Norsk Romsenter
NORWEGIAN SPACE CENTRE
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SEASAR 2012
The 4th International Workshop on Advances in SAR Oceanography

Sentinel-1 Processor and Core products

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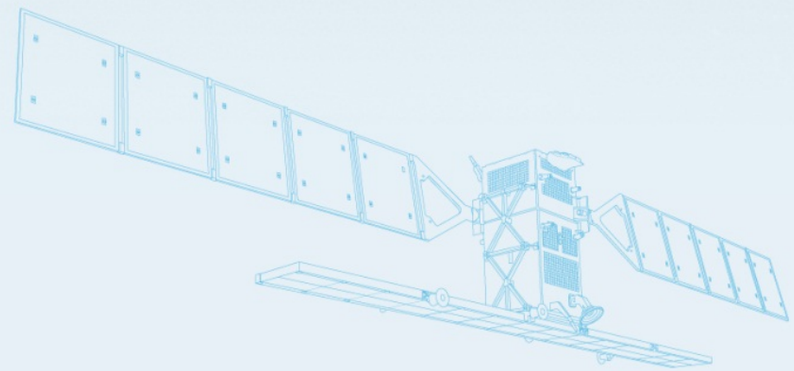
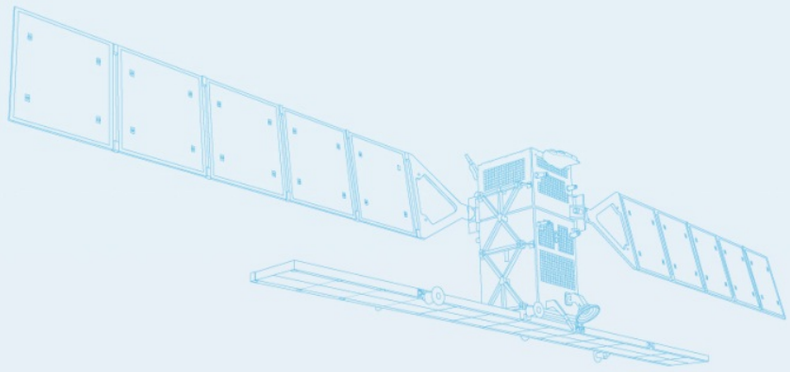
ESA/ESRIN



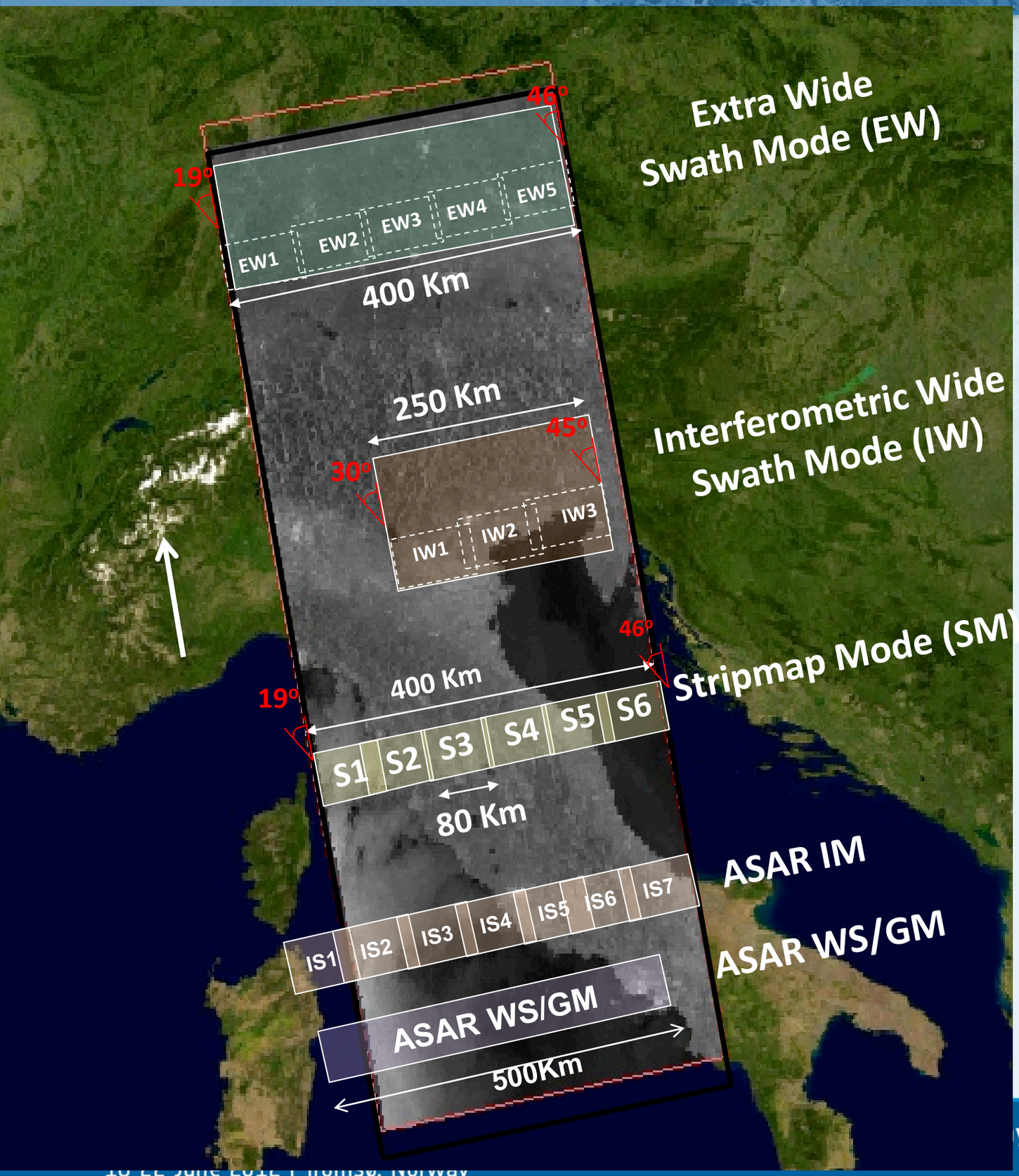
18-22 June 2012 | Tromsø, Norway

Presentation layout

- S-1 Acquisition Modes (recall)
- S-1 Instrument Processing Facility (IPF)
- S-1 L1 Product Family description
- S-1 L2 Product Family description



S-1 acquisition modes



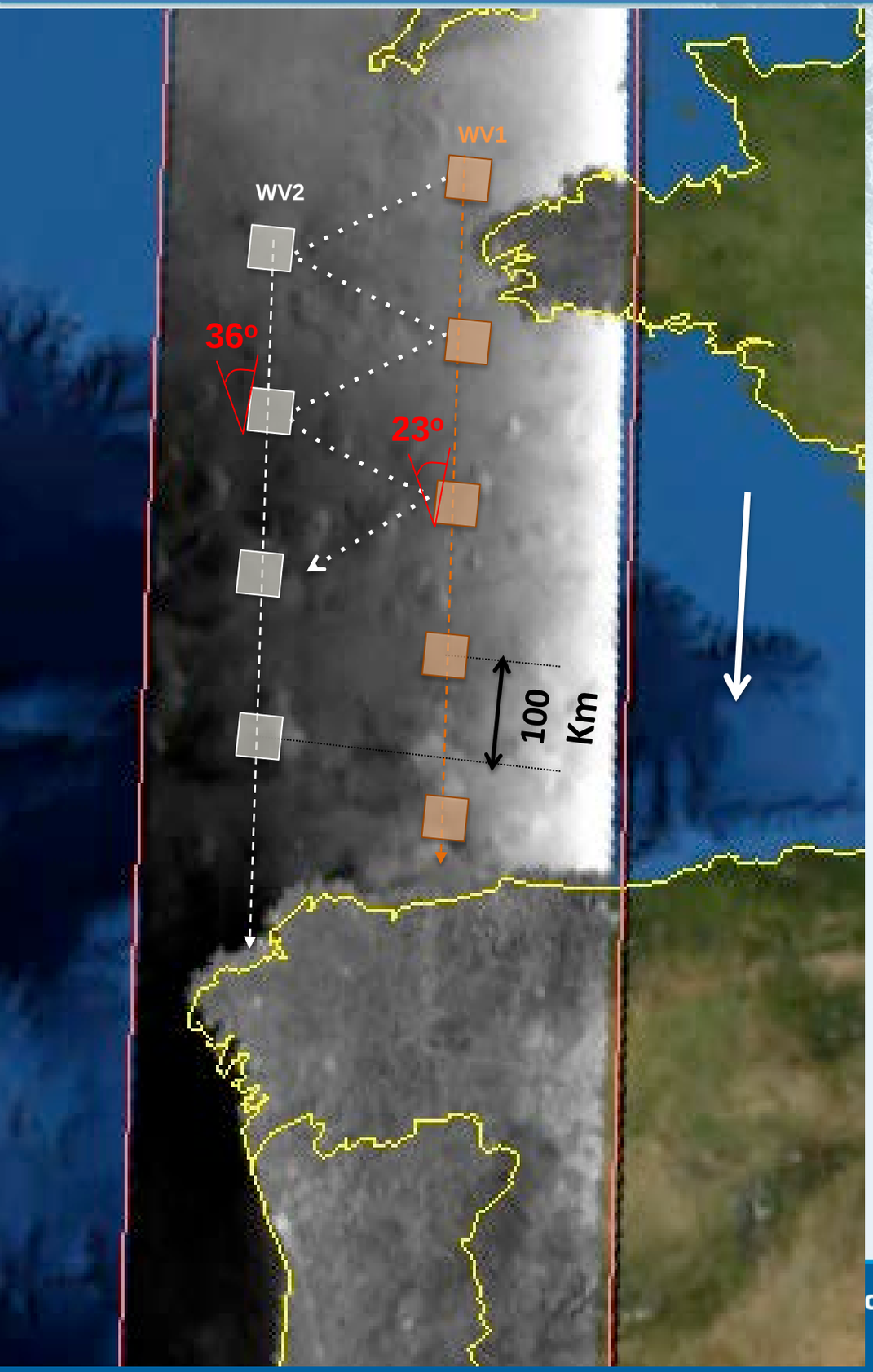
- S-1 can be operated in 4 exclusive acquisition modes
- High Bit Rate Modes:
  - Stripmap (SM)
  - Interferometric Wide Swath (IW)
  - Extra Wide Swath (EW)

  IW and EW are operated under the TOPS acquisition mode

- Low bit Rate Mode
  - Wave Mode (WV)

- HBR are single or dual polarisation, LBR is single polarisation only

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 VV)	Single (HH or VV)
Resolution	WV1: 74.5MHz WV2: 48.2MHz	16MHz

1) For WV, the default polarisation is VV for continuity purposes. Recommendations are welcome!

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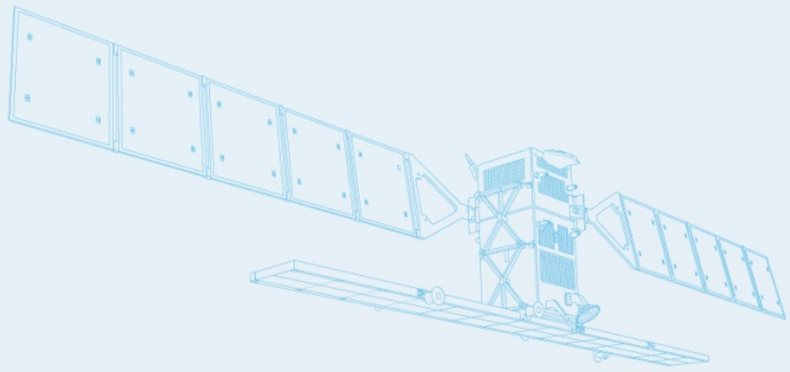
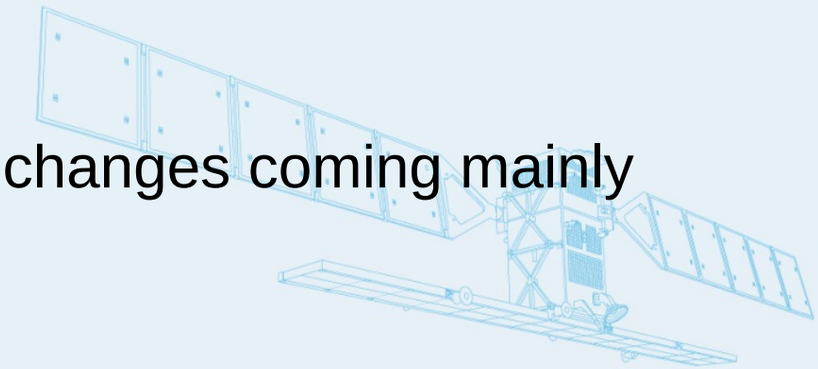


