



→ RADAR VISION FOR COPERNICUS



# Sentinel-1 Mission Status

*Pierre Potin, Sentinel-1 Mission Manager, ESA  
on behalf of the ESA Sentinel-1 Team*

*MDIS / Form@ter 2017  
16-20 October 2017  
Clermont-Ferrand, Besse-en-Chandesse*



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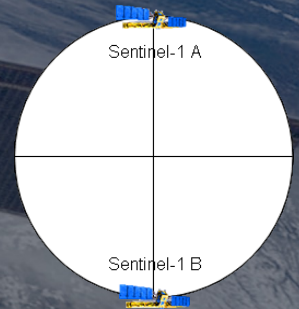


European Space Agency

# Sentinel-1: Copernicus radar imaging mission for ocean, land, emergency



- Part of the Copernicus Programme led by the European Union
- Mission based on 2 identical satellites (S1A & S1B) and a highly performing ground segment
- Main satellites characteristics:
  - C-band Radar instrument
  - Instrument duty cycle of 25 min/orbit in HBR modes and 75 min/orbit in LBR (Wave)
  - Sun-synchronous orbit at 693 km altitude
  - Inclination:  $98.18^\circ$
  - 7 years lifetime, consumables for 12 years
  - Mean LST: 18:00h at ascending node
  - 12-day repeat cycle at Equator (6 days with 2 satellites)
- Instrument operations based on a predefined observation scenario
- Systematic data processing with open & free data access
- Gradual increase of the mission operational capacity from the S1A launch up to the mission constellation routine operations



# Sentinel-1 Mission Phases



S1A Operational qualification

S1A Space Segment Commissioning

S1 Mission Operations Qualification

S1A Routine Operations

S1B Space Segment Commissioning

S1 Mission Routine Operations

S1A-Launch  
3 April  
2014

S1A IOCR  
Sep  
2014

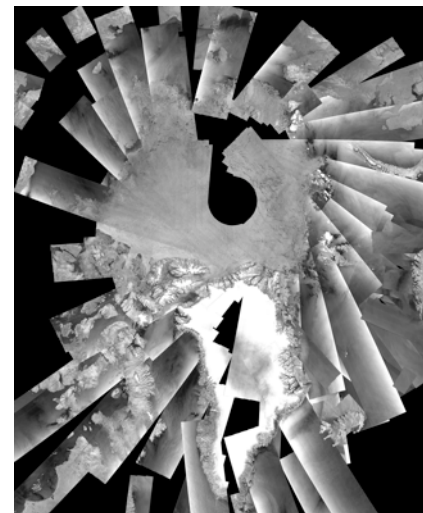
1st S1A  
ROR  
9 June  
2015

S1B Launch  
25 April  
2016

S1B  
IOCR  
Sep  
2016

18 Oct 2017

- **Sentinel-1 nominal routine operations continue**
  - Sentinel-1A and -1B data routinely provided to Copernicus Services (in particular the Copernicus Marine Environment Monitoring Service) and users worldwide
  - On-going support to various activations from the Copernicus Emergency Management Service and International Charter Space and Major Disasters
  - Use of EDRS service has been progressively increased as part of routine operations, for both Sentinel-1A and Sentinel-1B
- **Sentinel-1 constellation generates now 11 TB of products daily** (against a formal specification of 3 TB)
- **Upcoming activities**
  - Start of gradual increase of Quasi Real Time observations in response to Copernicus and Member States needs
  - Identify and implement mission evolution to support new user needs, assess an increased system capacity enabling further mission exploitation, etc.



# Operational use of European Data Relay System (EDRS)

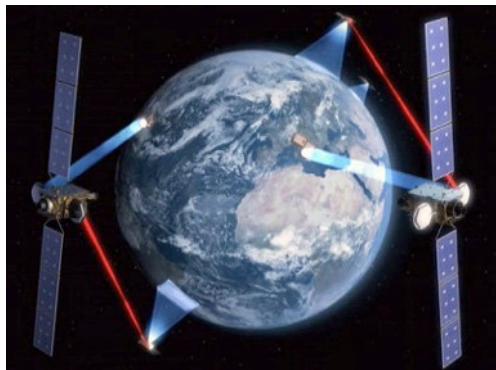


The European Data Relay System service provides complementary acquisition of Sentinel-1 mission data addressing in particular:

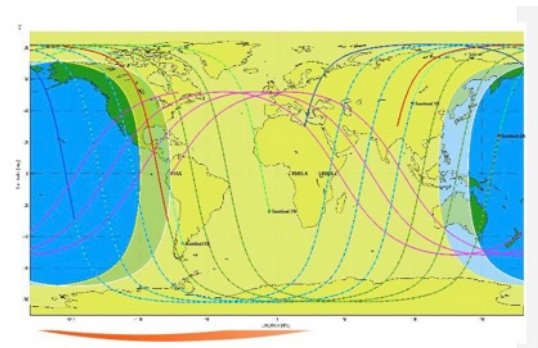
- **increased coverage**
- **enhanced timeliness, including quasi-real time** (QRT) observation capabilities, in particular outside Europe

The main functions provided by the service are:

- Sentinels mission **data transmission via Optical** (Laser) **link** to the GEO satellites
- Mission **data relay** between the GEO satellites and the Ka-band ground receiving terminals
- Mission **data reception, decommutation and provision** to the service interface point (Copernicus WAN circulation network)



EUTELSAT 9B hosting EDRS-A



EDRS-Sentinels geometrical visibility map

Sentinel-1 Mission Status – ESA | Slide 5

# Sentinel-1 Constellation operations

# Operational services status summary



There is a large committed team and a set of efficient operational services contributing to the Sentinel-1 operations performance:

- COPERNICUS WAN Service
- Svalbard X-Band Acquisition Service
- Matera X-Band Acquisition Service
- Maspalomas X-Band Acquisition Service
- UK-PAC Long Term Archiving Service
- DLR-PAC Long Term Archiving Service
- Mission Performance Service
- Precise Orbit Determination Service
- Data Access Service
- E2E Production Operations Service

# Sentinel-1 observation scenario

## Main thematic domains & components



Land cover:  
agriculture, forestry,  
hydrology, etc.

Maritime  
surveillance

European coverage

Sea-ice, icebergs,  
lake-ice

Emergency

Calibration/validation

Ground deformation:  
Tectonic, volcanoes,  
landslides, subsidence...  
(InSAR applications)

Security

Global land mapping

Sea state

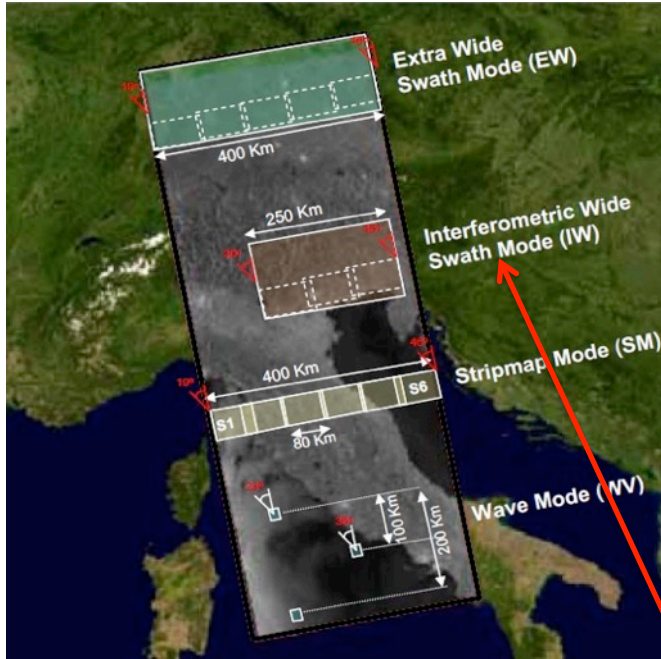
Ice sheets, glaciers,  
permafrost, snow, etc

PR actions  
(infrequent)



# Sentinel-1 observation scenario

## SAR Operational Modes



EW

IW

SM

WV

GRD Level 1 product resolution	Swath Width	Polarisation
50m (3 ENL)	> 400 km	HH+HV or VV+VH
20m (5 ENL)	> 250 km	HH+HV or VV+VH
9m (4 ENL)	> 80 km	HH+HV or VV+VH
50m (140 ENL)	20 x 20 km <sup>2</sup> at 100 km spacing	HH or VV

