# Sentinel-1 Mission Overview

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- S-1 Space Project Team
- S-1 PDGS Team

PolinSAR 2013

# Outline

- Mission objectives

- S-1 Acquisition Modes

- S-1 Piloting Modes

- S-1 Product Family

- S-1 Product Preliminary Results

# Sentinel-1 Mission Objectives

Provision routinely and systematically of SAR data to *GMES services* and *National services* focussing on the following applications:

- ✓ Monitoring of marine environment (e.g. oil spills, sea ice zones)
- ✓ Surveillance of maritime transport zones (e.g. European and North Atlantic zones)
- ✓ Land Monitoring (e.g. land cover, surface deformation risk)
- ✓ Emergency response in support of crisis situations (e.g. natural disasters and humanitarian aid)
- ✓ Climate Change (e.g. Polar Monitoring, ice shelves and glaciers)
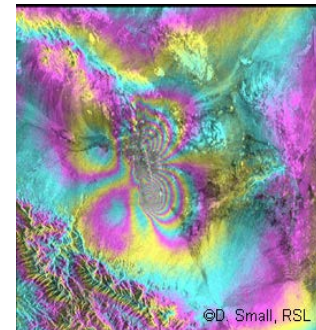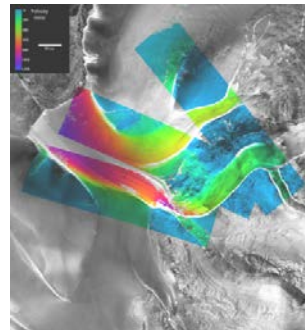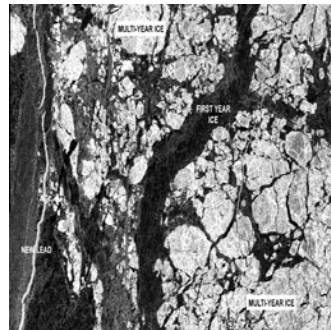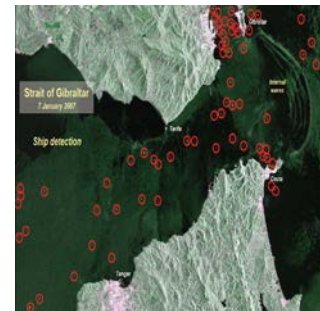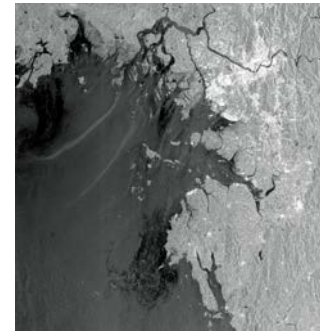
# S-1 Facts and numbers

- Constellation of two satellites C-band SAR (A & B units)

- Designed for 7 years life time with consumables for 12 years

- Near-Polar sun-synchronous (dawn-dusk) orbit at 698 km

- 12 days repeat cycle (1 satellite), 6 days for the constellation

- Both Sentinel-1 satellites in the same orbital plane (180 deg phased in orbit)

- On-board data storage capacity (mass memory) of 1400 Gbit

- Launch of Sentinel-1A scheduled for October 2013

| Paramter | Value |
|---|---|
| Career Frequency | 5.405Ghz |
| Antenna size | 12.3 x 0.82m |
| Chirp bandwith | 48-88 MHz |
| Polarisation | Single and Dual Polarisation |
| PRF | 1000-3000Hz |
| Instrument Mass | 945Kg |
| CSAR DC power | 3.87KW |
| Data Compression | Echo: FDBAQ<br>Noise: BAQ-5<br>Cal: Bypass |
| Bit quantisation | FDBAQ: variable up to 16bits<br>Noise: 5 bits<br>Cal: 10 bits |
| Instrument operation | 25min / orbit in SM, IW or EW<br>75min/ orbit WV |
| Downlink rate | 2x260Mbps |
| Look Direction | right |

# S-1 SAR Acquisition Modes
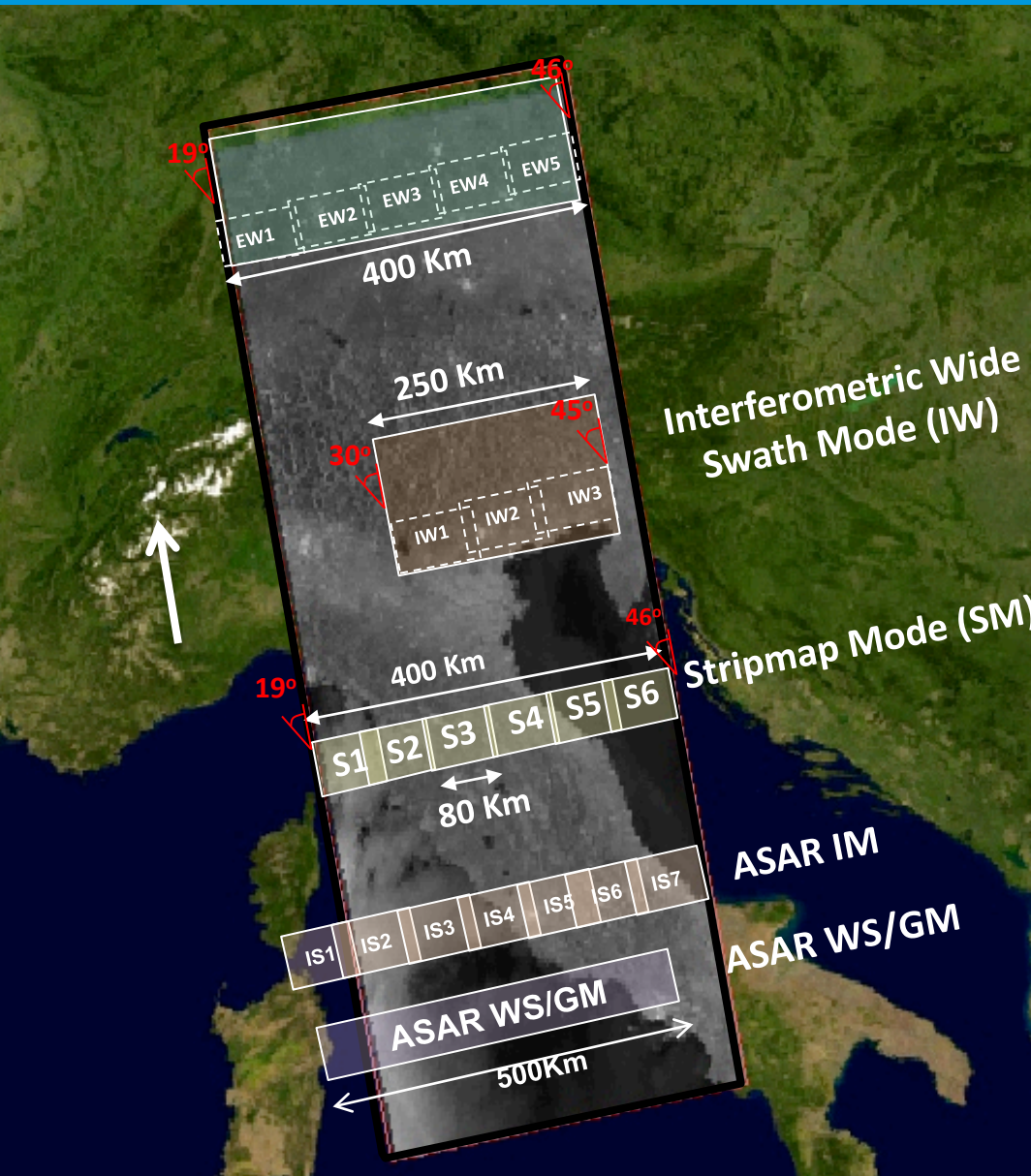


- S-1 can be operated in 4 exclusive acquisition modes

- High Bit Rate Modes:
    - Stripmap (SM)
    - Interferometric Wide Swath (IW)
    - Extra Wide Swath (EW)

  *IW and EW are operated under the TOPS acquisition mode*

  HBR are single or dual polarisation,

- Low bit Rate Mode
    - Wave Mode (WV)

