The Copernicus Sentinel-3 Mission: Status and First Results

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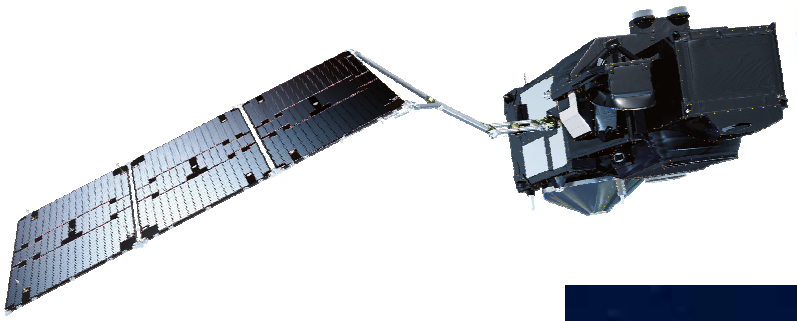
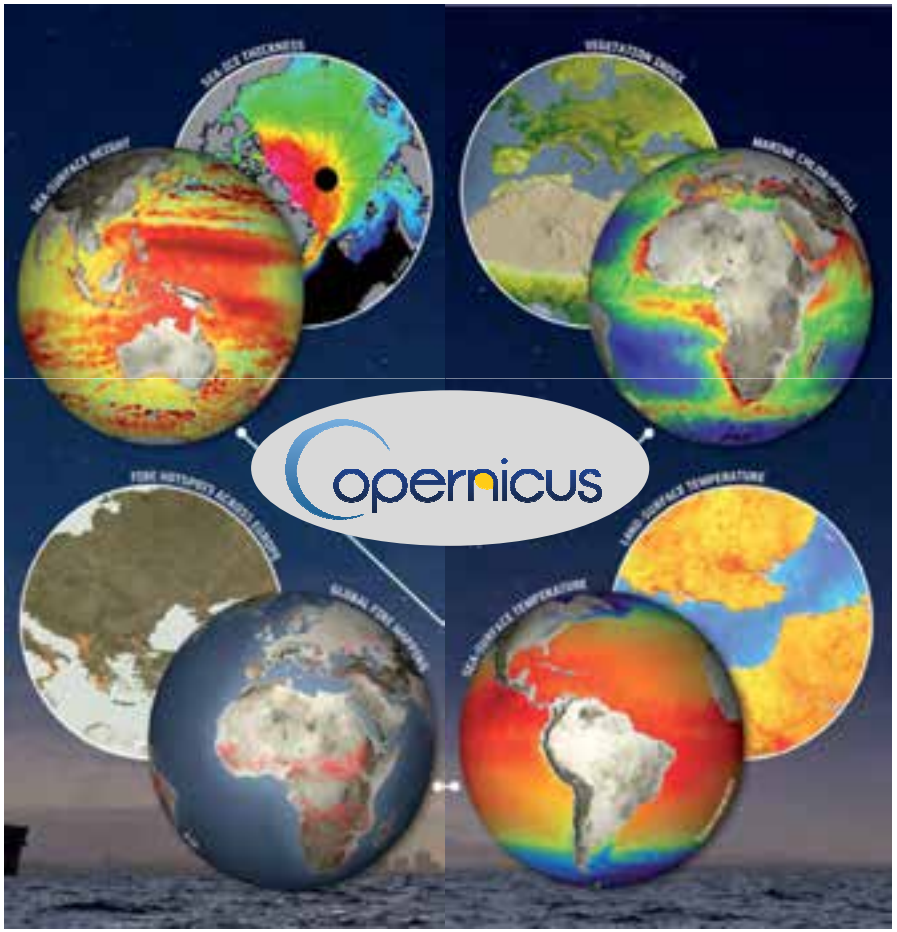
A new Era of altimetry, New challenges, La Rochelle, France 31st October 2016

Outline



- Copernicus
- Sentinel-3A
- Sentinel-3B
- Flexible approach
  - L1A
  - Orbit change
  - Potential Tandem Mission
- Current status
- Performance (CNES)



Copernicus Overview

In-situ component not represented here

- Land Monitoring
- Marine Environment Monitoring
- Atmosphere Monitoring
- Emergency Management
- Climate Change
- Security

copernicus

A Programme of the European Union

www.copernicus.eu

European Commission

- Overall Programme Management
- Coordination of the Services Component
- Cross-cutting user-uptake activities

EUMETSAT

- Operations of S3 (marine part), S4, S5, S6 and Jason-3

esa European Space Agency

- Technical coordination of the Space Component
- Development and procurement of Copernicus Sentinel missions
- Coordination and procurement of Contributing Missions data
- Operations of S1, S2, S3 (land part), S5P