S-1 IPF development

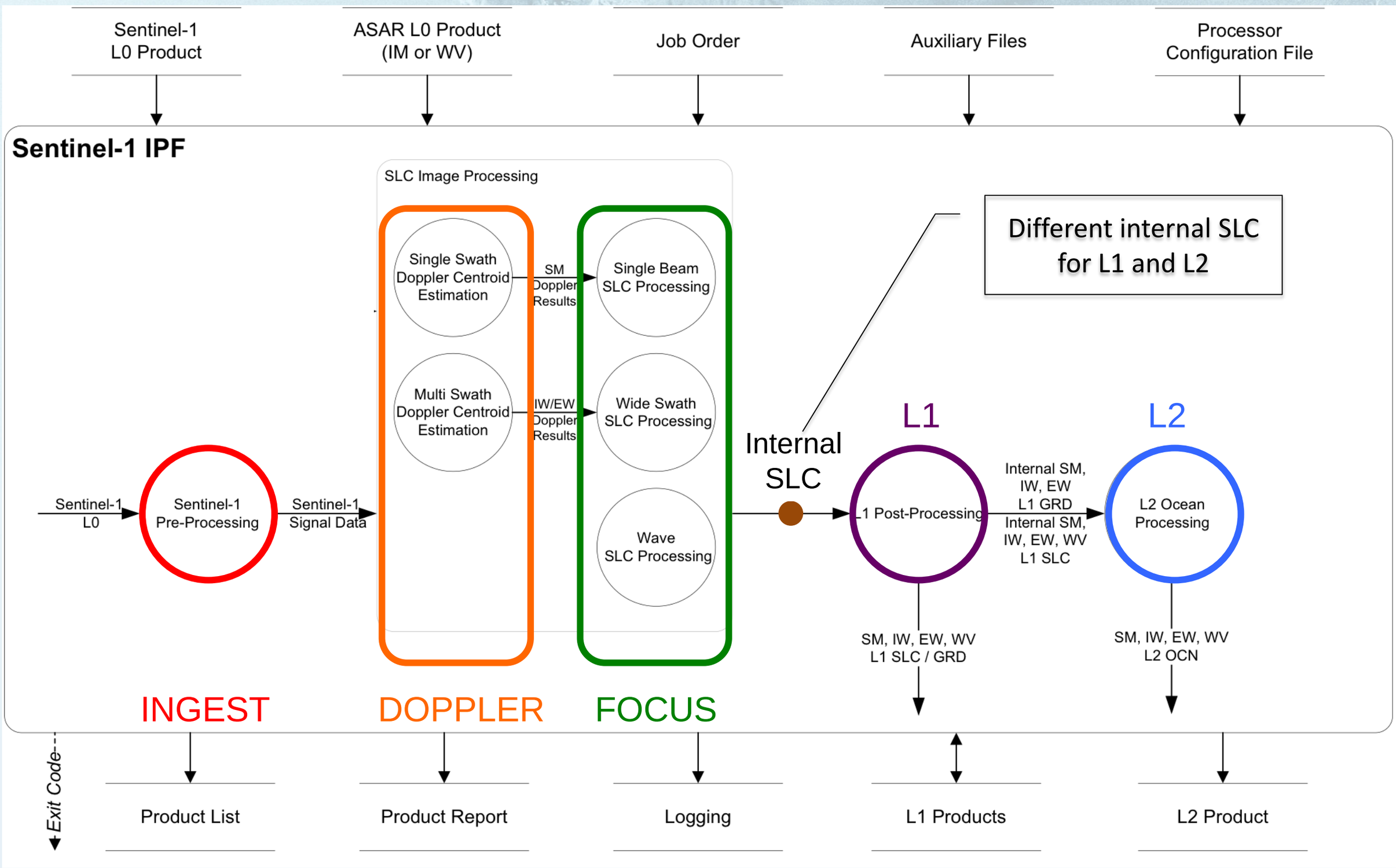
- S-1 Instrument Processing Facility (IPF) development started in 2008:
  - Definition of algorithm for core Level-1 (L1) and Level-2 (L2) products
  - Definition of product family and format
  - Development of the processor for L1 and L2

Contract awarded to a consortium composed by MDA and Aresys for L1 and Norut and CLS for the L2 part

  - First phase almost completed (Acceptance review by September at latest):
    - Including acceptance of L2
  - Second Phase: synchronize the IPF with latest changes coming mainly from the instrument should start right after.



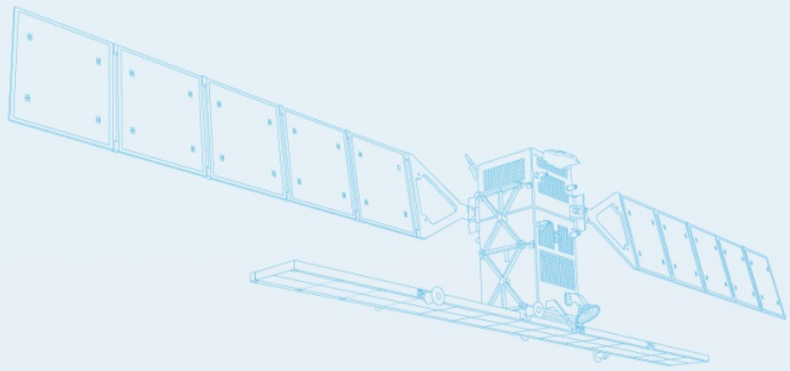
S-1 IPF architecture



S-1 IPF architecture

Multi-stage architecture:

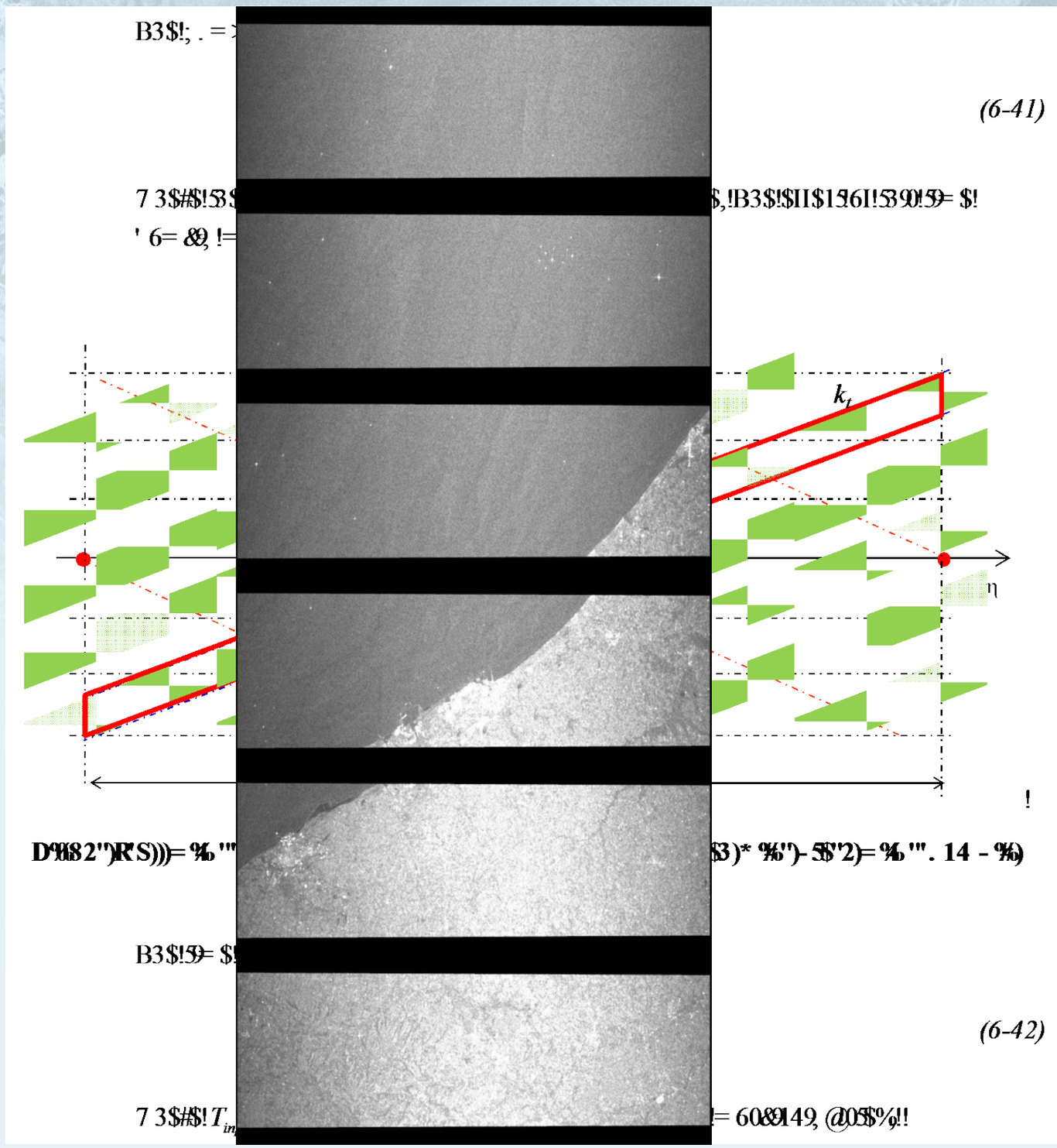
- Ingest:
  - FDBAQ decoding
  - Source Packet de-multiplexing (echo, noise, calibration)
  - Raw Data Correction
- Doppler Centroid estimation
  - Absolute and relative Doppler centroid estimation
- SAR focusing (3 modules)
  - SM focusing
  - TOPS Focusing
  - WV Focusing
- L1 post-processing
  - Radiometric correction
  - Slant to ground range projection
  - Detection and multi-looking
  - Burst and Swath merging
  - Thermal denoising for L1 GRD
- L2 post-processing
  - Ocean swell spectra
  - Ocean wind fields
  - Ocean Surface Radial Velocity



S-1 IPF project documentation

The following items will be opened to the users in the second half of 2012:

- S-1 Product Definition
- S-1 Product Format Specification
- S-1 Detail Processing Model
  - For L1 and L2
- S-1 Auxiliary Data File format Specification
- S-1 IPF interface control document
- S-1 L0, L1 and L2 samples products



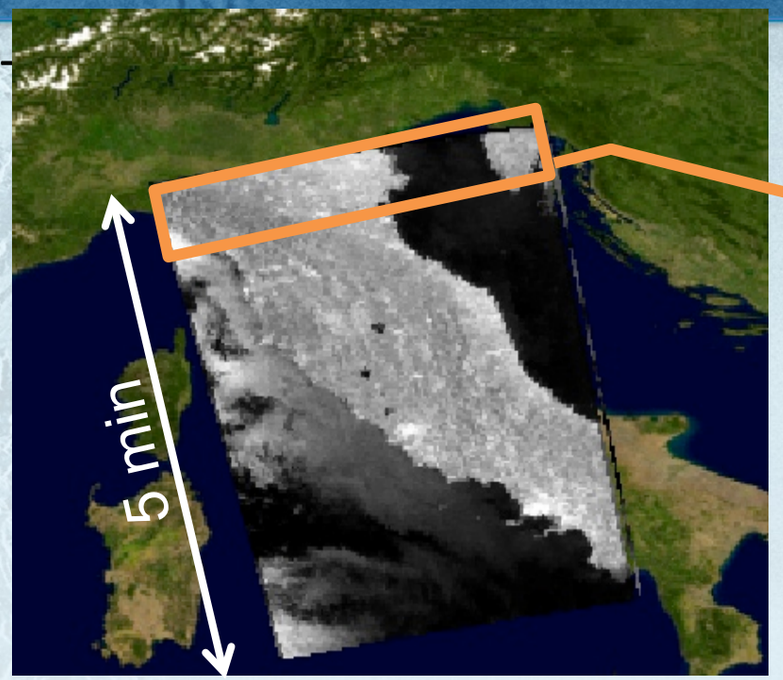
S-1 processing scenario

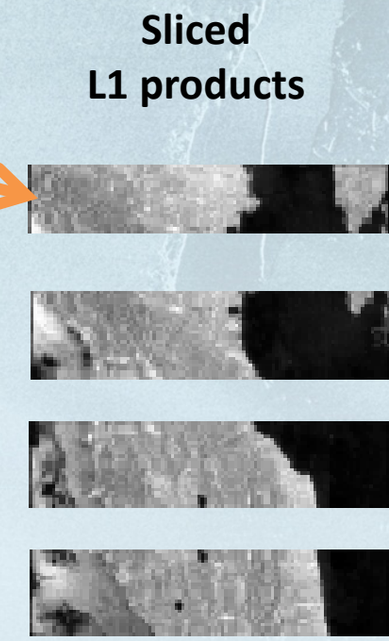
- S-1 will acquire data-takes according to a pre-defined planning.
- For SM, IW and EW the L0 products will be generated as <u>slices</u> and systematically processed to L1 and L2 <u>slice</u> products.

- L1 (slices) products are of seamless quality and are directly concatenable:
  - No data gap or duplicated lines
  - No geometric, radiometric, phase discontinuity
  - Annotations are concatenable

- Concatenation is let to the user appreciation and is not performed by the PDGS

- WV data is not sliced and the full segment is processed into L2.
  → *WV L1 products are not systematically generated*

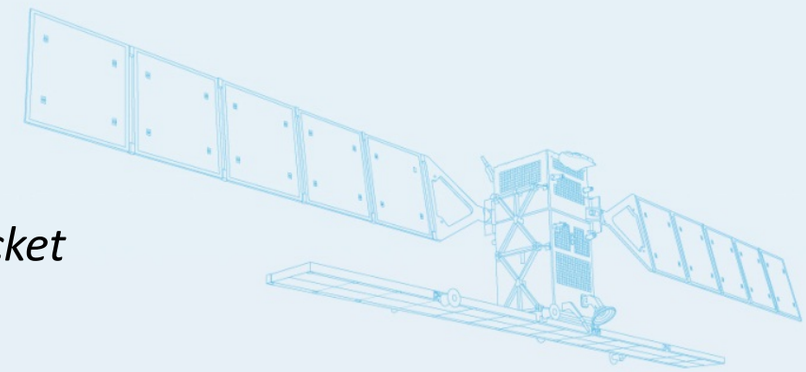




S-1 IPF throughput

- Throughput[1] achieved by one IPF processing node (preliminary numbers):
  - 14s of IW L0 dual pol → L1: ~ 3.25 – 4 mins
  - 60s of EW L0 dual pol → L1: ~5.73mins
  - 60s of WV L1 single pol → L1: ~38.1s

- At PAC/CGS several processing nodes are available to process the L0 slices in parallel



1) Performance achieved with:

- *CPU: Intel Xeon 5680, 3.33 GHz, with 2 sockets and 6 cores per socket*
- *RAM: 96 GB DDR3-1333 RAM (48 GB per socket)*

