→ RADAR VISION FOR COPERNICUS

esa
sentinel-1
→ RADAR VISION FOR COPERNICUS

SENTINEL-1 Mission Status

Nuno Miranda, ESA

Sentinel-1 Mission Manager

FRINGE 2023

Sentinel-1 Team:

Ramón Torres,
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Ignacio Navas-Traver,
Mario Cossu

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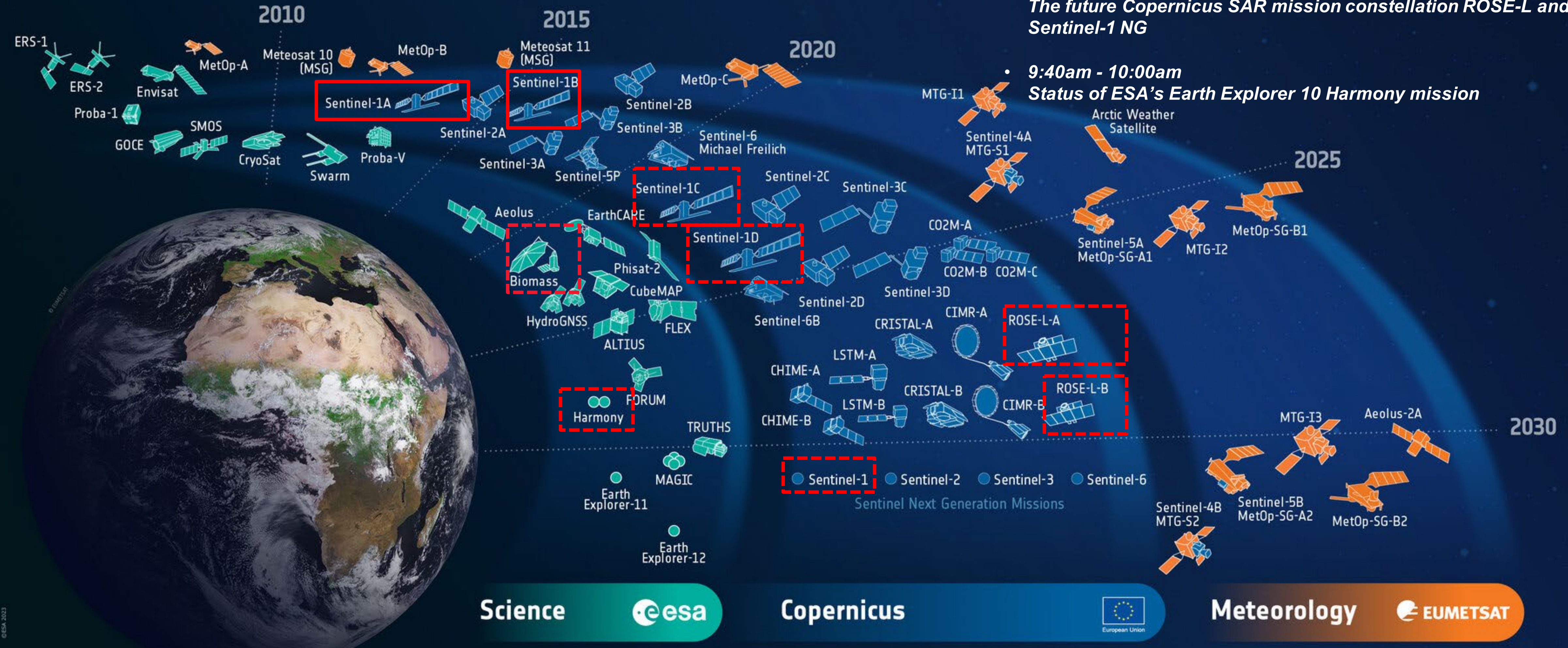
ESA Earth Observation Programme @ FRINGE23

Tomorrow:

- *9:00am - 9:20am*
  Overview and preparation status of ESA's Earth Explorer 7 Biomass mission
- *9:20am - 9:40am*
  The future Copernicus SAR mission constellation ROSE-L and Sentinel-1 NG
- *9:40am - 10:00am*
  Status of ESA's Earth Explorer 10 Harmony mission


2010
2015
2020
2025
2030
ERS-1
ERS-2
Proba-1
Envisat
MetOp-A
SMOS
GOCE
CryoSat
Swarm
Meteosat 10 (MSG)
MetOp-B
Proba-V
Sentinel-1A
Sentinel-2A
Sentinel-3A
Meteosat 11 (MSG)
Sentinel-1B
Sentinel-5P
MetOp-C
Sentinel-2B
Sentinel-3B
Sentinel-6 Michael Freilich
Sentinel-1C
Sentinel-2C
Sentinel-3C
Aeolus
EarthCARE
Biomass
Phisat-2
CubeMAP
HydroGNSS
FLEX
ALTIUS
Sentinel-1D
Sentinel-2D
Sentinel-3D
Sentinel-6B
MTG-I1
Sentinel-4A MTG-S1
Arctic Weather Satellite
CO2M-A
CO2M-B
CO2M-C
Sentinel-5A MetOp-SG-A1
MTG-I2
MetOp-SG-B1
CRISTAL-A
CIMR-A
ROSE-L-A
LSTM-A
CHIME-A
CRISTAL-B
CIMR-B
ROSE-L-B
LSTM-B
CHIME-B
FORUM
Harmony
TRUTHS
MAGIC
Earth Explorer-11
Earth Explorer-12
Sentinel-1
Sentinel-2
Sentinel-3
Sentinel-6
Sentinel Next Generation Missions
MTG-I3
Aeolus-2A
Sentinel-4B MTG-S2
Sentinel-5B MetOp-SG-A2
MetOp-SG-B2
Science
esa
Copernicus
European Union
Meteorology
EUMETSAT
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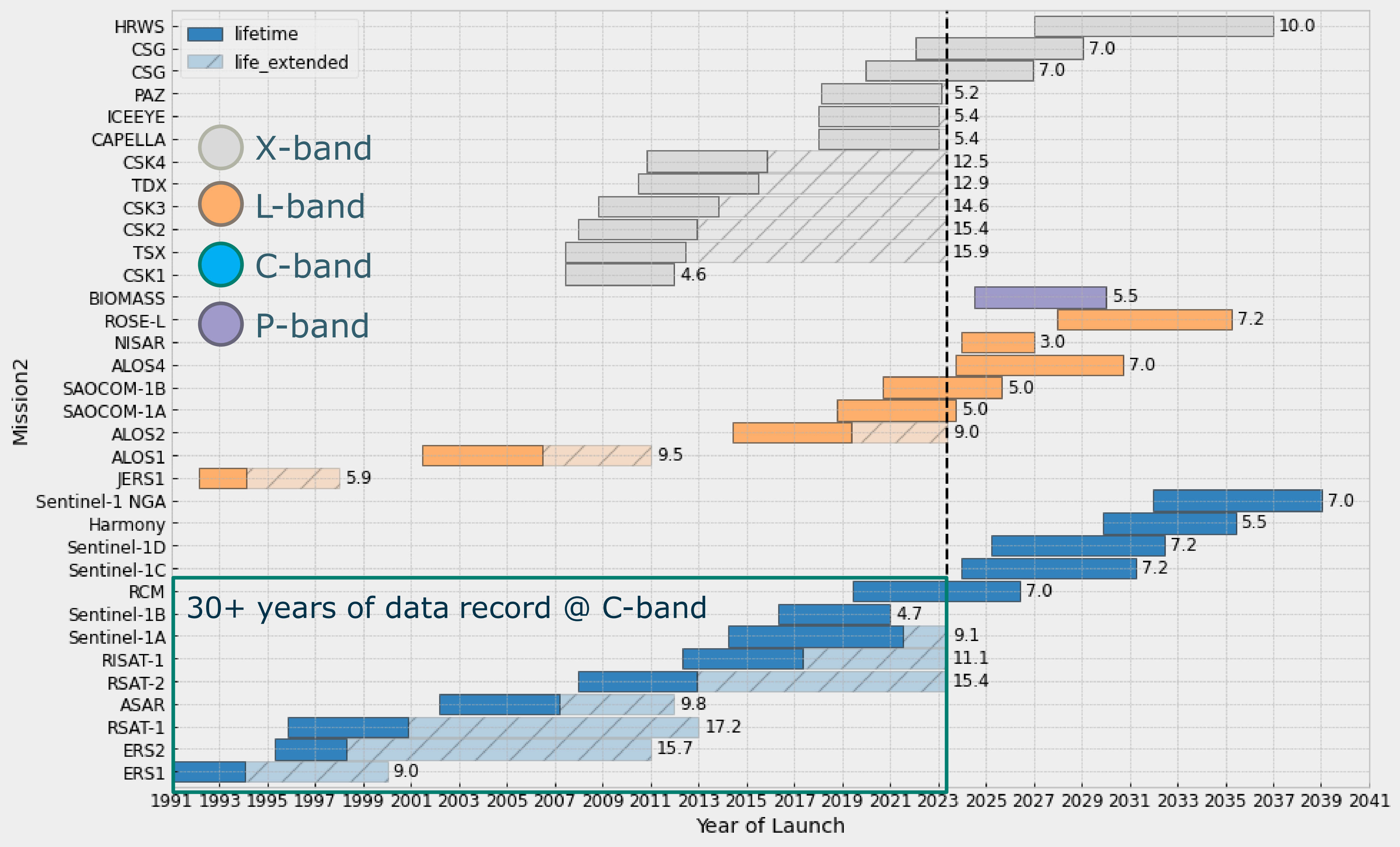
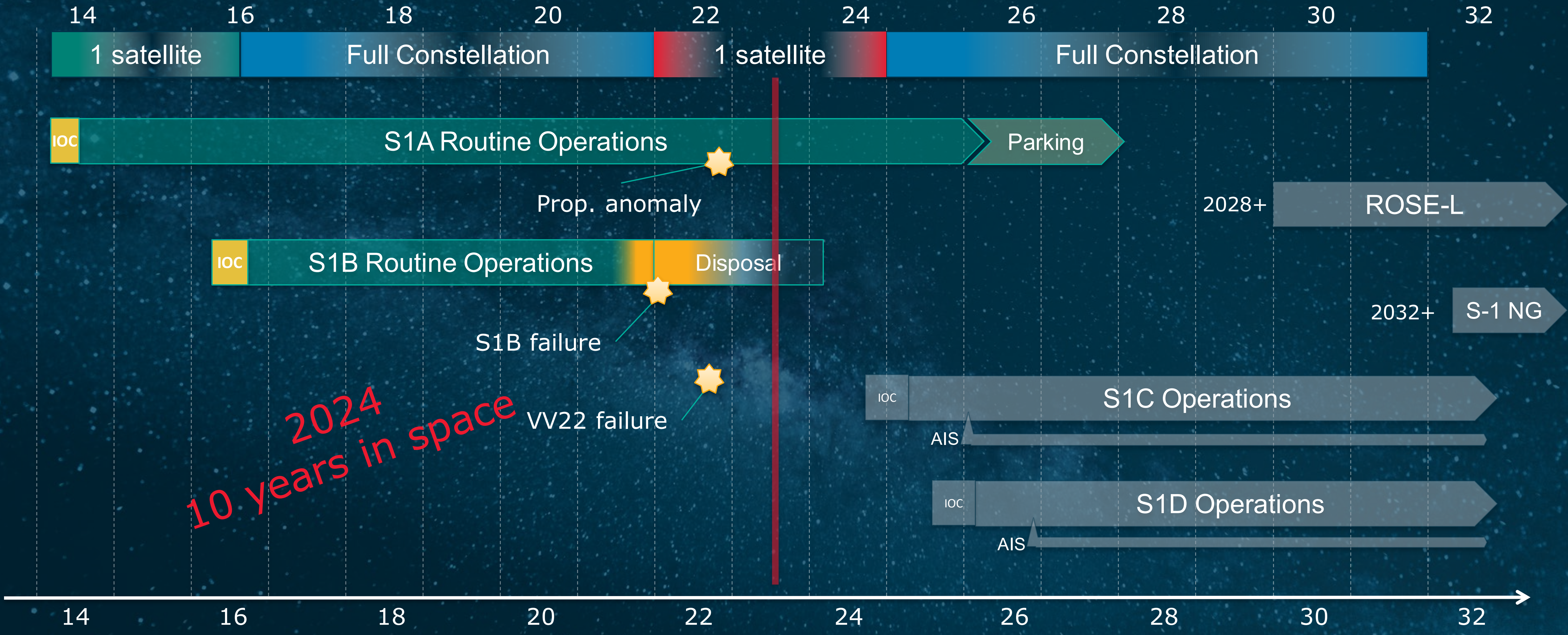
SAR C-band data record