…plus other partners…

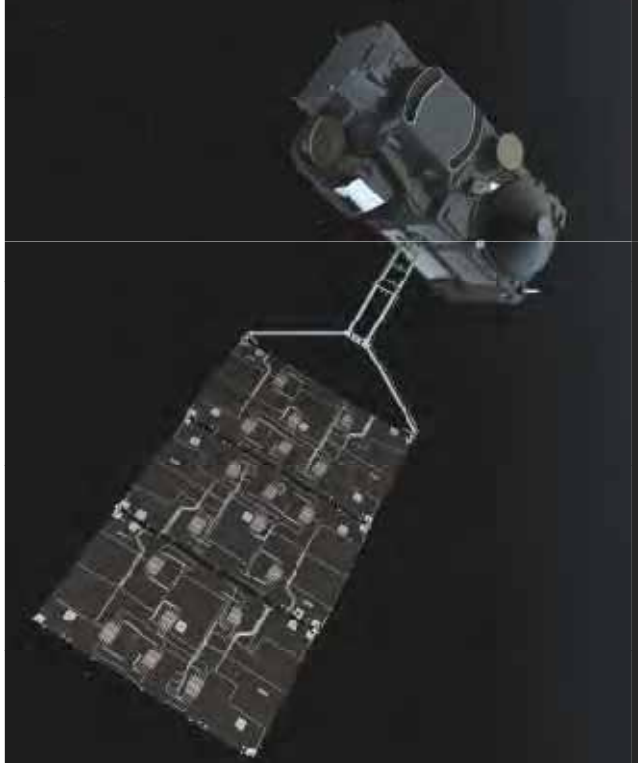
copernicus Europe's eyes on Earth

Sentinel-3: A bigger Picture for Copernicus

Sentinel-3A STM

A multi-Satellite mission

Sentinel-3A: 2015-



To meet Mission Requirements

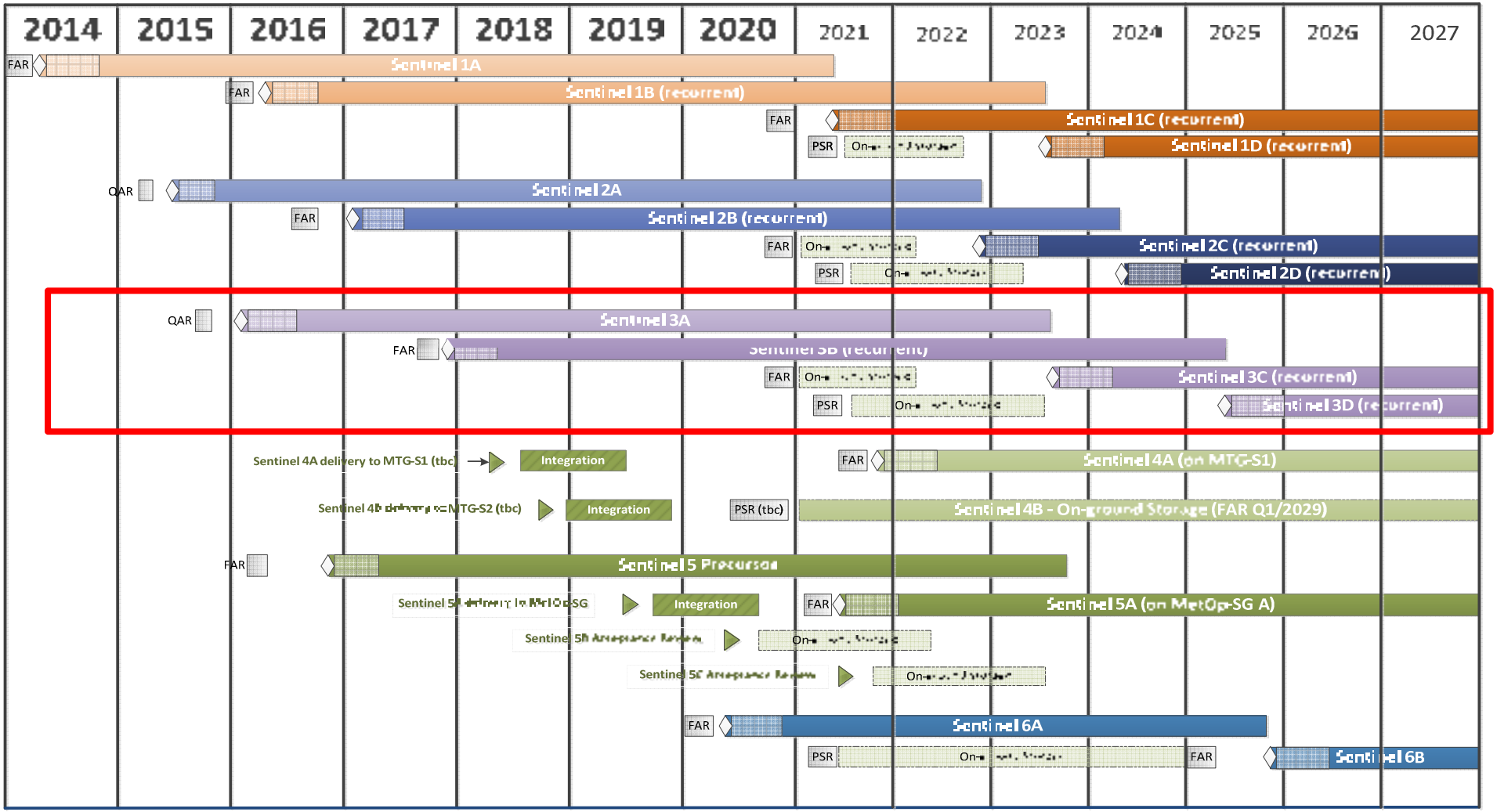
The Sentinel-3 Mission is composed of two identical satellites

Flown together in the same orbital plane separated by 140°

Follow-on Satellites (Sentinel-3C and Sentinel-3D) are now being procured.