IW: main mode over land and coastal areas



# Image Acquisition in Interferometric Wide Swath mode (IW)

Terrain Observation  
by Progressive Scans  
(TOPS)

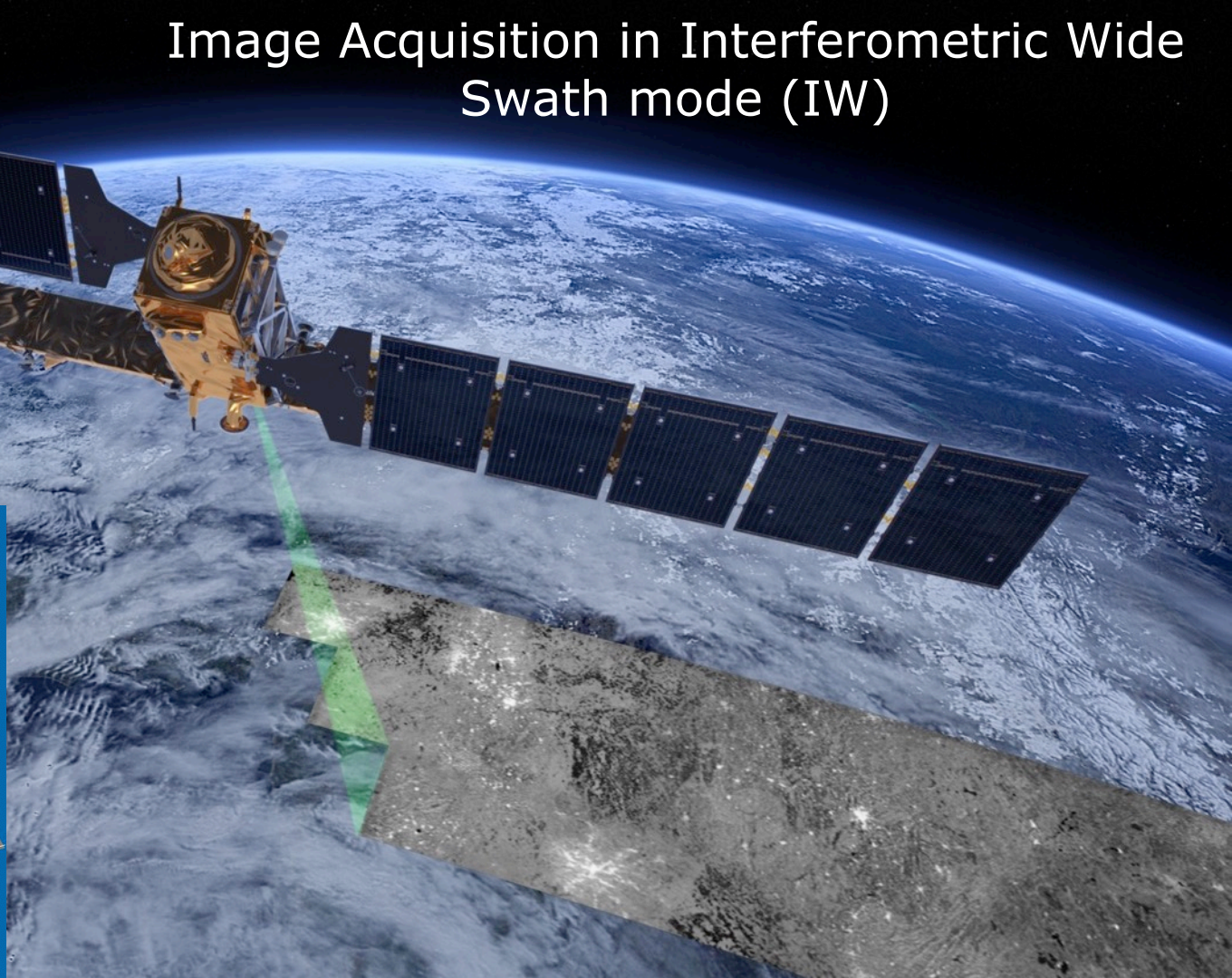
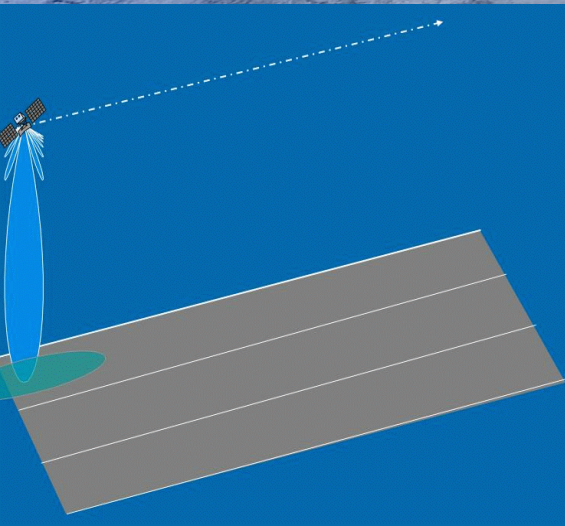
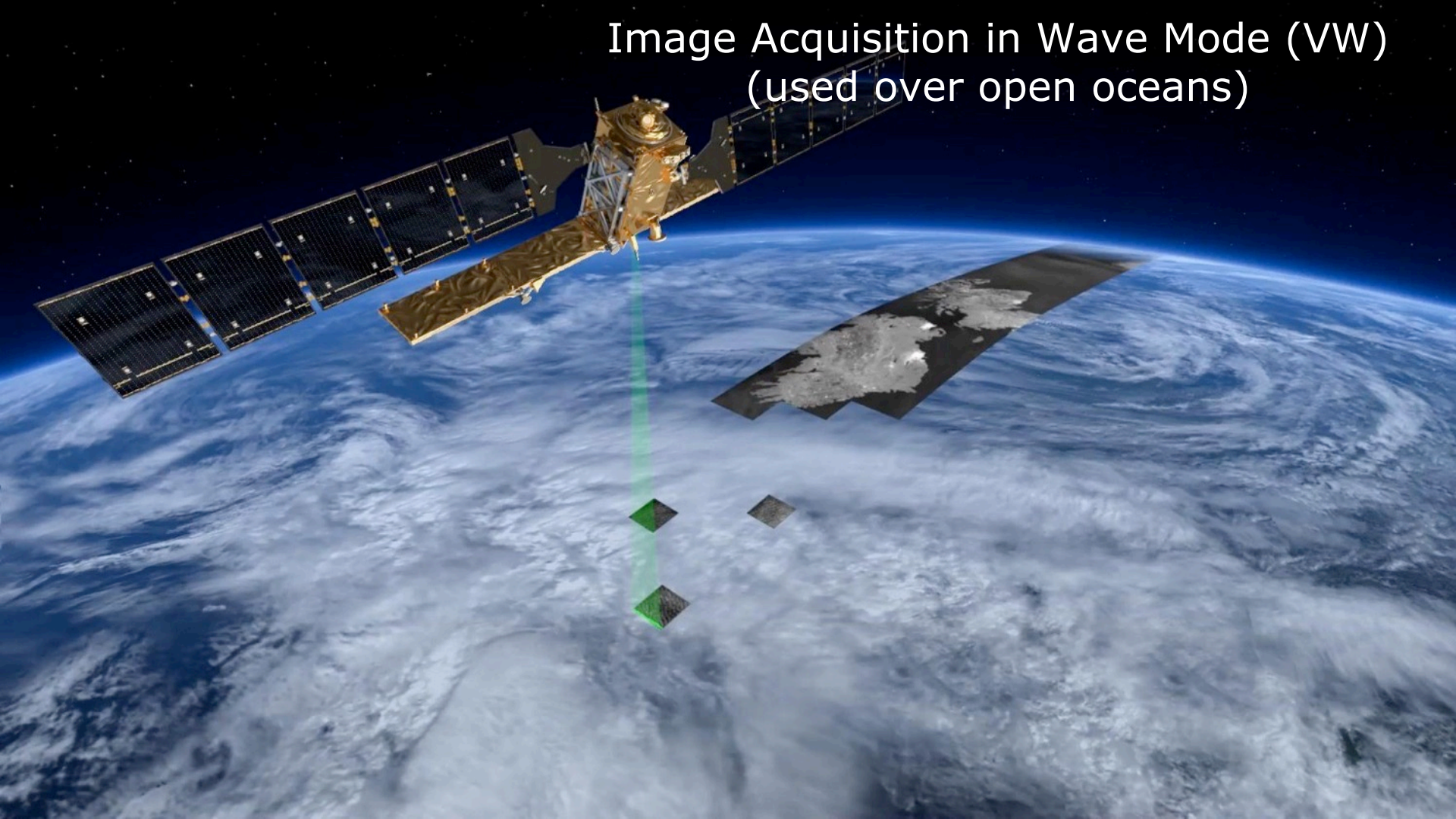