  LBR is single polarisation only

- SAR duty cycle per orbit:
    - up to *25 min* in any of the HBR modes
    - up to *74 min* in Wave mode
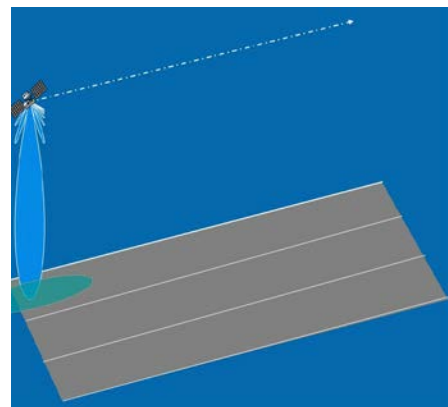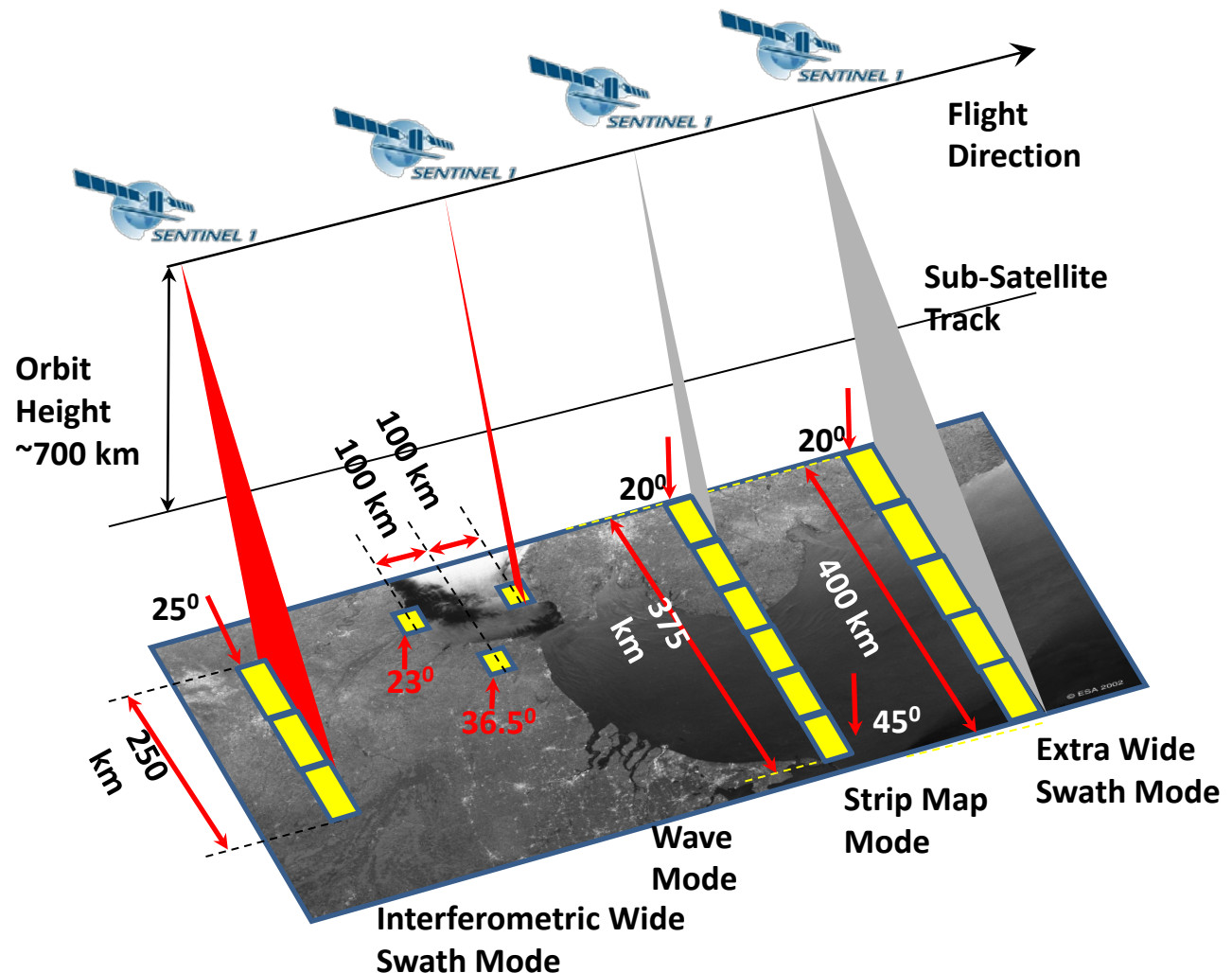
# Sentinel-1 Wave Mode
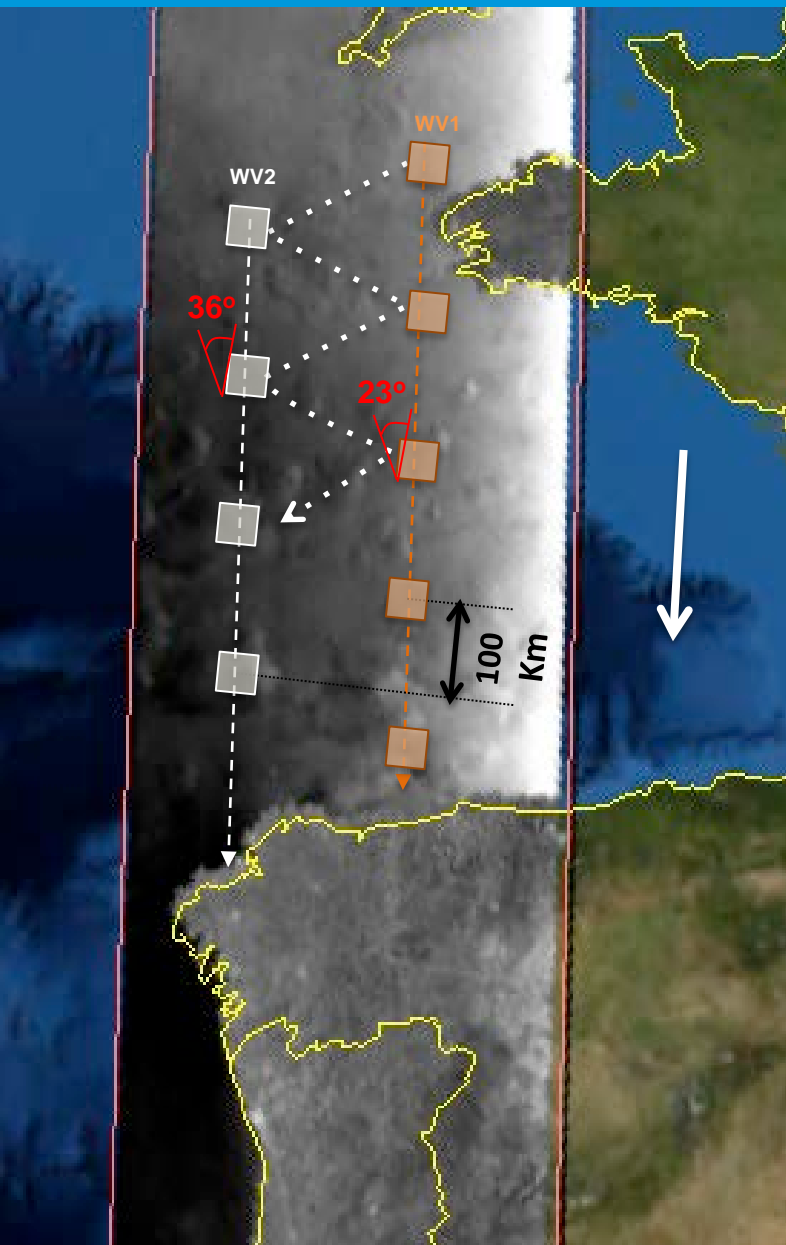


- S-1 WV mode is the default mode over open ocean where no other mode is requested by a GMES/national services

- S-1 WV is the direct continuation of ERS and ASAR WV mission with several differences:

| | Sentinel-1 | ASAR |
|---|---|---|
| swath | Alternating (*leap-frog*): WV1: 23° equivalent to SM/S2 WV2: 36.5° equivalent to SM/S4 | Single IS2 : 23° equivalent to IM/IS2 |
| Imagette size | 20x20 Km (gd rg x azi) | 10x20 Km |
| Imagette sampling | 100 Km | 100 Km |
| Polarisation [1] | Single (HH or <u>VV</u>) | Single (HH or <u>VV</u>) |
| Resolution | WV1: 74.5MHz WV2: 48.2MHz | 16MHz |

*1) For WV, the default polarisation is VV for continuity purposes.*

# Sentinel-1 SAR Modes: TOPS

Flight Direction

Sub-Satellite Track

Orbit Height ~700 km

100 km
100 km

$25^0$

$23^0$

$36.5^0$

$20^0$

375 km

$20^0$

400 km

$45^0$

250 km

Interferometric Wide Swath Mode

Wave Mode

Strip Map Mode

Extra Wide Swath Mode

# Sentinel-1 Orbital Tube and Baseline

- Satellite will be kept within an *Orbital Tube* around a Reference Mission Orbit (RMO)