30+ years of data record @ C-band

Sentinel-1 First Generation timeline


14
16
18
20
22
24
26
28
30
32
1 satellite
Full Constellation
1 satellite
Full Constellation
IOC
S1A Routine Operations
Parking
Prop. anomaly
2028+
ROSE-L
IOC
S1B Routine Operations
Disposal
S1B failure
2032+
S-1 NG
2024
10 years in space
VV22 failure
IOC
S1C Operations
AIS
IOC
S1D Operations
AIS
14
16
18
20
22
24
26
28
30
32

Sentinel-1 Mission in a Nutshell

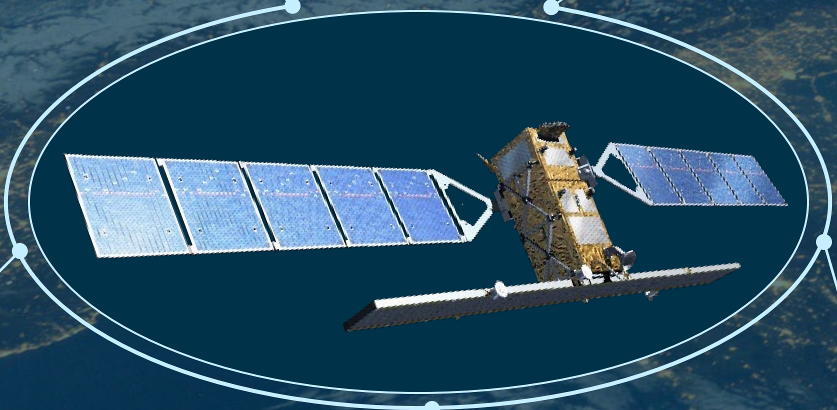
MISSION PROFILE

- Constellation of two identical SAR C-band satellites: (A & B → C units)
- Near-Polar, sun-synchronous (dawn-dusk) orbit at 698 km altitude
- 7.25 years lifetime (consumables for 12 years)
- 12-day repeat cycle (each satellite), 6 days for the constellation

OPERATIONS

- Systematic SAR data acquisition using a predefined observation scenario
- Instrument duty cycle of max. 25 min/orbit in High Bit Rate modes (30 min outside eclipse) and 75 min/orbit in Low Bit Rate mode (Wave)

Full, Free and Open



PROGRAMMATICS

- Sentinel-1C launch 2024
- Sentinel-1D currently in storage to be launched as soon as possible S-1C