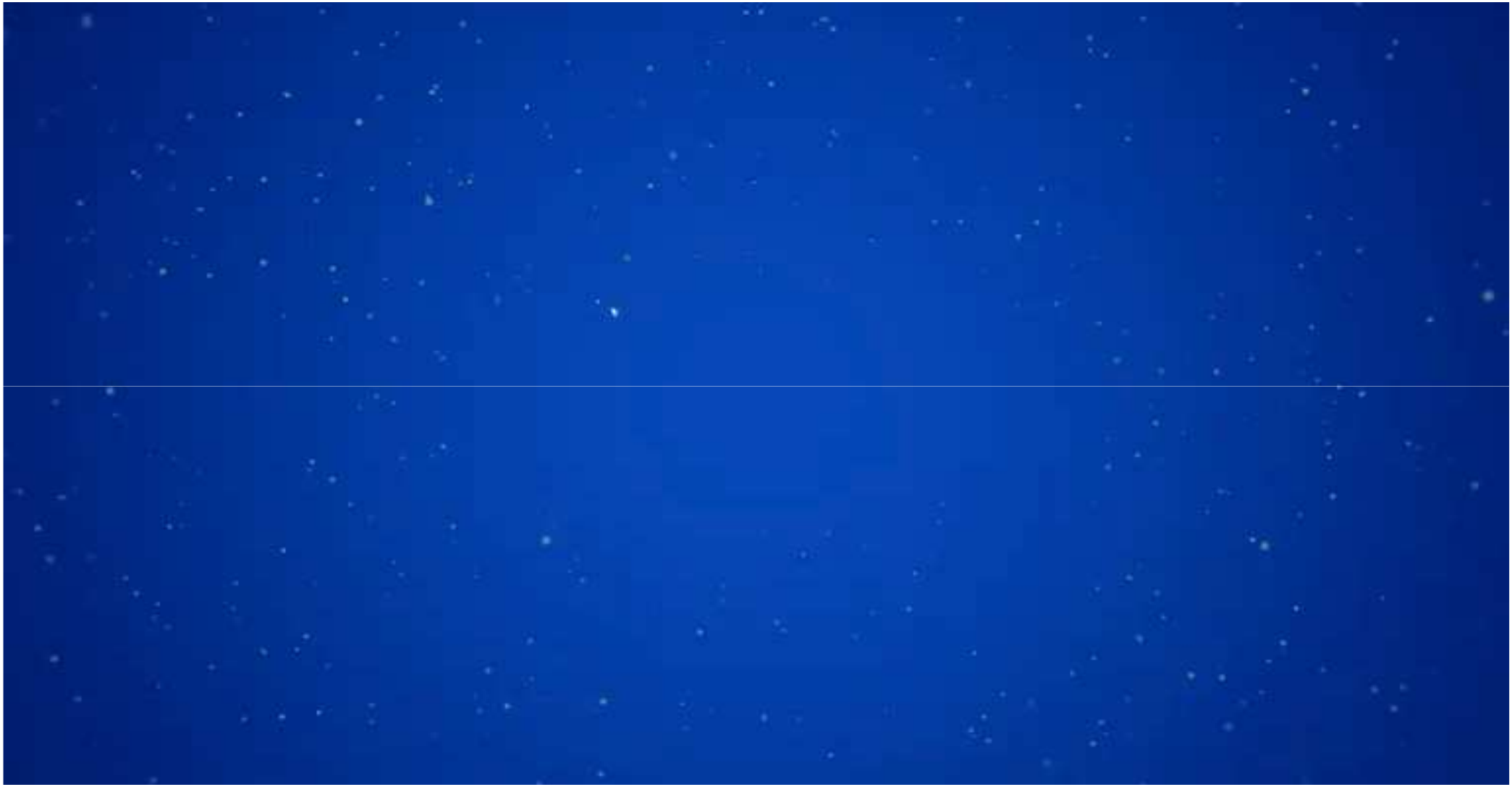
Sentinel-3B: 2017-

The Copernicus Sentinel Deployment Schedule



Status: 22 March 2016

Launch campaign Plesetsk, Russia…



Sentinel-3A Launched 16th February 2016 from Plesetsk, Russia, @17:57 GMT

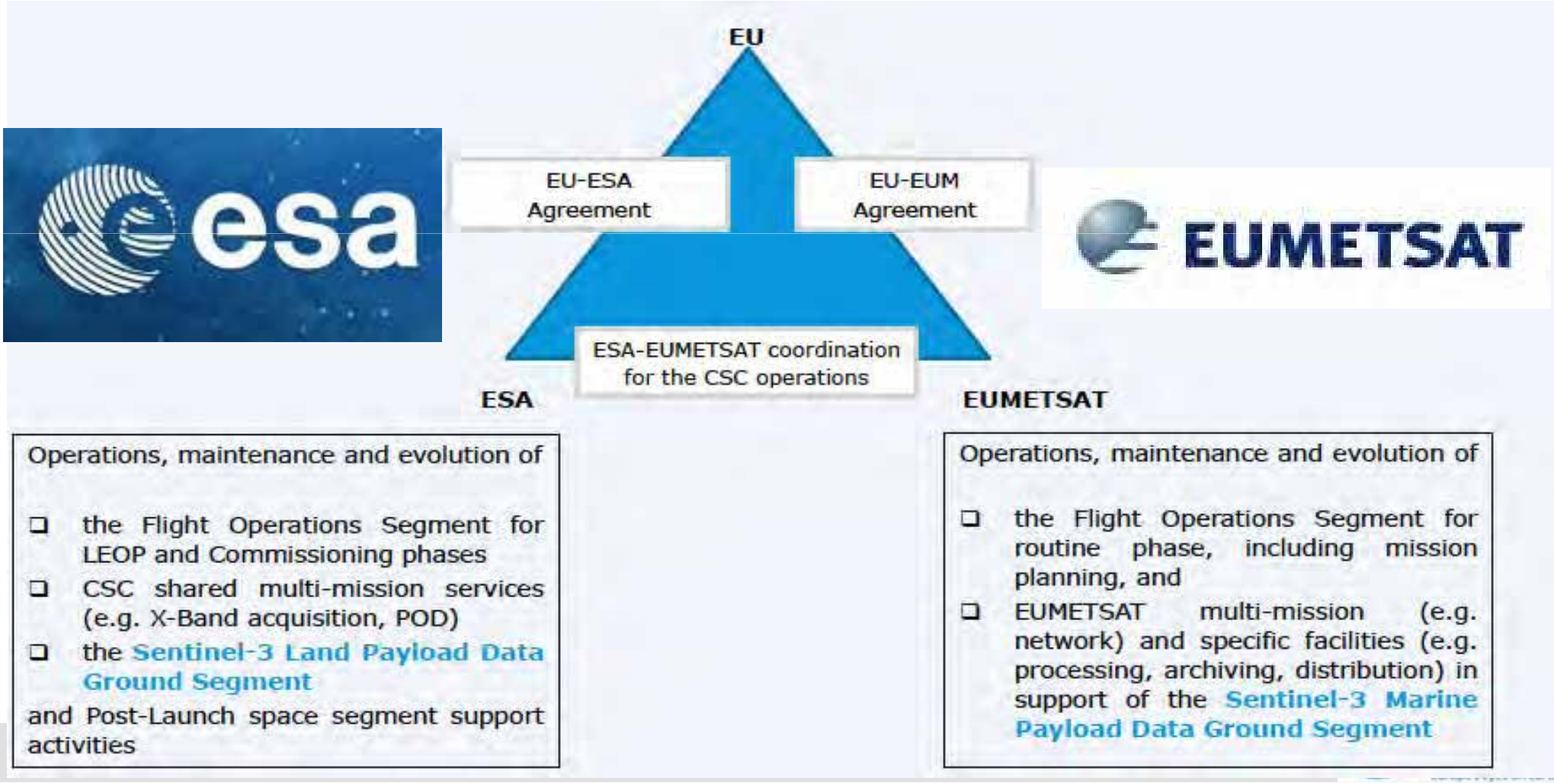
Sentinel-3a launch from Plesetsk Cosmodrome 16th February 2016

(Credit: Antero Isola)

And finally on-orbit…

ESA & EUMETSAT share operations

- **EU Copernicus Regulation**: full, open and free data policy, defining responsibilities for ESA and EUMETSAT and overall financial envelope
- **Dedicated EU-ESA and EU-EUMETSAT Copernicus agreements**



