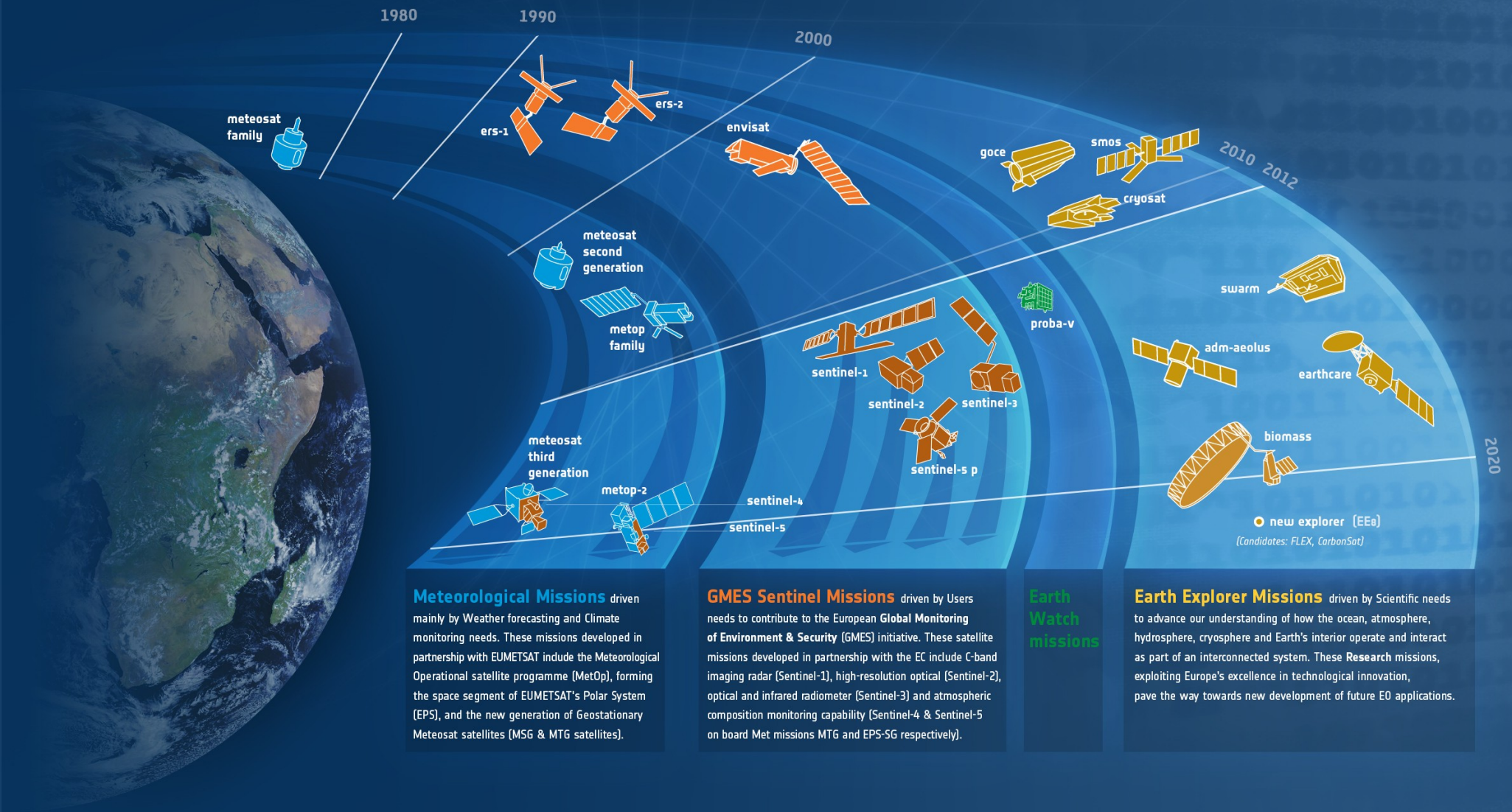
The GMES/Copernicus Sentinels Missions and their Exploitation for Science and Applications

Yves-Louis DESNOS,
Head of R&D section and Senior Advisor
Science, Applications, and Future Technologies Department
ESA Directorate of Earth Observation Programmes
European Space Agency
ESRIN, FRASCATI, ITALY

European Space Agency

→ THE ESA EARTH OBSERVATION PROGRAMME



Meteorological Missions driven mainly by Weather forecasting and Climate monitoring needs. These missions developed in partnership with EUMETSAT include the Meteorological Operational satellite programme (MetOp), forming the space segment of EUMETSAT's Polar System (EPS), and the new generation of Geostationary Meteosat satellites (MSG & MTG satellites).

GMES Sentinel Missions driven by Users needs to contribute to the European **Global Monitoring of Environment & Security** (GMES) initiative. These satellite missions developed in partnership with the EC include C-band imaging radar (Sentinel-1), high-resolution optical (Sentinel-2), optical and infrared radiometer (Sentinel-3) and atmospheric composition monitoring capability (Sentinel-4 & Sentinel-5 on board Met missions MTG and EPS-SG respectively).

Earth Watch missions

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

OBSERVING OUR PLANET FOR A SAFER WORLD

A joint ESA/European Commission initiative, **Global Monitoring for the Environment and Security (GMES)/Copernicus** is the response to Europe's need for geo-spatial information services. It will provide autonomous and independent access to information for policy-makers, particularly for environment and security issues.

ESA is implementing the space component: developing the **Sentinel** satellite series, its ground segment and coordinating data access.

What is Copernicus?

Copernicus Services Component

Competences

European Commission

Coordination & Management

- Space Component
- Services Component
- In-Situ Component

European Commission

EEA

Programme Name

Copernicus Space Component - Status

S1A/B: Radar Mission; Launch S1A beginning 2014/end 2015

S2A/B: High Resolution Optical Mission; Launch 2014/2016

S3A/B: Medium Resolution Imaging and Altimetry Mission; Launch 2014/2017

S4A/B: Geostationary Atmospheric Chemistry Mission; Launch 2019/2027

S5P: Low Earth Orbit Atmospheric Chemistry Mission; Launch 2015

S5A/B: Low Earth Orbit Atmospheric Chemistry Mission; Launch 2020/2027

Jason-CS: Altimetry Mission; Launch beginning 2019/2025

GMES Sentinel Data Policy

- ✓ **The Sentinel data policy will be jointly decided by ESA and EC**
- ✓ **ESA Member States and EC have prepared joint principles of a Sentinel data policy in Sep 2009, which focus on:**

➔ **Access to Sentinel data by anybody (European and non-European users) and for any use ("full and open")**

➔ **Free of charge data licenses ("free")**

➔ **Some restrictions may be required (e.g. security, technical constraints, etc.)**

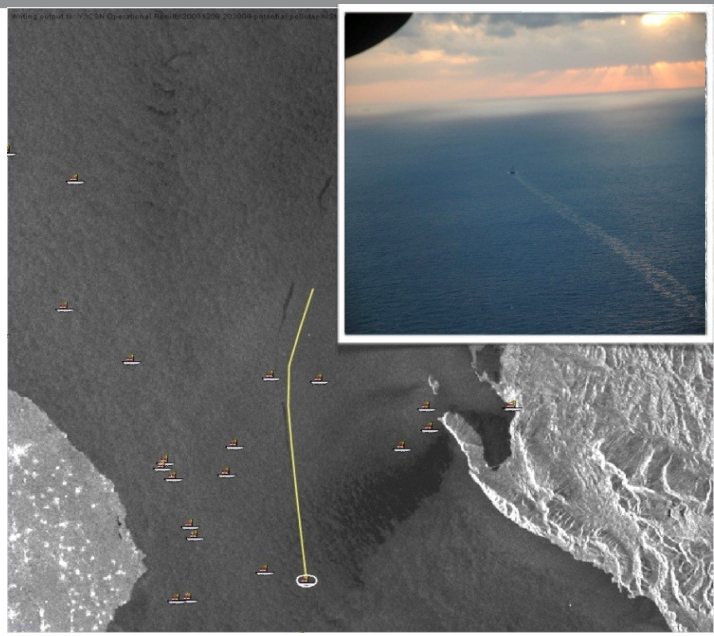
- ✓ **EC has been mandated by its Member States and the European Parliament to define the overall GMES data and information policy**
  ➔ Sentinel data policy is part of it
- ✓ **The Sentinel data policy is expected to be finalized in 2013**

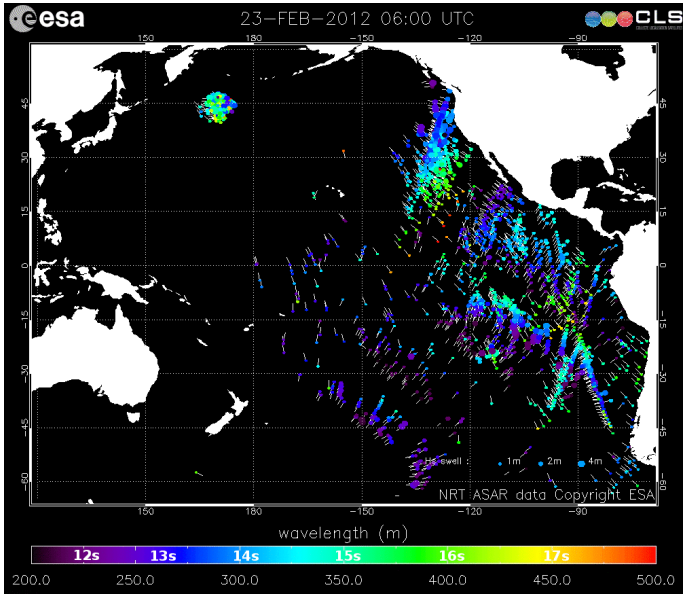

SENTINEL-1
esa
P.CARRIL 2007

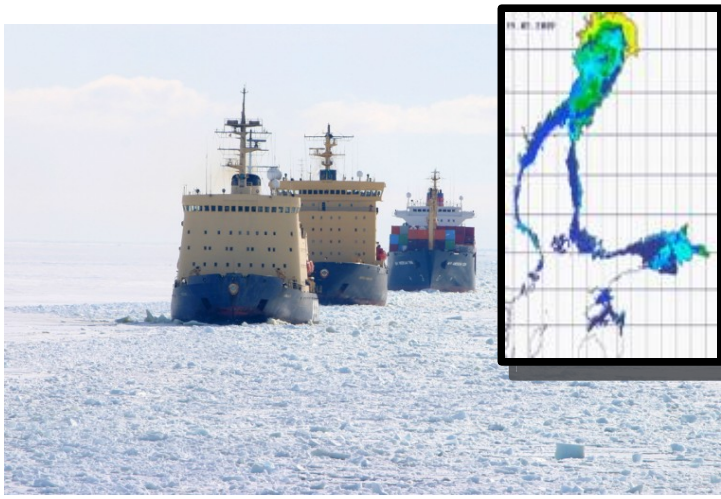
Sentinel-1 Mission Objectives

Provide routinely and systematically SAR data to GMES Services and National services:

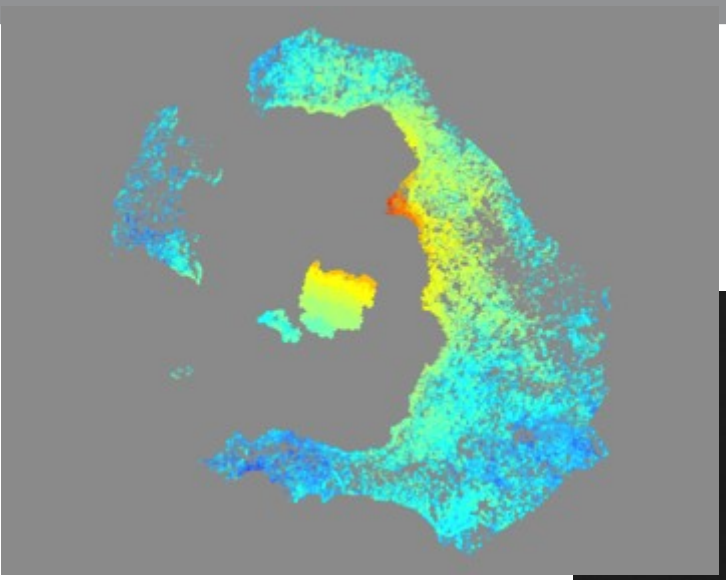
- ✓ Marine Monitoring (e.g. oil spill, sea ice)
- ✓ Land Monitoring (e.g. land cover, surface deformation)
- ✓ Emergency Response
- ✓ Climate Change (e.g. Polar caps incl. ice shelves and glaciers)
- ✓ Security (e.g. vessel detection)



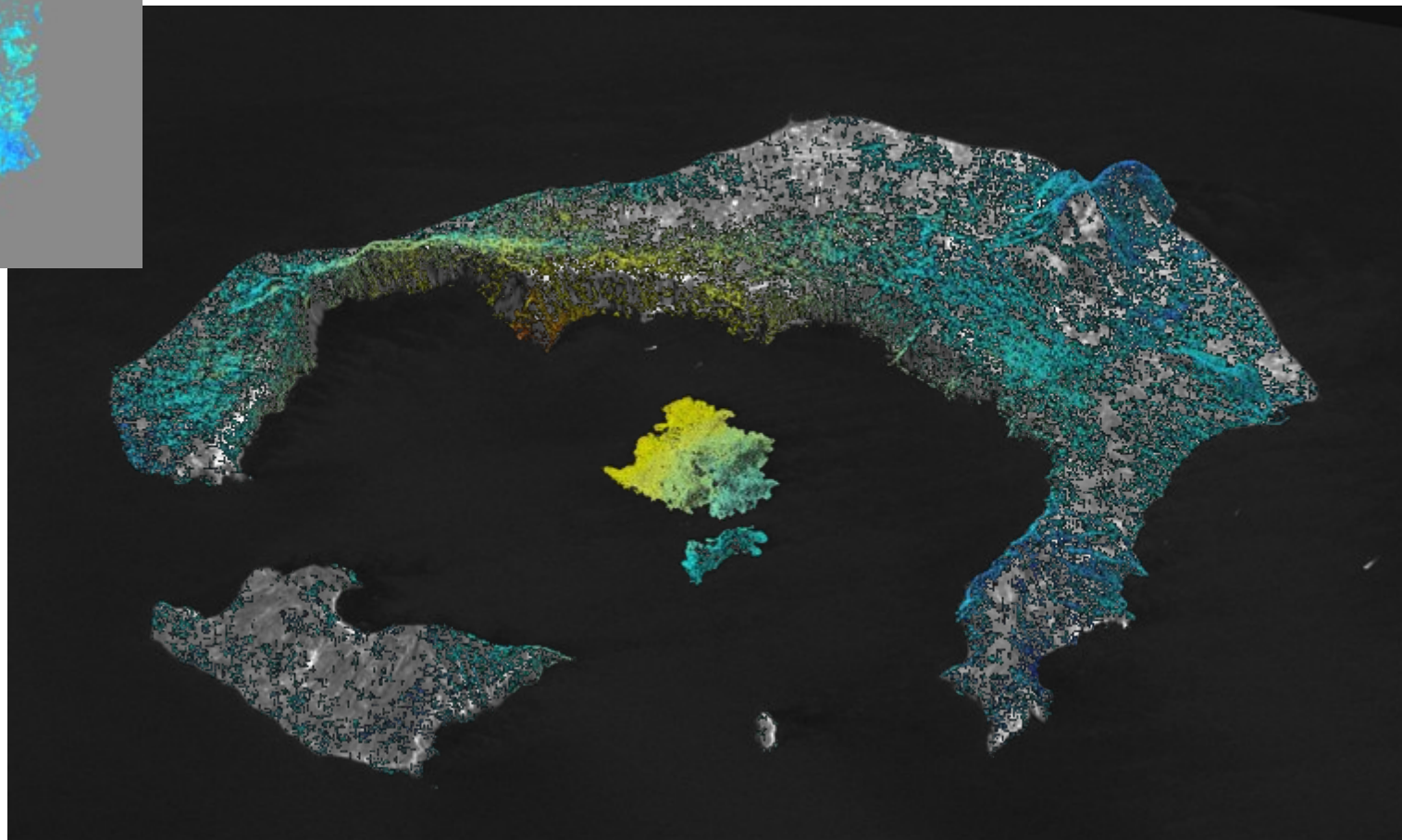




Continued ENVISAT exploitation
Santorini Volcanic Complex



An unrest of Santorini Volcanic Complex was observed from beginning of 2011, while currently the deformation signals show decreasing rates of uplift.



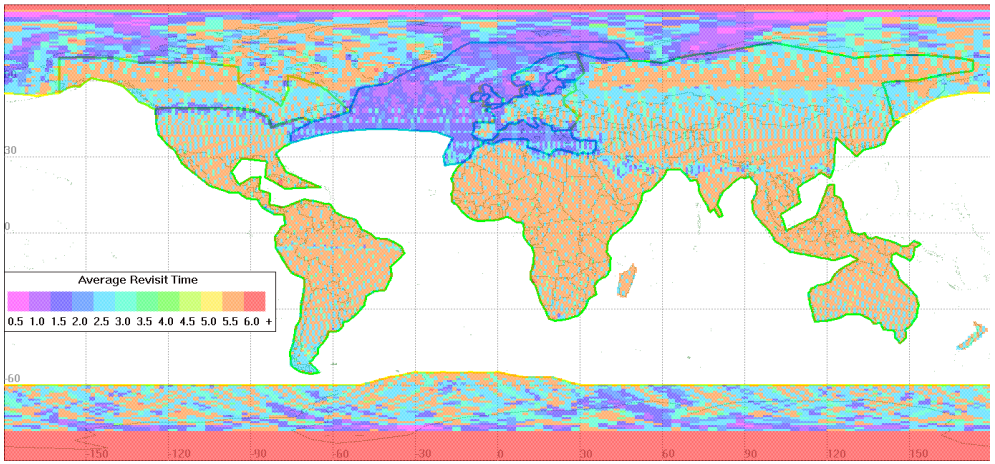
Ground deformation rates from advanced InSAR processing of ENVISAT ASAR data acquired between March 2011 – March 2012

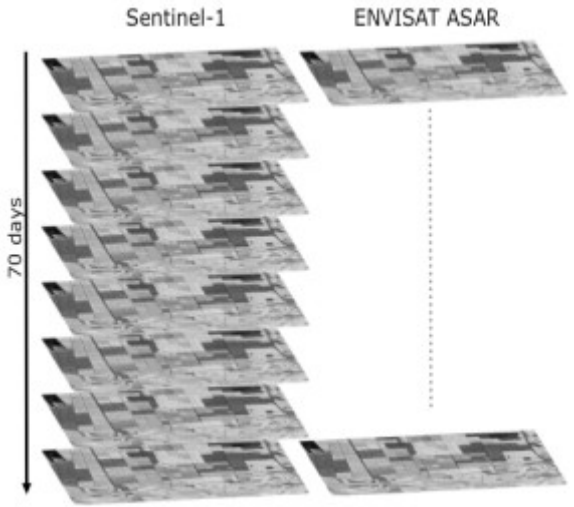
Credit Michael Foumelis ESA
ESRIN & HUA

Sentinel-1 Key Requirements

- Provide C-band SAR data continuity of ERS/ENVISAT type of missions at medium resolution (10 m and lower)
- Greatly improved coverage and revisit (i.e. as compared to ENVISAT)
- Conflict-free operations (wide swath and dual-pol modes)
- High system availability (SAR duty cycle and data latency)
- Data quality similar or better than ERS/ENVISAT (e.g. equalized performance across the swath)

Average Revisit Time with S-1A + S-1B Satellites

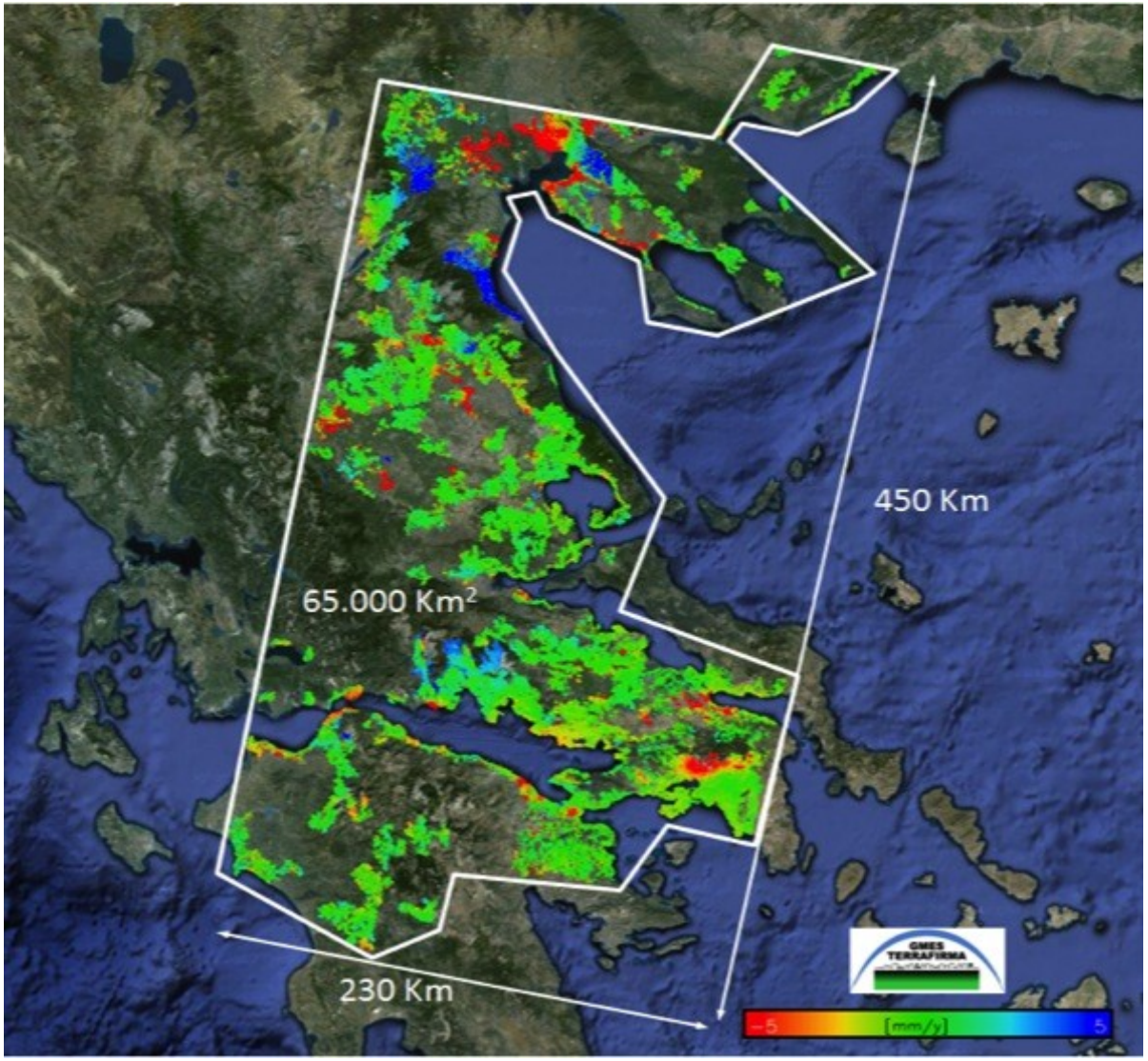




Wide Area Processing (WAP) - Greece

In the framework of the ESA GMES Terrafirma project, the German space agency (DLR) processed nine radar images from the ERS mission to produce this ground motion map covering a 65,000 km2 area of Greece. The map shows strong subsidence in the Thessaly plain, as well as ground motion associated with an earthquake in the area close to the city of Athens.

