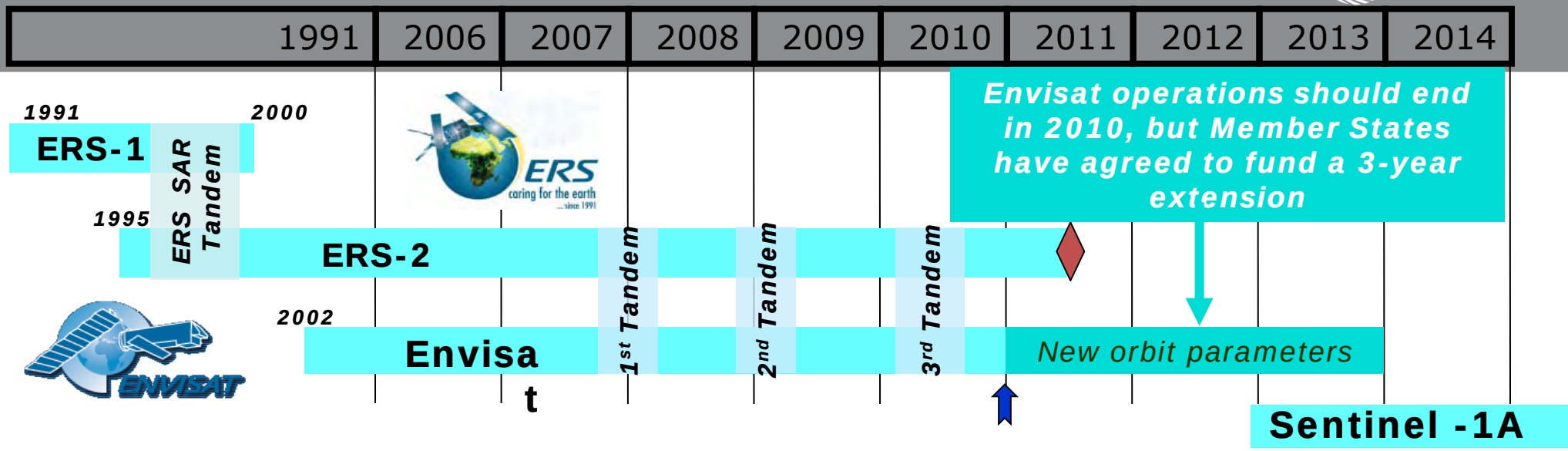
# ESA SAR products for Interferometry

Terrafirma meeting
December 2010

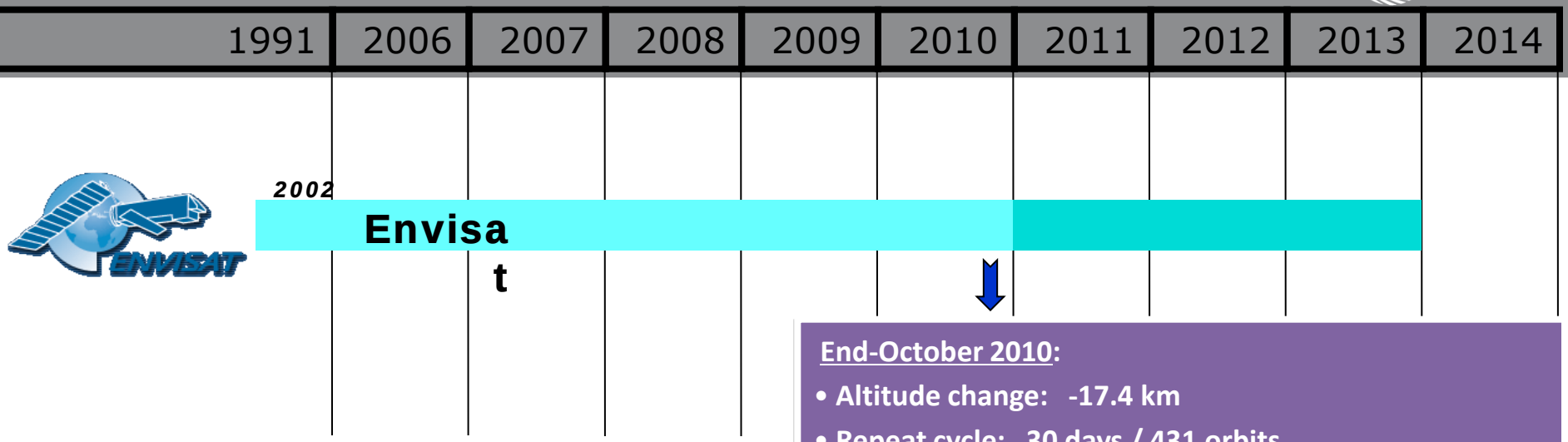
*Nuno Miranda*

# ESA SAR Mission context




- **ERS-2 will be de-orbit in summer 2011**
  - **Flying in gyro-less mode since 2001 → Doppler stability issue**
  - **Ice phase mode is likely to happen from Feb-2011 (3days/43 orbits)**
- **ASAR mission is extended until end-of 2013 on a new orbit and with new orbit control parameters:**
  - **All applications are maintained but (operational) interferometry**
- **Sentinel-1A is planned to be launch in December 2012 (S-1B in 2014+)**

# Envisat Mission Extension



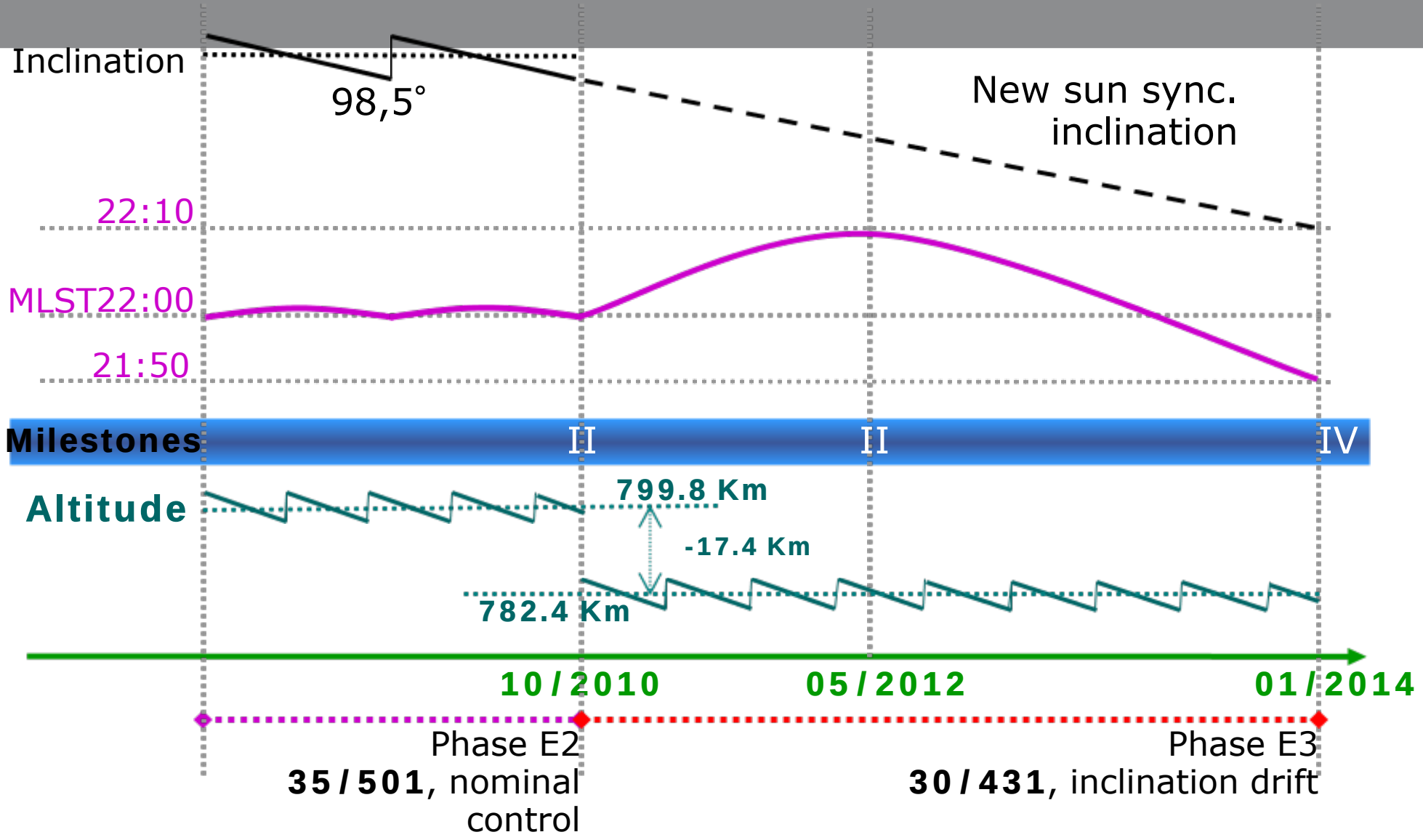

**End-October 2010:**

- Altitude change: -17.4 km
- Repeat cycle: 30 days / 431 orbits
- Orbit control: altitude control with inclination drift
- Mean Local Solar Time variation: +/- 10 min.