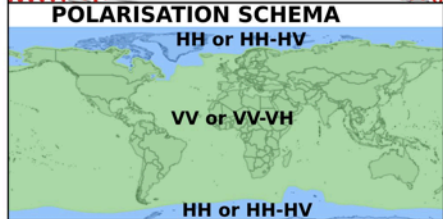
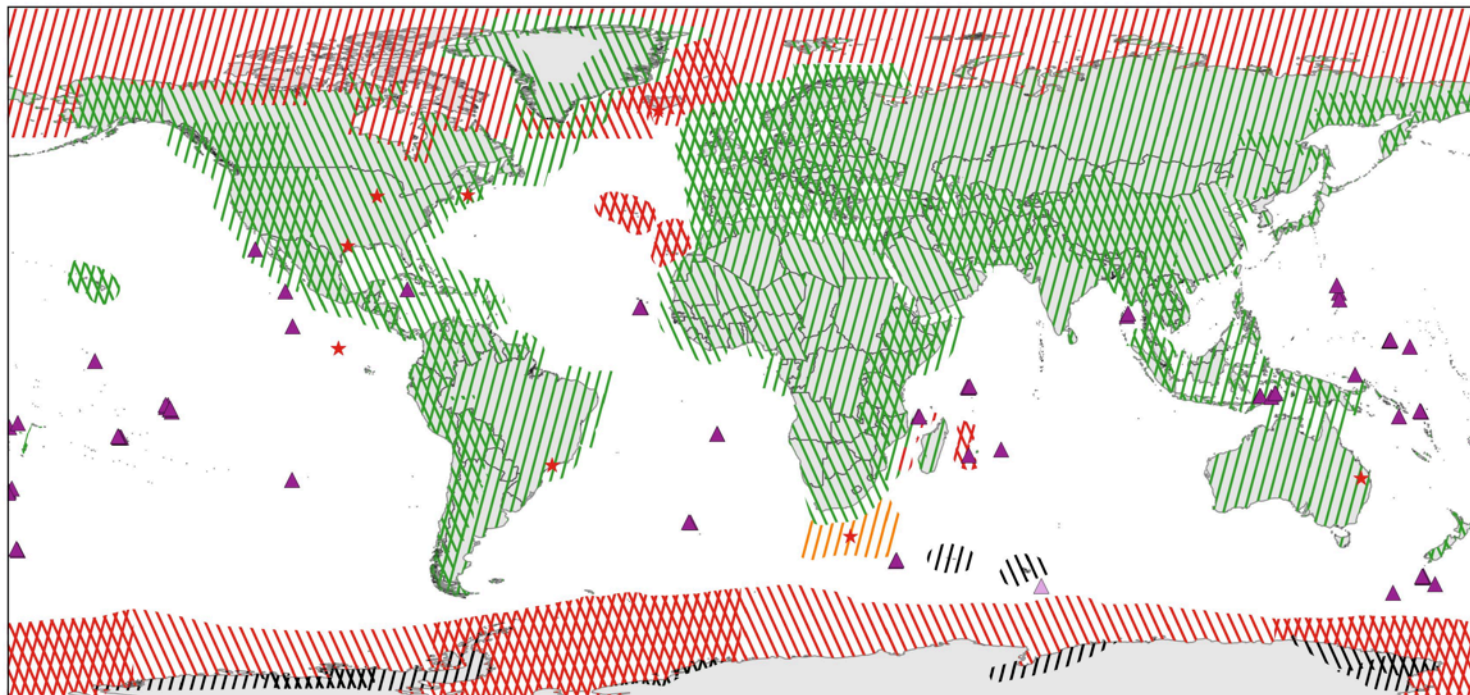
Image Acquisition in Wave Mode (VW)  
(used over open oceans)



# Sentinel-1 Constellation Observation Scenario: Mode - Polarisation - Observation Geometry



validity start: 05/2017

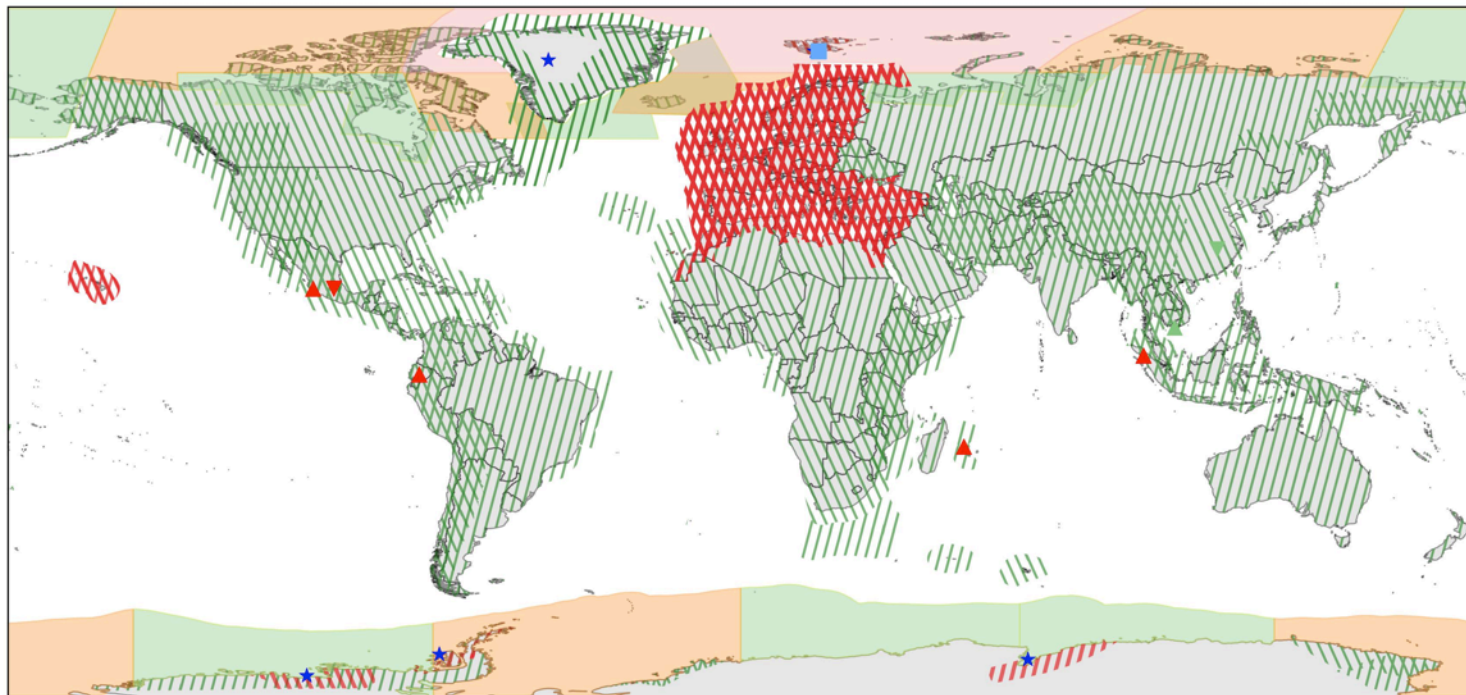


<b>MODE / POLARISATION</b>		▲ SM mode / dual-polarisation	★ Calibration Site
■ IW mode / dual polarisation	▲ SM mode / single-polarisation	(locally different modes or polarisations possible)	
■ IW mode / single polarisation			
■ EW mode / dual polarisation			
■ EW mode / single polarisation			
<b>PASS</b>			
▨ ASCENDING			
▨ DESCENDING			