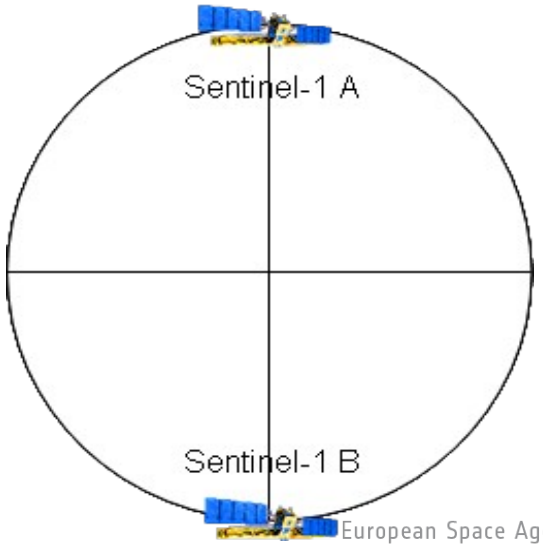
Credits
DLR/Terrafirma/ ESA/
TerraMetrics 2012



SAR: Subsidence Italy - Rome - Fuimicino

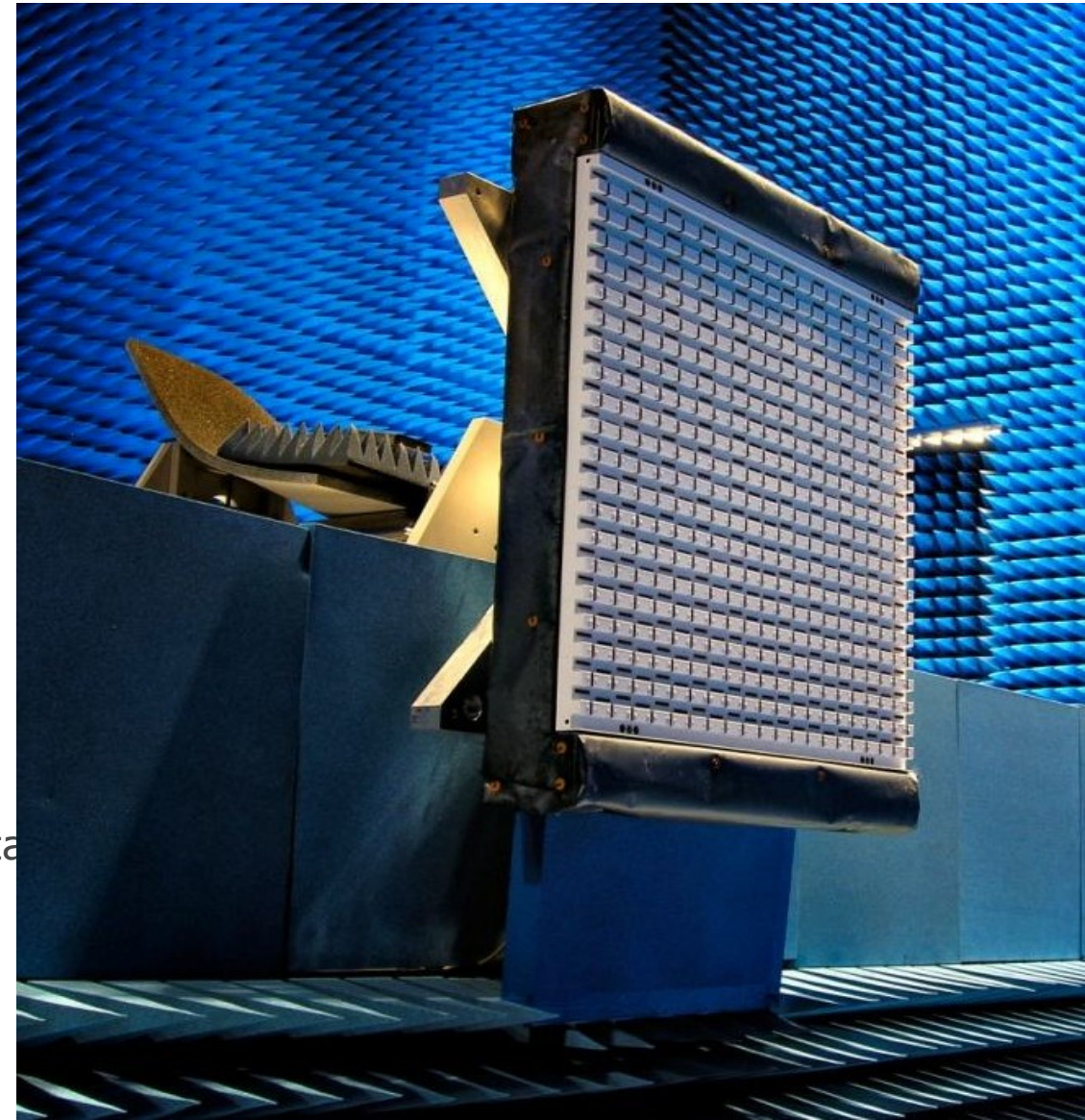
Sentinel–1 Mission Facts

- Constellation of two satellites (A & B units)
- C-Band Synthetic Aperture Radar Payload
- Near-Polar sun-synchronous (dawn-dusk) orbit at 693 km altitude
- Both S-1 satellites are in the same orbit (180 deg. phased in orbit)
- 12 days repeat cycle (1 satellite), 6 days for the constellation
- 7 years design life time with consumables for 12 years
- Launch of Sentinel-1 A scheduled for May 2013 followed by Sentinel-1 B 18 months later



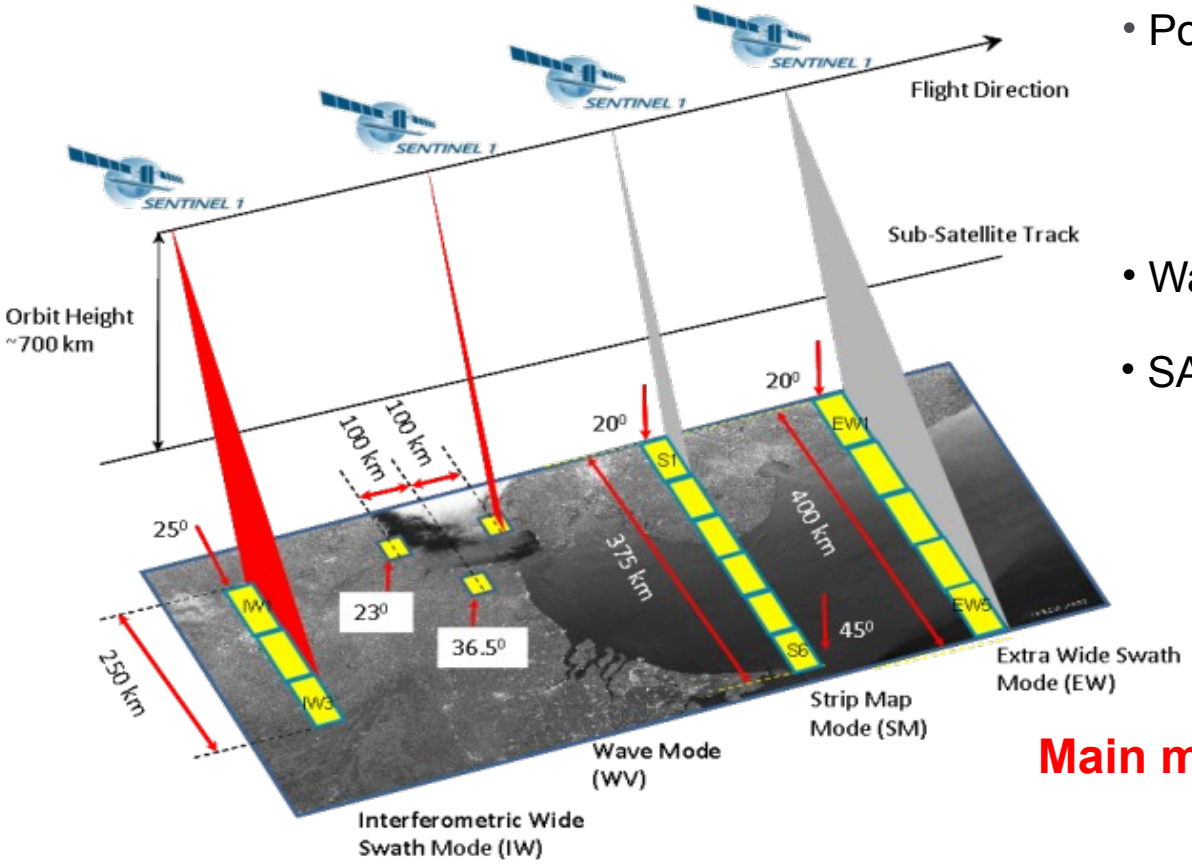
Sentinel–1 Technical Facts

- C-Band SAR instrument operates at centre frequency of 5.405 GHz
- On-board data storage capacity (mass memory) of 1400 Gbit
- Two X-band RF channels for data downlink with 2 X 260 Mbps
- On-board data compression using Flexible Dynamic Block Adaptive Quantization
- Optical Communication Payload for data transfer via laser link with the GEO European Data Relay Satellite (ERDS) system



Sentinel-1 SAR Imaging Modes (1/3)

4 mutually exclusive SAR modes with different resolution and coverage

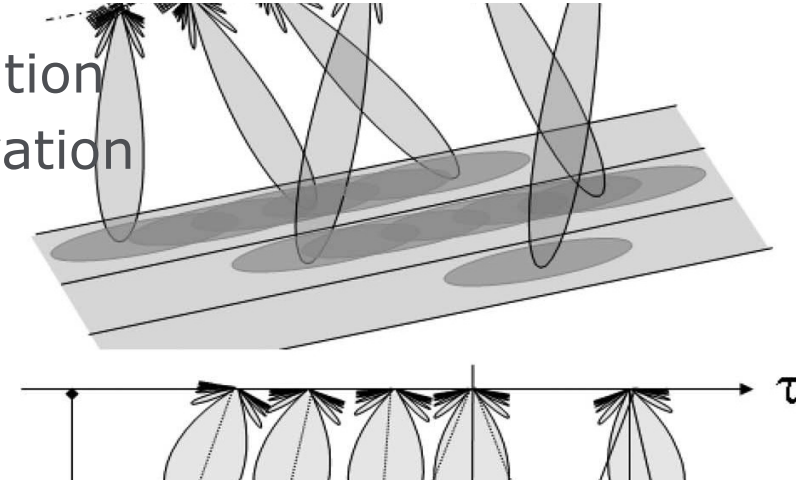


- Polarisation schemes for IW, EW & SM:
  - ✓ single polarisation: HH or VV
  - ✓ dual polarisation: HH+HV or VV+VH
- Wave mode: HH or VV
- SAR duty cycle per orbit:
  - ✓ up to 25 min in any of the imaging modes
  - ✓ up to 74 min in Wave mode

Main modes of operations: IW and WV

S-1 acquisition modes (2/3)

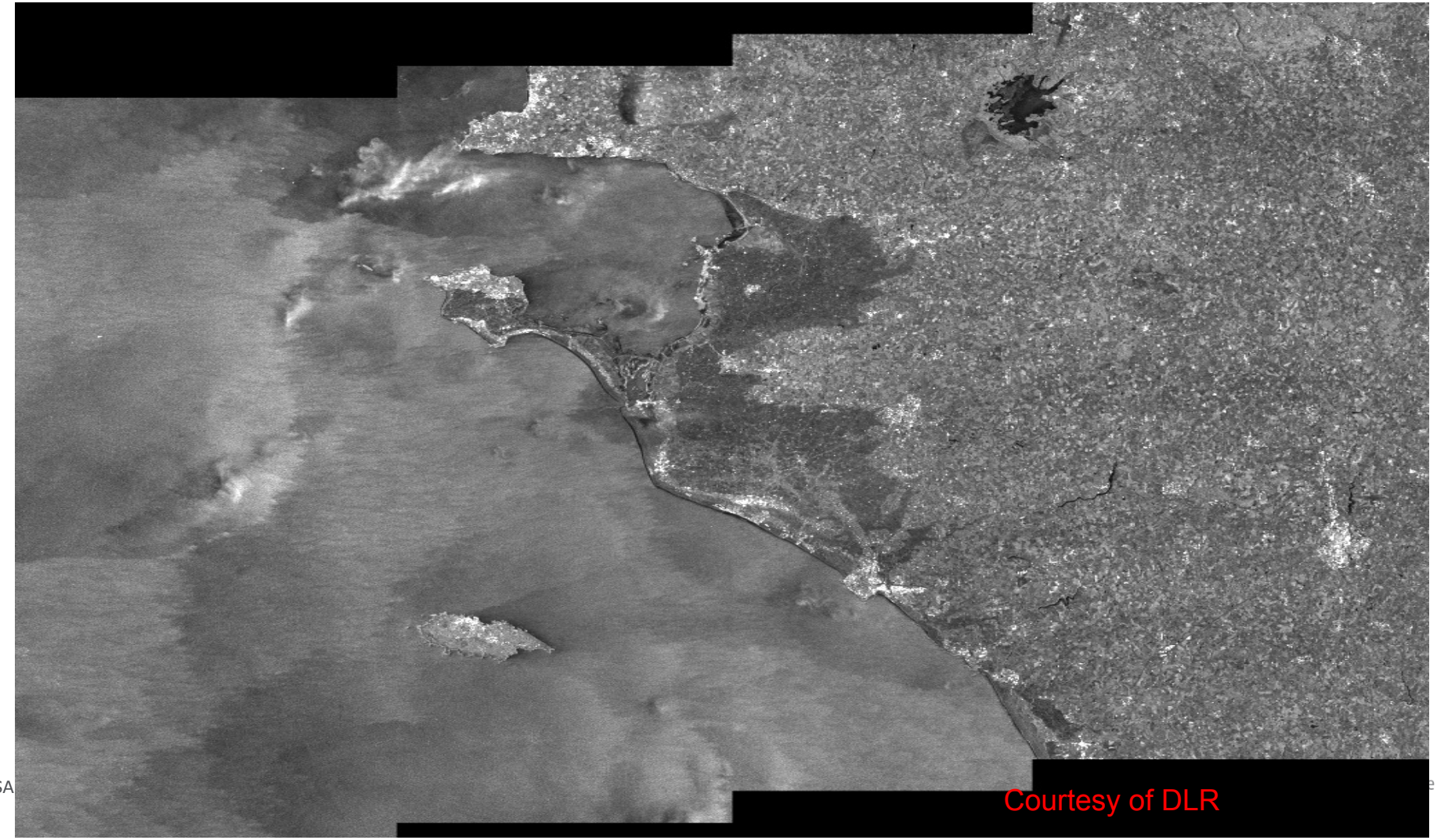
- SM is the continuation of ERS/ASAR Image modes
- IW and EW modes relies on TOPS(1) acquisition mode combining electronic steering in elevation and azimuth:
  - IWS : 3 sub-swath IW1- IW3
  - EWS : 5 sub-swath EW1-EW5
- WV is the continuation of ERS/ASAR WV mission but alternates swath between imagettes.
  - Although using the same bandwidth as SM, WV is a LBR due to coarse spatial sampling



(1) De Zan, F.; Guarnieri, A.M.; , "TOPSAR: Terrain Observation by Progressive Scans," *Geoscience and Remote Sensing, IEEE Transactions on* , vol.44, no.9, pp.2352-2360, Sept. 2006

Challans: TOPSAR image

Time acquisition: July 9th, 2007 at 6.26 am



Sentinel-1 SAR Imaging Modes (3/3)

Mode	Access Angle	Single Look Resolution	Swath Width	Polarisation
Interferometric Wide Swath	> 25 deg.	Range 5 m Azimuth 20 m	> 250 km	HH+HV or VV+VH
Wave mode	23 deg. and 36.5 deg.	Range 5 m Azimuth 5 m	> 20 x 20 km Vignettes at 100 km intervals	HH or VV
Strip Map	20-45 deg.	Range 5 m Azimuth 5 m	> 80 km	HH+HV or VV+VH
Extra Wide Swath	> 20 deg.	Range 20 m Azimuth 40 m	> 400 km	HH+HV or VV+VH

Image Quality Parameters for all Modes (worst case)

Radiometric accuracy (3 σ)	1 dB
Noise Equivalent Sigma Zero	-22 dB
Point Target Ambiguity Ratio	-25 dB
Distributed Target Ambiguity Ratio	-22 dB

Sentinel-1 observation scenario

High level strategy:

- optimum use of SAR duty cycle (25 min/orbit), taking into account the various constraints (e.g. limitation in the number of X-band RF switches, mode transition times)

- Wave Mode continuously operated over open oceans, with lower priority w.r.t. the other high rate modes

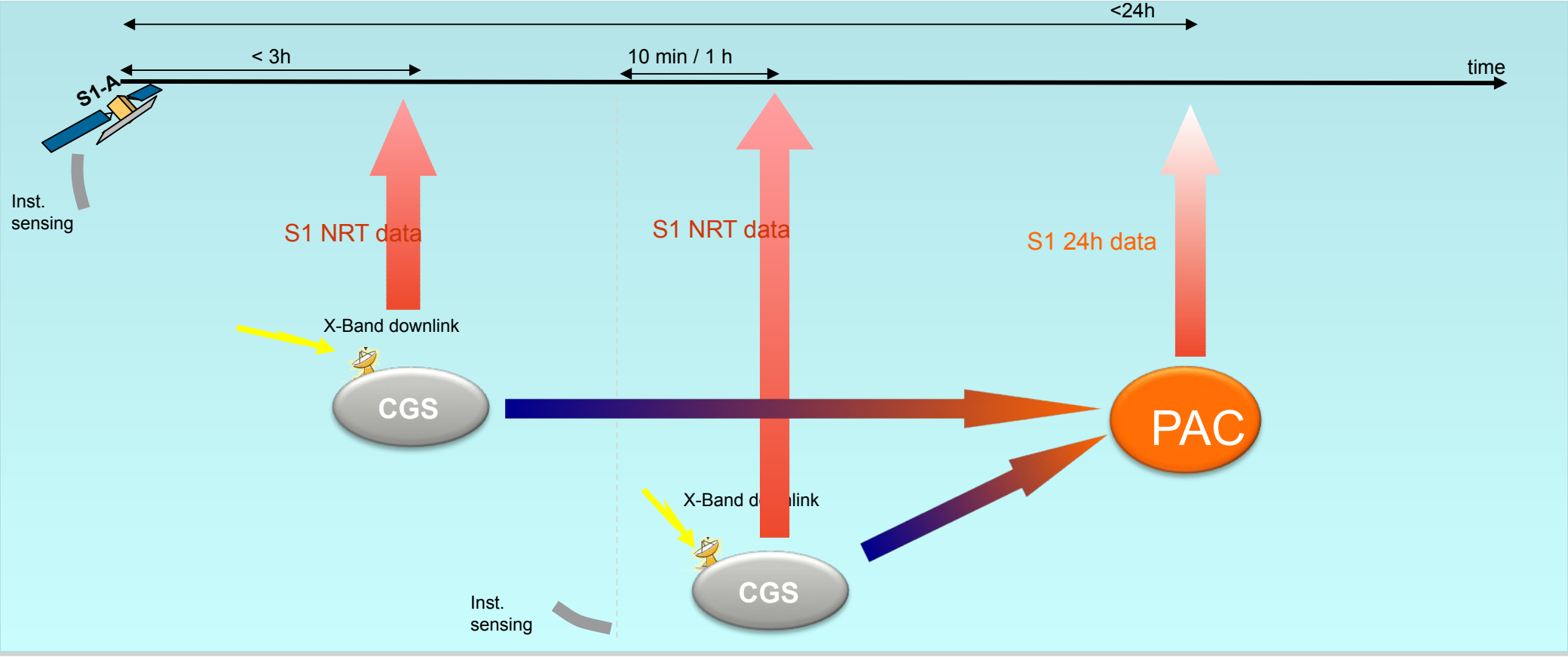
- IW or EW modes operated over pre-defined geographical areas:
  - Over land: pre-defined mode is IWS
  - Over seas and polar areas, and ocean relevant areas: pre-defined mode is either IWS or EWS

- In exceptional cases only, emergency observation requests may alter the pre-defined observation scenario, with e.g. the use of the Strip Map mode

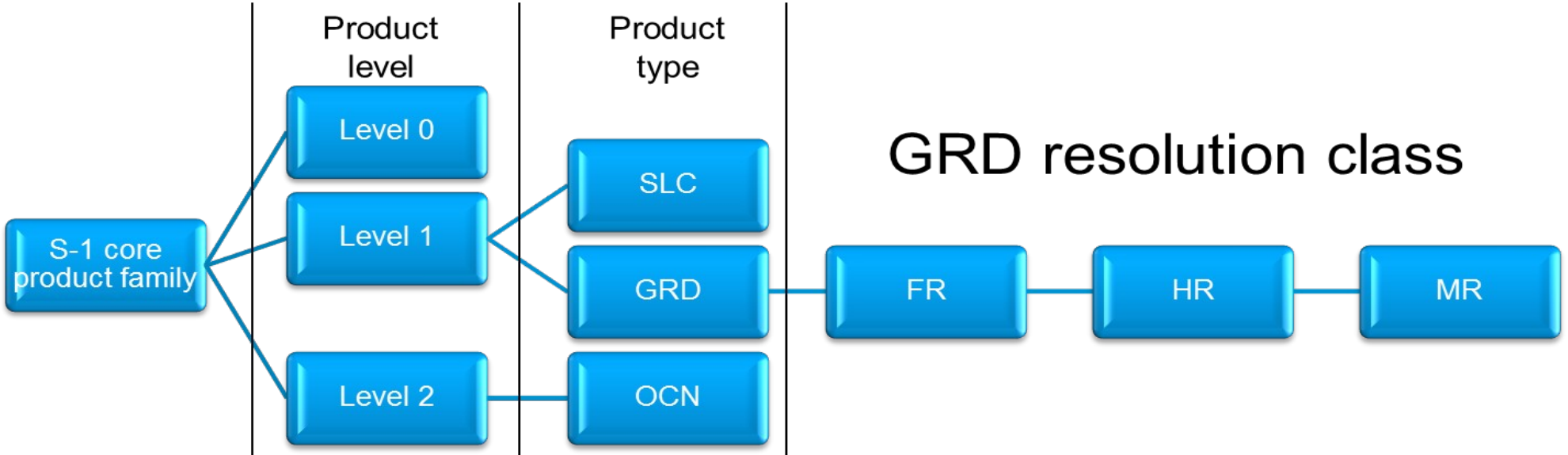
Sentinel-1 PDGS Data Timeliness

Data access to systematically generated products is provided according to the following timeliness:

- Standard timeliness: within 24h from sensing for all systematic products
- NRT timeliness:
  - < 3h from sensing (within 1h from downlink)
  - < 1h from sensing for data acquired in direct downlink over specific areas (e.g. European waters).



S-1 Product Family



Acquisition Mode	L0/1/2	Product type	GRD_FR	GRD_HR	GRD_MR
SM	✔	✔	✔	✔	✔
IW	✔	✔		✔	✔
EW	✔	✔		✔	✔
WV	✔	✔			

S-1 Product Family

LEVEL-0 PRODUCTS

•(FD)BAQ encoded, unprocessed instrument source packets, with additional annotations and auxiliary information to support the processing

LEVEL-1 PRODUCTS

•Slant-Range Single-Look Complex Products (SLC)

- Focused data in slant-range geometry, single look with phase and amplitude information with complete geo-reference information

•Ground Range Detected Products (GRD)

- Focused data projected to ground range using an Earth ellipsoid model, detected and multi-looked. Original satellite path direction preserved and with complete geo-reference information.