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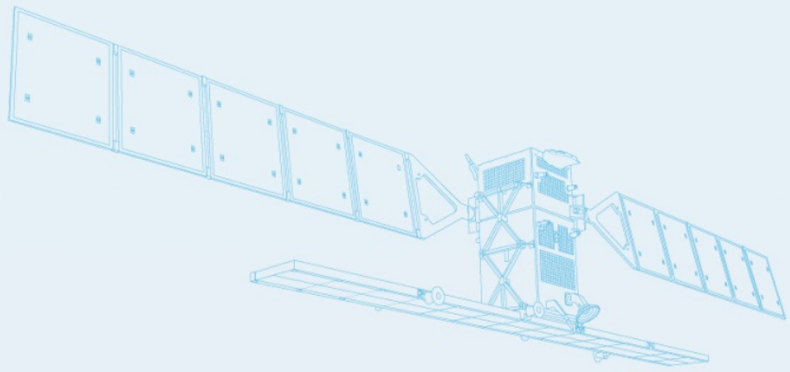
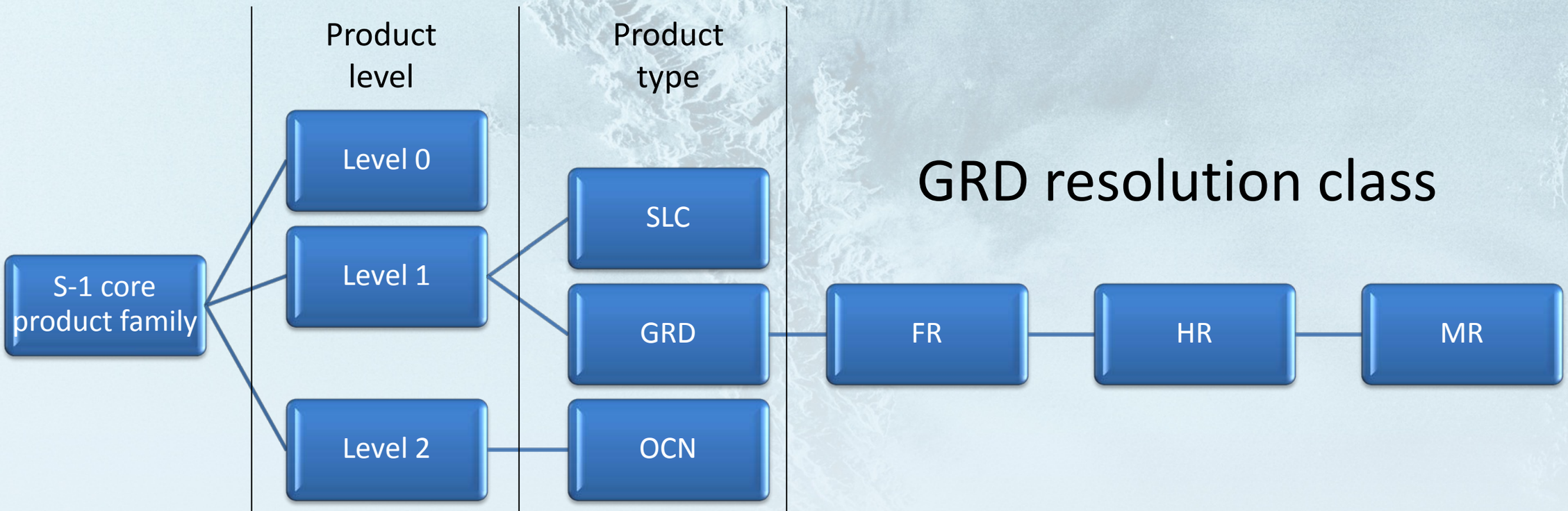


Sentinel-1 core product family



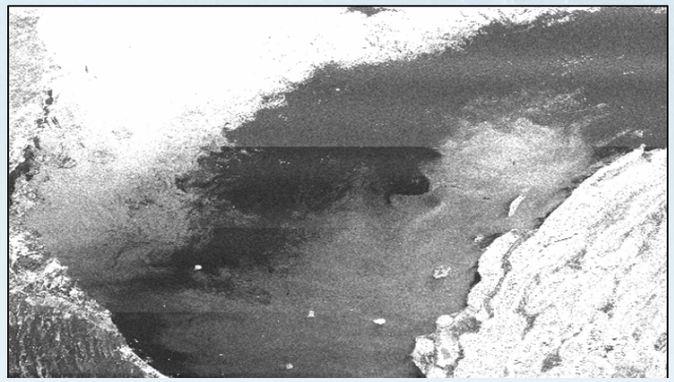
Acquisition Mode	L0/1/2	Product type	GRD_FR	GRD_HR	GRD_MR
SM	✔	✔	✔	✔	✔
IW	✔	✔		✔	✔
EW	✔	✔		✔	✔
WV	✔	✔			

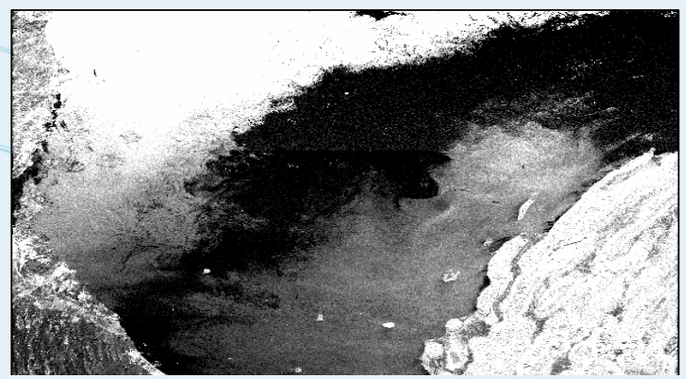
S-1 Level-1 Product Family

LEVEL-1 PRODUCTS

- **Slant-Range Single-Look Complex Products (SLC)**
  - Focused data in slant-range geometry
  - Single look with phase and amplitude information
  - Complete geo-reference information corrected for the azimuth bi-static delay
  - Elevation antenna Pattern and Range Spreading Loss natively corrected

- **Ground Range Detected Products (GRD)**
  - Focused data projected to ground range using an Earth ellipsoid model and with original satellite path direction preserved
  - Detected and multi-looked. Several resolution classes are possible depending on the product type:
    - Full Resolution (FR): ~9m resolution
    - High Resolution (HR): ~20-50m resolution
    - Medium Resolution (MR): ~85-95m resolution
  - Complete geo-reference information corrected for the azimuth bi-static delay
  - Elevation antenna Pattern and Range Spreading Loss natively corrected
  - Thermal noise removal





ASAR WS after / before thermal noise remova

S-1 L1 product characteristics

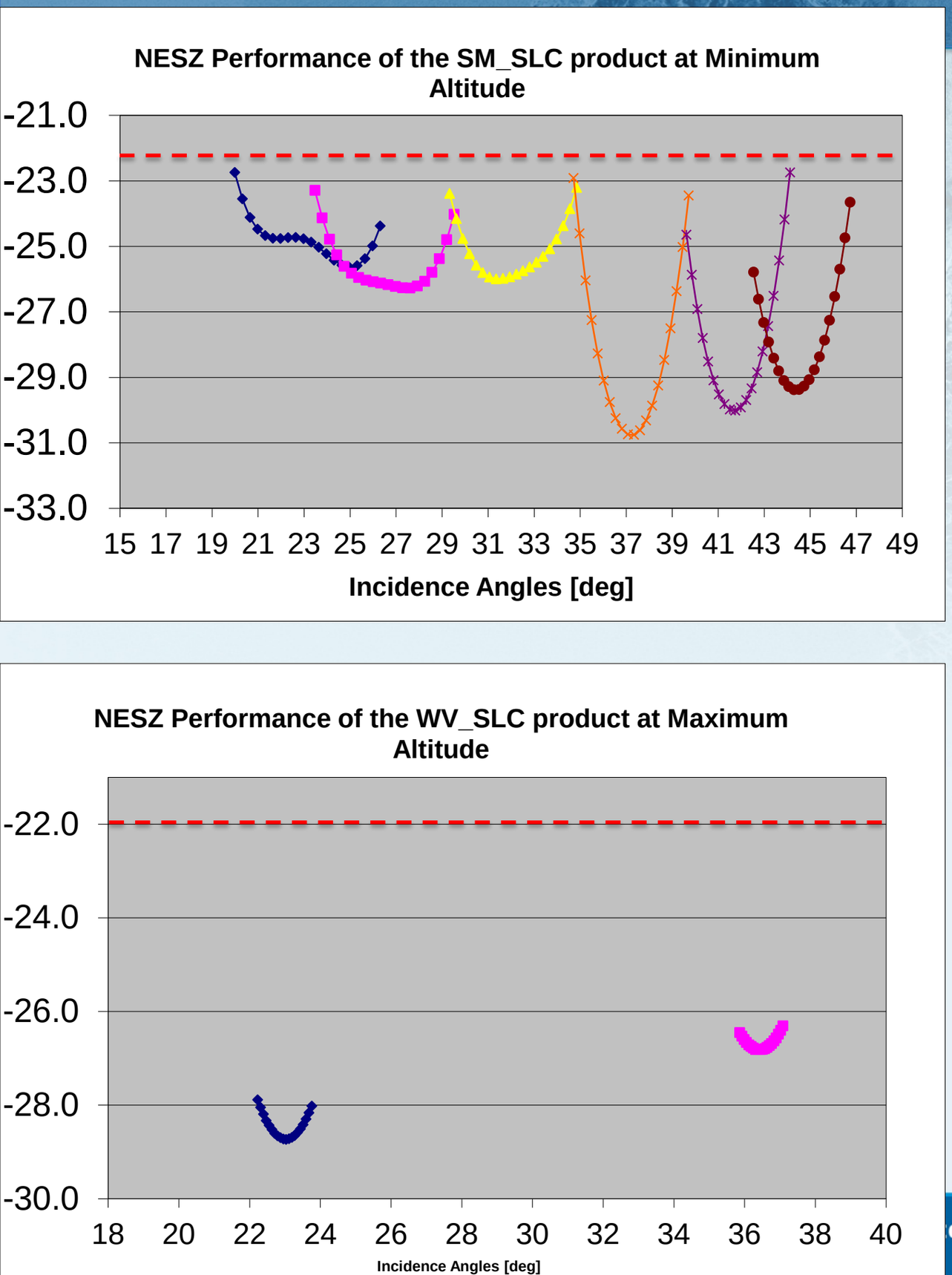
Acq. Mode	Product Type	Resol. Class	Resol. [m] [rg x az] (1)(2)	Spacing [m] [rg x az] (2)	No. Looks	polarisation	Data Volume [MB] (3)	Ground coverage [km]	PSLR [dB]	ISLR [dB]	DTAR [dB]	PTAR [dB]	NESZ [dB]
SM	SLC		[1.7 x 4.3] to [3.6 x 4.9]	[1.5 x 3.6] to [3.1 x 4.1]	1	Single: (H or V) or Dual (HH/HV or VV/VH)	3300	80	< -21.2	< -16.7	<-22.3	<-32.3	<-22
	GRD	FR	9 x 9	4 x 4	4		1600						
		HR	23 x 23	10 x10	36		265						
		MR	84 x 84	40 x 40	484		18						
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
	GRD	HR	20 x 22	10 x 10	5		822						
		MR	88 x 89	40 x 40	110		52						
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
	GRD	HR	50 x 50	25 x 25	3		504						
		MR	93 x 87	40 x 40	12		199						
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

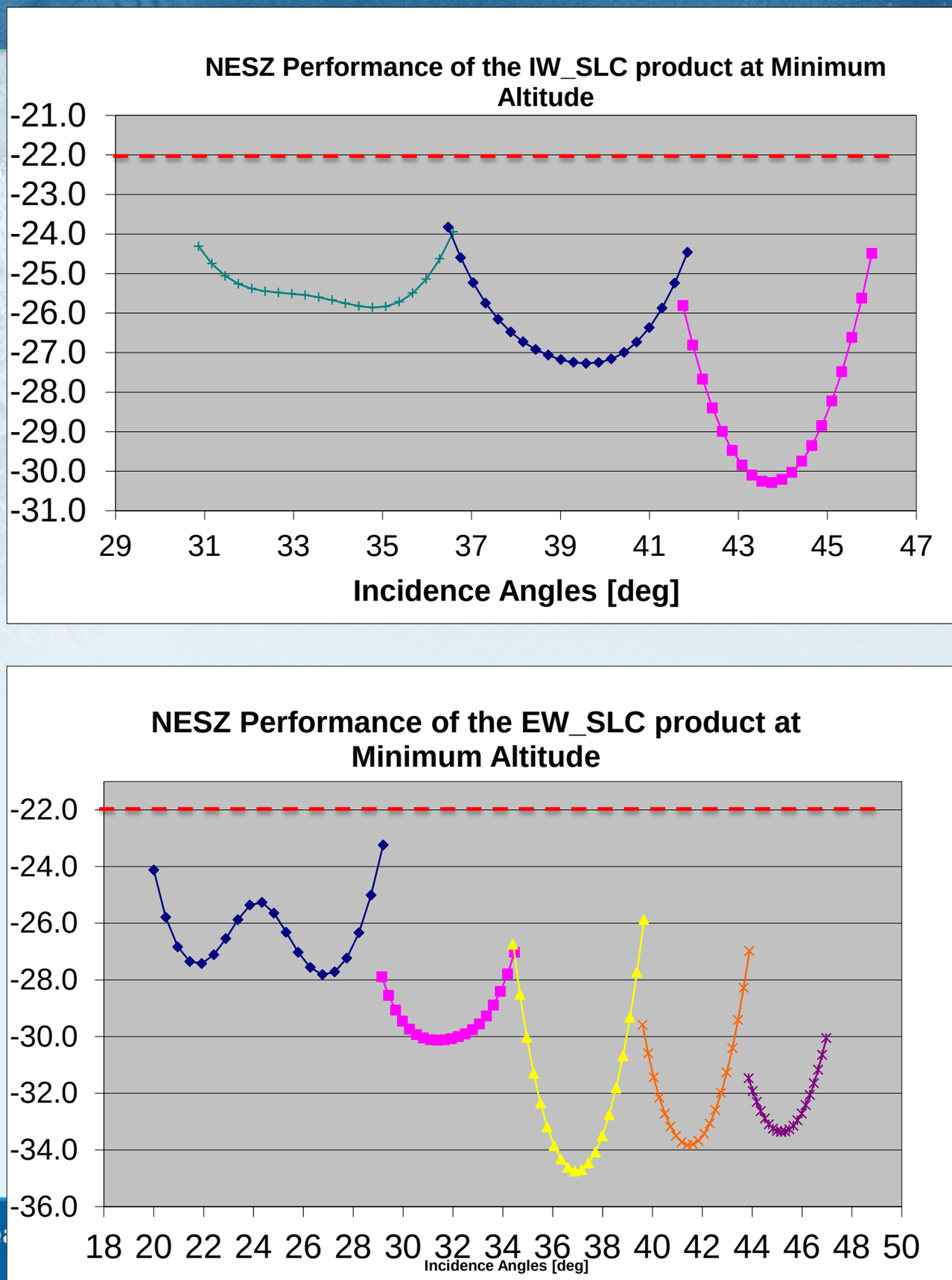
(1) For GRD, the resolution given at mid-range, mid-orbit and value at mid-orbit altitude, averaged over all swaths.