What happened since launch

16 Feb	Successful Launch
October 2016	Release of Level 1 data
Ramp-up phase IOCR+9months	Release of Level 2 data

Sentinel-3A satellite platform and payloads are functionally in very good health

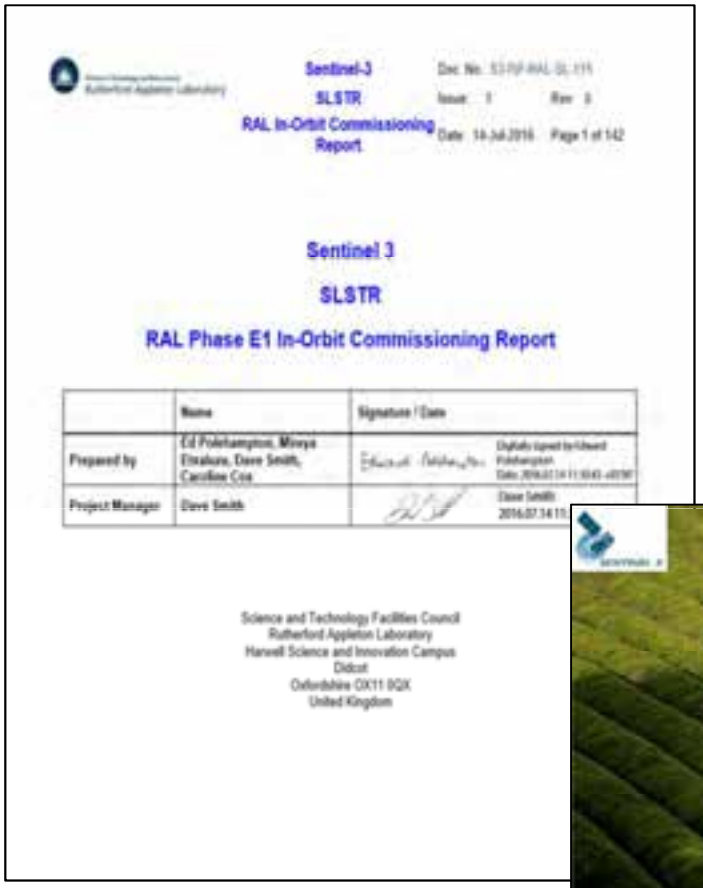
S3-STM Data access to S3VT validation teams and MPC for some time and following feedback reprocessing data now

Official S-3 STM data release "L1A, L1B, L2 WAT & LAN" planned early December 2016 to the international user community.

L1B-S have still to be QC'd before official data release. Planned in Q1 2017.

Payload characterization…

Extensive pre-and post launch performance analysis…

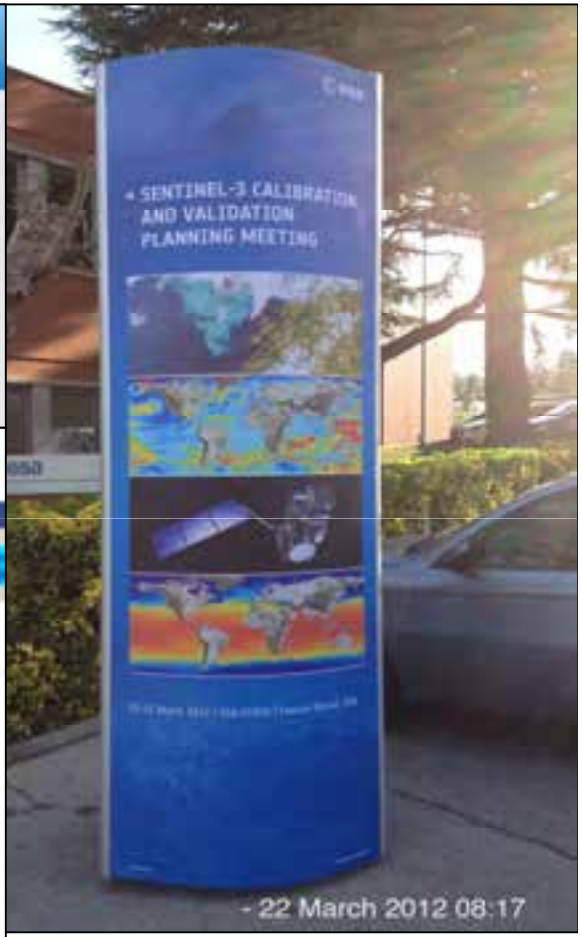

Sentinel-3
SLSTR
RAL In-Orbit Commissioning Report
Sentinel 3
SLSTR
RAL Phase E1 In-Orbit Commissioning Report
Science and Technology Facilities Council
Rutherford Appleton Laboratory
Harwell Science and Innovation Campus
Didcot
Oxfordshire OX11 0QX
United Kingdom


ThalesAlenia Space
Sentinel-3
SRAL Phase E1 verification report
Product Tree Code: 14 000 000

Written by	Responsibility	Date
	Sentinel-3 Topography Mission Manager	
	Documentation Officer	
	SRAL Technical Officer	
	SRAL PA Manager	
	SRAL Project manager	

Operational Core Products - full technical documentation at https://sentinel.esa.int

User interaction and feedback at all levels…



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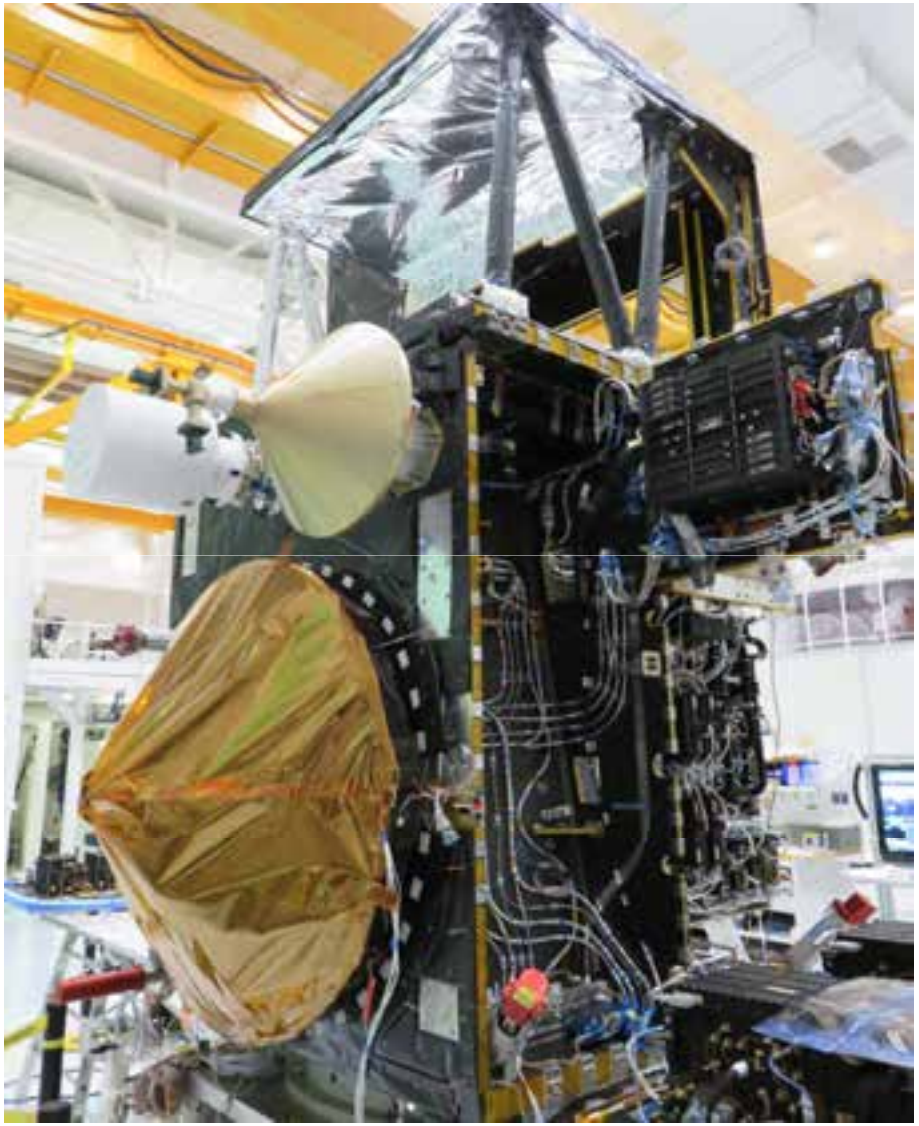
Sentinel-3B: status