S-1 L1 product characteristics

Acq. Mode	Product Type	Resolution Class	Resolution [1, 2] [Rng x Azi] [3] [m]	Pixel Spacing [2] [Rng x Azi] [m]	No. Looks [Rng x Azi]	ENL [4]
U+ !	UD9 !	!	E,J !b!] ,[!7=! [,P!b!] ,Q!	E,a !b![,P!7=! [,E!b!] ,E!	E!b!E!	E!
	` <@! !	M< !	Qx Q!	] !b!] !	I !b!I !	[,Q!
		h < !	I [!b!I [!	EG!bEG!	P!b!P!	[ ] ,] !

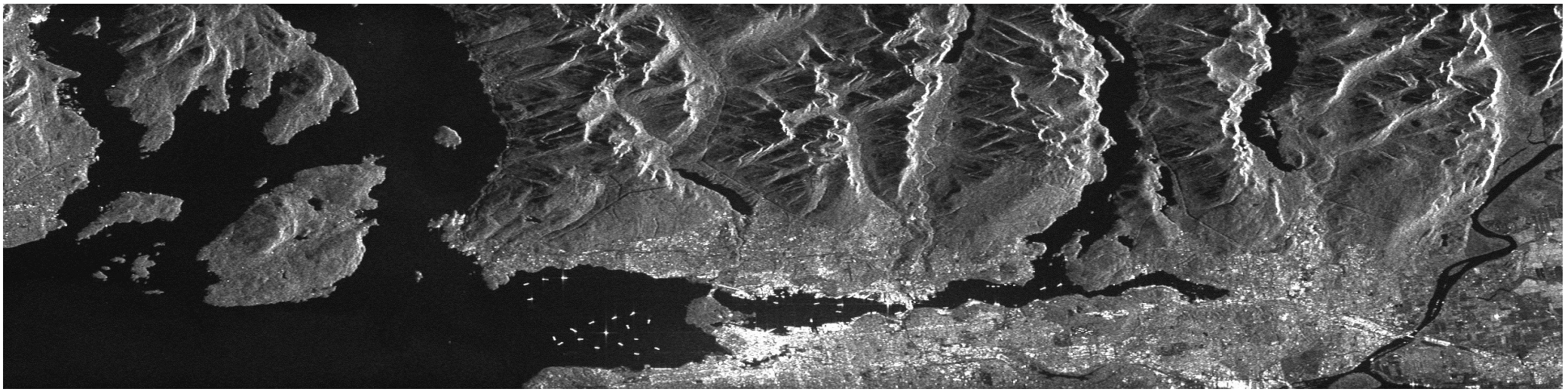
(1)For GRD, the resolution given at mid-range, mid-orbit and value at mid-orbit altitude, averaged over all swaths.

(2)For SLC the resolution and pixel spacing is range dependent

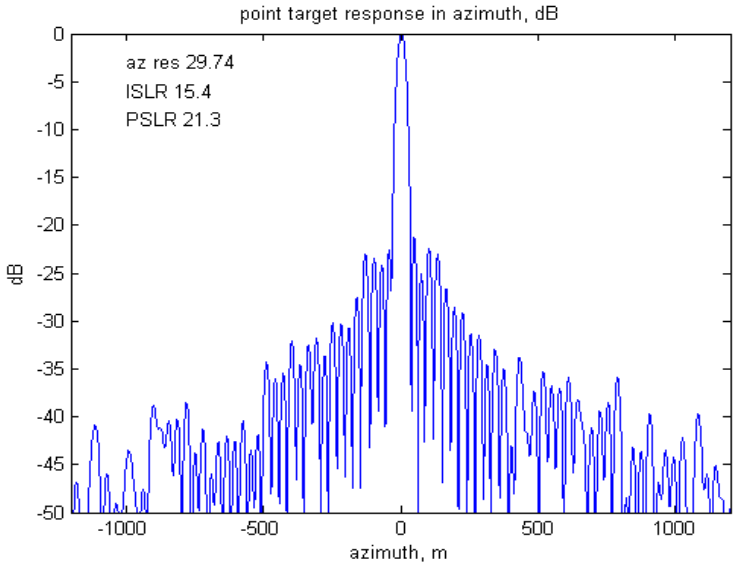
(3) For SLC products, the range coordinate is in slant range. All the other products are in ground range.

(4)For GRD IW/EW, the ENL is averaged over all swaths.

First Radarsat 2 image in TOPS



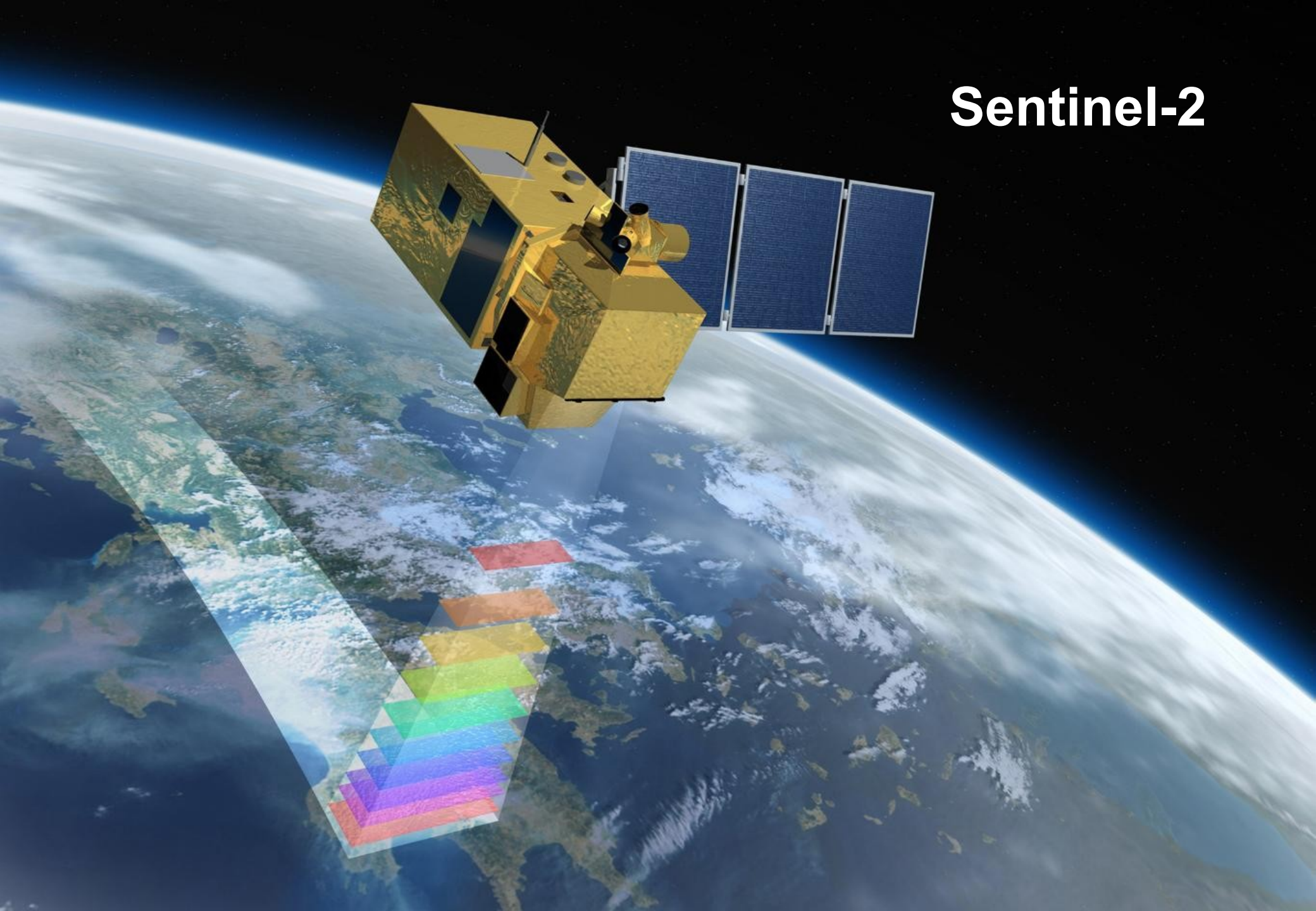
The first RADARSAT-2 TOPS mode over Vancouver. (courtesy Radarsat 2 / MDA ,P. LIM)



point target analysis of a bright point around the airport

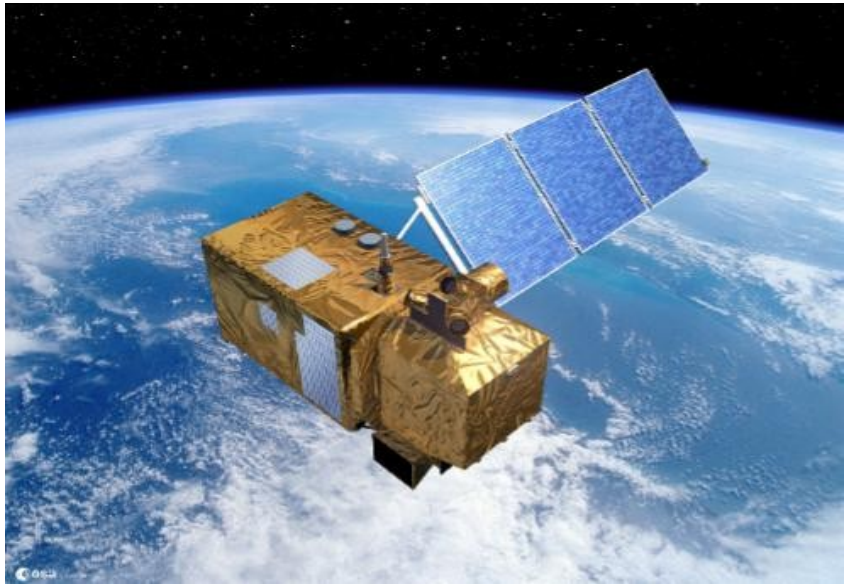
Sentinel 1 summary

- Sentinel-1 data products maintain data quality of ESA's previous SAR missions (ERS-1/-2, ENVISAT ASAR)
  - Continuity in performance for geophysical products
  - Potential to meet *evolving* GMES service needs
- In response to GMES service needs, substantial improvements are integrated into mission design
  - Revisit frequency
  - Coverage
  - Timeliness and reliability of service
  - Conflict free operations


Sentinel-2

Sentinel-2
Mission Highlights

Super-spectral Imaging Mission



Launch : mid 2014

Applications:
- Generic land cover maps
- Risk mapping and fast images for disaster relief
- generation of leaf coverage, leaf chlorophyll content and leaf water content

Push-broom filter based multi spectral imager with 13 spectral bands (VNIR & SWIR)

Spatial resolution: 10, 20 and 60 m

Field of view: 290 km

2 x 280Mbps concurrent channels
~18 min downlink required per orbit for data playback

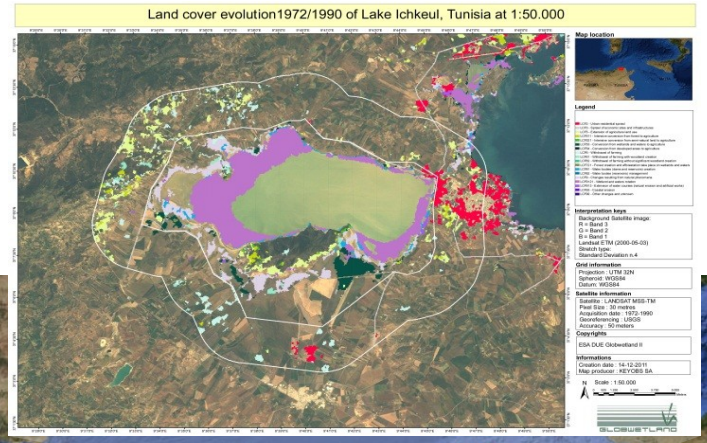
5 days repeat cycle (in twin spacecraft configuration)

Sun synchronous orbit at 786 km mean altitude

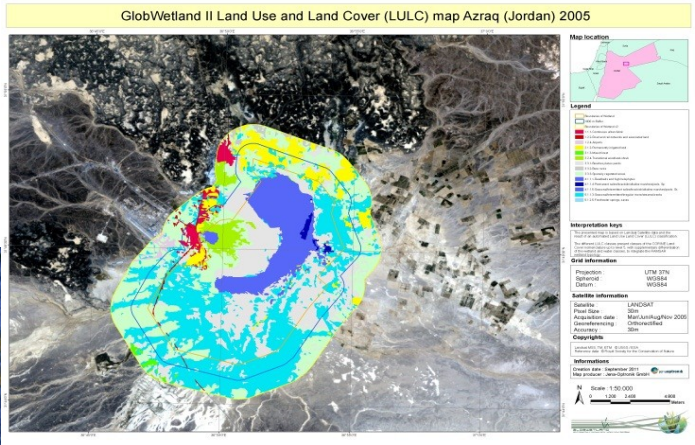
7 years design life time, consumables for 12 years

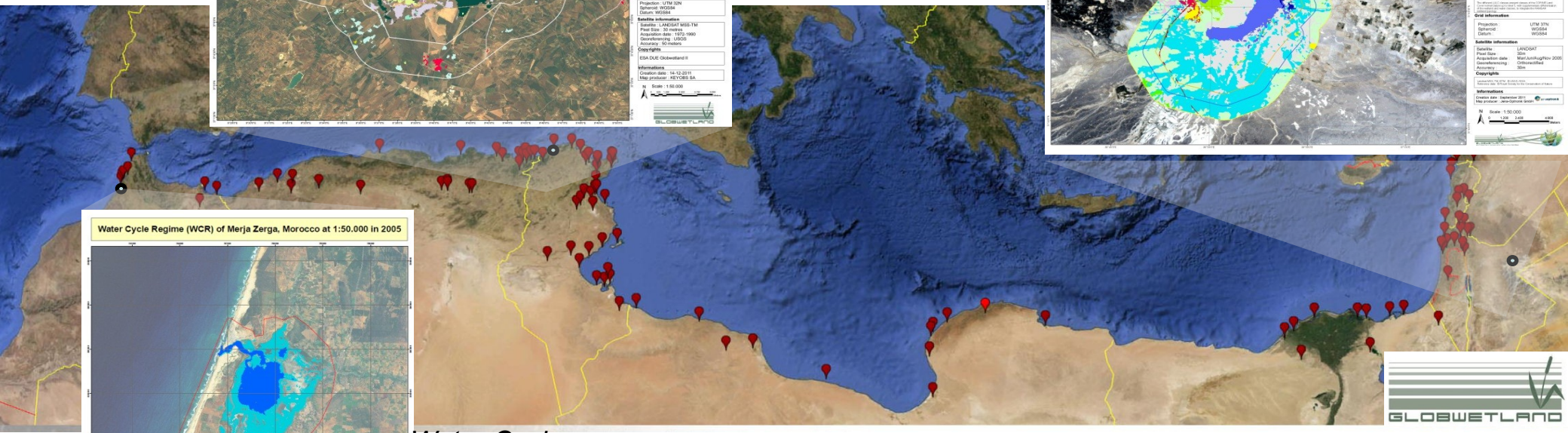
Mapping Wetlands

Land Use Land Cover maps



Change Detection maps





Water Cycle Regimes

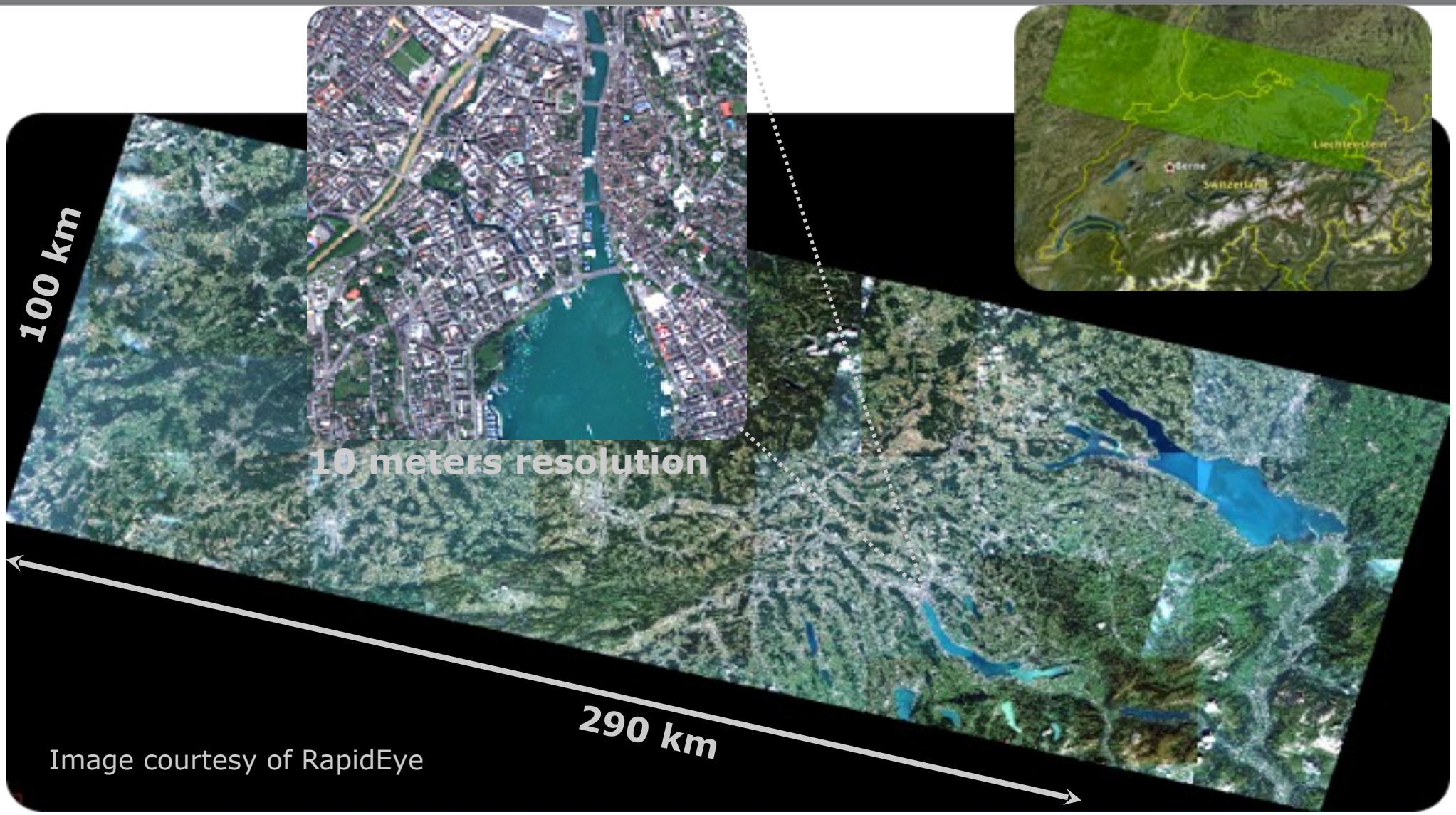
Sentinel 2, an observation asset of the future Global Wetlands Observation System (GWOS) for the inventory, assessment and monitoring of wetlands, worldwide.

Sentinel-2 services

General services: Global carbon, Crop monitoring, Spatial planning (vegetation, urban), Forest monitoring, Water services, Soil erosion, large scale natural or man made disasters, surveillance of infrastructures

Thematic services: Sustainable management of developing countries, Nature protection services, support to humanitarian aid, Food security

SENTINEL-2 Mock-up Image

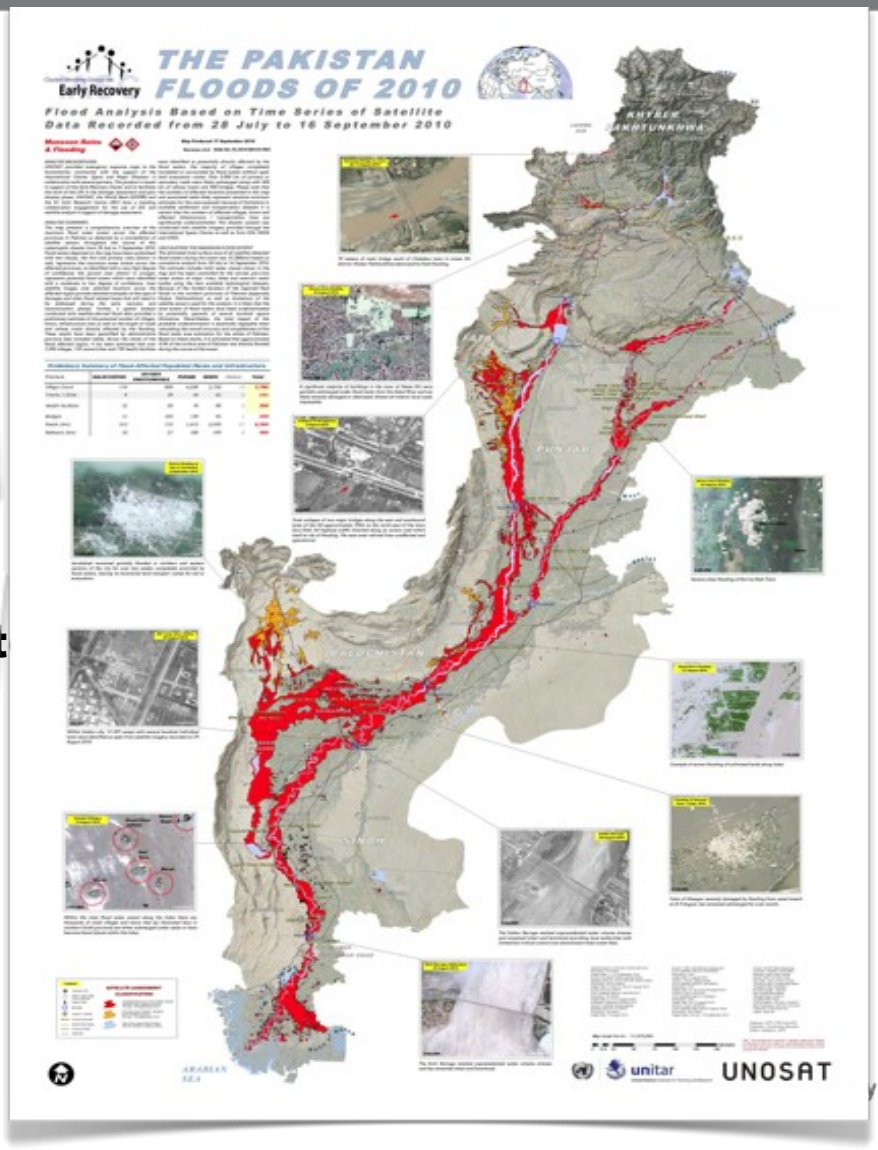


Disaster Management

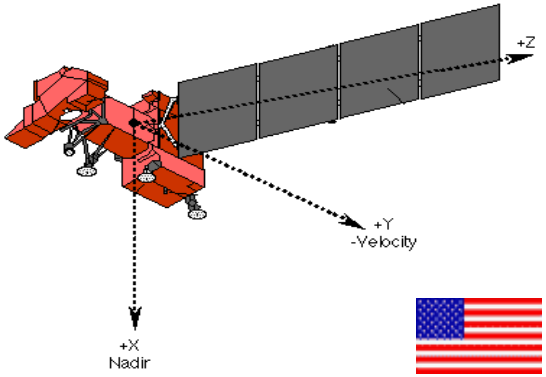
International CharterSp

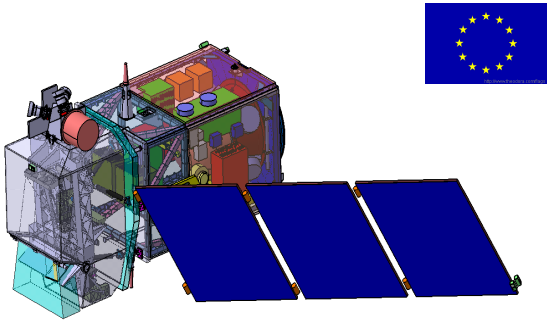
324 activations since 2000

The example of the 2010 Pakistan Floods



Sentinel-2 precursor missions

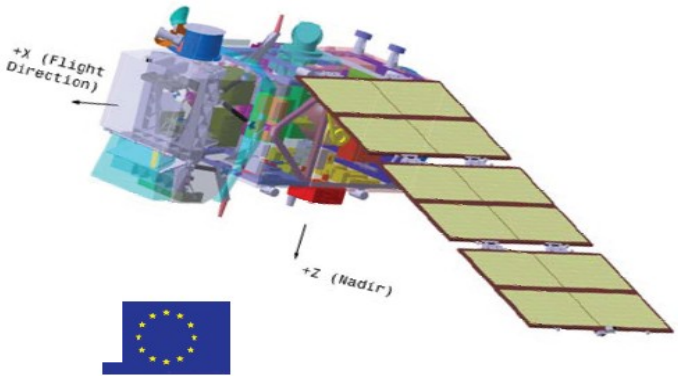


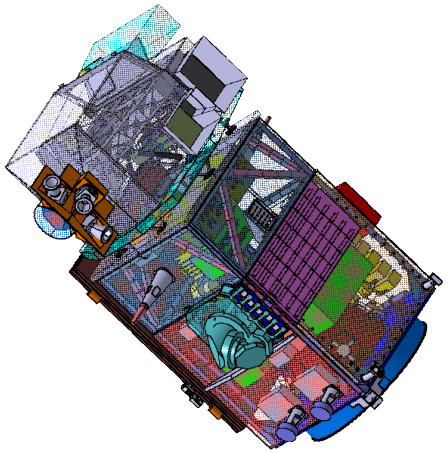


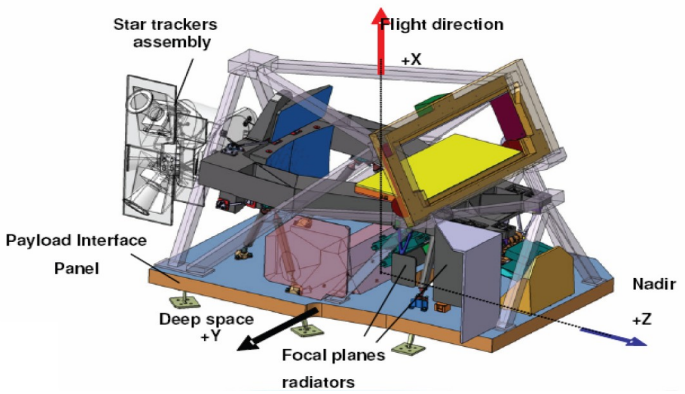
	Landsat	SPOT	Sentinel-2	
Number in series	7 + 1*	5	starting with 2	
Launch	1972 to 1999*	1986 to 2002	first launch 2013	
Measurement principle	scanner	pushbroom	pushbroom	
Earth coverage	16	26	5	days
Swath	185	2*60	290	km
Multispectral bands	7	4+1(panchromatic)	13	
Spatial sampling distance	30, 60	10, 20	10, 20, 60	m