- *Orbital Tube* radius is 50 m (rms)

- Orbit control is achieved by applying *across-track dead-band* control at the most *Northern point* and *Ascending Note* crossing
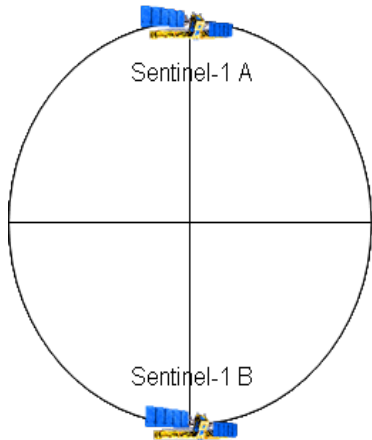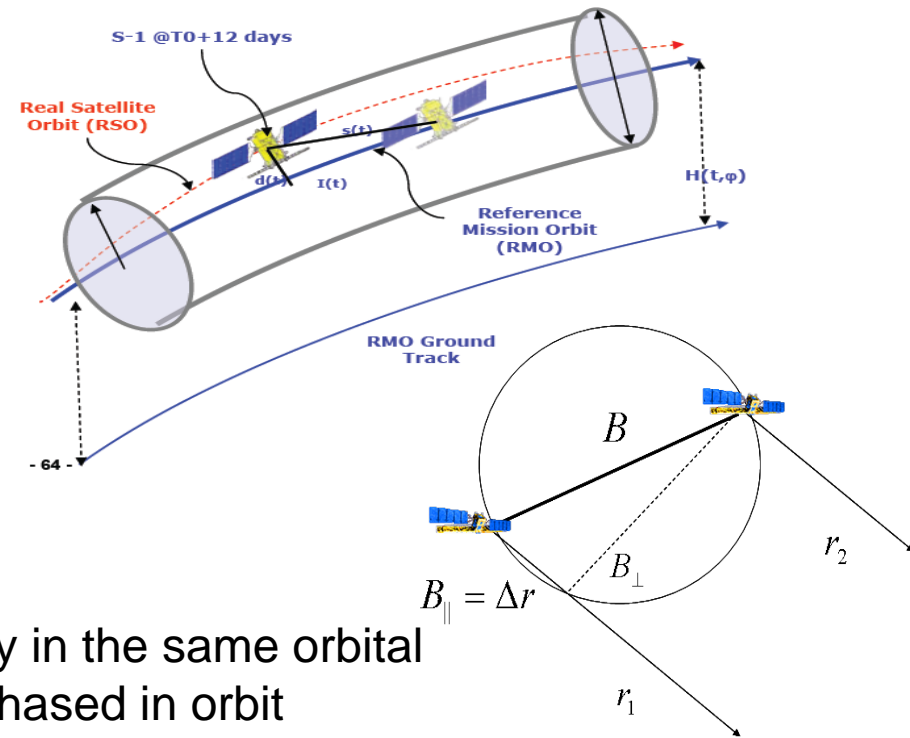


- Sentinel-1 A & B will fly in the same orbital plane with *180 deg.* phased in orbit

- *12-day repeat* orbit cycle for each satellite

- Formation of SAR interferometry (InSAR) data pairs having time intervals of *6-days*
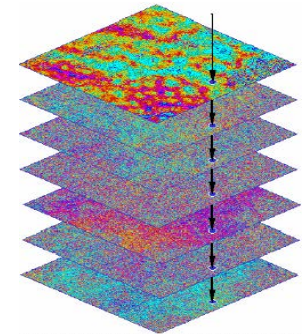
# S-1 Attitude Steering Mode



## Roll-steering mode

- Satellite altitude changes around the orbit

- Introduction of additional satellite *roll angle* depending on latitude to maintain a quasi "*constant*" *slant range*

  - at $H_{min}$ = 697.6 km $\Rightarrow \theta_{off\text{-}Nadir}$ = 30.25°

  - at $H_{max}$ = 725.8 km $\Rightarrow \theta_{off\text{-}Nadir}$ = 28.65°

- *Advantages:*

  - *Single PRF* round orbit per swath or subswath (except for the SM S5)

  - Fixed set of constant *Elevation antenna beam patterns*

## Total zero-Doppler steering mode

- Yaw and pitch adjustments around the orbit to account for Earth rotation effect

- Provides Doppler centroid at about 0 Hz
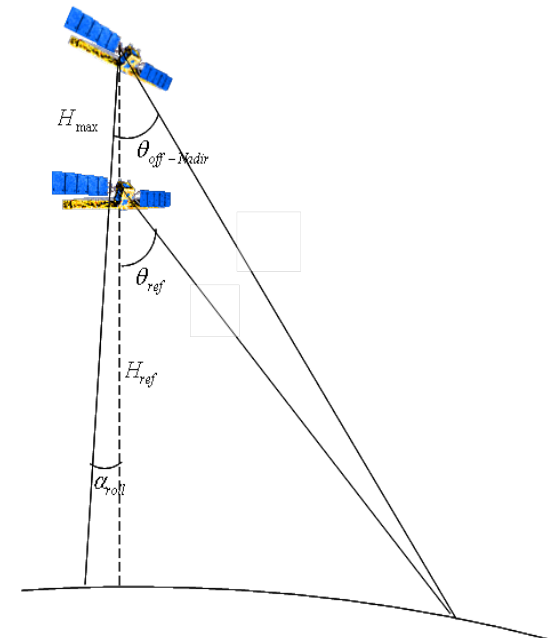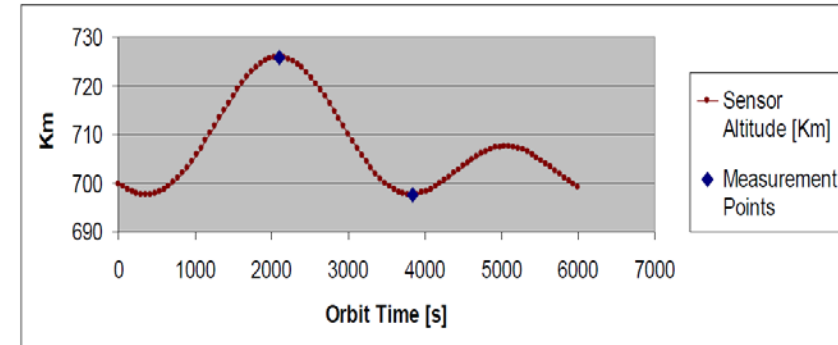
# S-1 Product tree

| | SM | IW | EW | WV |
|---|:---:|:---:|:---:|:---:|
| **Level-0 product** — RAW | ✔ | ✔ | ✔ | ✔ |
| **Level -1** — SLC / GRD | ✔ | ✔ | ✔ | ✔ |
| Full Res. | ✔ | | | |
| High Res. | ✔ | ✔ | ✔ | ✔ |
| Medium Res. | ✔ | ✔ | ✔ | ✔ |
| **Level-2 OCeaN** — OCN | ✔ | ✔ | ✔ | ✔ |

SLC: **S**ingle **L**ook **C**omplex

GRD: **G**round **R**ange **D**etected

GRD resolution class

# L1 product characteristics (1/2)

| | | SLC | GRD |
|---|---|---|---|
| general characteristics | pixel value | Complex (I,Q) | Magnitude detected |
| | Projection | Slant range | Ground range |
| | Pixel encoding | 16 bits I; 16 bits Q | 16 bits |
| | Pixel Meaning | Intensity proportional to $\beta^0$ (radar brightness) | |
| | coordinate system | Zero-Doppler | |
| | path orientation | Natural | |
| | Pixel sampling | SM/WV: Natural<br>IW/EW: resampled to common sampling in azimuth and range | Resampled to square pixels Respecting Nyquist criteria |
| | Number of channels | Npol x Nsubswath | Npol |
| radiometric characteristics | Rg Spread Loss correction | performed | performed |
| | Elev. Antenna Pattern correction | Annotated and corrected | Annotated and corrected |
| | calibration vectors | Annotated but not applied (considering ellipsoid earth model) | |
| | thermal denoising | - | Annotated and corrected |
| | TOPS descalloping | performed for TOPS only | |
| geometric characteristics | azimuth bi-static correction | performed | |
| | Geocoding | Performed and geolocation grid provided | |
| | Orbit state vectors | Provided | |
| | Attitude angles | Provided | |