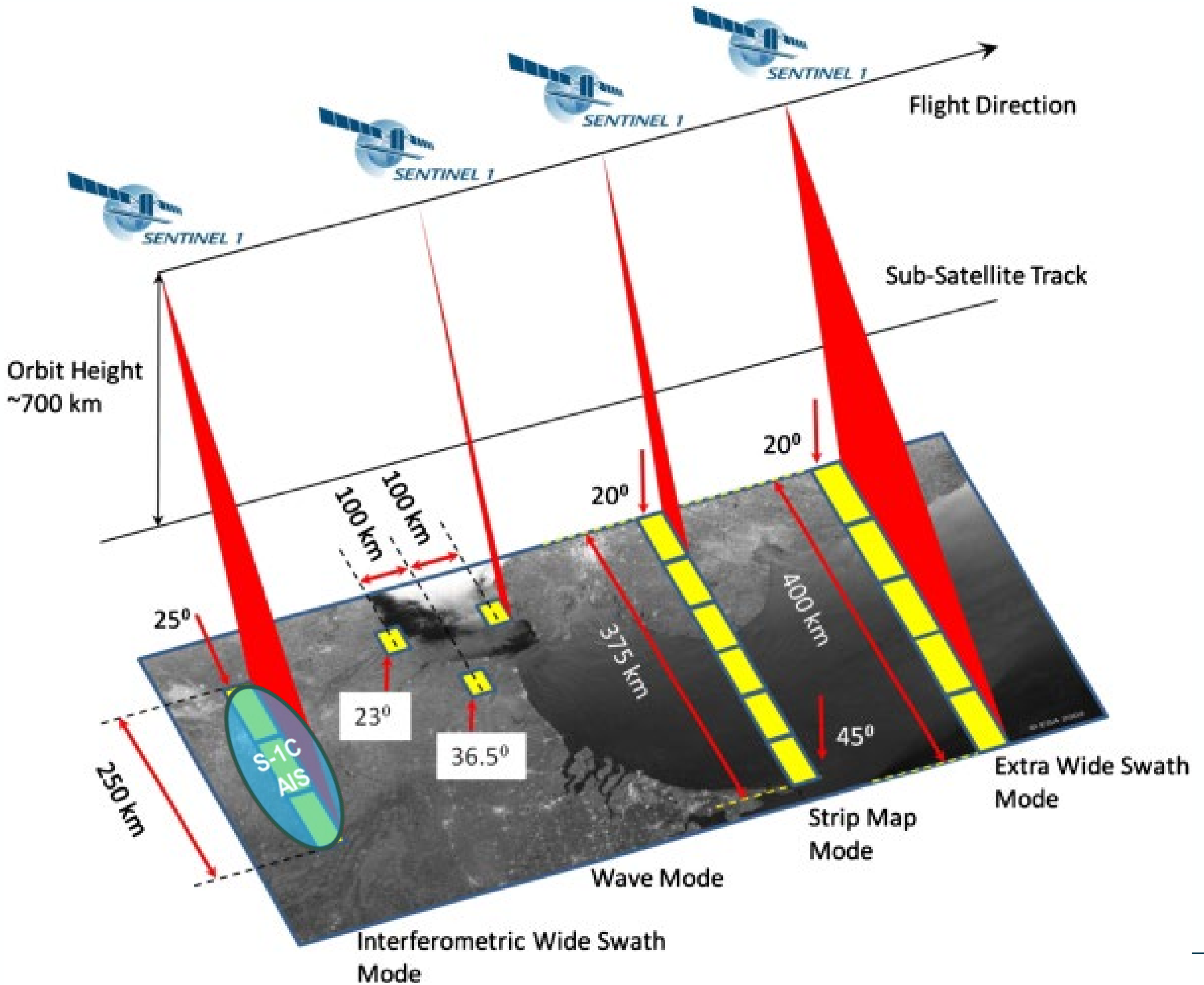
PAYLOAD

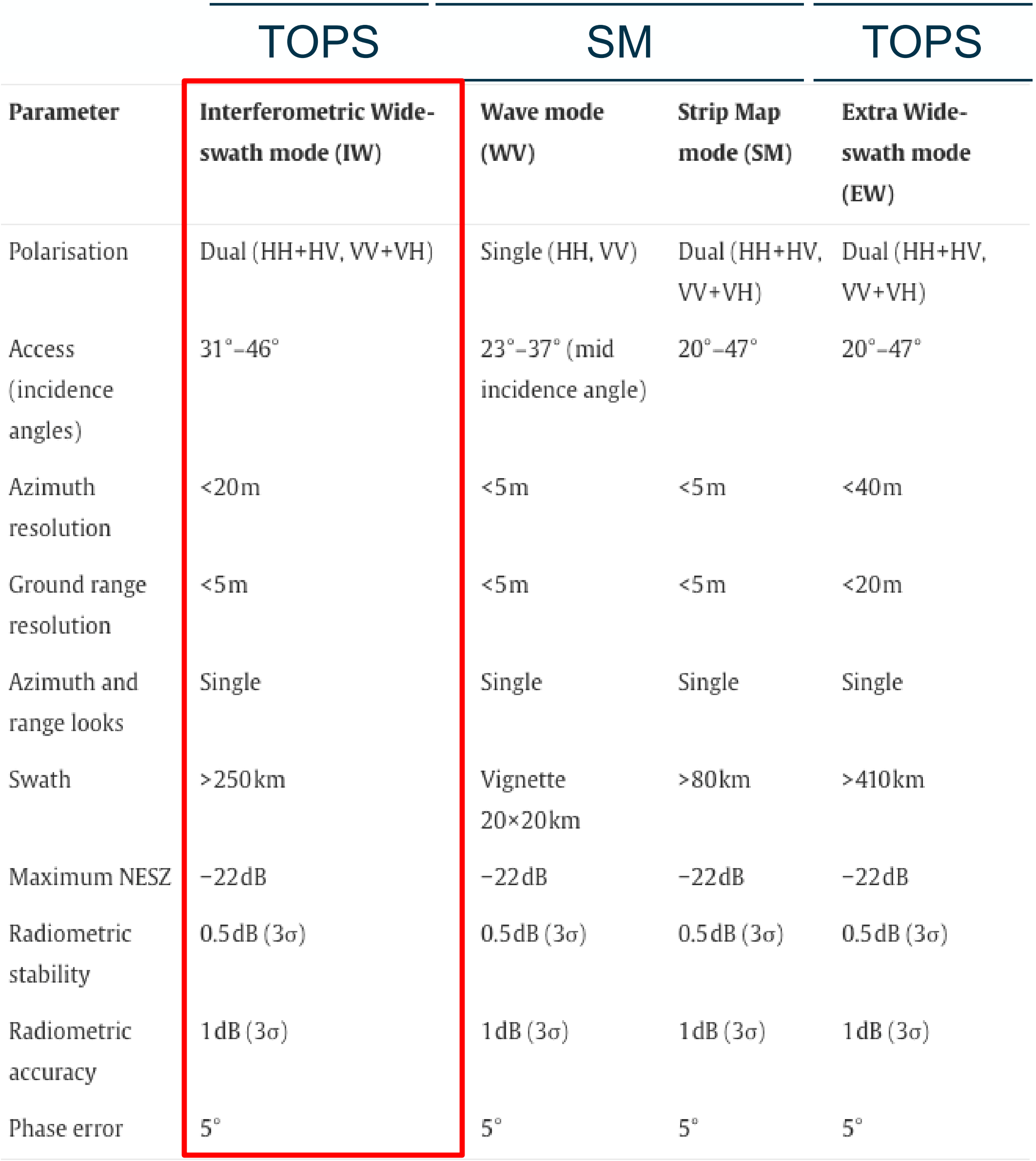
- C-Band SAR
  - Centre frequency: 5.405 GHz
  - Polarizations: HH, VV, HH/HV, VV/VH
  - Incidence angle: 20º - 45º
  - Radiometric accuracy: 1 dB (3σ)
  - Radiometric stability: 0.55 dB (3σ), 0.45 (3σ) for S-1 C/D
  - NESZ: -22 dB
  - DTAR: -22 dB
- AIS Instrument marine surveillance (for S-1 C and D)

IMAGING MODES

- Strip Map Mode: 80 km swath and 5x5 m (range x azimuth) resolution
- Interferometric Wide-Swath Mode: 250 km swath, 5x20 m resolution
- Extra-Wide-Swath Mode: 400 km swath and 20x40 m resolution
- Wave Mode: 5x5 m resolution, leap-frog sampled images of 20x20 km

Sentinel-1 Imaging Modes

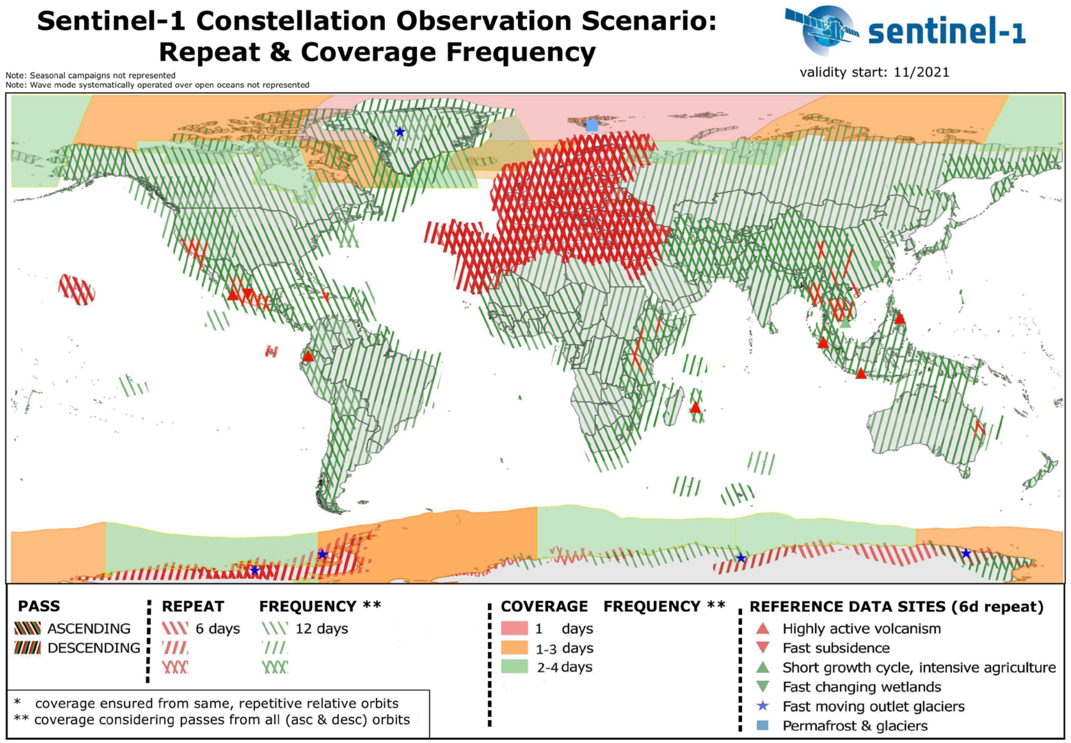

SENTINEL 1
SENTINEL 1
SENTINEL 1
SENTINEL 1
Flight Direction
Sub-Satellite Track
Orbit Height
~700 km
100 km
100 km
20⁰
20⁰
25⁰
23⁰
36.5⁰
375 km
400 km
45⁰
250 km
S-1C AIS
Extra Wide Swath Mode
Strip Map Mode
Wave Mode
Interferometric Wide Swath Mode



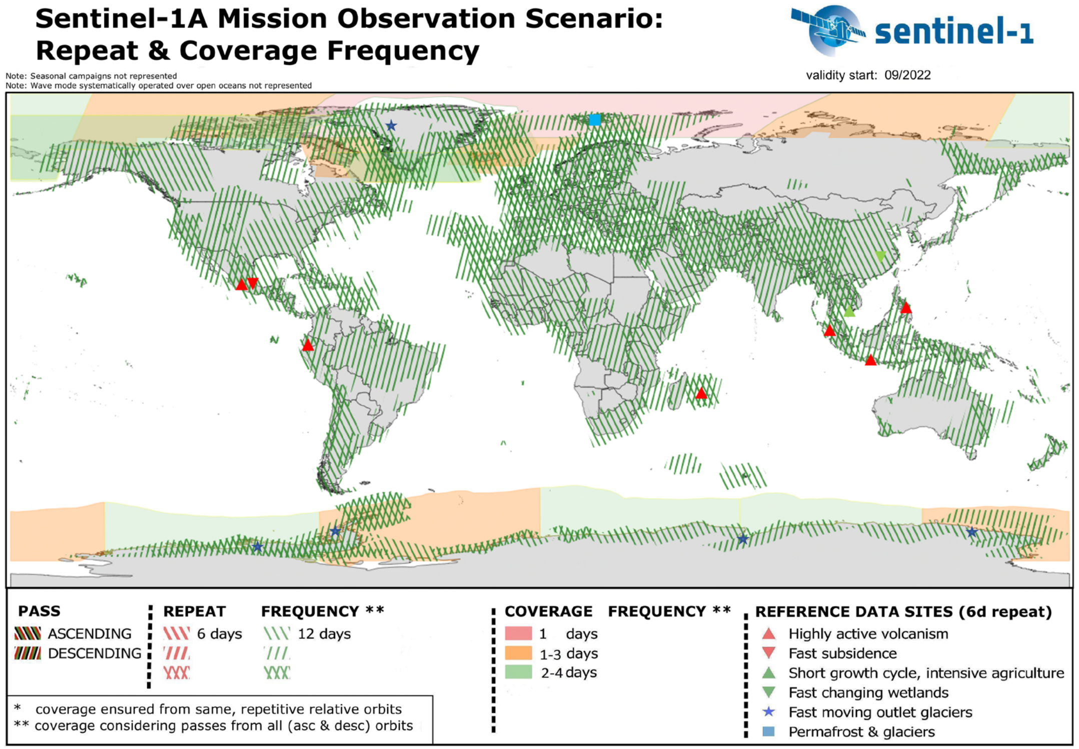
	TOPS	SM		TOPS
Parameter	**Interferometric Wide-swath mode (IW)**	**Wave mode (WV)**	**Strip Map mode (SM)**	**Extra Wide-swath mode (EW)**
Polarisation	Dual (HH+HV, VV+VH)	Single (HH, VV)	Dual (HH+HV, VV+VH)	Dual (HH+HV, VV+VH)
Access (incidence angles)	31°–46°	23°–37° (mid incidence angle)	20°–47°	20°–47°
Azimuth resolution	<20m	<5m	<5m	<40m
Ground range resolution	<5m	<5m	<5m	<20m
Azimuth and range looks	Single	Single	Single	Single
Swath	>250km	Vignette 20×20km	>80km	>410km
Maximum NESZ	−22dB	−22dB	−22dB	−22dB
Radiometric stability	0.5dB (3σ)	0.5dB (3σ)	0.5dB (3σ)	0.5dB (3σ)
Radiometric accuracy	1dB (3σ)	1dB (3σ)	1dB (3σ)	1dB (3σ)
Phase error	5°	5°	5°	5°

Sentinel-1 observation plan

The largest provider of SAR data worldwide


Sentinel-1 Constellation Observation Scenario:
Repeat & Coverage Frequency
sentinel-1
Note: Seasonal campaigns not represented
Note: Wave mode systematically operated over open oceans not represented
validity start: 11/2021
PASS
ASCENDING
DESCENDING
REPEAT
6 days
FREQUENCY **
12 days
COVERAGE
FREQUENCY **
1 days
1-3 days
2-4 days
REFERENCE DATA SITES (6d repeat)
Highly active volcanism
Fast subsidence
Short growth cycle, intensive agriculture
Fast changing wetlands
Fast moving outlet glaciers
Permafrost & glaciers
* coverage ensured from same, repetitive relative orbits
** coverage considering passes from all (asc & desc) orbits