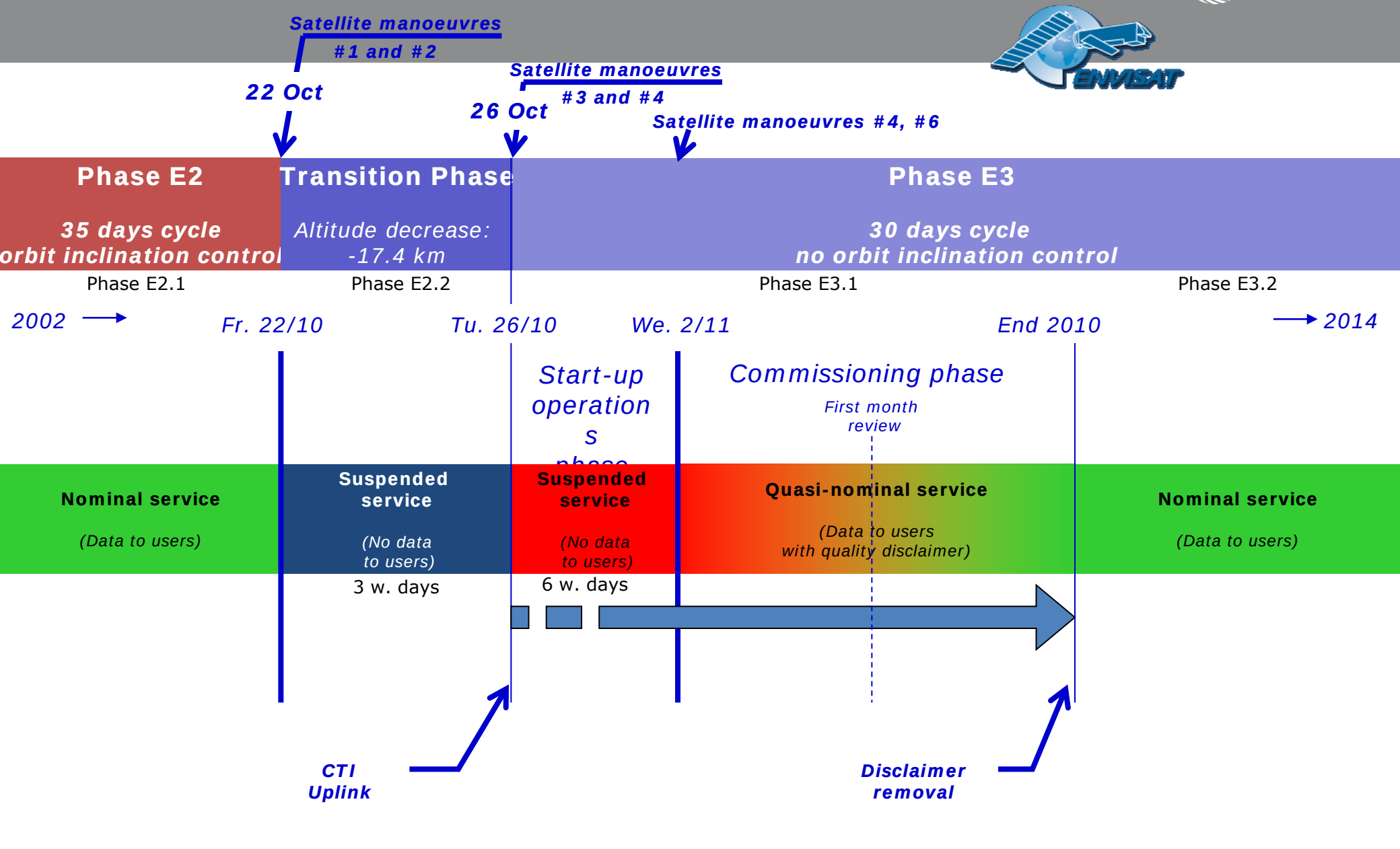
**The new orbital parameters allow:**

1. to keep current nominal mission until October 2010,
2. to extend the mission until end 2013,
3. to allow operations of all instruments with small or no degradation of their measurements, and minor impact on data quality, *excepted for SAR interferometry*
4. to commit with the satellite disposal rules.

# Mission Extension Scenario



# Envisat Mission extension

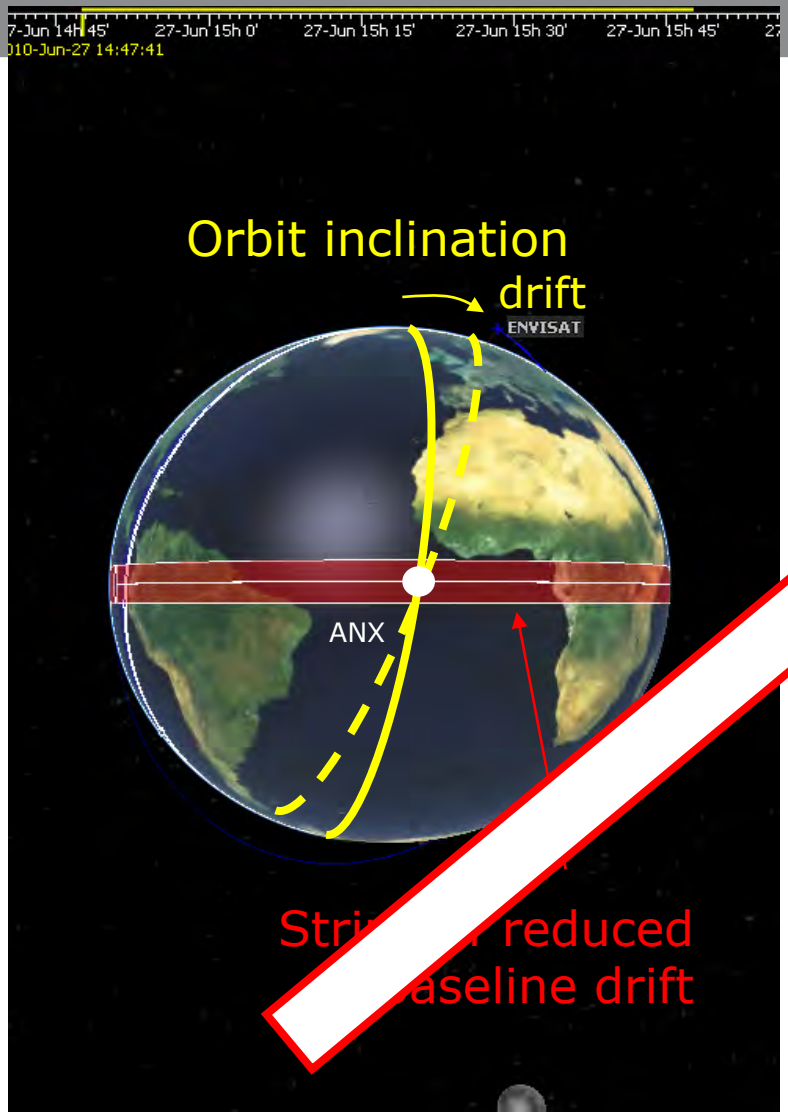


# ASAR Instrument reconfiguration

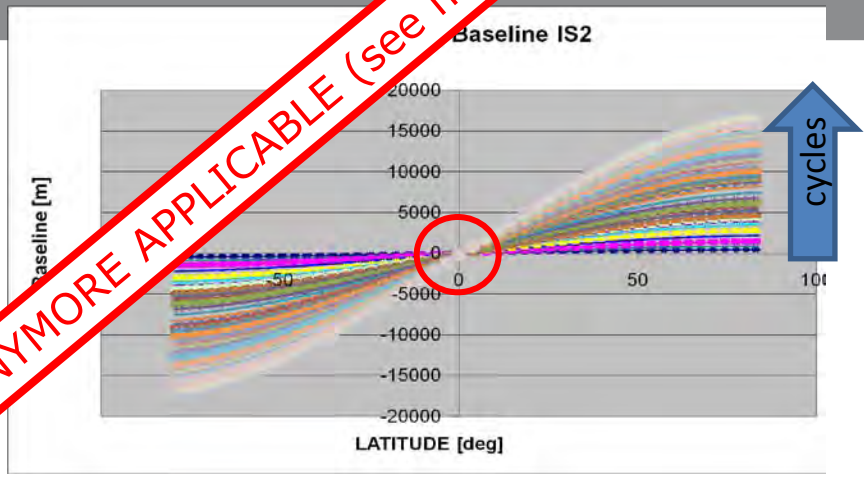
- The orbit lowering implies that the ASAR instrument needs to be reconfigured with optimal parameters for each swath

- Instrument reconfiguration drivers:
  - Keep the beams as per current definition → conserving the same antenna excitation coefficients and thus the same radiating beam pattern
    - ➔ no beam recalibration necessary
  - Maintain the instrument performance as today (e.g. no nadir return in Rx window, DTAR, sensitivity,…)
    - ➔PRF, SWST, SWL and Tx pulse length have been re-optimised
    - ➔New swath definition