Red: difference w.r.t. ASAR

# L1 product characteristics (2/2)

| Acq. Mode | Product Type | Resol. Class | Resol. [m] [rg x az] (1)(2) | Spacing [m] [rg x az] (2) | ENL | polarisation | Data Volume [MB] (3) | Ground coverage [km] | PSLR [dB] | ISLR [dB] | DTAR [dB] | PTAR [dB] | NESZ [dB] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | Single: (H or V) or Dual (HH/HV or VV/VH) | 3300 / 1600 | 80 | < -21.2 | < -16.7 | <-22.3 | <-32.3 | <-22 |
| SM | GRD | FR | 9 x 9 | 4 x 4 | 3.8 | Single: (H or V) or Dual (HH/HV or VV/VH) | 265 | 80 | < -21.2 | < -16.7 | <-22.3 | <-32.3 | <-22 |
| SM | GRD | HR | 23 x 23 | 10 x10 | 27 | Single: (H or V) or Dual (HH/HV or VV/VH) | | 80 | < -21.2 | < -16.7 | <-22.3 | <-32.3 | <-22 |
| SM | GRD | MR | 84 x 84 | 40 x 40 | 357 | Single: (H or V) or Dual (HH/HV or VV/VH) | 18 | 80 | < -21.2 | < -16.7 | <-22.3 | <-32.3 | <-22 |
| IW | SLC | | [2.7 x 22] to [3.5 x 22] | 2.3 x 17.4 | 1 | single or dual | 3100 | 250 | < -21.2 | < -16.7 | <-22.5 | <-27.2 | <-22 |
| IW | GRD | HR | 20 x 22 | 10 x 10 | 4.4 | single or dual | 822 | 250 | < -21.2 | < -16.7 | <-22.5 | <-27.2 | <-22 |
| IW | GRD | MR | 88 x 89 | 40 x 40 | 81 | single or dual | 52 | 250 | < -21.2 | < -16.7 | <-22.5 | <-27.2 | <-22 |
| EW | SLC | | [7.9 x 42] to [14.4 x 44] | 5.9 x 34.7 | 1 | single or dual | 2200 | 400 | < -21.2 | < -16.7 | <-23.1 | <-27.4 | <-22 |
| EW | GRD | HR | 50 x 50 | 25 x 25 | 2.7 | single or dual | 504 | 400 | < -21.2 | < -16.7 | <-23.1 | <-27.4 | <-22 |
| EW | GRD | MR | 93 x 87 | 40 x 40 | 9.6 | single or dual | 199 | 400 | < -21.2 | < -16.7 | <-23.1 | <-27.4 | <-22 |
| WV | SLC | | [2.0 x 4.8] to [3.1 x 4.8] | [1.7 x 4.1] to [2.7 x 4.1] | 1 | Single | 400 | 20 | < -21.2 | < -16.7 | <-23.1 | <-27.4 | <-22 |

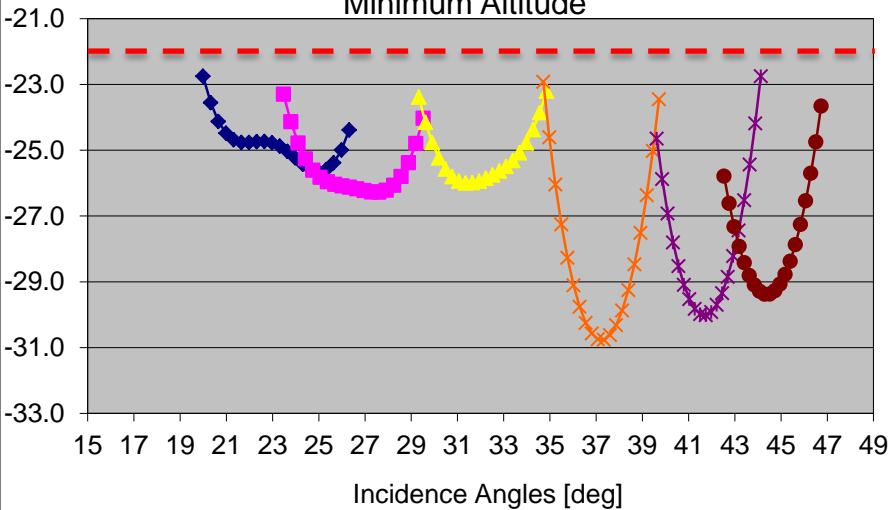(1) For GRD, the resolution given at mid-range, mid-orbit altitude, averaged over all swaths.

(2) For SLC, given in slant-range.

(3) Volume given for a single pol and for a product duration of 25s for SM and IW, 60s for EW and WV . To be multiplied by 2 in dual pol case
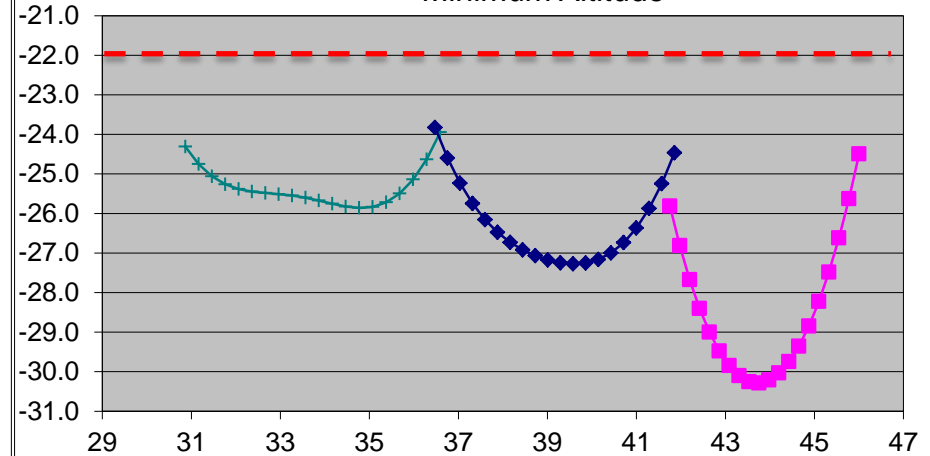
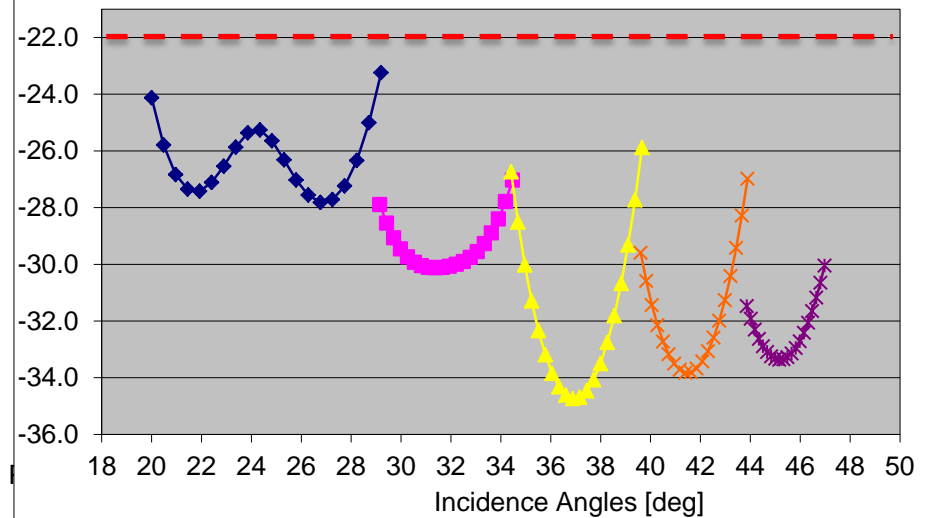# NESZ theoretical performance