S-1A and B

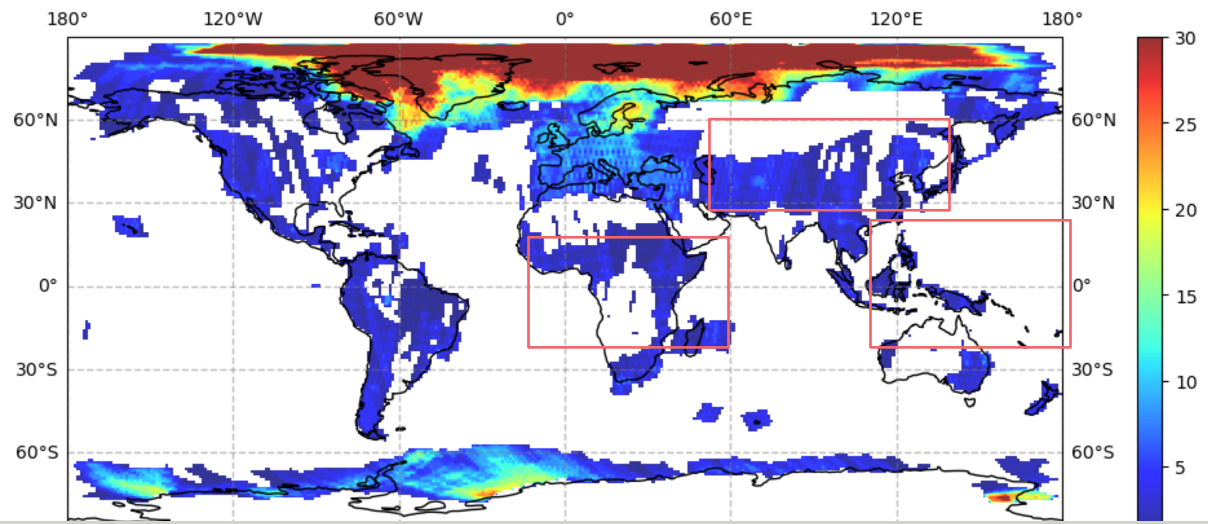

Sentinel-1A Mission Observation Scenario:
Repeat & Coverage Frequency
sentinel-1
Note: Seasonal campaigns not represented
Note: Wave mode systematically operated over open oceans not represented
validity start: 09/2022
PASS
ASCENDING
DESCENDING
REPEAT
6 days
FREQUENCY **
12 days
COVERAGE
FREQUENCY **
1 days
1-3 days
2-4 days
REFERENCE DATA SITES (6d repeat)
Highly active volcanism
Fast subsidence
Short growth cycle, intensive agriculture
Fast changing wetlands
Fast moving outlet glaciers
Permafrost & glaciers
* coverage ensured from same, repetitive relative orbits
** coverage considering passes from all (asc & desc) orbits

S-1A only (>2021)

Observation plan details available at:

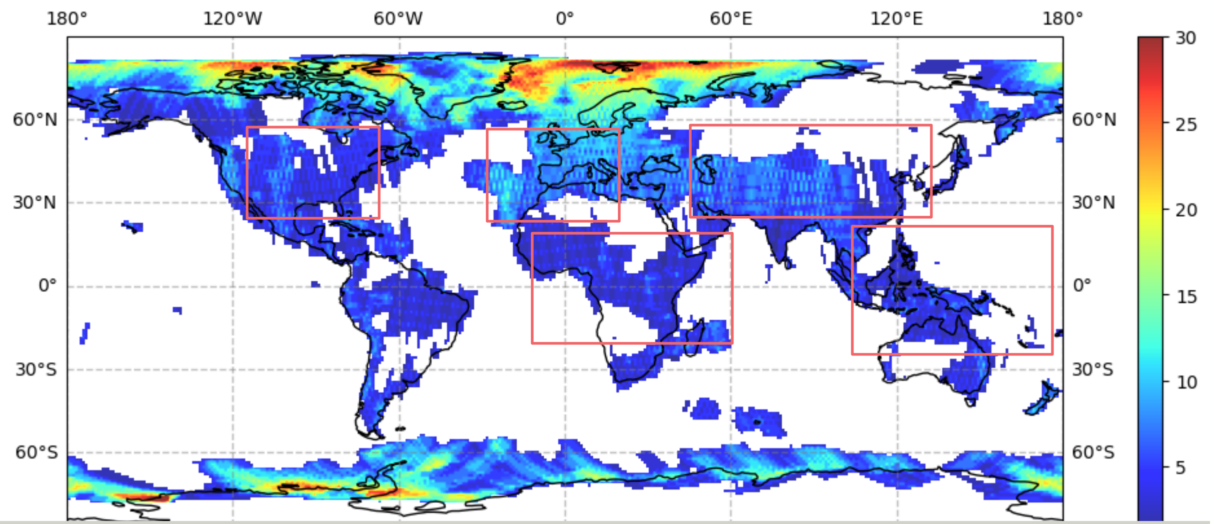
https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario/

World largest SAR provider



180°
120°W
60°W
0°
60°E
120°E
180°
60°N
30°N
0°
30°S
60°S
30
25
20
15
10
5

Jan. 2016 **Pre** Sentinel1-B



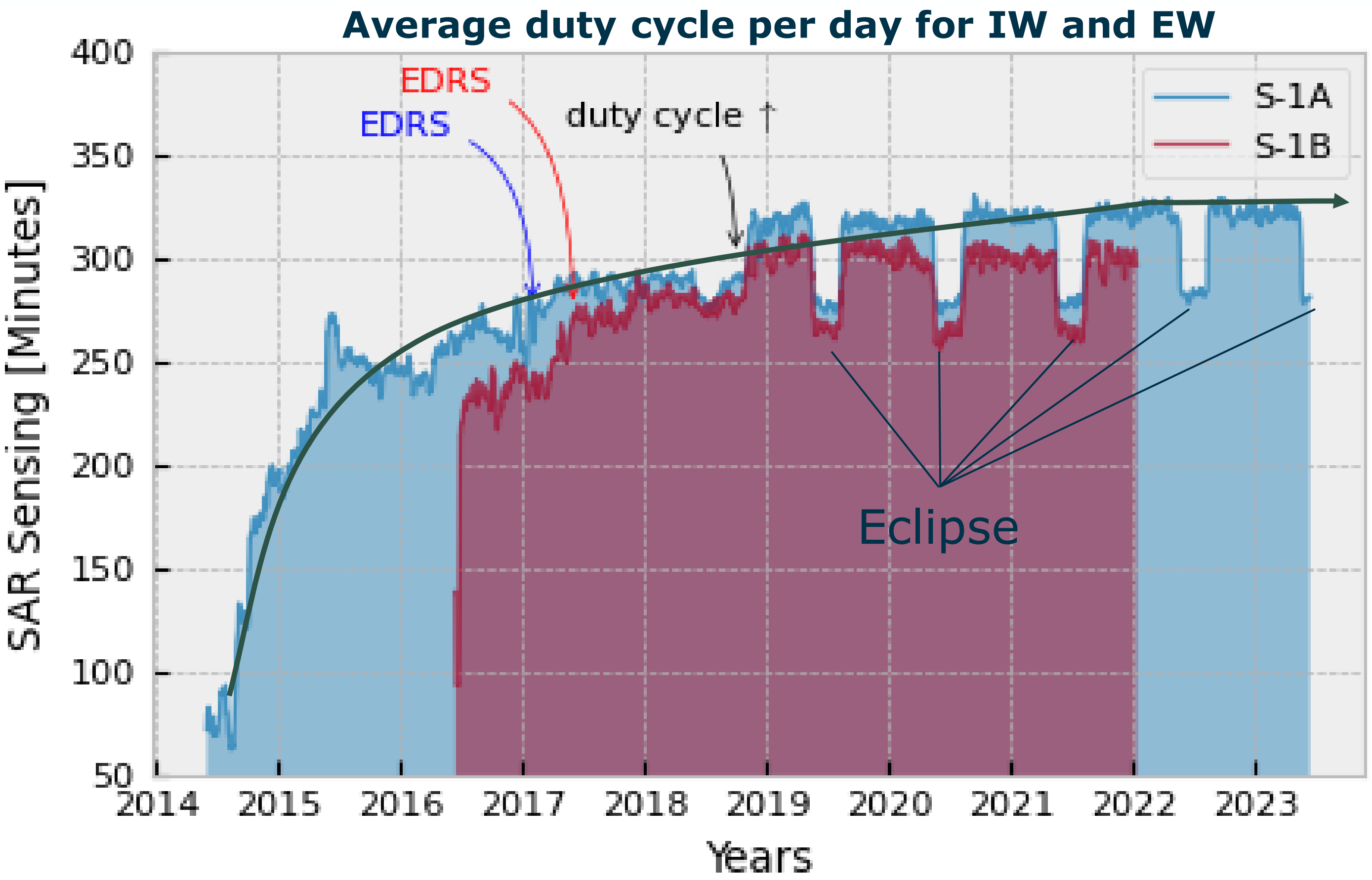
180°
120°W
60°W
0°
60°E
120°E
180°
60°N
30°N
0°
30°S
60°S
30
25
20
15
10
5

Jan. 2023 **Post** Sentinel1-B

- Current S-1A observation scenario (compared to 2016) is **tuned to preserve time series worldwide**

- Data sensing over Arctic is for most of it covered by RCM (RCM/Sentinel Contingency agreement)

