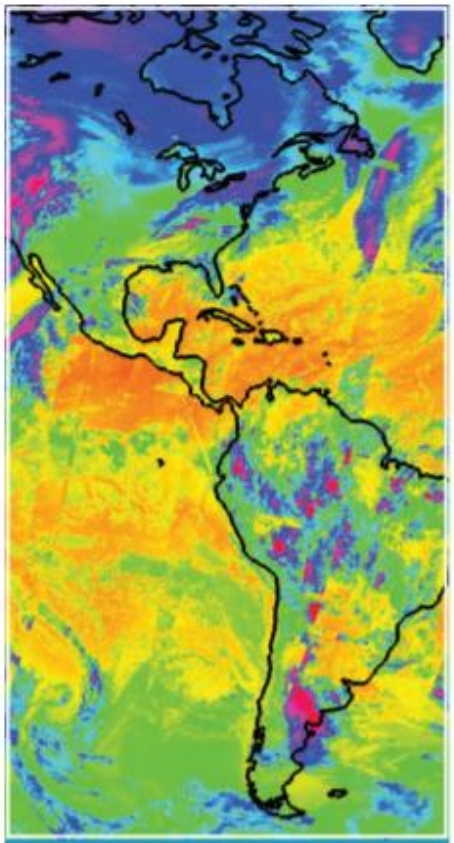
JPSS Sensors

Instrument	Spectral coverage	Resolution	Mission
ATMS Advanced Technology Microwave Sounder	22 bands from 23 GHz to 183 GHz	15.8-74.8 km	Provide sounding profiles of atmospheric temperature and moisture in conjunction with CrIS
CrIS Cross-Track Infrared Sounder	1305 bands from 3.92 μm to 15.38 μm	FOV 14 km 1km vertical layer	Produce high vertical resolution temperature and water vapor information needed to maintain and improve weather forecast skill out to 5 to 7 days in advance
VIIRS Visible Infrared Imaging Radiometer Suite	22 bands Coverage from 412 nm to 12 μm	400 m	Collects images and radiometric data used to provide information on the Earth's clouds, atmosphere, oceans and land surfaces
OMPS Ozone Mapping and Profiler Suite	Mapper 0.3-0.38 μm Profiler 0.25-0.31 μm	Mapper 50 km Profiler 250 km	Measures the concentration of ozone in the Earth's atmosphere and tracks the health of the ozone layer

Weather Satellites

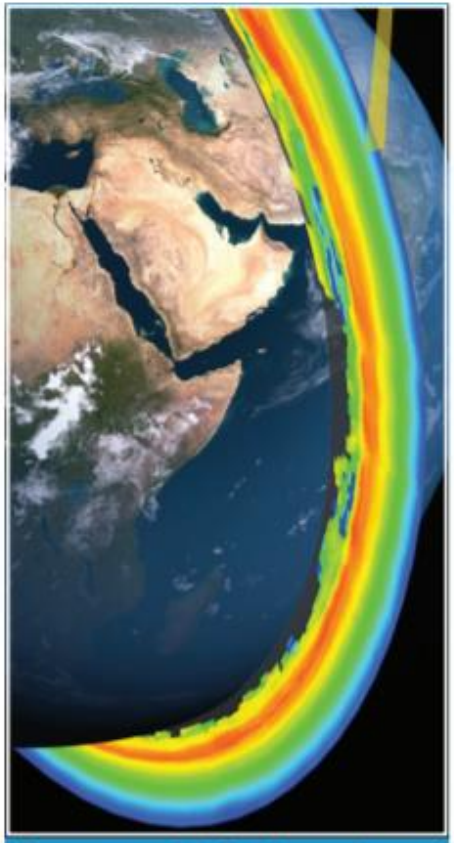


ATMS channel 18-microwave antenna temperature at 183.3 GHz. 11/08/2011



Composite of three days of CrIS data Jan 21, 23, 25th, 2012 - Credit: NOAA/NASA

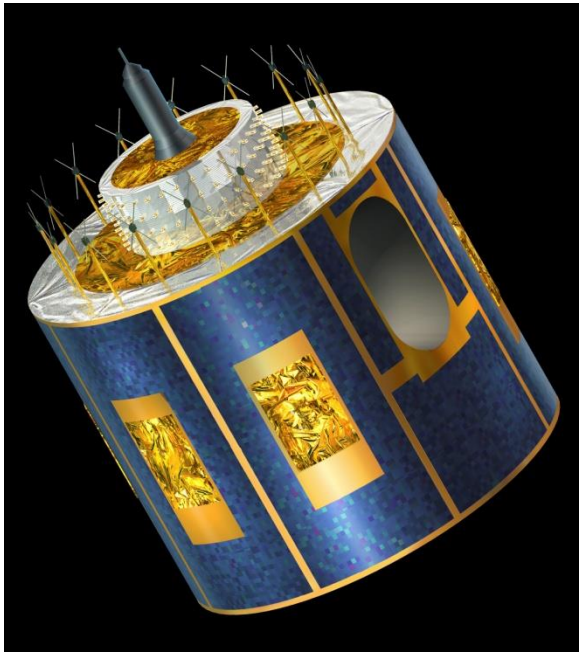
Tropical Cyclone Chapala as seen by Suomi NPP's VIIRS instrument on 11/1/2015 Credit: NOAA/NASA



Cross-section of the Earth's ozone layer as measured by the OMPS - Credit: NOAA/NASA

Meteosat Second Generation (MSG)

O MSG é um projecto conjunto entre a ESA e o EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) consiste numa série de 4 satélites meteorológicos geoestacionários que está operacional desde 2021.



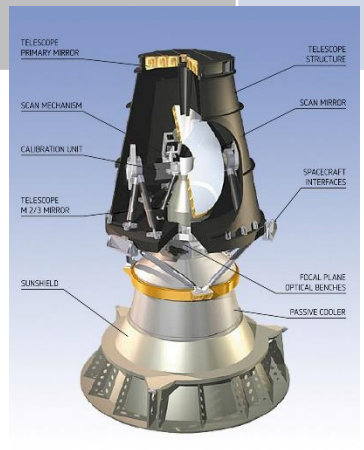
Estes satélites têm dois instrumentos:

SERIVI (Spinning Enhanced Visible and InfraRed Imager) com 12 canais espectrais. Tem como objectivo a previsão meteorológica.

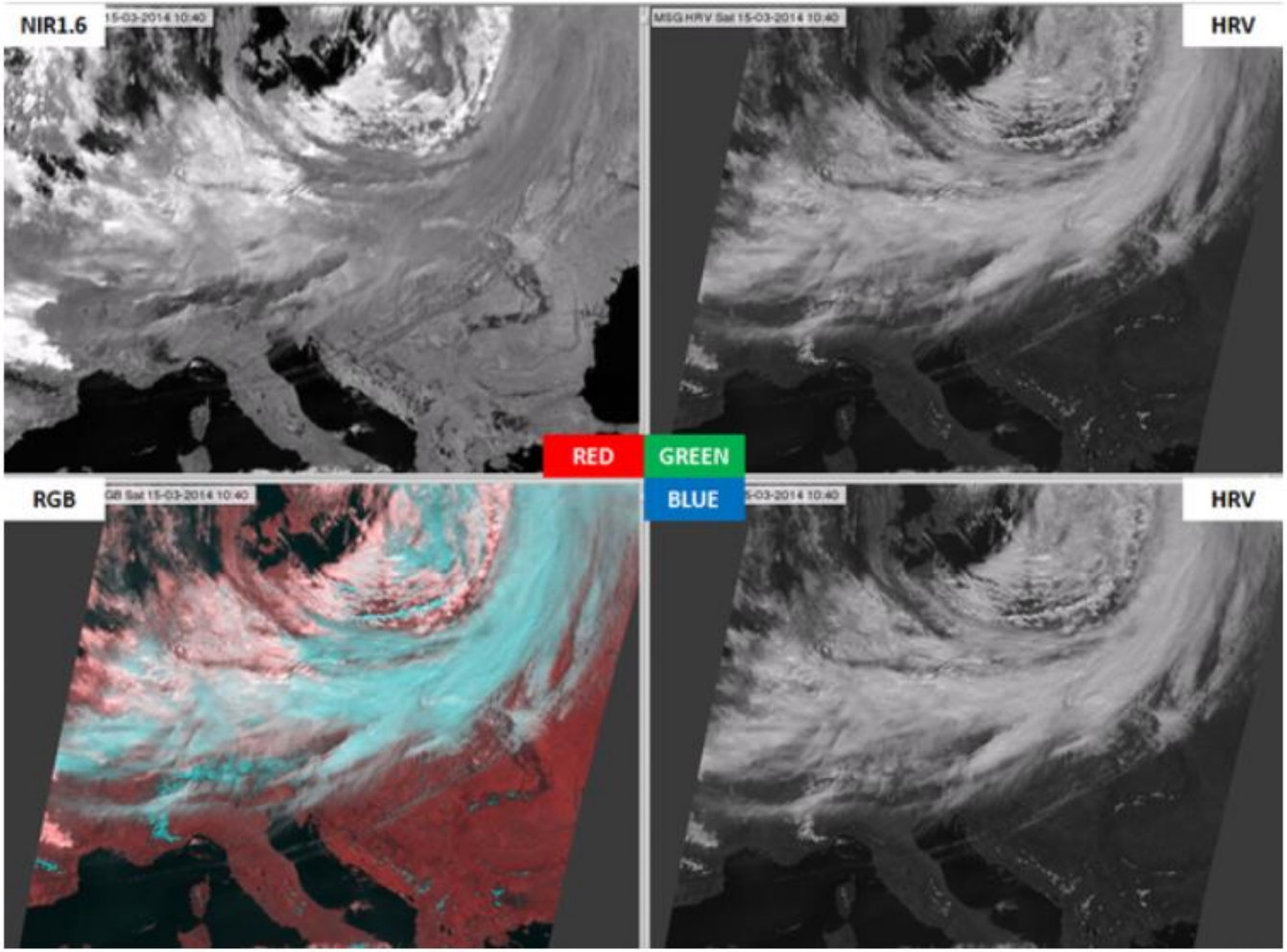
GERB (Geostationary Earth Radiation Budget) que suporta estudos climáticos

Weather Satellites

Instrument	Spectral coverage	Resolution	Mission
SEVIRI Spinning Enhanced Visible and InfraRed Imager	8 bands in the thermal infrared from 3.9 to 13.4 μm	3 km	Provide permanent data about the temperatures of clouds, land and sea surfaces
	4 visible/NIR bands from 0.4 to 1.6 μm	1 km for the high resolution visible band 3 km for the NIR and the 3 other visible bands	NIR allows to discriminate clouds from snow and water clouds from ice clouds. In combination with the 2 visible bands VIS0.6 and VIS0.8, it improves the observation of aerosol, soil moisture and vegetation index.



Weather Satellites



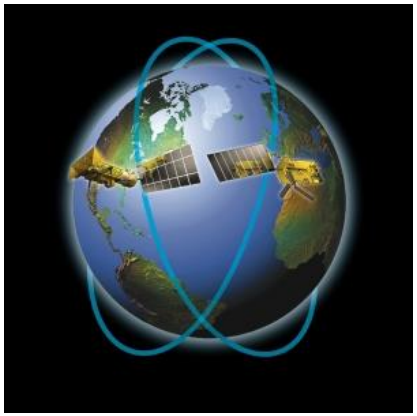
NIR1.6 (upper left), HRV (upper and bottom right) and HRV Fog RGB image (bottom left) for 15 March 2014

MetOp

MetOp é o primeiro satélite europeu de órbita polar dedicado à meteorologia.

MetOp é uma série de 3 satélites a ser lançado sequencialmente em 14 anos consistindo no segmento do espaço do EUMETSAT's Polar System (EPS).

O primeiro foi lançado em 2006 (A) e o segundo em 2012 (B) e o C foi lançado em 2018.



Sun-synchronous orbit, 09.30 mean local solar time
Inclination, 98.7 degrees to the Equator
Time for one orbit, 101 minutes
Repeat cycle, 29 days
Mean altitude Approximately 817 km

MetOp

Instrument	
IASI Infrared Atmospheric Sounding Interferometer	Infrared Michelson Interferometer for temperature sounding, water vapour, and ozone monitoring. IASI covers the spectral range from 3.62-15.5 μm, 2112 km swath width and a resolution of 12 km at nadir.
AMSU-A Advanced Microwave Sounding Unit A1 and A2	Microwave sounder for temperature sounding under clear and overcast conditions, 15 channels in the 23 to 90 GHz frequency range.
MHS Microwave Humidity Sounder	MHS is a self-calibrating, cross-track scanning, five-channel microwave, full-power radiometer operating in the 89 to 190 GHz range to provide information on atmospheric water vapour.
HIRS High Resolution Infrared Radiation sounder/4	Atmospheric Sounder for temperature and humidity profiles, surface temperature, cloud parameters and total ozone, 19 infrared channels (3.8-15μm), one visible channel.

MetOp

Instrument	
GOME-2 Global Ozone Monitoring Experiment-2	Nadir viewing UV and visible spectrometer to measure radiation back-scattered from the atmosphere and reflected from the earth surface in the UV and visible range 240-790 nm with a spectral resolution of 0.2-0.4 nm
AVHRR Advanced Very High Resolution Radiometer/3	Visible/infrared imaging radiometer for global measurement of cloud cover, sea surface temperature, ice, snow and vegetation cover and characteristics, six channels.
ASCAT Advanced Scatterometer	Pulsed radar in C-band at 5.2555 GHz for global sea surface wind vector measurement. ASCAT has two 500 km wide swaths with spatial resolution <50 km.
GRAS Global Navigation Satellite System Receiver for Atmospheric Sounding	Radio occultation receiver for atmosphere sounding of temperature and humidity profiles.

MetOp

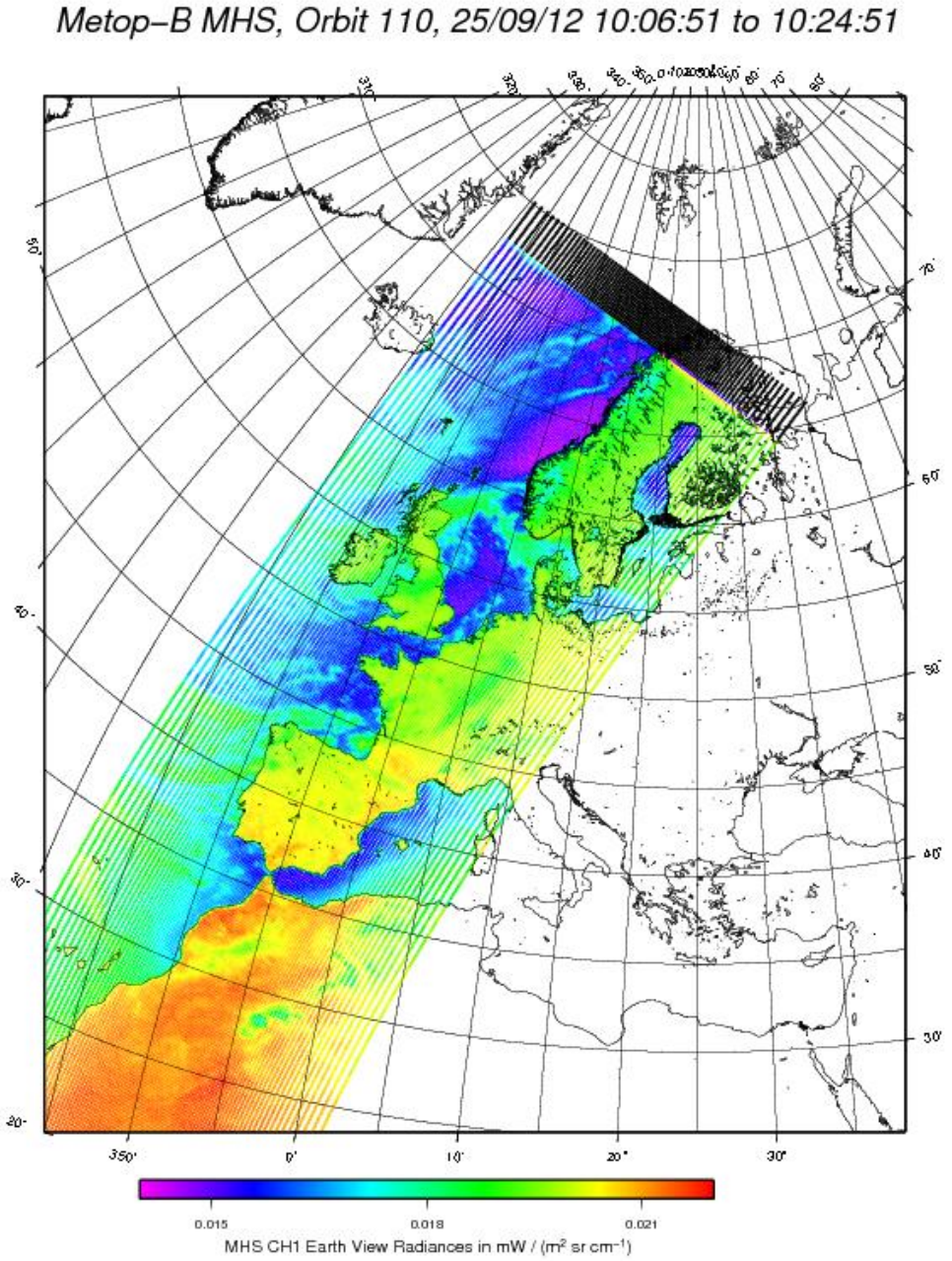
28 September 2012

Four of the instruments on the Metop-B weather satellite (AMSU-A, ASCAT, MHS, GRAS) have been activated this week and are delivering data.

The Microwave Humidity Sounder (MHS) delivers information on atmospheric humidity in all weather conditions.

Funciona em tandem com o Metop-A

2112 km swath width and a resolution of 12 km at nadir



Sentinel – 4 & Sentinel – 5

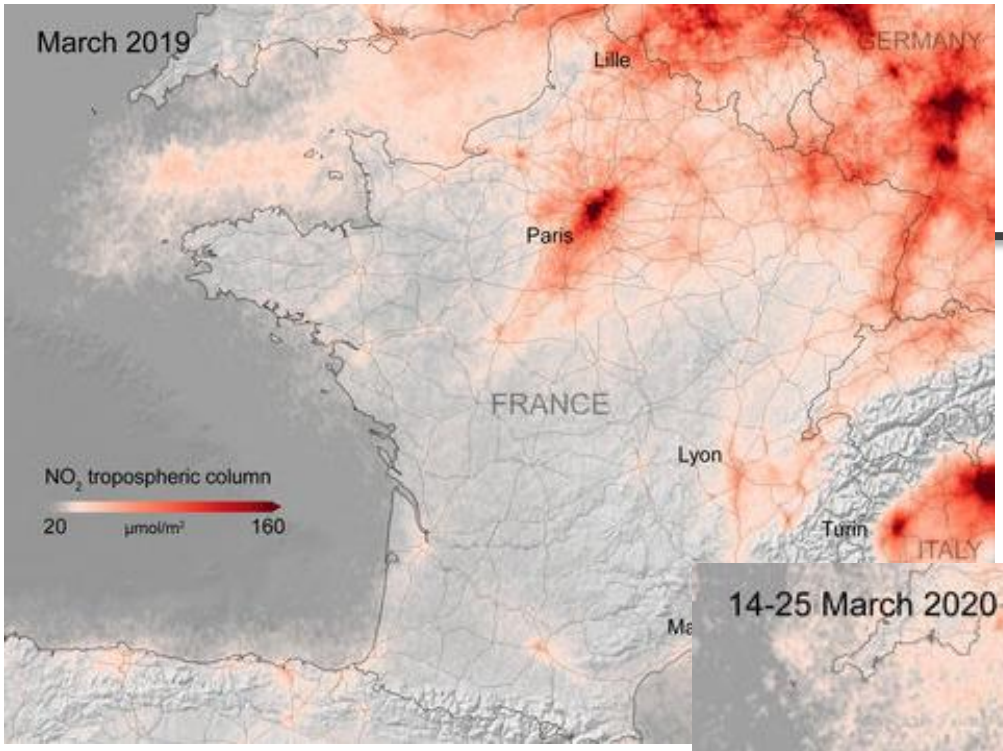
The instrument will be carried on the MetOp-SG A satellite.

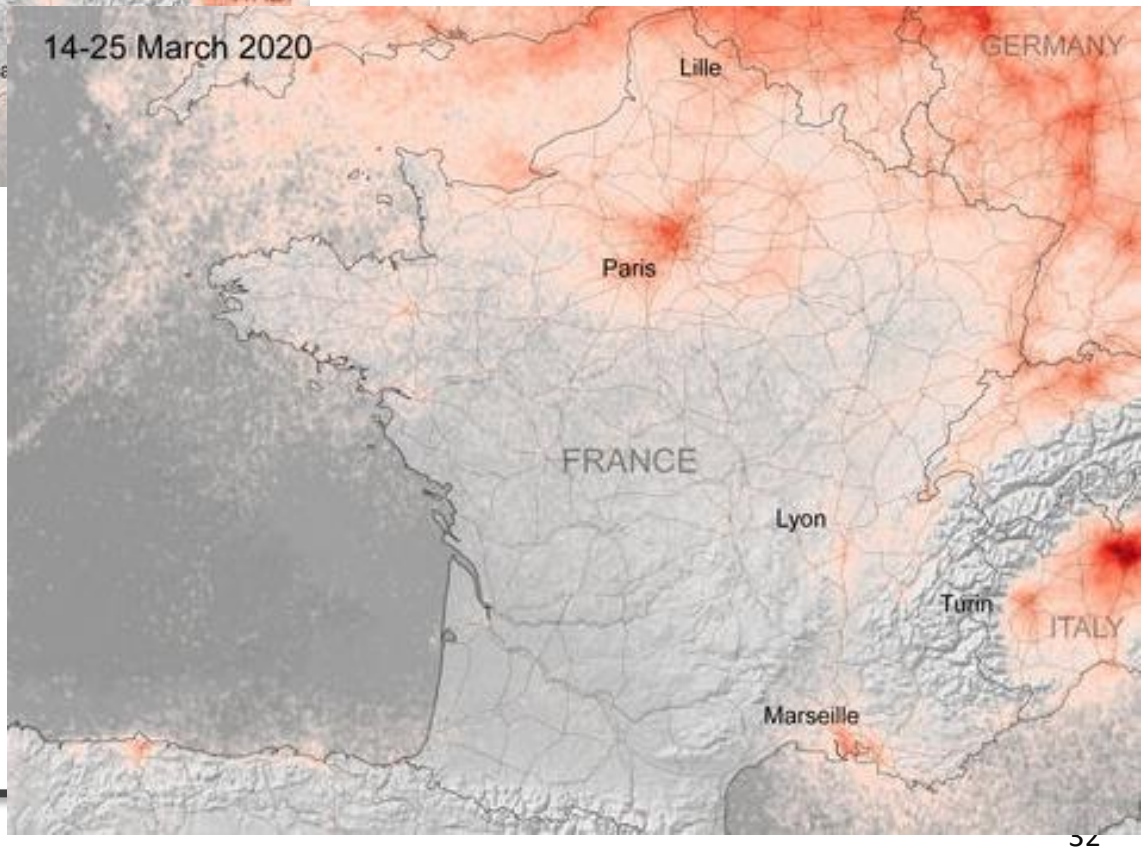
The missions SENTINEL-4, -5 and -5 precursor (S4, S5, S5P, respectively) are conceived as complementary elements of a constellation serving the specific needs of the Copernicus Atmospheric Monitoring Services (CAMS).

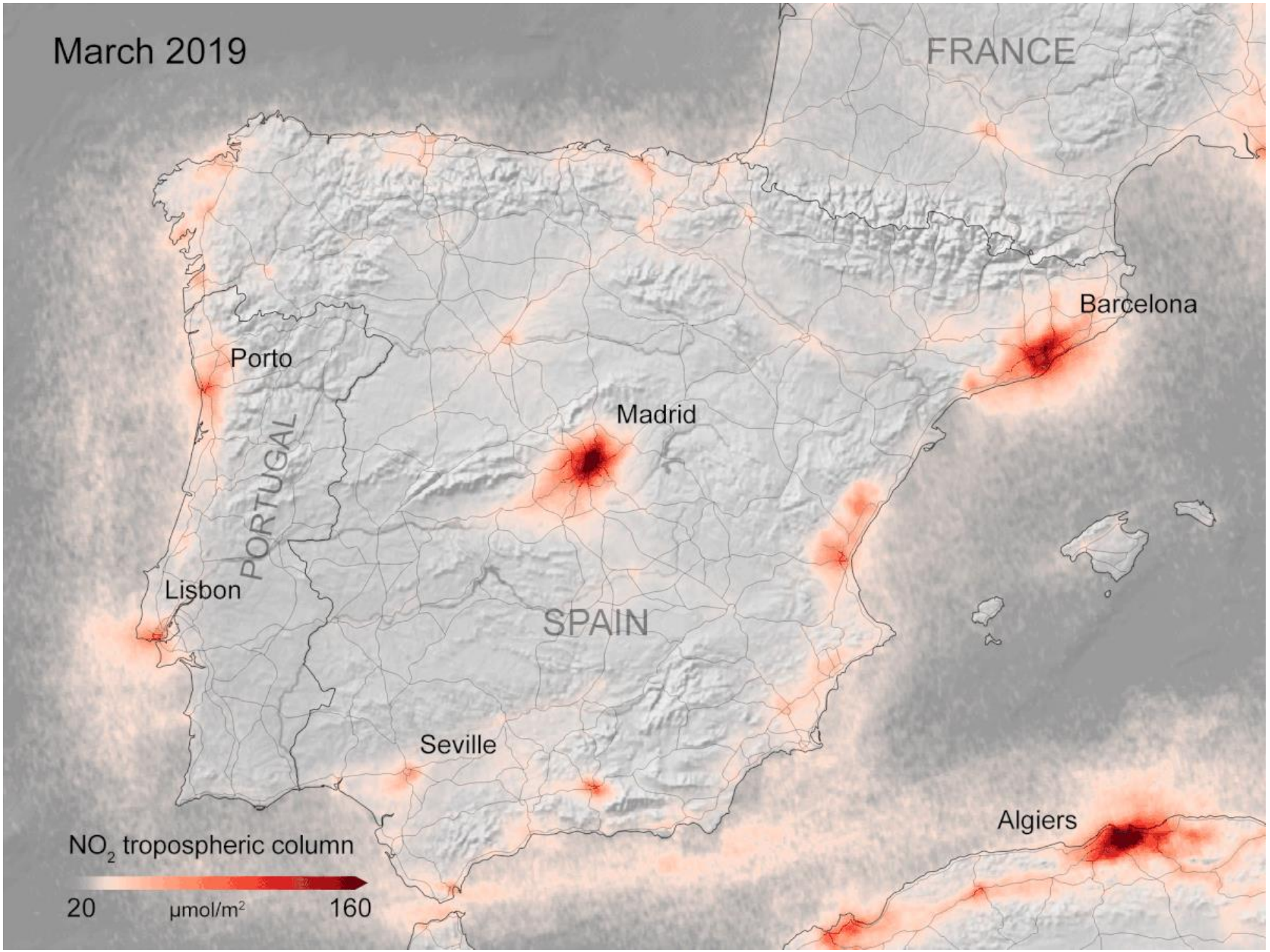
SENTINEL-5 is focused on air quality and composition-climate interaction with the main data products being O_3, NO_2, SO_2, HCHO, CHOCHO and aerosols.

Additionally SENTINEL-5 will also deliver quality parameters for CO, CH_4, and stratospheric O_3 with daily global coverage for climate, air quality, and ozone/surface UV applications.

The SENTINEL-5 mission consists of high resolution spectrometer system operating in the ultraviolet to shortwave infrared range with 7 different spectral bands: UV-1 (270-300nm), UV-2 (300-370nm), VIS (370-500nm), NIR-1 (685-710nm), NIR-2 (745-773nm), SWIR-1 (1590-1675nm) and SWIR-3 (2305-2385nm).


March 2019
Lille
GERMANY
Paris
FRANCE
Lyon
Turin
ITALY
NO_2 tropospheric column
20
µmol/m²
160


14-25 March 2020
Lille
GERMANY
Paris
FRANCE
Lyon
Turin
ITALY
Marseille


March 2019
FRANCE
Barcelona
Porto
Madrid
PORTUGAL
Lisbon
SPAIN
Seville
Algiers
NO2 tropospheric column
20
µmol/m2
160

LANDSAF (http.//landsaf.meteo.pt)

LSA SAF

LAND SURFACE ANALYSIS
SATELLITE APPLICATIONS FACILITY

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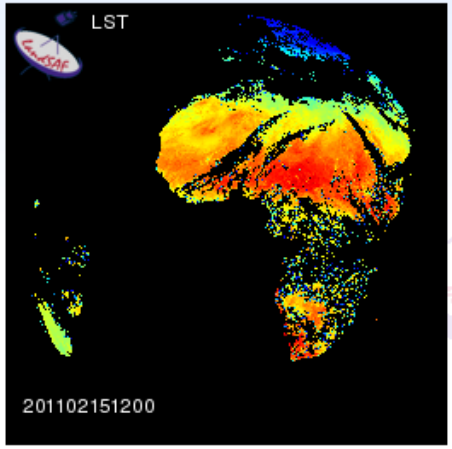
The scope of Land Surface Analysis Satellite Applications Facility (LSA SAF) is to increase benefit from EUMETSAT Satellite (MSG and EPS) data related to:

- Land
- Land-Atmosphere interaction
- Biospheric Applications

The LSA SAF performs:

- R&D Programs.
- Operational Activities
  - Generation
  - Archiving
  - Dissemination



See colour legends...

of land surface related products.