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

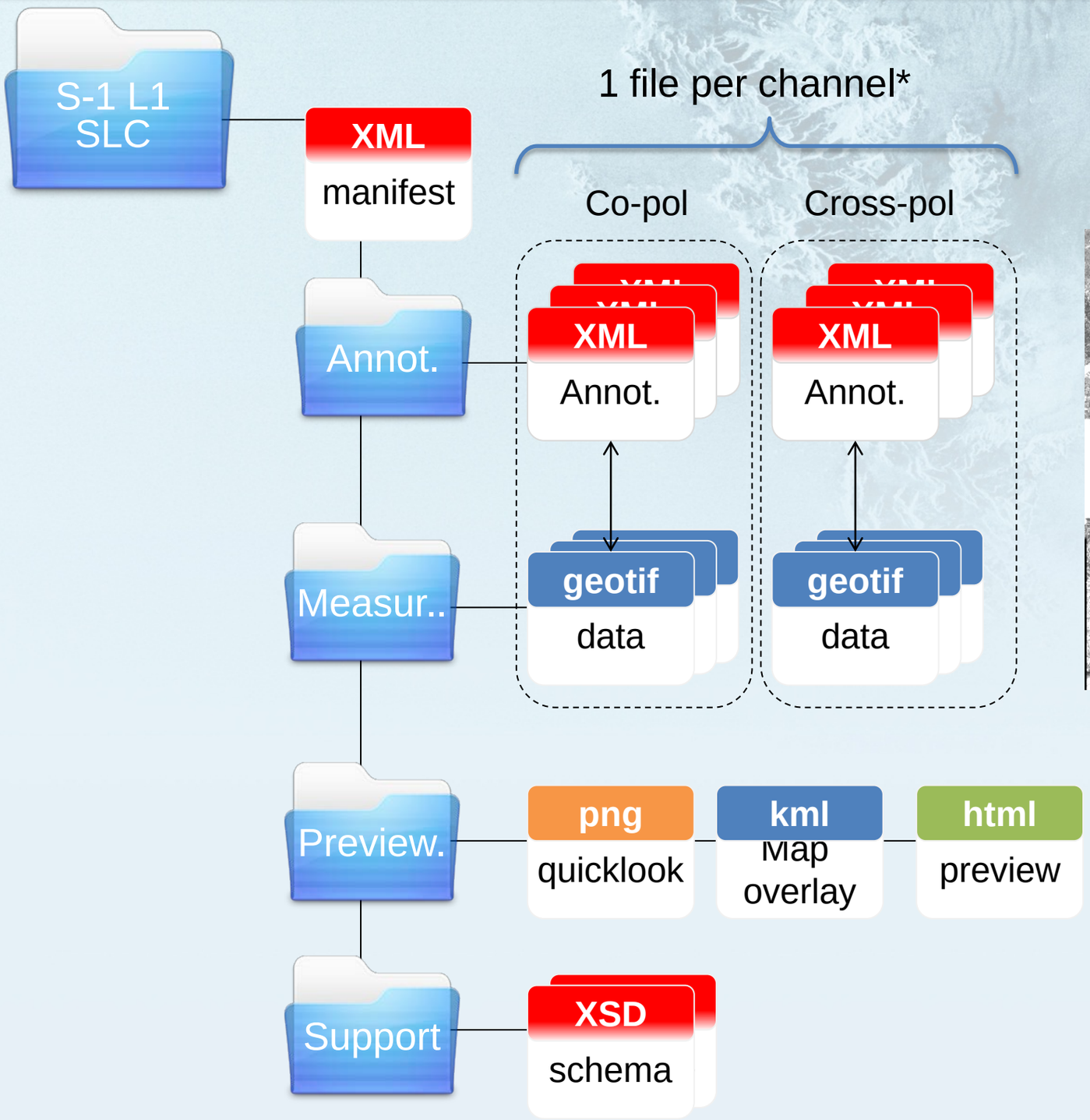
(3) Volume given for a single pol and for a product duration of 25s for SM and IW, 60s for EW and WV . To be multiplied by 2 in dual pol case

NESZ performance



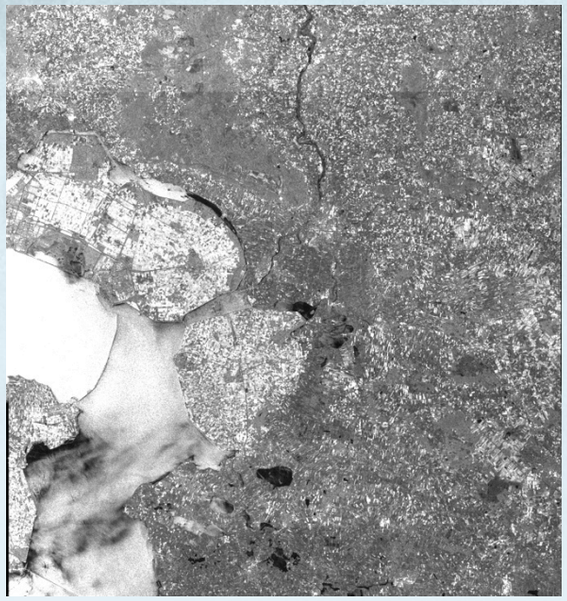


S-1 SLC product format overview

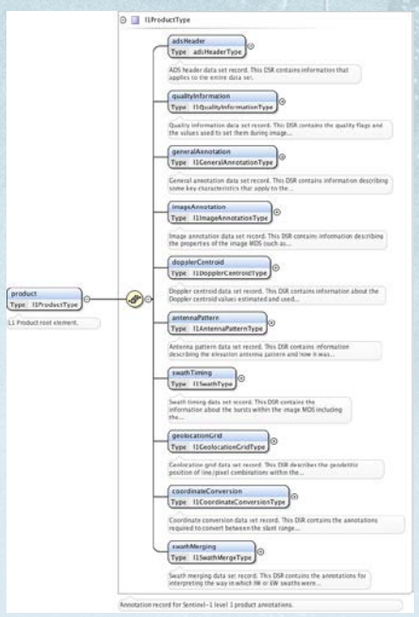


* A channel is a polarisation or a sub-swath or an imagette

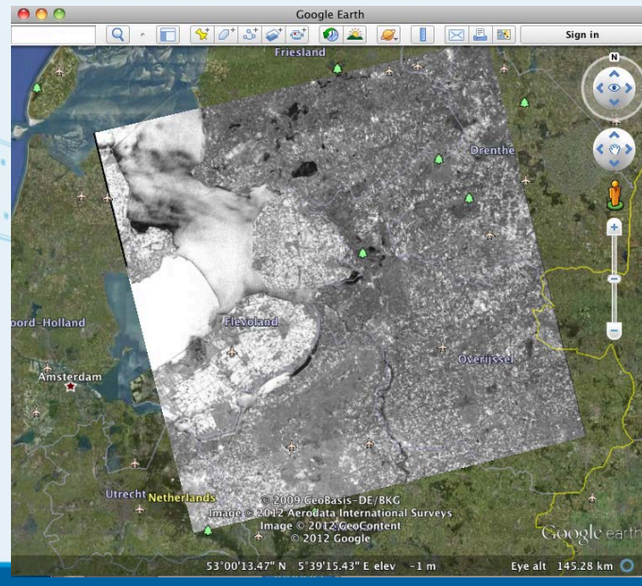
“Geotiff imagery”



“XML annotations”