# Sentinel-1 Constellation Observation Scenario: Revisit & Coverage Frequency



validity start: 05/2017

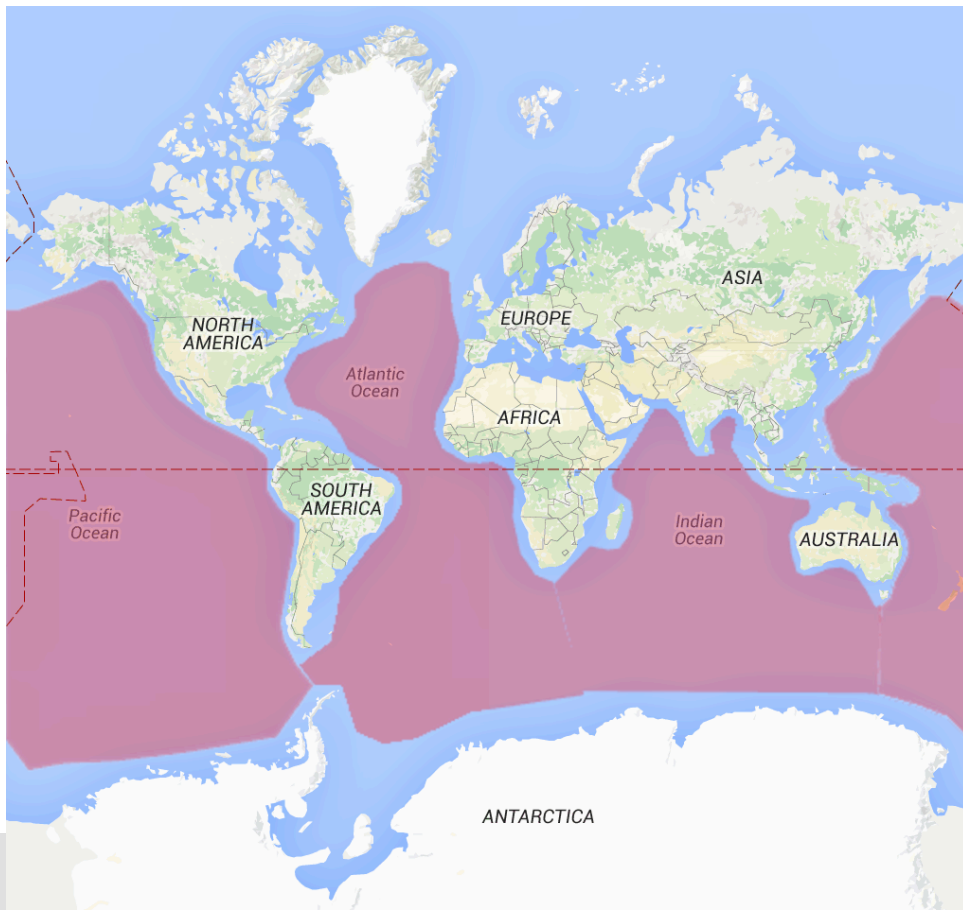


PASS	REVISIT	FREQUENCY *	COVERAGE	FREQUENCY **	REFERENCE DATA SITES (6d repeat)
<ul style="list-style-type: none"> <li>ASCENDING</li> <li>DESCENDING</li> </ul>	<ul style="list-style-type: none"> <li>6 days</li> <li>12 days</li> <li>18 days</li> </ul>	<ul style="list-style-type: none"> <li>12 days</li> <li>18 days</li> </ul>	<ul style="list-style-type: none"> <li>1 days</li> <li>1-3 days</li> <li>2-4 days</li> </ul>	<ul style="list-style-type: none"> <li>6 days</li> <li>12 days</li> <li>18 days</li> </ul>	<ul style="list-style-type: none"> <li>Highly active volcanism</li> <li>Fast subsidence</li> <li>Short growth cycle, intensive agriculture</li> <li>Fast changing wetlands</li> <li>Fast moving outlet glaciers</li> <li>Permafrost &amp; glaciers</li> </ul>

\* coverage ensured from same, repetitive relative orbits  
 \*\* coverage not considering repetitiveness of relative orbits

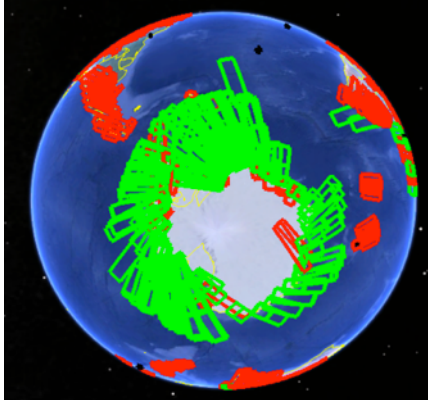
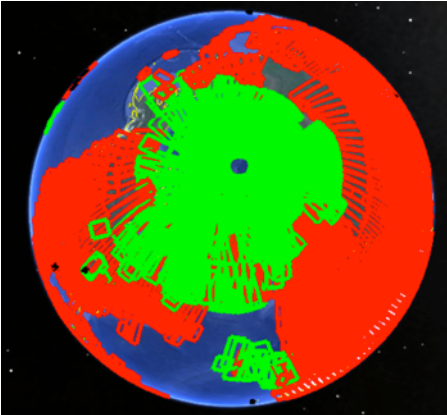
# Sentinel-1 Observation Scenario

## WAVE Mode Operations

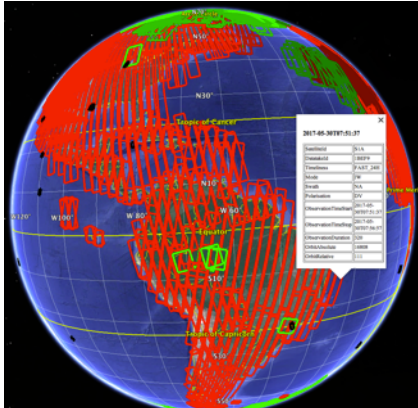
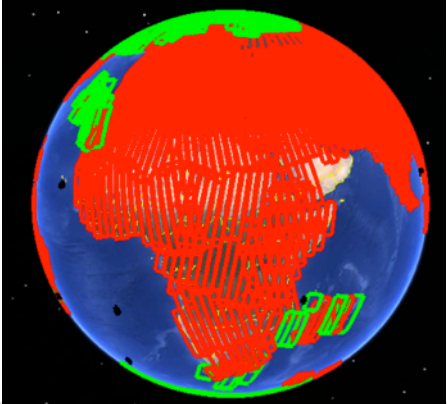


- Wave Mode is a SAR mode operated by default over open oceans, where the other modes (IW, EW, SM) are not operated
- Areas where the Wave mode is routinely used are shown in pink (status Nov. 2015)
- Wave mode is a low rate mode operated in single polarisation VV, up to 75 min per orbit period of 100 min

# Sentinel-1 observation scenario



KML files providing detailed information on the planned acquisitions, regularly published on Sentinel Online



<https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario/acquisition-segments>



## GLOBAL Production & Dissemination Operations Scenario

Production scenario			
Processing scenario	Instrument mode	Systematic Product Type	Timeliness
Systematic Global	SM IW EW	L0, L1 GRDH L0, L1 GRDH, <b>L1 SLC</b> L0, L1 GRDM	Fast-24h
	WV	L2 OCN	Fast-24h

## GLOBAL Fast24 Production & Dissemination Status

Since Oct.2014 for S1A and since Sept.2016 for S1A:

- All acquired SAR data is systematically processed to L0 and disseminated
- All acquired IW & SM data is systematically processed to L1-GRDH and disseminated
- All acquired EW data is systematically processed to L1-GRDM and disseminated

Since July-2015:

- All WV mode data is systematically processed to L2 and disseminated



# S1 Systematic GLOBAL processing for IW SLC

The ground segment operations performance has allowed to extend the initial regional SLC systematic processing to a global SLC availability

**From 01.10.2014:**

Sentinel-1A IW data acquired over key tectonic and volcanic areas has been processed and made available as IW L1 SLC

**Between 10.2014 & 07.2015:**

The regional S1A IW SLC processing has been gradually extended to cover the CEOS tectonic and volcanic areas.