Latest News:

Product Development Status:

MSG/SEVIRI based products

Wild Fires
- Fire Radiative Power - PIXEL
- Fire Radiative Power - GRID

Vegetation Parameters
- Fraction of Vegetation Cover
- Leaf Area Index
- Fraction of Absorbed Photosynthetic Active Radiation

Snow Cover
- Snow Cover (daily)
- Snow Cover (15 mins)

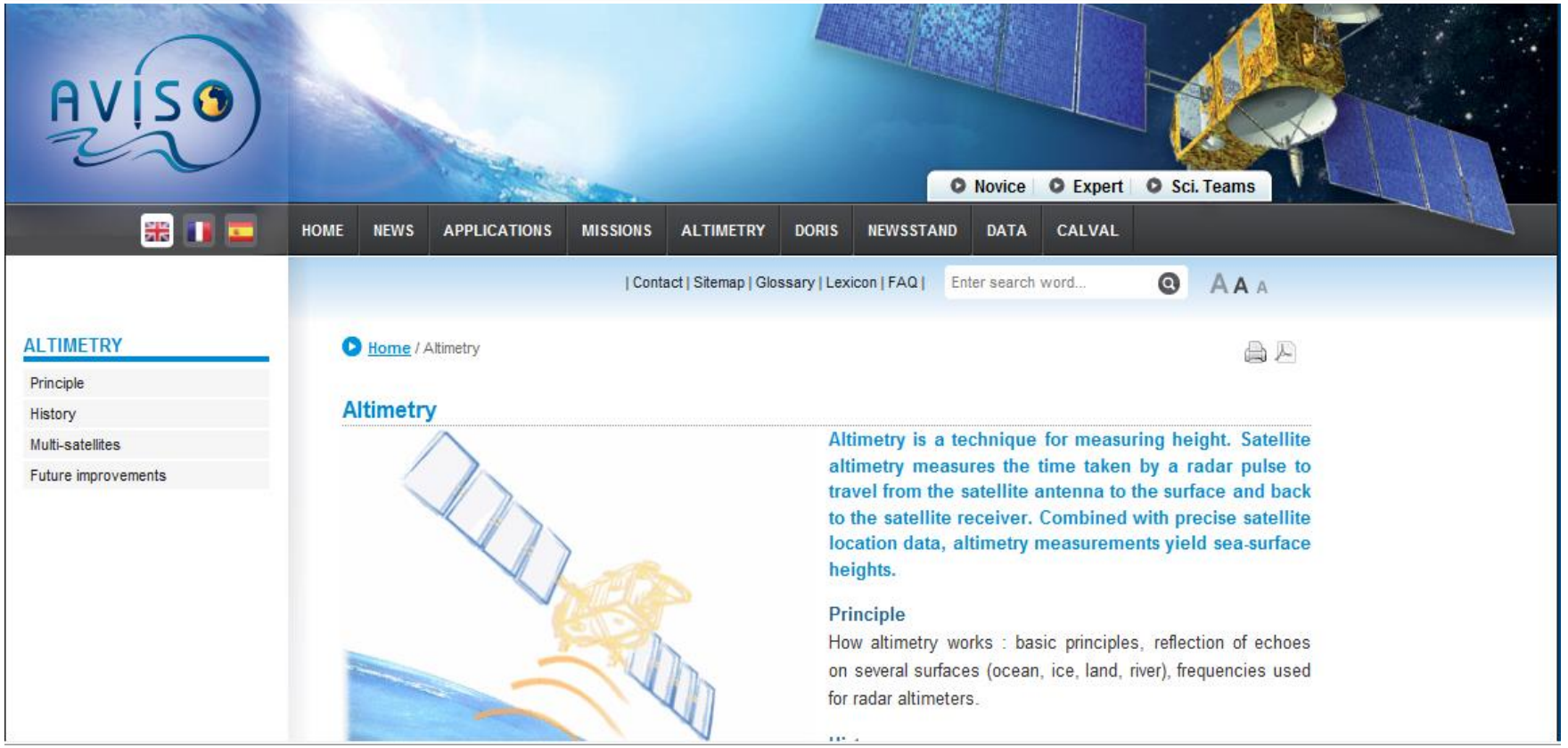
Other
- Bi-Directional Reflectance Factor
- Land Surface Emissivity

Albedo
- Surface Albedo
- MSG Ten Day Surface Albedo

Land Surface Temperature
- Land Surface Temperature (15 mins)

Altimetria Espacial / Satellite Altimetry

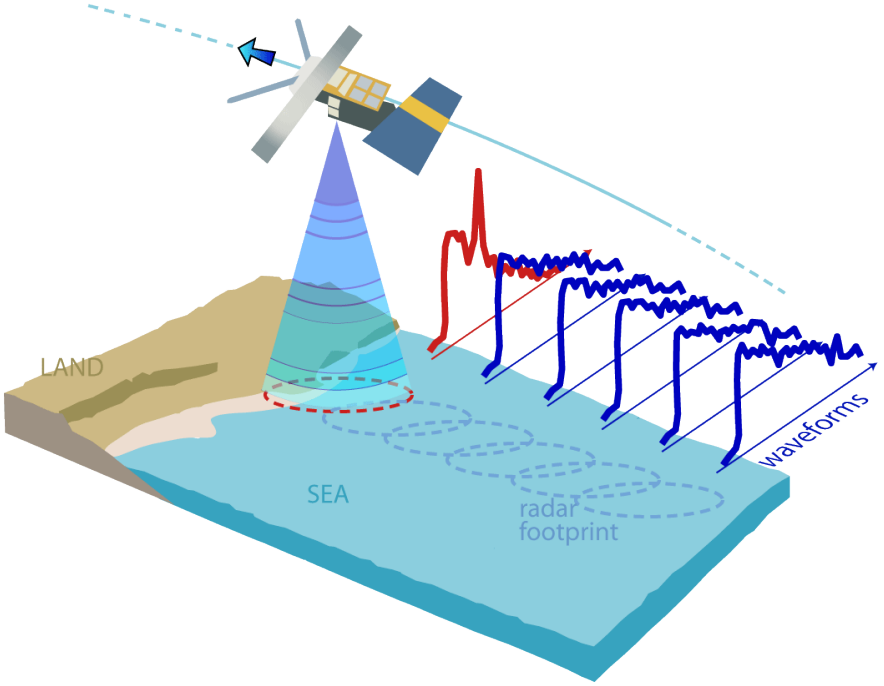
Altimetria Espacial é uma técnica de medir a altitude. É medido o tempo que leva um pulso radar a viajar do satélite à superfície e regressar ao satélite.



Satellite Altimetry

Altimetry is a technique for measuring height. **Satellite altimetry** measures the time taken by a radar pulse to travel from the satellite antenna to the surface and back to the satellite receiver. Combined with precise satellite location data, altimetry measurements yield **sea-surface heights**.

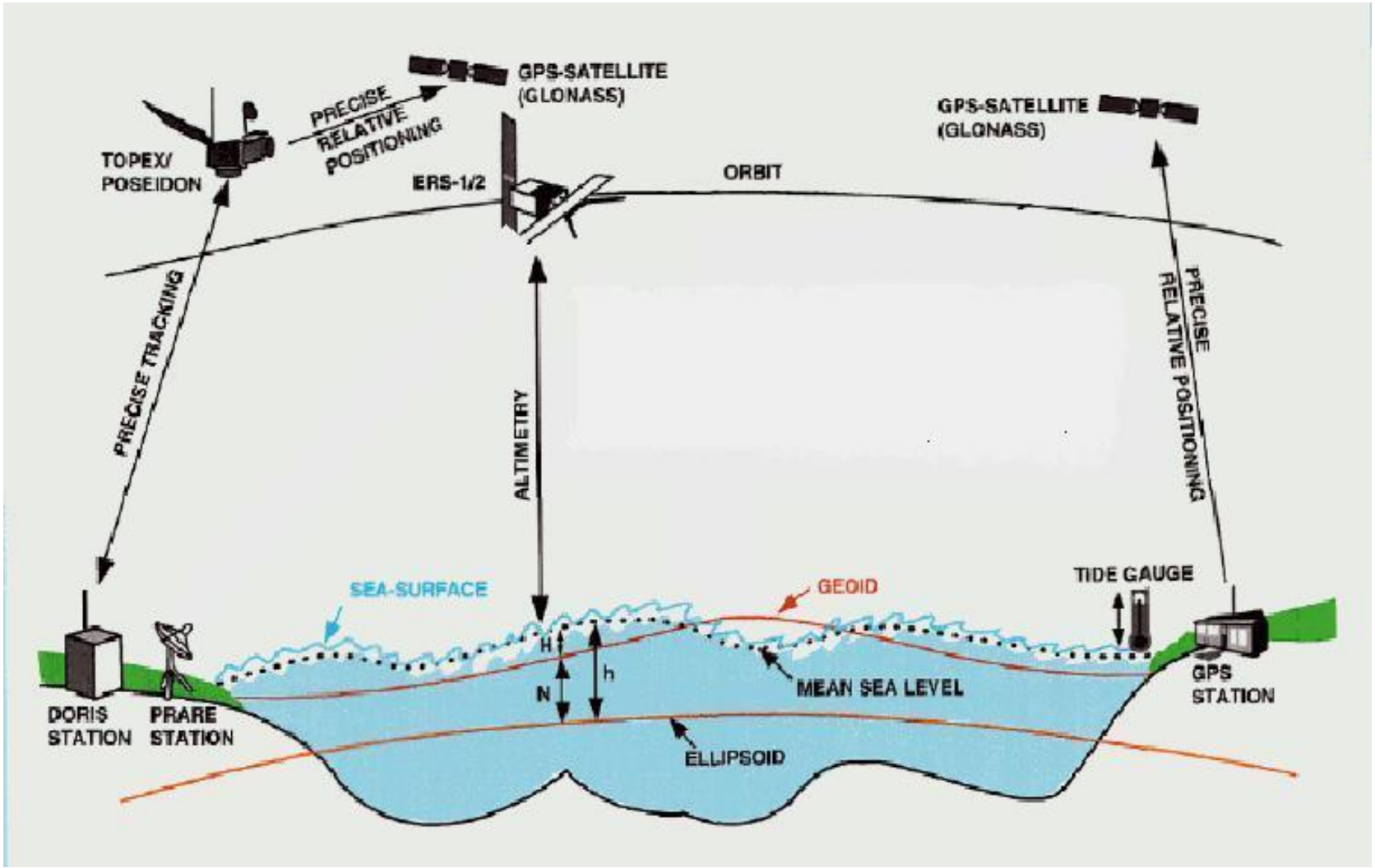
The magnitude and shape of the echoes (or waveforms) also contain information about the characteristics of the surface which caused the reflection. The best results are obtained over the **ocean**, which is spatially homogeneous.



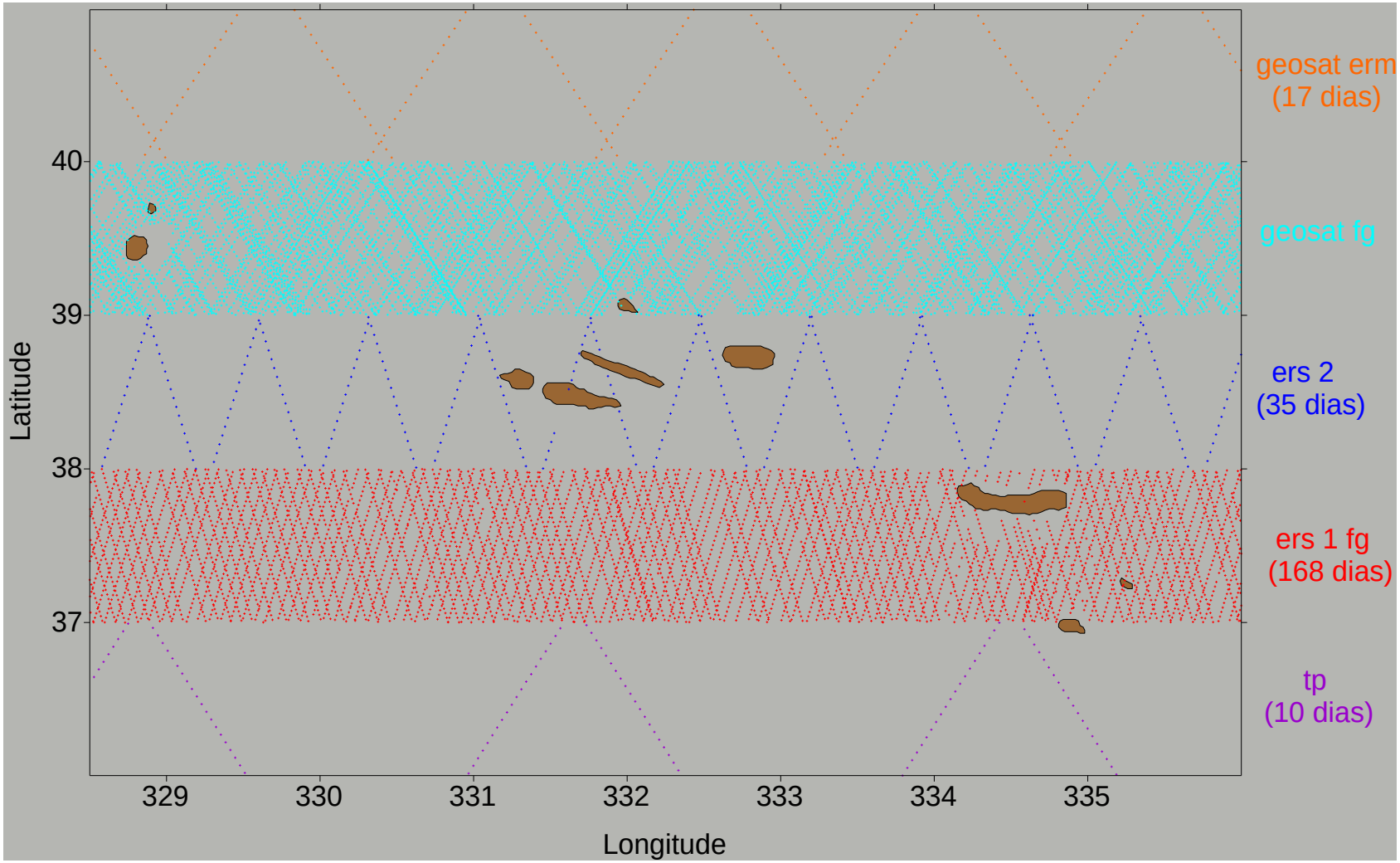
Altimetria Espacial

O resultado da Altimetria Espacial são as altitudes da superfície do mar, ou topografia do mar (Sea Surface Heights)

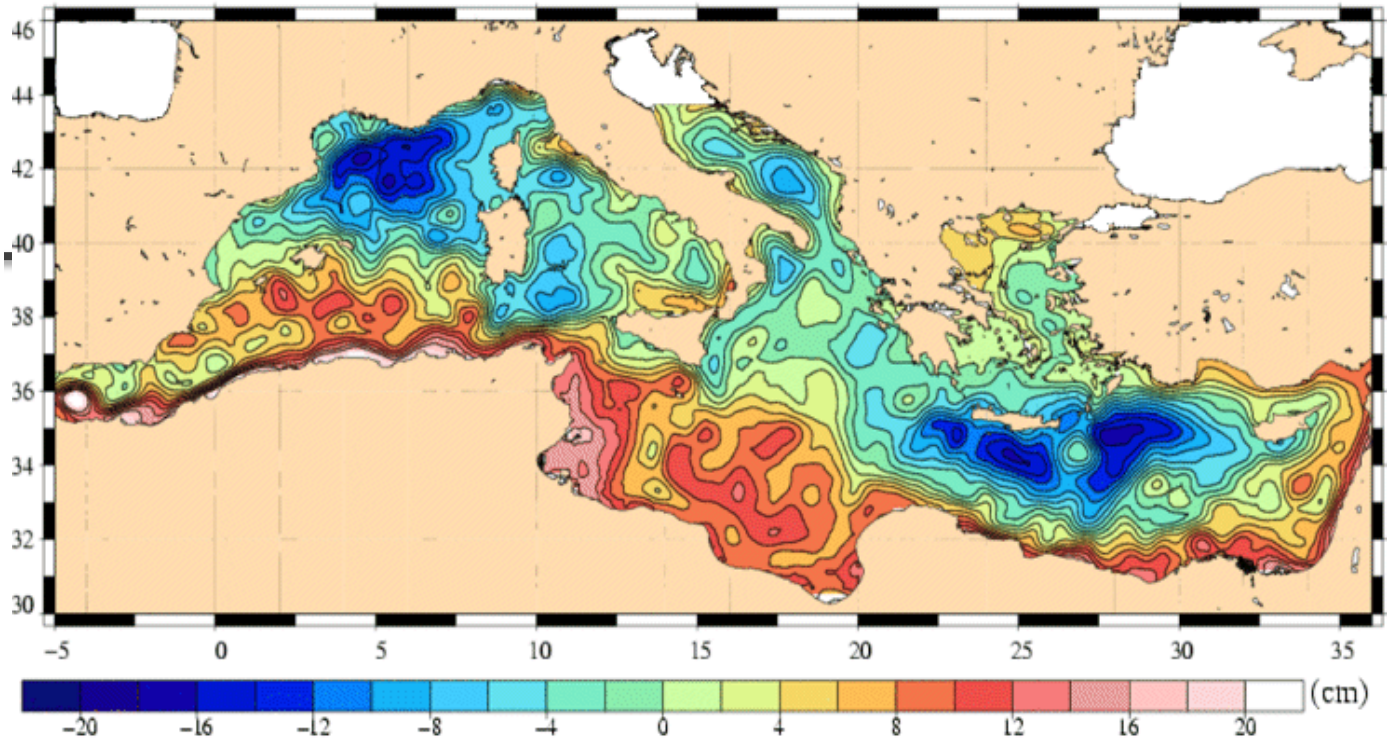
Altimetria Espacial

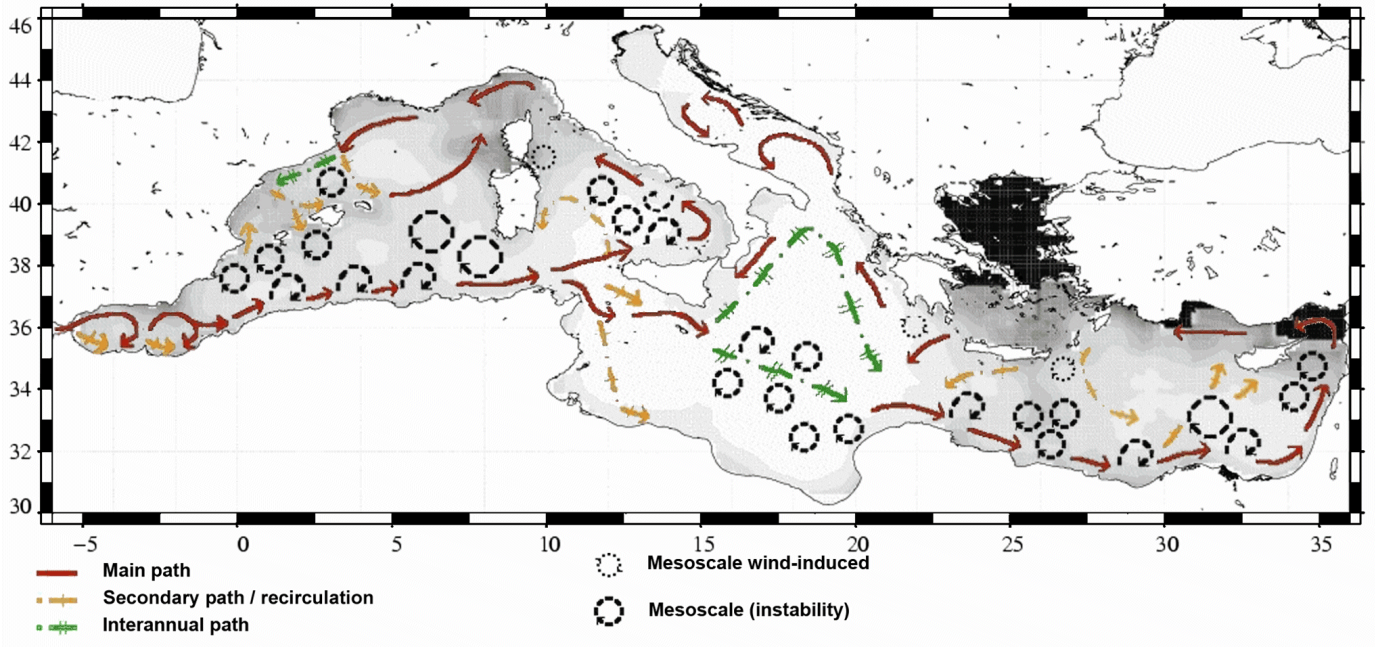


Altimetria Espacial



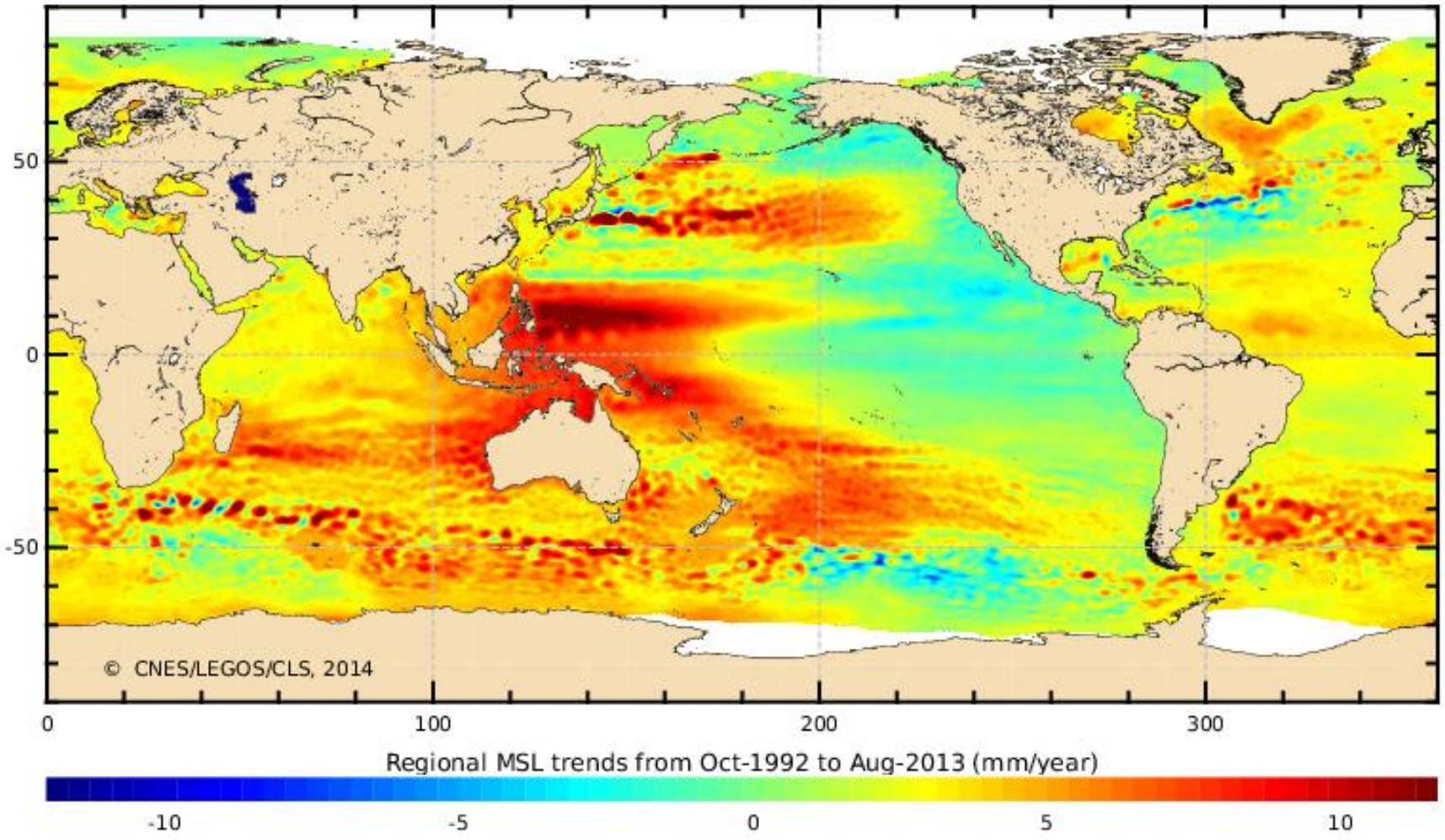
Topografia Dinâmica Média (1993-1999). Calculada a partir de dados altimétricos, dados Grace e gravimetria de satélite.



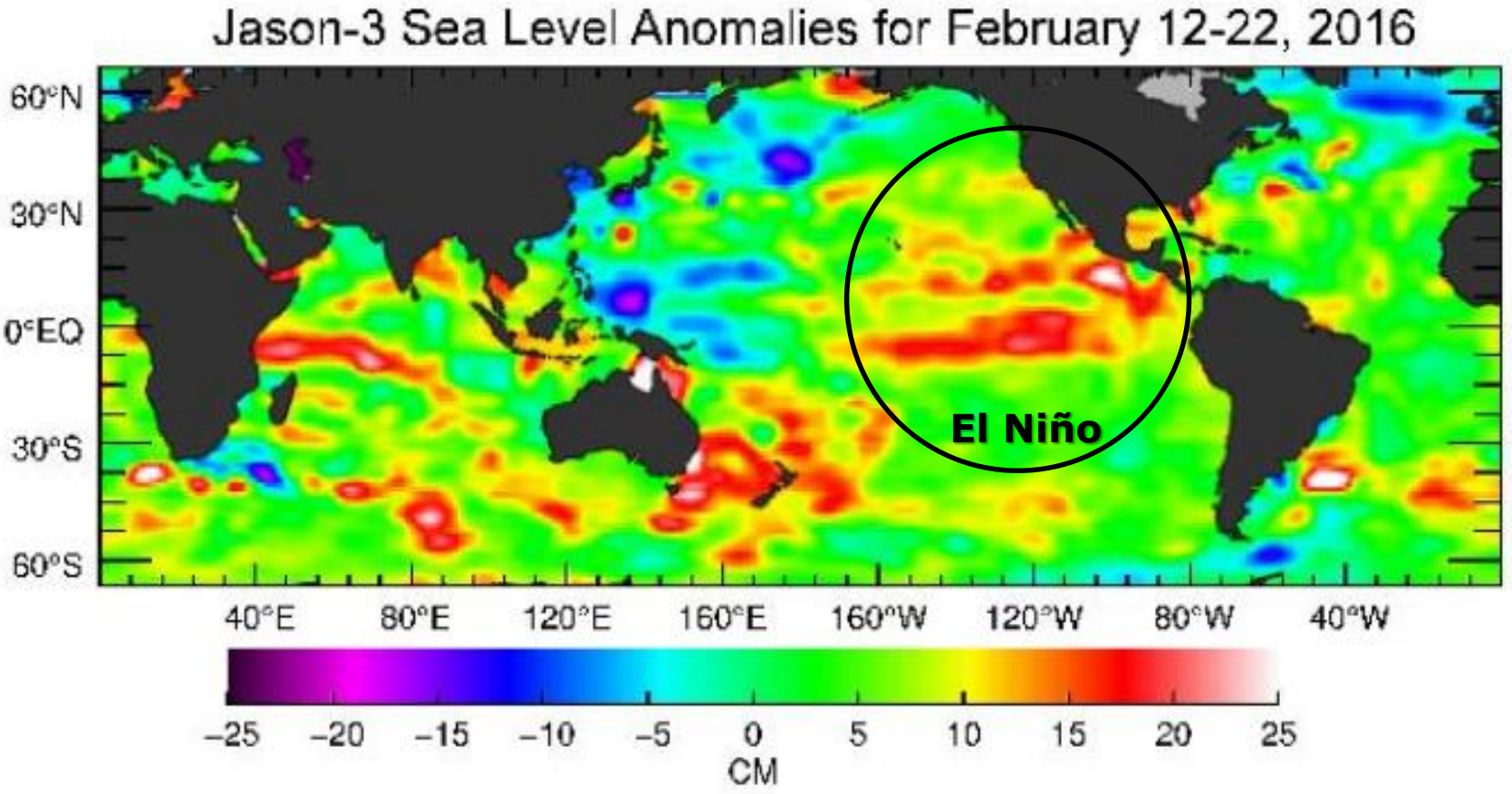


Circulação deduzida da topografia dinâmica e da altimetria de 1993-2004

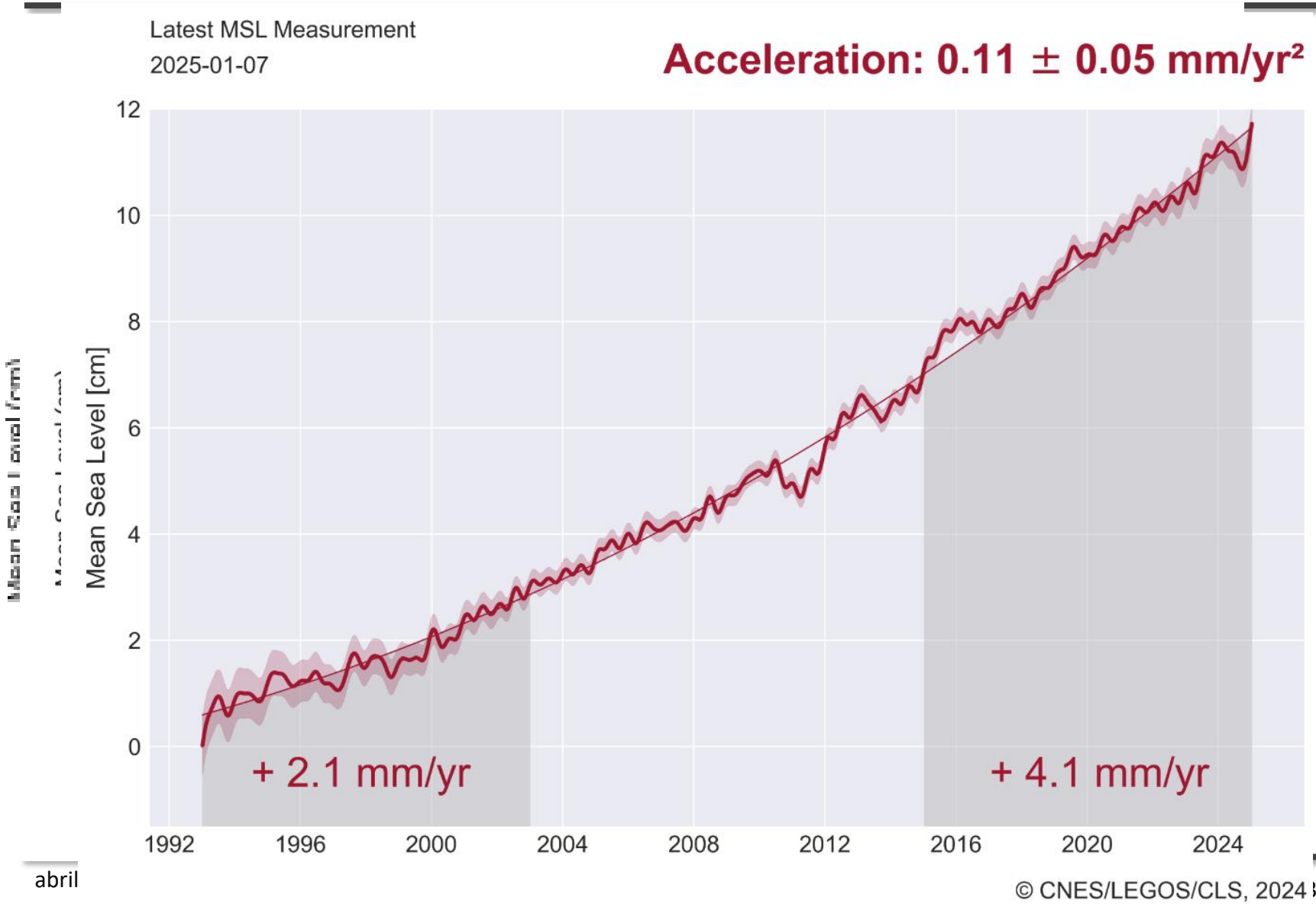
Altimetria Espacial



Satellite Altimetry



Altimetria Espacial



Satellite Altimetry

ESA Altimetry Missions

esa

European Space Agency

Satellite Altimetry

Sentinel-3 is primarily an **ocean mission**, however, the mission is also able to provide atmospheric and land applications. The **Sentinel-3** mission continues the monitoring of the sea state, wind speed, sea-ice and ice thickness as started by the ERS-1 (1991), ERS-2 (1995), Envisat (2002) and CryoSat (2010) missions.