* LCDM mission targeted 2012

Sentinel-2 Satellite & Payload







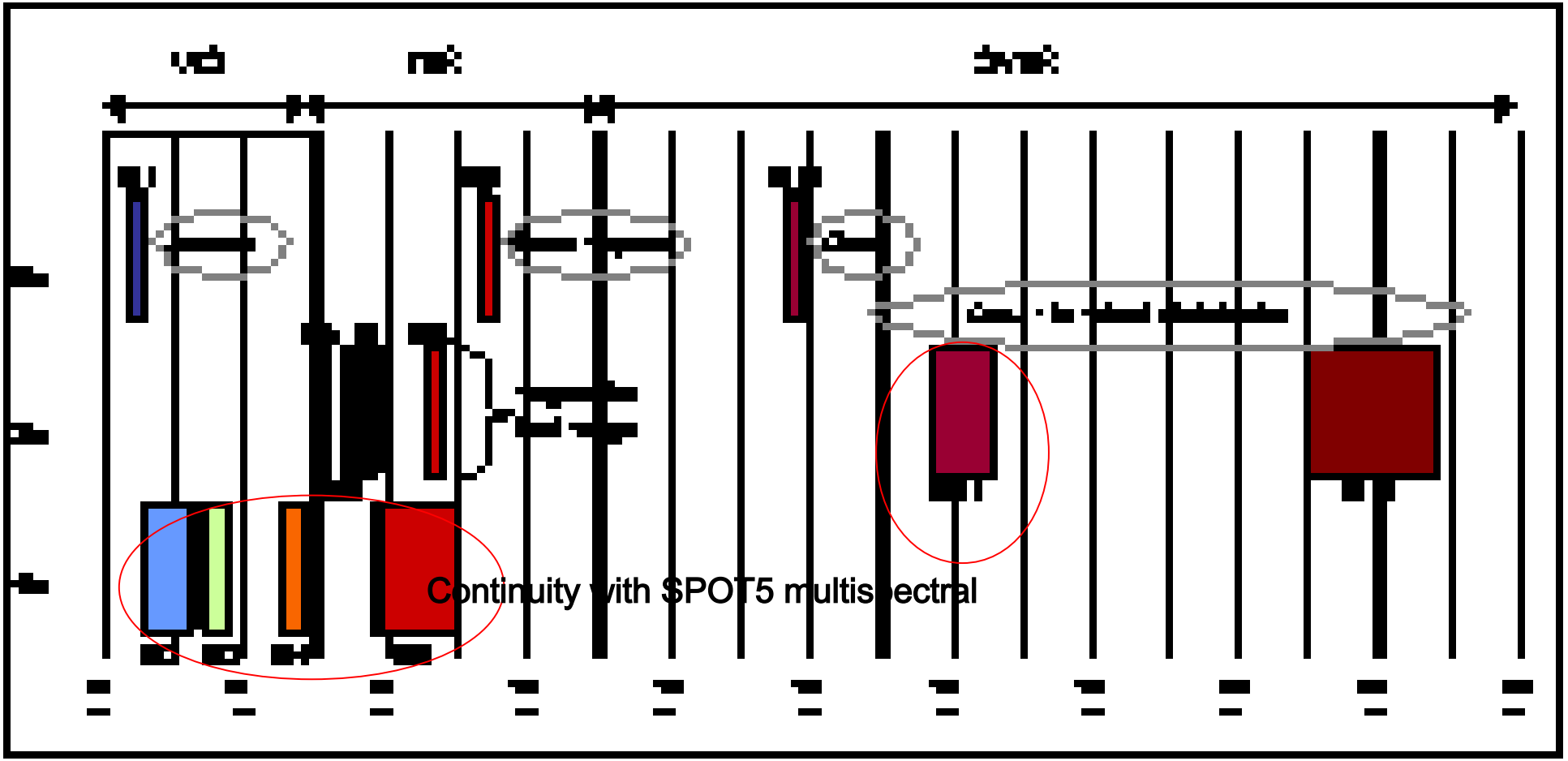
Satellite

- Satellite mass: 1200KG
- Satellite power consumption: 1400W (1700W at Solar Array level, GaAs triple junction), 87Ah battery
- Hydrazine propulsion system (117Kg)
- TT&C using S band (64Kb/s up – 2018Kb/s down), with authenticated/encrypted commands
- X band mission data distribution (520 Mbits/sec)
- Mission data onboard storage: > 2.4 Tbits
- Optical Communication Payload
- Wheels, magnetometers, magnetorquers, star trackers, coarse sun and earth sensors, accurate Inertial Measurement Unit and 2f GPS

MultiSpectral instrument

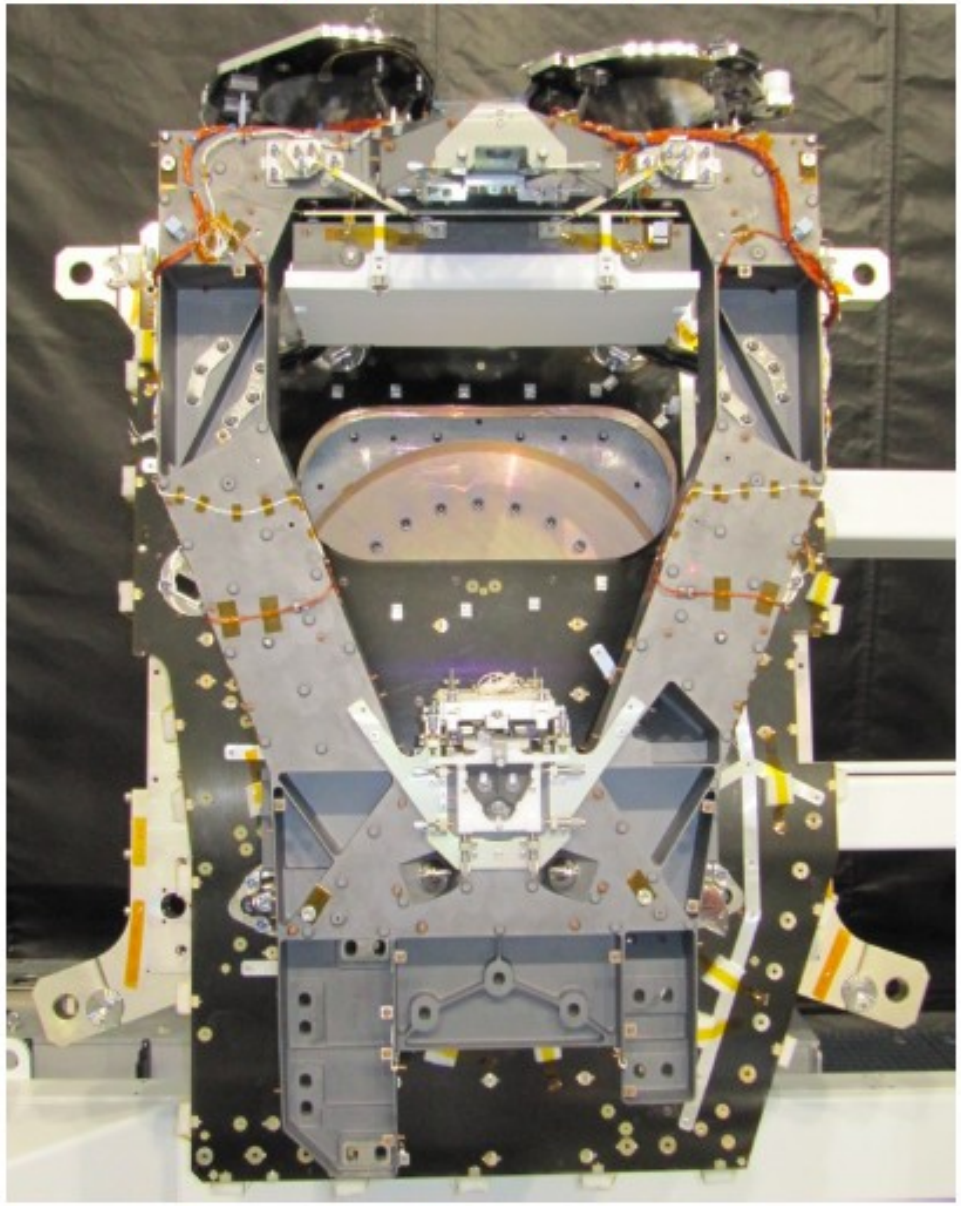
- Filter based push broom imager (280KG, 1m^3)
- Three mirrors silicon carbide telescope, with dichroic beam splitter
- Focal plane arrays: Si CMOS VNIR detectors, HgCdTe SWIR detectors passively cooled (190K)
- Onboard wavelet compression (~1/3)
- Integrated video & compression electronics (state of the art wavelet compression)
- Radiometric resolution 12bits
- Radiometric accuracy < 5%

Sentinel-2 spectral bands

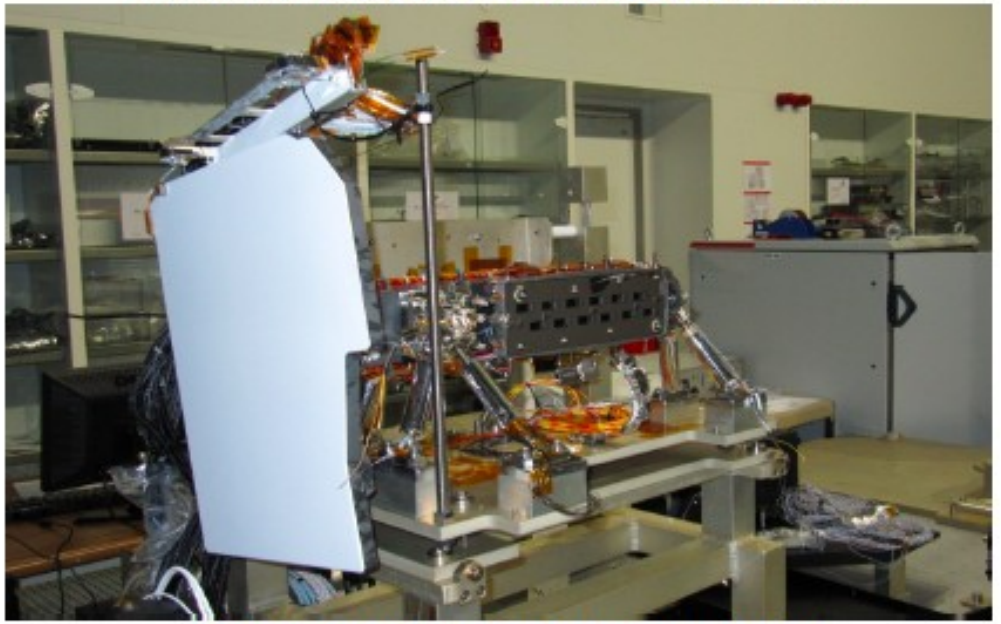


Spectral bands versus spatial resolution

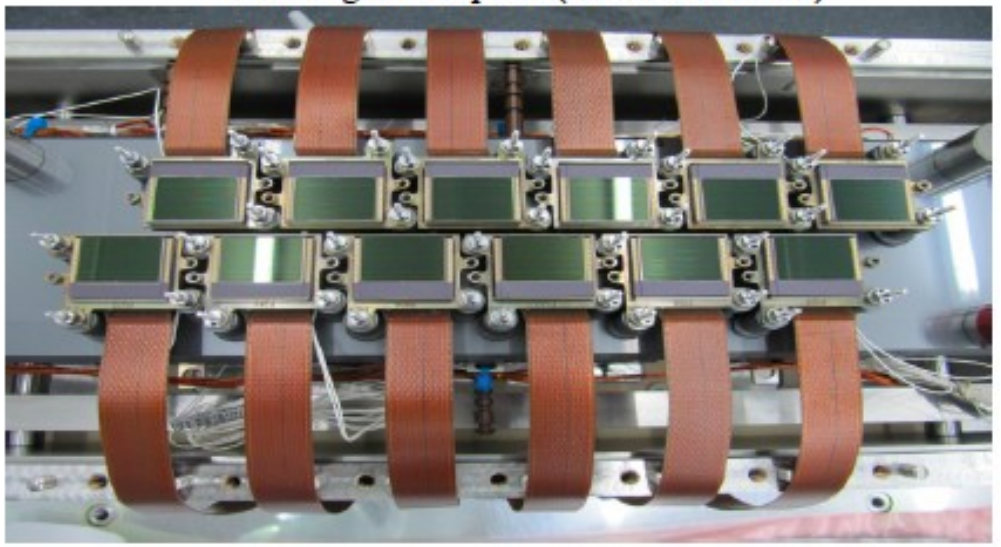
Instrument flight telescope (Astrium-F, BOOSTEC, AMOS)



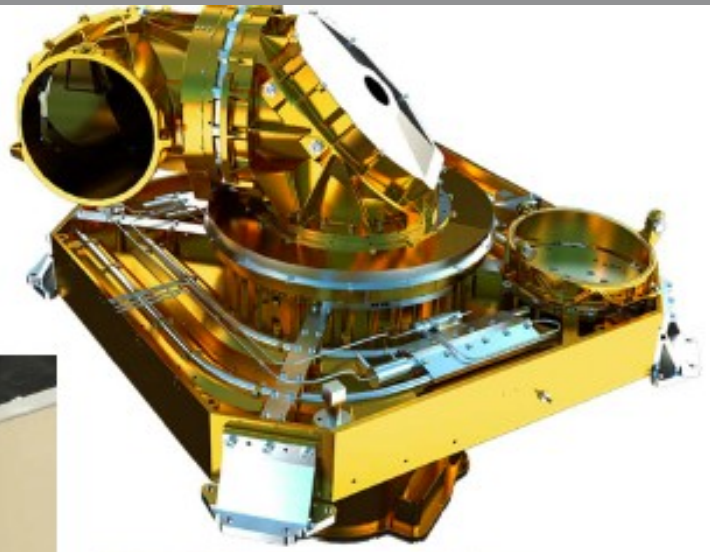
SWIR flight focal plane (Astrium-F & SOFRADIR)



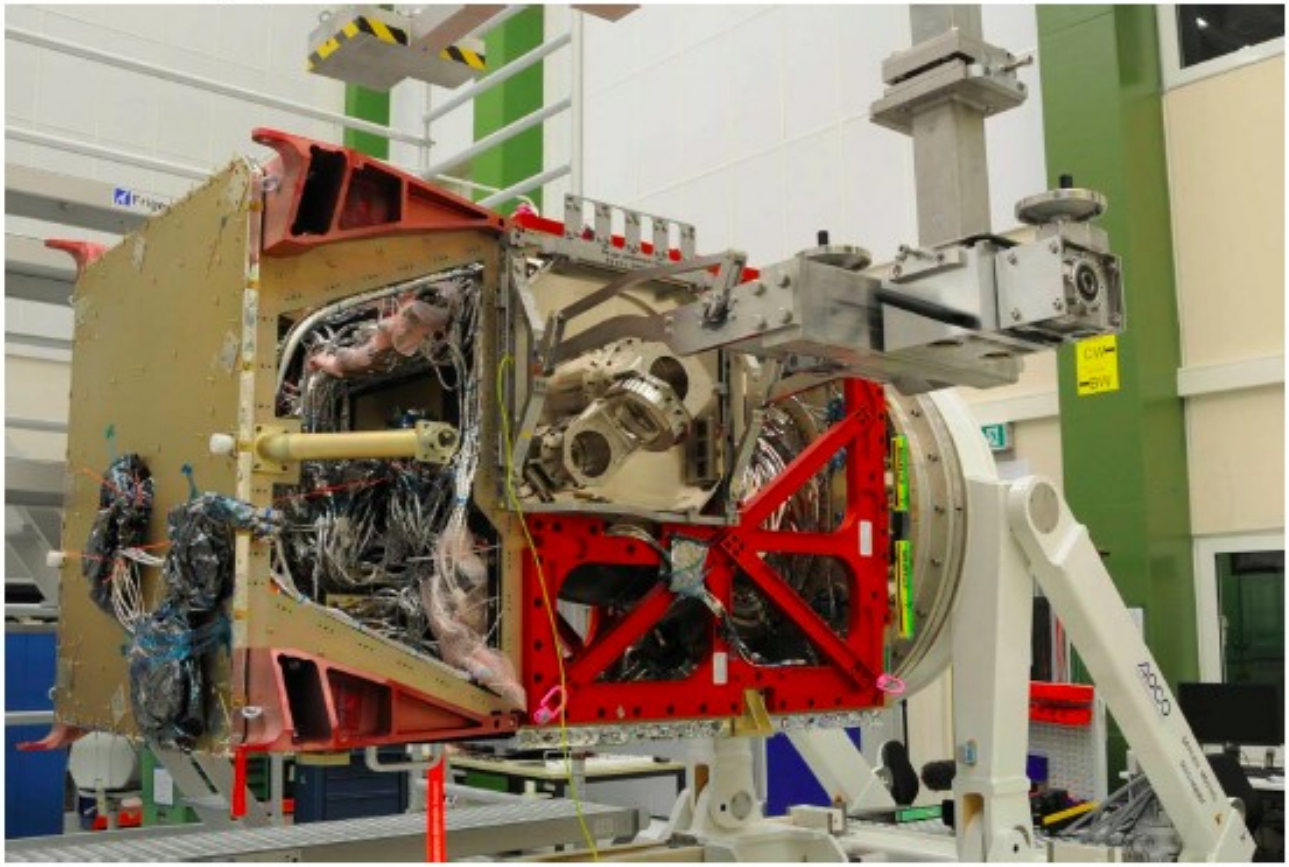
VNIR flight focal plane (Astrium-F & E2V)



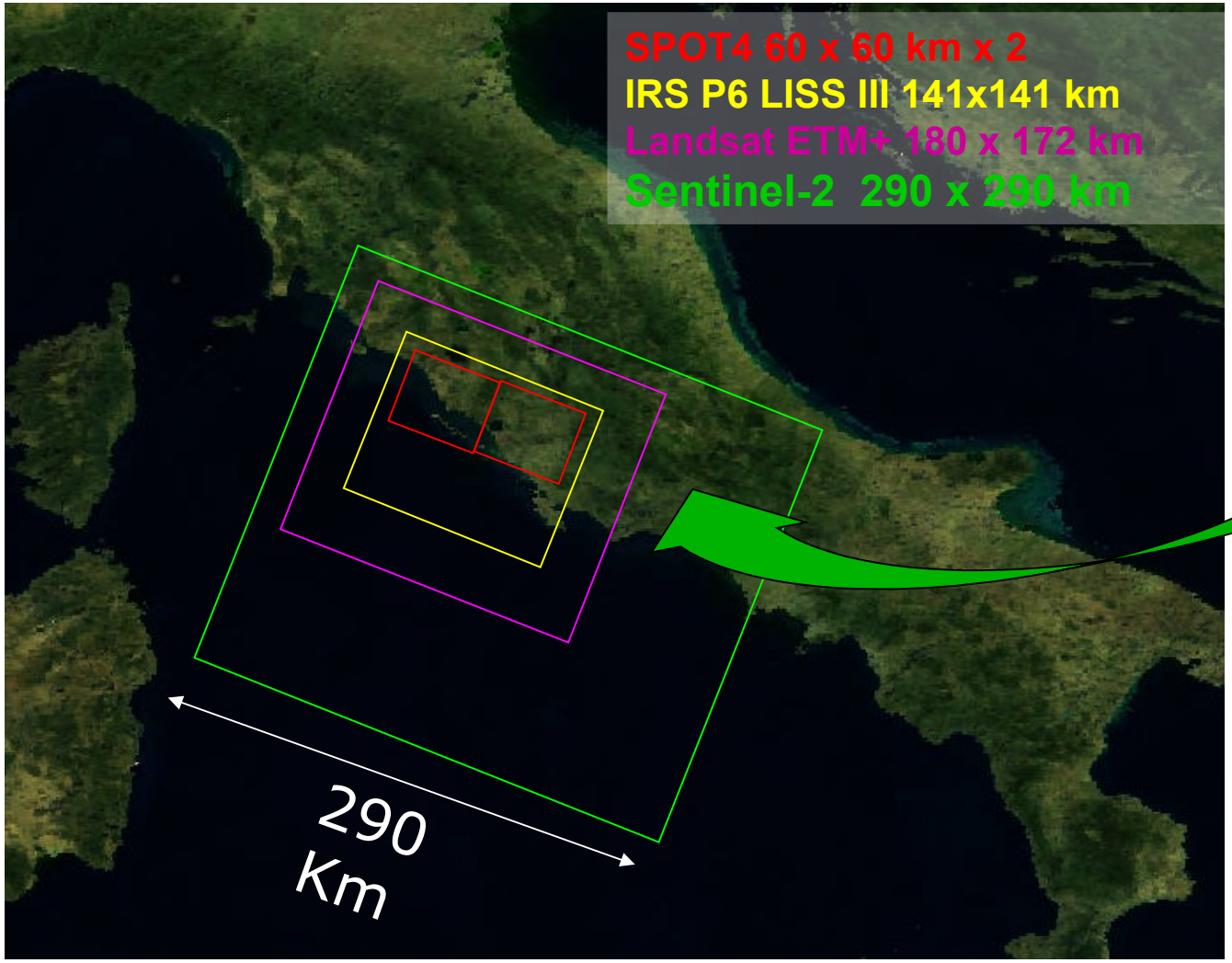
Optical Communication payload (DLR(D) and TESAT-D)