- SRAL and PCDU (Power Conditioning and Distribution Unit) panels have been finalised, the SRAL antenna has been integrated onto the platform.
- MWR mechanical/electrical integration to the Satellite is in progress.
- Mechanical and electrical integration of DORIS into Sentinel-3B is in progress
- Sentinel-3B FAR planned for Sept-Oct 2017, still compatible with a launch before end 2017
- Flight Acceptance Review – October 2017
- Launch on Rockot from Plesetsk in late 2017.



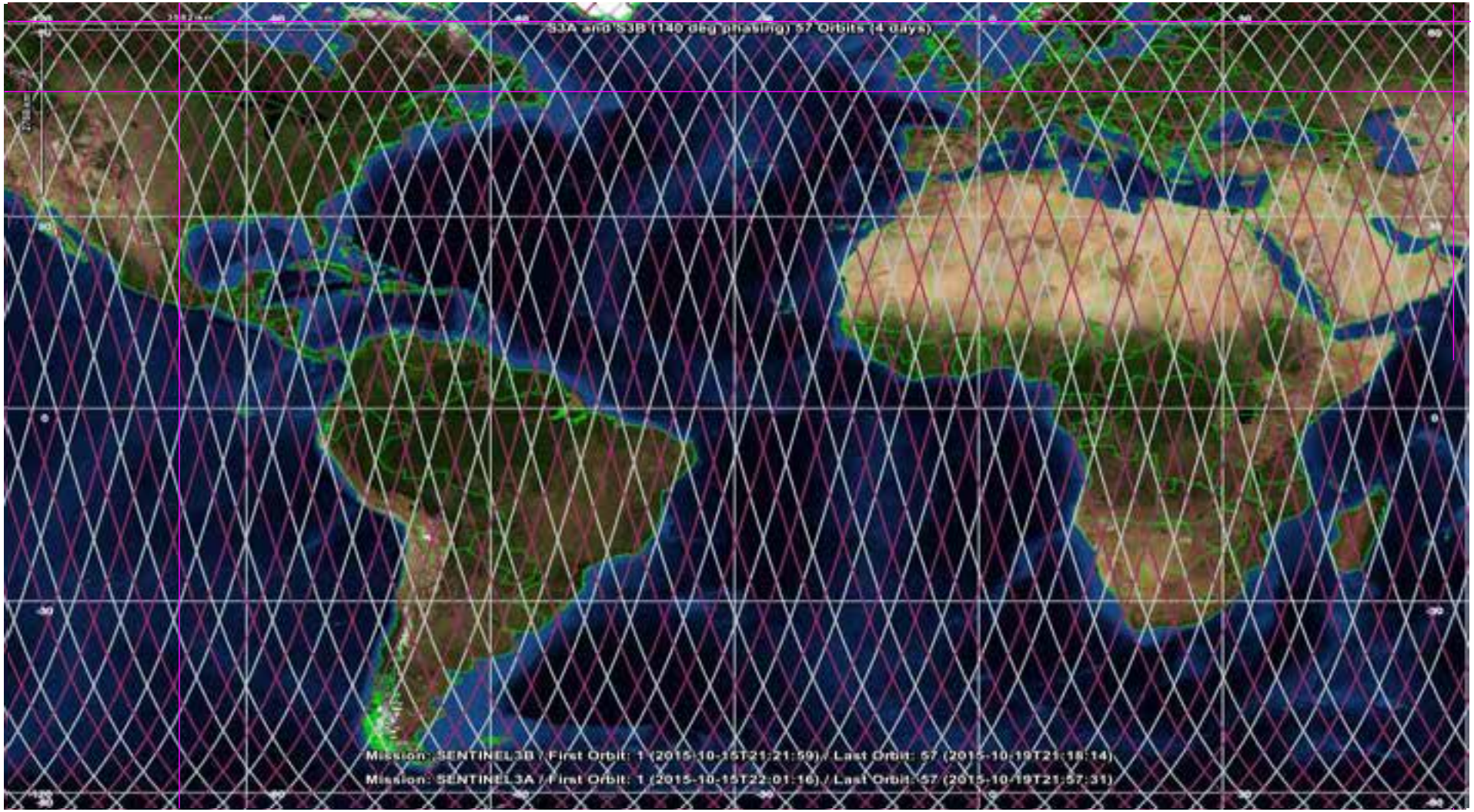
User driven evolution…

- **The science of today become the operations of tomorrow…**
- Several elements of user driven evolution for the S3A mission have emerged and have been addressed:
  - **100% SRAL SAR coverage instead of just coastal zones and sea ice → better SNR**
  - **New products requested including L1A SAR data → Performance Evolution**
  - **Orbit phase optimization for topography mission → better sampling of mesoscale structure**
- Each has been taken up by the EC following user request and extensive technical and programmatic discussions with ESA and EUMETSAT
- **An excellent process has been established to respond effectively and relatively quickly to these large mission changes.**