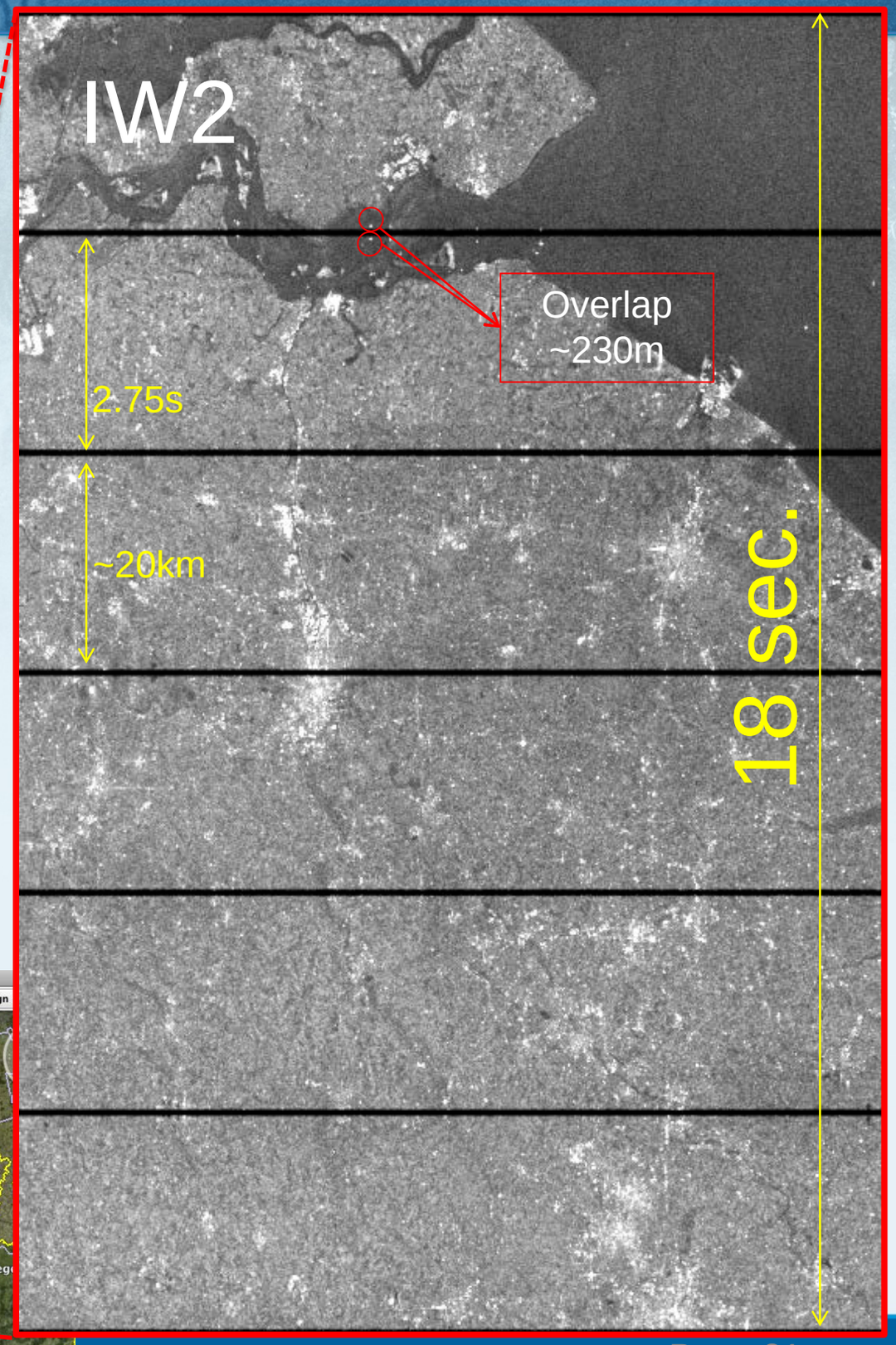


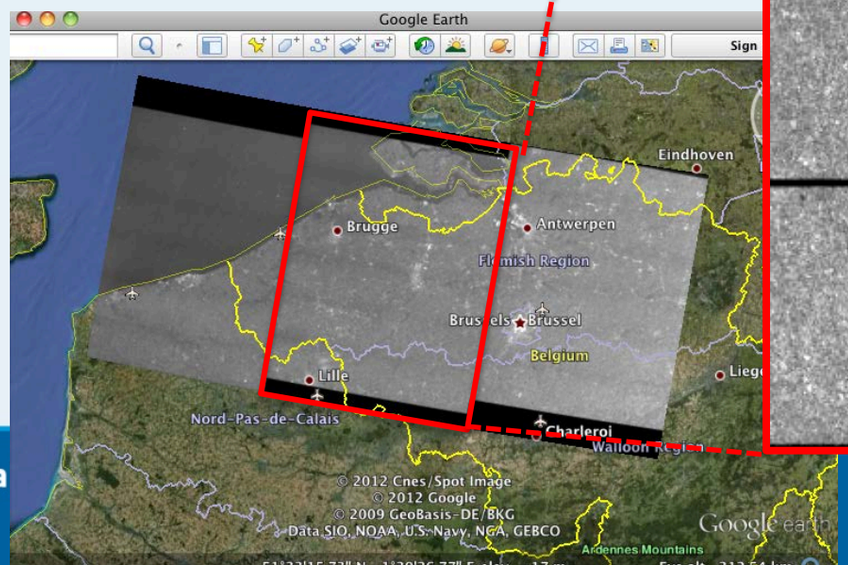
“KML map overlay + quicklook

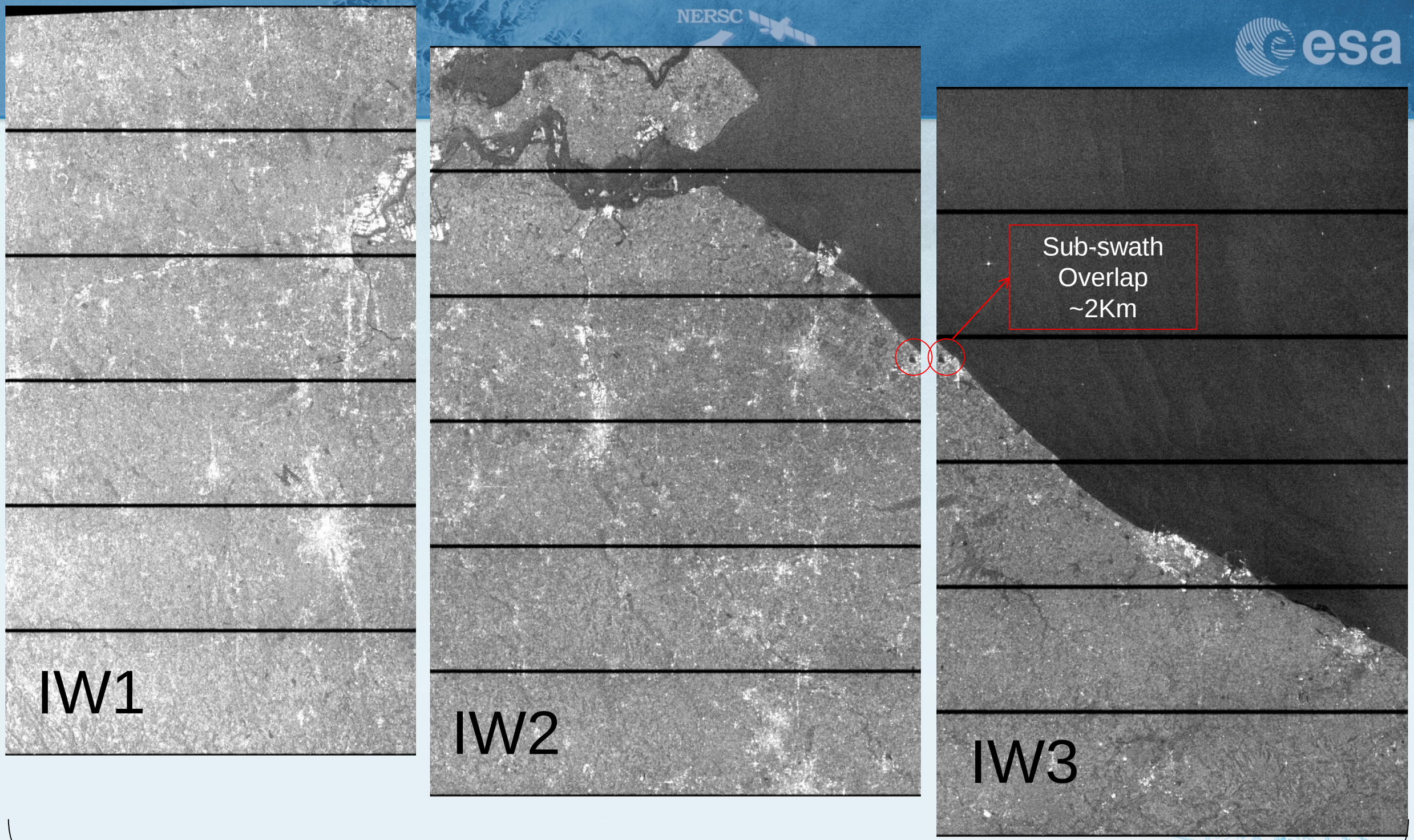


IW Product: first samples

- IW SLC data block follows the convention introduced by the ASAR WSS:
  - Collection of focussed burst separated by 0-padding
- IW SLC Data provided in slices of 25s:
  - ~9 bursts in each slice covering ~250x170km
- Data block is composed by:
  - 3 (6) images (geotiff) for single (dual) pol
- Focused burst duration (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
  Longer burst than for ASAR

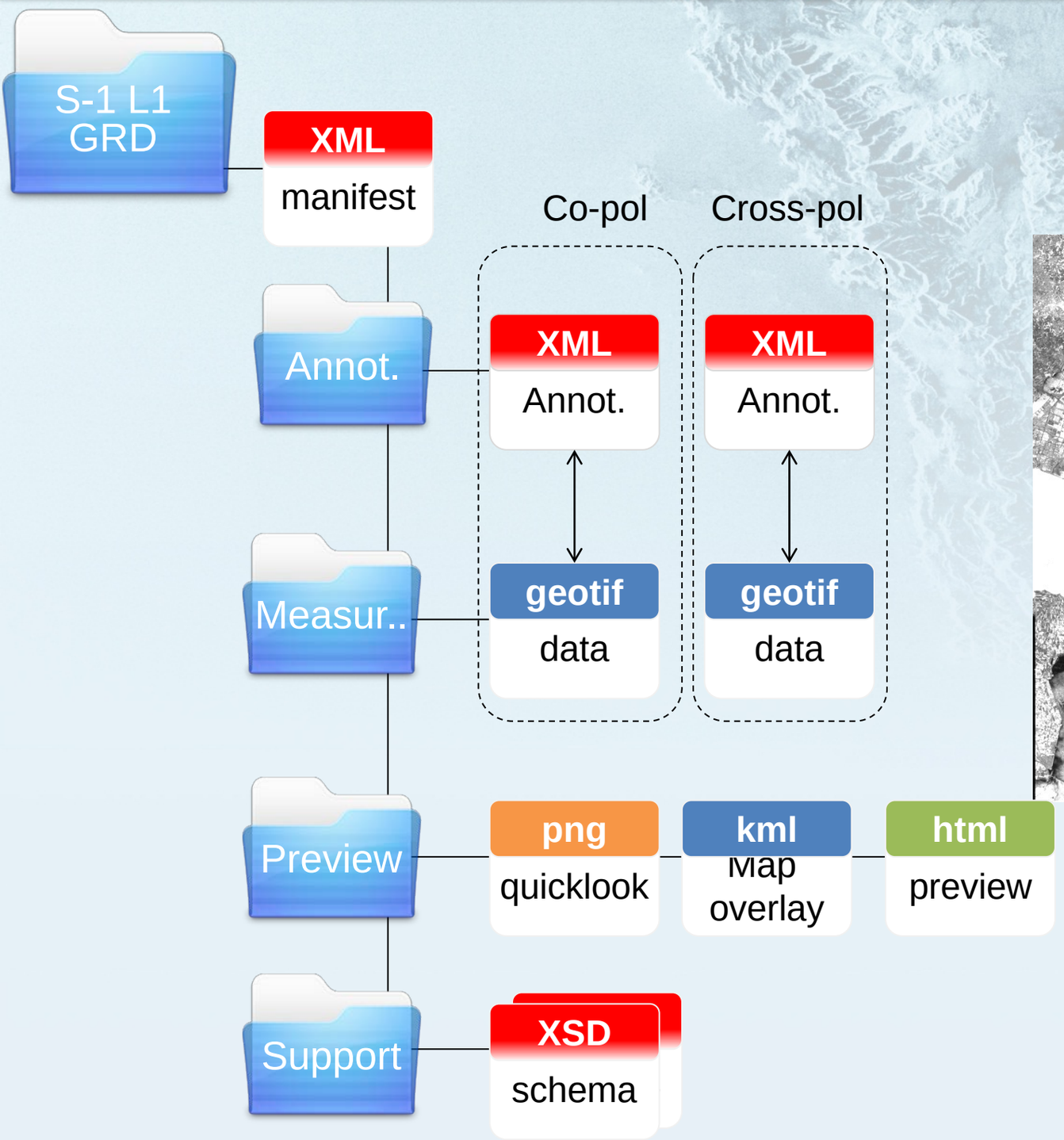




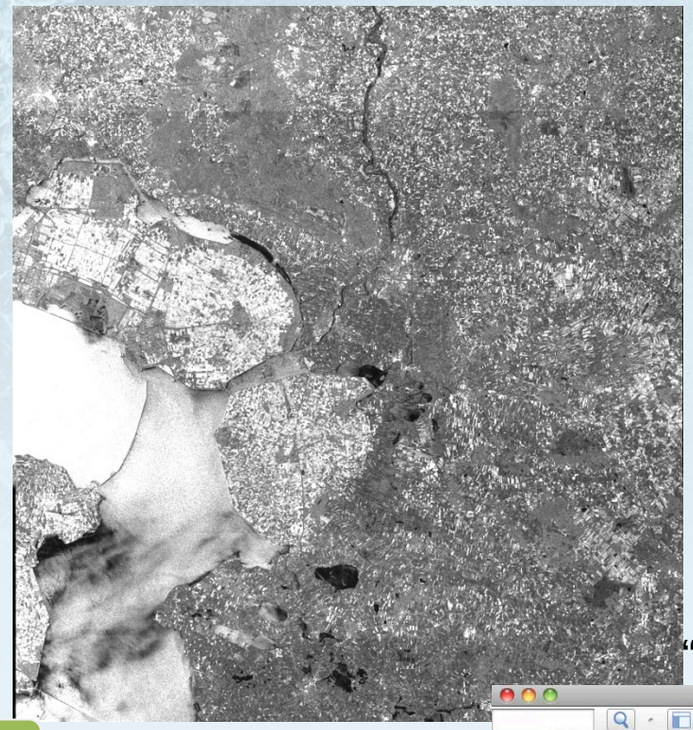


IW SLC: collection of focused burst per sub-swath

S-1 GRD product format overview



“Geotiff imagery”



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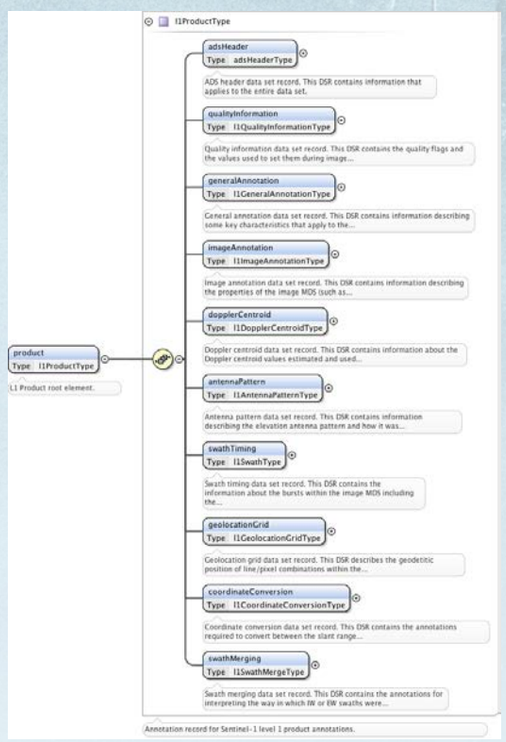