# ASAR extension: interferometry (December 2009)




Baseline analysis

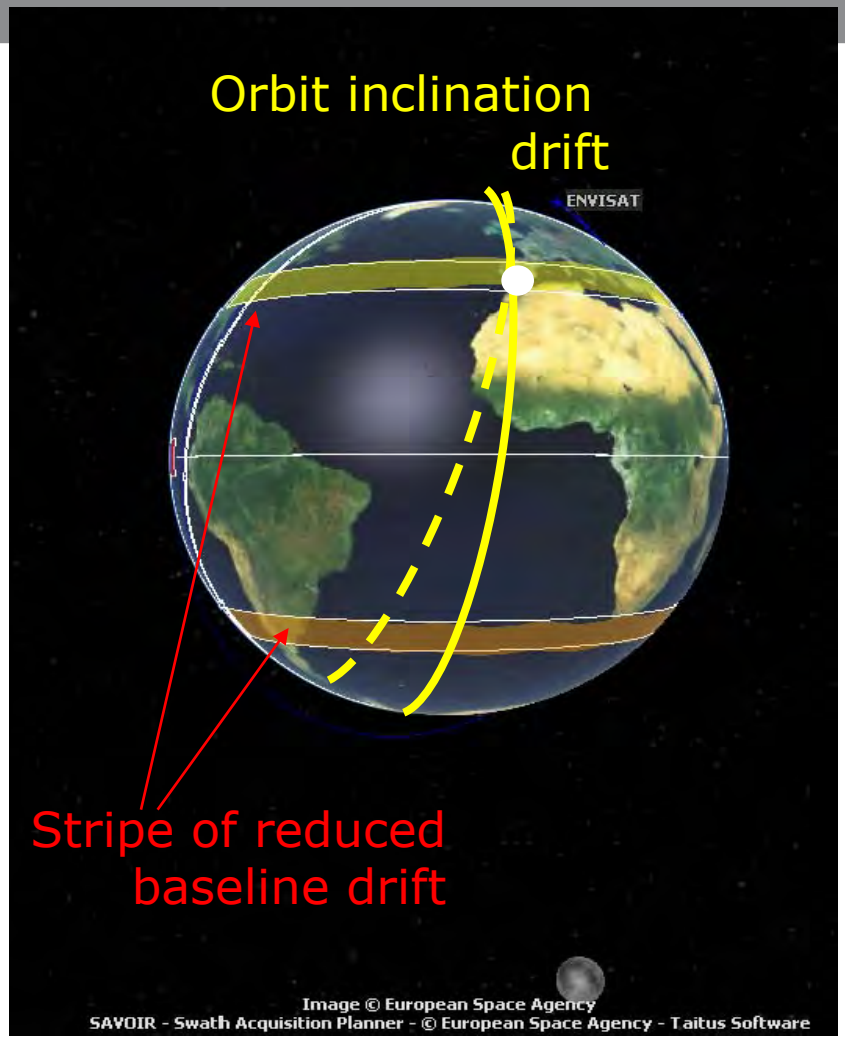


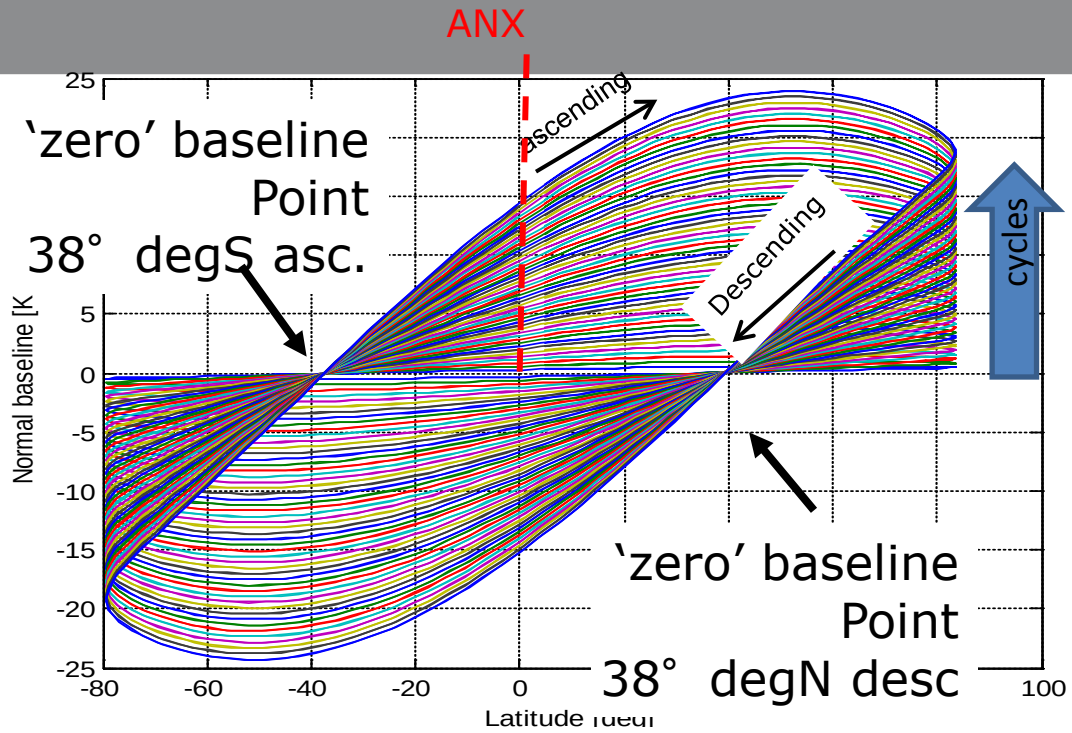

NOT ANYMORE APPLICABLE (see next slide)

Inclination drift induces an increase of the baseline that is latitude dependent:

- Equator: small baseline increase
- Increase with the latitude
- It is possible to identify an area centered around the equator where baseline remains small → maximising the chances of finding interferometric pairs

# ASAR extension: interferometry (December 2010)



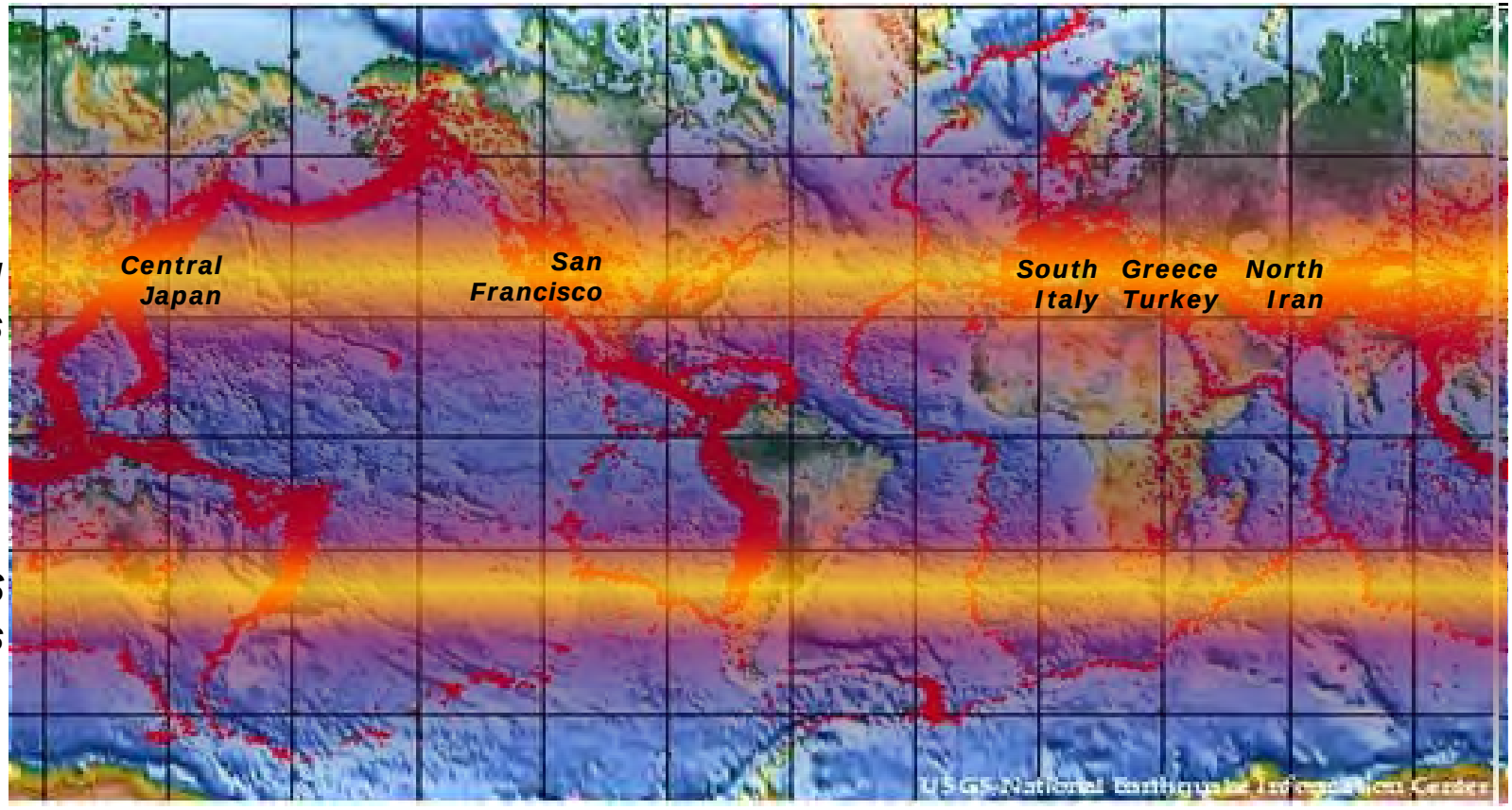

- Rotation of the orbital node such that the reduced baseline area matches with interesting tectonics area:
  - 38deg North descending allowing to cover: South Italy, California, Turkey, Iran, Japan,…
  - 38degN ascending (symetrical to the previous

# ASAR InSAR after Oct. 2010

For differential interferometry, smallest multi-pass baseline values will be within a band centred at 38 deg. latitude North (for descending pass) and at 38 deg. latitude South (for ascending pass).