The Sentinel-3 mission's main objective is to measure **sea-surface topography**, sea-and land-surface **temperature** and ocean- and **land-surface colour** with high-end accuracy and reliability in support of **ocean forecasting systems**, and for **environmental** and **climate monitoring**.

Sentinel -3

SENTINEL-3 is an European Earth Observation satellite mission developed to support

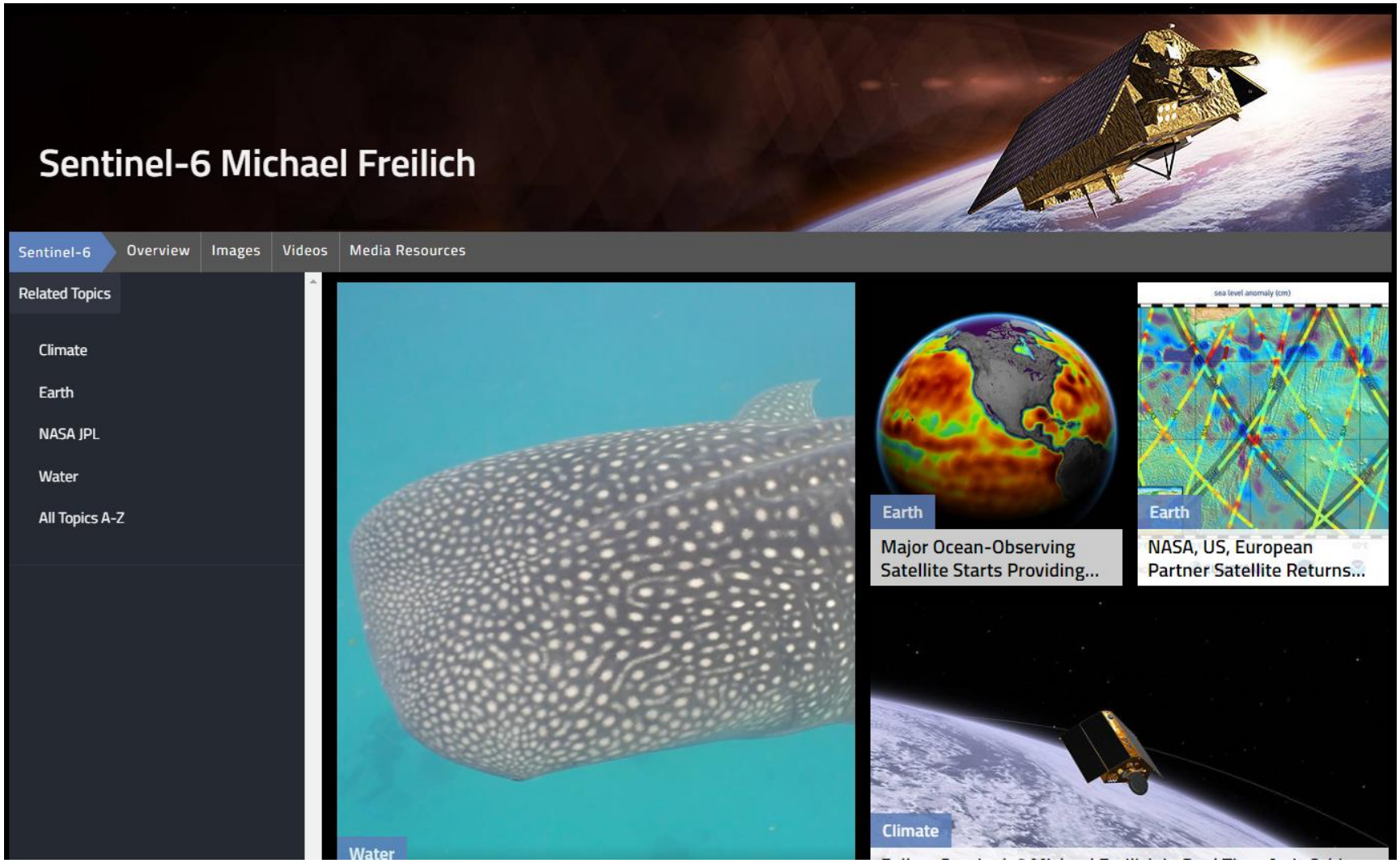
GMES ocean, land, atmospheric, emergency, security and cryospheric applications.

The SENTINEL-3 mission is jointly operated by ESA and EUMETSAT to deliver operational ocean and land observation services.

The spacecraft carries four main instruments:

OLCI: Ocean and Land Colour Instrument
SLSTR: Sea and Land Surface Temperature Instrument
SRAL: SAR Radar Altimeter
MWR: Microwave Radiometer.

Sentinel-6 (NASA/ESA)



Sentinel-6

The mission

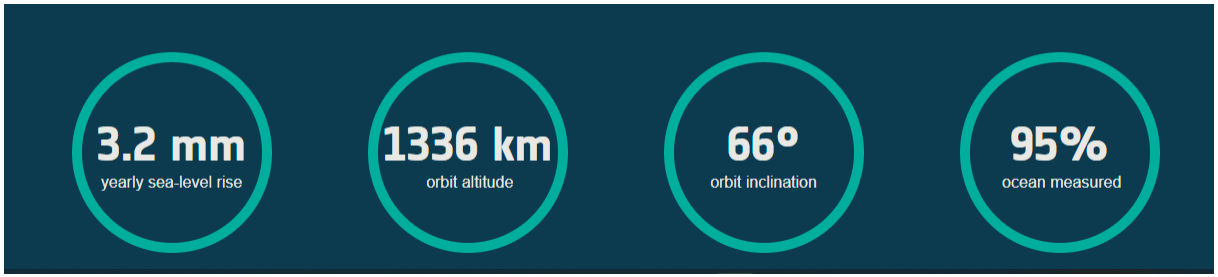
With global mean sea level rising because of climate change, Copernicus Sentinel-6 is the next radar altimetry reference mission to extend the legacy of sea-surface height measurements until at least 2030. The satellite carries a Poseidon-4 radar altimeter and a microwave radiometer.

The launch

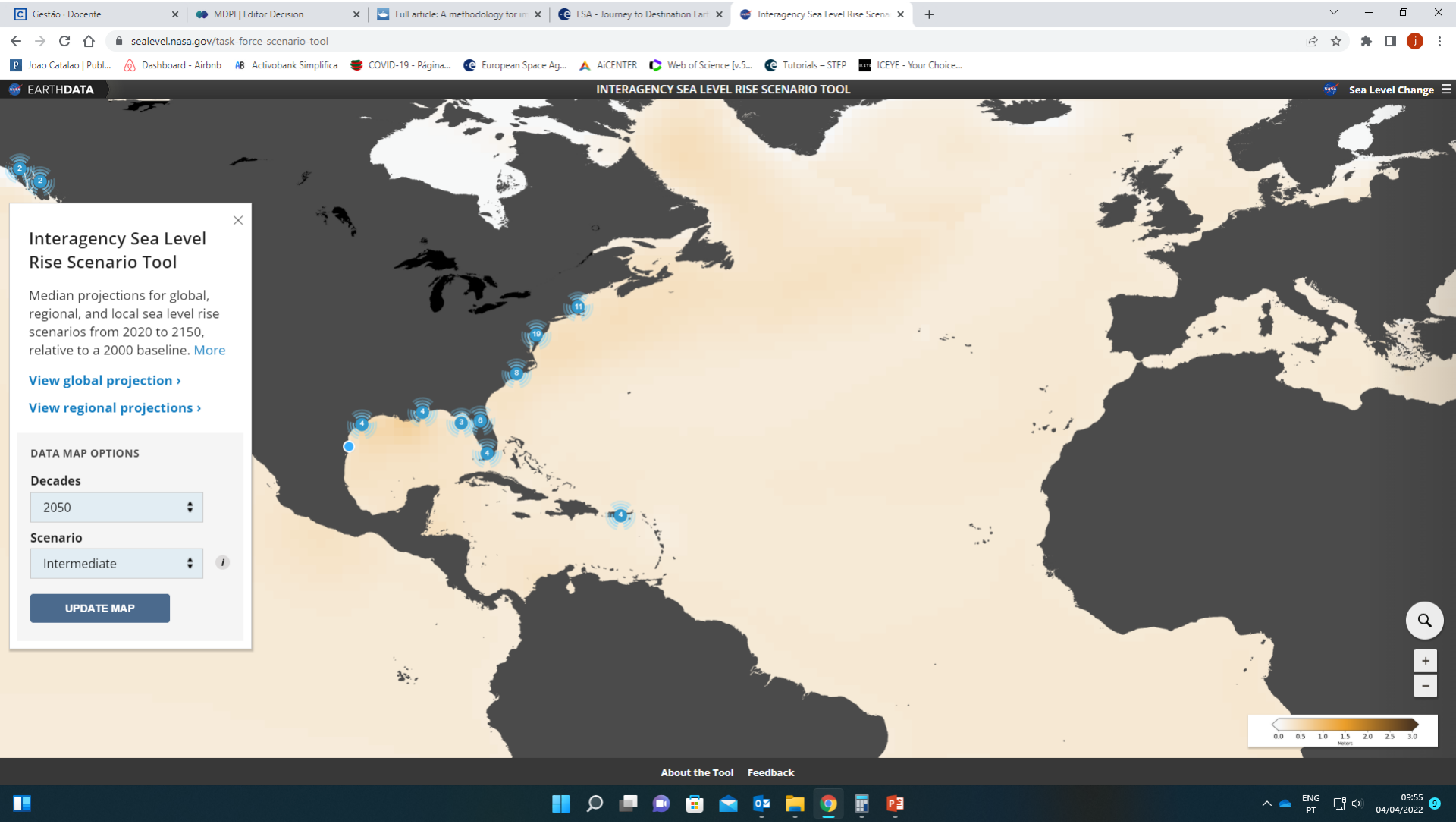
Date: 21 November 2020

Site: Vandenberg, California, US

Rocket: SpaceX Falcon 9

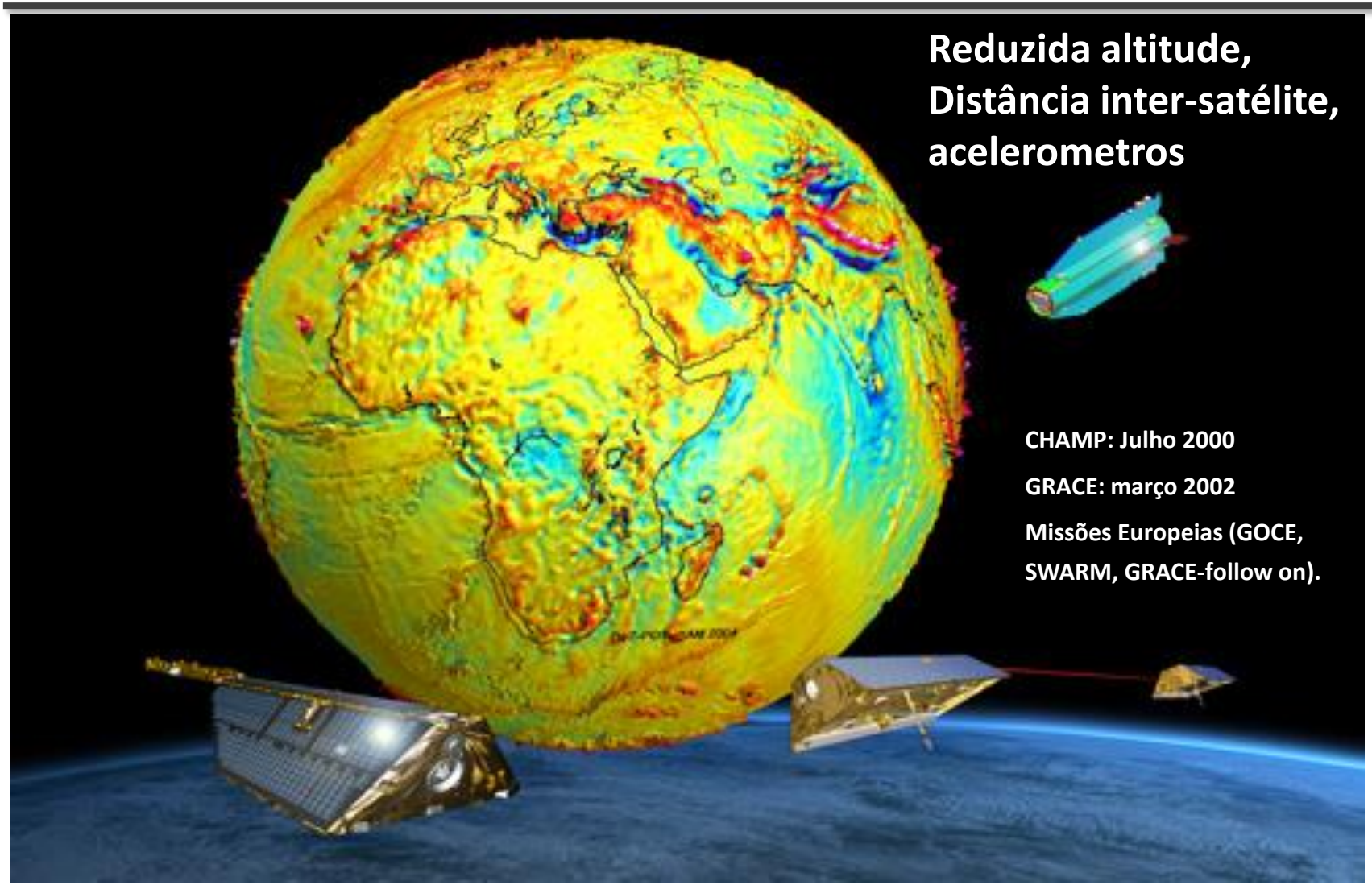


https://youtu.be/OXf4Mf4TQeI

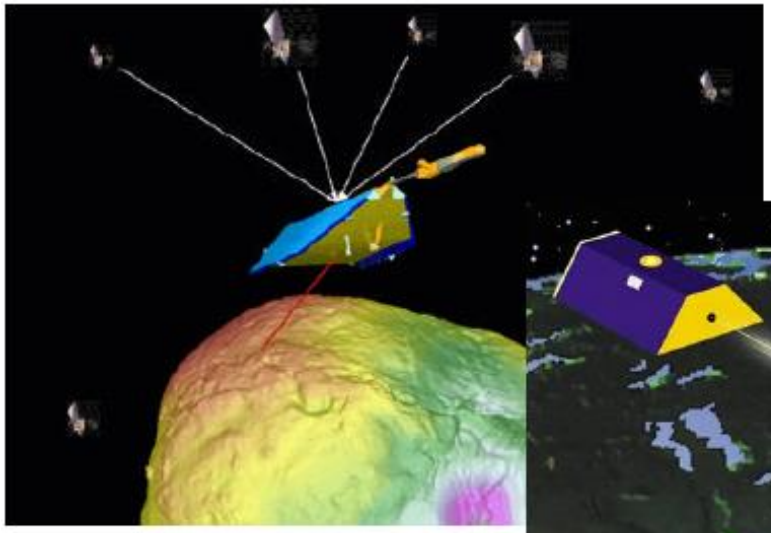


https://sealevel.nasa.gov/task-force-scenario-tool

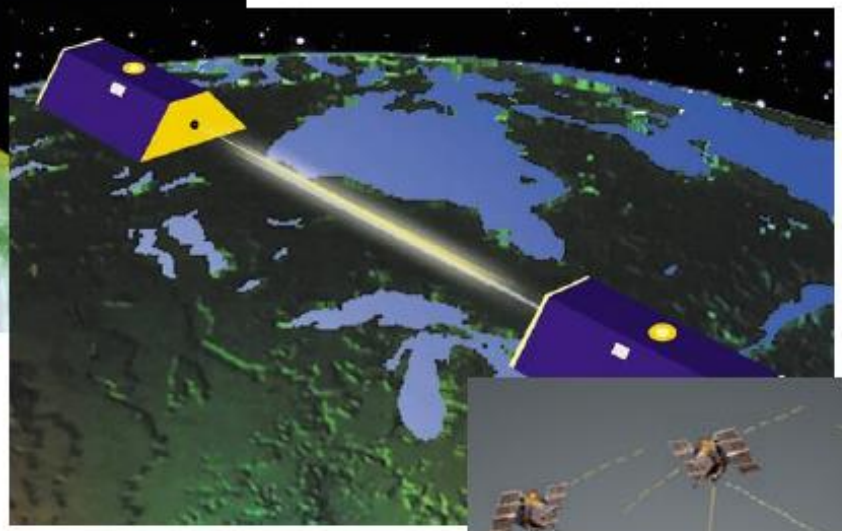
Missões Geopotenciais Espaciais



Missões Geopotenciais Espaciais



CHAMP

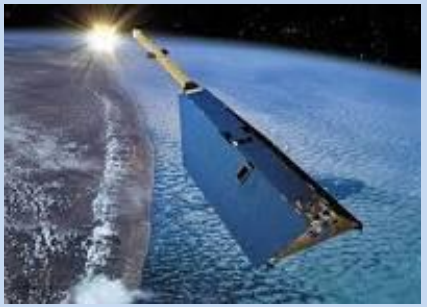


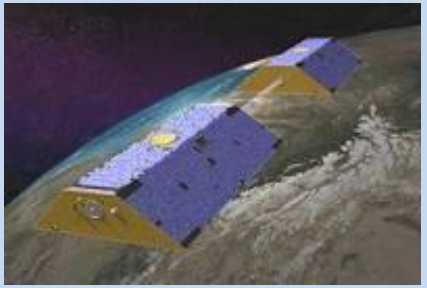
GRACE

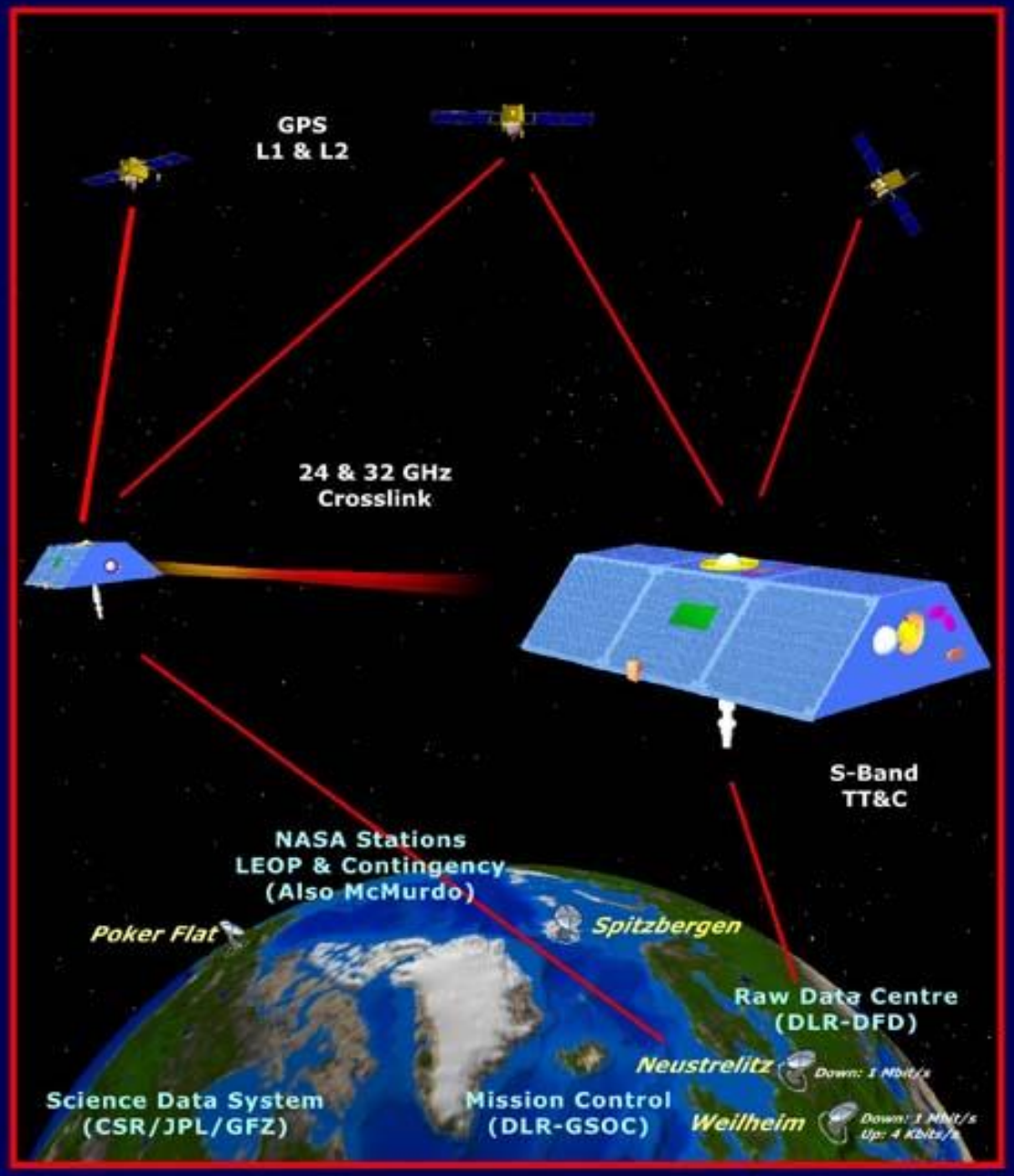
GOCE

Gravity Field Missions

CHAMP	Magnetic field determination/ Temporal variations of the gravity field
GRACE GRACE-FO (2017)	Improved knowledge of the geoid estimates of time variable components
GOCE	Highly precise static geoid determination







GRACE Mission

Science Goals

High resolution, mean & time variable gravity field mapping for Earth System Science applications.

Mission Systems

Instruments

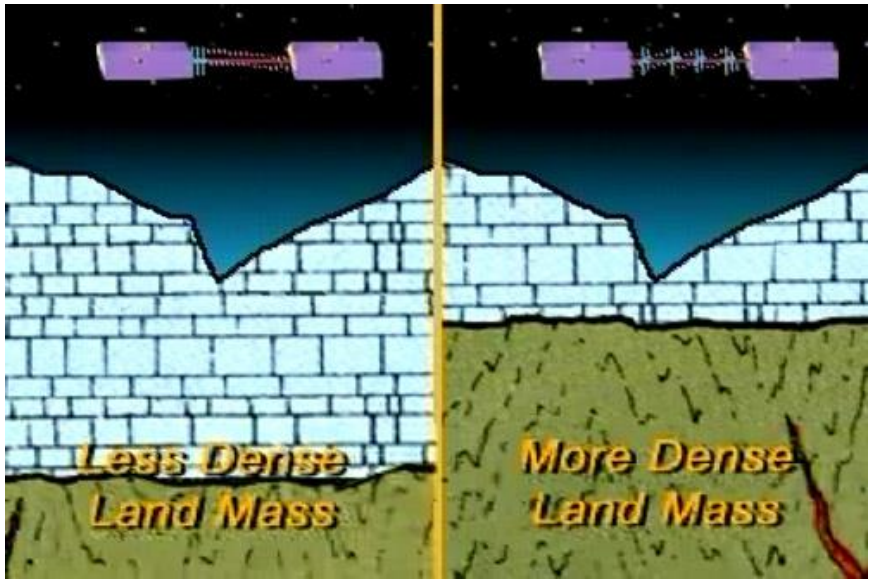
- KBR (JPL/SSL)
- ACC (ONERA)
- SCA (DTU)
- GPS (JPL)

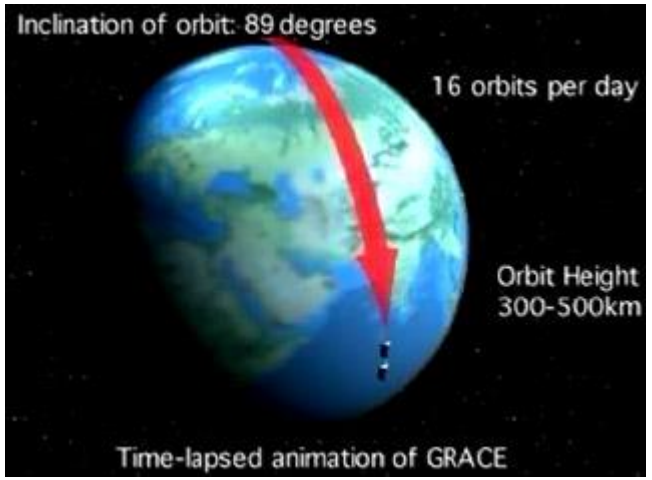
Satellite (JPL/DSS)
Launcher (DLR/Eurockot)
Operations (DLR/GSOC)
Science (CSR/JPL/GFZ)

Orbit

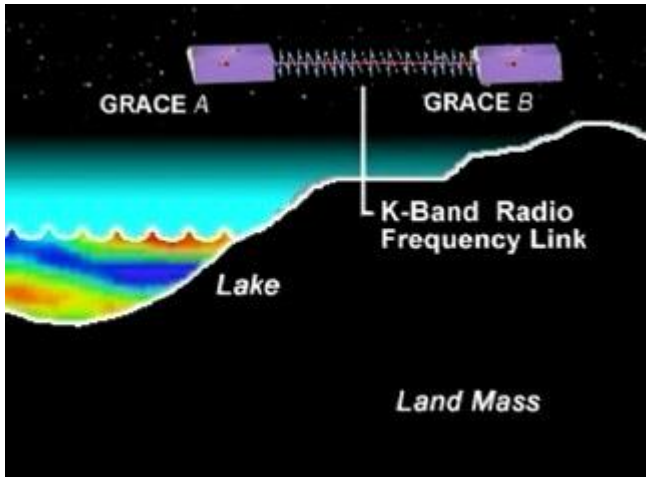
Launch: March 2002
Altitude: 485 km
Inclination : 89 deg
Eccentricity: ~0.001
Lifetime: 5 years
Non-Repeat Ground Track
Earth Pointed, 3-Axis Stable