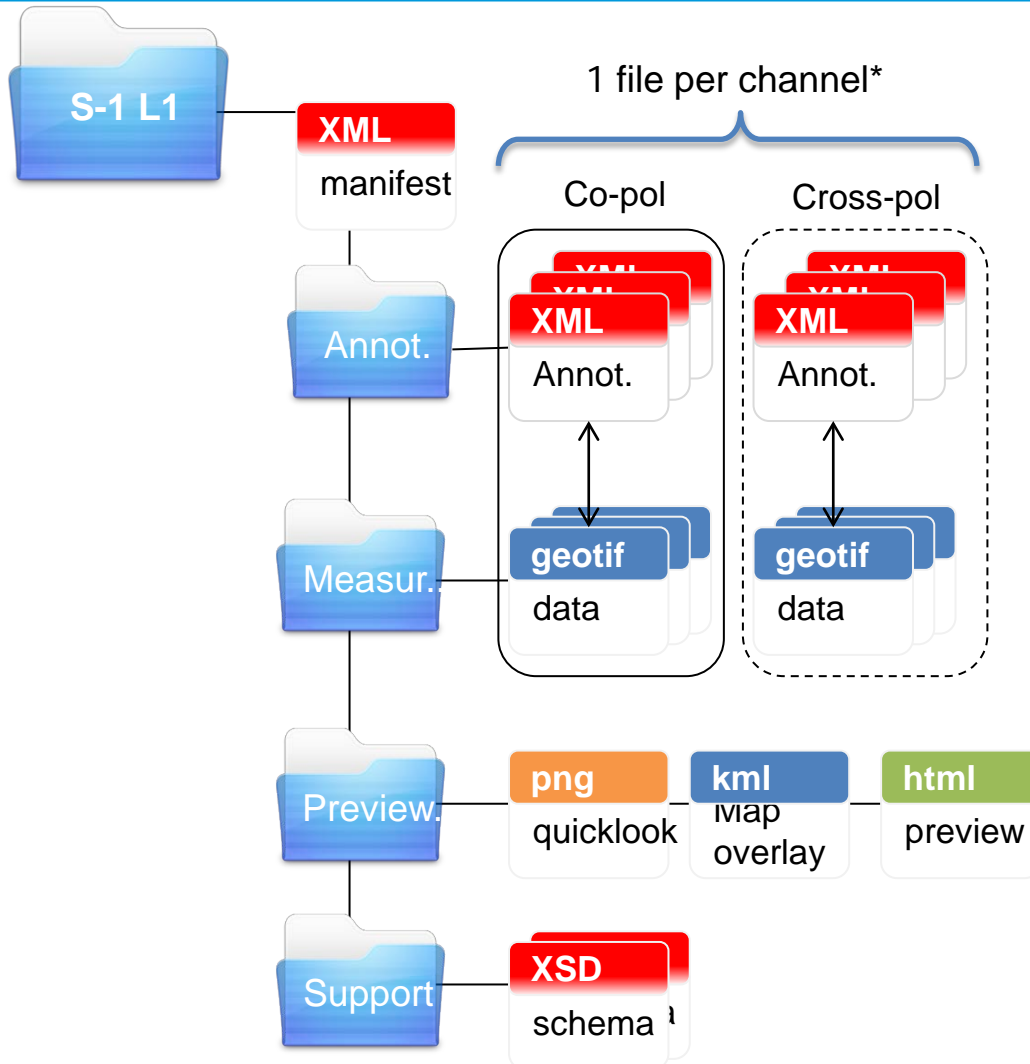NESZ Performance of the SM_SLC product at Minimum Altitude

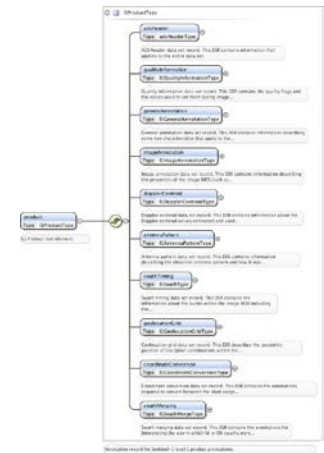NESZ Performance of the IW_SLC product at Minimum Altitude

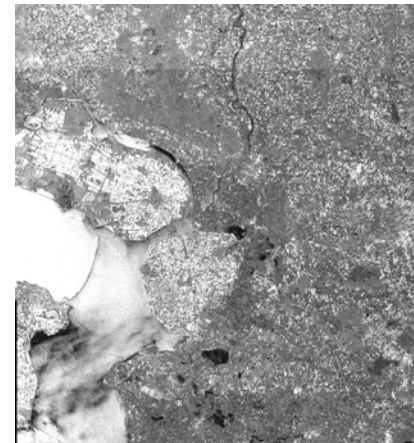NESZ Performance of the EW_SLC product at Minimum Altitude
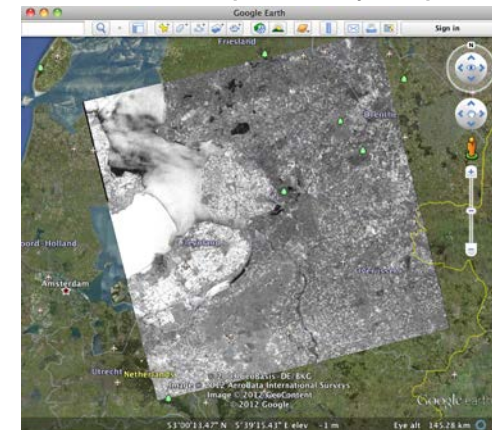
# S-1 product format overview



"XML annotations"

"Geotiff imagery"

"KML map overlay + quick[look]"

**S-1 L1**

**XML** manifest

1 file per channel*

Co-pol    Cross-pol

**XML** Annot.

**XML** Annot.

**geotif** data

**geotif** data

Annot.

Measur.

Preview.

**png** quicklook    **kml** Map overlay    **html** preview

Support    **XSD** schema

- A channel is a polarisation or a sub-swath or an imagette
- For SLC sub-swaths are provided separately for GRD sub-swaths are mosaicked

# IW Product: first samples

- IW SLC data block follows the convention introduced by the ASAR WSS:
  - Collection of focused overlapping burst separated by 0-padding
- IW SLC provided in slices of 25s:
  - ~9 bursts covering ~250x170km
- Data block is composed by:
  - 3 (or 6) images (geotiff) for single (dual) pol
- Focused burst length (2.75s) is just enough overlap to ensure continuous ground coverage in azimuth
  - Burst overlap: ~[405, 230, 180]m
- Sub-swath overlap < 2km
- Pixel sampling common in azimuth and range