***38 deg N***
***Descending pass***

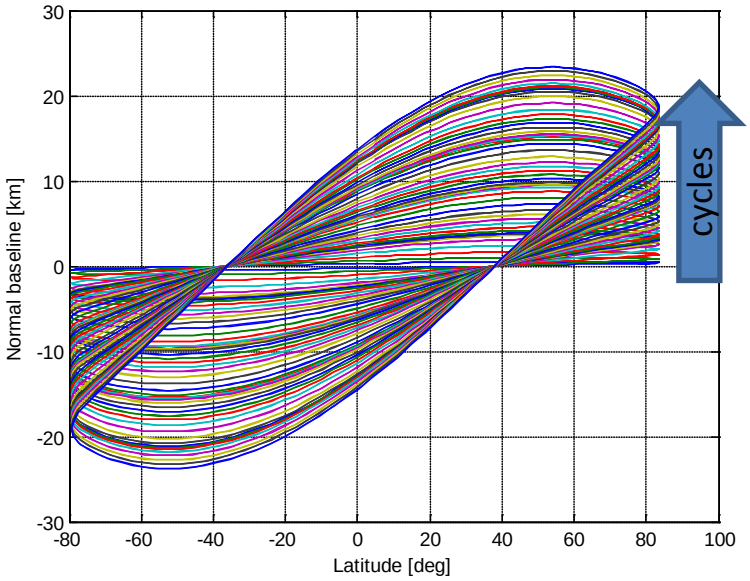
***38 deg S***
***Ascending pass***



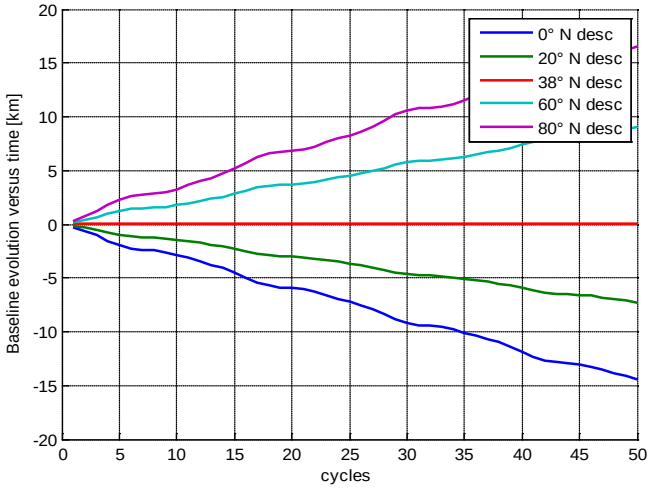
# Baseline evolution

- Theoretical baseline evolution:
  - The orbit drift continuous in time but in a latitude dependent fashion

Swath IS6




  - Small consecutive baseline can be achieved on areas close to 38° N desc.



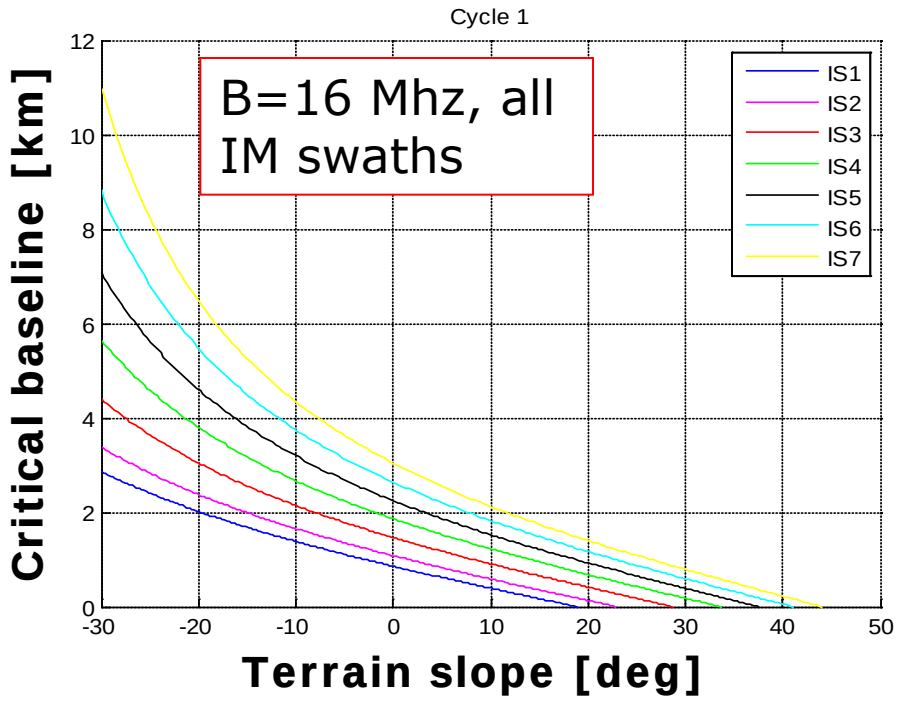
# ASAR extension: interferometry

What is the interferometric area extent?

- It depends on the swath (critical baseline, Bcrit)
- Far beams (e.g. IS6) are less sensitive to the baseline than near beams (e.g. IS2)

- Considering the entire mission extension (40 cycles) and a threshold of Bcrit/2
  - Area extent IS2: ±1.3deg
  - Area extent IS6: ± 4deg

- ASAR interferometric BRM is now move to IS6/HH



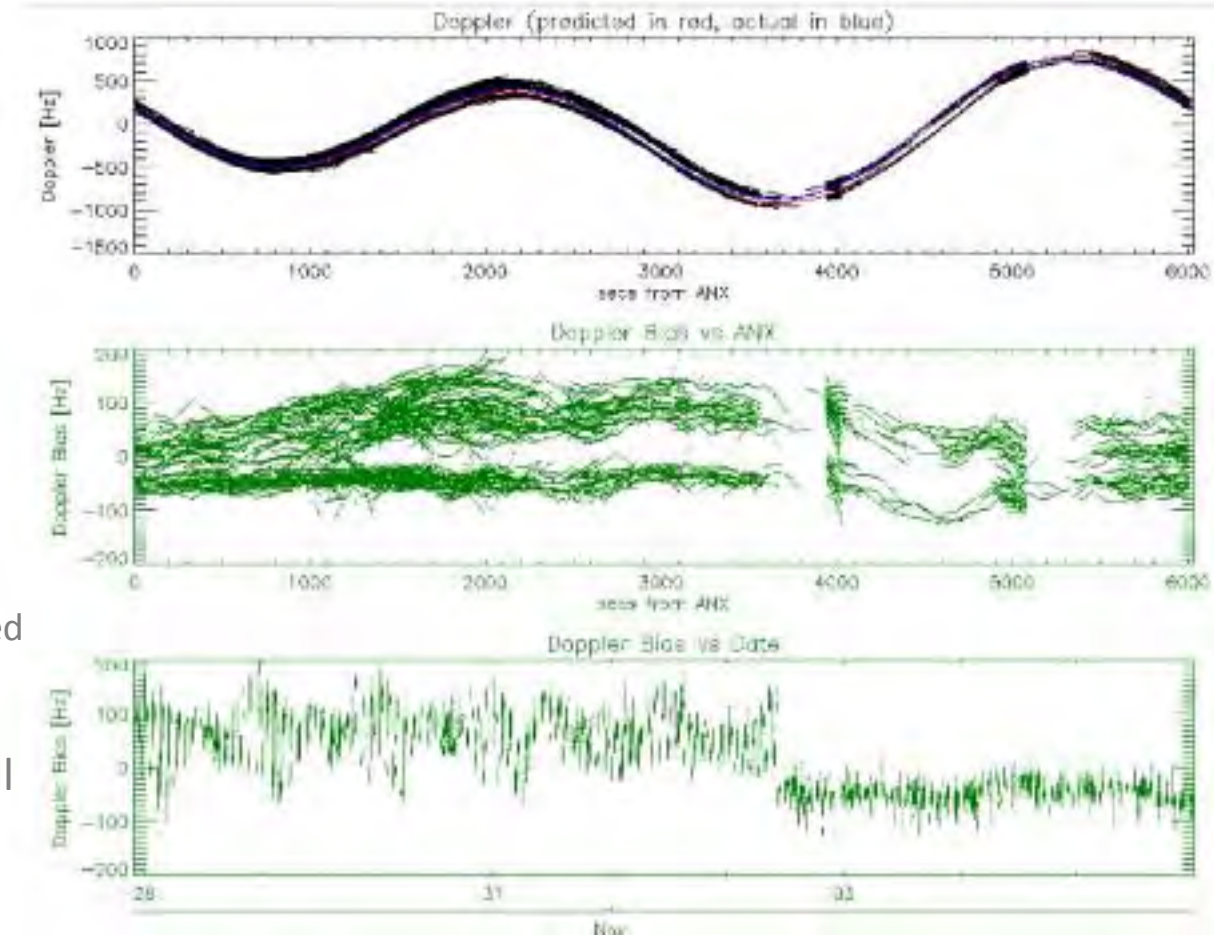

$$B_{crit} = \frac{\lambda . B . R_s . \tan(\vartheta - \alpha)}{c}$$

# ASAR verification phase results

- Verification activities started on the 26/10 as expected:
  - Overall data quality was nominal
  - Problem on WSM timeline →solved in the very first days by the circulation of a new INS ADF
  - Problem on GM: corruption over south pole (seems to be corrected since last week)