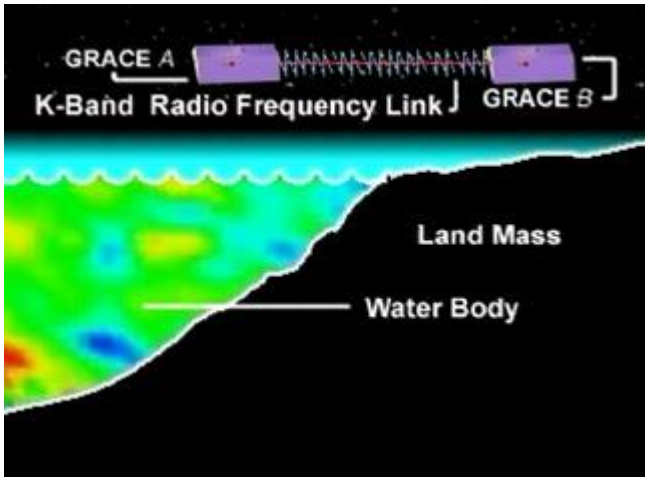
GRACE





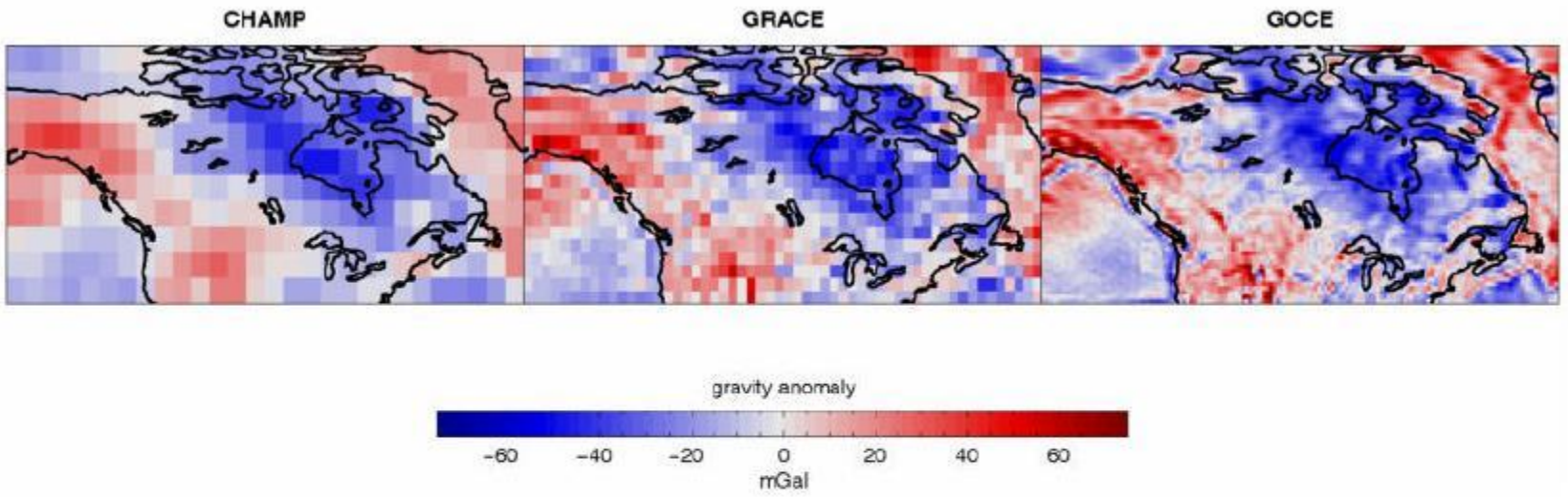
Distância = 220 km





Missões Geopotenciais Espaciais

Resolução Espacial



$L = 50$

$\lambda / 2 = 400$ km

$\Delta T = 1$ month

$L = 100$

$\lambda / 2 = 200$ km

$\Delta T = 1$ month

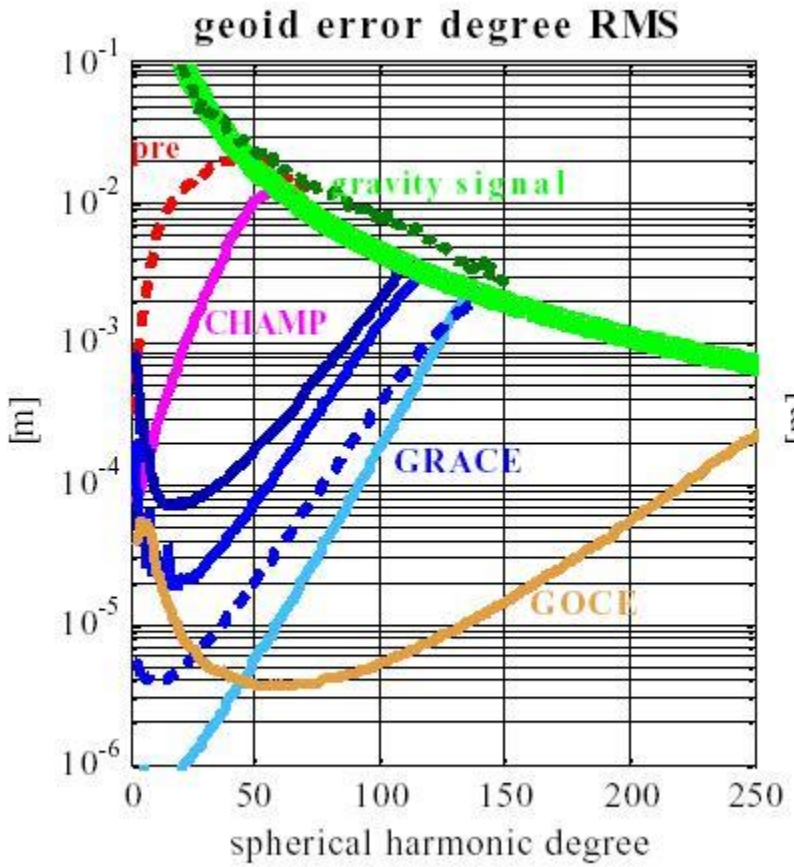
$L = 300$

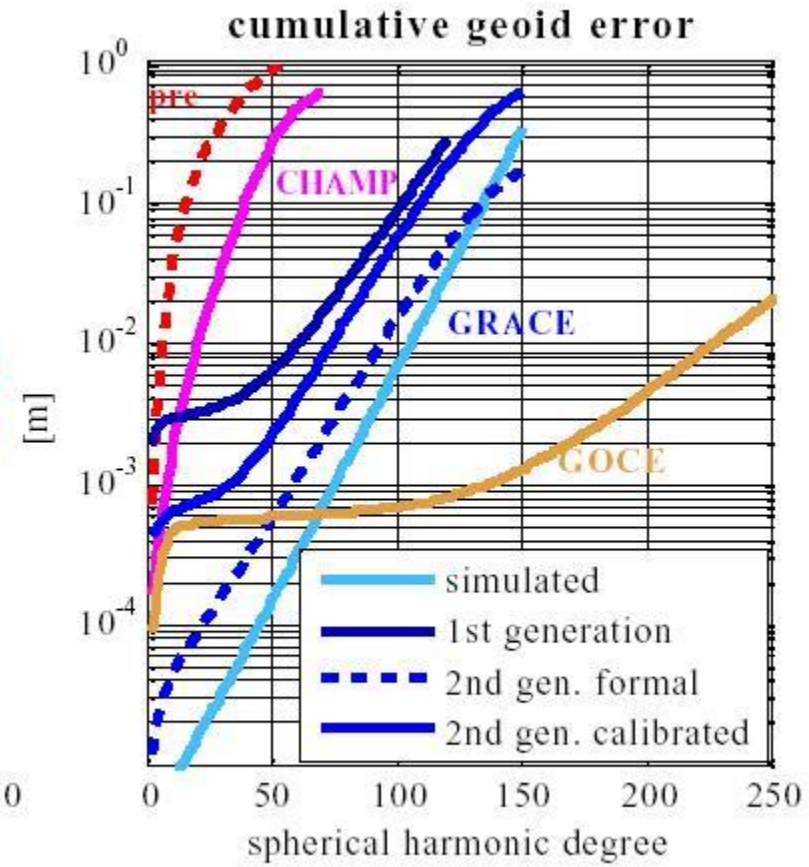
$\lambda / 2 = 70$ km

$\Delta T = \text{N/A}$

Missões Geopotenciais Espaciais

Resolução Espectral





GRACE

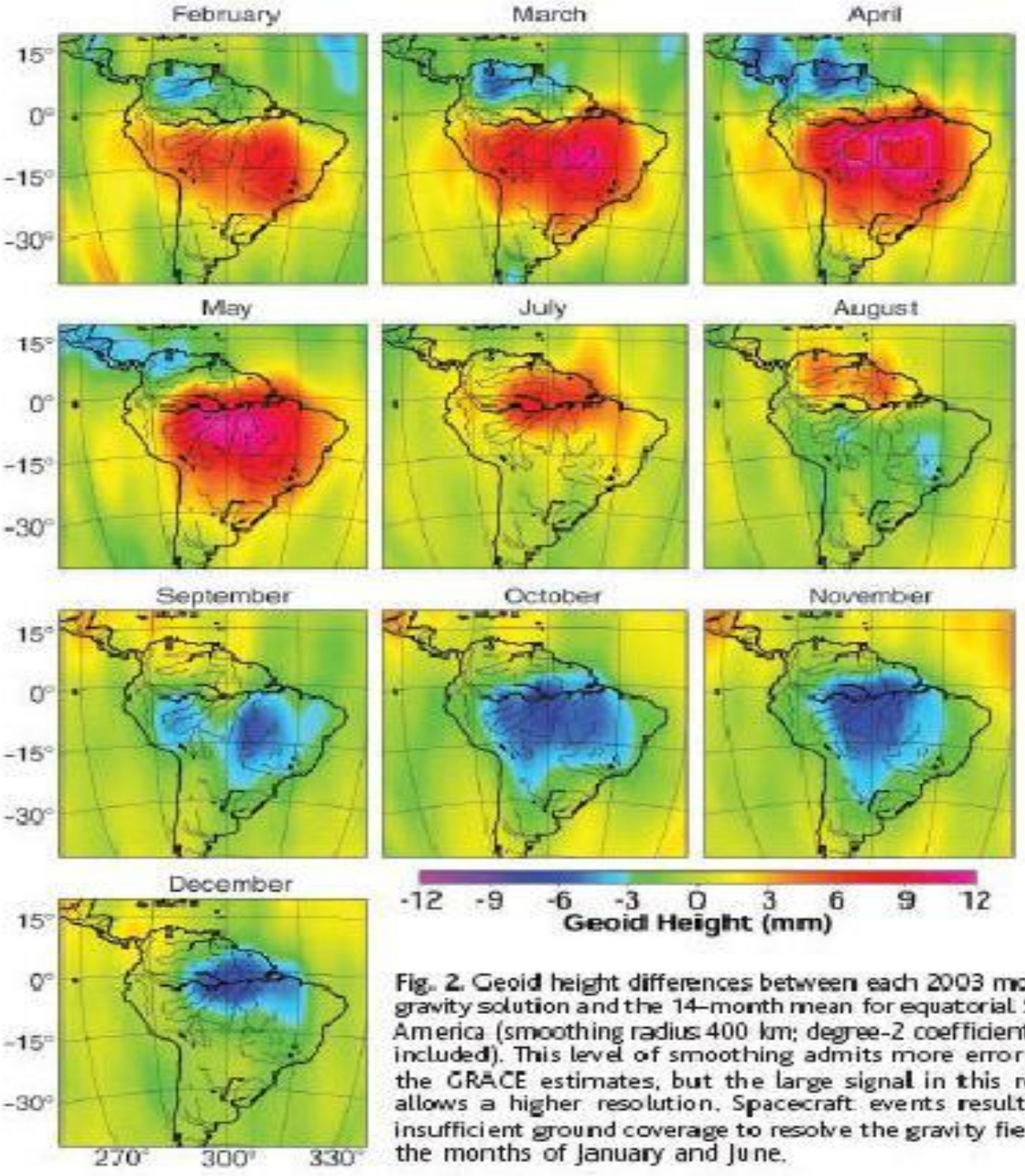


Fig. 2. Geoid height differences between each 2003 monthly gravity solution and the 14-month mean for equatorial South America (smoothing radius 400 km; degree-2 coefficients not included). This level of smoothing admits more error from the GRACE estimates, but the large signal in this region allows a higher resolution. Spacecraft events resulted in insufficient ground coverage to resolve the gravity field for the months of January and June.

Tapley et al.
23 JULY 2004
SCIENCE
Vol 305, pp 305-307

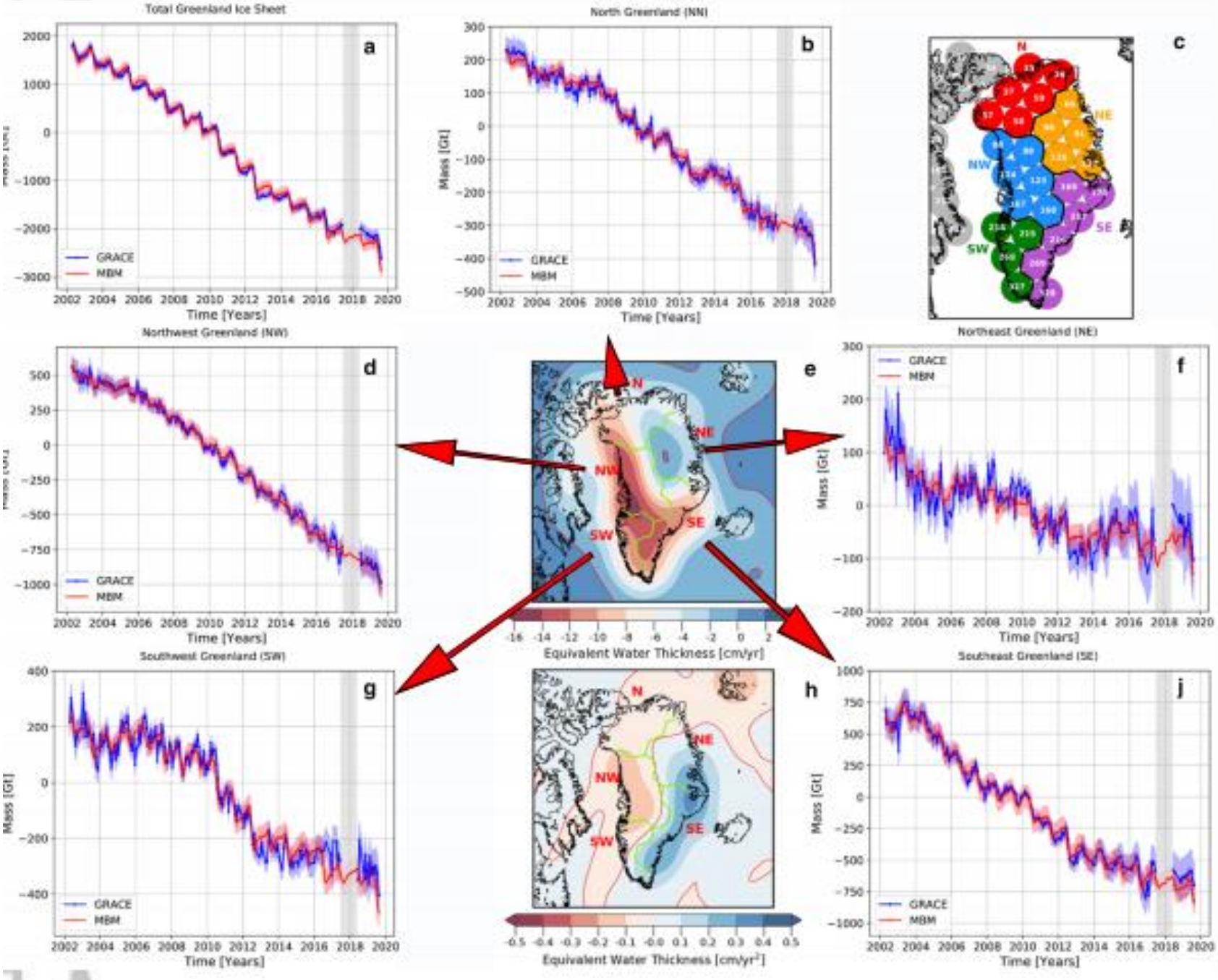
Continuity of ice sheet mass loss in Greenland and Antarctica from the GRACE and GRACE Follow-On missions. Isabella Velicogna et al., GRL, April 2020

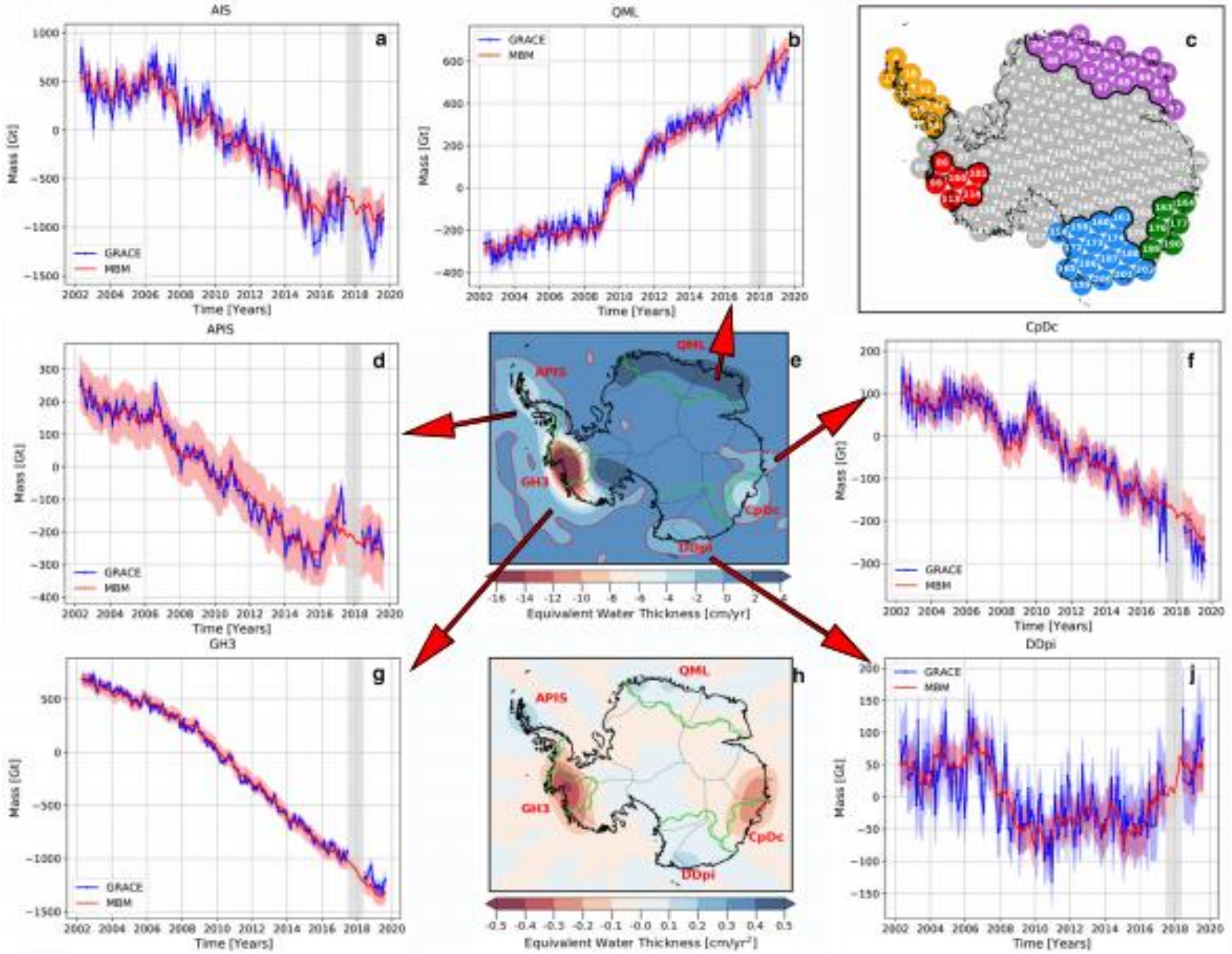
Abstract

In Greenland, the GRACE-FO data reveal an exceptional summer loss of 600 Gigatonnes in 2019 following two cold summers.

In Antarctica, ongoing high mass losses
in the Amundsen Sea Embayment of West Antarctica,
the Antarctic Peninsula, and
Wilkes Land in East Antarctica
cumulate to 2130, 560, and 370 Gigatonnes, respectively, since 2002.

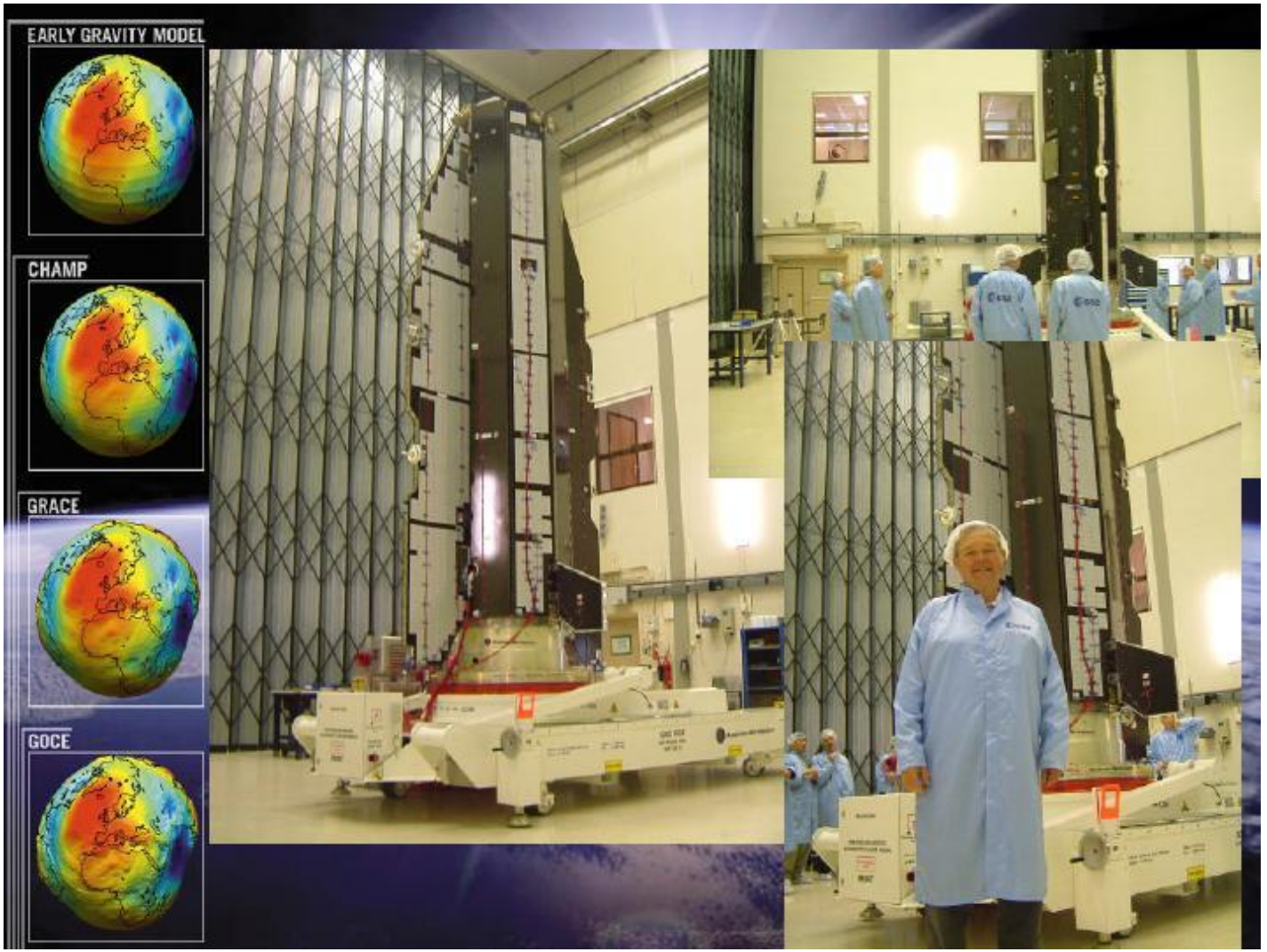
A cumulative mass gain of 980 Gigatonnes in Queen Maud Land since 2009, however, led to a pause in the acceleration in mass loss from Antarctica after 2016.


Total Greenland Ice Sheet
a
GRACE
MBM
Time [Years]
North Greenland (NN)
b
Mass [Gt]
GRACE
MBM
Time [Years]
c
N
NE
NW
SE
SW
Northwest Greenland (NW)
d
GRACE
MBM
Time [Years]
N
NE
NW
SE
SW
Equivalent Water Thickness [cm/yr]
Northeast Greenland (NE)
e
f
GRACE
MBM
Mass [Gt]
Time [Years]
Southwest Greenland (SW)
g
GRACE
MBM
Mass [Gt]
Time [Years]
N
NE
NW
SE
SW
Equivalent Water Thickness [cm/yr²]
Southeast Greenland (SE)
h
j
GRACE
MBM
Mass [Gt]
Time [Years]

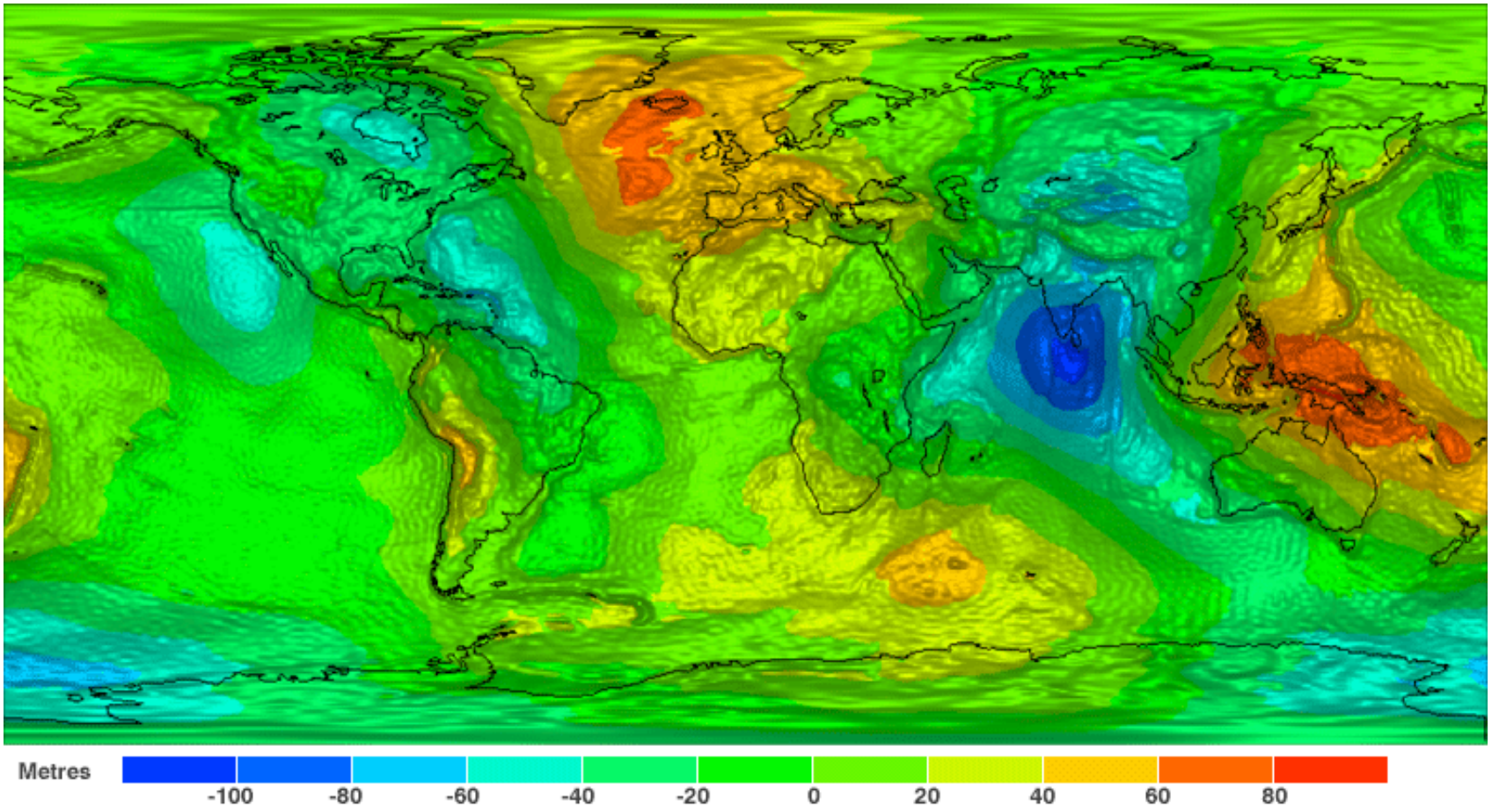

AIS
a
Mass [Gt]
Time [Years]
GRACE
MBM
QML
b
c
APIS
d
GH3
g
CpDc
f
DDpi
j
e
h
Equivalent Water Thickness [cm/yr]
Equivalent Water Thickness [cm/yr²]

Ciências ULisboa

GOCE

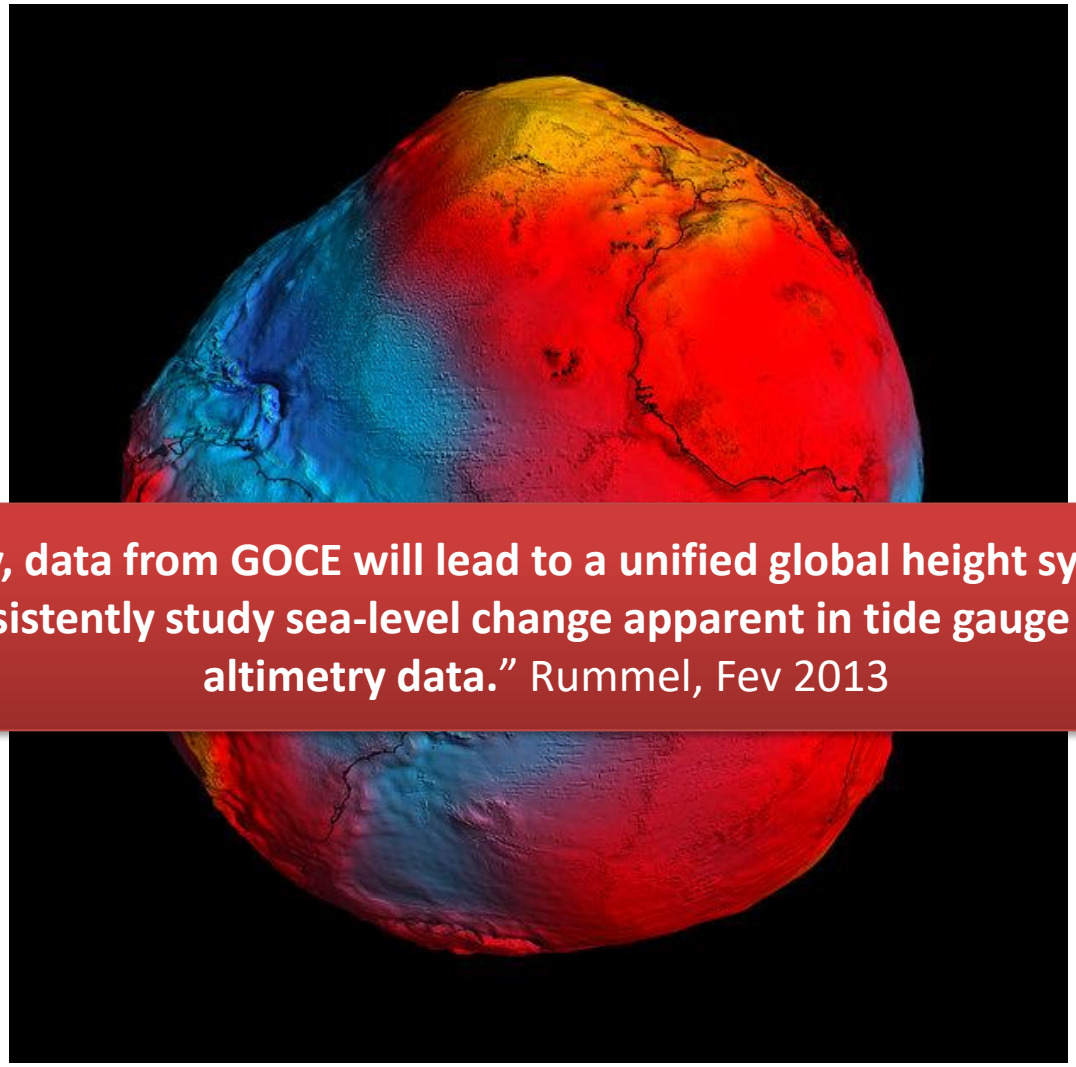


GOCE



Global gravity model based on GOCE satellite data

GOCE - Geoid Model

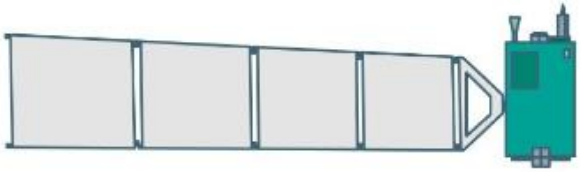


Importantly, data from GOCE will lead to a unified global height system so that we can consistently study sea-level change apparent in tide gauge and satellite altimetry data." Rummel, Fev 2013

2013

The idea behind ESA's GENESIS mission is simple: a fixed framework is needed to chart the relative positions of locations across our planet, and satellites in orbit serve as the foundation of this framework. Fix a satellite's own position in space accurately enough and you can measure Earth beneath it much more precisely too.

To achieve this goal down to millimetre level, ESA's GENESIS satellite will combine and co-locate the four reference existing 'geodetic' – or Earth-measuring – techniques on a single platform for the first time. In so doing it will serve to identify and subtract inherent biases within each of these techniques, allowing, in turn, improvements in the accuracy and consistency of the reference frame that is used to organise much of the underlying functions of our civilisation. A new Invitation to Tender is giving European industry the chance to contribute to this groundbreaking mission.

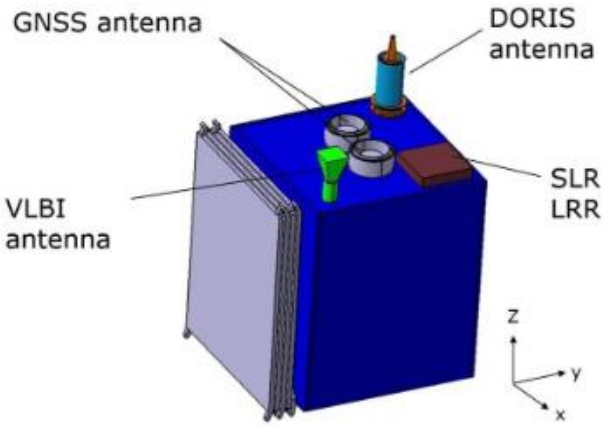


— Preliminary GENESIS satellite design

GENESIS is part of ESA's FutureNAV programme, approved at ESA's Council at Ministerial Level last November, seeking to respond to new satnav concepts and trends in an effective, agile way, bolstering European competitiveness in this vital sector.

Mapping planet Earth for better positioning

GENESIS will combine all four geodetic methods of fixing satellite positions in space: Very Long Baseline Interferometry, VLBI, originally an astronomical technique that combines multiple radio observations from different sites to resolve a given object in high resolution; radio ranging (using France's DORIS system); satellite navigation; and laser ranging (using the International Laser Ranging Service).