IW1

IW2

IW3

Sub-swath Overlap ~2Km
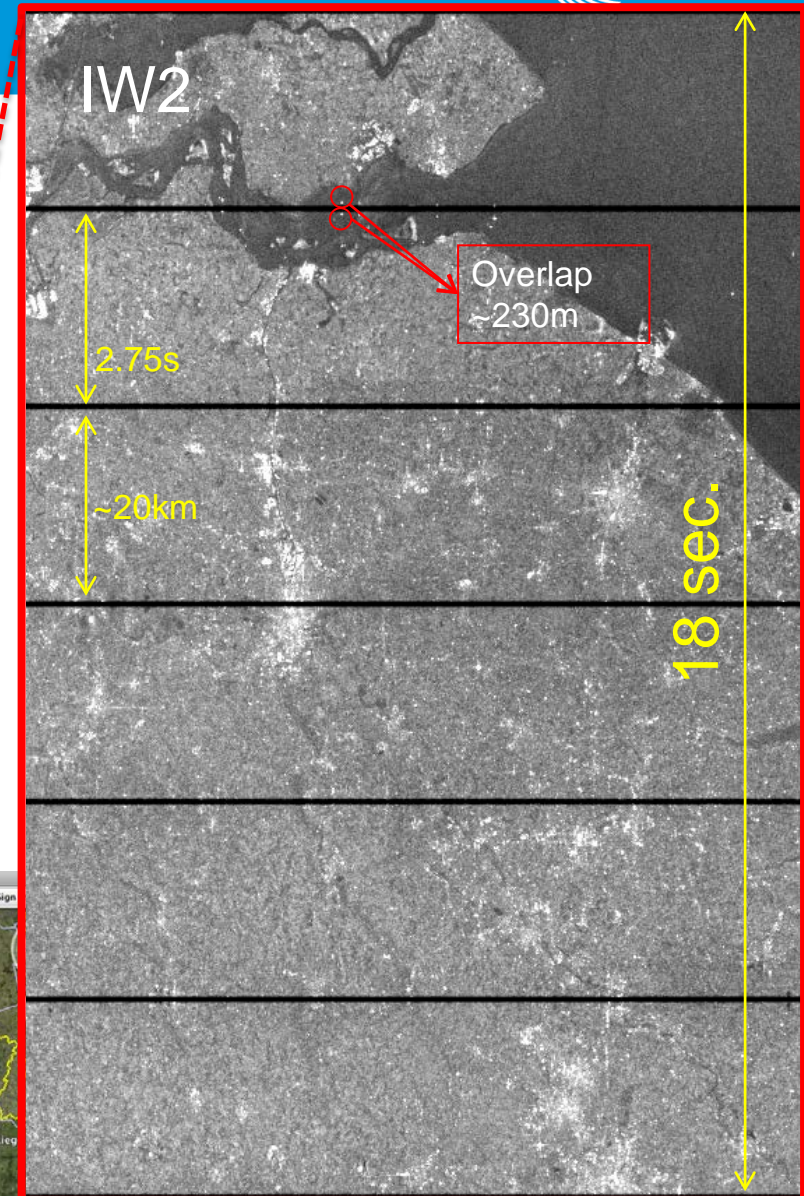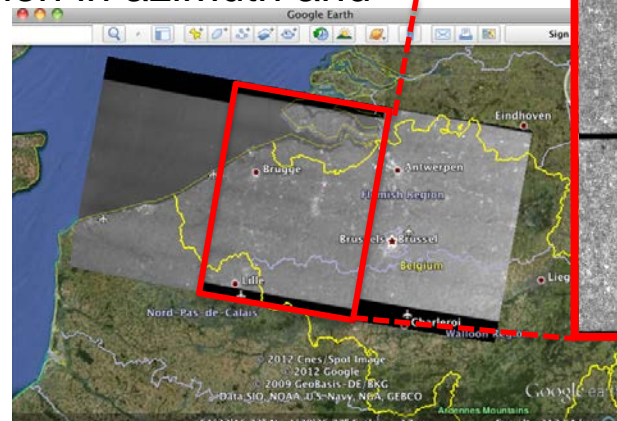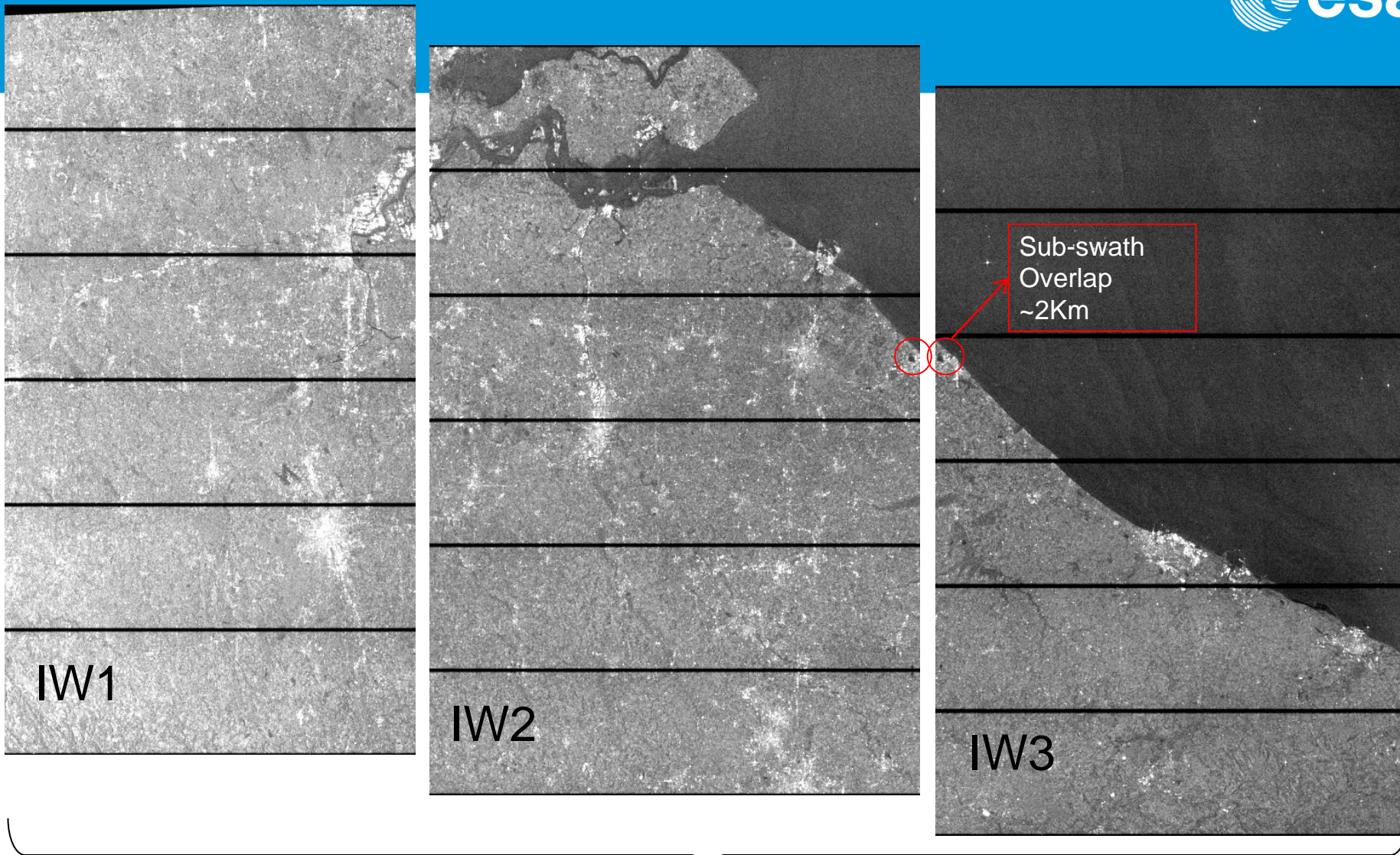
IW SLC:  collection of focused burst per sub-swath

European Space Agency

Natural spectral characteristics of the TOPS SLC

– Spectrogram shows linear frequency rate:

  • A total Doppler Bandwidth of ~4kHz is spanned

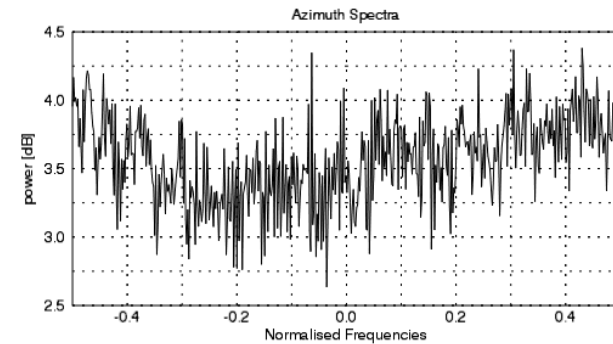– The azimuth spectra is **scrambled** due to the linear frequency modulation
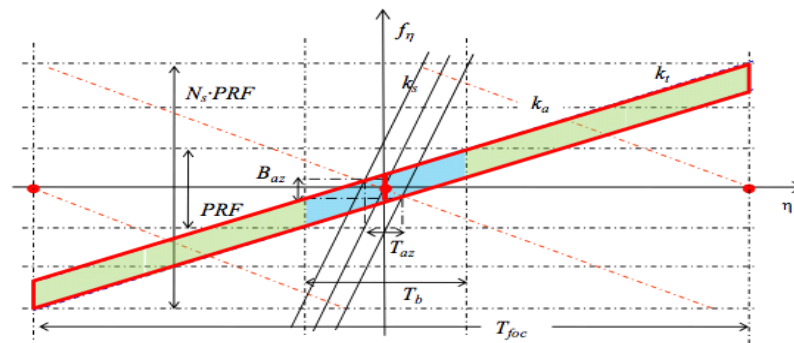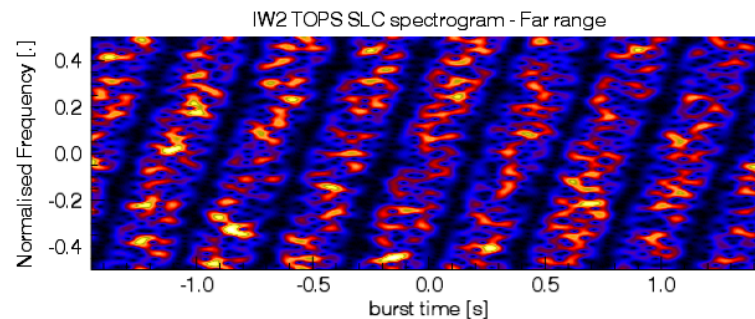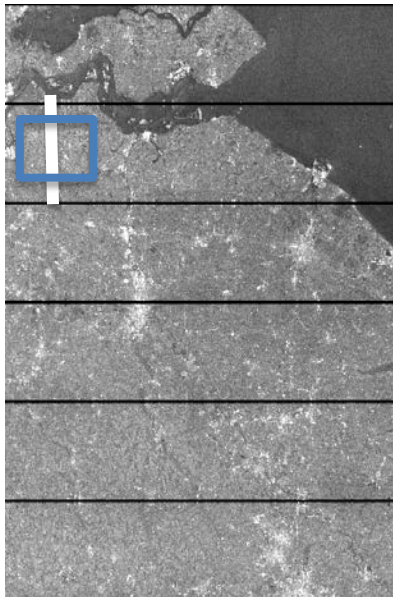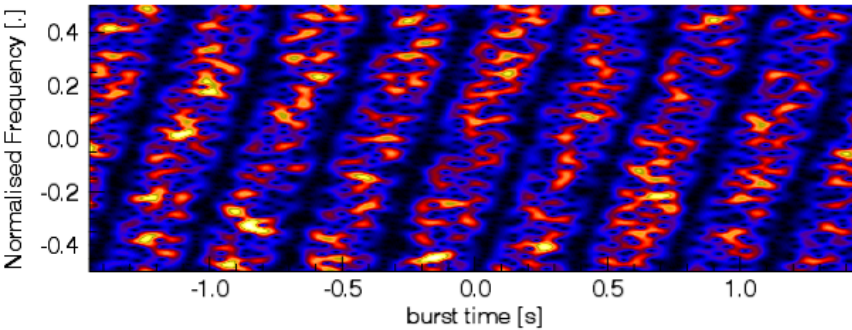