# ASAR verification phase results

- All mode characteristics have been checked ✔
- Antenna performance nominal 
  - No changes in T/R characteristics → same EAP are applicable
- ASAR Pointing is nominal since ✔
  - 02/11/2010 YSM → S-YSM
- Instrument calibration is nominal ✔
  - Transponder measurement are as expected
- Orbital control and baseline are under verification. The final orbital control will not be ready before january 2011
- Eoli-SA still not accessible for data acquired since E2010+ ✖



# Sentinel-1 mission and products

- Mission characteristics overview
- Product definition
- Slicing concept
- Product format
- Data policy principles

# S–1 C-band SAR mission

- ✓ **Continuity of ERS and ENVISAT missions**

- ✓ **GMES radar imaging mission for ocean / sea, land and emergency services**

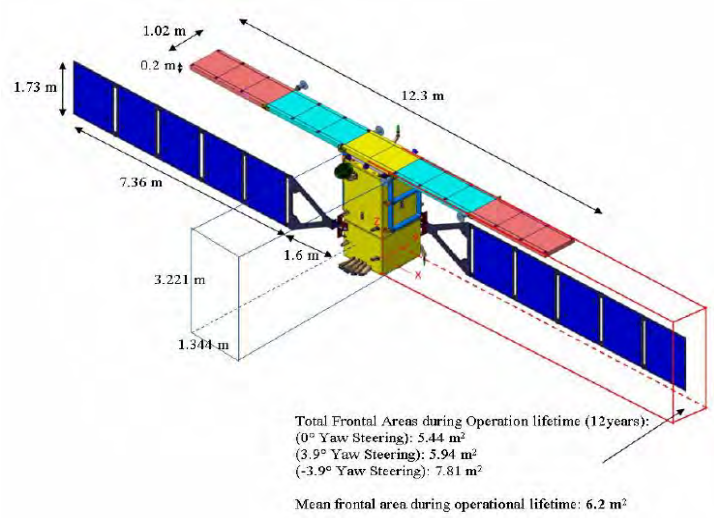

- ✓ **Applications:**

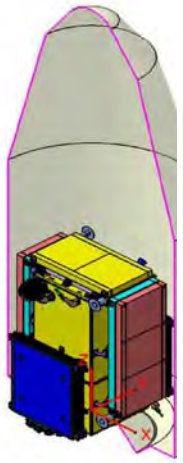
- monitoring sea ice zones and the polar environment
- surveillance of marine environment
- monitoring land surface motion
- mapping in support of civil protection / humanitarian aid, in crisis situations
- mapping of land surfaces: forest, water and soil, agriculture, etc.

**The Sentinel-1 mission is based on a constellation of 2 satellites**

- Sentinel-1A to be launched end 2012
- Sentinel-1B under procurement, launch date is TBD (indicatively 2014/2015)

# S–1 satellite system

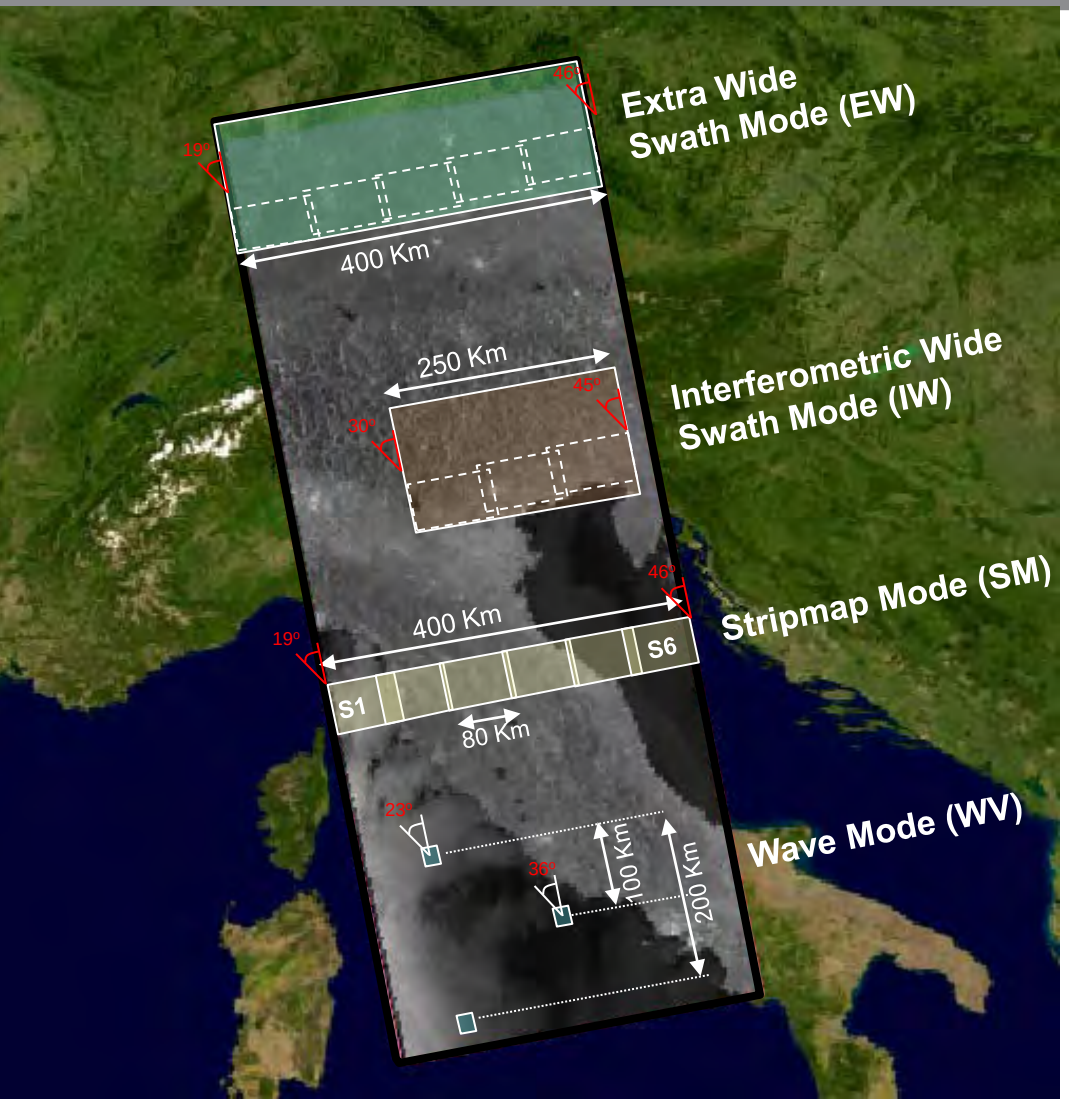


| System Parameter | Value |
|---|---|
| Radar Carrier Frequency | 5.405 GHz |
| RF Peak Power | 4.368 kW |
| Incidence Angle Range | 20°-46° |
| Look direction | Right |
| Antenna Length | 12.3 m |
| Azimuth Beam Width | 0.23° |
| Azimuth Beam Steering Range | -0.9° to +0.9° |
| Antenna width | 0.82 m |
| Elevation Beam Width | 3.43° |
| Elevation Beam Steering Range | -13.0° to +12.3° |
| Maximum Range Bandwidth | 100 MHz |
| Pulse Repetition Frequency (PRF) Range | 1000 Hz - 3000 Hz |
| Polarisation Options | Single (HH, VV)<br>Dual (HH+HV, VV+VH) |
| Attitude Steering | Zero-Doppler Steering and Roll Steering |

- 2300 Kg spacecraft mass
- 7 years design life time, consumables for 12 years
- Sun synchronous dawn-dusk orbit at 693 Km mean altitude
- 12 days/175 orbits repeat cycle (1 satellite), 6 days for the constellation
- The two satellites are in the same orbit but with a different mean anomaly
- C-Band SAR Payload with centre frequency 5.045 GHz

# S-1 imaging modes




Sentinel-1 SAR can be operated in 4 exclusive imaging modes with different resolution and coverage:

| Mode Rate | SAR Mode |
|---|---|
| High Bit Rate (HBR) | IW |
| | EW |
| | SM (S1 → S6) |
| Low Bit Rate (LBR) | WV |

For all of these operating modes, the same family of products is available to users.