— Geodetic payloads on GENESIS satellite

Each of these geodetic techniques have their own inherent biases, which affect the actual accuracy of the Terrestrial Reference Frame that we may achieve when combining them on Earth. By co-locating them together on the same satellite, with the instruments duly calibrated and synchronised, we may cross-check the results and remove these biases over time.

The final goal of the mission is to generate an updated more precise global model of Earth – the International Terrestrial Reference Frame, employed for everything from land surveying to measuring sea level rise – with an accuracy down to 1 mm, while tracking ground motion of just 0.1 mm per year. This improvement, at a stroke, will have a major impact in multiple navigation and Earth science applications, including enhancing the precision of

Earth Observation Satellites

Landsat Missions: Imaging the Earth Since 1972

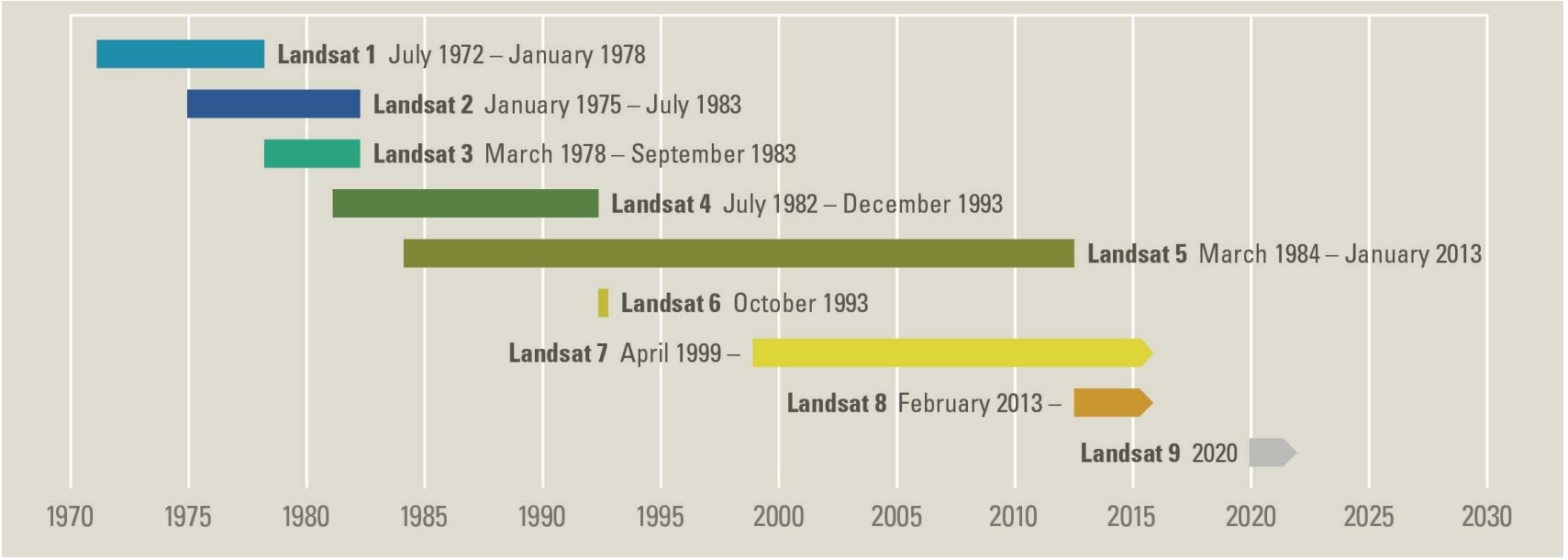
Earth Resources Technology Satellite (ERTS-1), later renamed **Landsat-1**, was launched on July 23, 1972.

The launches of **Landsat-2**, **Landsat-3**, and **Landsat-4** followed in 1975, 1978, and 1982, respectively.

Earth Observation Satellites

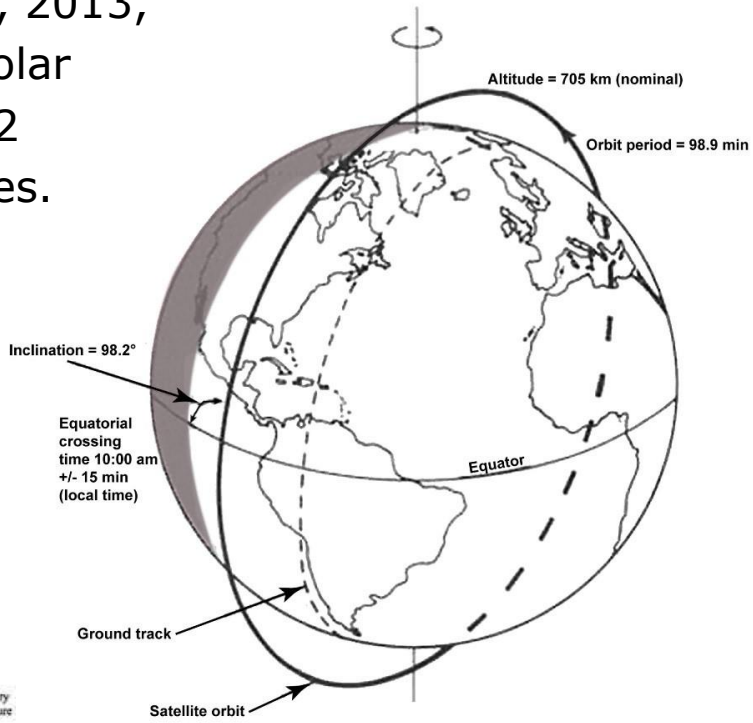
Landsat-5, launched in 1984, lasting 28 years and 10 months, officially setting a new Guinness World Record for "longest-operating Earth observation satellite."

Landsat-7 successfully launched in 1999 and, along with **Landsat-8**, launched in 2013, continues to provide daily global data. **Landsat-9** was launched in September 2021 (8 days revisit time).

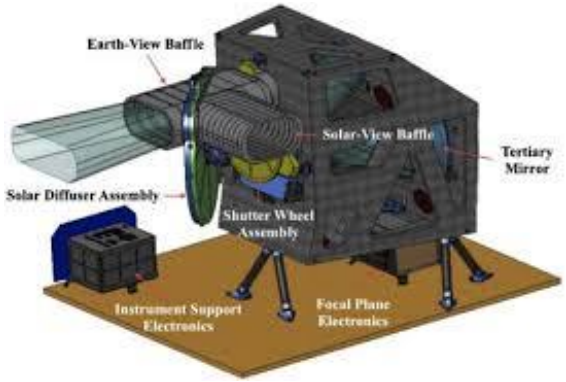


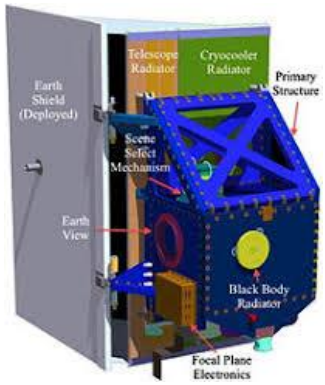
Earth Observation Satellites

Landsat-8 satellite, launched on February 11, 2013, orbits the Earth in a sun-synchronous, near-polar orbit, at an altitude of 705 km, inclined at 98.2 degrees, and circles the Earth every 99 minutes.

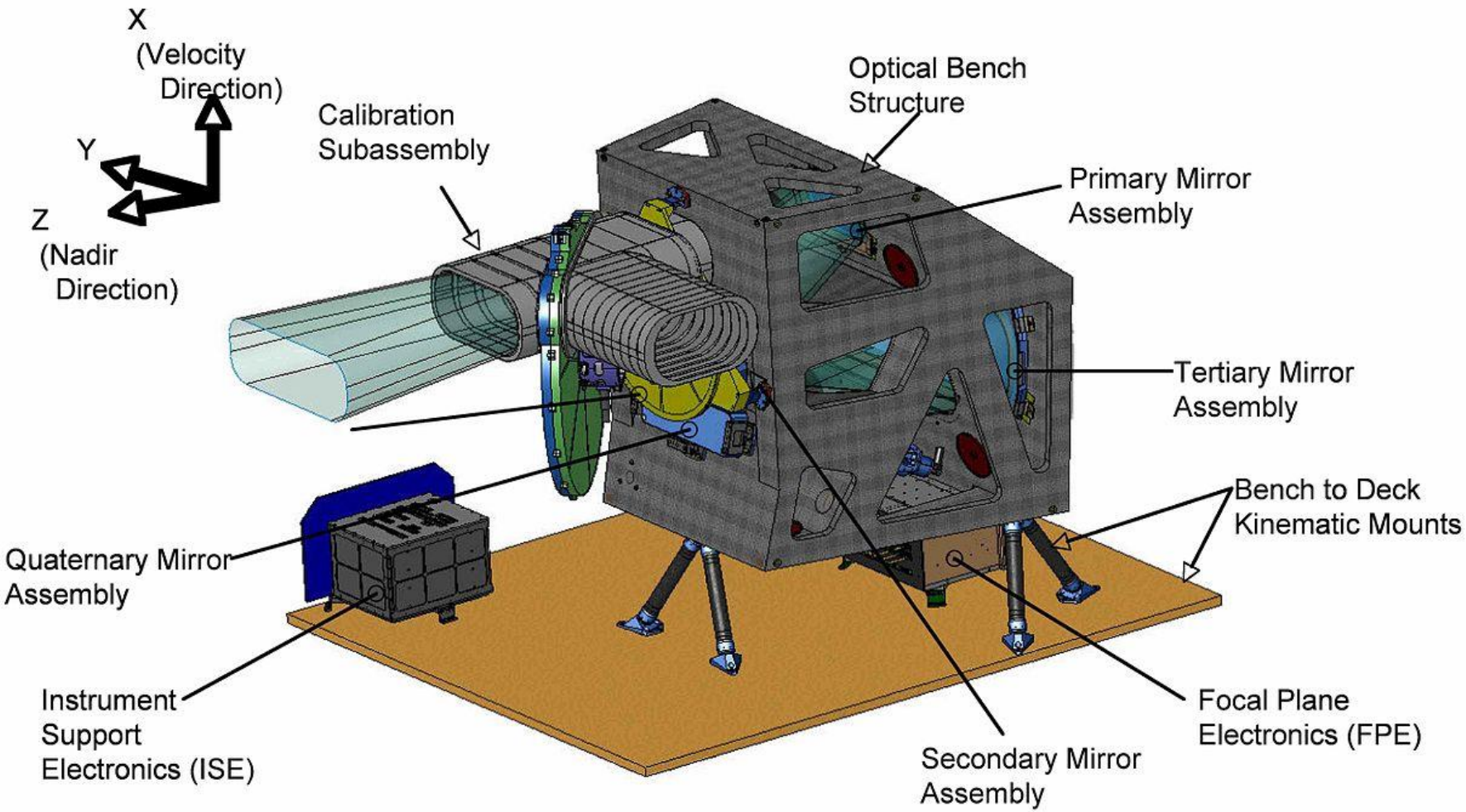


Landsat-8 carries two pushbroom instruments: the **Operational Land Imager (OLI)** and the **Thermal Infrared Sensor (TIRS)**.





OLI Instrument Overview



15-degree field-of-view, 7000 pixels per spectral band, exception of the 15 m panchromatic band that requires over 13,000 detectors (http://landsat.gsfc.nasa.gov/?p=5775)

1

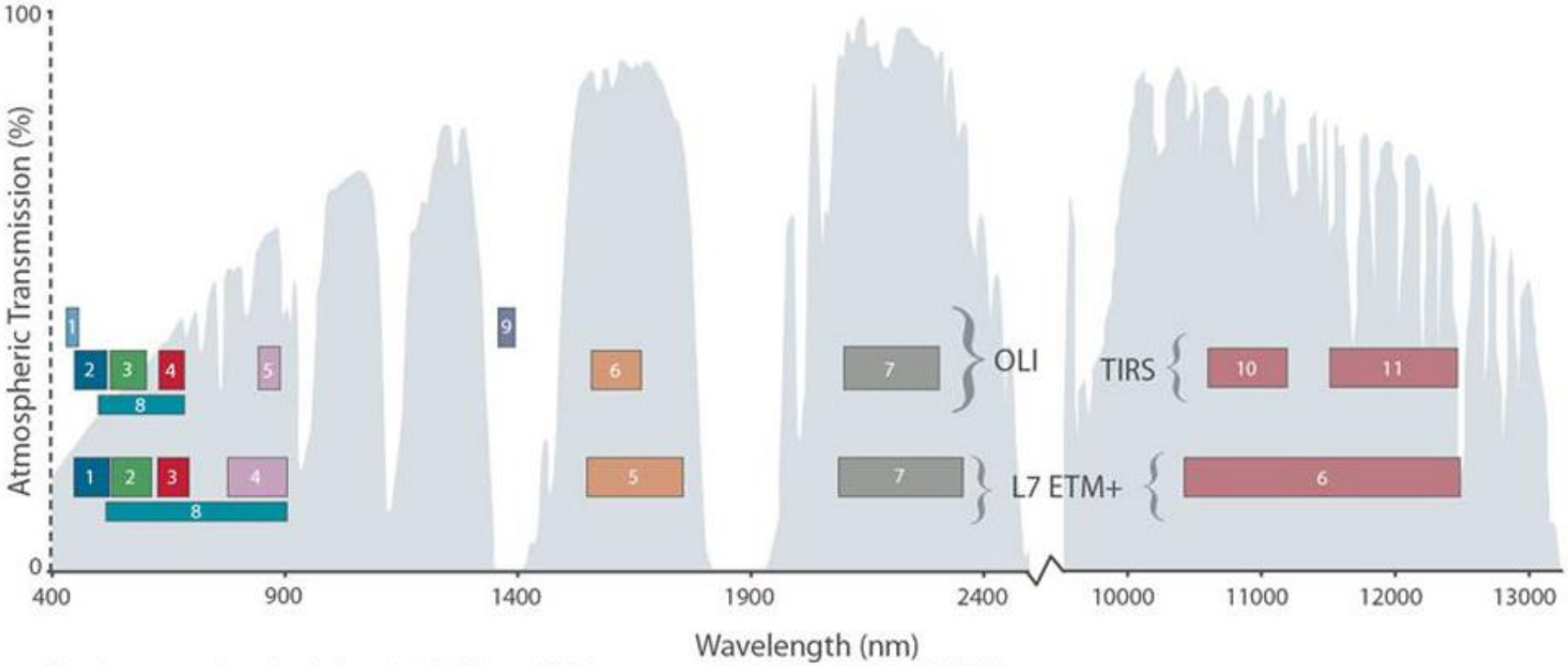
Earth Observation Satellites

Spectral Resolution	11 spectral bands OLI - 9 spectral bands, including a panchromatic band TIRS - 2 spectral bands
Spatial Resolution	15 m - 1 OLI panchromatic band 30 m - 8 OLI bands 100 m - 2 TIRS spectral bands
Radiometric Resolution	12-bits (16-bits when processed into Level-1 data products)
Temporal Resolution	16-day repeat cycle
Swath Width/ Scene Size	170 km x 185 km (106 mi x 115 mi) (7000*30m=210km)

Earth Observation Satellites

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Launched February 11, 2013	Bands	Wavelength (micrometers)	Resolution (meters)
	Band 1 - Coastal aerosol	0.43 - 0.45	30
	Band 2 - Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 - Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - SWIR 1	1.57 - 1.65	30
	Band 7 - SWIR 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100

LANDSAT 8 – Bands wavelenght



Bandpass wavelengths for Landsat 8 OLI and TIRS sensor, compared to Landsat 7 ETM+ sensor

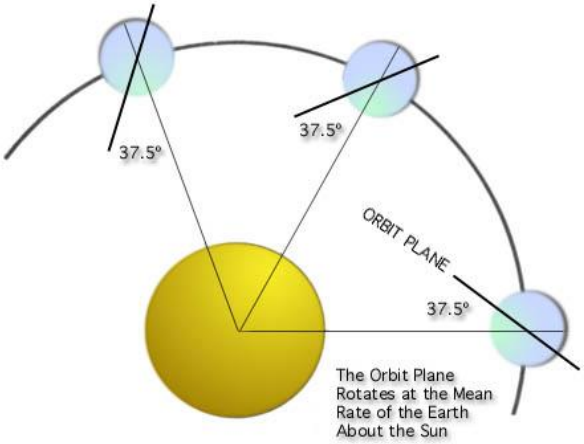
Note: atmospheric transmission values for this graphic were calculated using MODTRAN for a summertime mid-latitude hazy atmosphere (circa 5 km visibility).

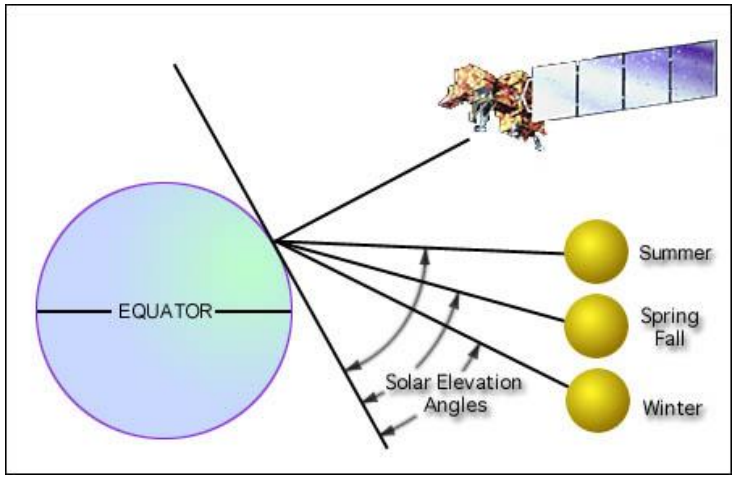
New infrared channel (band 9) for the detection of cirrus clouds.

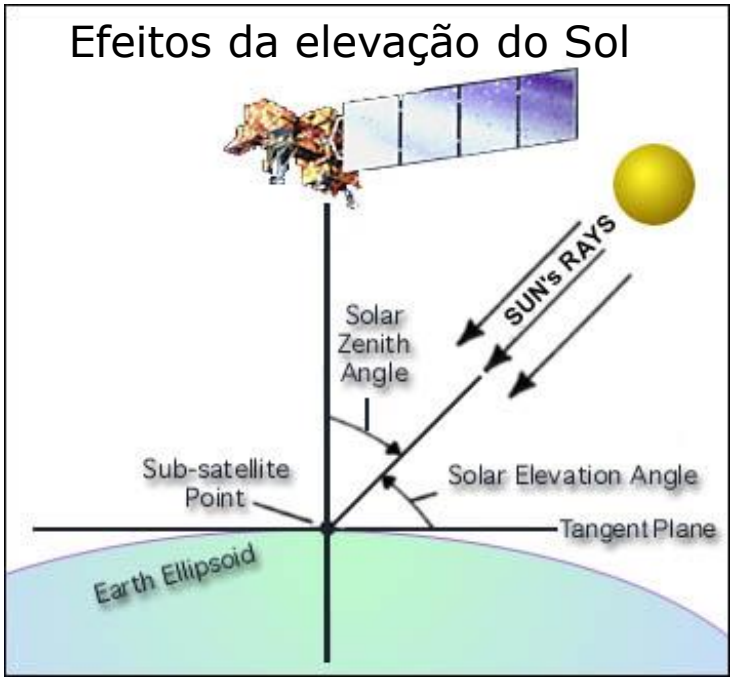
Radiometric quantization (12-bits)

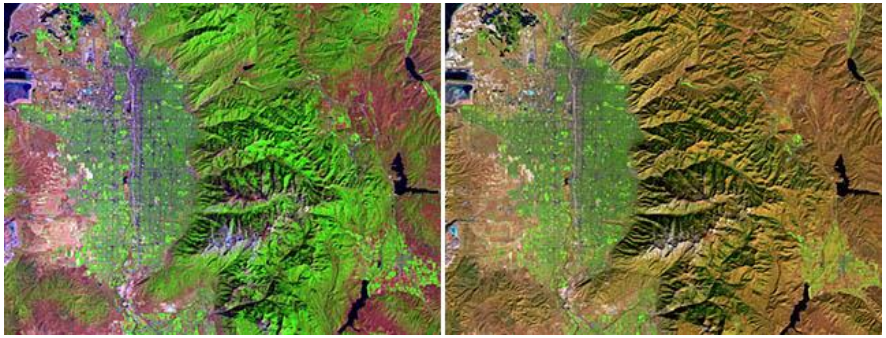
LANDSAT – seazonal effects

Nodo descendente às 10:00









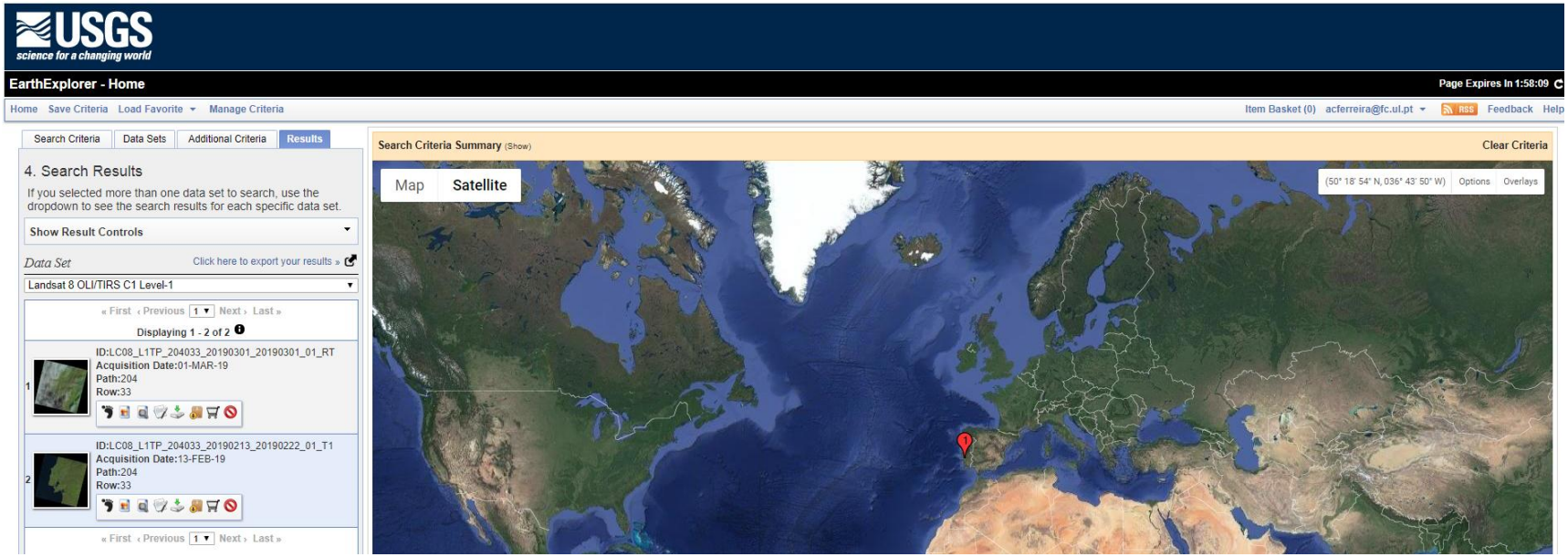
Effects of Seasonal Changes on Solar Elevation Angle

Earth Observation Satellites

The **USGS Earth Explorer** is a quick and easy way to download free Landsat imagery and other remote sensing data.

https://earthexplorer.usgs.gov/

Images are delivered as .tar.gz compressed files (approximately 1 GB) which are unzipped as GeoTIFF files (approximately 2 GB).



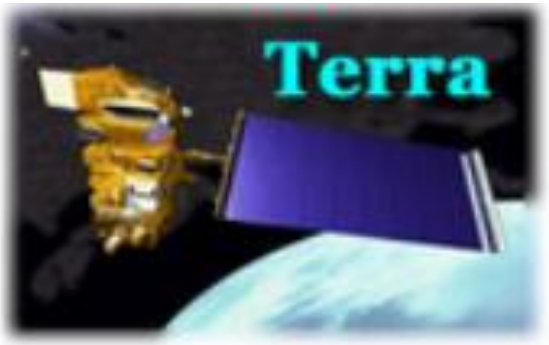
Earth Observation Satellites

Landsat-8 (13.02.2019)

Earth Observation Satellites

MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the **Terra** (December 1999, originally known as EOS AM) and **Aqua** (May, 2002, originally known as EOS PM) satellites.

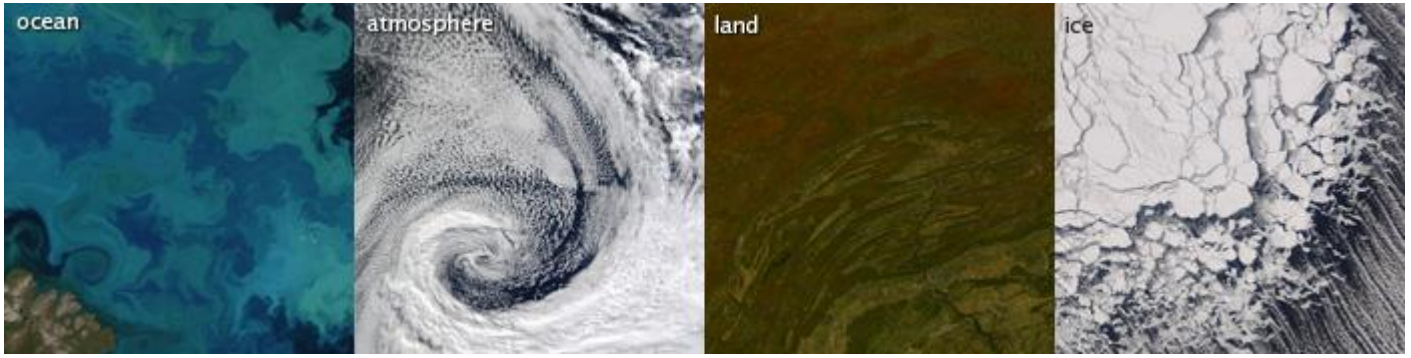
Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning (10:30 am), while **Aqua** passes south to north over the equator in the afternoon (01:30 pm).



Earth Observation Satellites

The MODIS instrument, operating both the Terra and Aqua spacecraft, has a viewing **swath width of 2,330 km** and views the entire surface of the Earth every 1 to 2 days, acquiring data in **36 spectral bands** between 0.4 and 14.4 µm, at three spatial resolutions - 250m, 500m, and 1,000m.

The many **data products** derived from MODIS observations describe features of the **land**, **oceans** and the **atmosphere** that can be used for studies of processes and trends on local to global scales.