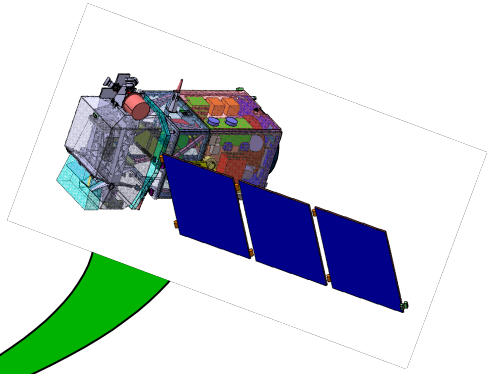


Sentinel-2 flight platform & propulsion module (ASTRIUM-D and CASA(E)



Sentinel-2 swath

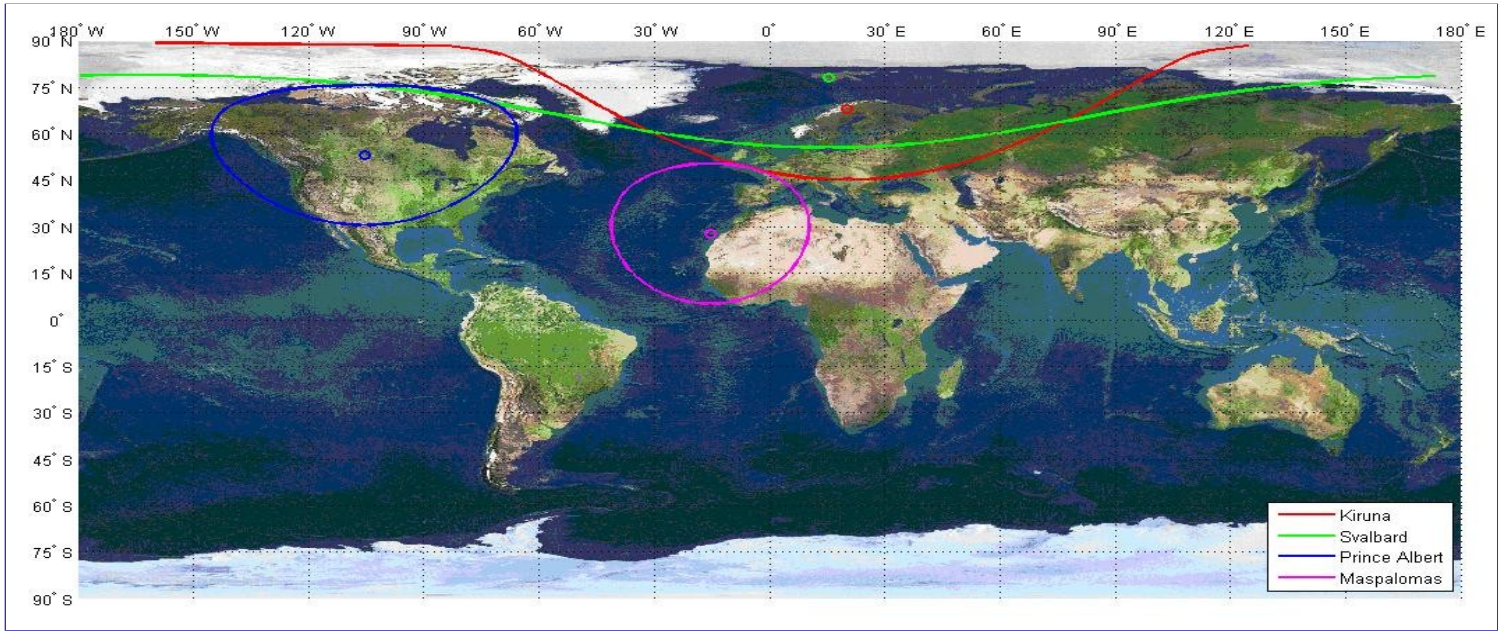




High revisit time → assured by twin satellite observations performed over a very large swath

Sentinel-2 data delivery

- Data delivered to 4 core GS within 1-3 hours after acquisition.
- X band data downlink with instrument data rate of 490 Mbit/s (after onboard wavelet compression)
- Laser Communication through geo terminal (can be operated simultaneously with the X band subsystem).
- 900 Gbyte per day (1000 CDs): cloud-free images will be further processed.



Core Ground Stations used for the simulation:

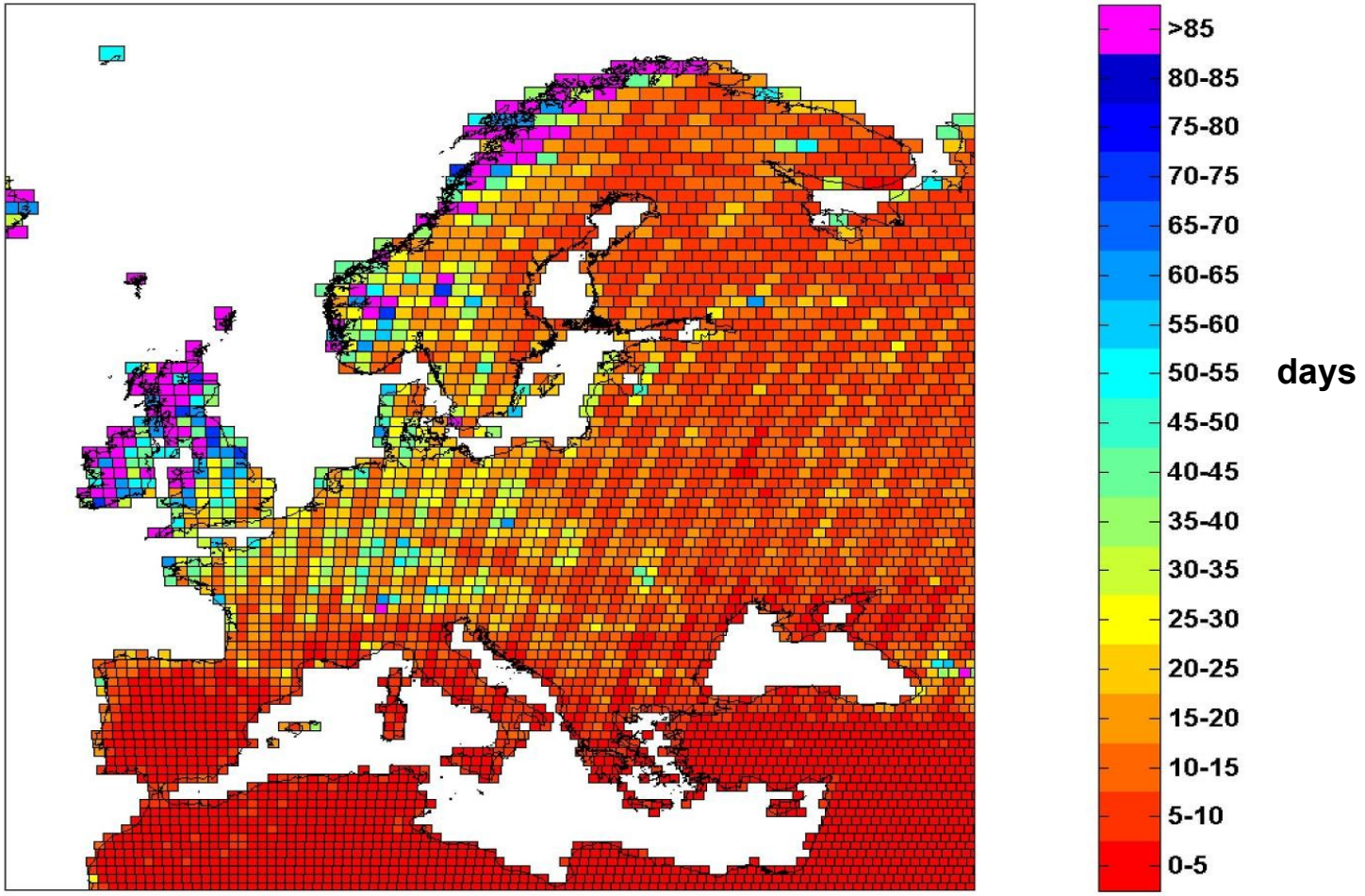
Kiruna, Svalbard, Maspalomas, Prince Albert

Final network to be confirmed as part of the S2 PDGS design consolidation

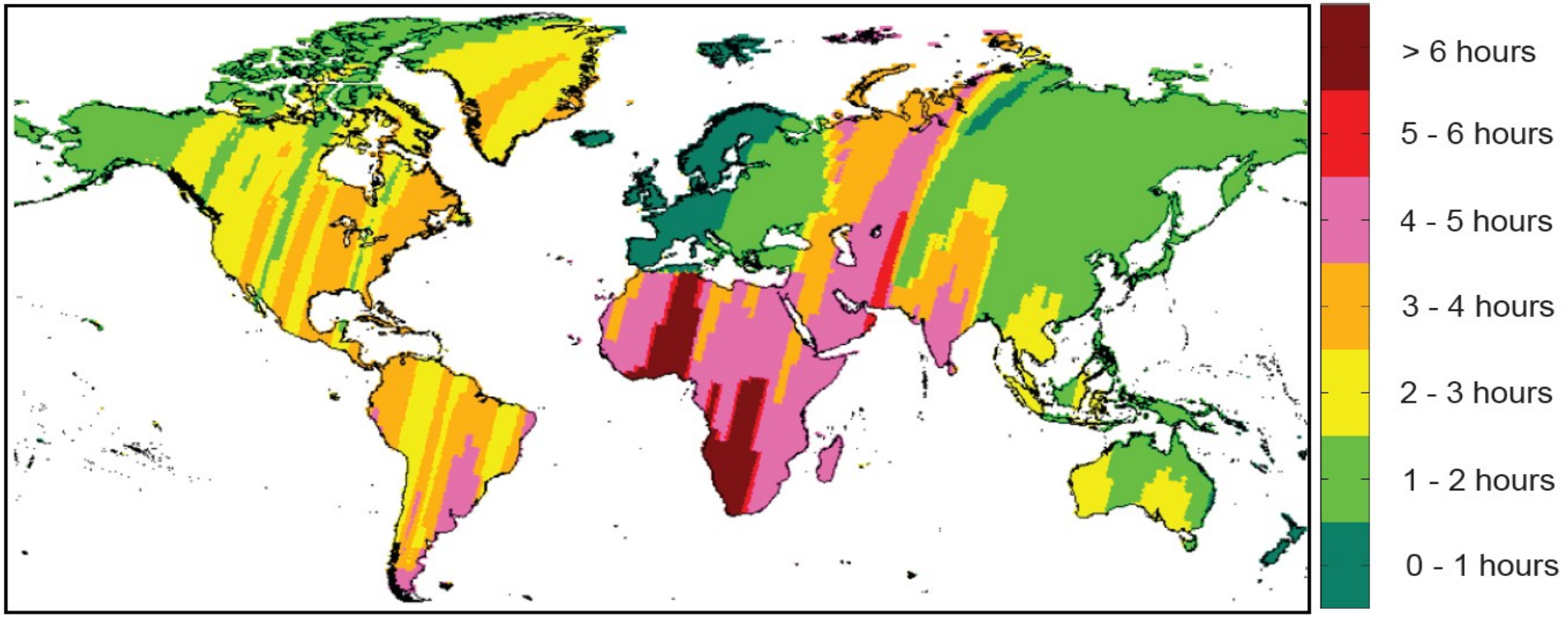
Sentinel-2 revisit time

Revisit time over Europe in summer with 2 satellites

Maximum effective coverage time for SC1 & SC2 (days) (<15% cloud cover; 68% confidence)



Sentinel-2 data latency



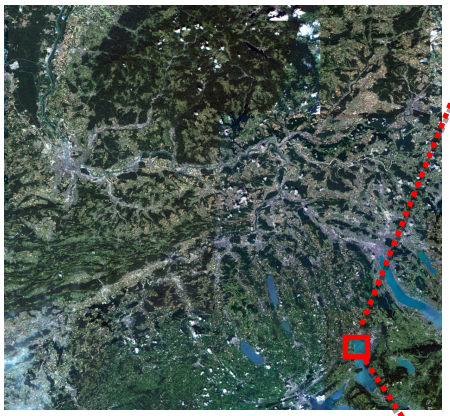
Latency can be controlled by priority / NRT assignment:

User Products List

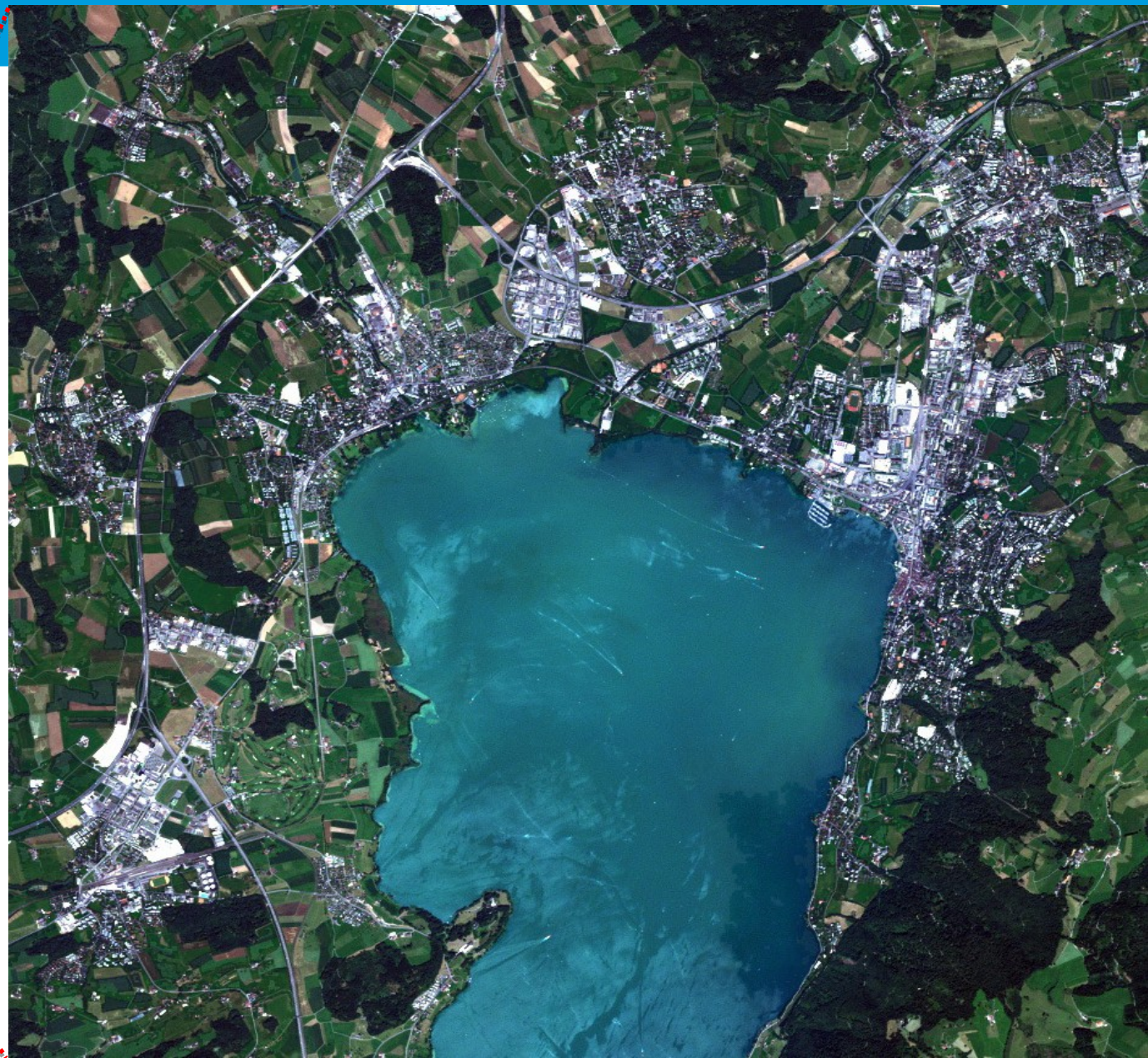
Name	High-level Description	Production	Preservation Strategy	Volume
Level-1B *	Top-of-atmophere radiances in sensor geometry.	Systematic	Long-term	~27 MB (each 25x23km^2)
Level-1C	Top-of-atmosphere reflectances in cartographic geometry.	Systematic	Long-term	~500 MB (each 100x100km^2)
Level-2A	Bottom-of-atmosphere reflectances in cartographic geometry (prototype product).	On user side (using Sentinels Exploitation Tools)	N/A	~600 MB (each 100x100km^2)

*: The use of Level-1B product requires advanced expertise in geometrical processing.

Level-1C Product

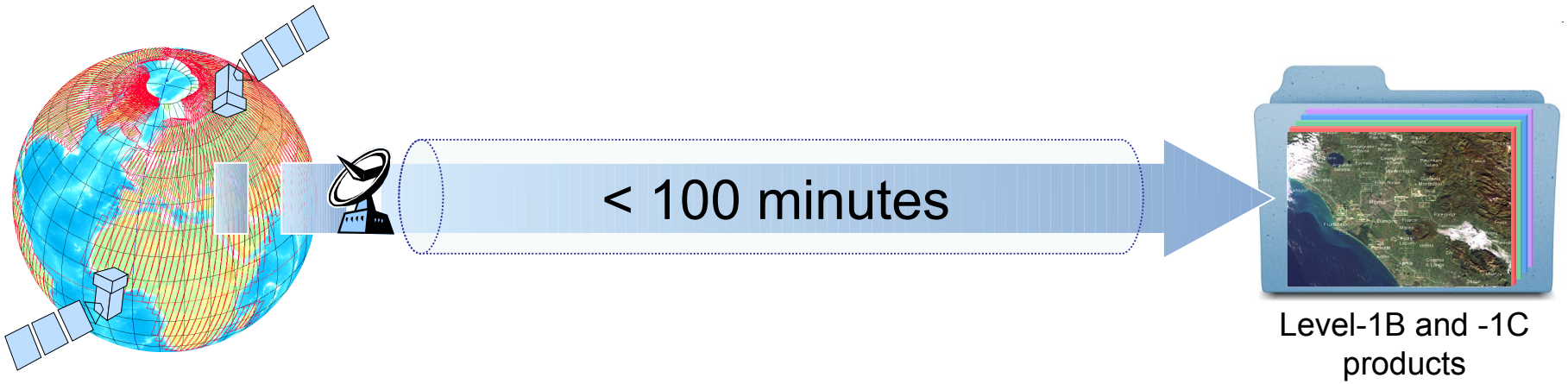


RGB composite
of a Level-1C Tile



Sentinel-2 Core PDGS Processing Concept and Timeliness

Processing of all data up to Level-1C within 100 minutes after satellite downlink

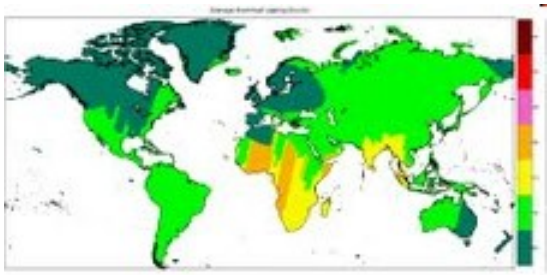


Level-1B and -1C products

The timeliness pattern is cascading from the core station network, it will range from:

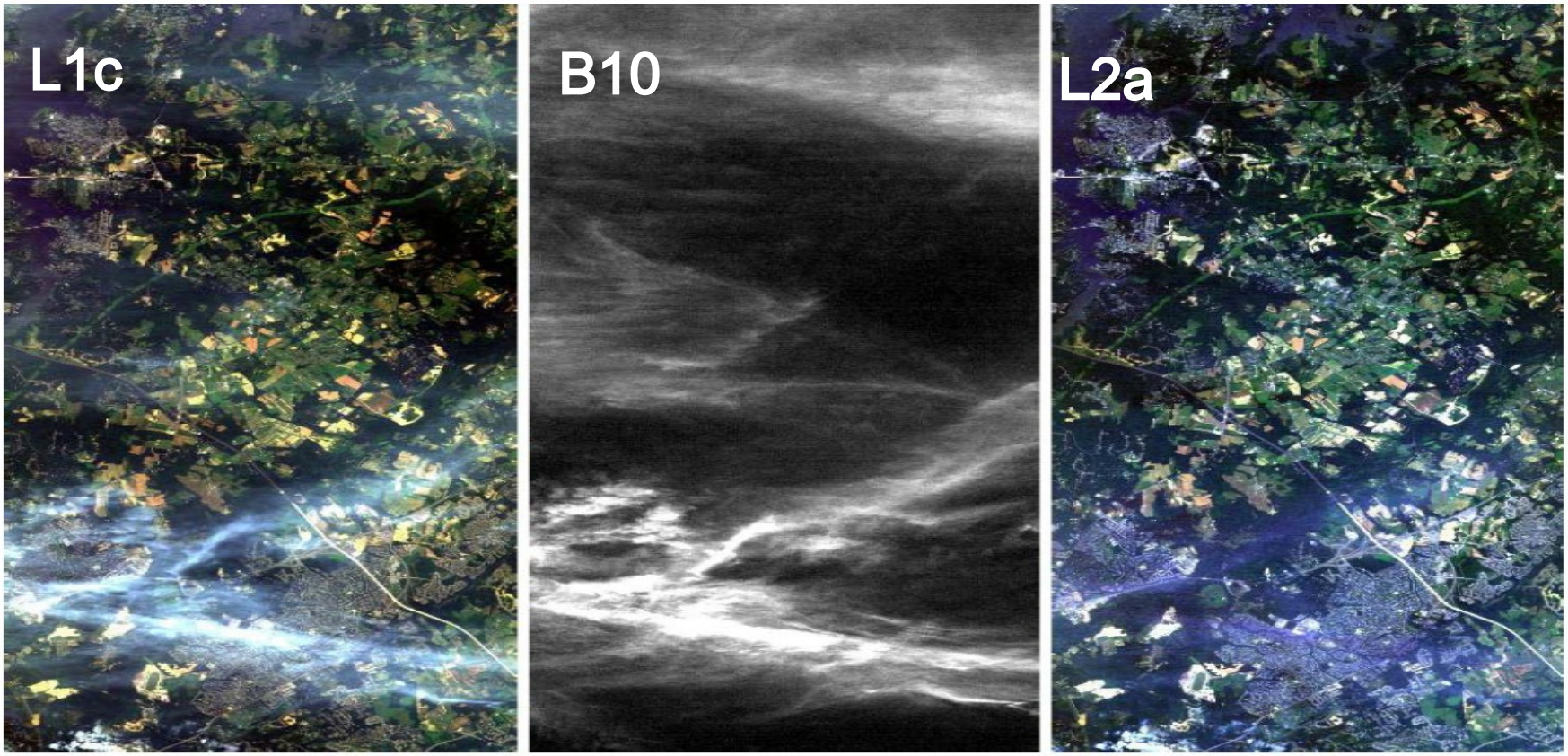
→ 100mins from sensing in direct visibility

→ NTC between 3h and 24h depending of the observation pattern and the core stations location