Sentinel-1 Duty Cycle optimisation

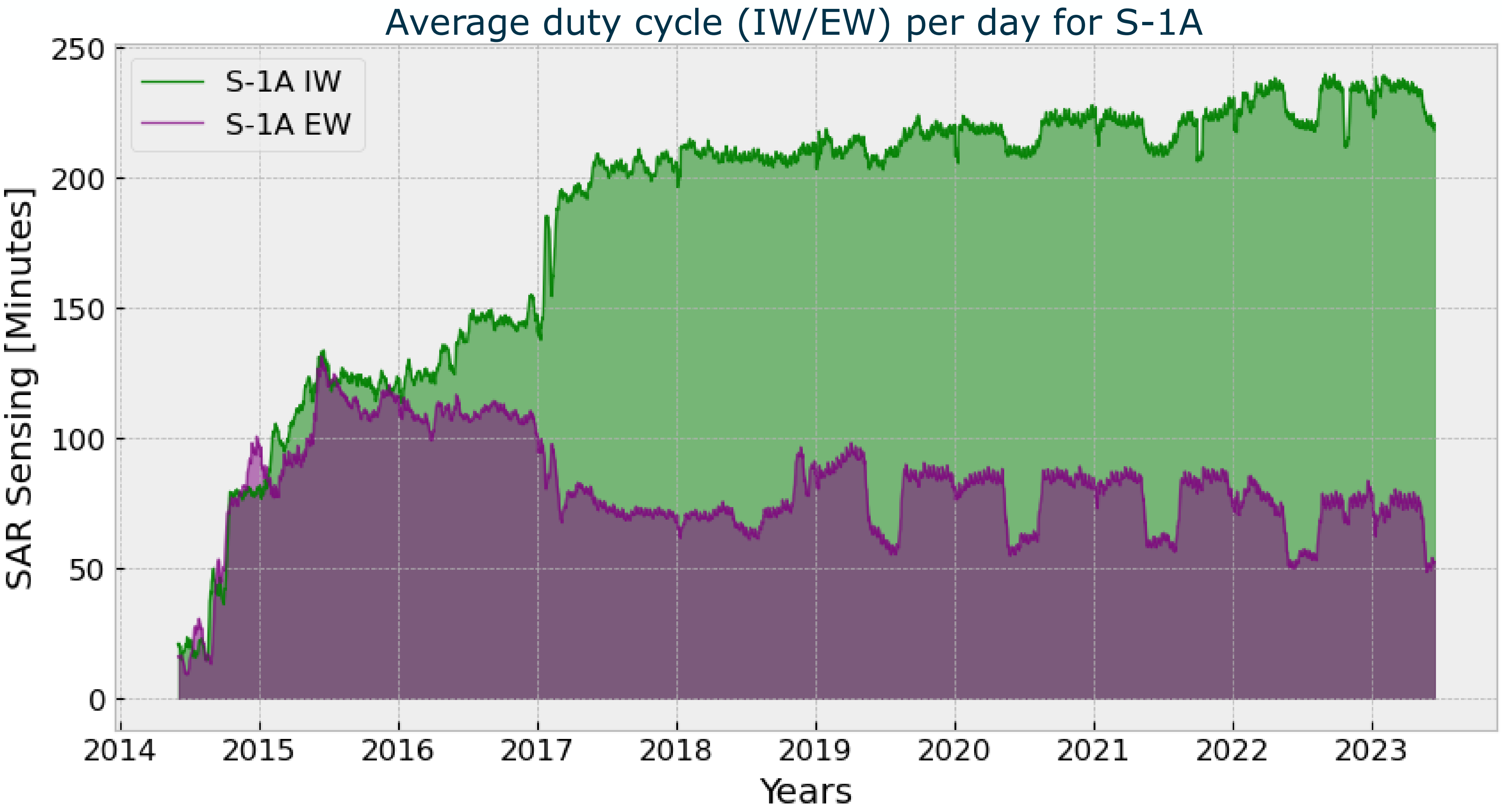


SAR duty cycle has been increased as result of operations optimisation:

- **2014-2015 |** Initial ramp-up
- **2017 |** inclusion of EDRS in routine ops
- **2018 |** Relaxation of 25 min constraint outside eclipse
- **2021** | sligth increase of S-1A DC to cope with S-1B loss

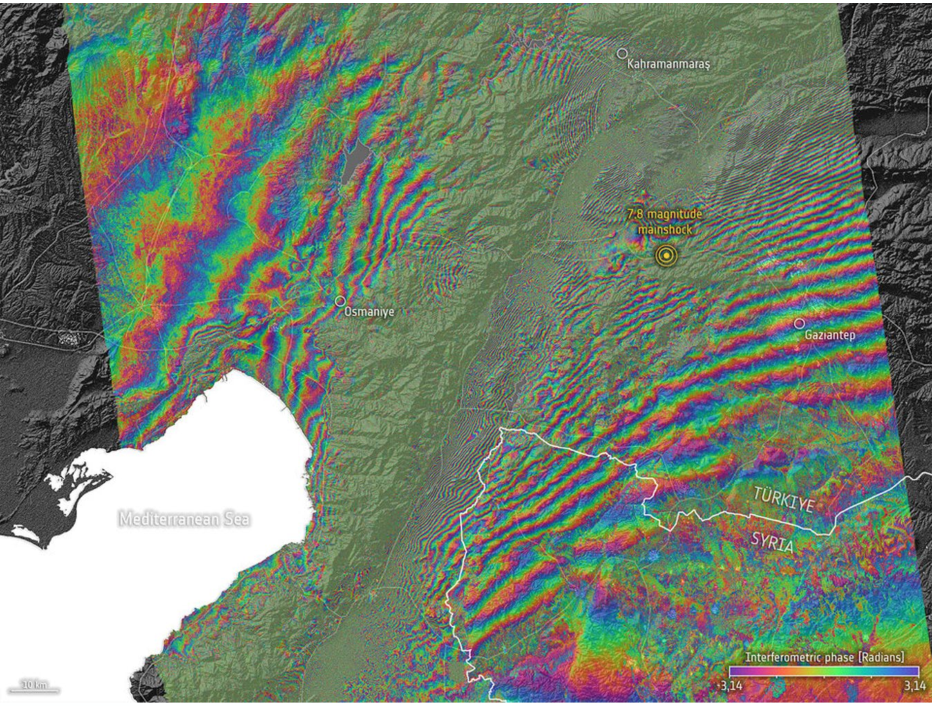
- S-1A is used at is maximum capacity → no new substantial acquisition can be accommodated
- **SAR DUTY CYCLE |** Sentinel-1 can acquire up to 30min (per unit) of HBR (IW& EW) within an 100min rolling window (outside eclipse season)

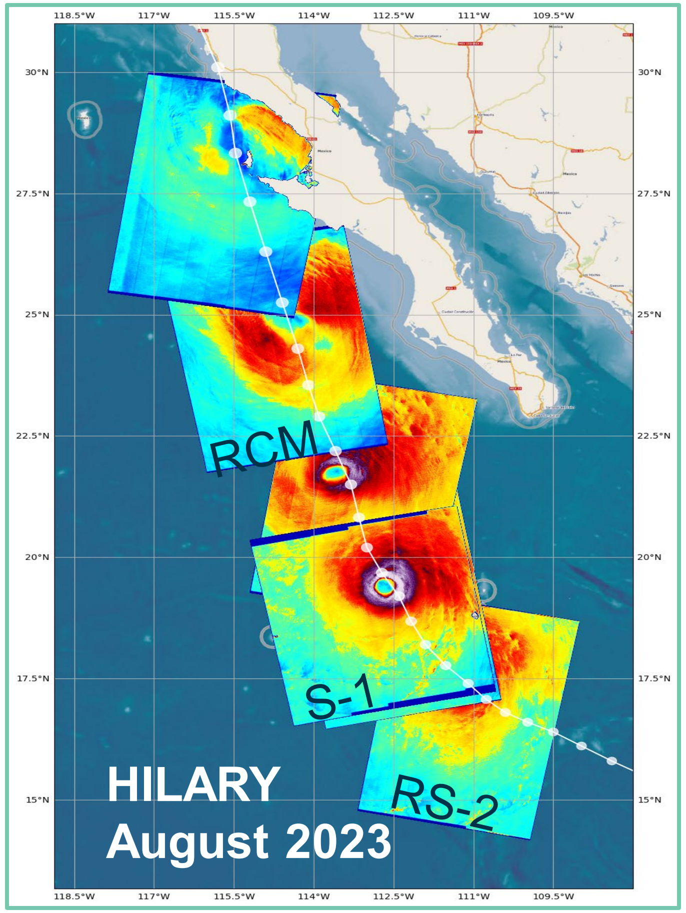
IW Sensing Increase



Rapid response to crisis

This systematic strategy makes Sentinel-1 prompt in providing archive and fresh information to support extreme event


Kahramanmaraş
7.8 magnitude mainshock
Osmaniye
Gaziantep
Mediterranean Sea
TÜRKIYE
SYRIA
Interferometric phase [Radians]
-3.14
3.14