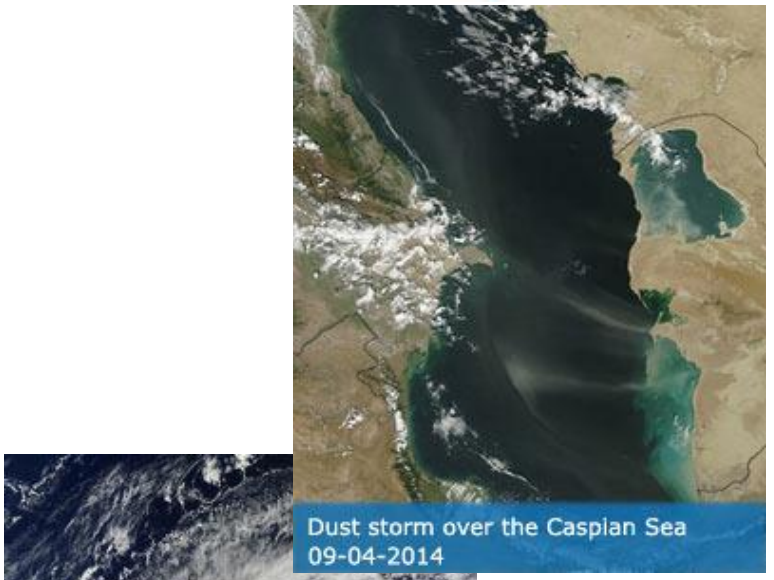
Earth Observation Satellites

MODIS level 1 data, geolocation, cloud mask, and atmosphere products:
http://ladsweb.nascom.nasa.gov/

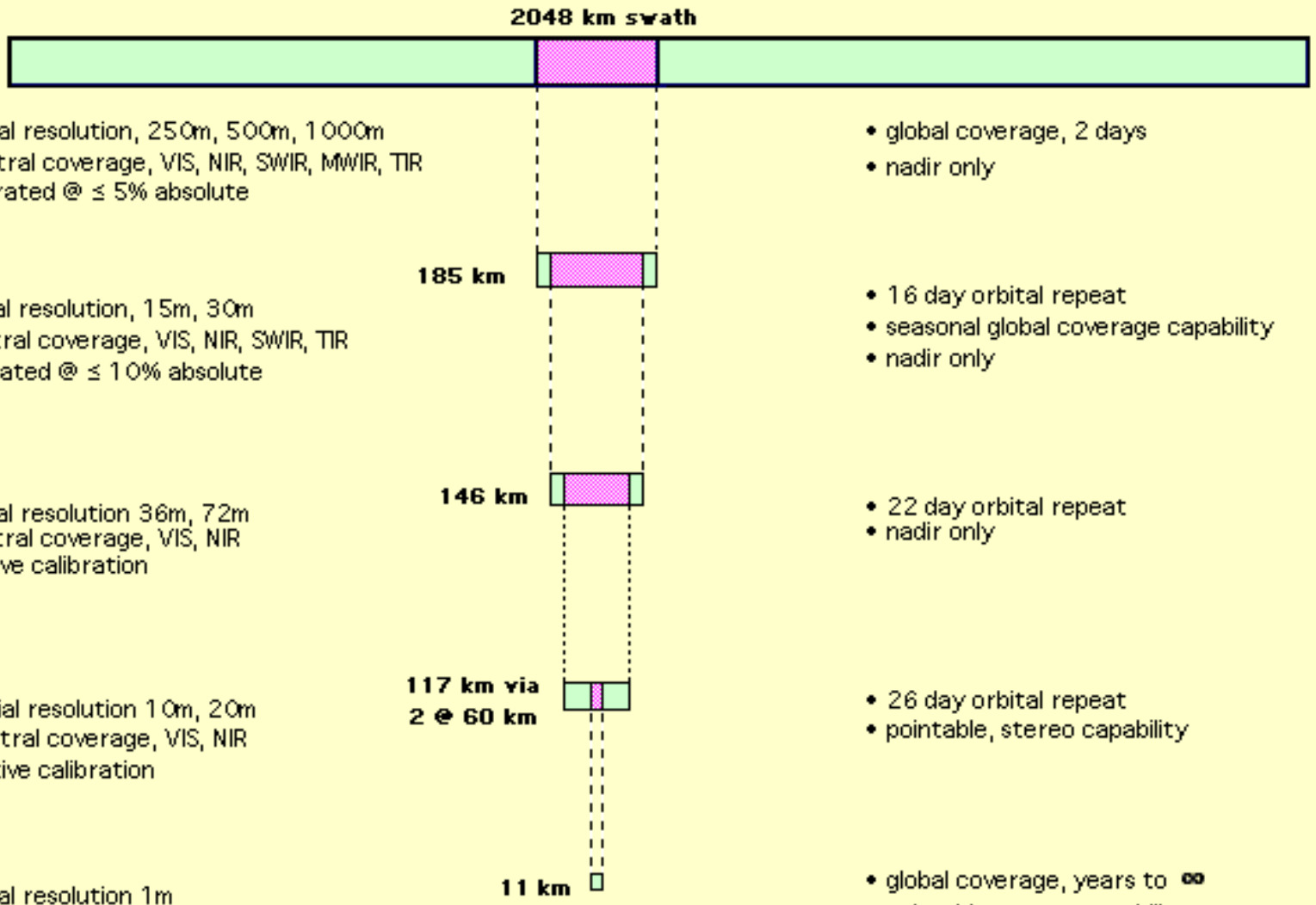
MODIS land products:
https://lpdaac.usgs.gov/

MODIS cryosphere products:
http://nsidc.org/daac/modis/index.html

MODIS ocean color and sea surface temperature products:
http://oceancolor.gsfc.nasa.gov/



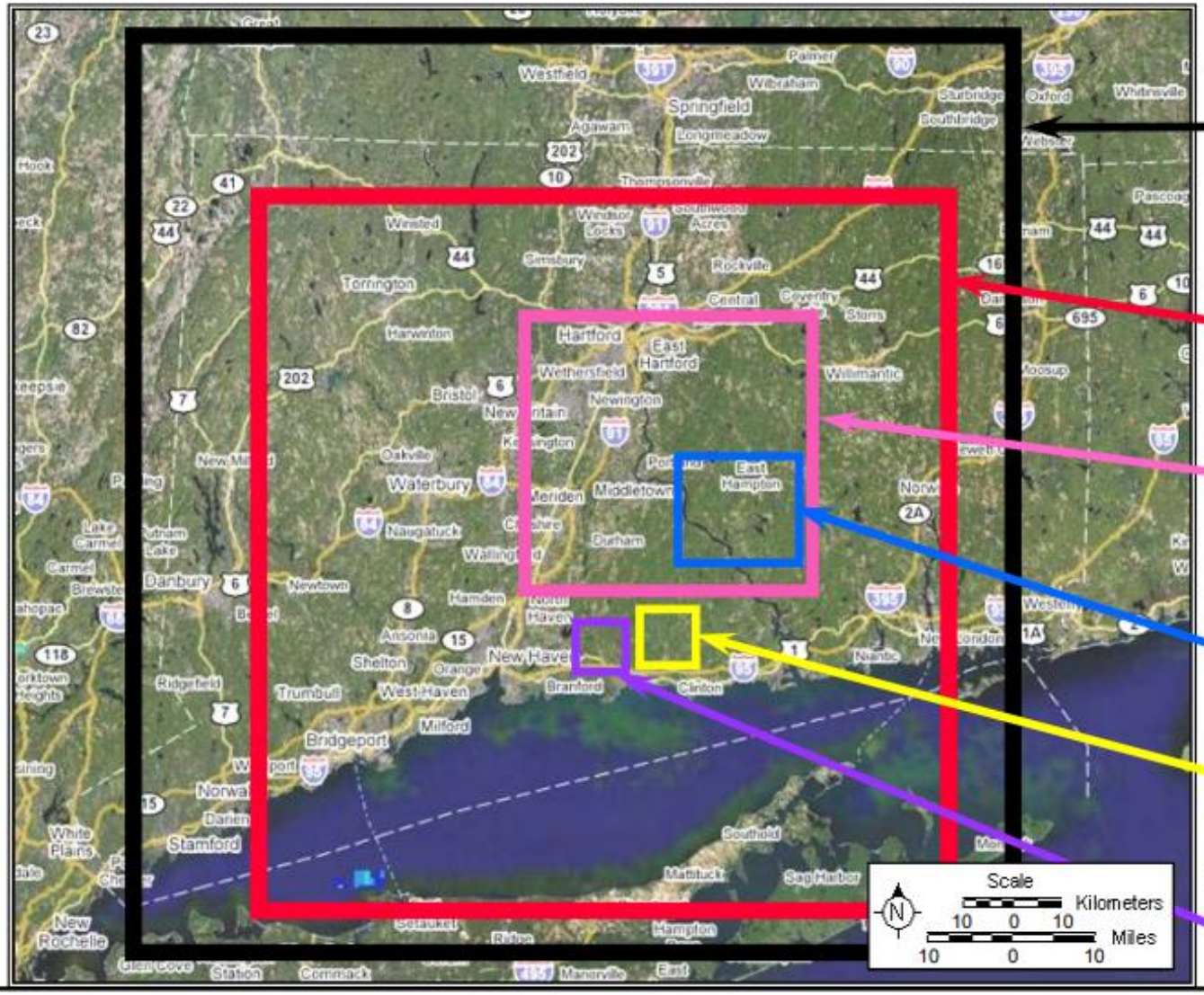
Landsat's Unique Niche Leads to a High Resolution Global Seasonal Archive Capability



Looking More Closely at Resolution

Looking More Closely at Resolution

Selected Satellite Footprints



Landsat 7

185 by 170 km
30-m multispectral

Indian Remote Sensing

145 by 145 km
25-m multispectral

SPOT

60 by 60 km
20-m multispectral

QuickBird 2

16 by 16 km
2.5-m multispectral

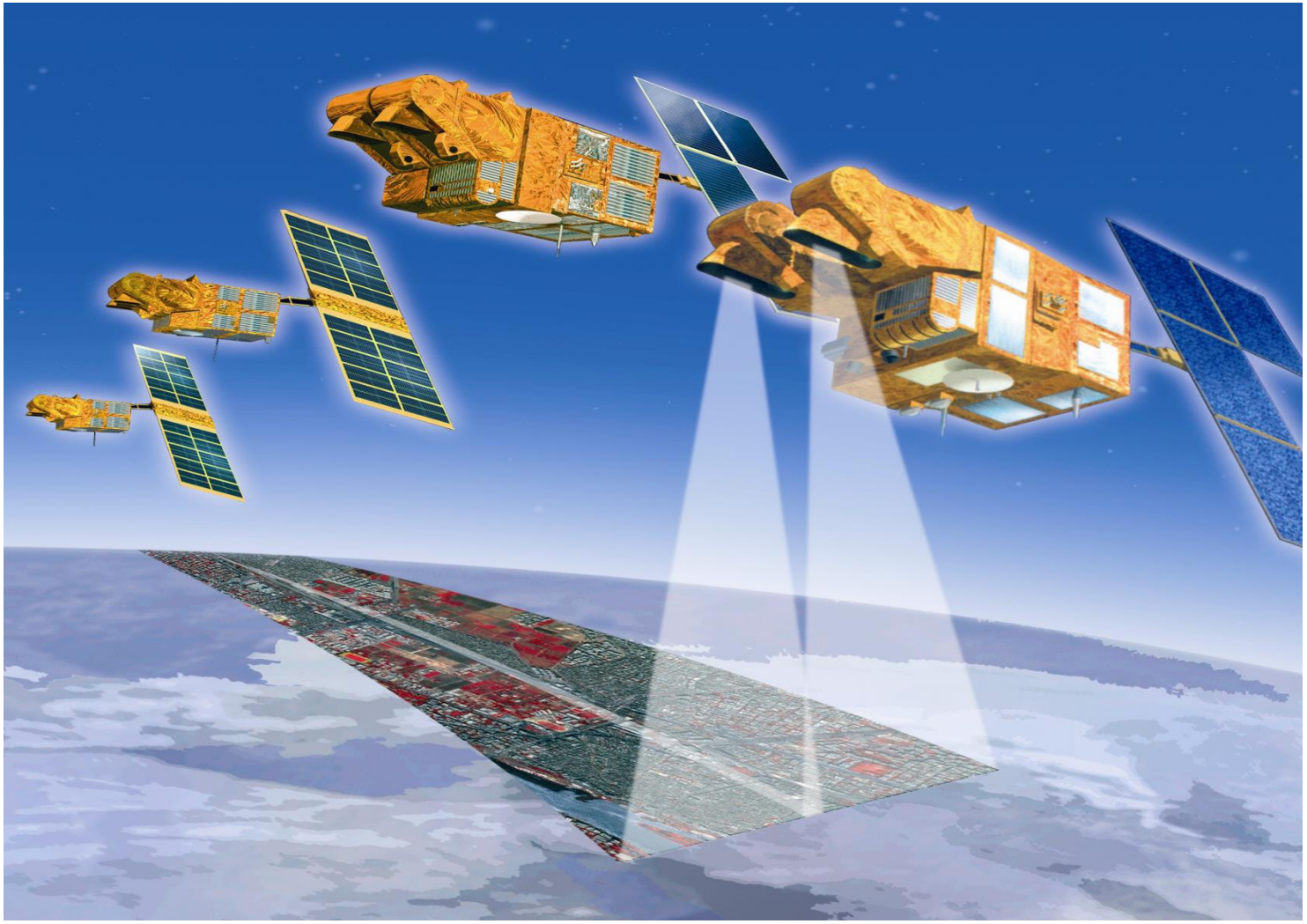
IKONOS

11 by 11 km
4-m multispectral

OrbView 3

8 by 8 km
4-m multispectral
1-m panchromatic

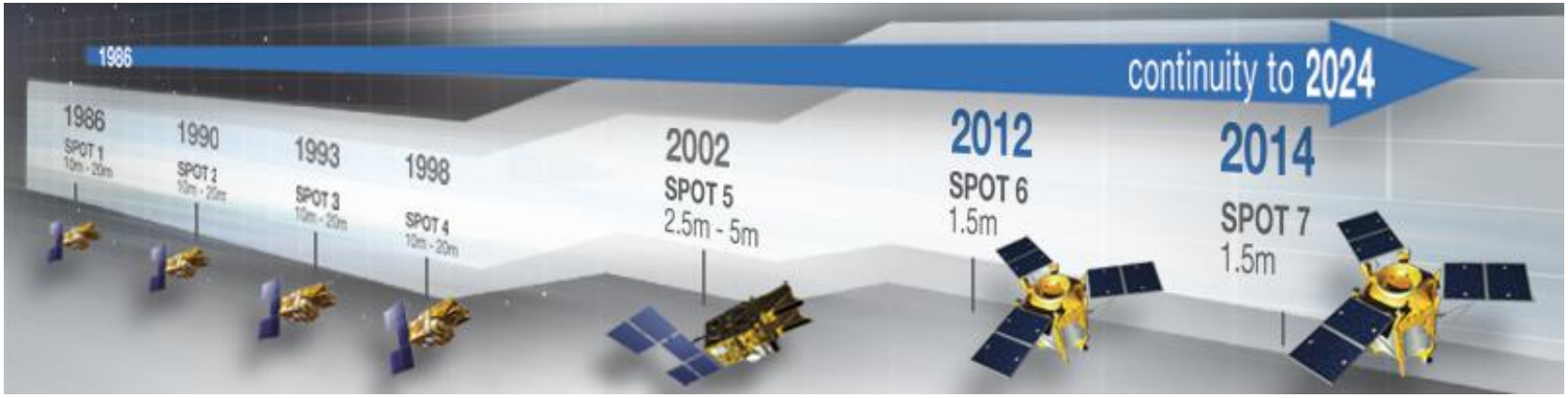
SPOT (Système Pour l'Observation de la Terre)



Earth Observation Satellites

The SPOT Constellation

The system has been operational since 1986 when **SPOT-1** was launched. SPOT-2 was placed in orbit in January 1990, followed by SPOT-3 in September 1993, SPOT-4 in March 1998 and SPOT-5 in May 2002. System continuity is assured by the **SPOT-6** and **SPOT-7** constellation.



SPOT – Eletromagnetic Spetrum

Sensors	Electromagnetic Spectrum	Pixels Size	Spectral bands
SPOT 5	Panchromatic B1 : green B2 : red B3 : near-infra-red B4 : short-wawe infrared (SWIR)	2.5 m or 5 m 10 m 10 m 10 m 20 m	0.48 - 0.71 µm 0.50 - 0.59 µm 0.61 - 0.68 µm 0.78 - 0.89 µm 1.58 - 1.75 µm
SPOT 4	Monospectral B1 : green B2 : red B3 : near-infra-red B4 : short-wawe infrared (SWIR)	10 m 20 m 20 m 20 m 20 m	0.61 - 0.68 µm 0.50 - 0.59 µm 0.61 - 0.68 µm 0.78 - 0.89 µm 1.58 - 1.75 µm
SPOT 1 SPOT 2 SPOT 3	Panchromatic B1 : green B2 : red B3 : near-infra-red	10 m 20 m 20 m 20 m	0.50 - 0.73 µm 0.50 - 0.59 µm 0.61 - 0.68 µm 0.78 - 0.89 µm

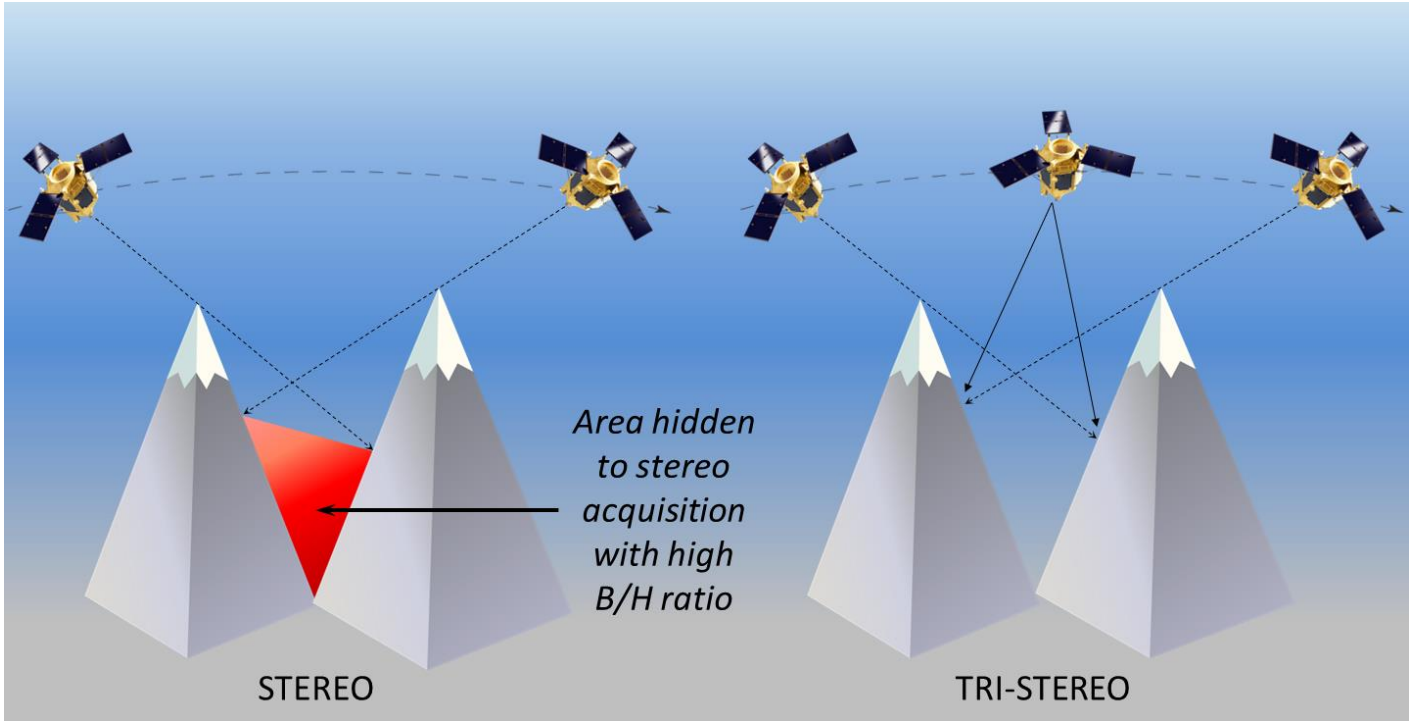
SPOT – Stereoscopy

	Stereoscopic Instruments		
	SPOT 5		
Instrument	HRS along-track stereoviewing	HRG stereoviewing capa across track	
Spectral bands and resolution	1 panchromatic (10 m) (resampled every 5 m along track) → 10 m across track, 5 m along track	2 panchromatic (5 combined to genera 2.5-metre produc 3 multispectral (10 1 short-wave infrared	
Spectral range	P: 0.49 – 0.69 µm	P: 0.48 – 0.71 µm B1: 0.50 – 0.59 µm B2: 0.61 – 0.68 µm B3: 0.78 – 0.89 µm B4: 1.58 – 1.75 µm	
Imaging swath	600 km x 120 km		
Image dynamics			
Base/height ratio (B/H)	~ 0,84 (± 20°)		
Absolute location accuracy (no ground control points, flat terrain)	10 m (1 σ)*	30 m (1 σ)*	350 m

HRS (High-Resolution Stereoscopic imaging instrument)

Multispectral Missions

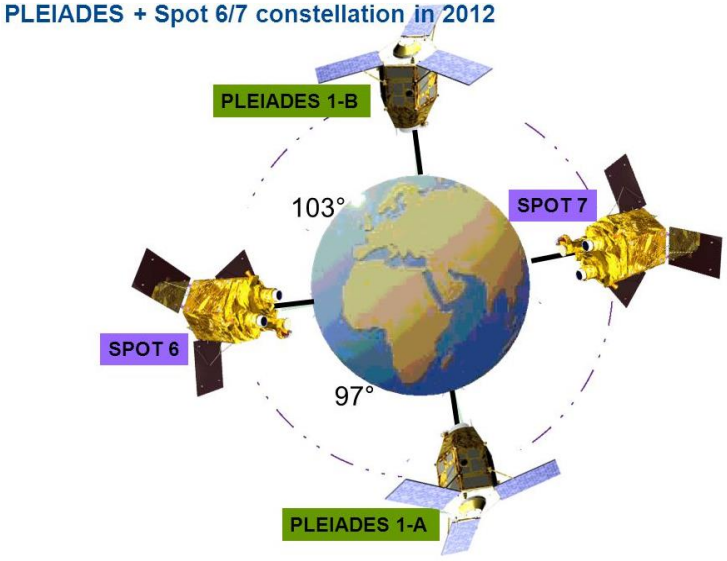
Both SPOT and Pleaides have **stereoscopic image acquisition capability** along the track (forward/backward): along-track stereo pairs and stereo triplets.



Earth Observation Satellites

SPOT-6 satellite joined the **Pleiades Constellation** and later **SPOT-7** in 2014 after proposed launch.

SPOT-6 and **SPOT-7** will cover wider areas with a resolution of **1.5m**, **Pléiades-1A** (2011) and **Pléiades-1B** (2012) will be focused on more targeted zones with a greater level of detail (**50 cm** products).



Earth Observation Satellites

	SPOT-6/7	Pleiades-1A/1B
Spectral Resolution	5 spectral bands, including a panchromatic band	5 spectral bands, including a panchromatic band
Spatial Resolution	1.5 m - panchromatic band 6 m - 4 multispectral bands (B,G,R,NIR)	0.5 m - panchromatic band 2 m - 4 multispectral bands (B,G,R,NIR)
Radiometric Resolution	12-bits	12-bits
Temporal Resolution	Twice daily, anywhere	Daily (Pleiades-1A and 1B)
Swath Width/ Scene Size	60 km at nadir	20 km at nadir

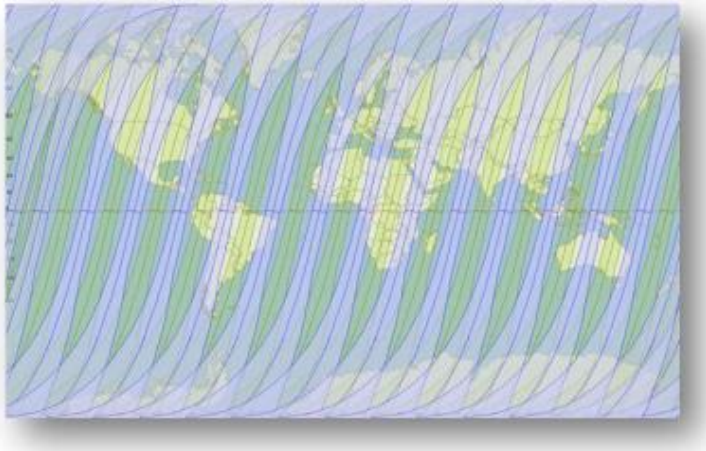
Same orbital plane. Inclination 98.2 degrees, Repeat cycle 26 days

Ciências ULisboa

Orbital Characteristics and Viewing Capability

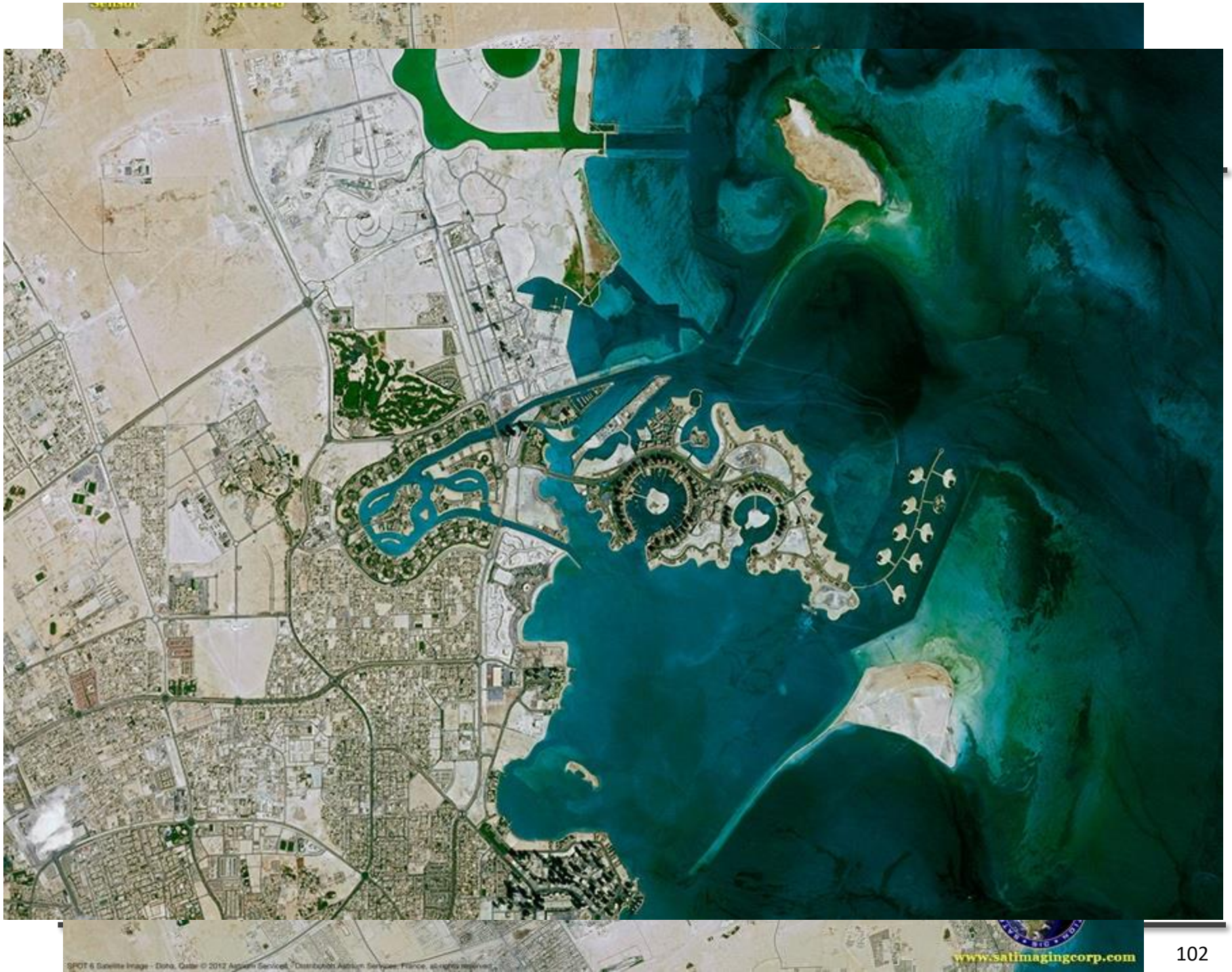
The SPOT 6 and SPOT 7 missions are designed to provide large area coverage and detailed information on individual targets. This is possible thanks to the superior agility of the satellite.

Orbit	Sun-synchronous; 10:00 AM local time at descending node
Period	98.79 minutes
Cycle	26 days
Viewing Angle	Standard: +/- 30° in roll | Extended: +/- 45° in roll
Revisit	▪ 1 day with SPOT 6 and SPOT 7 operating simultaneously ▪ Between 1 and 3 days with only one satellite in operation[1]
Pointing Agility	Control Moment Gyroscopes allow quick maneuvers in all directions for targeting several areas of interest on the same pass (30° in 14 seconds, including stabilization time)
Acquisition Capacity	Up to 6 million km^2 daily with SPOT 6 and SPOT 7 when operating simultaneously
Nominal Imaging Mode	▪ 60-km swath strips oriented along North-South axis ▪ Up to 600km length
Stereo Capability	Single pass stereo and tri-stereo (fore, nadir and aft mode)



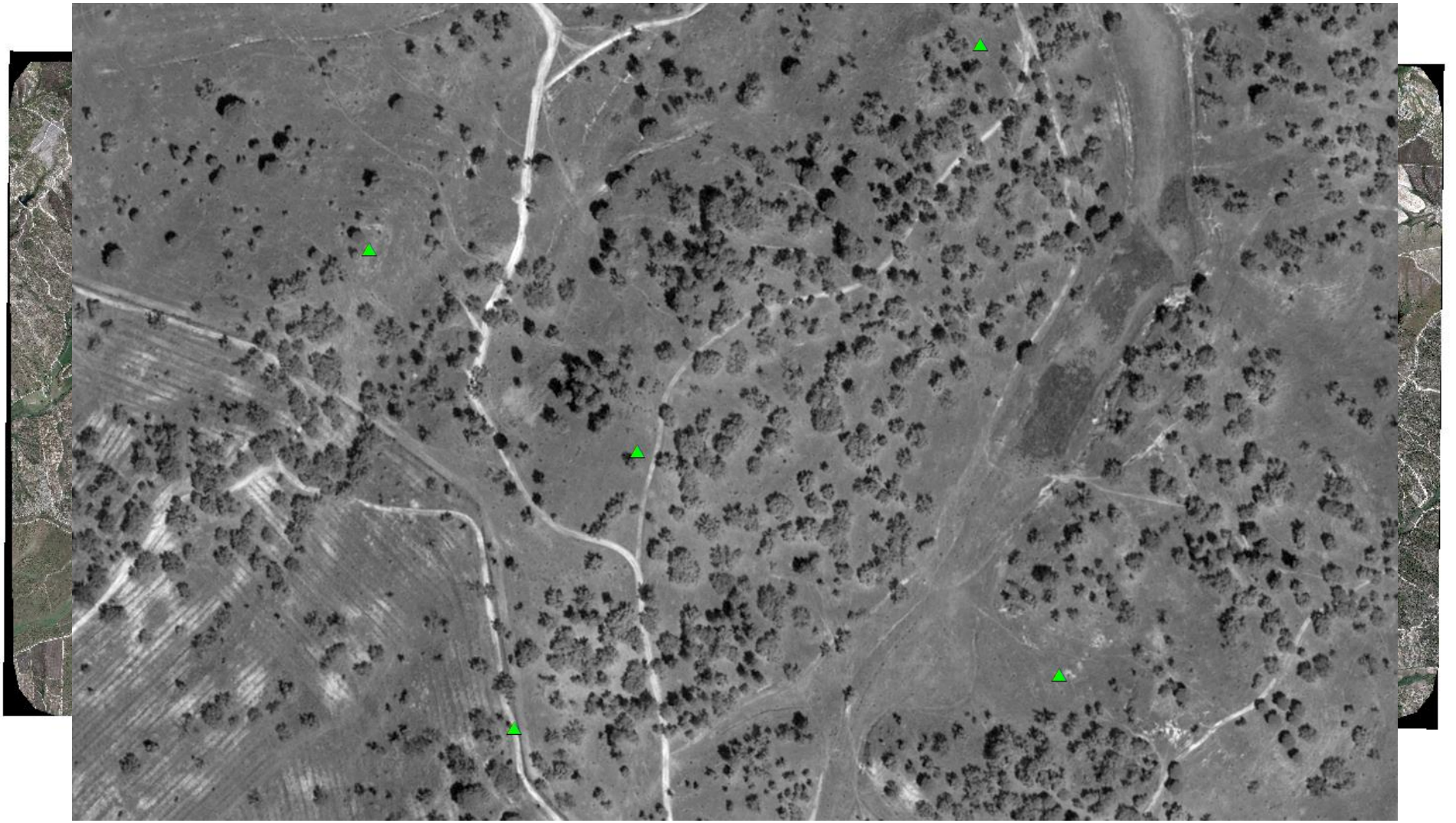
Daily revisit for the SPOT 6 and SPOT 7 constellation:

SPOT 5 – Imagem 2.5 m


SPOT 6 Satellite Image - Doha, Qatar © 2012 Astrium Services/Spot Image, Distribution Astrium Services/Spot Image, France, all rights reserved.
www.satimagingcorp.com

SPOT – Imagem 5 m

Pleiades – Pan, resolução 0.5 m

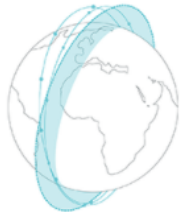


Pleiades – resolução 2 m

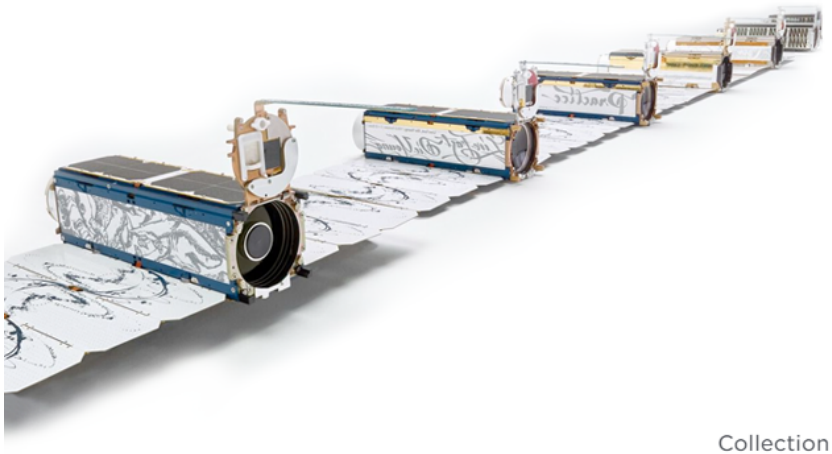
PlanetScope

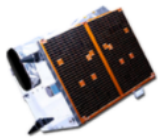
Our constellations

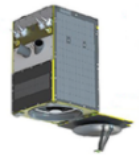
Planet operates more than 200 satellites that together provide an unprecedented dataset of Earth observation imagery. With a unique combination of coverage, frequency, and resolution Planet delivers geospatial insights at the speed of change, helping you get the most nuanced understanding of changing ground conditions.