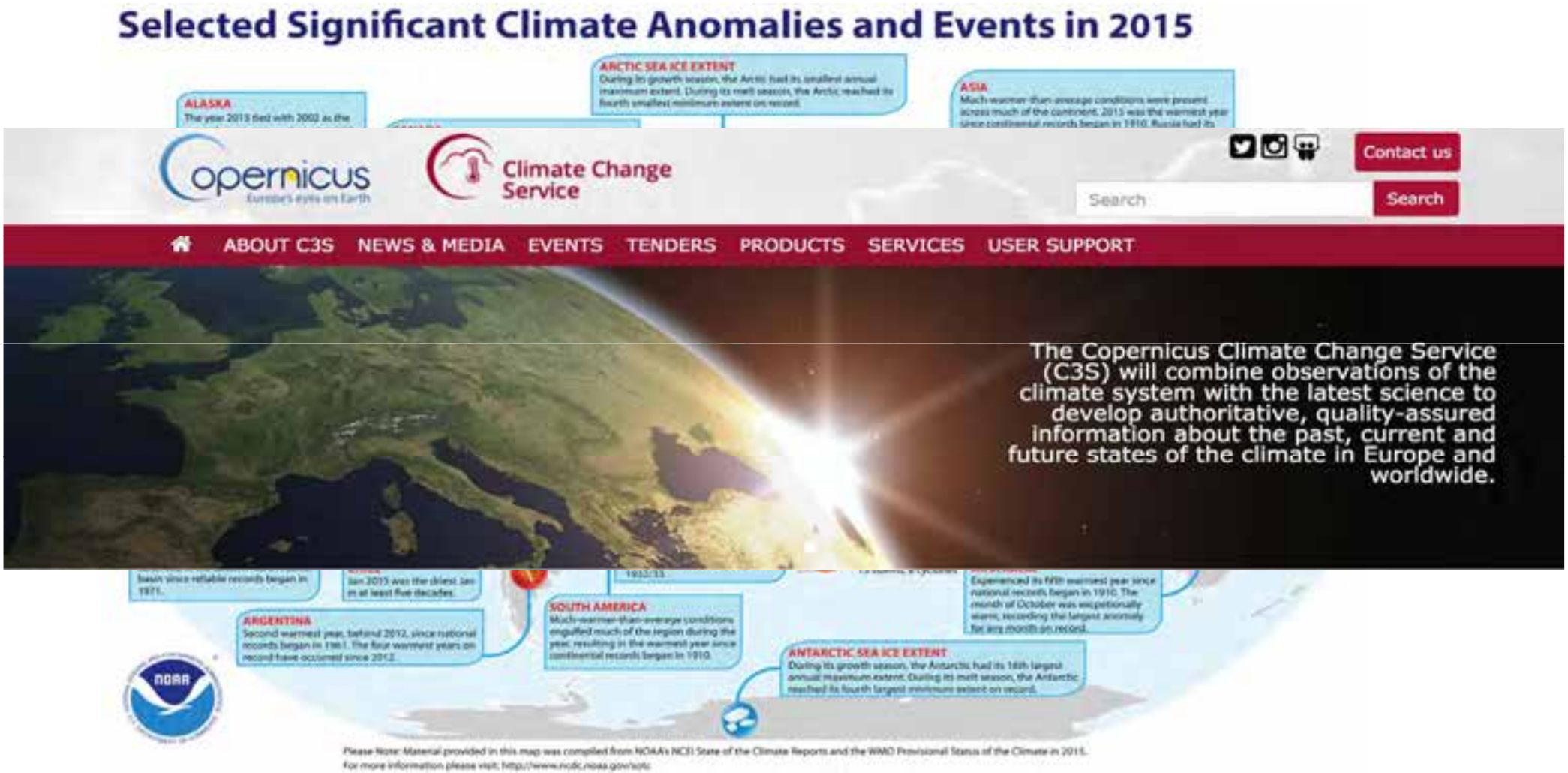
Product Level	Product Description	Relevance for
L1A	Unpacked L0 data processed to engineering parameters with geo-location information	SAR processing specialists allowing fundamental studies on SAR processing such as Doppler beam formation and calibration studies using ground-based Transponders
L1B-S	Geo-located, Calibrated gathered azimuth formed complex (I and Q) power echoes after slant/Doppler range correction	geophysical retrieval algorithm developers (over ocean, land and ice surfaces), surface characterisations studies (e.g. impact of sea state bias, wave directional effects etc) and QC systems
L1B	Geo-located, Calibrated Multi-looked power waveforms	geophysical retrieval algorithm developers and QC systems

Open Source Delay Doppler Altimeter Studio (DeDop) tool http://www.dedop.org

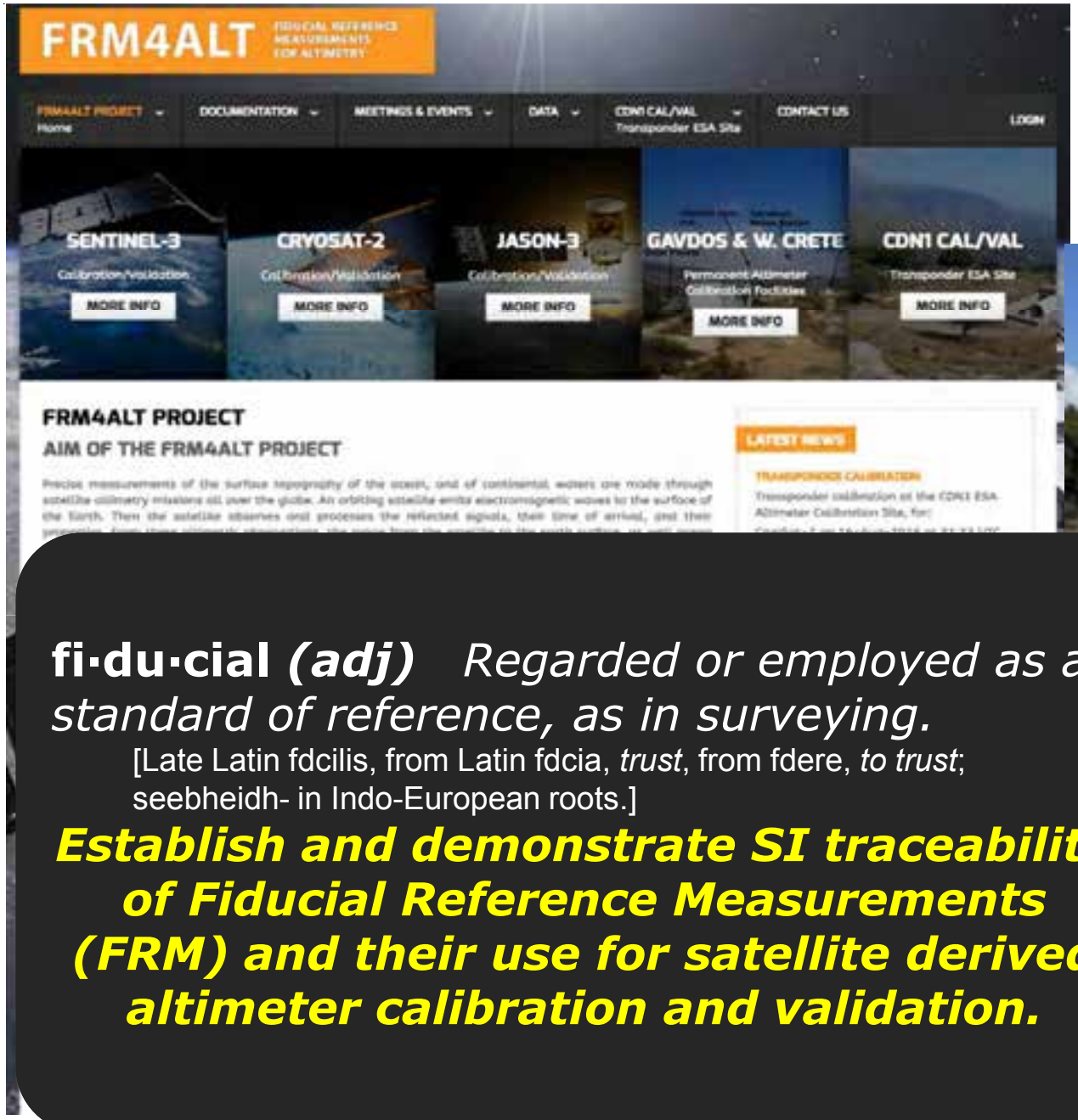
Optimising the Constellation: Sentinel-3B phasing to 140° (instead of 180°) after 4 days