Figure 6-13   Time-frequency Diagram of a TOPSAR Azimuth Line after Time-domain Unfolding
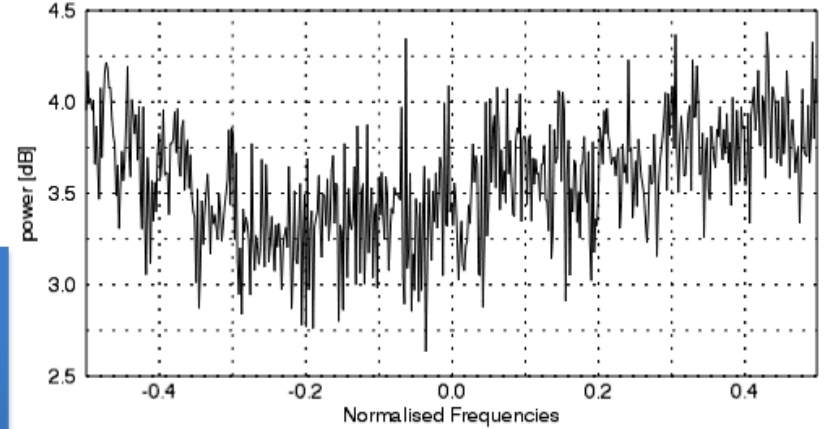
# S-1 TOPS SLC characteristics



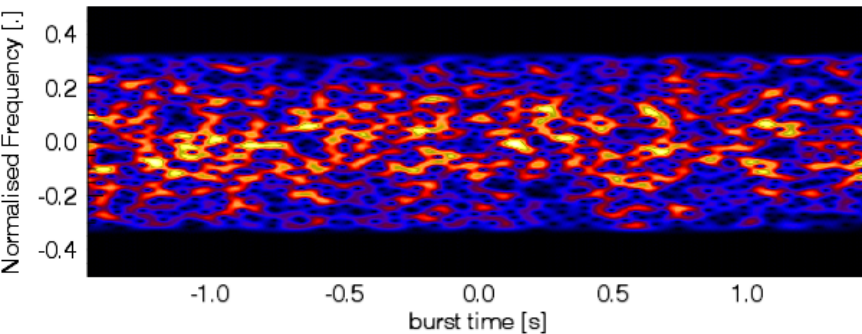IW2 TOPS SLC spectrogram - Far range



Azimuth Spectra

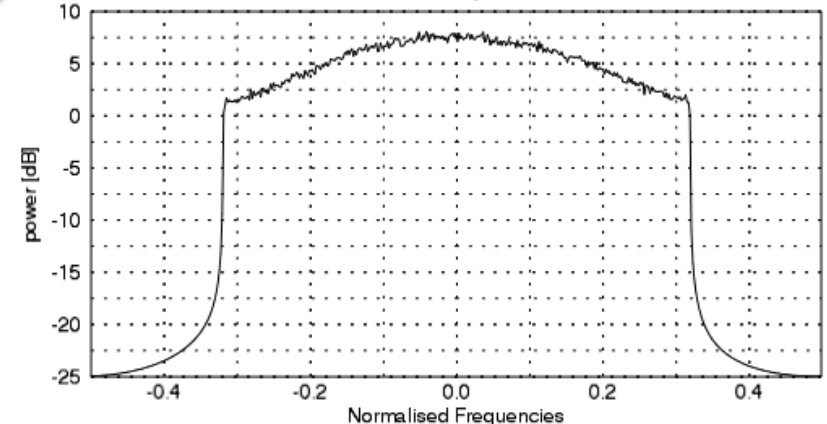- Deramping the burst is necessary to perform any spectral operation

Deramping
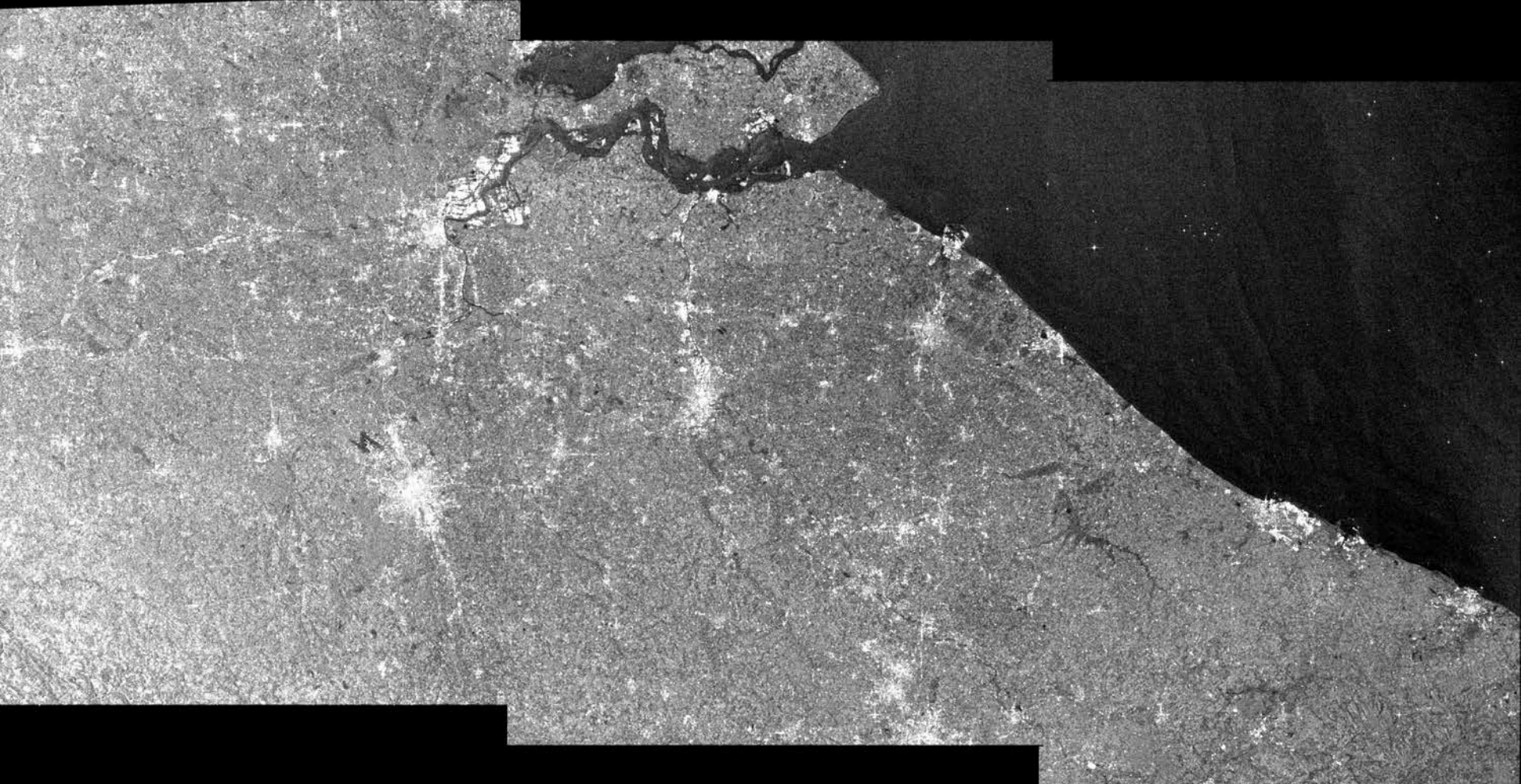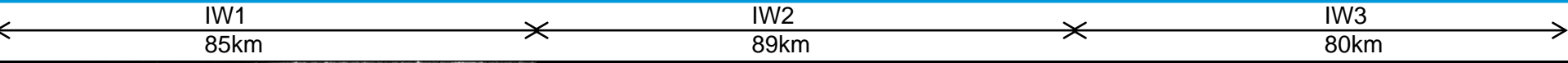


IW2 TOPS SLC spectrogram - Far range



Azimuth Spectra

# IW GRD : first sample



| IW1 | IW2 | IW3 |
| --- | --- | --- |
| 85km | 89km | 80km |

European Space Agency

# Geometric verification

Requirement:

- The S-1 L1 products shall have a range/azimuth location error less than or equal to 0.25 of a pixel.