Planet's constellation of satellites orbit the poles every 90 minutes, capturing the entire Earth's landmass every day.



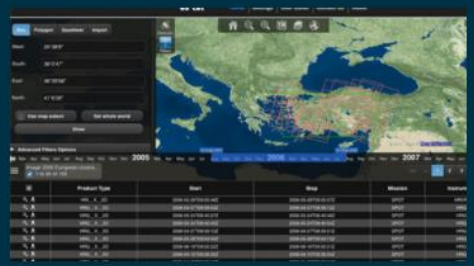




	180+ PLANETSCOPE	5 RAPIDEYE	21 SKYSAT
Collection capacity	**350M+ km²/day**	**Archive back to 2009**	**400K km²/day**

PlanetScope

Featured



ESA's Earth Observation Catalogue and its services

EO-CAT is the EO Catalogue tool allowing users to search ESA and Third Party Mission collections.

PlanetScope

About PlanetScope

The PlanetScope satellite constellation consists of mu

Mission Parameters

Orbit altitude	475 km
Orbit type	Sun-synchronous
Orbit inclination	98°
Repeat Cycle	Daily
Equator Crossing Time	9:30 - 11:30 am (local solar time)

PlanetScope Camera

The PlanetScope camera on each DOVE cubesat operates currently in four bands - red, green,

Sensor Type	Three-band frame Imager or four-band frame Imager with a split-frame NIR filter (DOVE-C) Four-band frame imager with butcher-block filter providing blue, green, red, and NIR stripes (DOVE-R) Eight-band frame imager with butcher-block filter providing blue, green, red, red-edge, and NIR stripes (SuperDove)
Spectral Bands Blue Green Red RedEdge NIR	 455 – 515 nm 500 – 590 nm 590 – 670 nm 733 – 748 nm 780 – 860 nm
Ground Sample Distance (nadir)	3.9
Frame Size	24 km x 8 km (approximate) for DOVE-C 24 km x 16 km (approximate) for DOVE-R 32.5 km x 19.6 km (approximate) for SuperDove
Maximum Image Strip per orbit	20,000 km^2
Revisit Time	Daily at nadir (2017)
Image Capture Capacity	200 million km^2/day

PlanetScope

VISUAL PRECISION, ANALYTIC POWER

Access color-corrected 3-band and sensor-calibrated multispectral products. Basic, orthorectified, radiance, and surface reflectance imagery are available.



	PLANETSCOPE	RAPIDEYE	SKYSAT
Bands	4 (RGB, NIR)	5 (RGB, red edge, NIR)	5 (RGB, NIR, pan)
Products	Color enhanced Visual Analytic	Color enhanced Visual Analytic	Visual Panchromatic Pansharpened multispectral Analytic
Pixel Resampled	3 m	5 m	Visual, panchromatic, pansharpened multispectral: 0.5m
Radiometric Resolution	Visual: 8 bit Analytic: 16 bit		Visual: 8 bit Analytic, panchromatic, and pansharpened multispectral: 16 bit
Positional Accuracy	<10 m RMSE		
File Format	GeoTIFF		

Ciências ULisboa

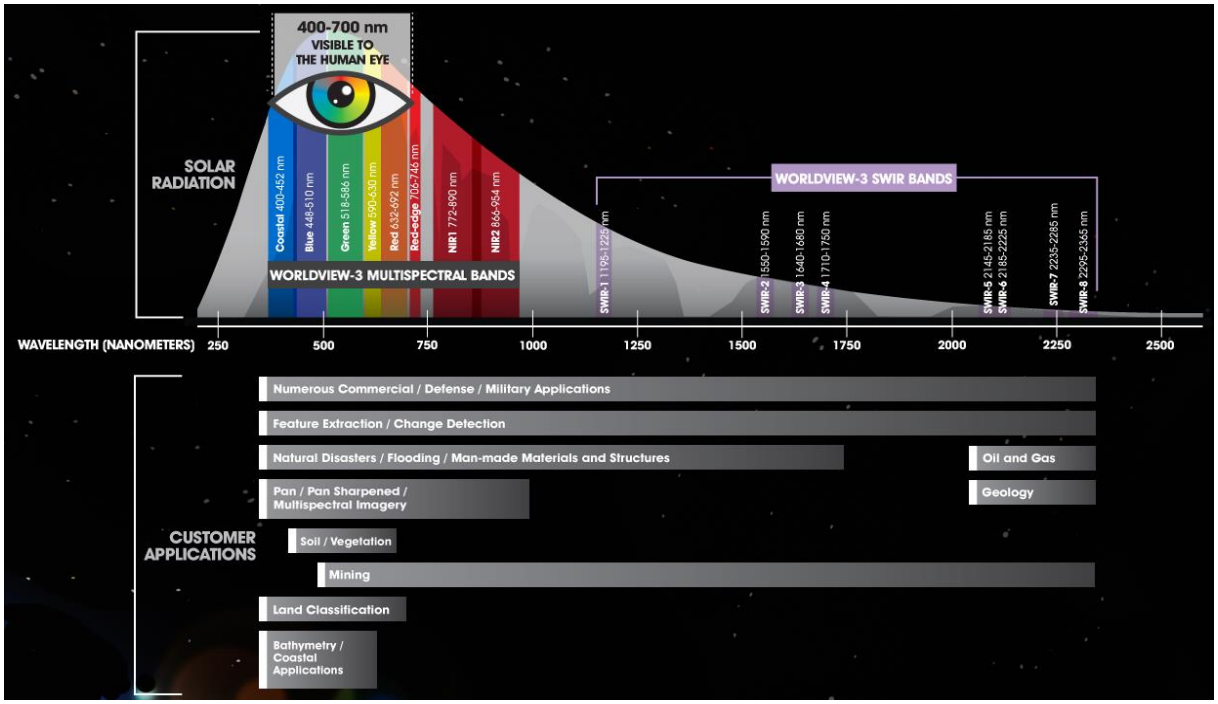
PlanetScope

Other Systems

http://www.satimagingcorp.com/satellite-sensors/worldview-3/

WorldView-3 satellite sensor is the first multi-payload, super-spectral, high-resolution commercial satellite sensor operating at an altitude of 617 km.

WorldView-3 provides **31 cm** panchromatic resolution, 1.24 m multispectral resolution, 3.7 m short wave infrared resolution.

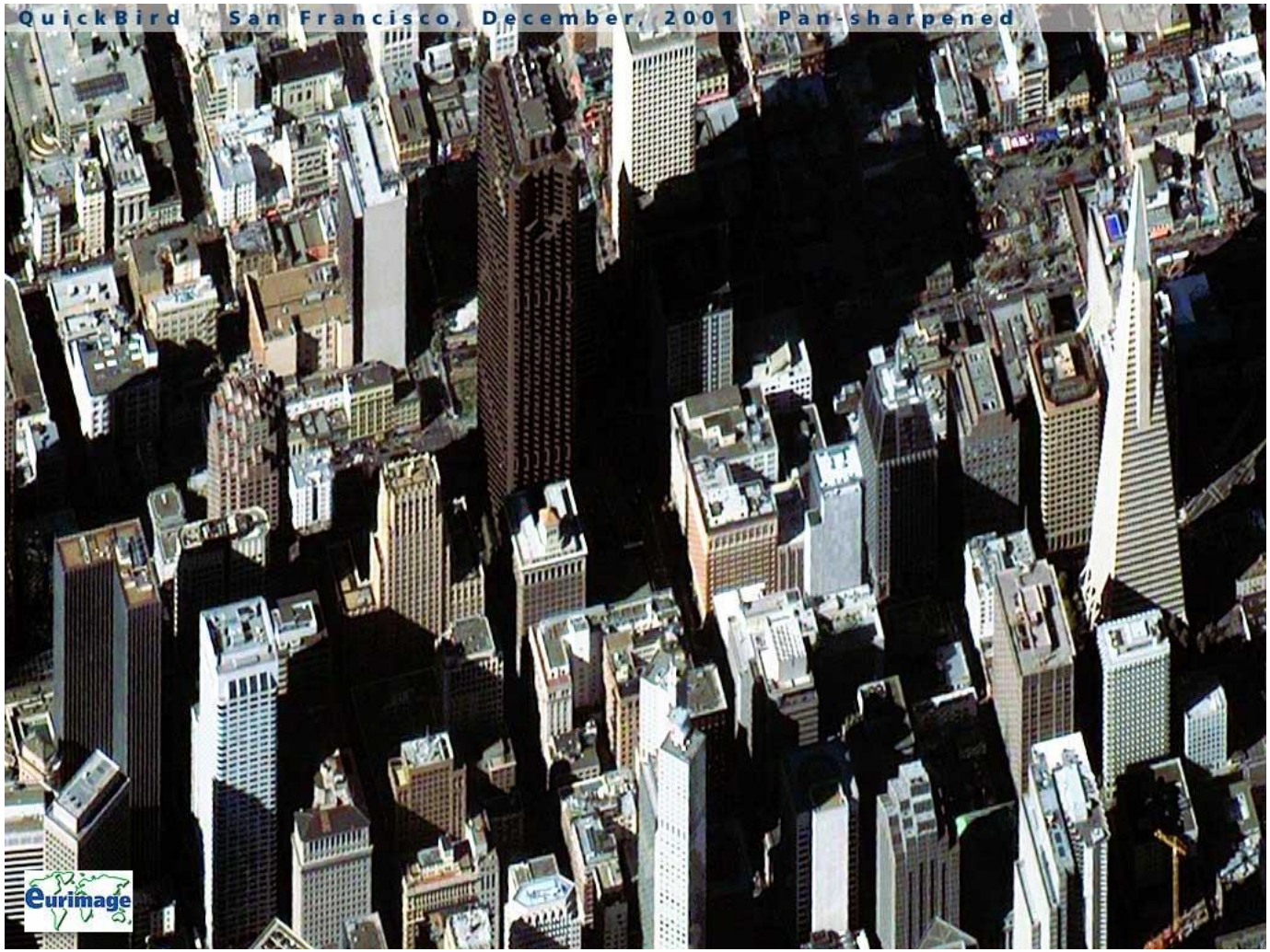


- GeoEye-1 (0.46m)
- GeoEye-2 (0.34m)
- WorldView-1 (0.46m)
- WorldView-2 (0.46m)
- WorldView-3 (0.31m)
- Pleiades-1A (0.5m)
- Pleiades-1B (0.5m)
- KOMPSAT-3A (0.55m)
- KOMPSAT-3 (0.7M)
- QuickBird (0.65m)
- IKONOS (0.82m)
- SkySat-1 (0.9m)
- SkySat-2 (0.9m)
- TripleSat (1m)
- TerraSAR-X
- SPOT-6 (1.5m)
- SPOT-7 (1.5m)
- Other Satellites (2m-20m)

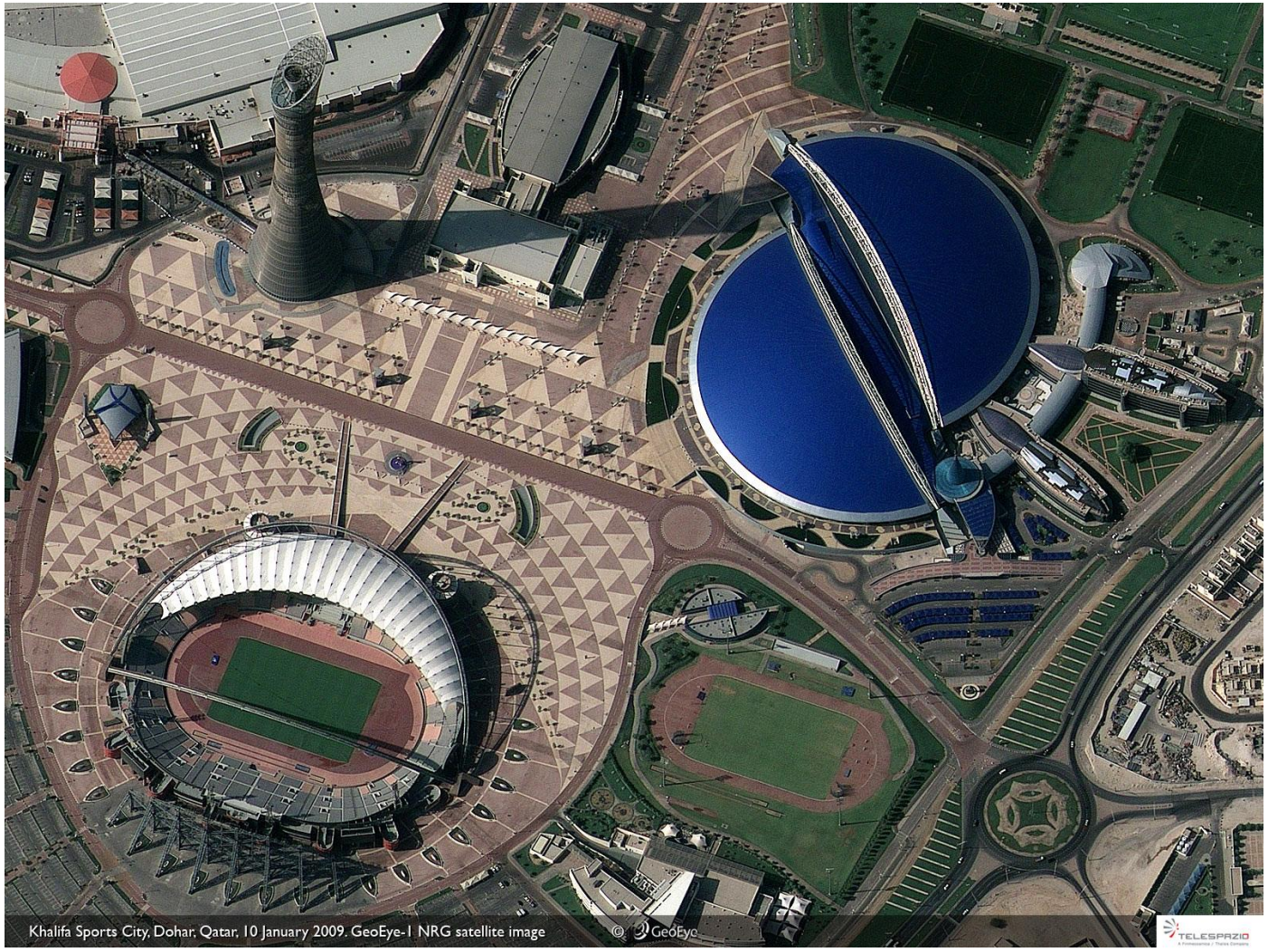
Ciências
ULisboa

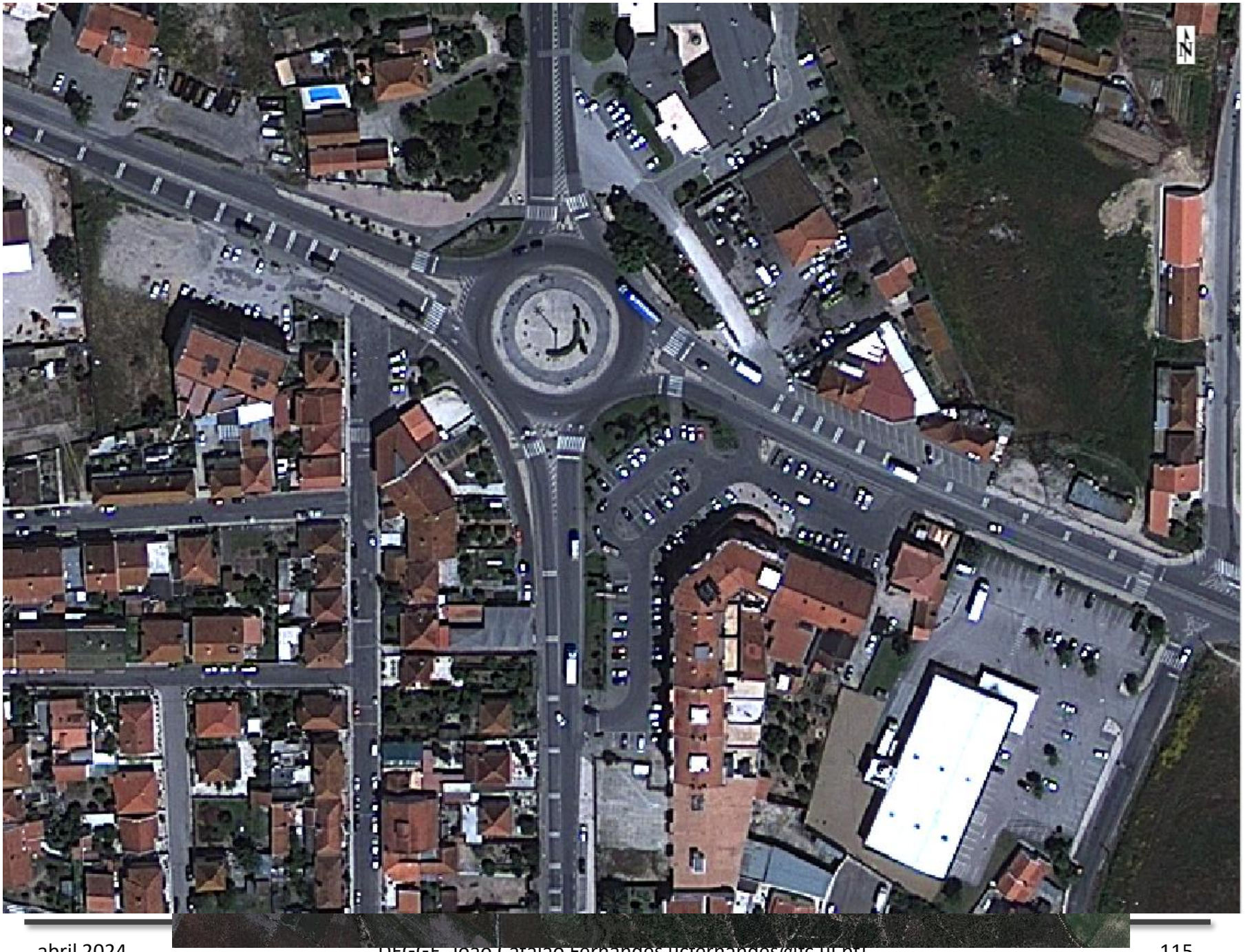
QUICKBIRD

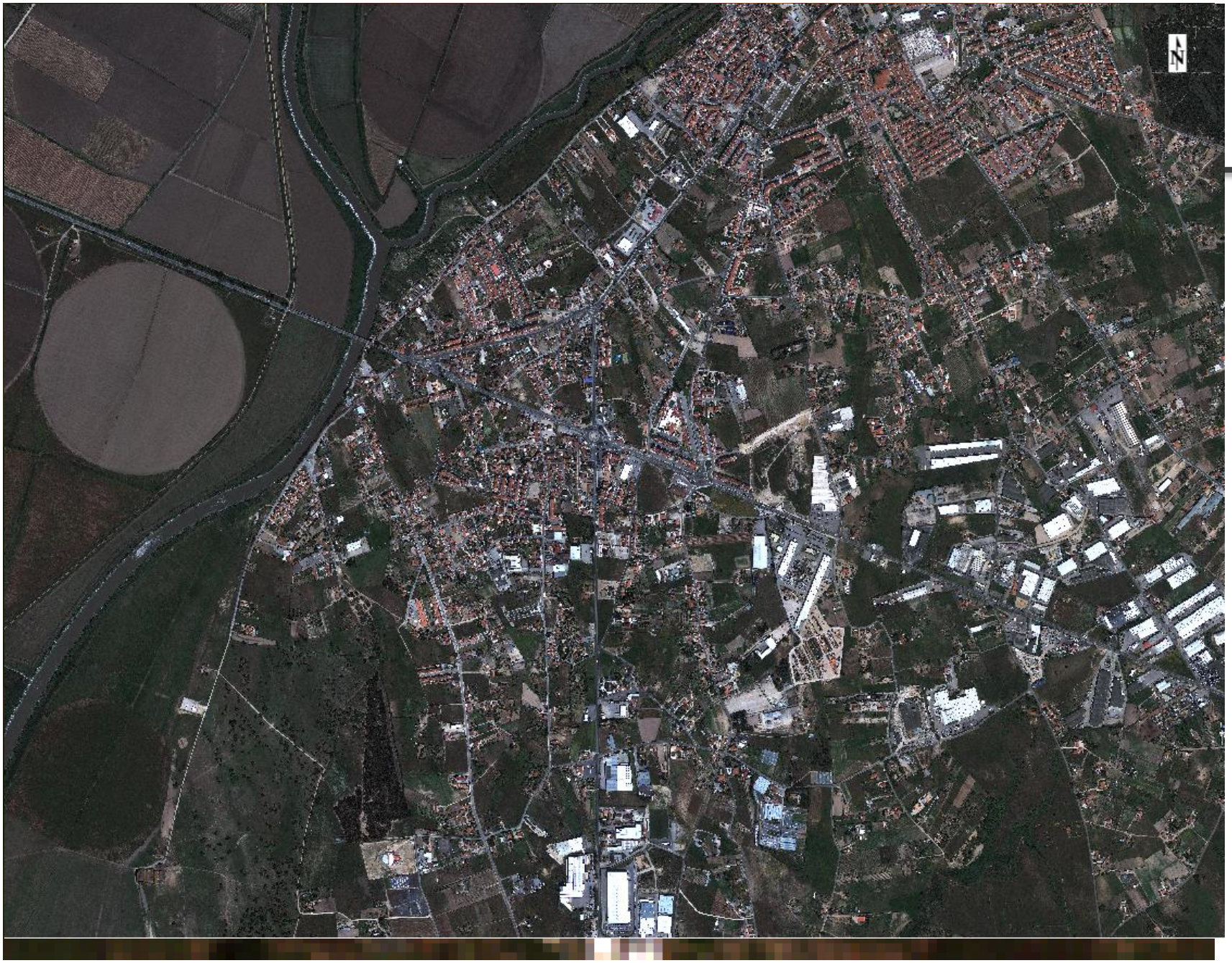
QUICKBIRD


QuickBird San Francisco, December, 2001 Pan-sharpened
Eurimage

GeoEye

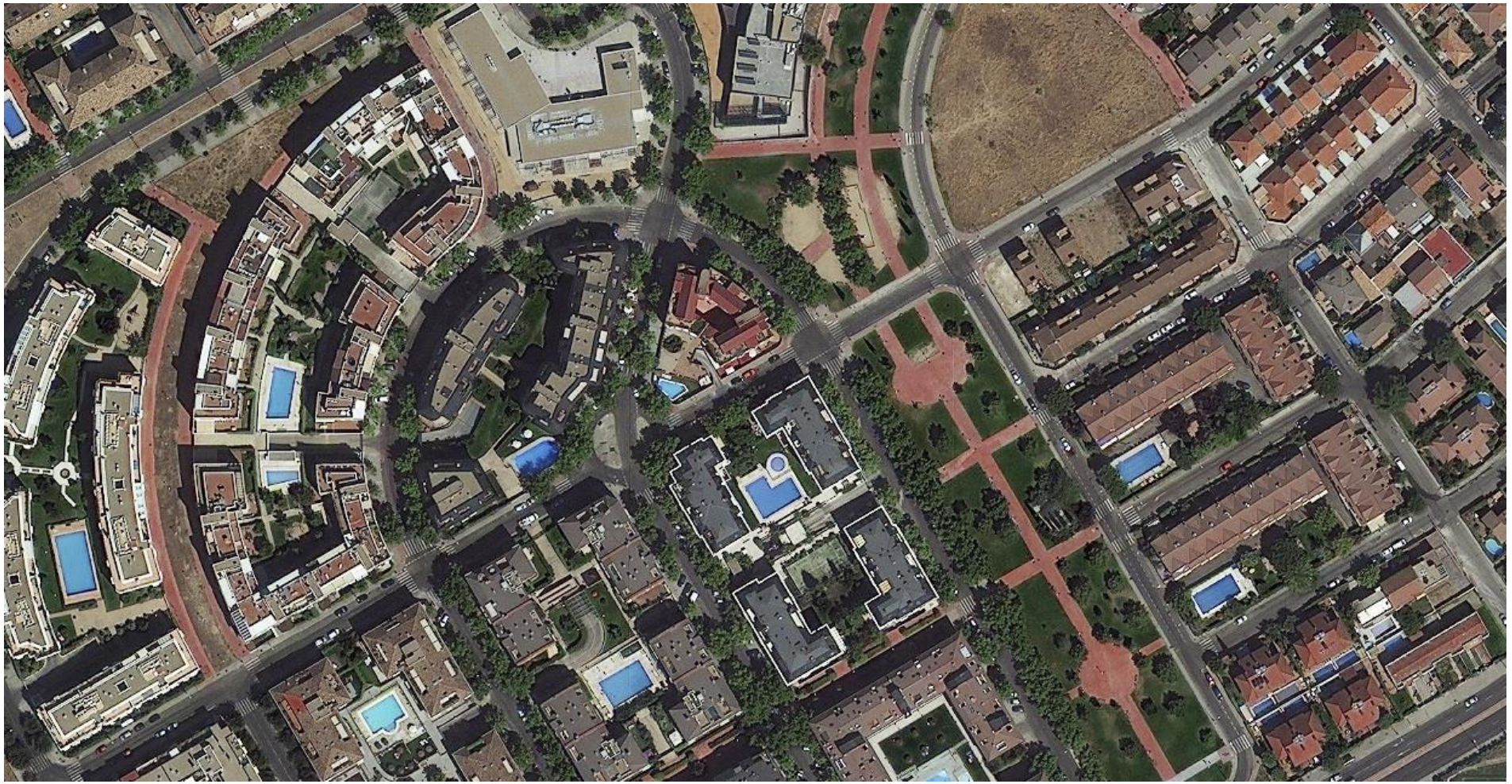

Khalifa Sports City, Dohar, Qatar, 10 January 2009. GeoEye-1 NRG satellite image
© GeoEye
TELESPAZIO





Worldview

8 bandas, 0.31 / 1.24 m




Worldview
2m
N

Disponibilização da OrtoSat2023

Cobertura de imagens de satélite de 30 cm para Portugal Continental

/ 07 06 2024 /

https://smos.dgterritorio.gov.pt/vi-smos/

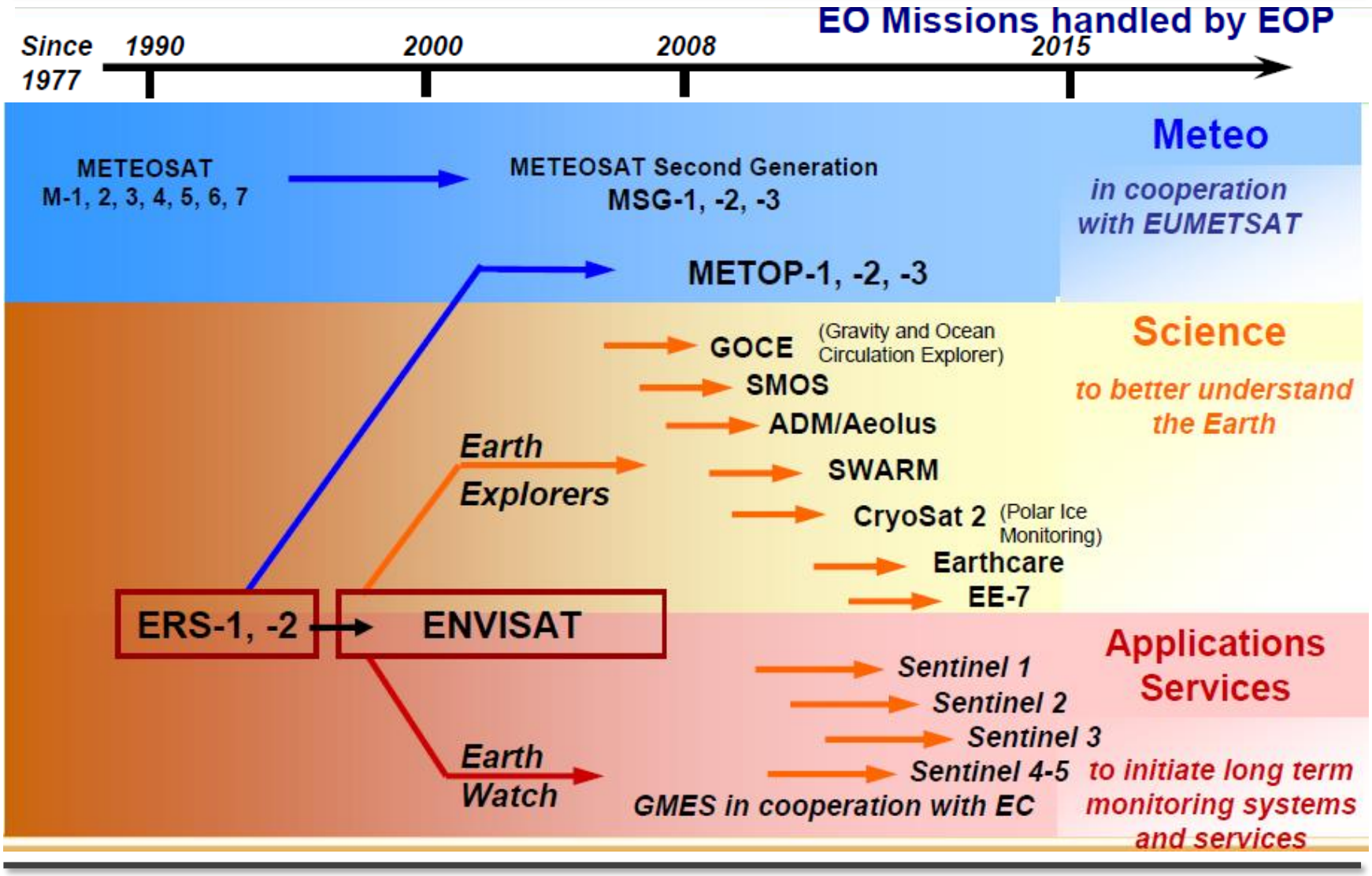
OrtoSat2023 (30 cm)

Ortofoto 2018 (25 cm)

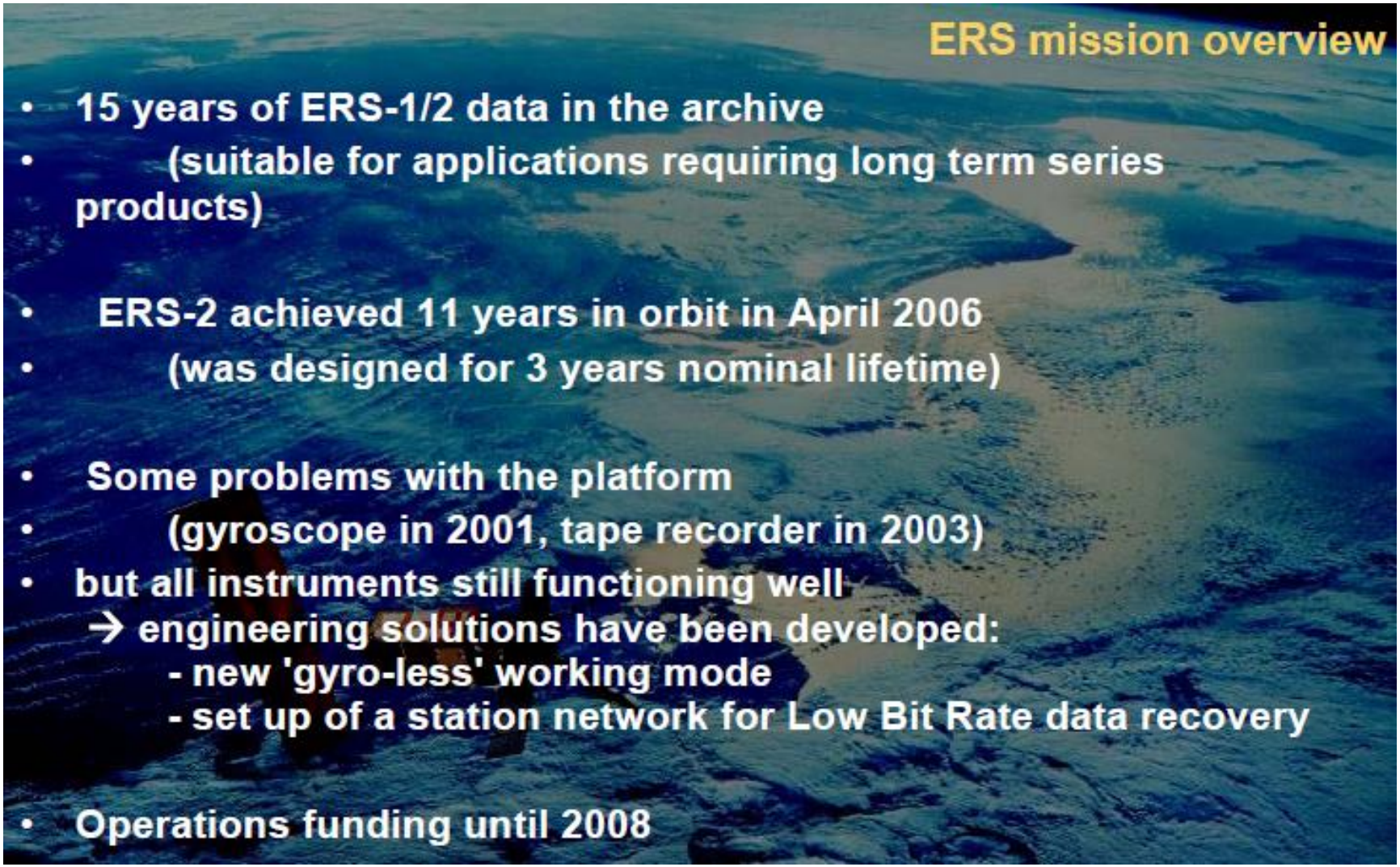
Esta cobertura de imagens, designada OrtoSat2023, foi obtida com imagens de satélite Pléiades Neo adquiridas durante o ano de 2023 sobre o território de Portugal continental. A cobertura é composta por um mosaico equalizado e ininterrupto de imagens ortorretificadas com uma resolução espacial de 30 cm.