Sentinel-2 correction channels

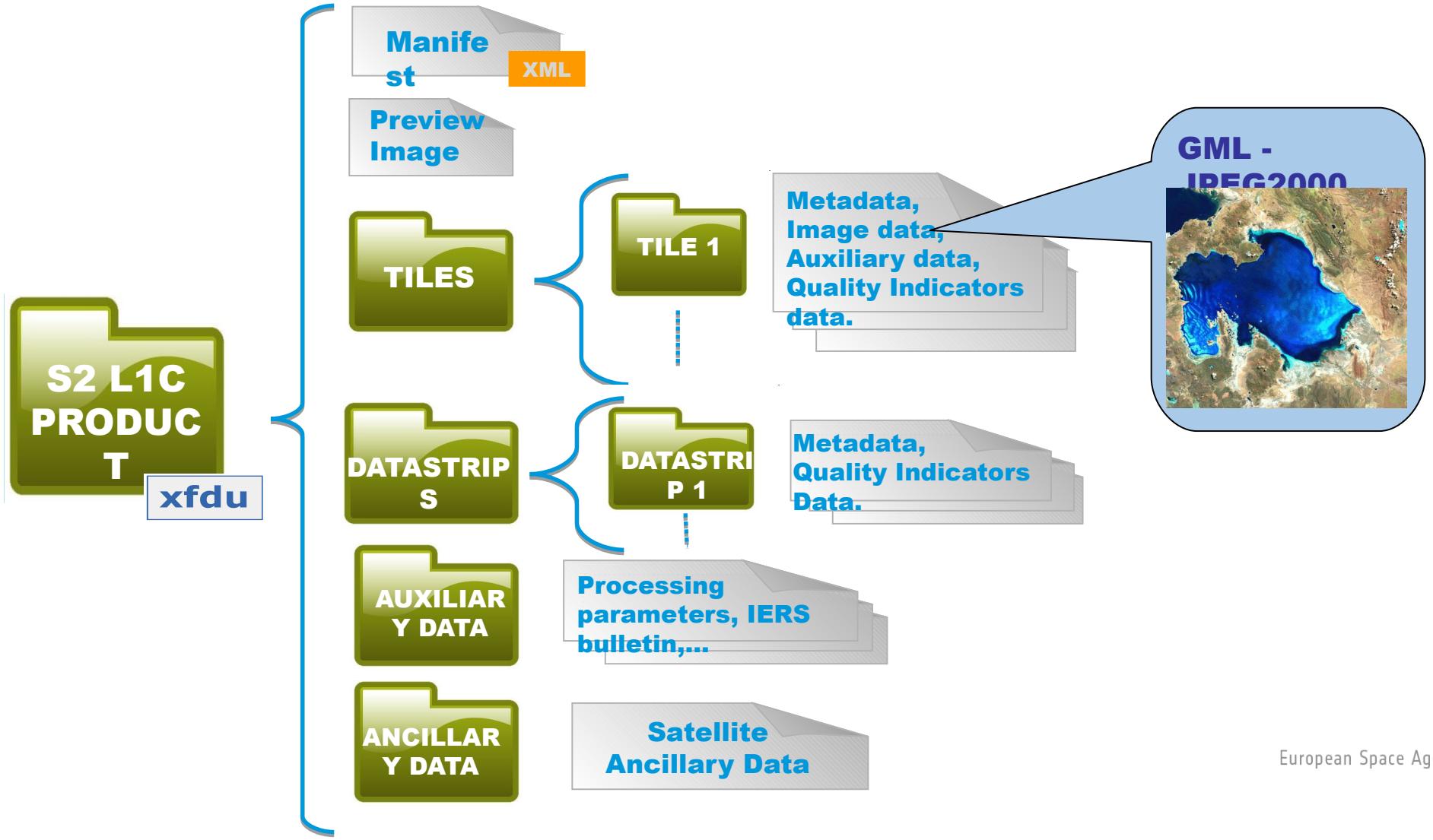
Thin cirrus corrections within a Level 2 image



Simulated Sentinel-2 scene containing cirrus clouds. True color coding: R/G/B = bands 4/3/1 (665, 560, 443 nm).
Left: original scene, center: cirrus band (1.375 µm), right: after cirrus and atmospheric correction. Credits: DLR for data simulation and NASA/JPL for AVIRIS data supply

Products Physical Format

- Two packaging formats proposed to users: Sentinel-SAFE and DIMAP.



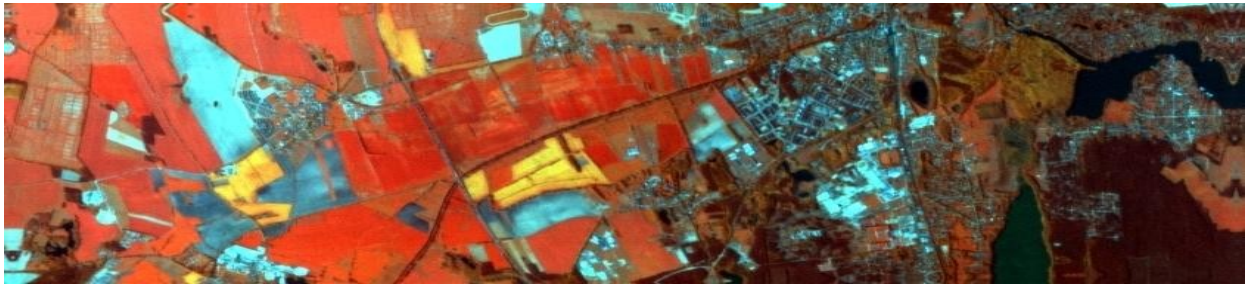
Data Quality

Radiometric Quality	
Absolute radiometric uncertainty	3 % (goal) , 5 % (threshold)
Inter-band relative radiometric uncertainty	3%
Linearity knowledge accuracy	1%
Modulation Transfer Function (MTF)	0.15 to 0.3 (for 10m bands) <0.45 (for 20 & 60m bands)
Geometric Quality	
Absolute geolocation uncertainty	20m 2σ (threshold) 12.5m 2σ (goal) with GCPs
Multi-temporal registration	0.3 pixel 2σ (goal) with GCPs
Multi-spectral registration (for any couple of spectral bands)	0.3 pixel 3σ

Sentinel-2 L2b simulated products

Natural color composite (B4, B3, B2)

Visible Near Infrared composite (B8, B4, B3)



Land Cover Classification (using all Bands)

Simulated Sentinel-2 images

	Urban
	Water
	Forest 1
	Forest 2
	Bare soil 1
	Bare soil 2
	Cultivated field 1
	Cultivated field 2

Sentinel-2 Summary

A very large swath (290*km*)

A high revisit frequency (5 days periodicity @ equator)

Systematic acquisition of all land surfaces and coastal waters

High spatial resolution (given the swath - 10*m* / 20*m* / 60*m*)

Accurate geo-location (20m without Ground Control Points)

Accurate multi-temporal pixel co-registration (0.3 SSD)

Onboard calibration using a full field of view Sun diffuser

A large number of spectral bands (13 in VNIR-SWIR domain)

***global* and *frequent* imaging, accurate cloud screening, atmospheric corrections, and geophysical variables retrieval**

More information at http://www.esa.int/gmes


Sentinel-3

Sentinel-3
Mission Highlights

Launch : 2014

Applications:
- Sea/land colour data and surface temperature
- sea surface and land ice topography
- coastal zones, inland water and sea ice topography
- vegetation products

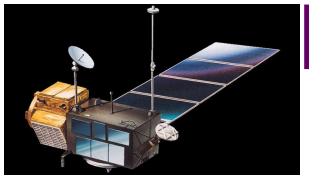
1198 kg spacecraft mass

Sun synchronous orbit at 814.5 km mean altitude over geoid

27 days repeat cycle

7 years design life time, consumables for 12 years

Sentinel-3 Mission Heritage



1992: TOPEX / Poseidon-1

Poseidon-1

2001: JASON-1

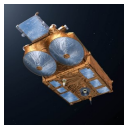
Poseidon-2

2008: JASON-2

Poseidon-3

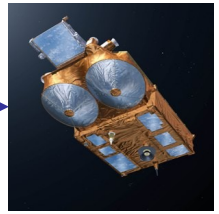
2012:AltiKa

SARAL



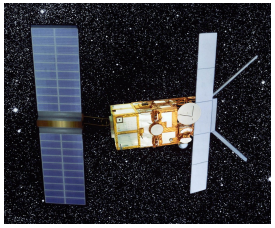
2005: CryoSat-1

SIRAL



2010: CryoSat-2

SIRAL



1992: ERS-1
1995: ERS-2

RA

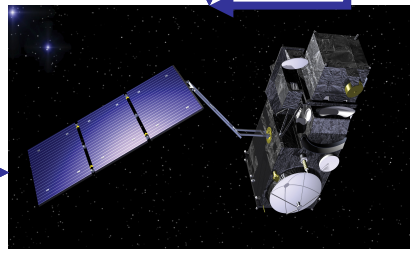
ATSR

2002: ENVISAT

RA-2

AATSR

MERIS



2013: Sentinel-3

SRAL, MWR, POD

SLSTR

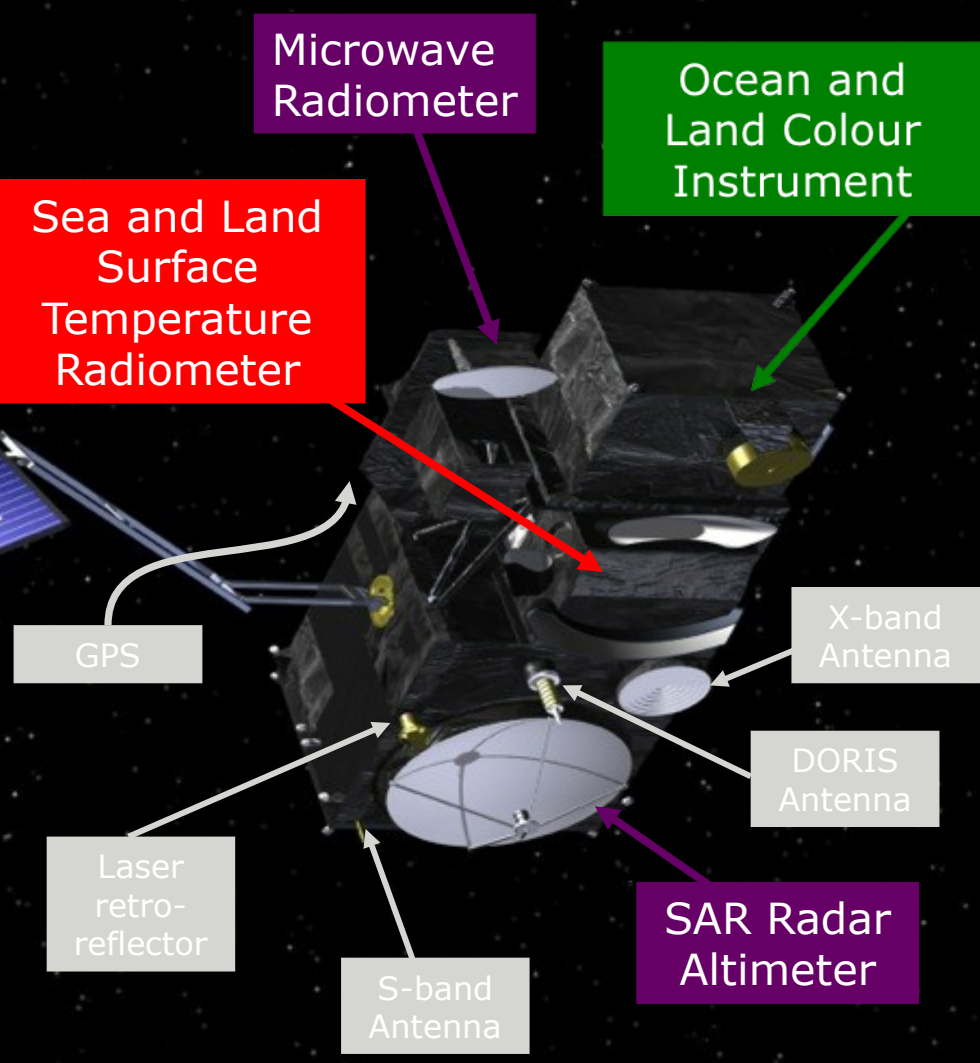
OLCI

Vegetation

1998: SPOT-4

Sentinel-3: Continuity of ENVISAT Ocean Observation

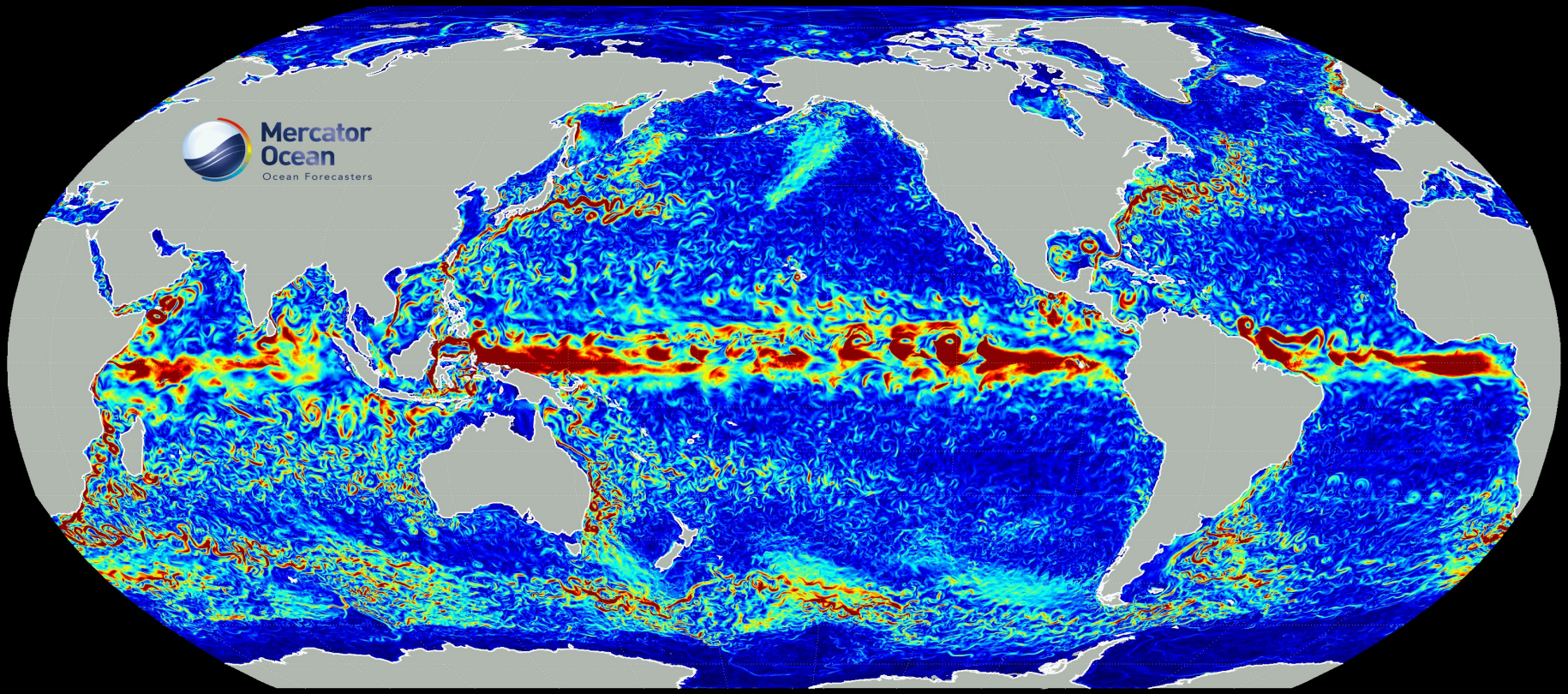
Main satellite characteristics
- 1250 kg maximal mass
- Volume in 3.89 m x 2.202 m x 2.207 m
- Average power consumption of 1100 W
- 7.5 years lifetime (fuel for 5 add. years)
- Large cold face for optical instruments thermal control
- Modular accommodation for a simplified management of industrial interfaces
- Launch S3A April 2014
- Launch S3B later



Observation Data Management:
- **21.25 Gb (170 Gbit) of observation data per orbit**
- **Space to ground data rate 2 x 280 Mbps X-Band**
- **1 ground contact per orbit**
- **3h delivery timeliness (from satellite sensing)**

Sentinel-3 Applications

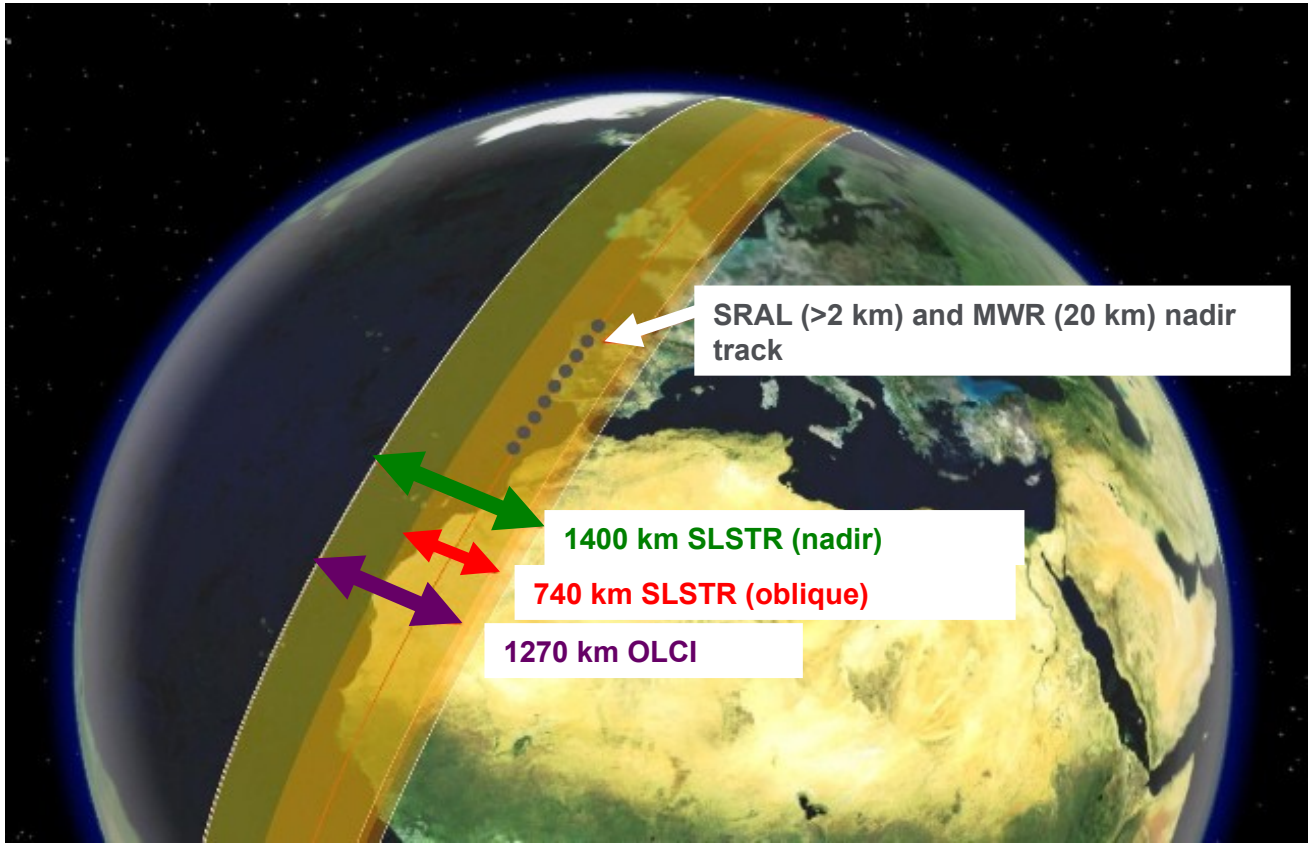
- Mercator Global 1/12 Nov 2011 (6 day forecast) Surface Velocity m/s



0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8

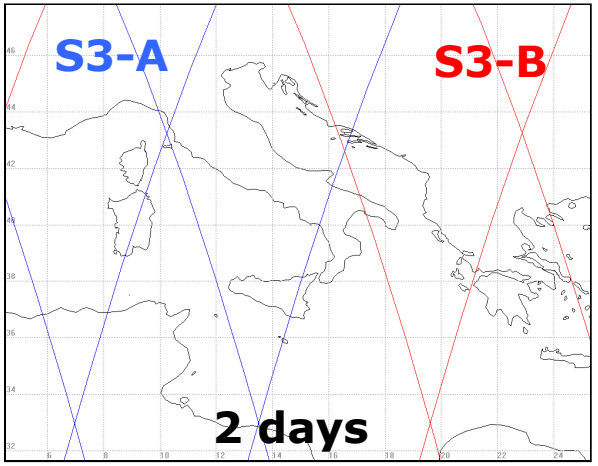
Sentinel-3: Instrument Swath and Satellite Orbit

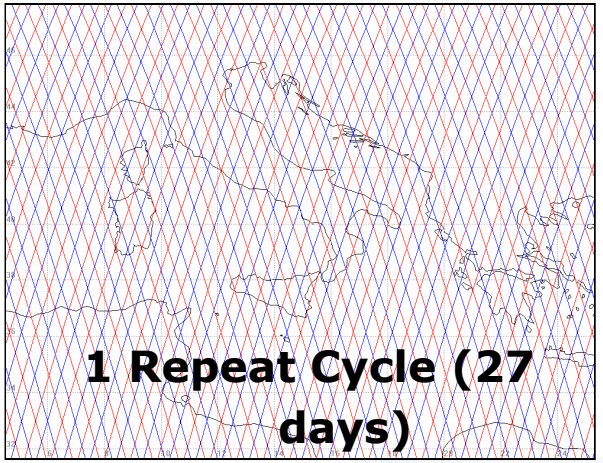
Instrument Swath Patterns



Orbit type	Repeating frozen SSO
Repeat cycle	27 days (14 + 7/27 orbits/day)
LTDN	10:00
Average altitude	815 km
Inclination	98.65 deg

Ground Track Patterns

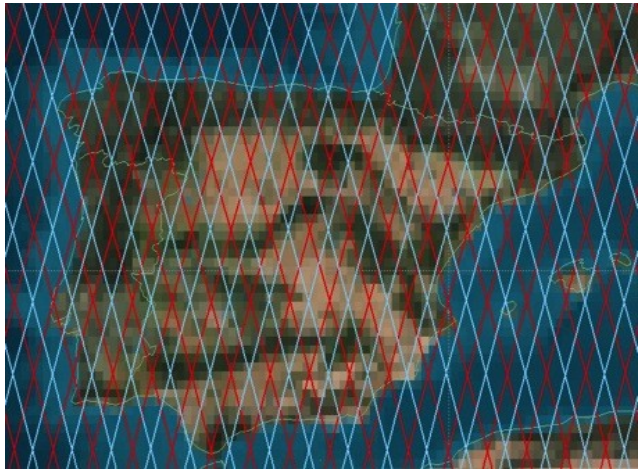




GMES
Observing our planet for a safer world

S3: Revisit time and coverage

Topography Mission: ground track repeatability, dense spatial sampling



Ground tracks ~52 km separation after 1 complete cycle (27 days)

		Revisit at Equator	Revisit for latitude > 30°	Req.
Ocean Colour (Sun-glint free, day only)	**1 Satellite**	< 3.8 days	< 2.8 days	< 2 days
	2 Satellites	< 1.9 days	< 1.4 days	
Land Colour (day only)	**1 Satellite**	< 2.2 days	< 1.8 days	< 2 days
	2 Satellites	< 1.1 day	< 0.9 day	
SLSTR dual view (day and night)	**1 Satellite**	< 1.8 days	< 1.5 days	< 4 days
	2 Satellites	< 0.9 day	< 0.8 day	