**Since 28.07.2015:**

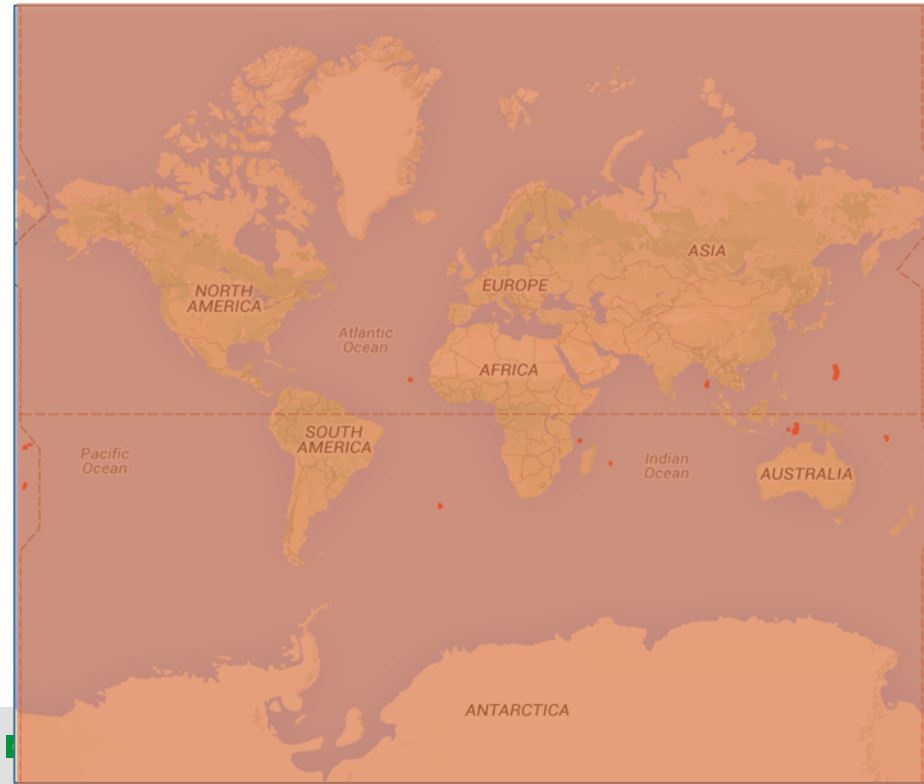
All S1A IW over Land and Ice masses are available systematically as SLC

**Since 14.04.2016:**

All S1A IW data is available systematically as SLC

**Since S1B data access opening on 26.09.2016:**

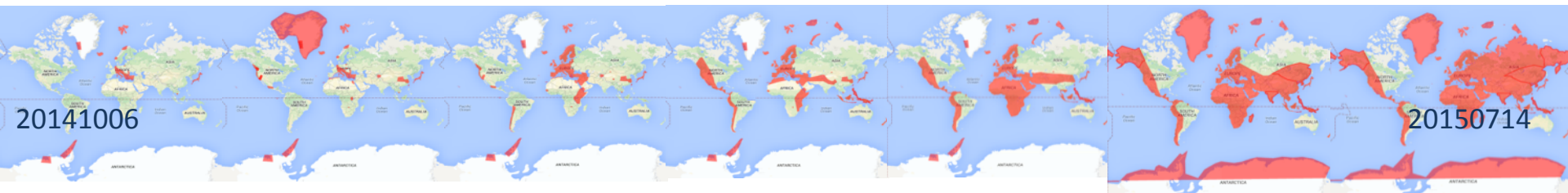
All S1B IW data is available systematically as SLC





# Sentinel-1 Systematic GLOBAL processing for IW SLC (past data)

- Backwards processing of IW SLC over areas not included in the SLC processing scenario since 2014.10.06 has started in started in summer 2016



- Missing IW SLC for all areas in the past have being gradually made available on-line during 2016
- On-line availability of IW SLC products for all S1A data acquired since Oct. 2014 over land and ice masses has been completed in November 2016.

**All Sentinel-1 data acquired in IW over Land and Ice masses since the Sentinel-1A data access opening is now available as SLC products on-line to all users.**

## REGIONAL Production & Dissemination Scenario

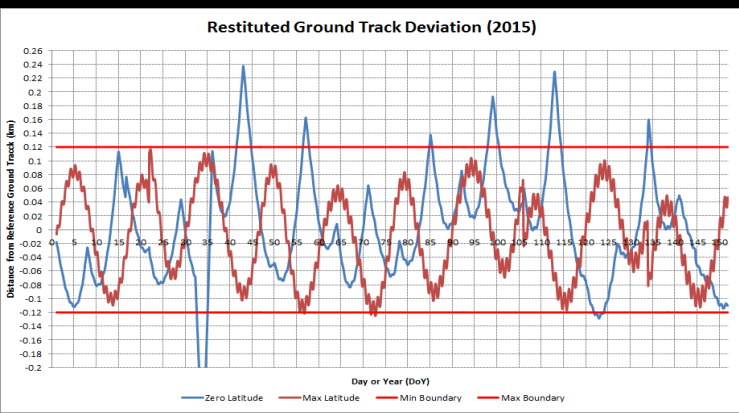
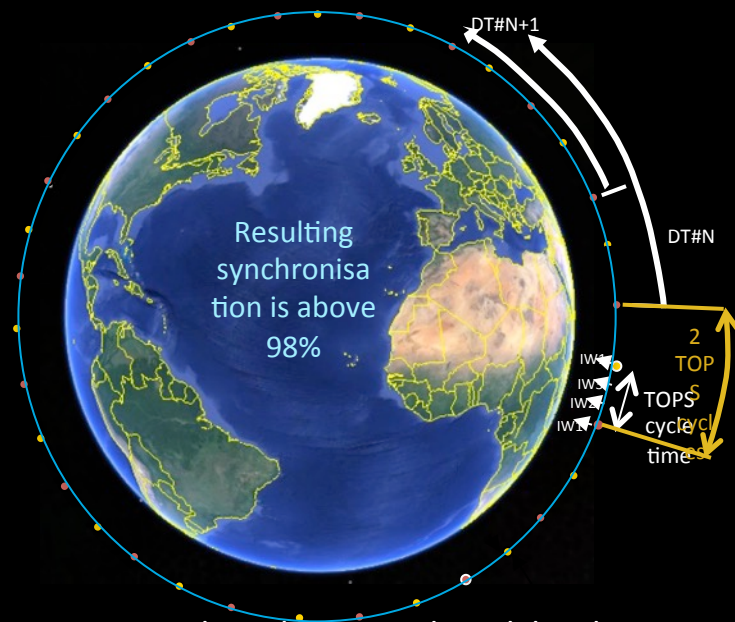
Production scenario status			
Processing scenario	Instrument mode	Systematic Product Type	Timeliness
Systematic Regional NRT	EW	L1 GRDM	NRT
Systematic Regional L2 OCN	EW/IW	L2 OCN	Fast24
Systematic Regional => <b>GLOBAL</b> SLC	<b>SM</b>	L1 SLC	Fast24h

**For SM mode, the availability of SLC products is now Systematic Global**  
All data acquired in SM is systematically made available as SLC  
since April 2016 for S1A and since September 2016 for S1B

# TOPS interferometry – Burst synchronisation

S1 TOPS interferometry is made possible by the accurate burst-synchronisation planning and small baselines are ensured by tight orbit control within a small orbital tube

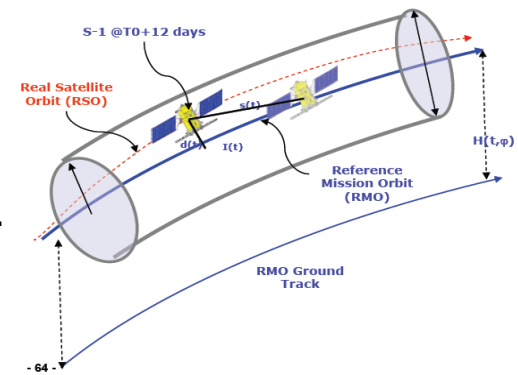
TOPS burst-synchronisation is ensured by the mission planning process and the satellite position commanding. Data take start is “tied” to match a synchronisation tie-point along the orbit  
Current separation of tie-points is 2 TOPS cycles and planning is moved forward to match the next tie-point.