The systematic processing into specific product type is done according to pre-defined areas.

# S-1 SAR product family

## LEVEL-0 PRODUCTS

Compressed, unprocessed instrument source packets, with additional annotations and auxiliary information to support the processing.

## LEVEL-1 PRODUCTS

### Level-1 Slant-Range Single-Look Complex Products (SLC)

Focused data in slant-range geometry, single look with phase and amplitude information.

### Level-1 Ground Range Detected Geo-referenced 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.

## LEVEL-2 PRODUCTS (Not presented)

### Level-2 Ocean (Wind, Wave and Currents) products (OCN)

Ocean wind field, swell wave spectra and surface currents information as derived from SAR data. L2 ocean products are available for all modes.

# S-1 observation scenario

- Objective: Implement a pre-defined and conflict-free observation plan, aiming at fulfilling, to the max. feasible extent, the observation requirements from the various GMES and National services (Europe and Canada)
Note: other observation requirements may be accommodated when feasible, i.e. in absence of technical or budget constraints.

- Need to find *a priori* the solutions on the potential conflict among services (e.g. different SAR operation modes / polarisation required over same area)

- The observation plan shall be regularly updated based on:
  - The evolution of the requirements from the services
  - The constraints on the space and ground segment resources (data volume generated by the mission, instrument duty cycle, core ground station network and overall data acquisition strategy, etc.)
  - The main system capacity scenarios (e.g. inclusion of the 2nd Sentinel-1 satellite, use of European Data Relay System)

# S-1 processing concept

| Processing Concept | Instrument mode | Product Type |
|---|---|---|
| Systematic Global | SM, IW, EW | SAR L0<br>SAR L1 GRD |
| | WV | SAR L2 OCN |
| Systematic Regional | SM,IW,EW | SAR L0<br>SAR L1 GRD<br>SAR L1 SLC<br>SAR L2 OCN |
| Systematic Local | SM,IW,EW | SAR L0<br>SAR L1 GRD |
| Archive | SM,IW,EW, WV | SAR L0<br>SAR L1 GRD<br>SAR L1 SLC<br>SAR L2 OCN |

**Global:**

Applies to all acquired data

**Regional:**

Applies to data acquired over well defined geographical areas, including areas required in NRT

**Local:**

Applies to well defined geographical areas fulfilling specific constraints (e.g. within the stations coverage area)

# S-1 SAR Level-0 Products: Overview

- SAR Level-0 products contain the sequence of FDBAQ compressed SAR ISP for a data take, including noise, internal calibration and echo source packets.

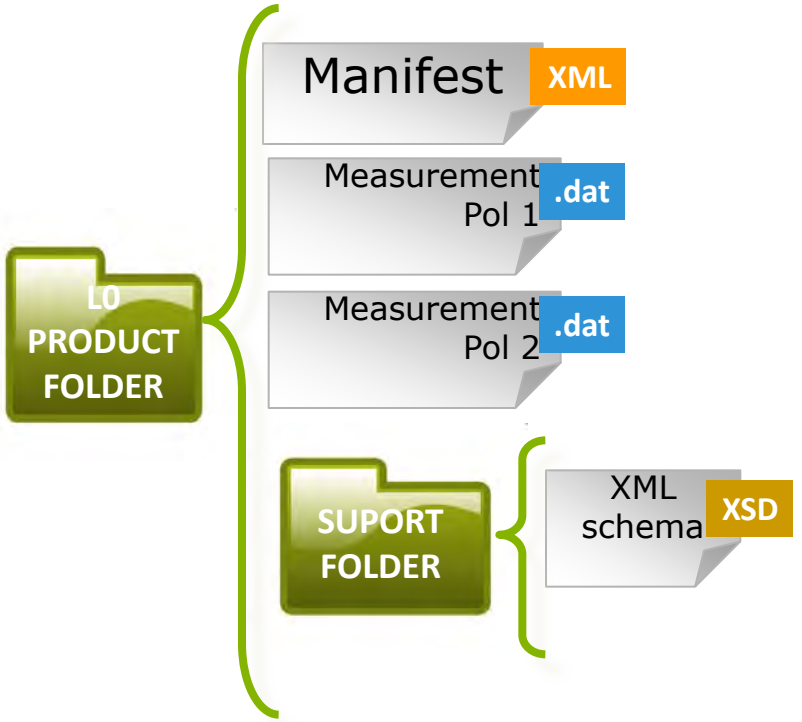
- Orbit and attitude information is embedded into the instrument source packets sequence

- For dual polarisation data, data for each polarisation is available separately within the Level-0 product.

- Level-0 product size is indicated in table below for different product lengths

- L0 format the SAFE format as top level container

| MODE | | Data take Length | | |
|---|---|---|---|---|
| | | 1 min | 10 min | |
| Single Pol | SM | 1.8 | 18.3 | GB |
| | IW | 1.7 | 16.6 | |
| | EW | 0.5 | 5.2 | |
| Dual Pol | SM | 3.7 | 36.6 | |
| | IW | 3.3 | 33.3 | |
| | EW | 1.0 | 10.4 | |