- The S-1 L1 products shall have a geometric misregistration between pixels across the parameter update boundary less than or equal to 0.5 pixels in range and in azimuth (E.g. targets located in TOPS burst overlap)
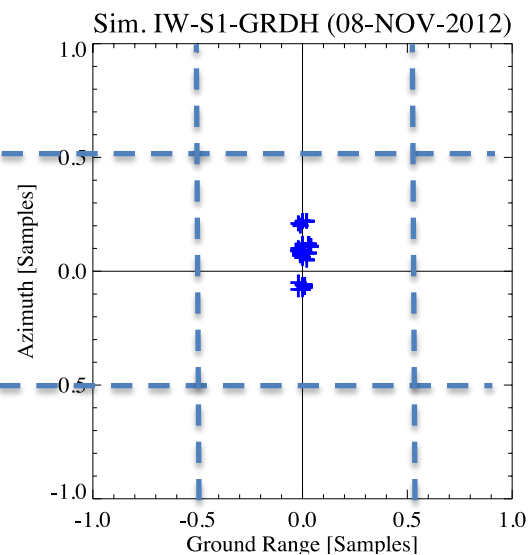
Verification method:

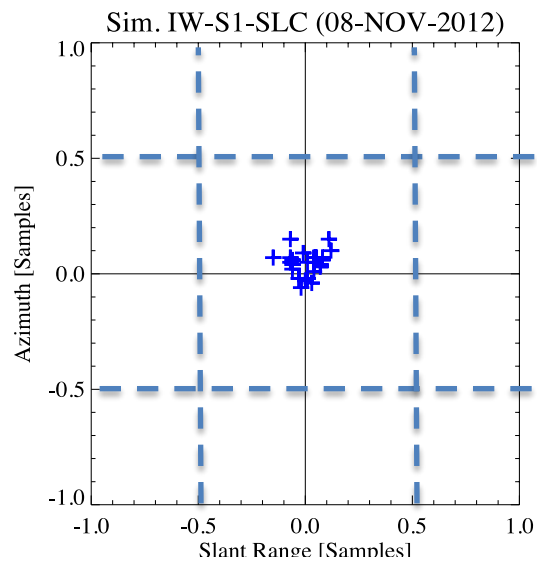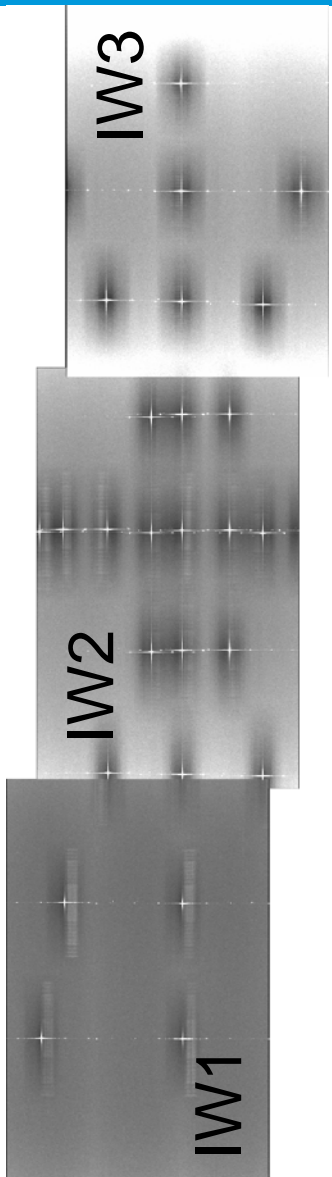Performing absolute location error measurement on:

- real ASAR data (IM) generated by the S-1 processor (free from simulation error) → *similar measurements as PF-ASAR are obtained*
- S-1 simulated with point targets (could contain simulation errors)

# SM Absolute Location Error



Sim. SM-S1-SLC (9-AUG-2012)

Sim. SM-S1-GRDF (9-AUG-2012)

GRDM        30
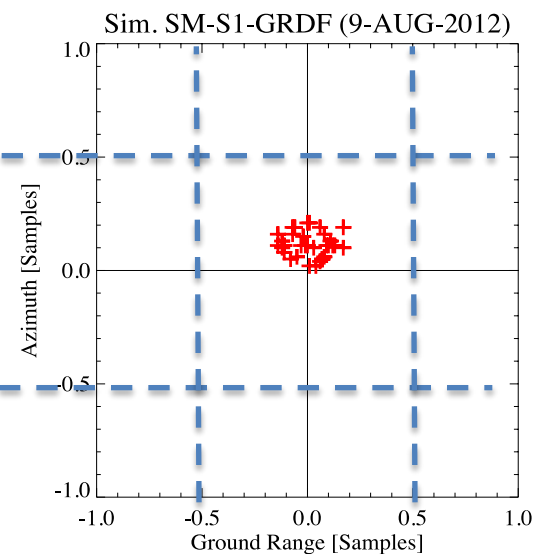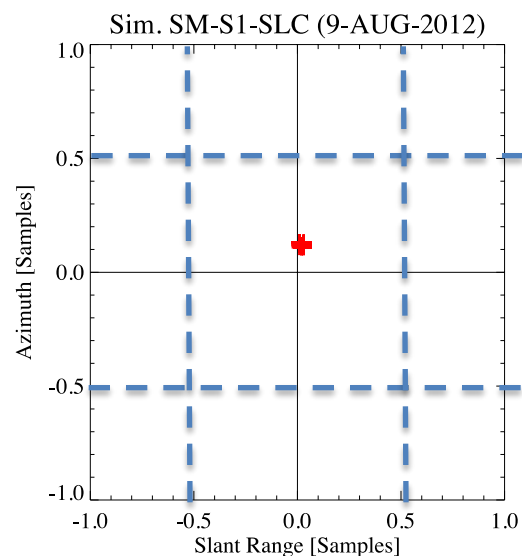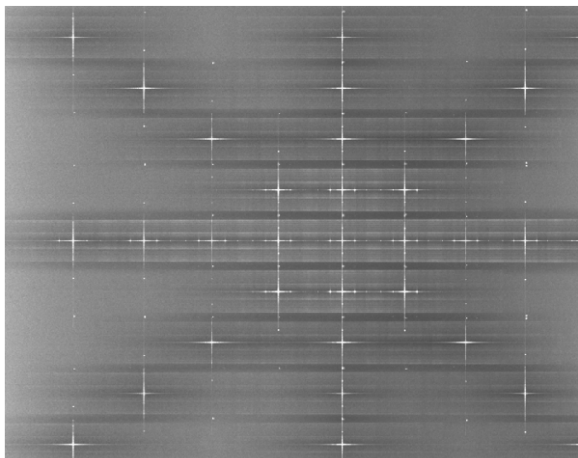
# IW Absolute Location Error



GRDM        30

# Product Performance verification

| Acq. Mode | Product Type | Resol. Class | Resol. [m] | | ENL | | PSLR [dB] | | ISLR [dB] | | DTAR [dB] | | PTAR [dB] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Req. | Meas. | Req. | Meas. | Req. | Meas. | Req. | Meas. | Req. | Meas. | Req. | Meas. |
| SM | SLC | | [1.7 x 4.3] to [3.6 x 4.9] | 1.7x4.3 | 1 | 0.99 | < -21.2 | -20.7 | < -16.7 | -15.7 | <-22.3 | -35.0 | <-32.3 | -47.5 |
| | GRD | FR | 9 x 9 | 7.9x7.9 | [3.5-3.7] | 3.83 | | | | | | | | |
| | | HR | 23 x 23 | 22x22 | [26-30] | 27.28 | | | | | | | | |
| | | MR | 84 x 84 | 82x82 | [350-398] | 357.32 | | | | | | | | |
| IW | SLC | | [2.7 x 22] to [3.5 x 22] | 3x22 | 1 | 0.99 | < -21.2 | -20.4 | < -16.7 | -16.2 | <-22.5 | -25.0 | <-27.2 | -32.9 |
| | GRD | HR | 20 x 22 | 20x22 | 4.4 | 4.81 | | | | | | | | |
| | | MR | 88 x 89 | 86x87 | 88 | 87.94 | | | | | | | | |
| EW | SLC | | [7.9 x 42] to [14.4 x 44] | 12x44 | 1 | 0.99 | < -21.2 | -20.7 | < -16.7 | -16.3 | <-23.1 | -25.0 | <-27.4 | -27.6 |
| | GRD | HR | 50 x 50 | 48x48 | 2.7 | 2.95 | | | | | | | | |
| | | MR | 93 x 87 | 93x86 | 9.6 | 9.90 | | | | | | | | |

- Thank you