Since the 7<sup>th</sup> August 2014, the orbit ground track has been maintained with a dead band of  $\pm 120\text{m}$  at the equator and at the maximum latitudes. This corresponds to an orbital tube of radius 100m w.r.t the reference orbit.

# S1A & S1B Orbit Maintenance (1)

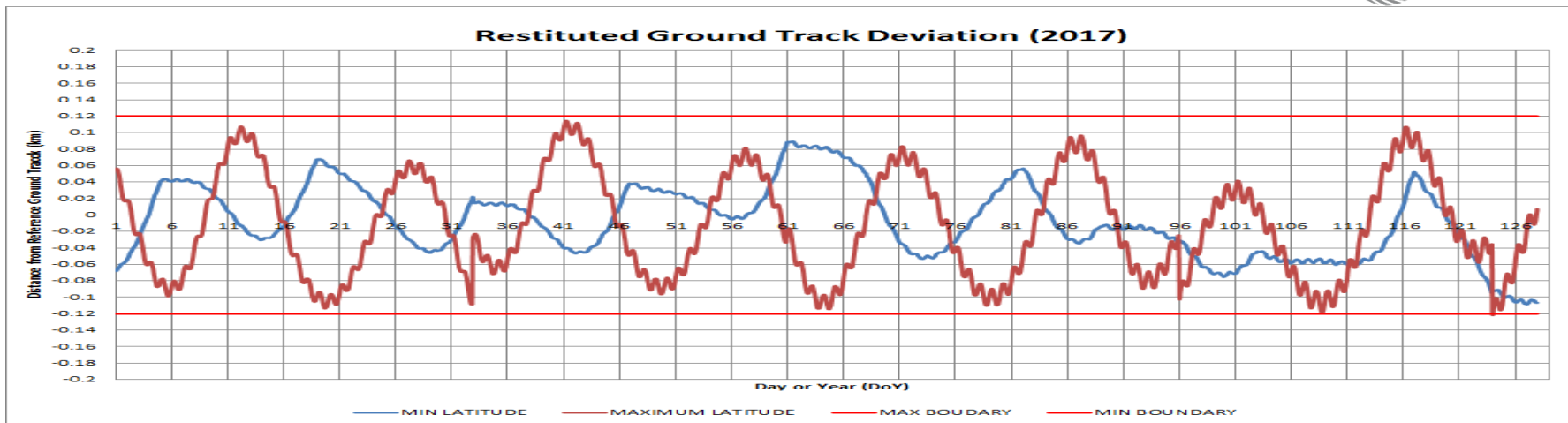
- The orbit ground track is maintained within a dead band of  **$\pm 120\text{m}$  at the equator and at the maximum latitudes**. This corresponds to an orbital tube of radius 100m w.r.t the reference orbit.
  - S1A: Since 7<sup>th</sup> August 2014
  - S1B: Since the 16<sup>th</sup> June 2016
- For each satellite, a **single fixed weekly Orbit Control Manoeuvre (OCM) slot** is used to execute **any** required In-Plane (IP) and/or Out-of-Plane (OOP) OCMs, i.e. Wed/Thurs **21:15 to 01:45 UTC**
- Overall the Orbit Maintenance operations concept has proven to very effective and successful
- Typically, for each satellite:
  - 1 or 2 In-Plane (IP) OCMs are required each week => **between 50 and 75 per year**
  - 1 Out-Of-Plane (OOP) OCM is required every 4 to 5 weeks => **approx. 12 per year**
- S1A and S1B OCM manoeuvres have become synchronised, with the same OCM types and similar durations being performed by each satellite each week



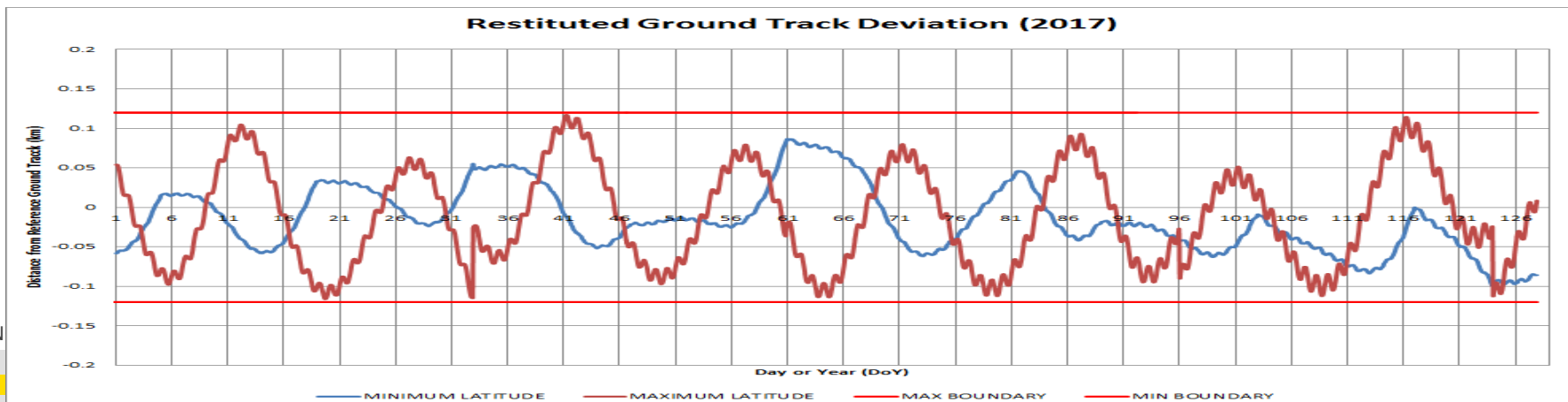
# S1A & S1B Orbit Maintenance (2)



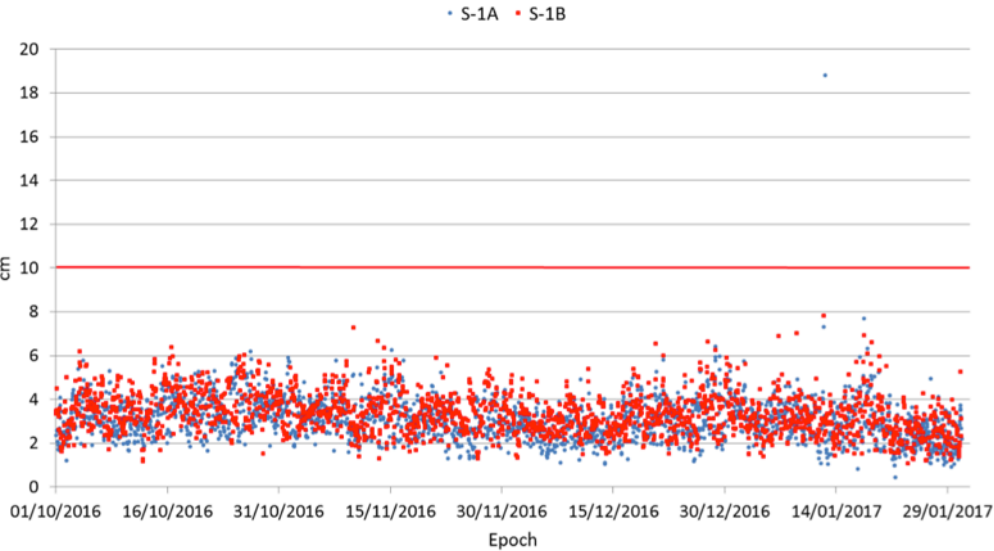
S1A



S1B



# Sentinel-1 Precise Orbit Determination Restituted Orbits



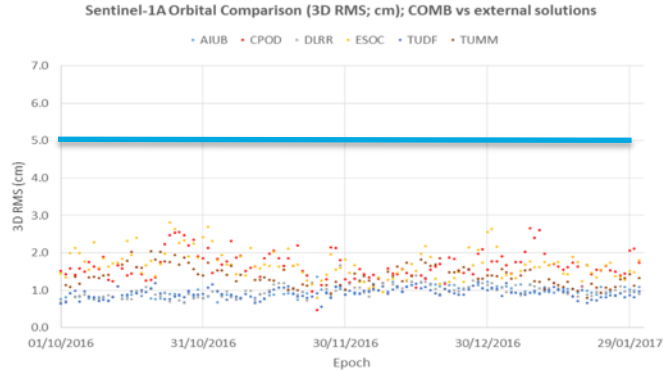
Average of daily 2D rms [cm]		
	S1A	S1B
< 3 cm	51.10%	39.50%
< 5 cm	96.90%	94.30%
< 10 cm	99.80%	99.60%
< 20 cm	99.90%	99.60%