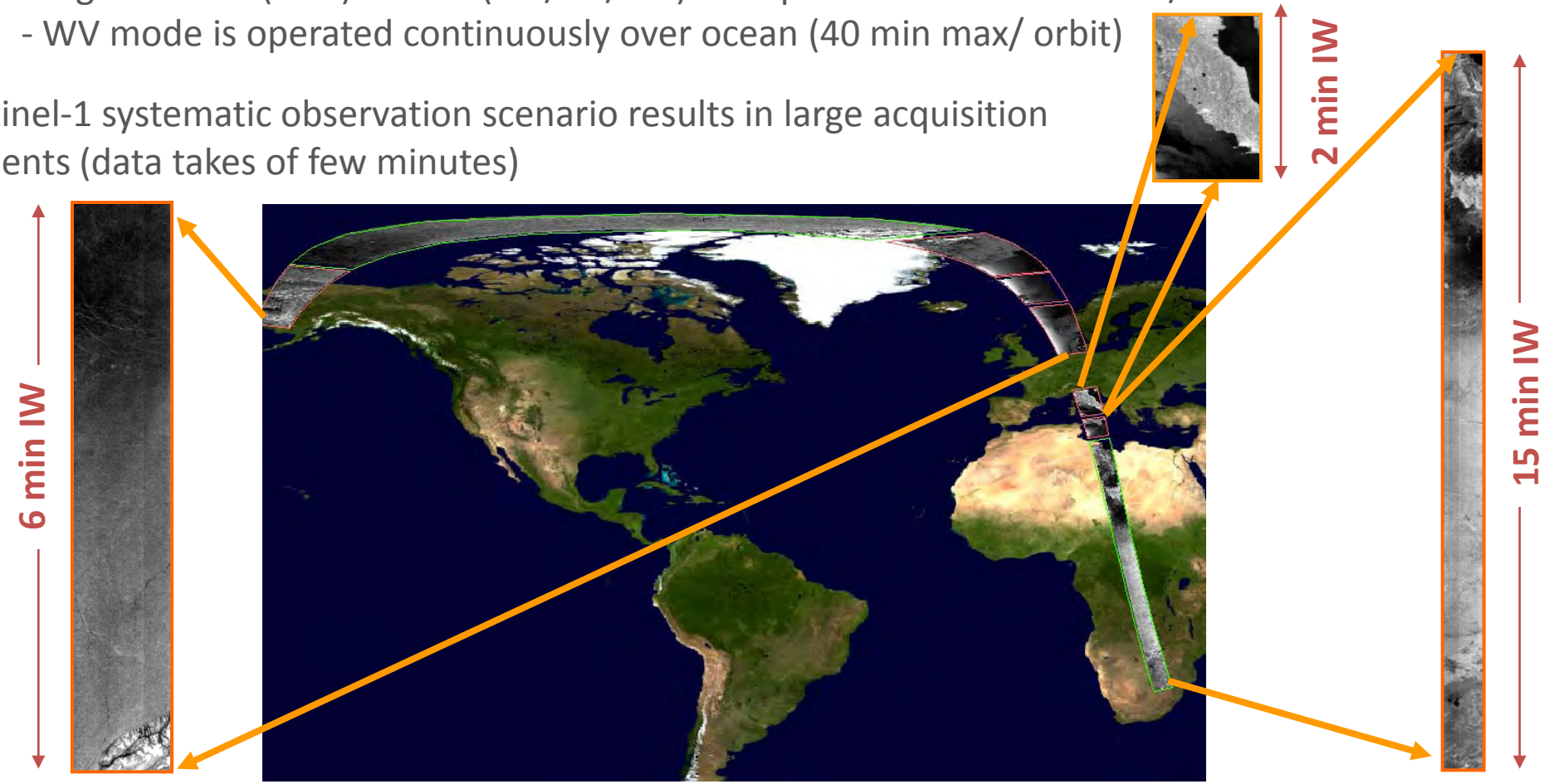
# S-1 SAR L1 product characteristics

| 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] |
|---|---|---|---|---|---|---|
| SM | SLC | | 1.7 x 4.3 to 3.6 x 4.9 | 1.5 x 3.6 to 3.1 x 4.1 | 1 x 1 | 1 |
| | GRD | FR | 9 x 9 | 4 x 4 | 2 x 2 | 3.9 |
| | | HR | 23 x 23 | 10 x10 | 6 x 6 | 34.4 |
| | | MR | 84 x 84 | 40 x 40 | 22 x 22 | 464.7 |
| | BRW | | 336 x 336 | 160 x 160 | N/A | N/A |
| IW | SLC | | 2.7 x 22 to 3.5 x 22 | 2.3 x 17.4 to 3 x 17.4 | 1 | 1 |
| | GRD | HR | 20 x 22 | 10 x 10 | 5 x 1 | 4.9 |
| | | MR | 88 x 89 | 40 x 40 | 22 x 5 | 105.7 |
| | BRW | | 1056 x 1044 | 480 x 480 | N/A | N/A |
| EW | SLC | | 7.9 x 42 to 14.4 x 44 | 5.9 x 34.7 to 12.5 x 34.7 | 1 x 1 | 1 |
| | GRD | HR | 50 x 50 | 25 x 25 | 3 x 1 | 2.9 |
| | | MR | 93 x 87 | 40 x 40 | 6 x 2 | 12.7 |
| | BRW | | 1860 x 1740 | 800 x 800 | N/A | N/A |
| WV | SLC | | 2.0 x 4.8 and 3.1 x 4.8 | 1.7 x 4.1 and 2.7 x 4.1 | 1 x 1 | 1 |
| | GRD | MR | 52 x 51 | 25 x 25 | 13 x 13 | 139.7 |

# S-1 Observation scenario (2)

- Sentinel-1 instrument operations:
  - High Bit Rate (HBR) modes (SM/IW/EW) are operated for max 25 min / orbit
  - WV mode is operated continuously over ocean (40 min max/ orbit)

- Sentinel-1 systematic observation scenario results in large acquisition segments (data takes of few minutes)

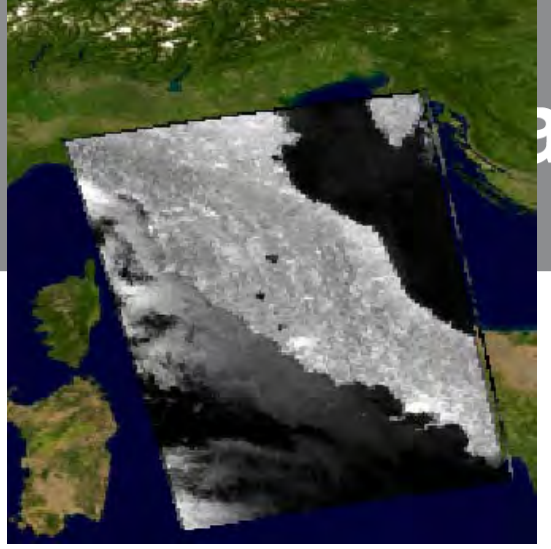


# S-1 slicing concept

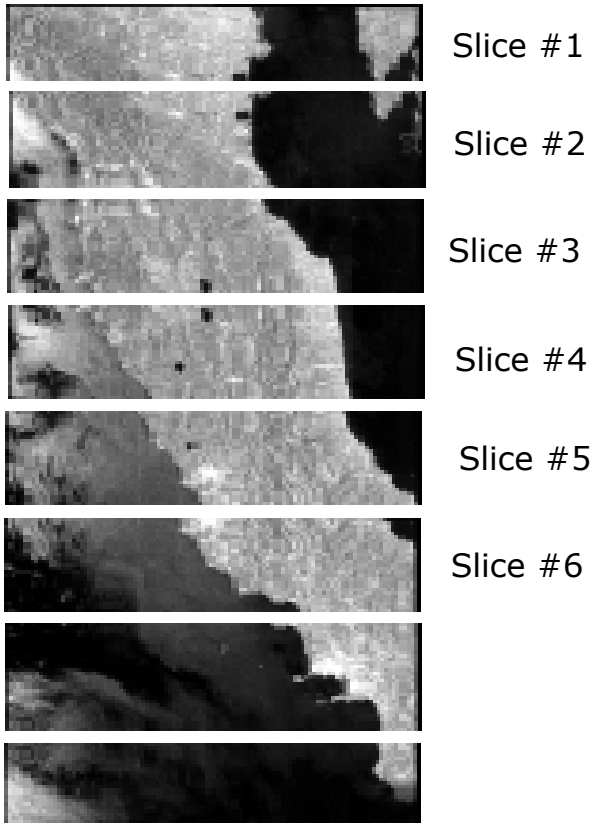
- For Sentinel-1, continuation of ENVISAT ASAR, users expect systematic access to long product stripes (e.g. similar to ASAR MR WSM or IMM products today systematically disseminated).
- Product size for L1 HBR modes would be hardly manageable at users side.
- Level-1 HBR products are segmented in “slices” of defined length along track, optimised per mode and product typeproducts for HBR

| | | Data volume in GB | | | | | |
|---|---|---|---|---|---|---|---|
| | | segment length [min] | | | | slice length [secs] | |
| | | SM | | IW | | SM | IW |
| segment length [min] | | 2 | 10 | 2 | 10 | 25 | 25 |
| Dual Pol | SLC | 36 | 182 | 30 | 150 | 8 | 6 |
| | GRD HR | 3 | 13 | 8 | 39 | 1 | 2 |

# S-1 slice products

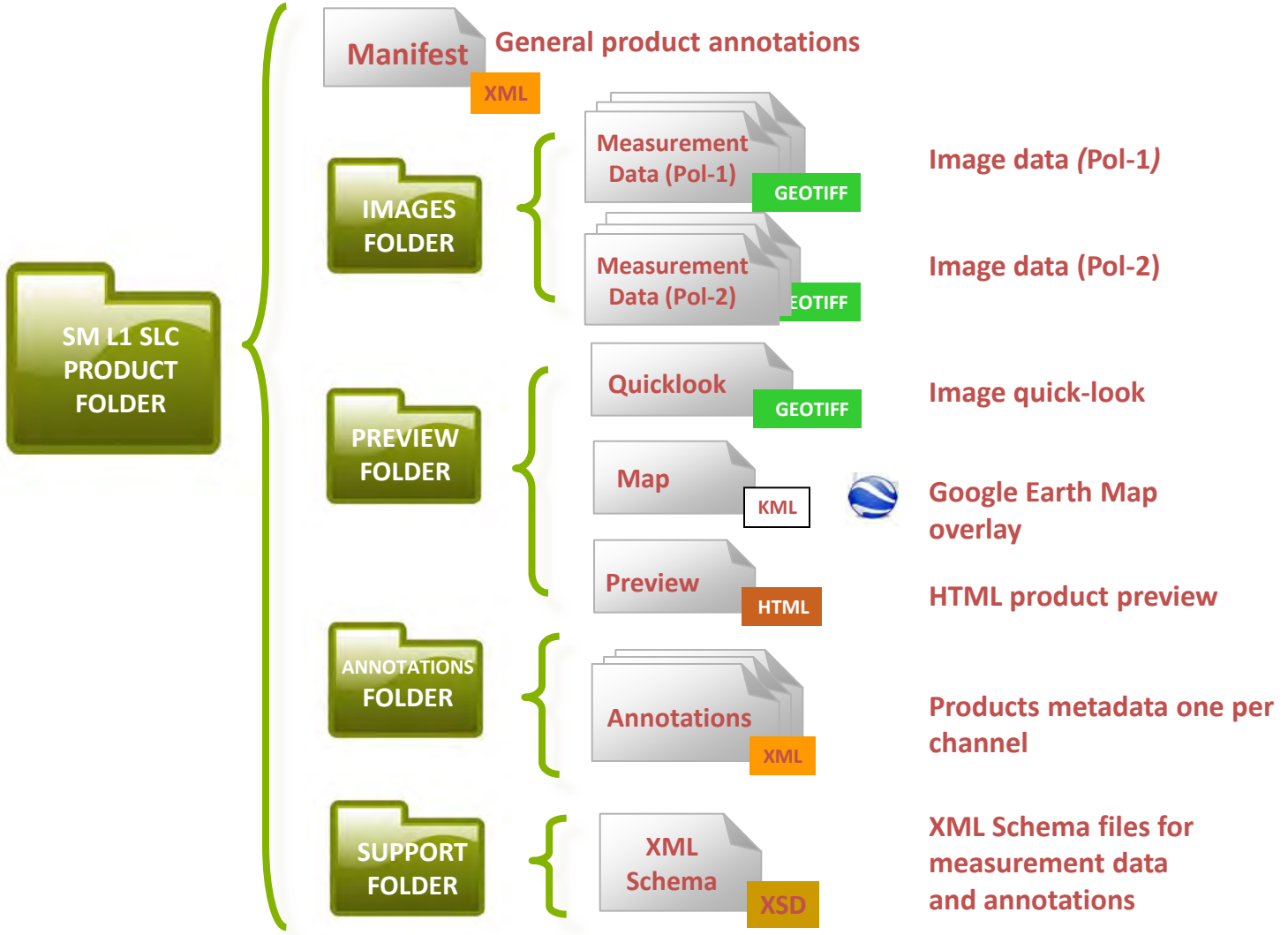


- HBR Level-1 slices cover a sub-set of the data take in along-track direction and the complete data take area in the across track direction.
- Slices are referred to the start of each acquisition segment.
- Slices are in the nominal product type projection (slant-range for SLC, ground range for GRD).
- Slices are stand-alone products and can be handled separately in terms of archiving and dissemination.
- Slices are seamlessly “concatenable” into a continuous product or “stripe” covering up to the complete data take.
- Slice concatenation may be performed before dissemination to deliver a concatenated stripe or after dissemination by the user