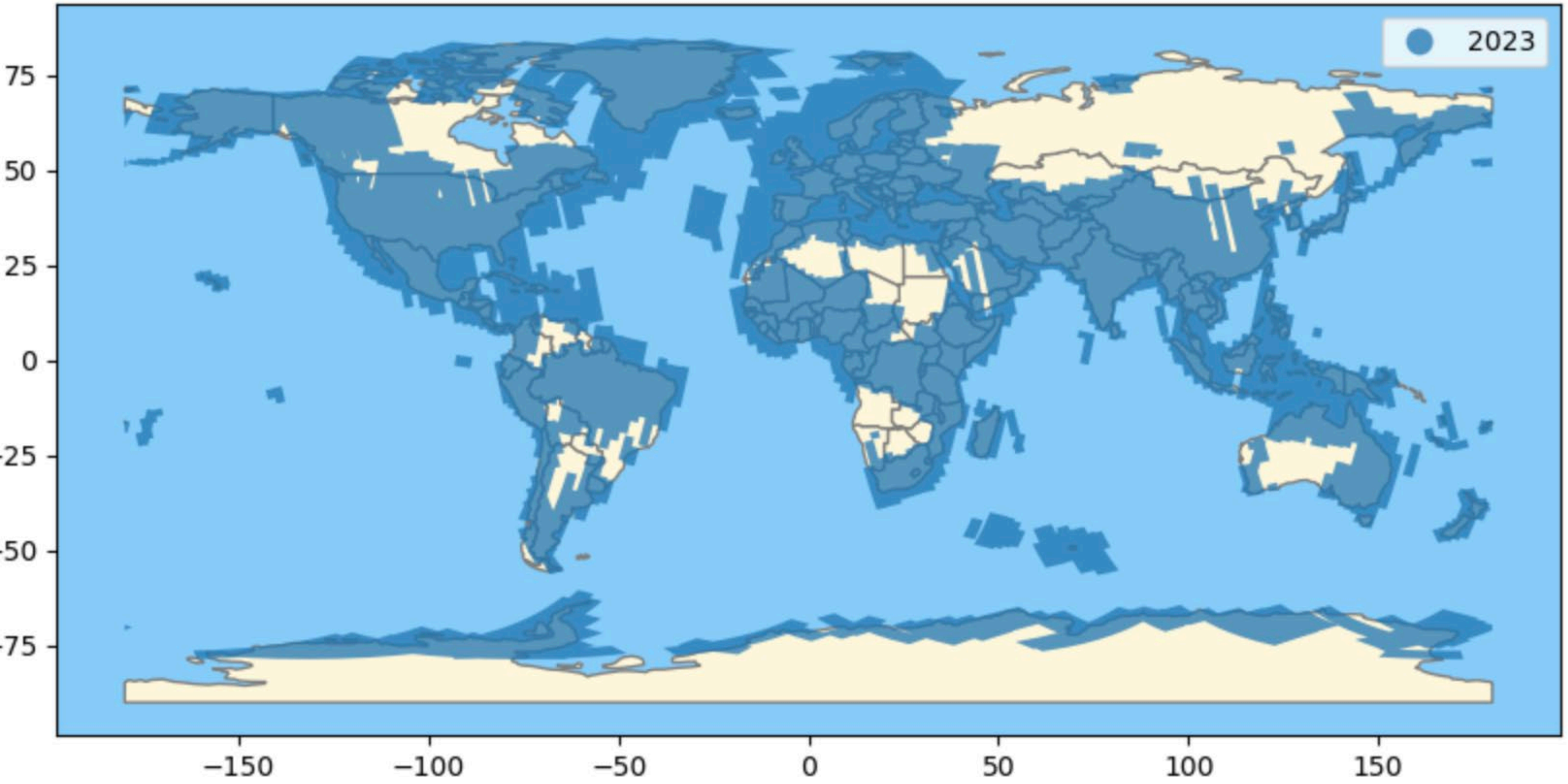

118.5°W
117°W
115.5°W
114°W
112.5°W
111°W
109.5°W
30°N
27.5°N
25°N
22.5°N
20°N
17.5°N
15°N
RCM
S-1
RS-2

HILARY
August 2023

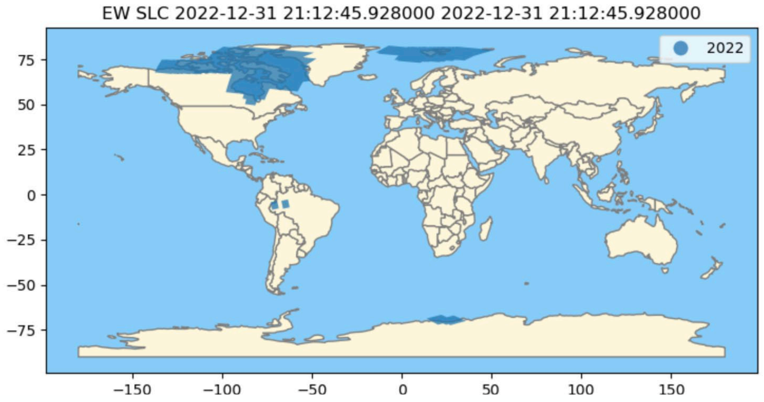
Chandpur - BANGLADESH

SLC Processing mask

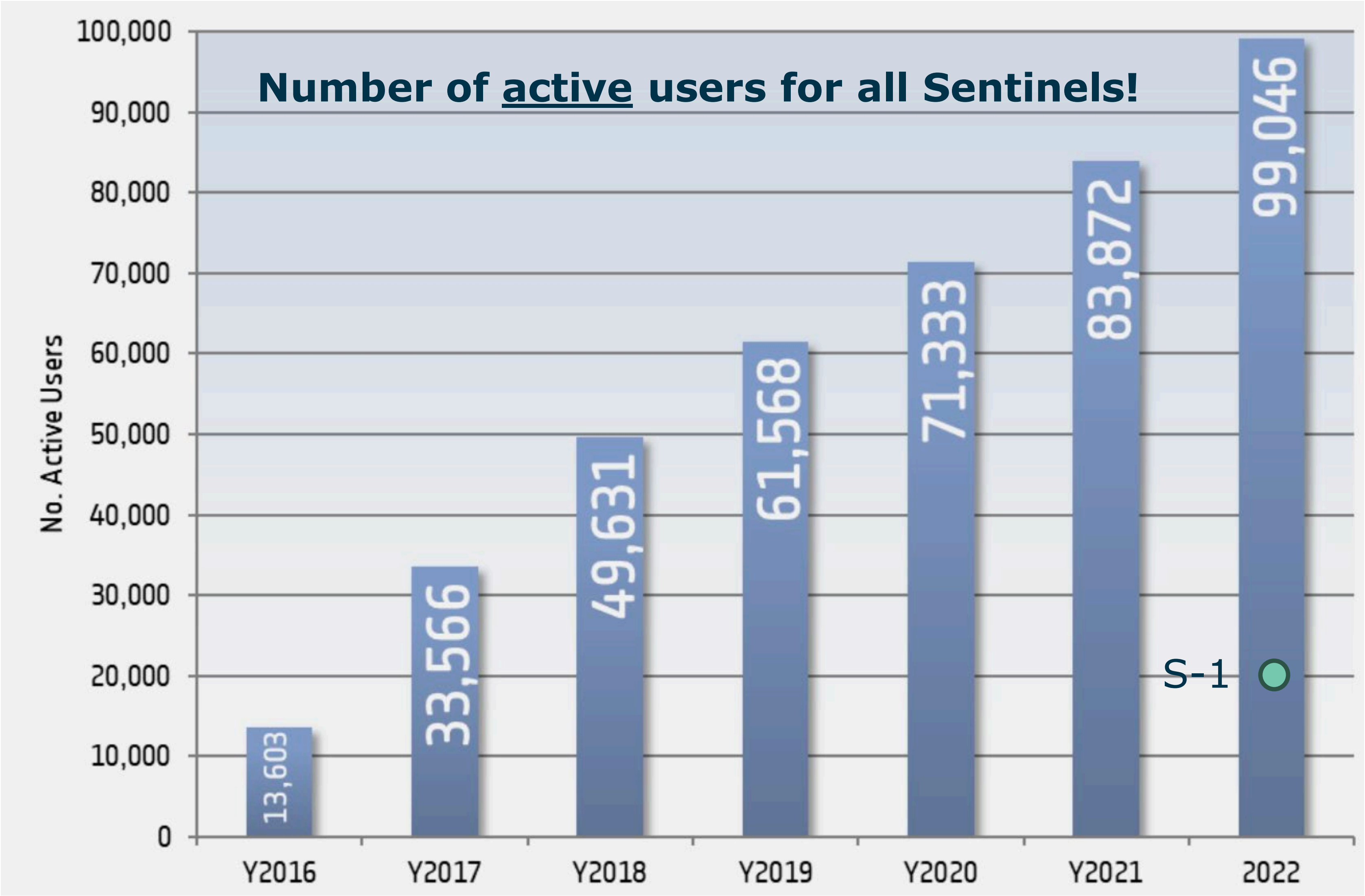
IW SLC Processing mask


● 2023
75
50
25
0
-25
-50
-75
−150
−100
−50
0
50
100
150

EW SLC Processing mask

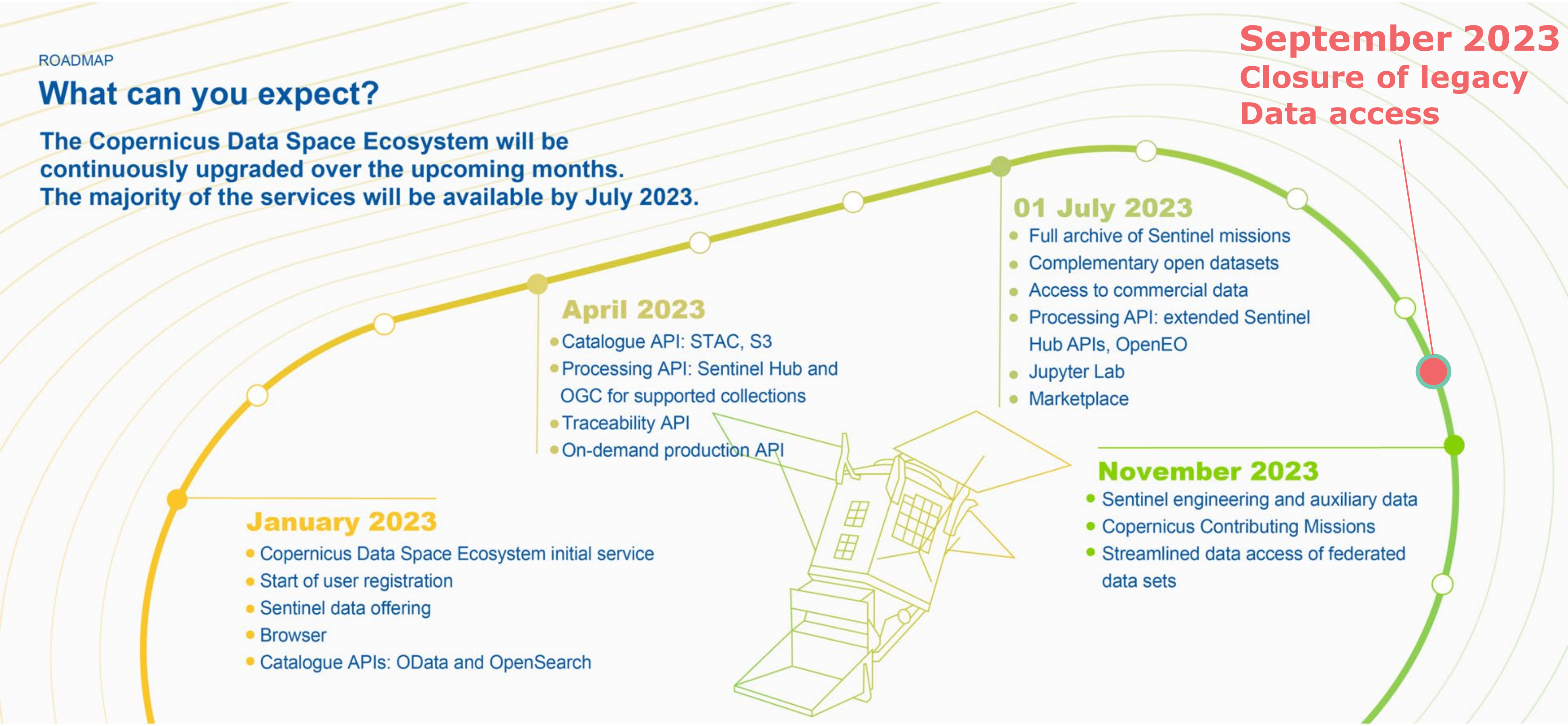

EW SLC 2022-12-31 21:12:45.928000 2022-12-31 21:12:45.928000
● 2022
75
50
25
0
−25
−50
−75
−150
−100
−50
0
50
100
150

Data access dashboard



- **Ever increasing number of active users**
  - **>20K S-1 active users**
- **3.6 TiB of data generated daily for S-1**
- **Data made available in few hours**
- **Archive Exploitation Ratio of 1:15 (entire archive downloaded 15 times**

Copernicus Data Space Ecosystem deployment schedule



ROADMAP

What can you expect?