Restituted orbit products (**AUX\_RESORB**)  
2D rms is about 5cm, well below the 10cm specifications



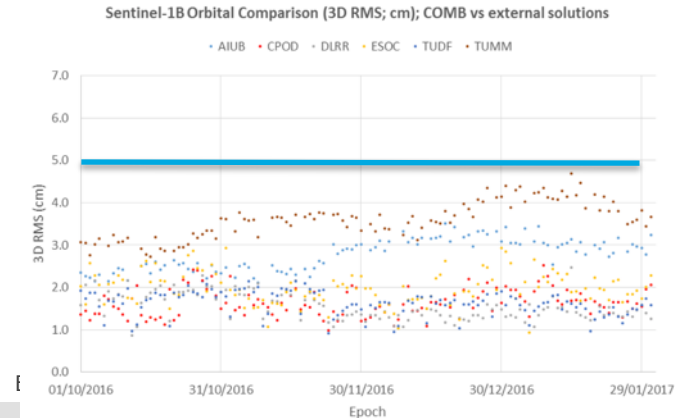
# Sentinel-1 Precise Orbit Determination

## Precise Orbits



S1A	Average of daily 3D rms [cm]
min	0.9
average	1.7
max	1.3
specification	5

Precise orbit products (**AUX\_POORB**)  
3D rms is about 2cm, well below the 5cm specifications

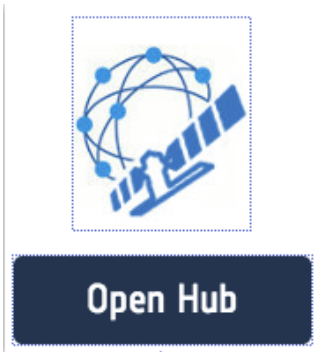


S1B	Average of daily 3D rms [cm]
min	1.6
average	2.0
max	1.7
specification	5



# Sentinel Open Hub: Free and Open Access to Sentinel data (previously called "Scientific" Hub)

<https://scihub.copernicus.eu/>



The screenshot shows the Copernicus Open Access Hub interface. On the left, there is a list of products with columns for 'Request Done', 'Download URL', and 'Mission'. The products listed are SAR-C data from Sentinel-1, with various file names and metadata. On the right, there is a map of Europe with several red rectangular bounding boxes overlaid, indicating search areas. The map includes labels for various countries and cities.

- Access through self-registration
- Automated download scripting capability and dedicated API-Hub
- Restriction on concurrent downloads

More than 100,000 users registered  
 1.8 Million Sentinel-1 products are available on-line for download,  
 representing about 2.7 PB of data.  
 More than 13 PB of data downloaded by users.

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ESA | Slide 24





# Sentinel Online web portal



http://sentinels.copernicus.eu

Sentinel-1 related documentation and technical notes available on this portal, as well as news and regular web stories

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Sen



European Space Agency

# Sentinel Data Access at ESA

## - Current configuration -



### Copernicus Open Access Hub

LATEST NEWS

98,839 Self registered Users

26,407,530 Products Downloaded  
20.65 PB Volume Downloaded

No Rolling Policy

Sentinel-1 NTC  
Sentinel-2  
Sentinel-3 (preops)