Orto Sat vs Ortoimagem

ESA Missions



ERS mission (European Remote Sensing)

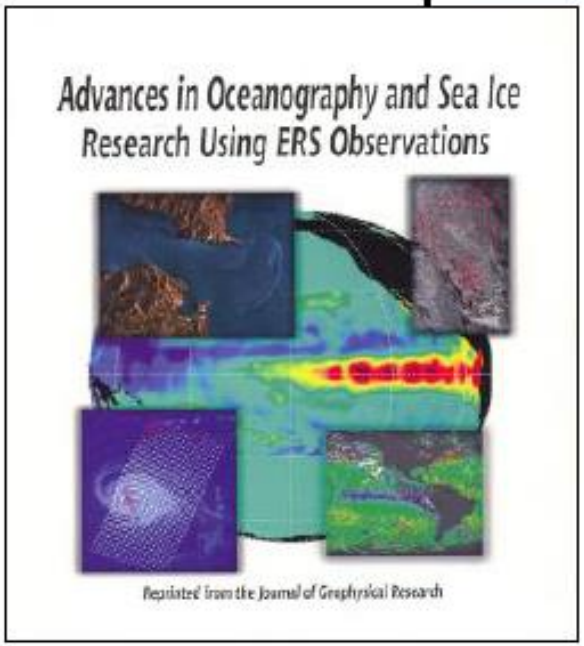


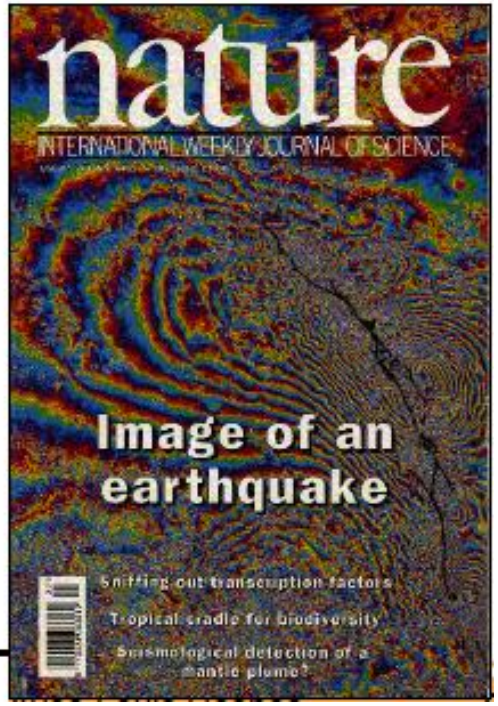
ENVISAT Mission

ERS missions - Science

ERS and Volcanic activities

Oceanography and sea Ice



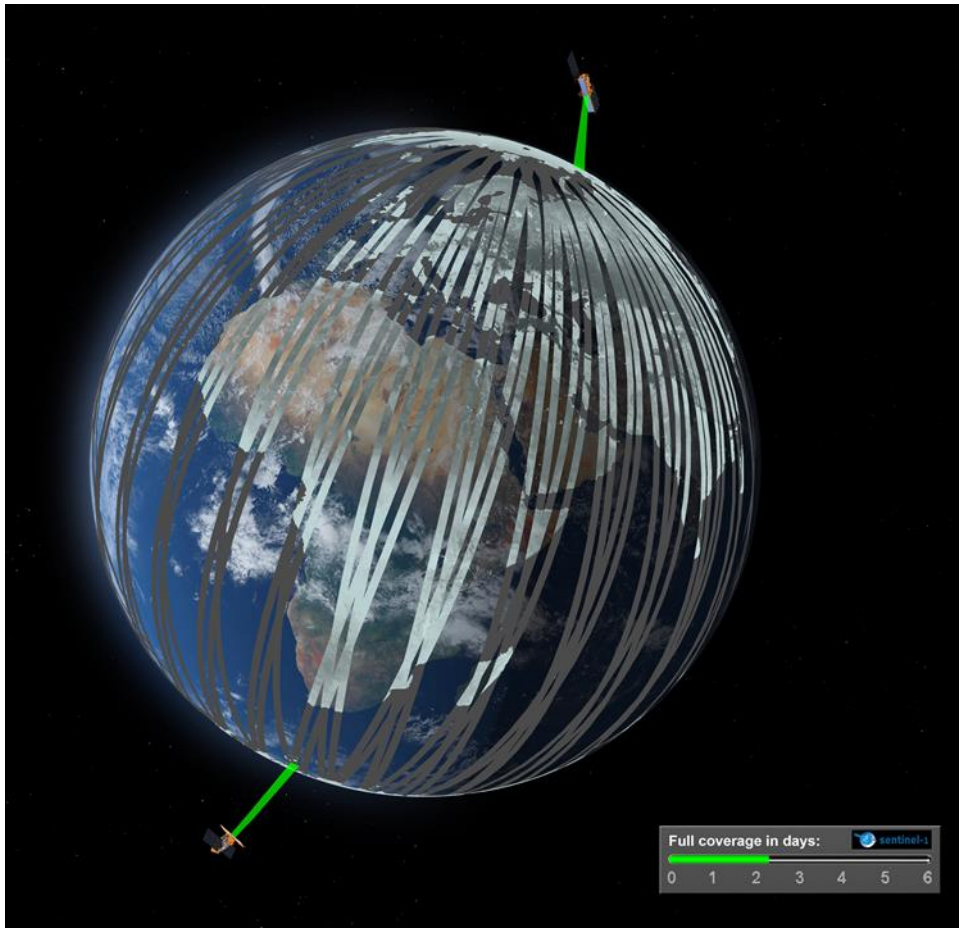


ERS and SAR Interferometry

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.



GMES

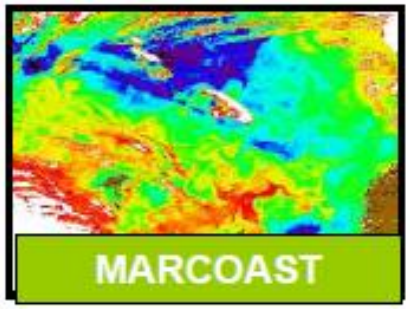
Global Monitoring for Environment and Security (GMES)

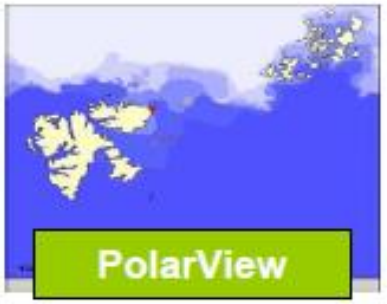
European autonomy in data sources for environment and security monitoring

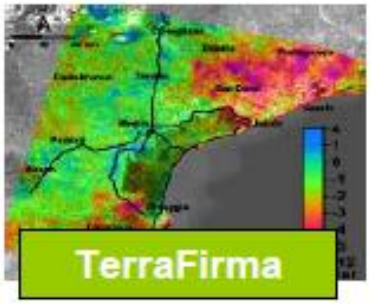
and

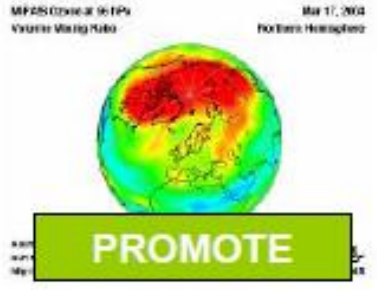
The European contribution to the Global Earth Observation System of Systems (GEOSS)

GMES - Services









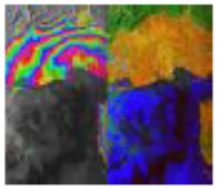
100 M€ by ESA MS

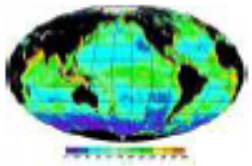
Period 2003-2008 (2009)

300+ user organisations

EC has invested another 100 M€

GMES – Componente Espacial





- **Sentinel 1 – SAR imaging**
  - All weather, day/night applications, interferometry, ocean/ice/land
- **Sentinel 2 – Superspectral imaging**
  - Continuity of Landsat, SPOT - type of data for land mapping
- **Sentinel 3 – Ocean monitoring**
  - Wide-swath ocean color, surface temperature and land mission & radar altimeter
- **Sentinel 4 – Geostationary atmospheric**
  - Atmospheric composition monitoring, trans-boundary pollution
- **Sentinel 5 – Low-orbit atmospheric**
  - Atmospheric composition monitoring

Sentinel -2

Sentinel-2 Mission

Sentinel-2 mission comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other.

It aims at monitoring variability in land surface conditions, and its wide swath width (290 km) and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days at mid-latitudes) will support monitoring of Earth's surface changes.

The coverage limits are from between latitudes 56° south and 84° north.

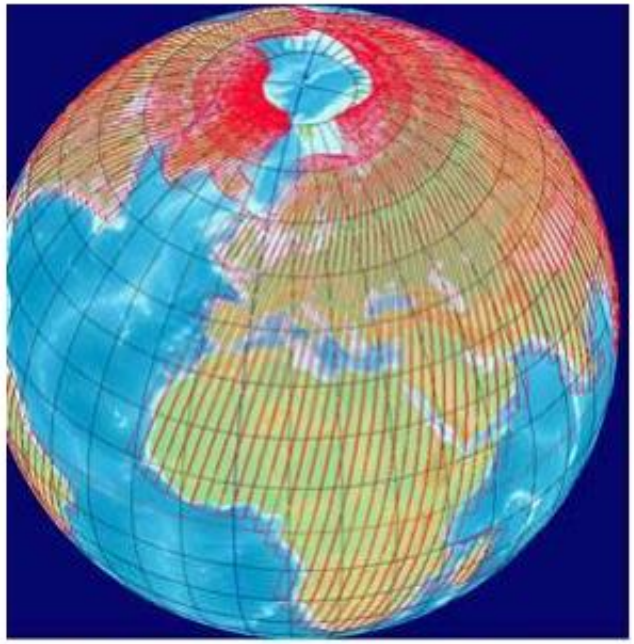
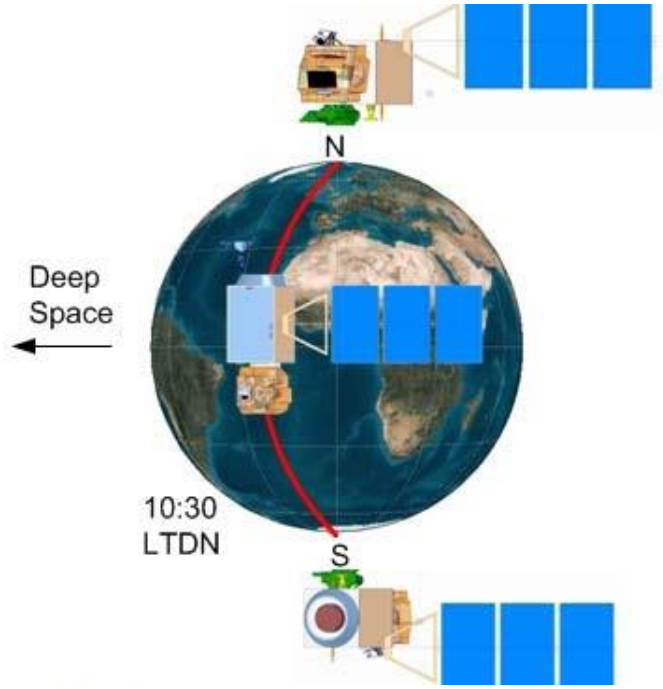


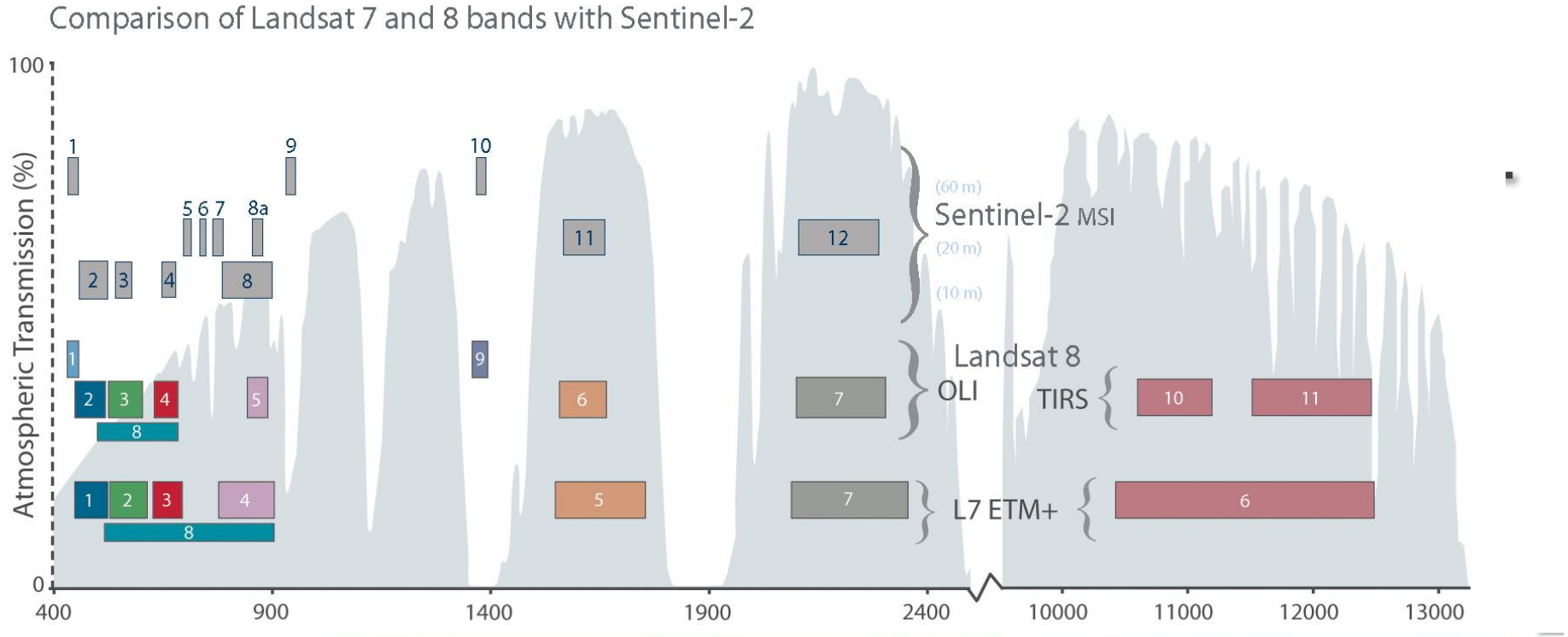
Figure 22: Modelled Sentinel-2 Coverage

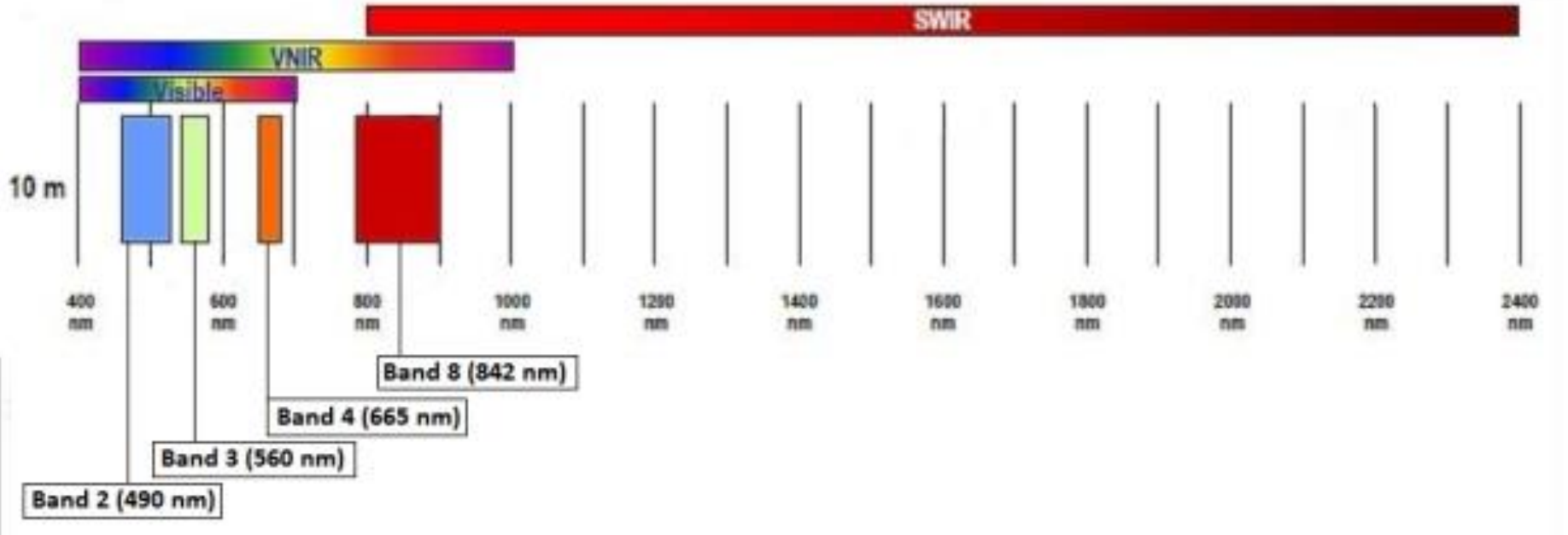
Sentinel -2

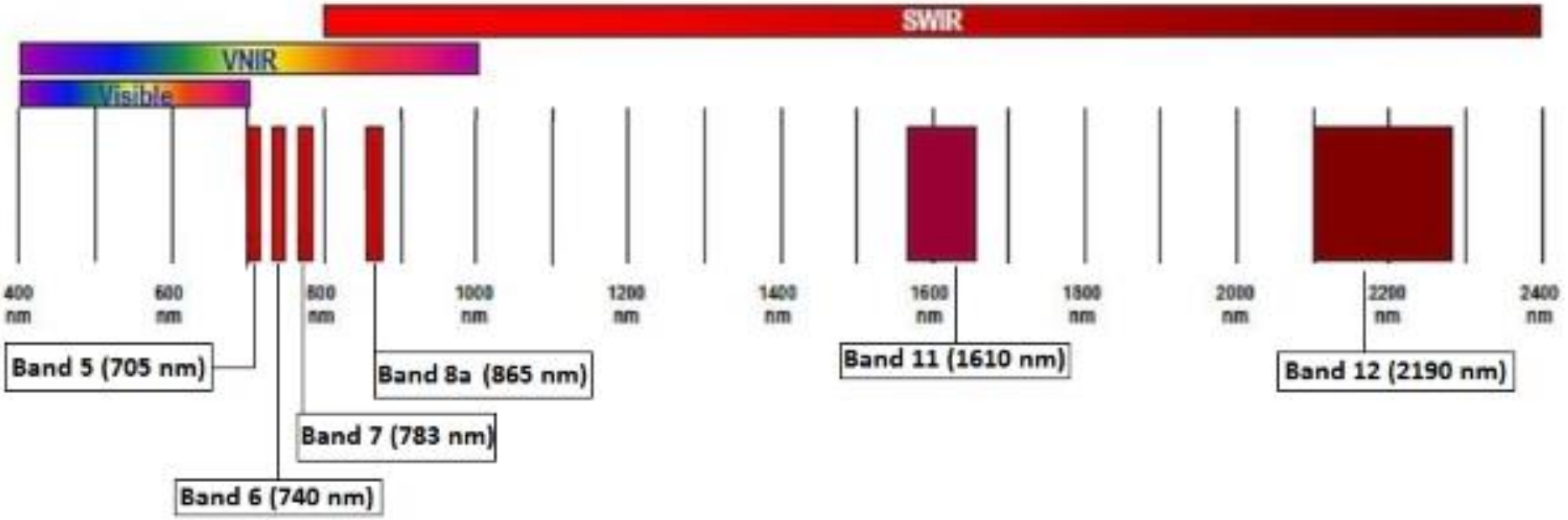
The **Sentinel-2** satellites are placed in the same sun-synchronous orbit, phased at 180° to each other, at an altitude of 786 km and an inclination of 98.5 degrees for 14.3 revolutions per day and a 10:30 Local Time of **Descending Node** that has been chosen to minimize cloud cover and ensure a good solar illumination of Earth's surface.

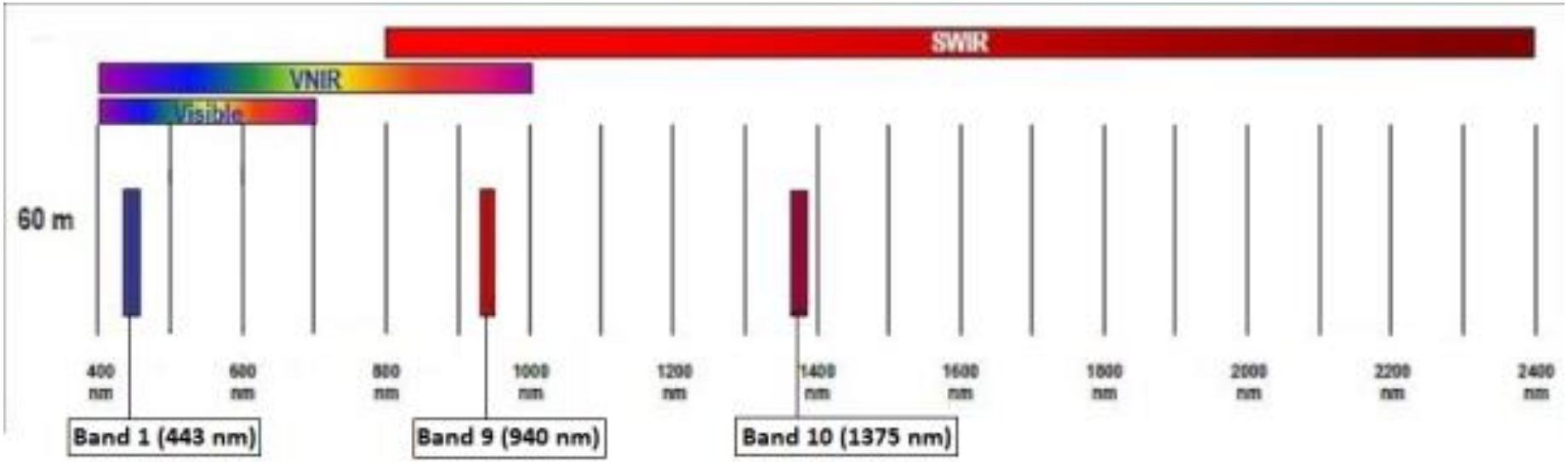
Sentinel-2 carries a single pushbroom sensor: the **Multispectral Imager (MSI)** that covers 13 spectral bands.



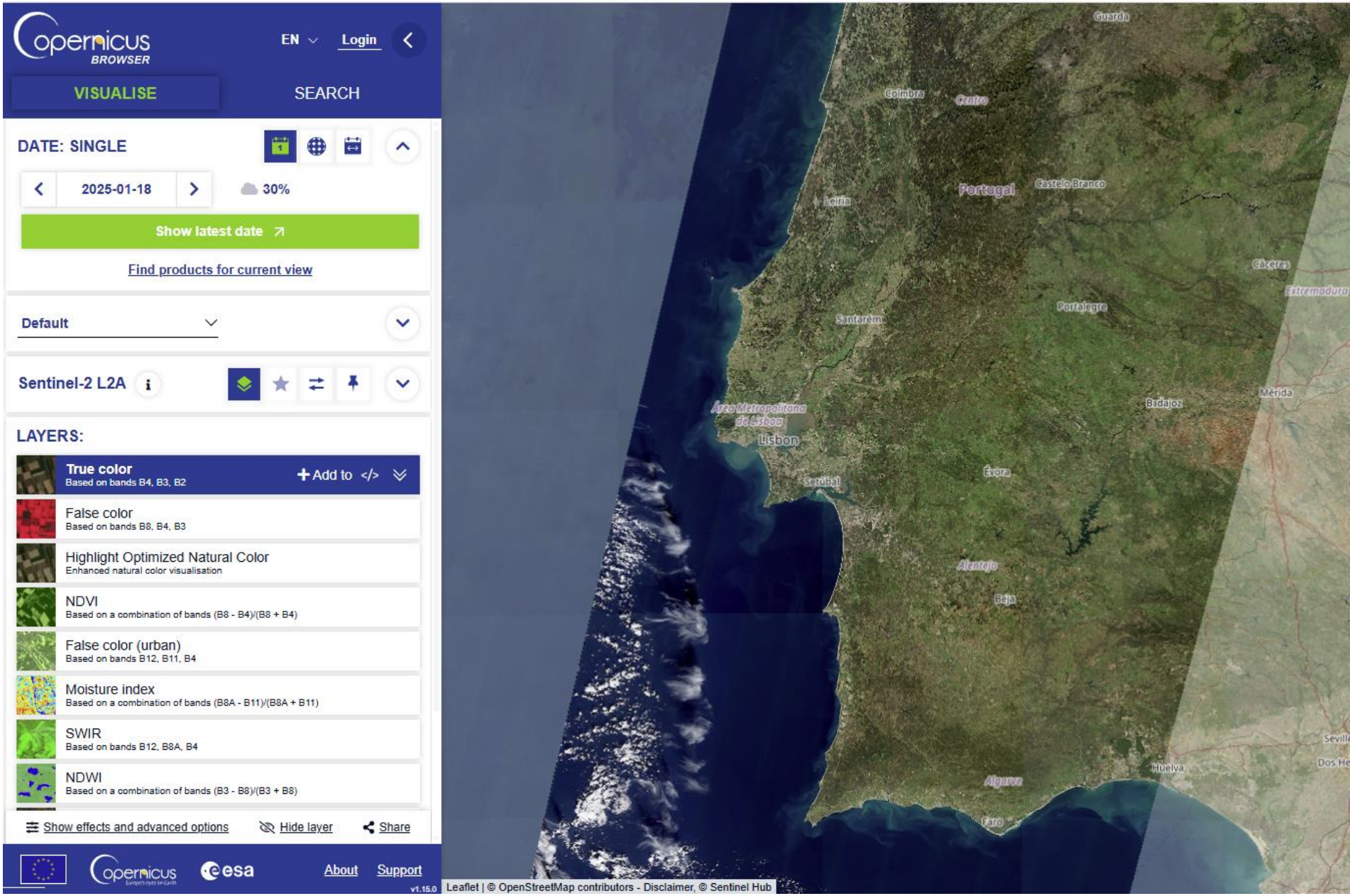

Comparison of Landsat 7 and 8 bands with Sentinel-2
Atmospheric Transmission (%)
100
0
400
900
1400
1900
2400
10000
11000
12000
13000
1
9
10
5 6 7
8a
2 3 4 8
11
12
(60 m)
Sentinel-2 MSI
(20 m)
(10 m)
1
9
2 3 4
5
6
7
Landsat 8
OLI
TIRS
10
11
8
1 2 3
4
5
7
L7 ETM+
6
8


SWIR
VNIR
Visible
10 m
400 nm
600 nm
800 nm
1000 nm
1200 nm
1400 nm
1600 nm
1800 nm
2000 nm
2200 nm
2400 nm
Band 8 (842 nm)
Band 4 (665 nm)
Band 3 (560 nm)
Band 2 (490 nm)


SWIR
VNIR
Visible
400 nm
600 nm
800 nm
1000 nm
1200 nm
1400 nm
1600 nm
1800 nm
2000 nm
2200 nm
2400 nm
Band 5 (705 nm)
Band 8a (865 nm)
Band 11 (1610 nm)
Band 12 (2190 nm)
Band 7 (783 nm)
Band 6 (740 nm)


SWIR
VNIR
Visible
60 m
400 nm
600 nm
800 nm
1000 nm
1200 nm
1400 nm
1600 nm
1800 nm
2000 nm
2200 nm
2400 nm
Band 1 (443 nm)
Band 9 (940 nm)
Band 10 (1375 nm)

https://browser.dataspace.copernicus.eu/



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