The Copernicus Data Space Ecosystem will be continuously upgraded over the upcoming months. The majority of the services will be available by July 2023.

January 2023
- Copernicus Data Space Ecosystem initial service
- Start of user registration
- Sentinel data offering
- Browser
- Catalogue APIs: OData and OpenSearch

April 2023
- Catalogue API: STAC, S3
- Processing API: Sentinel Hub and OGC for supported collections
- Traceability API
- On-demand production API

01 July 2023
- Full archive of Sentinel missions
- Complementary open datasets
- Access to commercial data
- Processing API: extended Sentinel Hub APIs, OpenEO
- Jupyter Lab
- Marketplace

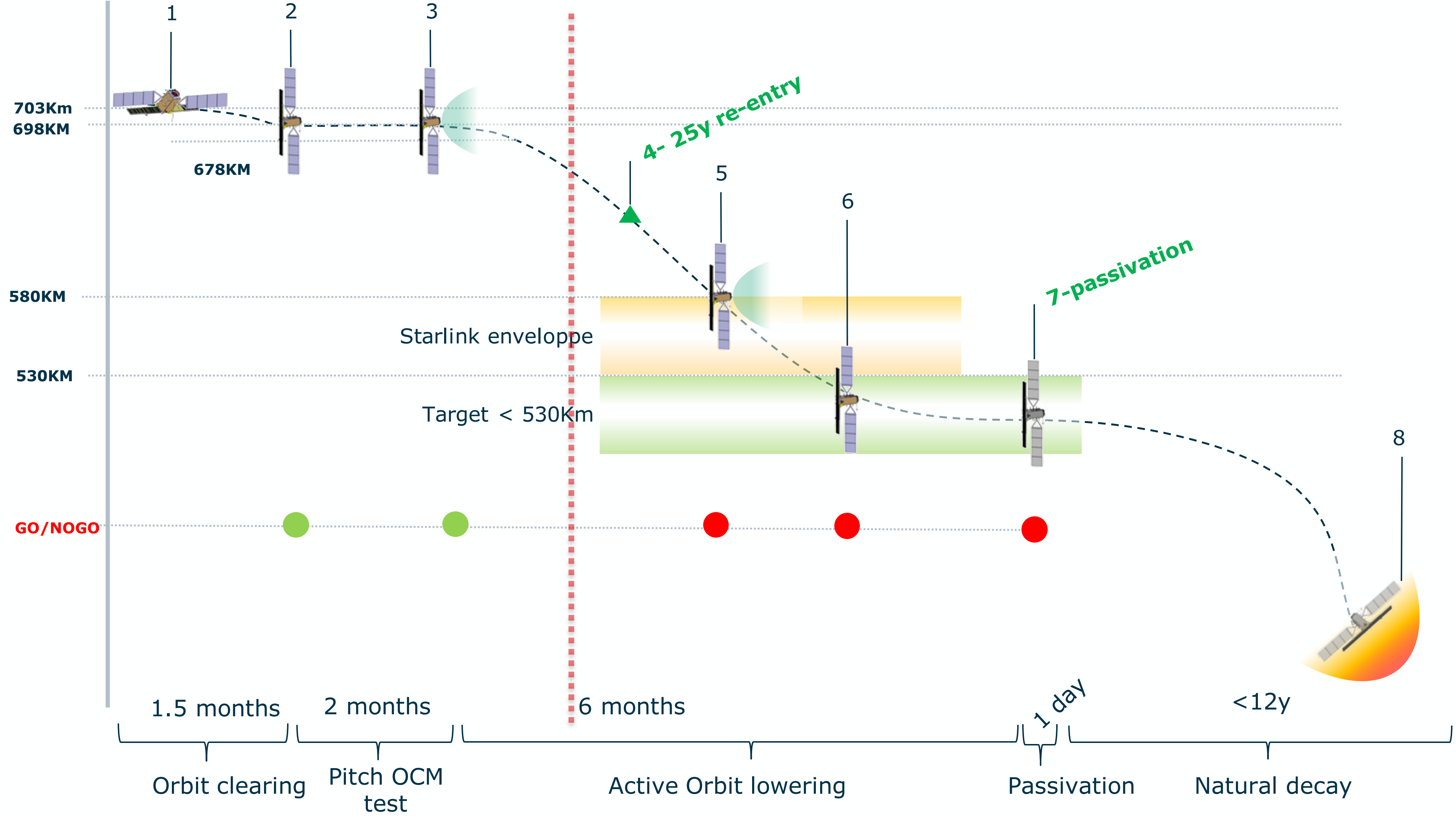
September 2023
Closure of legacy Data access

November 2023
- Sentinel engineering and auxiliary data
- Copernicus Contributing Missions
- Streamlined data access of federated data sets

https://documentation.dataspace.copernicus.eu/#/Roadmap

- **ALL L1 Data back online since launch**
- **New APIs for discovery & access**
  - **STAC & S3**
- **Capacity for on-demand processing**
- **Additional datasets**
- **Native Cloud Services**

Sentinel-1B Disposal approach


1
2
3
703Km
698KM
678KM
4- 25y re-entry
5
6
580KM
Starlink envelope
7-passivation
530KM
Target < 530Km
8
GO/NOGO
1.5 months
2 months
6 months
1 day
<12y
Orbit clearing
Pitch OCM test
Active Orbit lowering
Passivation
Natural decay

1.Orbit Clearing Start

2.Pitch In-plane OCM campaign Start

3.Active lowering start

4.25y re-entry [**September 23**]

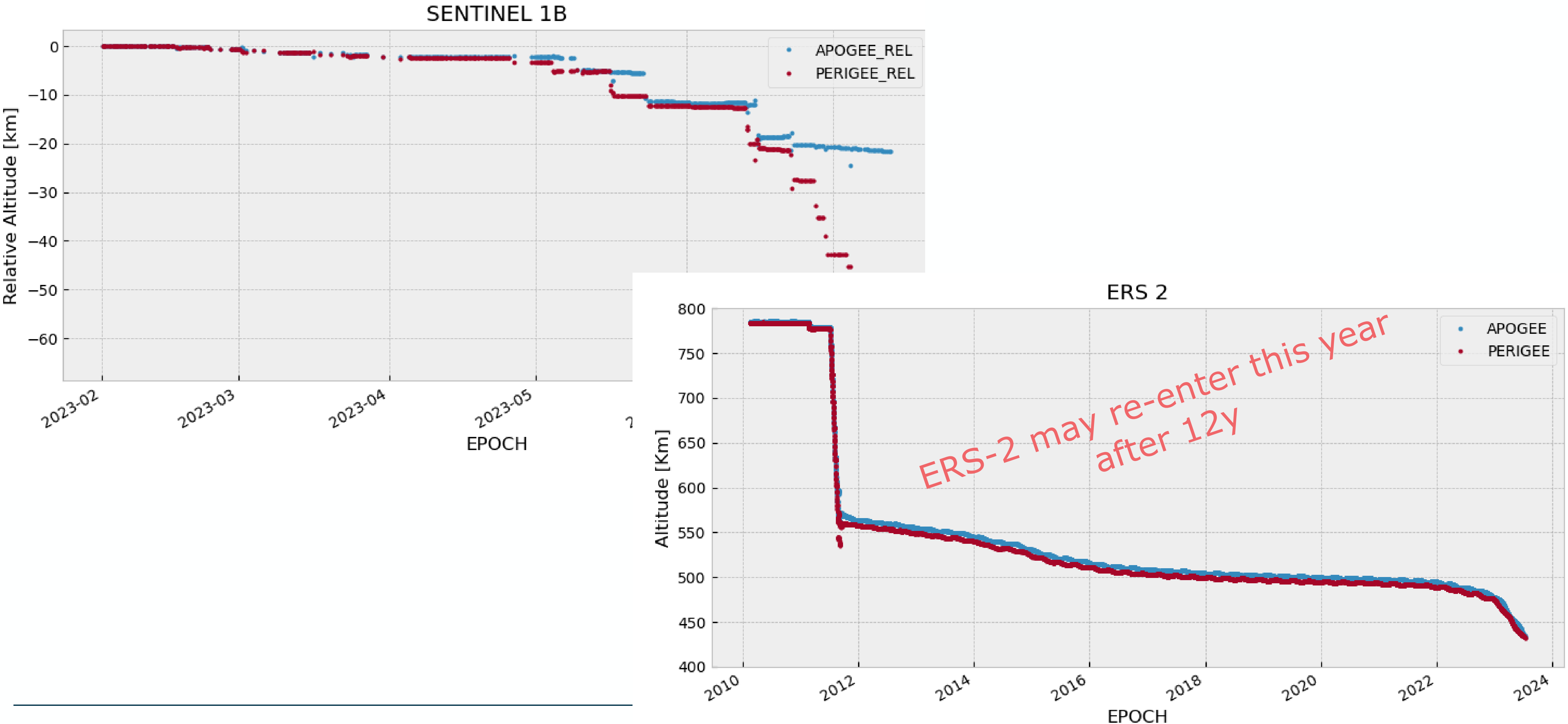
5.Starklink envelope reached

6.Fuel depletion burns

7.Passivation **[December 23]**

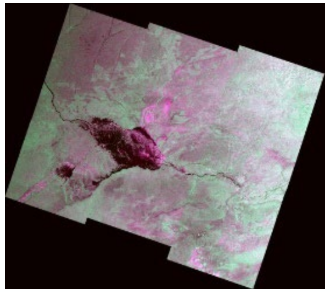
8.Re-entry in atmosphere **[<12y]**

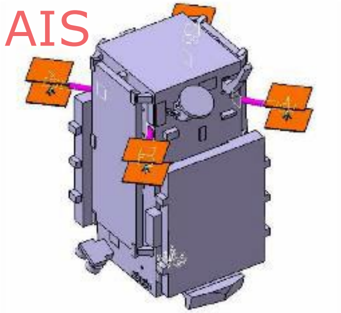
Sentine-1B Disposal approach



ERS-2 may re-enter this year after 12y

Copernicus Sentinel-1C/-1D Status





Sentinel-1C/-1D to continue and augment ***Sentinel-1A/-1B services***

- fully compatible w.r.t. SAR mode characteristics, observation geometry, image resolution and burst synchronization (InSAR)