Max 2 concurrent Downloads

### Collaborative Hub

LATEST NEWS

13 Collaborative GS  
6 Data Hub Relays

10,930,925 Products Downloaded  
10.21 PB Volume Downloaded

Node1: 30 days  
Node2: 9 days

Sentinel-1 NRT & NTC  
Sentinel-2

Max 10 concurrent downloads per Node

### International Hub

LATEST NEWS

4 International Agreements

3,981,390 Products Downloaded  
3.4 PB Volume Downloaded

30 days

Sentinel-1 NTC  
Sentinel-2 LIC

Max 10 concurrent downloads

### Copernicus Services Hub

LATEST NEWS

185 Registered Users

1,310,048 Products Downloaded  
1.06 PB Volume Downloaded

No Rolling Policy

Sentinel-1 NTC  
Sentinel-2

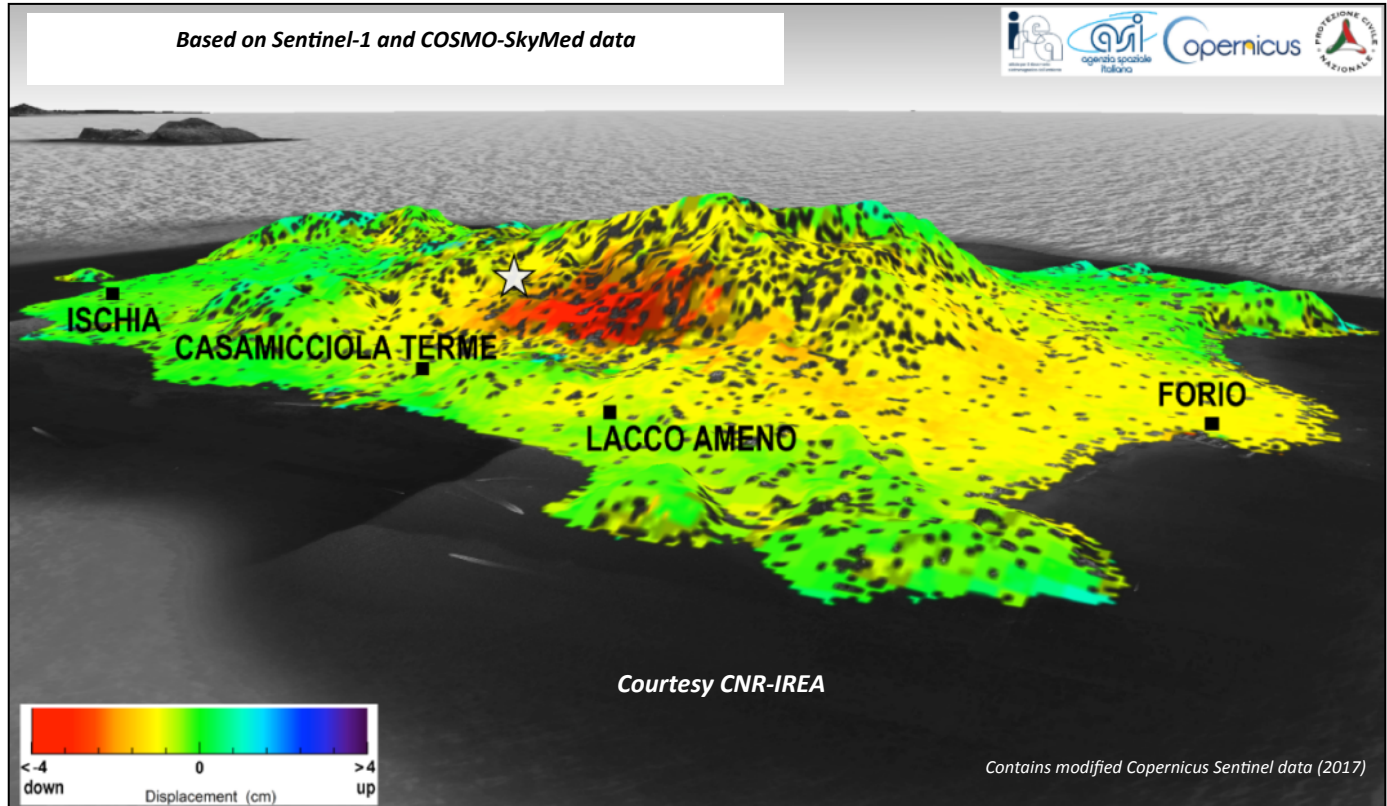
Max 10 concurrent downloads

# Ischia island (Italy) Map of displacements following the 21 August 2017 earthquake (Md 4.0)

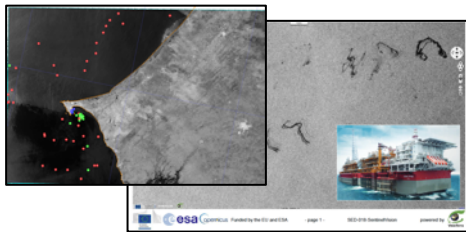


A subsidence of 4 cm observed over a large area

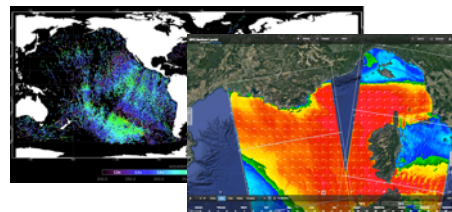
One of the objectives of the Italian Civil Protection is to obtain quickly information from its competence centres (in this case CNR-IREA and ASI) on ground movements and deformations due to earthquakes.



# Sentinel-1 applications → ever increasing

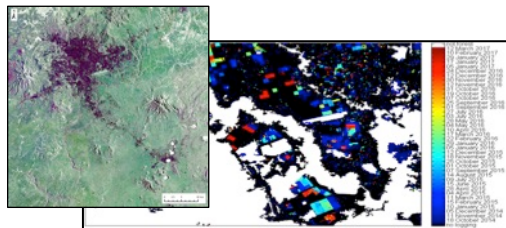
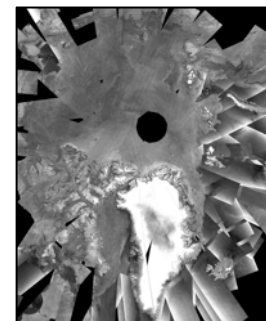


Maritime surveillance: oil spill monitoring, ship detection, illegal fisheries, etc.

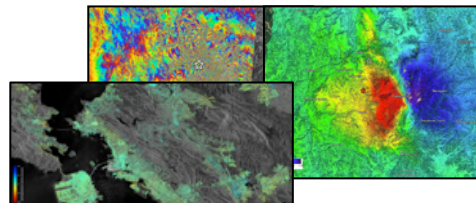


Sea state: wind, wave

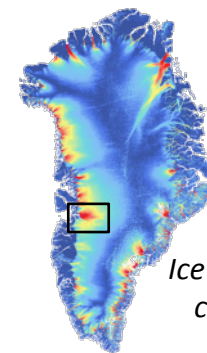
Sea ice and iceberg monitoring



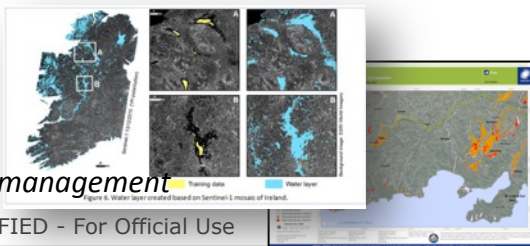
Land use, agriculture, forestry, logging, land classification, urban planning



Ground deformation: subsidence, landslides, earthquakes, volcanoes, infrastructure monitoring

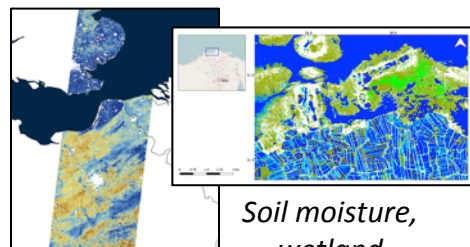


Ice sheets, glaciers, climate change

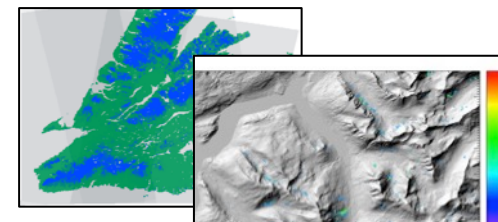


Emergency management

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Soil moisture, wetland



Snow, permafrost, avalanches, ...

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# Concluding remarks



- Sentinel-1 mission routine operations on-going, overall mission in a very good shape
  - High quality data routinely provided to Copernicus Services, Member States, International partners and to a wide spectrum of user communities worldwide for various thematic applications
  - The mission provides:
    - global and routine coverage, with a systematic production scenario,
    - open and free data access,
    - the long-term perspective,
- ➔ to further bring SAR applications (**and InSAR in particular**) into the operational domain, at local, national, regional, continental and global scale



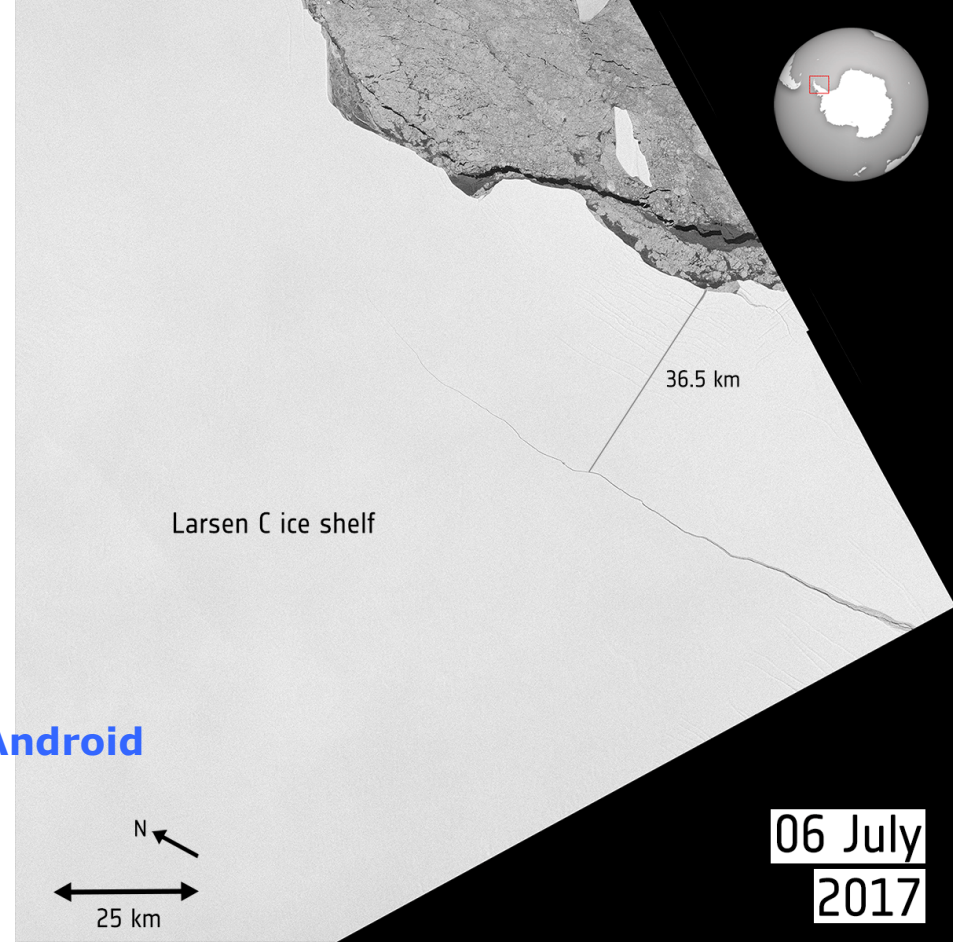
***Thank you for your attention!***

**Copernicus Programme: [copernicus.eu](http://copernicus.eu)**

**Sentinel Online: [sentinels.copernicus.eu](http://sentinels.copernicus.eu)**

**CSC Data Access: [spacedata.copernicus.eu](http://spacedata.copernicus.eu)**

**ESA Sentinel app: available for iOS and Android**



**06 July  
2017**