S3 OLCI: Technical details

Basic configuration similar to MERIS:

5 Camera Optical Sub Assemblies (COSA),

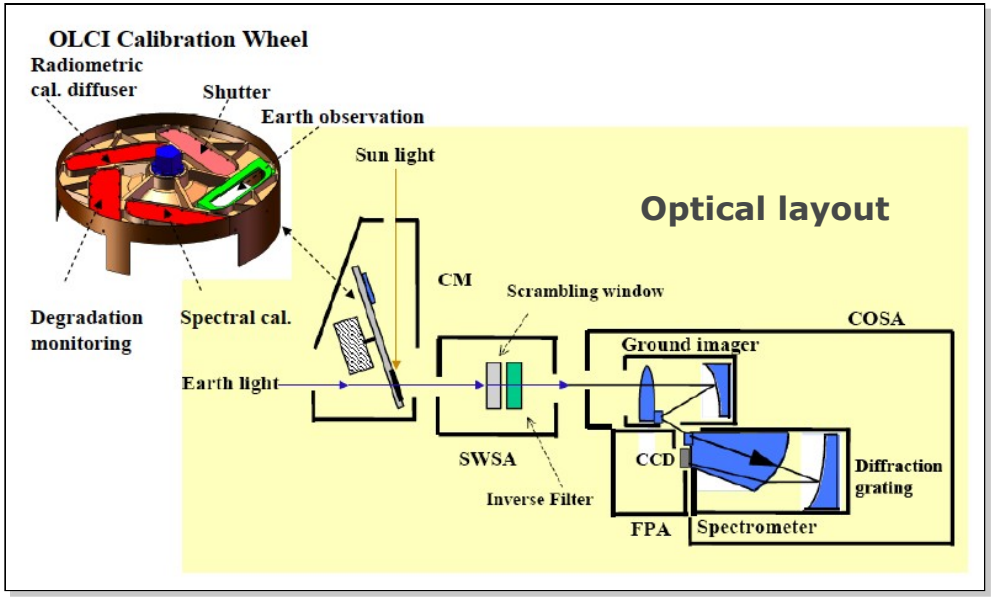
5 Focal Plane Assemblies (FPA),

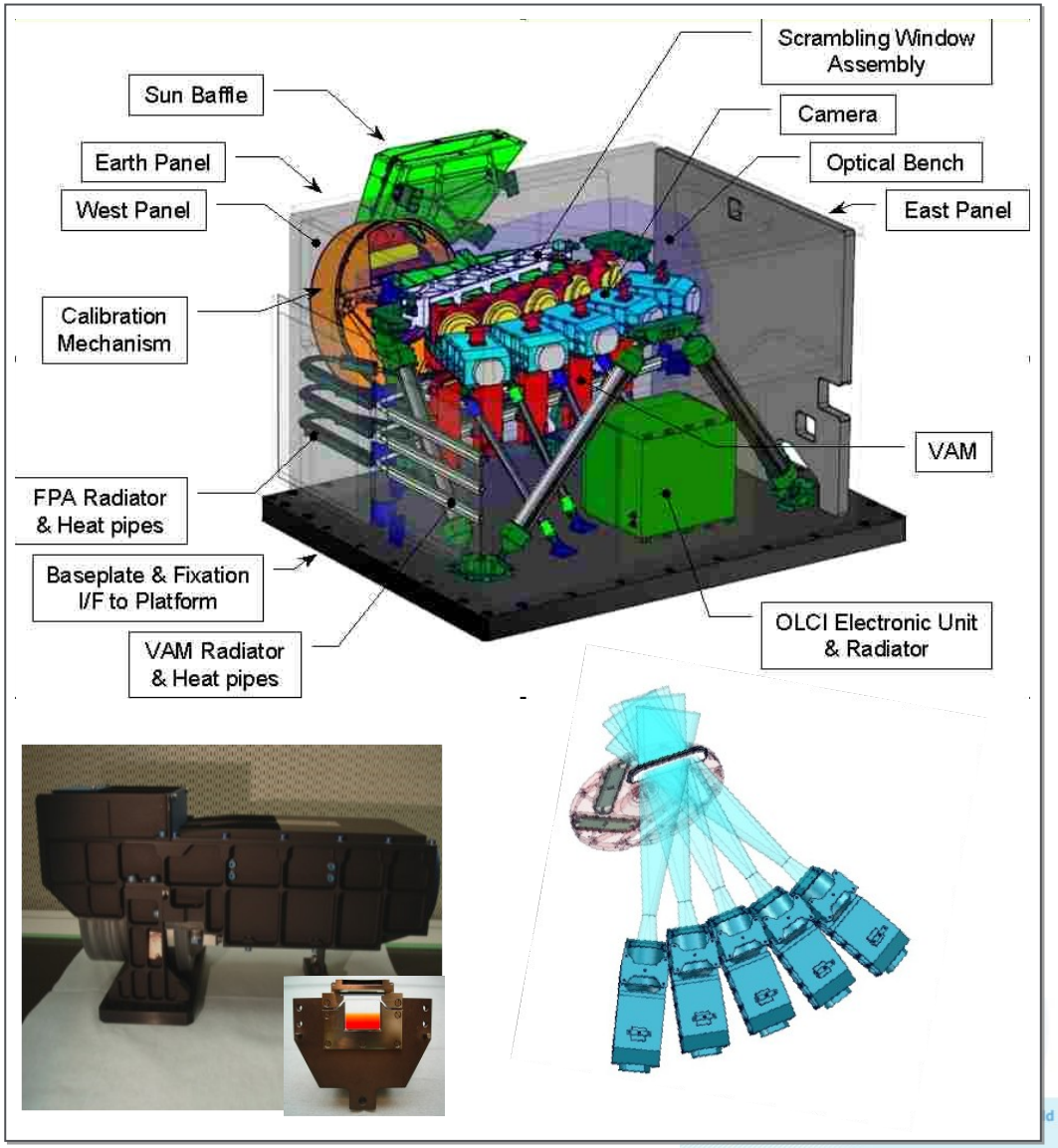
5 Video Acquisition Modules (VAM),

1 Scrambling Window Assembly (SWA),

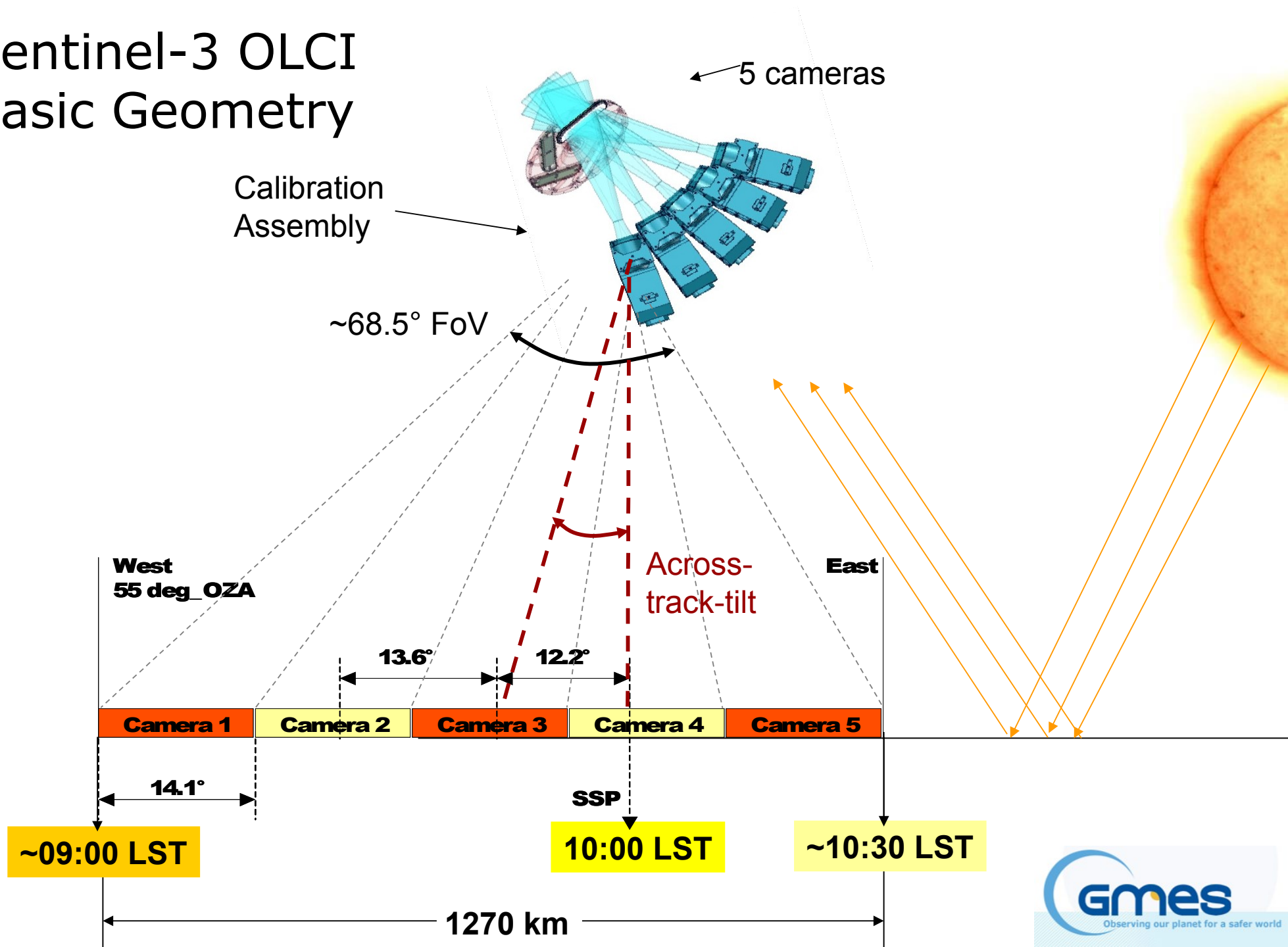
1 OLCI Electronic Unit (OEU) managing all the instrument functions,

1 calibration assembly allowing a radiometric and spectral calibration





Sentinel-3 OLCI Basic Geometry



OLCI: Ocean and Land Colour Instrument comparison to MERIS

Pushbroom Imaging Spectrometer (VIS-NIR) – similar to MERIS

Key Improvements:

- More spectral bands (from 15 to 21): 400-1020 nm
- Broader swath: 1270 km
- Reduced sun glint by camera tilt in west direction (12.20°)
- Absolute (relative) accuracy of 2% (relative 0.5%)
- Polarisation sensitivity < 1%
- Full res. 300m acquired systematically for land & ocean
- Reduced res. 1200m binned on ground (L1b)
- Improved characterization, e.g. straylight, camera boundary characterization
- Ocean coverage < 4 days, (< 2 days, 2 satellites)
- Timeliness: 3 hours NRT Level 2 product
- 100% overlap with SLSTR

=> Improved L2 products e.g., Cla, Transparency, TSM, Turbidity, PFTs, HAB, NDVI, MGVI, MTCI, faPAR, LAI

MERIS Bands	λ center	Width
Yellow substanace/detrital pigments	412.5	10
Chl.. Abs. Max	442.5	10
Chl & other pigments	490	10
Susp. Sediments, red tide	510	10
Chl. Abs. Min	560	10
Suspended sediment	620	10
Chl. Abs, Chl. fluorescence	665	10
Chl. fluorescence peak	681.25	7.5
Chl. fluorescence ref., Atm. Corr.	708.75	10
Vegetation, clouds	753.75	7.5
O_2 R-branch abs.	761.25	2.5
O_2 P-branch abs.	778.75	15
Atm corr	865	20
Vegetation, H_2O vap. Ref.	885	10
H_2O vap., Land	900	10

New OLCI bands	λ center	Width
Aerosol, in-water property	400	15
Fluorescence retrieval	673.75	7.5
Atmospheric parameter	764.375	3.75
Cloud top pressure	767.5	2.5
Atmos./aerosol correction	940	20
Atmos./aerosol correction	1020	40

S3: Sea and Land Surface Temperature Radiometer (SLSTR) Comparison AATSR

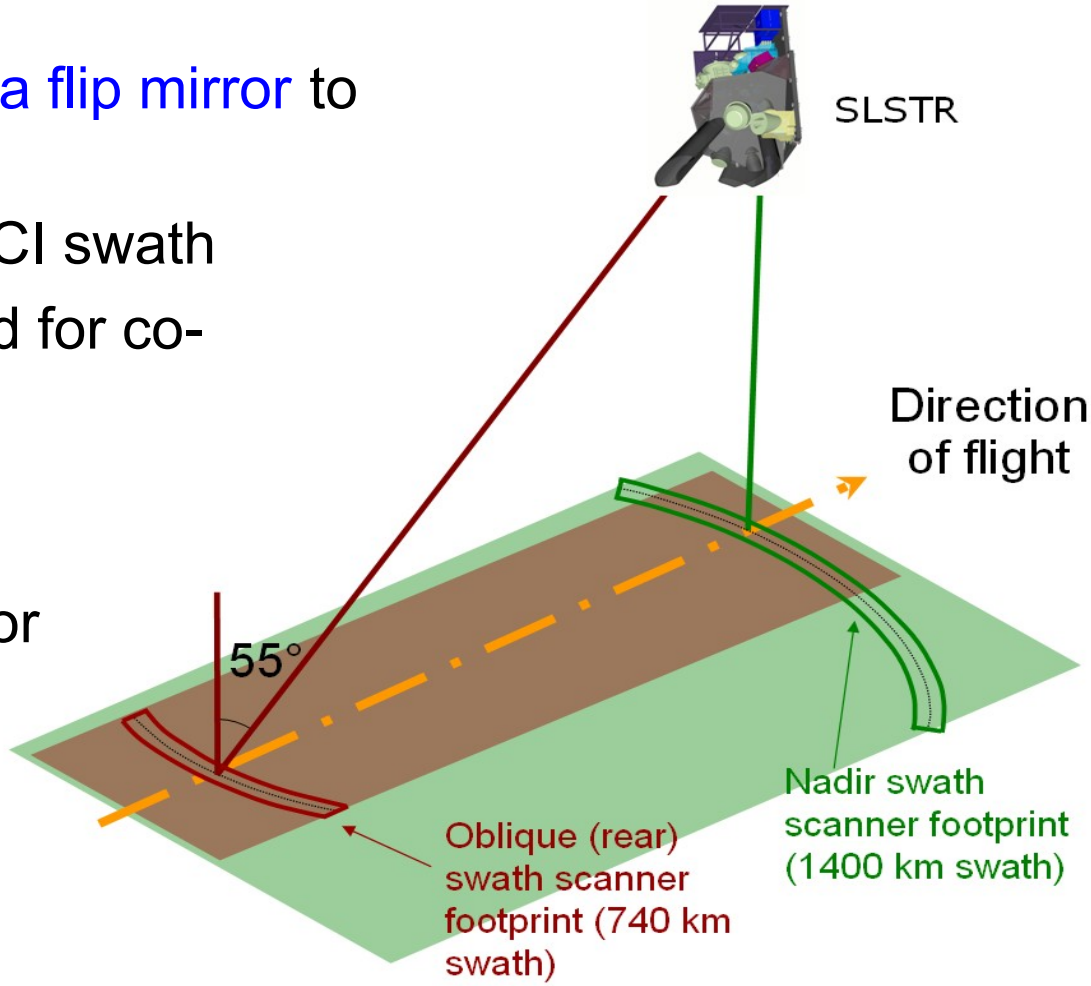
Key Improvements:

- number of spectral bands from 7 to 9 (new 1.3 and 2.2um) for better Ci Cloud detection
- increased resolution for VIS and SWIR channels (0.5 km @ nadir, TIR 1 km @nadir)
- maintain along track scanning with increased swath of oblique view to 750 km
- increased nadir swath coverage to 1400 km
- 100% overlap with OLCI
- improved coverage Ocean < 4 days (practically ~ 2 days)
- dedicated Active Fire channels
- Timeliness: 3 hours NRT Level 2 product

Thermal Structure in the Med, ENVISAT AATSR

S3 SLSTR: Basic Geometry

- Uses two scan mechanisms and a flip mirror to enable wider swath
- Nadir swath is offset to cover OLCI swath
- One VIS channel (865nm) is used for co-registration with OLCI swath
- Oblique view 55 deg inclination maintains a longer atmospheric path length compared to nadir for better atmospheric correction



S3 SLSTR: Bands

Absolute rad. Accuracy VI/SWIR S1–S6:
<5% (EOL)
<2% (BOL)

Absolute rad. Accuracy TIR S7/8/9: 0.2K
(goal: 0.1K)

Polarisation sensitivity:
S1–S6: < 0.07
S7/8/9:< 0.10

Stability:
S1–S6: <0.1%
S7/8/9: <0.08K

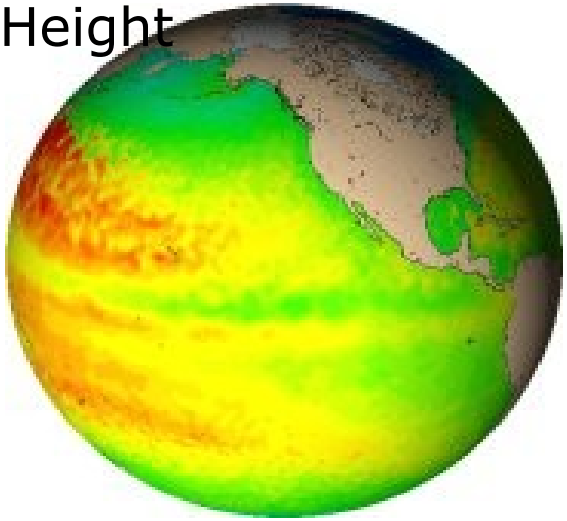
SLSTR Band	λcenter [μ m]	Δλ [μ m]	SNR [-] / NeDT [mK]	SSD [km]
S1	0.555	0.02	20	0.5
S2	0.659	0.02	20	0.5
S3	0.865	0.02	20	0.5
S4	1.375	0.015	20	0.5
S5	1.61	0.06	20	0.5
S6	2.25	0.05	20	0.5
S7	3.74	0.38	80 mK	1.0
S8	10.95	0.9	50 mK	1.0
S9	12	1.0	50 mK	1.0
F1	3.74	0.38	500	1.0
F2	10.95	0.9	400	1.0

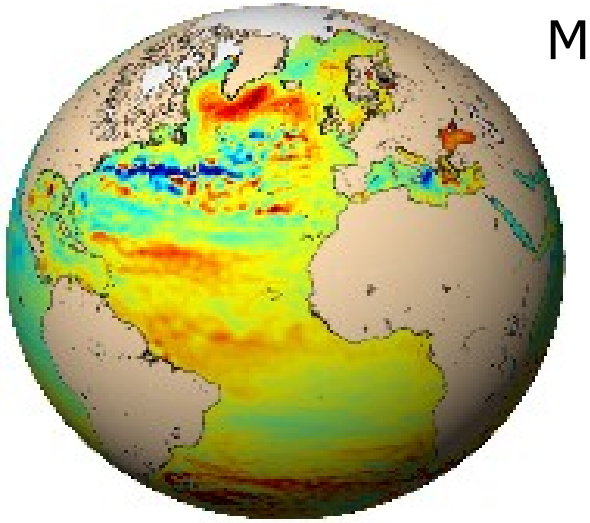
SLSTR is a self-calibrating instrument using on-board calibration device (blackbody cavities for TIR; Solar diffuser for the VIS-SWIR)

AATSR Heritage
SLSTR New Bands

S3 Topography Mission

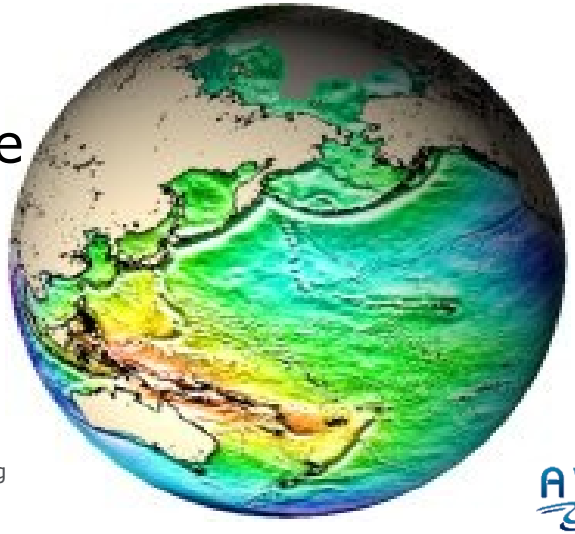
Sea Surface Height

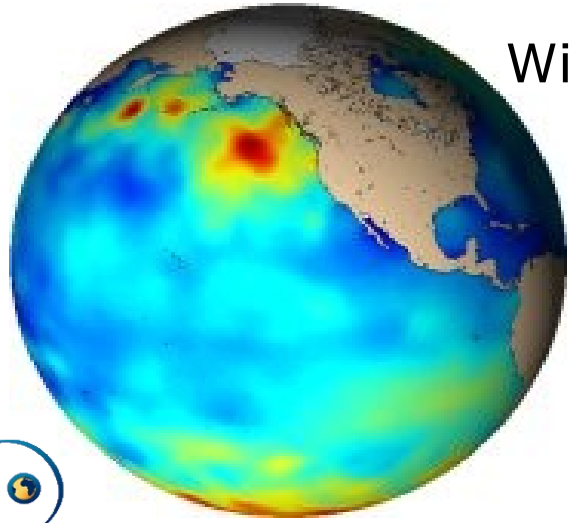




Mean Sea level

DEM, Tides,
River and lake
Heights, MSS
…

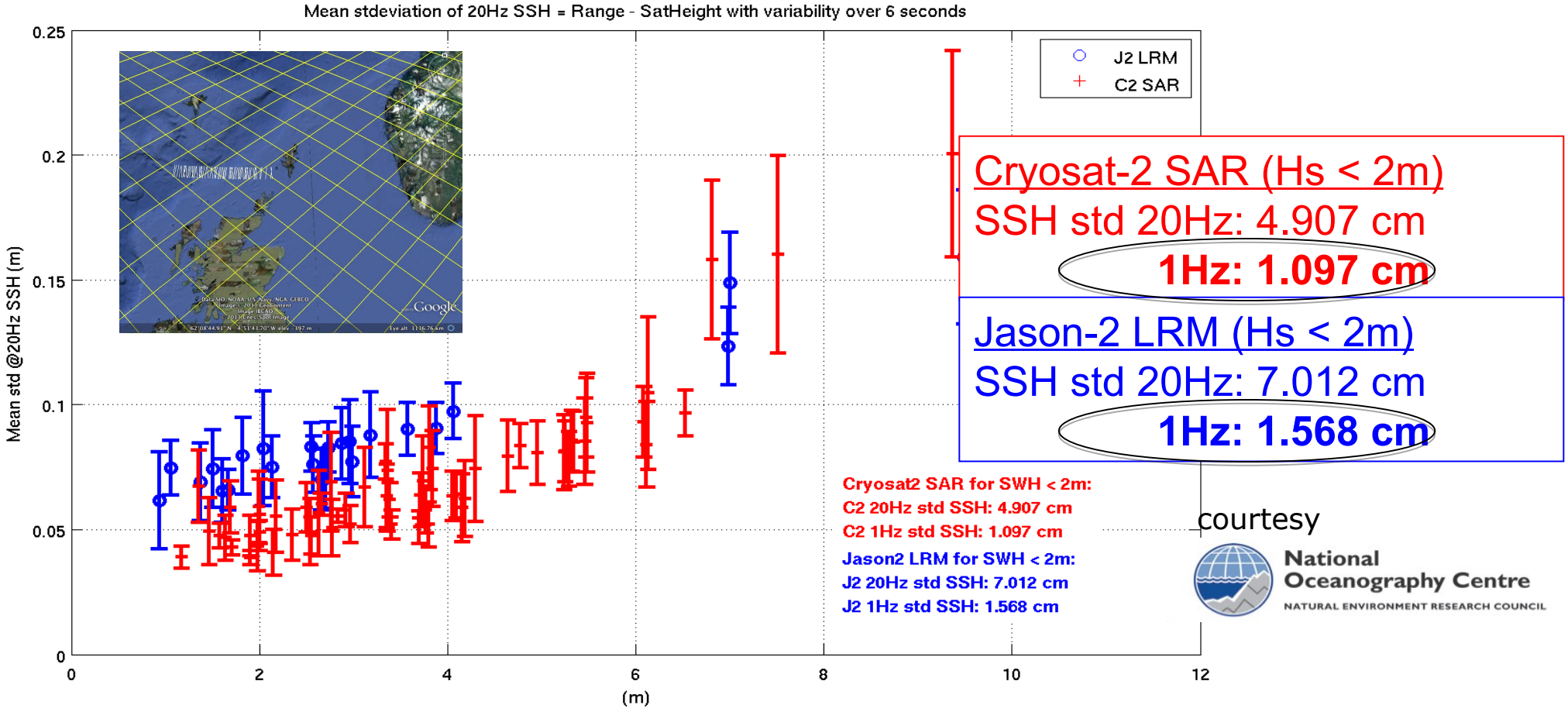




Wind and Waves

SAR Altimeter vs classical altimeter

Norwegian Sea: SSH accuracy (July 2010-Feb 2011)