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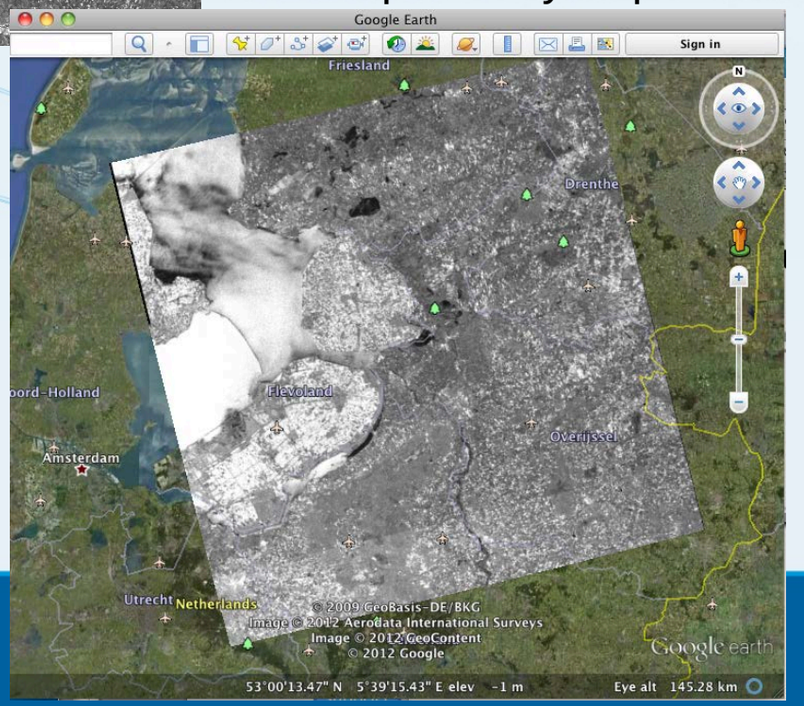
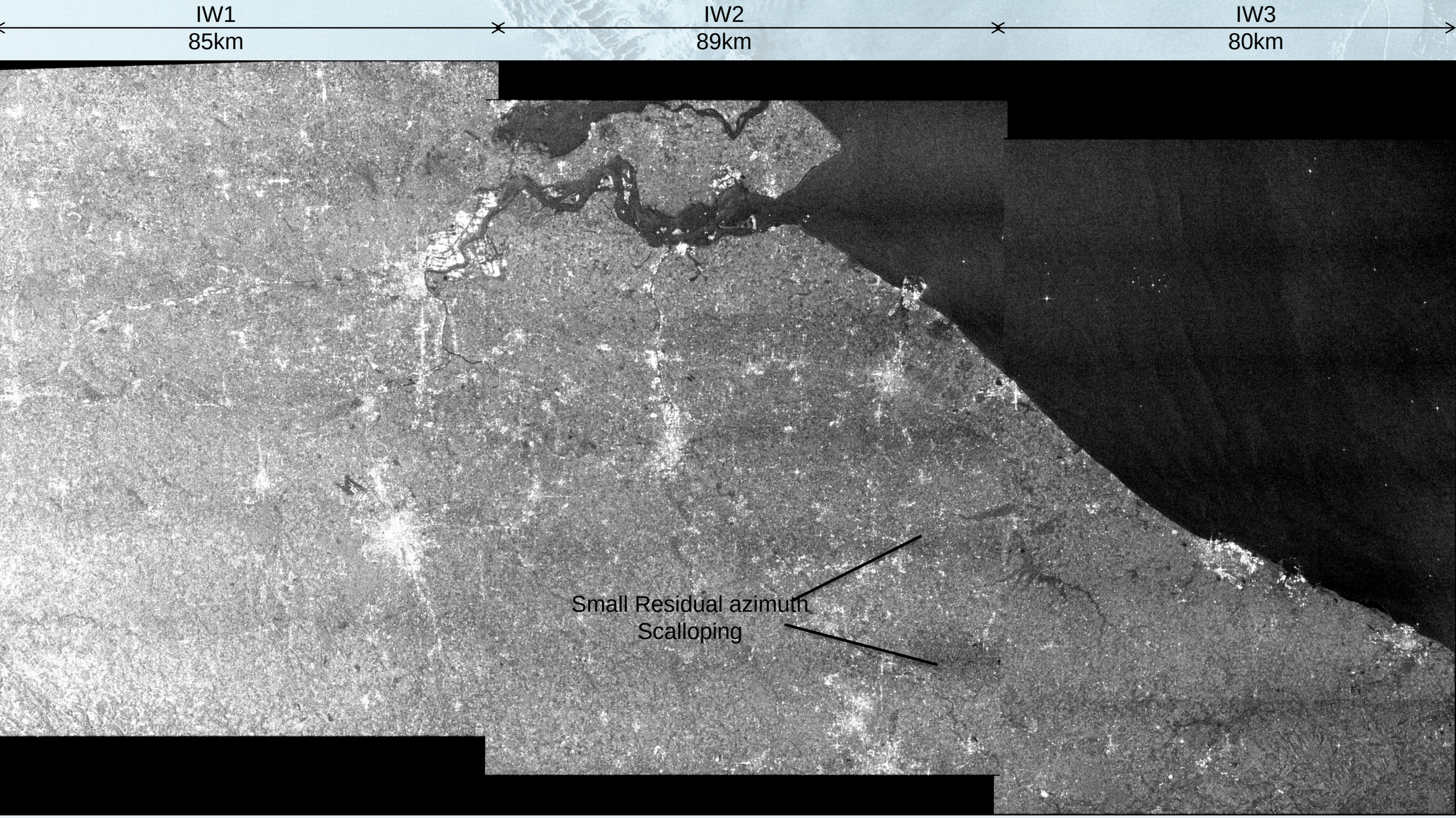


IW GRD : first sample



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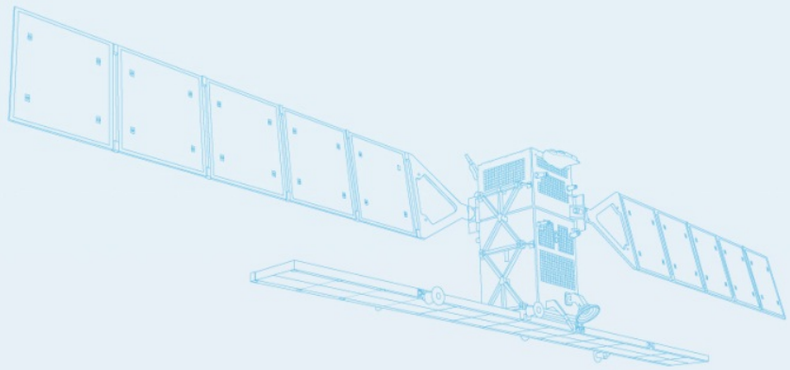


S-1 L2 OCEAN product

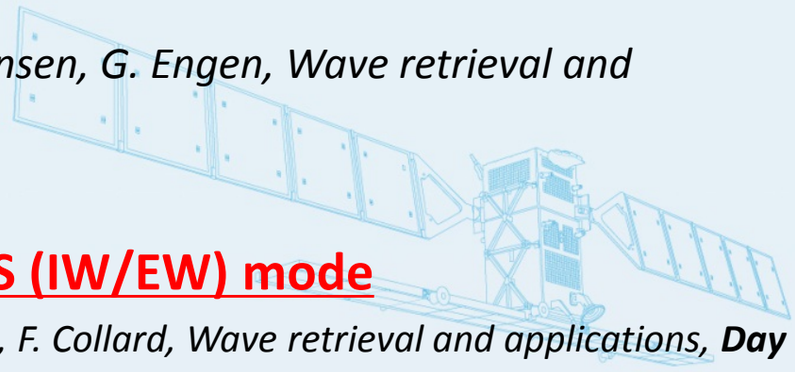
- The S-1 Level-2 product family is composed by the OCEAN (OCN) product designed to deliver geophysical parameters related to the wind, waves and surface velocity to a large panel of users

- The OCN product strongly inherits from ESA projects (i.e. globWave and WWC, Soprano):
  - Provides continuity of global SAR swell measurements at C-band SAR (using WV mode)
  - Complements the swell fields with wind and Radial Velocities
  - Extends the algorithms to the SM and TOPS mode (when possible)*

- Each L2 OCN product contains up to three geophysical components:
  - radial surface velocity (RVL)

    High precision Doppler frequency estimation for ocean applications, H. Johnsen, G. Engen, Wave retrieval and applications, ***Day 2, PM***
  - ocean surface wind field (OWI)
  - ocean swell wave spectra (OSW): **OSW is not available for TOPS (IW/EW) mode**

    SAR Wave Mode Processing – Improvements towards Sentinel-1 Mission, H. Johnsen, F. Collard, Wave retrieval and applications, ***Day 2, AM***



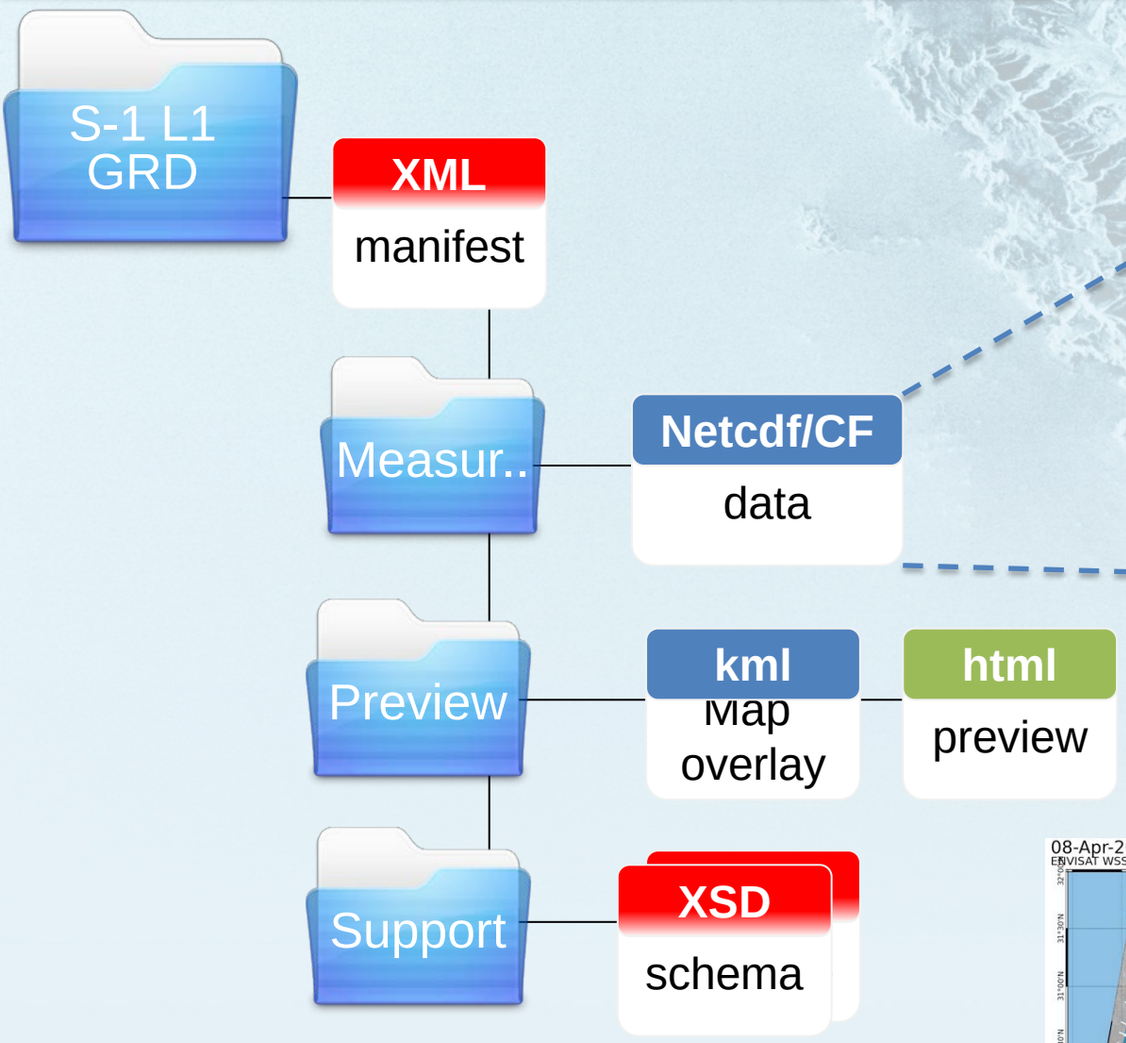
**SEASAR 2010 recommendation*

S-1 L2 product characteristics

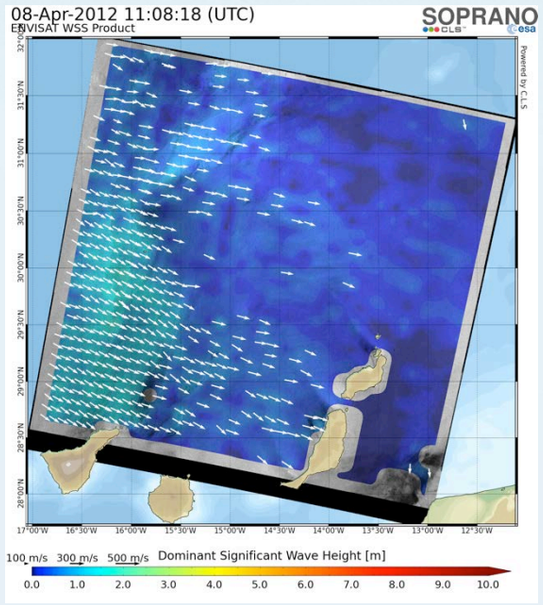
OSW component	parameter	unit	SM	WV	IW/EW	Limits
OSW	swell spectra	[m^4]	✔	✔	Not available	
	Quality cross-spectra	[m^2]	✔	✔		
	SAR SWH	[m]	Bias<1; RMSe<0.5			
	Dominant Wave Length	[m]	Bias<-10; RMSe<50			Within [30, 500]m
	Dominant Wave direction	[degN]	Bias<10; RMSe<40			
	Mean azi. Cut-off wavelength	[m]	[210, 260]m			Within [15, 800]m
	spatial resolution	[km x km]	20x20			
OWI	wind speed	[m/s]	RMSe < 2.0			Within [0, 25]m
	wind direction	[degN]	RMSe < 30			
	spatial resolution	[km x km]	1x1			
RVL	Radial Suface Velocity	[m/s]	RMS within [0.29, 0.38]			Within [-10, 10]
	Doppler Centroid Frequency	[Hz]	RMS within [2, 5]			Within [0, 60]Hz
	spatial resolution	[km x km]	1x1			

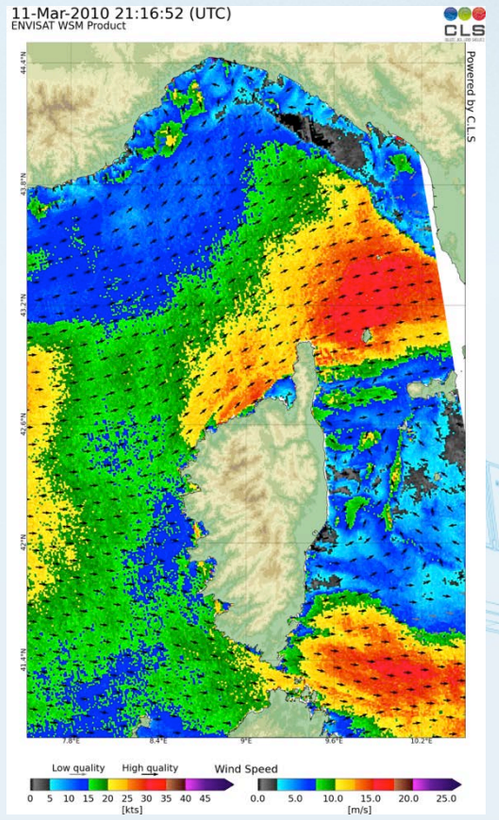
Details provided in the S-1 product definition