S3 also responds to the *NEW* C3S climate service…



http://www.ncdc.noaa.gov/sotc/service/global/extremes/201513.gif



EUMETSAT esa

http://www.frm4alt.eu

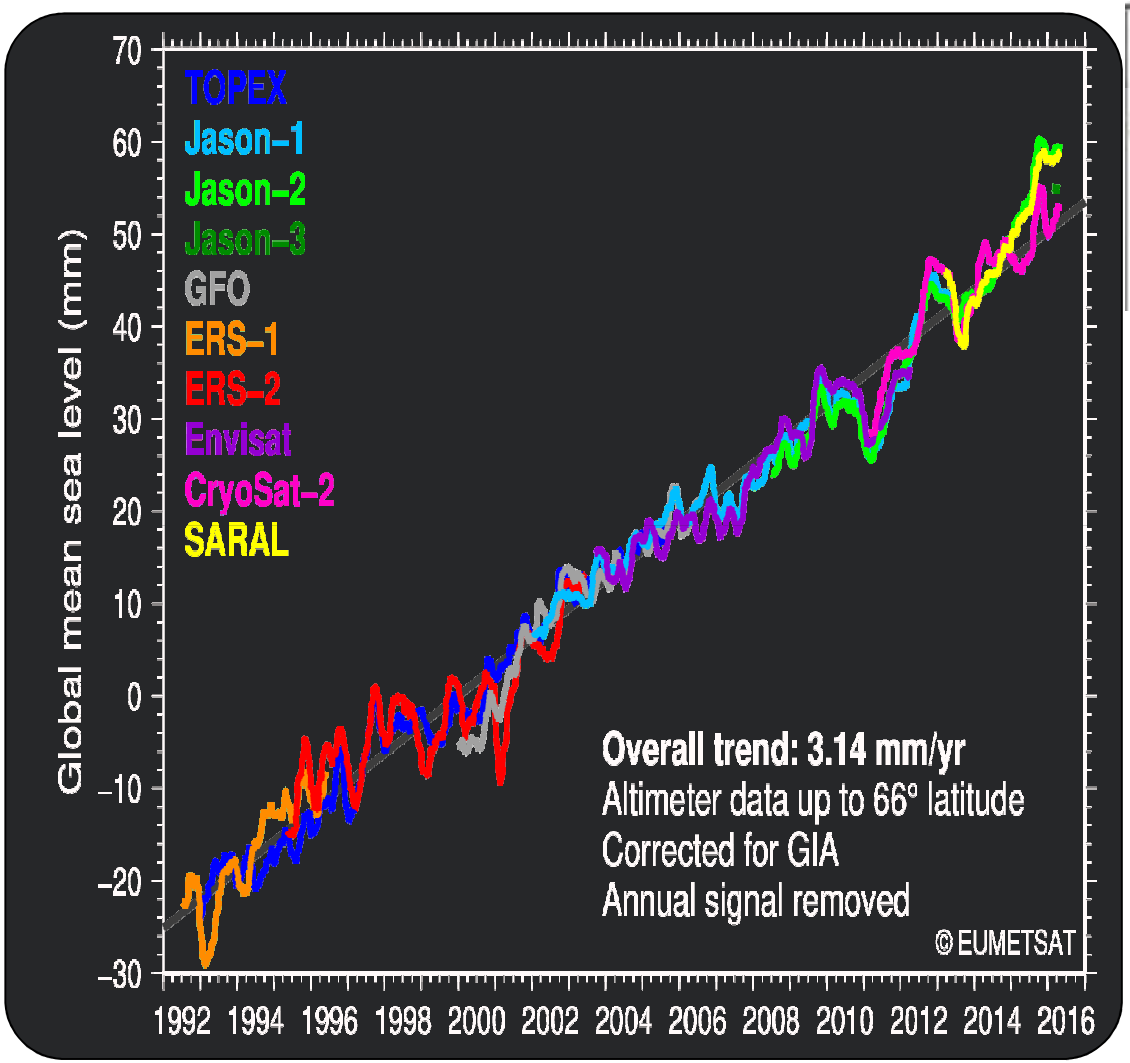
fi·du·cial *(adj)* *Regarded or employed as a standard of reference, as in surveying.*

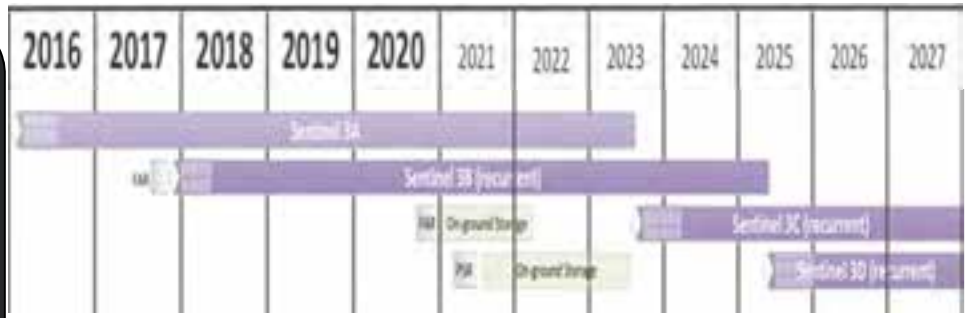
[Late Latin fdcilis, from Latin fdcia, *trust*, from fdere, *to trust*; seebheidh- in Indo-European roots.]