- **Sentinel-1C/D** built on S-1A/-1B design with ***Evolution*** and ***Improvements***
  - **AIS payload to provide ship identification data for augmentation of SAR images**
  - S-1C/D design compatible with Space Debris Casualty Ratio less than 10^{-4}
  - GNSS receiver compatibility with Galileo
  - **Interleaved Calibration Noise Pulses for thermal noise correction**
  - **Improved SAR Instrument Performance (radiometric accuracy)**
  - Satellite Manoeuvring (thruster performance)
  - SMU Processing Capability (LEON3 processor)
  - **Vega-C launcher qualification**
- ***Sentinel-1C*** ready for **launch**
- ***Sentinel-1D*** went into **storage** in Oct. 2021

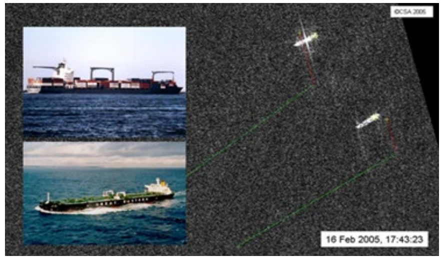
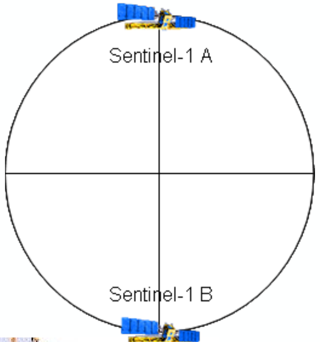
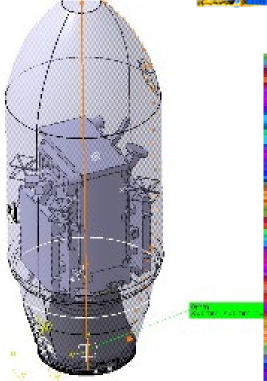
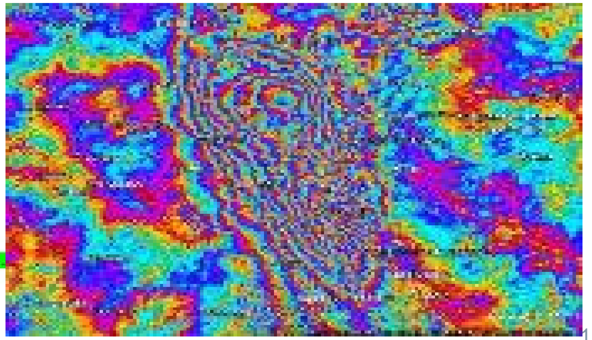


Image courtesy: P. Vachon, DRDC





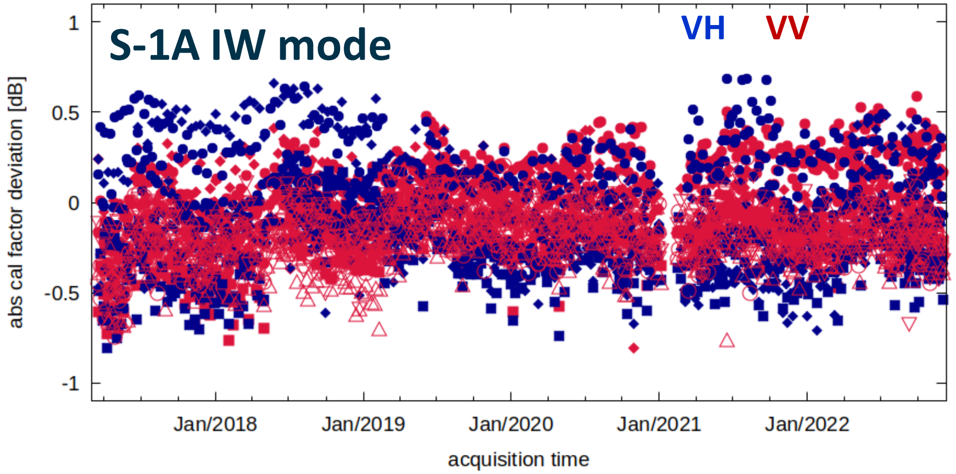


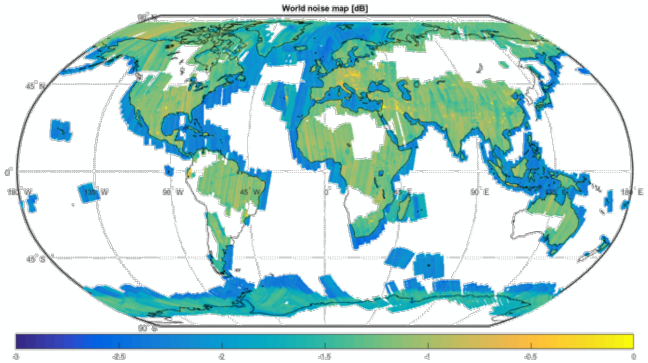
Improvements of Internal Calibration System

BETTER RADIOMETRIC PERFORMANCE| simplified internal calibration approach allowing to:

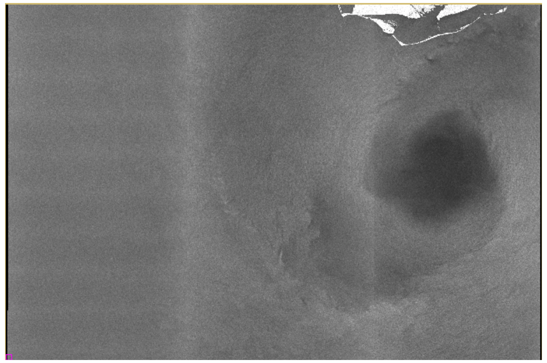
- Achieve a –*slightly*– better radiometric stability 0.45 dB (3σ) (compared to 0.55 dB (3σ) for S-1A&B)

- Introduce proper noise pulses all along the data-take for tracking the Earth brightness emissivity:
  - → Better denoising → better radiometric accuracy over low signal values (cross-pol data)
  - → Much reduced thermal noise patterm

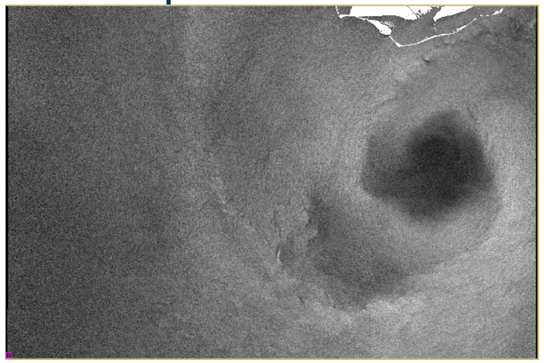




S-1 Earth brightness emissivity from noise pulses



S-1A/B

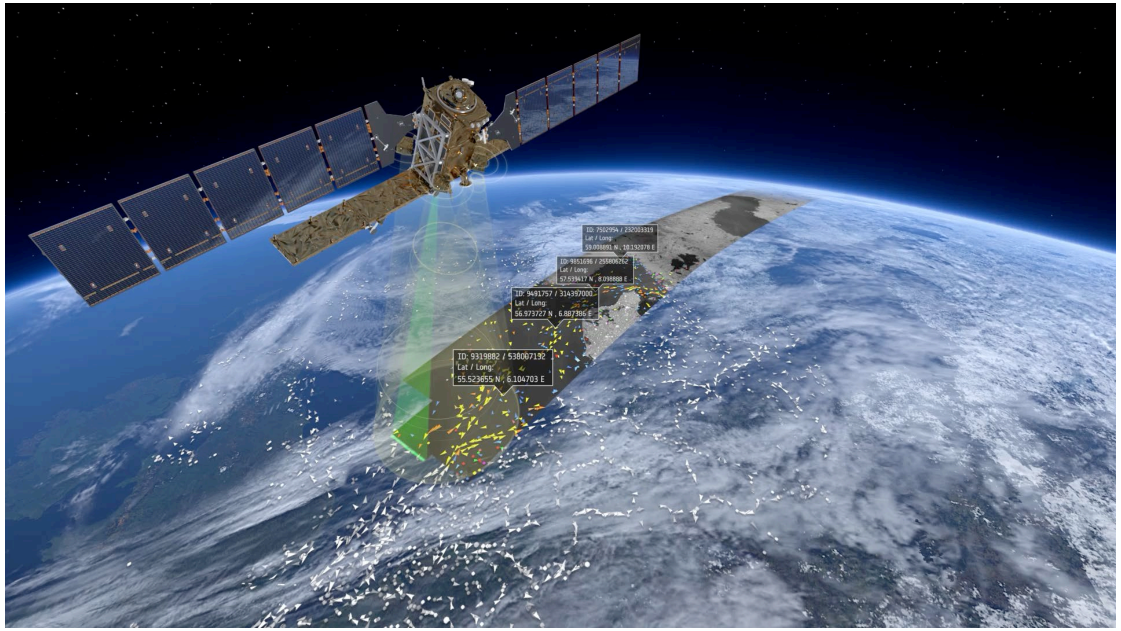


S-1C/D

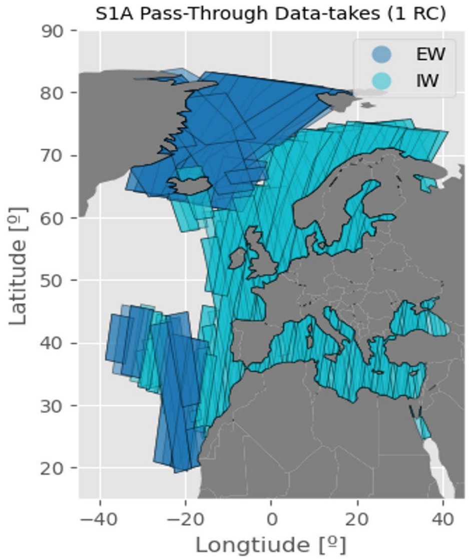
Sentinel-1C/D AIS Instrument

AIS Instrument for augmentation of SAR maritime services

- Provides ship identification data simultaneously with SAR images
- AIS footprint matches IWS for maximising SNR and minimising message collisions
- AIS observation scenario is under definition (likely ‘real-time’ scenario over Europe allowing for direct usage at stations. Elsewhere to be defined)
- AIS Data policy is under discussion with European Commission



S-1 Overpasses in direct downlink allowing for real time usage


S1A Pass-Through Data-takes (1 RC)
EW
IW
Latitude [º]
90
80
70
60
50
40
30
20
−40
−20
0
20
40
Longtiude [º]

Thank you