Cryosat-2 SAR (Hs < 2m)
SSH std 20Hz: 4.907 cm
1Hz: 1.097 cm

Jason-2 LRM (Hs < 2m)
SSH std 20Hz: 7.012 cm
1Hz: 1.568 cm

courtesy
National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Factor of ~1.5 improvement of Cryosat-2 SAR versus Jason-2 LRM

S3: Topography Mission

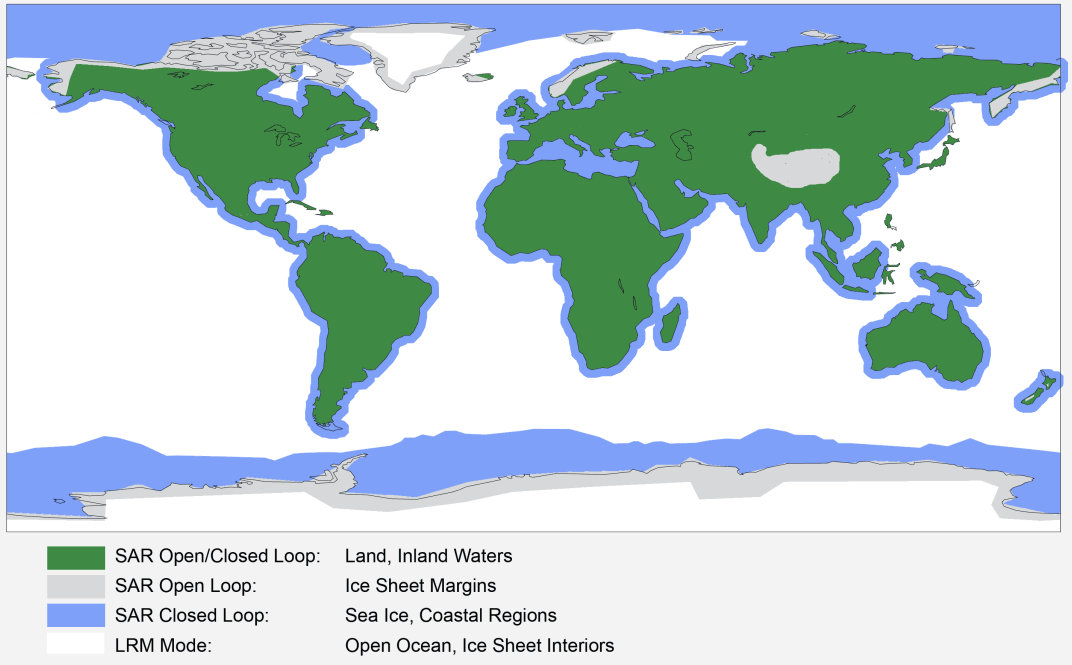
Topography package:

1. **Synthetic Aperture Radar Altimeter (SRAL)**
2. **Microwave Radiometer (MWR)**
3. **Precise Orbit Determination (POD)**

Key Improvements:

S

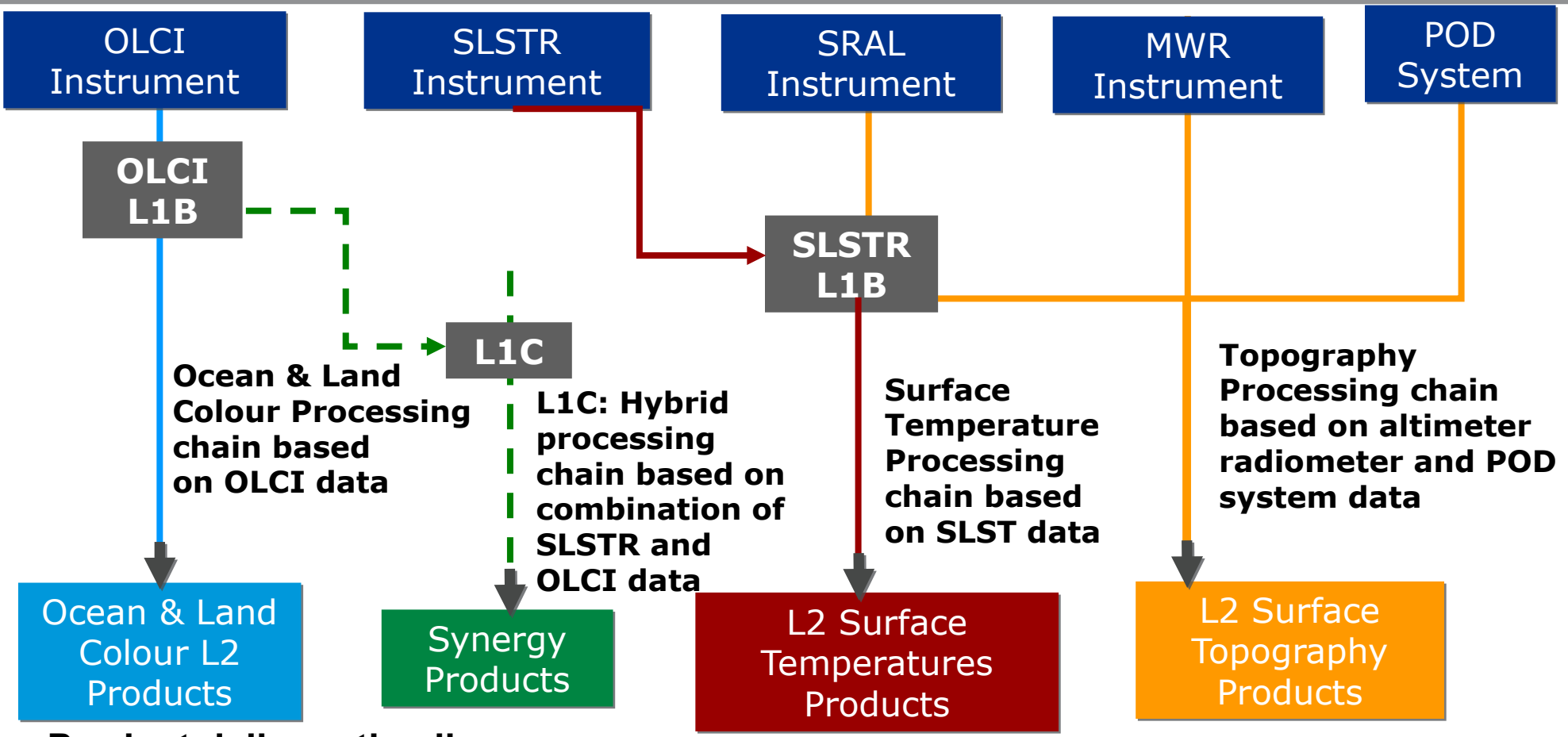
S3 Topography mission Mode mask



Observed surfaces

- Open ocean, coastal ocean
- Ice sheets (interiors and margins)
- Sea ice
- In-land water (rivers & lakes)

S3: Data processing chains



Product delivery timeliness:

- **Near-Real Time (< 3 hr) availability of L2 products (and L1b)**
- **1 to 2 days delivery of higher quality topography products for assimilation in models**

Sentinel – 3 Core GS User Products list

Level 1
ESA/EUMETSAT

LEVEL 1
- OLCI L1B
- SLSTR L1B

Marine products
EUMETSAT

LEVEL 2
- OLCI ocean color
- SLSTR sea
- SRAL L2

Land products
ESA

LEVEL 2
- OLCI Land
- SLSTR Land
- SYNERGY / VGT
- SRAL L2

Sentinel-3 Core PDGS
Optical geophysical parameters list

Geophysical Product	Application Domain	Spatial Resolution	Continuity	Measurement Source
Normalised Water Surface Reflectances		300 m , 1.2 km	Envisat	OLCI
Chlorophyll Concentration for open ocean waters		300 m , 1.2 km	Envisat	OLCI
Chlorophyll Concentration for Coastal waters		300 m , 1.2 km	Envisat	OLCI
Total suspended Matter		300 m , 1.2 km	Envisat	OLCI
Diffuse attenuation coefficient		300 m , 1.2 km	GCM* (e.g. Modis)	OLCI
Coloured Detrital and Dissolved Material		300 m , 1.2 km	Envisat	OLCI
Photosynthetically active radiation		300 m , 1.2 km	Envisat	OLCI
Aerosol Optical Depth over water		300 m , 1.2 km	Envisat	OLCI
Aerosol Angstrom exponent over water		300 m , 1.2 km	Envisat	OLCI
Integrated Water Vapour Column		300 m , 1.2 km	Envisat	OLCI
Sea Surface Temperature		1 km	Envisat	SLSTR
Land Surface Temperature		1 km	Envisat	SLSTR
Surface Reflectances over Land		300 m	Envisat	OLCI+SLSTR
Aerosol Optical Depth over Land	 	300 m	Envisat	OLCI+SLSTR
Aerosol Angstrom exponent over Land	 	300 m	Envisat	OLCI+SLSTR
Vegetation-like Surface Reflectances 1 day Synthesis		1 km	Vegetation	OLCI+SLSTR
Vegetation-like Surface Reflectances 10 days Synthesis		1 km	Vegetation	OLCI+SLSTR
Vegetation Normalised Difference of Vegetation Index		1 km	Vegetation	OLCI+SLSTR

GCM* : GMES Contributing Mission

Sentinel-3: Status summary

- Sentinel-3 A & B units are under development
- S3 satellite CDR close-out in Nov-2011

SLSTR Subsystem AIT is in full progress and will deliver to instrument in Summer/Autumn 2012 for instrument integration and testing.

SLSTR Instrument calibration and subsequent delivery targeted for 1st quarter 2013.

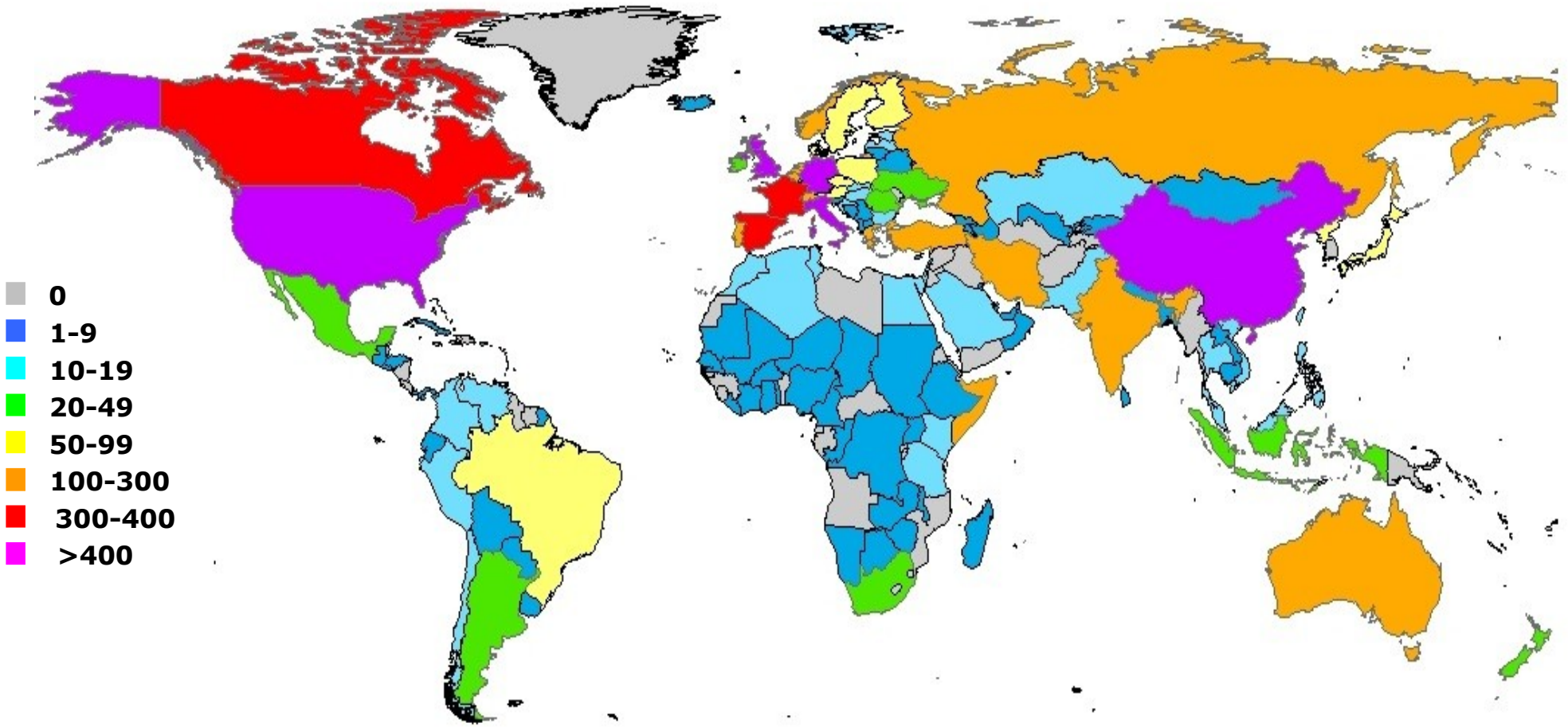
- Cal/Val and in-orbit verification plans for commissioning phase defined
- ESA coordinating with EUMETSAT the development of the ground segment
- SLSTR SSTskin L2P available from the start
- S3 Validation team call expected in late 2012 – International call

- **Launch of the Sentinel-3A currently foreseen for Apr 2014**
- **Launch of the Sentinel-3B expected ~18 months later**
  - EUMETSAT in charge of the operation of the marine Mission
  - ESA will be the operator of the land Mission
  - Sentinel operation will be funded by the European Commission (not yet established)

Sentinels for Science

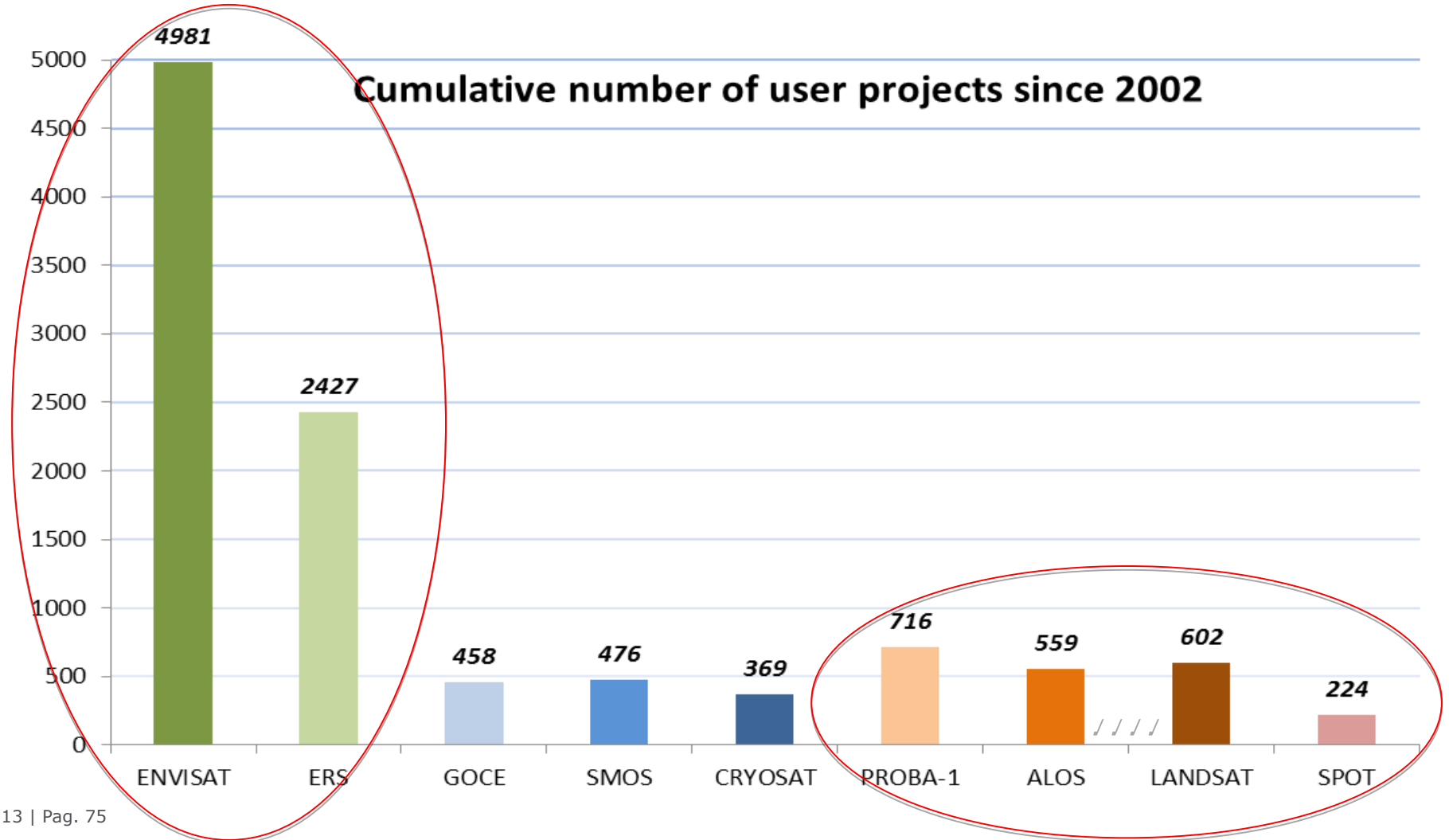
scientific exploitation
of operational missions

Fostering EO Research Worldwide
ESA PI Projects since 2000



Science User Community

Some 8500+ users exploiting ESA and ESA TPM data provided by ESA



OBJECTIVES

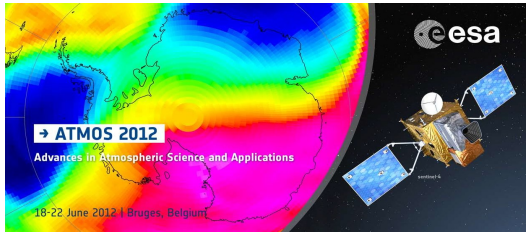
SEOM element of EOEP4 objectives :

- **Federate, support and expand** the Earth Observation research community
- **Strengthen the leadership** of European Earth Observation research community
- Enable the EO science community to **address new scientific research**

Please visit seom.esa.int

Sentinels Scientific Exploitation Preparation

In preparation for the Sentinels scientific exploitation a series of workshops have been organized by ESA to gather feedback and recommendations from the scientific community



18-22 June 2012
Bruges, BE
224 Participants

24-29 September 2012
Venise, IT
572 Participants

18-22 June 2012
Tromso, NO
107 Participants

15-19 October 2012
Frascati, IT
220 Participants

23-27 April 2012
Frascati, IT
338 Participants

9-13 September 2013
Edinburgh, UK
1000+ Expected

28 Jan-1 Feb 2013
Frascati, IT
170 Participants

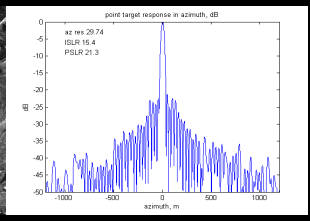
19-23 September 2011
Frascati, IT
368 Participants

seom
scientific exploitation of operational missions

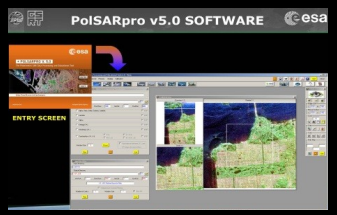
ACTION LINES

esa

Research and Development Studies



Scientific Toolboxes development



Science Users Consultations

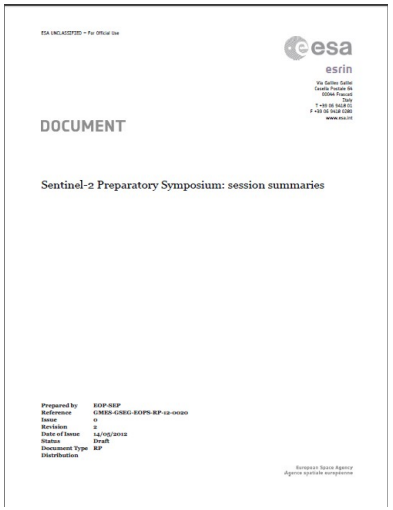
Training Next Generation of Earth Observation Scientists

Promoting Science Data use and Results

Science Use (SEOM Feedback Loop)

http://www.s2symposium.org/

RECOMMENDATIONS


DOCUMENT

Sentinel-2 Preparatory Symposium: session summaries

ACTION

R&D-New Methods
Scientific Toolboxes
Trainings
Workshops Results

REPORTING at next

SCIENTIFIC TOOLBOXES DEVELOPMENT (total of 1.7 MEuros),
all in open source in accordance with Principles for Sentinel Data Policy
[ESA/PB-EO(2009)98, rev. 1]

- **S1-ToolBox**: for scientific exploitation of S-1 data

ESA Intended Invitation To Tender 13.155.07

- **S2-ToolBox**: for scientific exploitation of S-2 data

ESA Intended Invitation To Tender 13.155.13

- **S3-ToolBox**: for scientific exploitation of S-3 data

ESA Intended Invitation To Tender 13.155.08

- **S3-ALT –Toolbox :** for scientific exploitation of SAR altimetry

In preparation

- **S5P-ATM-ToolBox:** for scientific exploitation of atmospheric missions

ESA Intended Invitation To Tender 13.155.16

RESEARCH and DEVELOPMENT STUDIES

for advanced methods (total of 1.6 MEuros)

- **S1-INSARAP:** to study S1/simulated data in TOPS for interferometric applications

ESA Intended Invitation To Tender 13.155.12

- **S1-OTOPS:** to study S1/simulated data in TOPS for various Ocean applications
- **S3ALT-COASTAL:** to prototype a Coastal Altimetry algo and product for SAR mode
- **S3ALT-HYDRO:** to develop a River and Lake product for SAR mode
- **S3ALT-LAND:** to develop a Land Altimetry product for SAR mode
- **S3-ACWATER:** to develop atmospheric correction for S-3 over complex waters
- **S5P ISAS:** to develop improved spectroscopy data bases for atmospheric Sentinels

ESA Intended Invitation To Tender 13.155.17

seom
scientific exploitation
of operational missions

Upcoming Events

esa

seom
scientific exploitation
of operational missions

THANK YOU !

esa