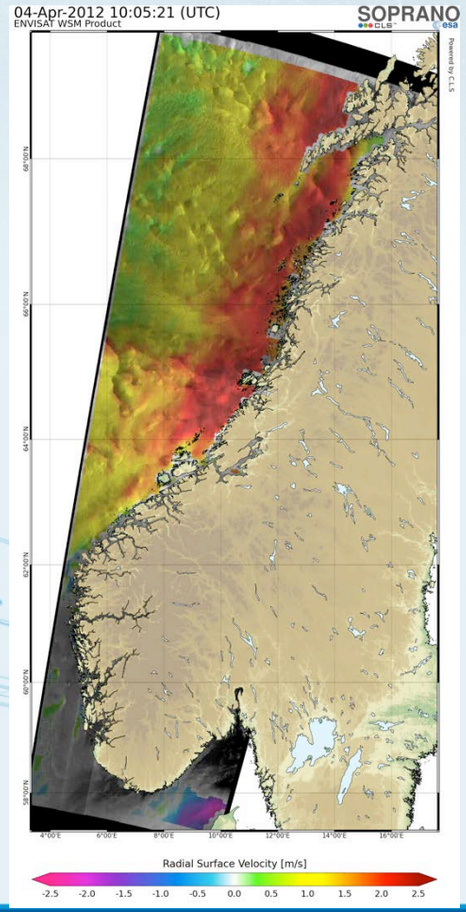
S-1 L2 OCN product overview



	OCN components		
	OSW	OWI	RVL
SM	✔	✔	✔
WV	✔	✔	✔
IW/EW	✖	✔	✔







L2 OCN: OWI component

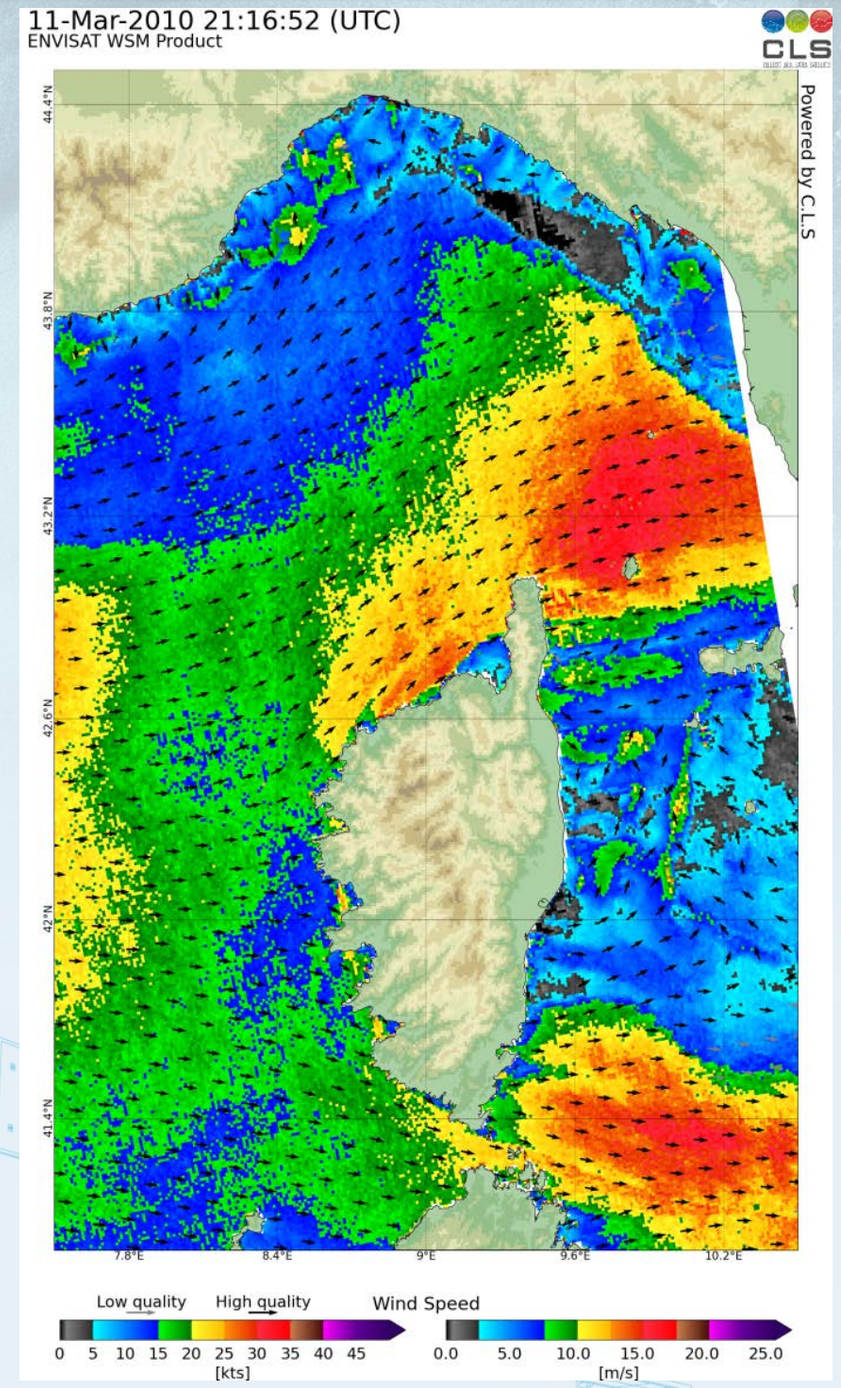
- OWI component is new wrt to ERS/ASAR. OWI provides wind fields (Speed and direction) at 10m:
  - SM/TOPS : resolution 1x1km
  - WV: 20x20km (One estimate per imagette)

- Available for all acquisition modes:
  - Over open ocean with WV mode
  - Over coastal areas with TOPS modes

- Algorithm:
  - Bayesian scheme (Kerbaol and al., 2007) using a priori ECMWF winds and CMOD-IFR GMF
  - Estimation based on the co-pol channel (no inversion combining co and cross-pol).
  - The Mouche polarisation ratio model is used (Mouche and al. 2006) [1]

- Limitation:
  - Low wind speed estimates are limited by the NESZ (<-22dB)
  - Under-estimation at winds > 25 m/s
  - Current can affect the estimation (Mouche, Seasar 2010)

- Product performance
  - Wind speed (U10)<2 m/s RMSe, *for winds within [0, 25] m/s*
  - Wind direction(degN) < 30° RMSe



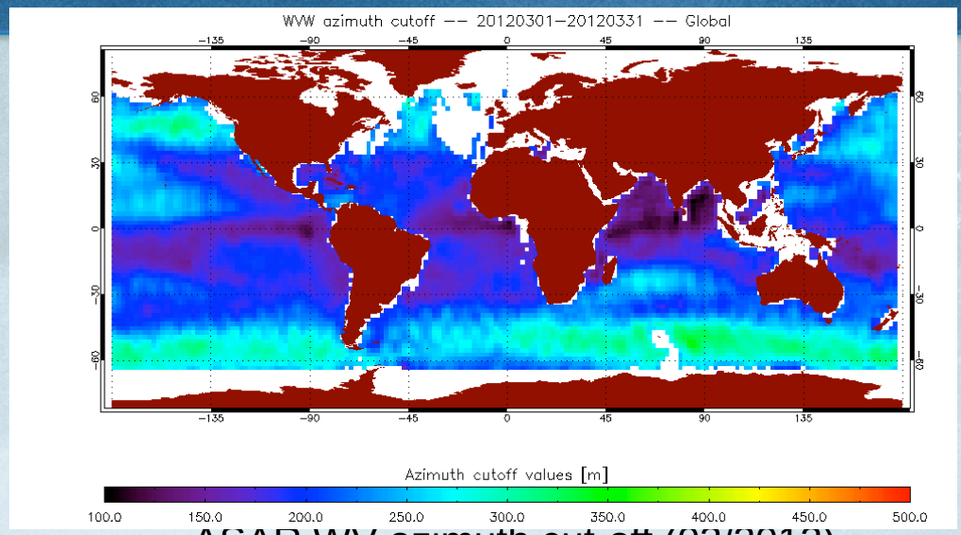
Courtesy of CLS

1) As per SEASAR 2010 recommendation

L2 OCN: OSW component

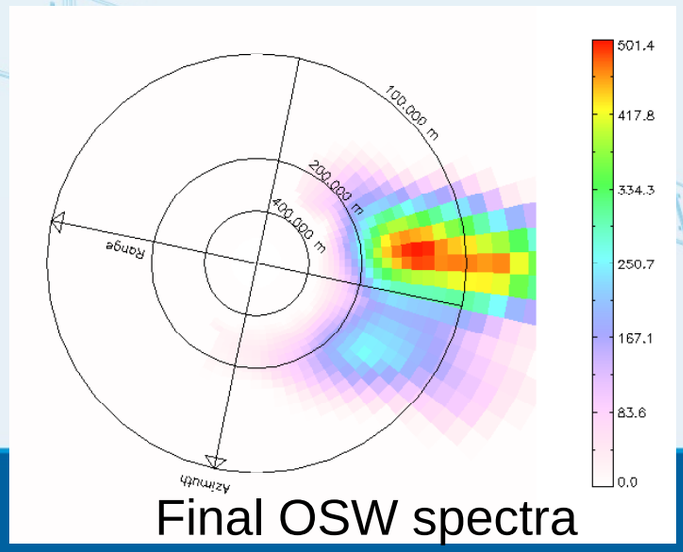
- OSW component provides continuity measurement of SAR swell spectra at C-band:
  - 2D ocean surface swell spectra estimated from inversion of the corresponding cross- spectra at spacing of 20x20km (i.e. one per imagette)
- Available for WV (global) and SM (local) acquisition modes
  - Not available for TOPS
- Algorithm scheme:
  - **Spectra derivation**: Derivation of co and cross-spectra by computed by performing inter-looking (3 looks) in azimuth
  - **Spectra inversion**: OSW obtained by inversion of the corresponding image cross-spectra using a refined MTF followed by spectra partitioning*
  - Generated from the co-polarisation channel
  - For coastal area a bathymetry model is used for wave dispersion in finite depth

*SAR Wave Mode Processing – Improvements towards Sentinel-1 Mission, H. Johnsen, F. Collard, Wave retrieval and applications, **Day 2, 08:50***



ASAR WV azimuth cut-off (03/2012)

OSW partition in 2 wave systems



Final OSW spectra

L2 OCN: RVL component

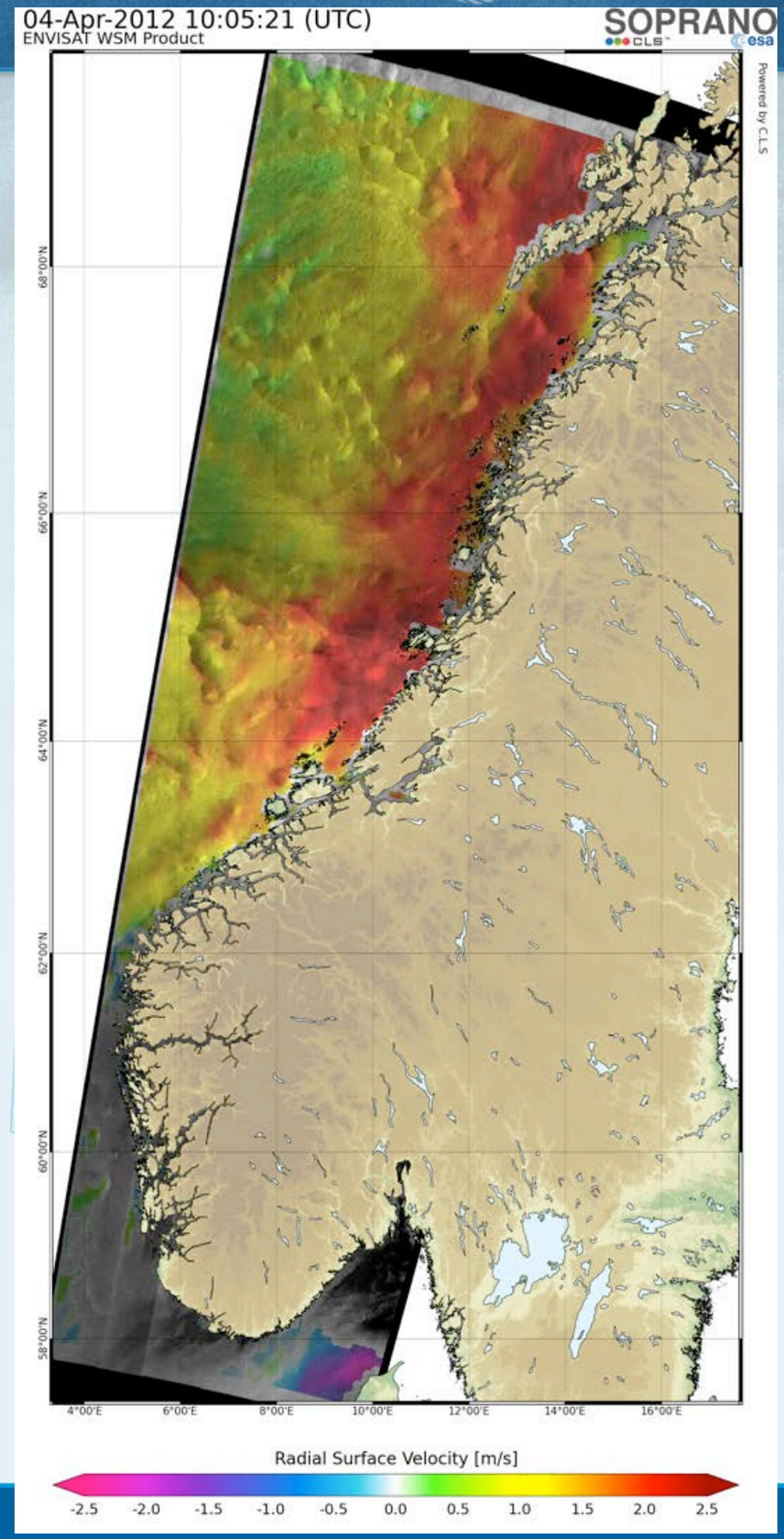
- ASAR was the first mission providing a Doppler grid to better understand the geophysical signature of the Doppler

- RVL component is the continuity of the ASAR Doppler grid

- RVL is provided for all acquisition modes:
  - SM/TOPS : resolution 1x1km
  - WV: 20x20km (One estimate per imagette)

- Algorithm
  - The core algorithm is a dedicated high-precision and high-resolution algorithm for estimation of Doppler frequency [Hz] and the corresponding standard deviation.