# S-1 L1 product format overview

Sentinel-1 Level-1 products follow the ESA SAFE format, which wraps a set of XML annotation files and the image file/s in geotiff format



# Sentinel-1 SAR Level-1 SLC Products Overview

- SLC products are images in the slant range by azimuth imaging plane
- Each SLC image pixel is represented by a complex (I and Q) magnitude value and therefore contains both amplitude and phase information.
- The processing for all SLC products is phase preserving and it results in a single look in each dimension using the full available TX signal bandwidth.
- SLC images are geo-referenced using orbit and attitude data from the satellite and provided in zero Doppler geometry
- SM SLC Products contain one image per polarisation channel (i.e. one or two images).
- SM SLC images are sampled at the natural pixel spacing (i.e. pixel spacing determined in azimuth by the pulse repetition frequency (PRF) and in range by the radar range sampling

# S-1 TOPS SLC products

- TOPS SLC products are the legacy of ASAR Scansar complex and inherits from the main characteristics

- IW and EW SLC products contain one image per sub-swath and one per polarisation channel, for a total of:
  - **3** (single polarisation) or **6** (dual polarisation) images for IW data
  - **5** (single polarisation) or **10** (dual polarisation) images for EW data

- Each sub-swath image consists of a series of bursts, where each burst has been processed as a separate SLC image.

- The individually focused complex burst images are included, in azimuth-time order, into a single sub-swath image, with black-fill demarcation in between.

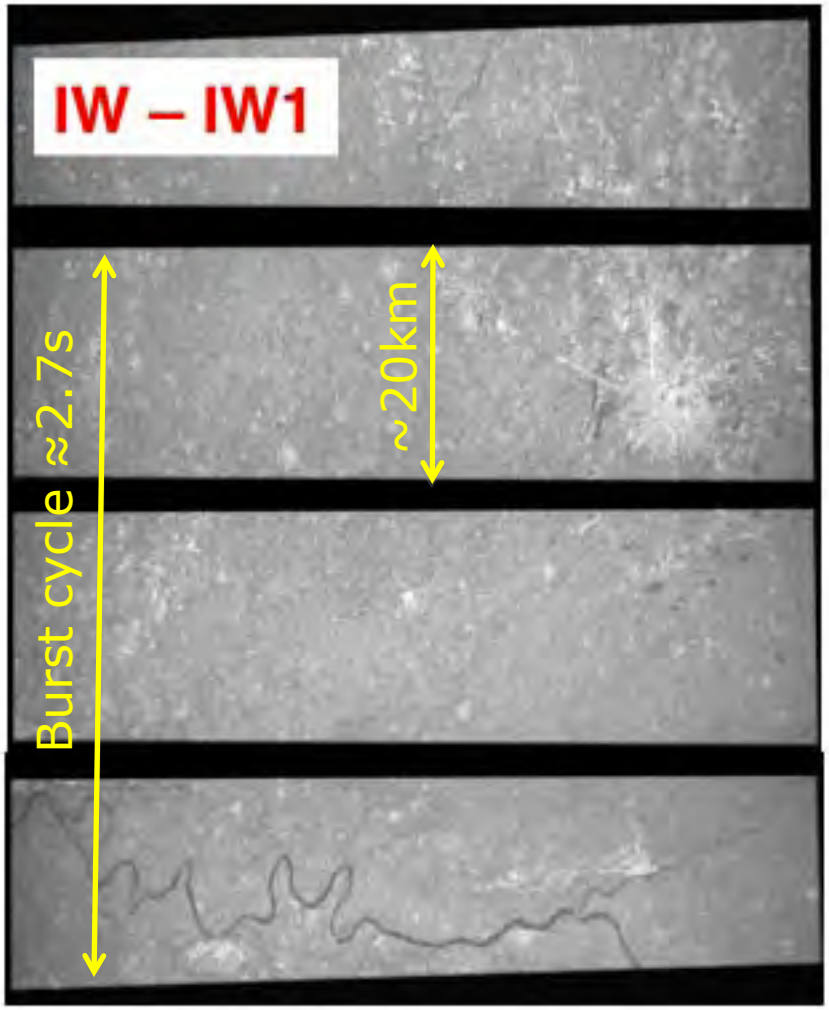
- Due to the one natural azimuth look inherent in the data, the imaged ground area of adjacent bursts will only marginally overlap in azimuth - just enough to provide contiguous coverage of the ground.

- The images for all bursts in all sub-swaths of an IW and EW SLC products are re-sampled to a common pixel spacing grid in range and azimuth.

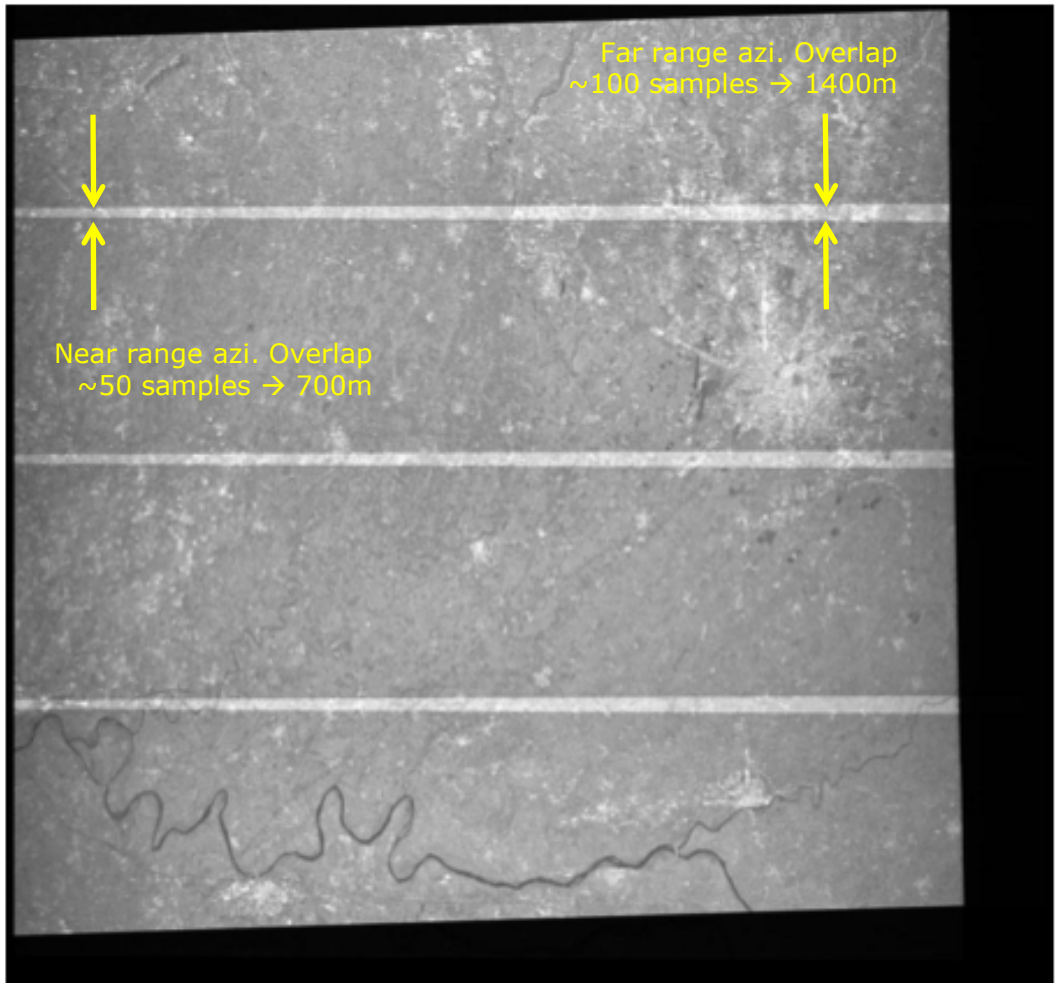
- Burst synchronisation is ensured for both IW and EW products

- Processing is phase preserving

# TOPS SLC products




IW1 SLC




IW1 SLC debursted

# Sentinel Data Policy Principles

## FREE and OPEN

- ✓**Anybody can access Sentinel data; no difference is made between public, commercial and scientific use**
- ✓**→ open access**

- ✓**Sentinel data will be made available to the users via a 'generic' online access mode**
- ✓**→ free of charge**

***In the event security restrictions would apply to specific Sentinel data affecting data availability or timeliness, specific operational procedures would be activated***