High precision Doppler frequency estimation for ocean applications*, H. Johnsen, G. Engen, Ocean current retrievals and applications,* ***Day 2, PM***



Recommendation from SEASAR 2010

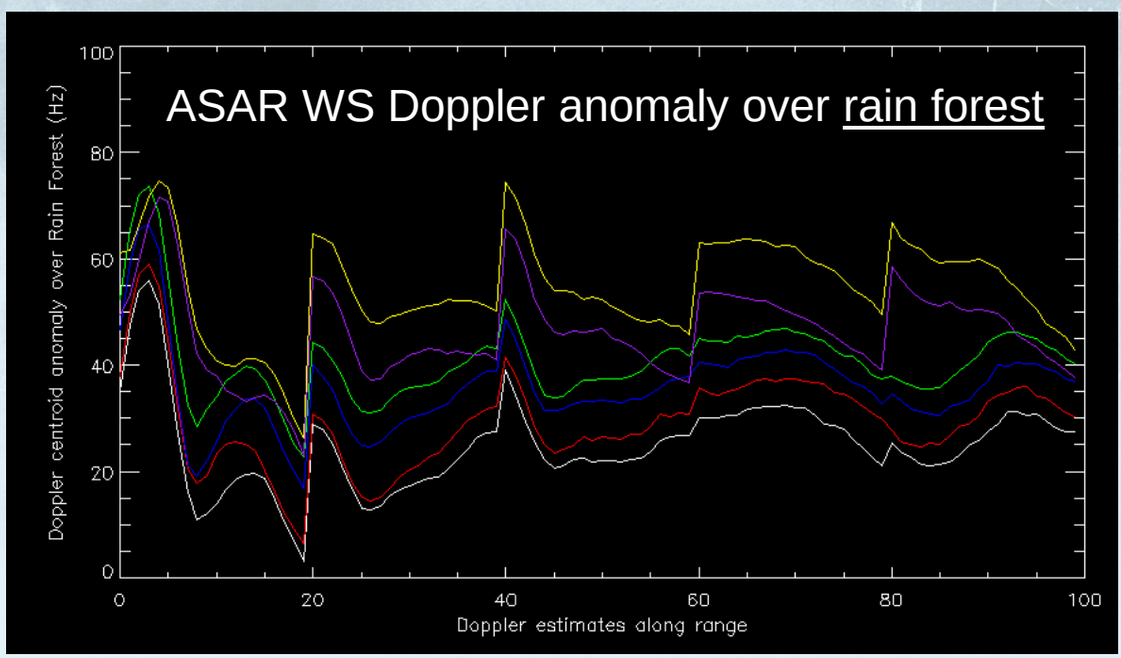
Ocean Current Application Session:

"Accuracy and resolution of Doppler Centroid estimation requires more investigation and preferably improvement"

Work has been carried following two roads:

- Doppler centroid characterization

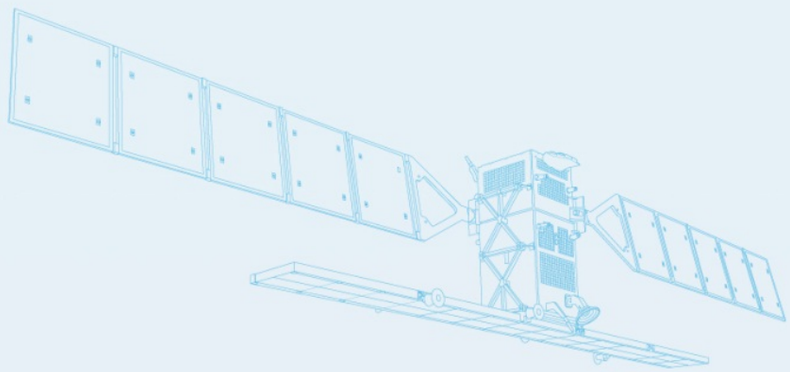
  Recchia, A.; Guarnieri, A.M.; Miranda, N.; Collard, F.; D'Aria, D.; Giudici, D.; , "Impact of the antenna stability on the Doppler Centroid frequency," *Geoscience and Remote Sensing Symposium (IGARSS), 2011 IEEE International* , vol., no., pp.1516-1519, 24-29 July 201



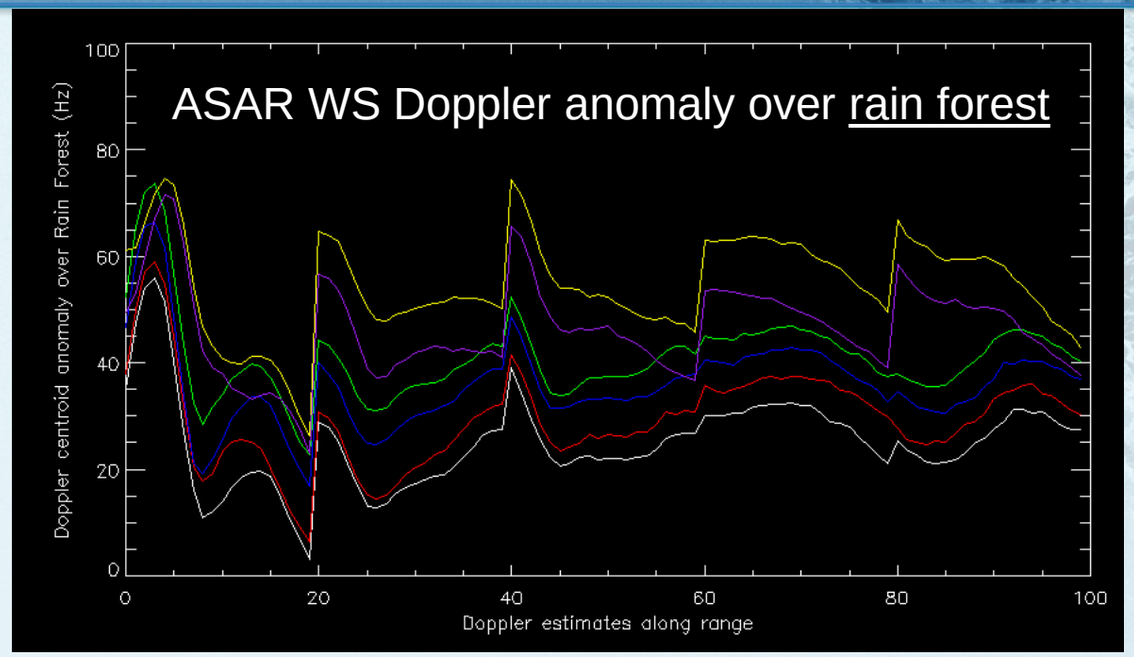
- Doppler centroid estimation improvement:

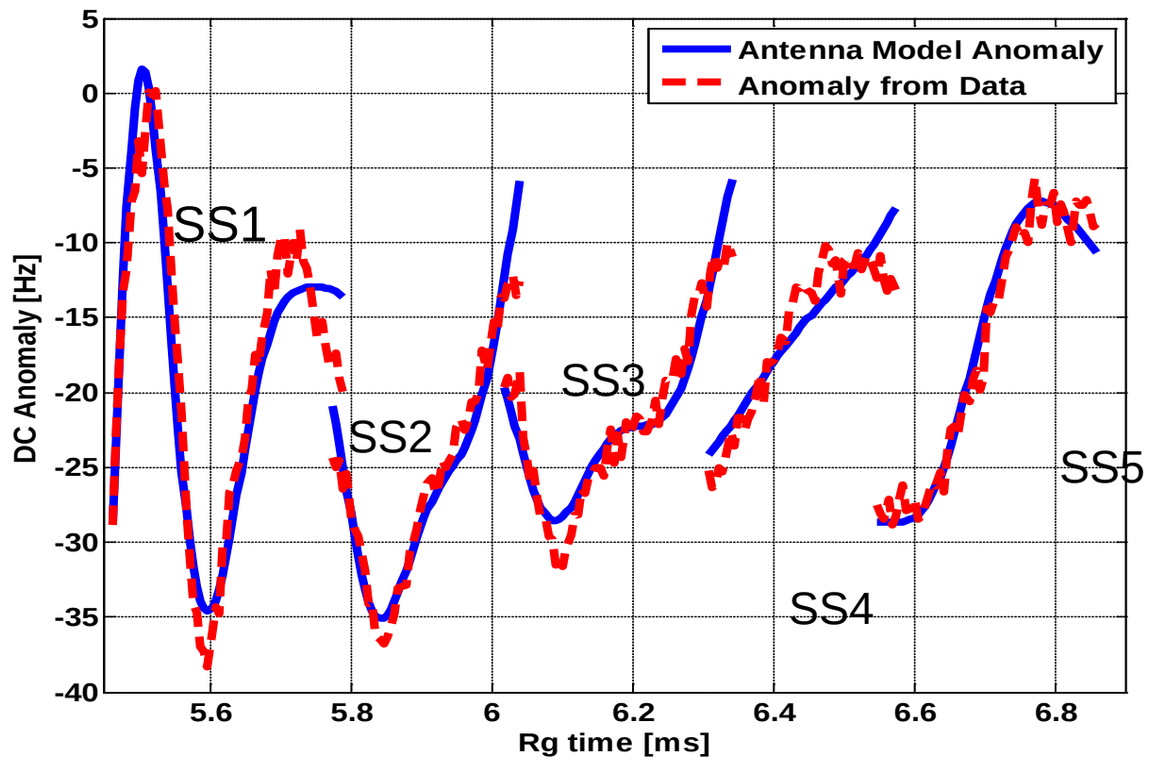
  SEASAR 2012 : Session: Ocean current retrievals and applications, Day 2: *High precision Doppler frequency estimation for ocean applications, H. Johnsen, G. Engen*

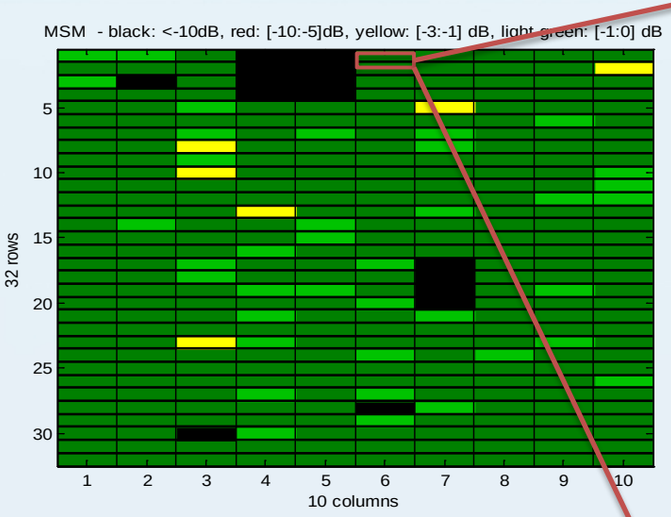
The two approaches are implemented in the S-1 IPF

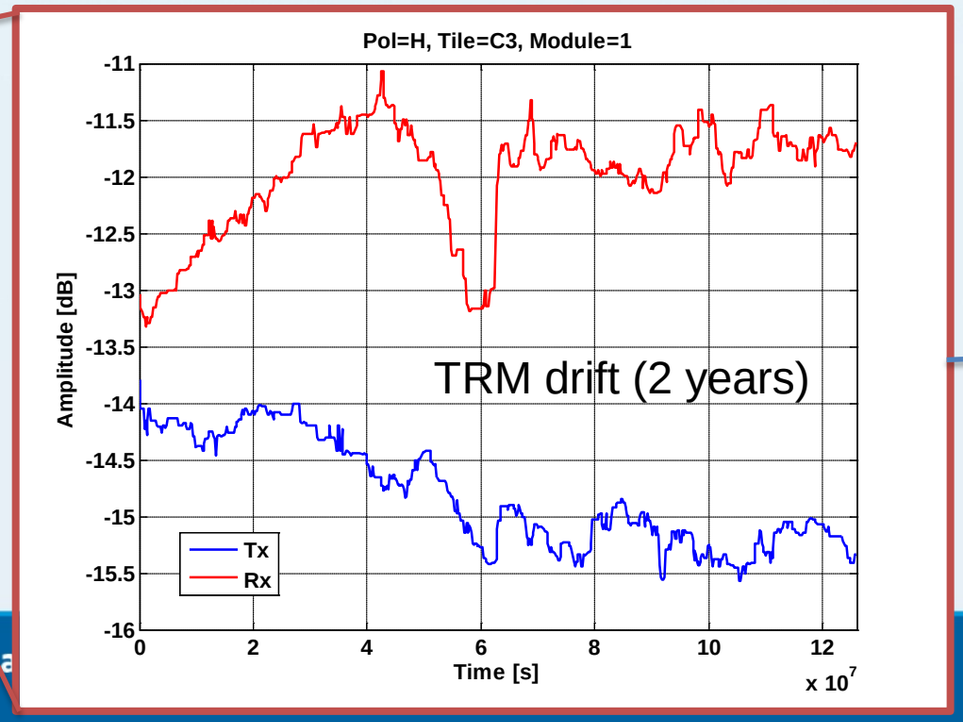


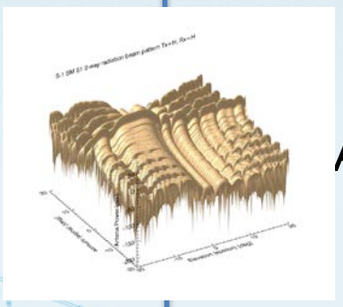
Recommendation from SEASAR 2010











Actual beam shap

Antenna Model

THANK YOU