Establish and demonstrate SI traceability of Fiducial Reference Measurements (FRM) and their use for satellite derived altimeter calibration and validation.

Copernicus Europe's eyes on Earth

Multi-satellite Climate data Records





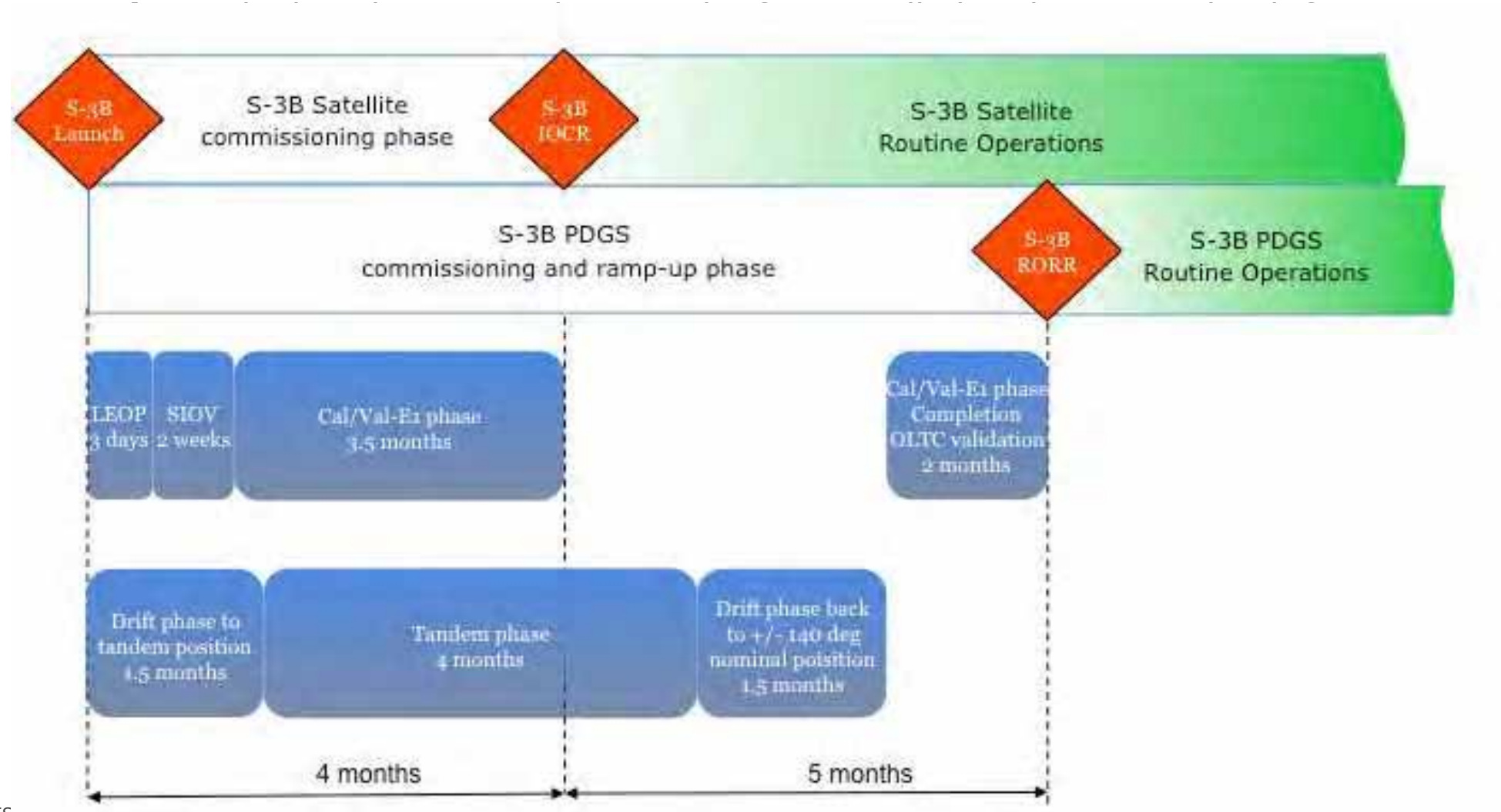
- **The S3 mission includes 4 satellites**
- Even though S3A and S3B are practically identical in design, ***it is anticipated that differences in performance of payload instruments will exist***
- It is essential that **relative (absolute) bias between S3A/B/C/D instruments are known properly** for Climate Data Record construction

S3 cross-satellite calibration (linking error): S3A/B Tandem flight feasibility

- There is a significant correlation between **end-to-end mission measurement uncertainties**:
  - Uncertainty due to geophysical **ocean space and time variability** (especially in regions dominated by mesoscale structure, 1-10 days, <10-50 km)
  - Uncertainty due to **atmospheric space and time variability**

- **A tandem phase** for the S3 Mission was studied at PDR
- **Flying S3A and S3B close (eg. 30s) on the same ground track (+/- 1km) together minimizes both of these aspects and maximizes the correlation between mission measurement errors**
- **GCOS Satellite Climate Monitoring Principles** (GCMP) requests a tandem flight for all satellite instruments
- This is **exactly the approach adopted routinely by the JASON altimeter time series** and stabilizes the Sea Level data set (S3 uses a transponder for range but not sigma-0)
- Exploratory studies to investigate the possibility of a limited duration (3-6 month) calibration tandem between S3A and S3B during Phase E1 would verify feasibility

Potential (not yet agreed) approach to a limited duration S3 Tandem phase during Phase-E1



Conclusions

- **Successful launch of Sentinel-3A on 16th February 2016**
- **Satellite and payload is stable and fully commissioned**
- **All ground segment facilities supporting Sentinel-3** are being commissioned both at ESA and EUMETSAT to full operations
- **Validation activities are well advanced and dedicated projects are in place to develop a culture of FRM validation.**
- **Sentinel-3B Satellite integration well advanced**. On track for a launch in late 2017.
- **Contract signed with Thales Alenia Space to build Sentinel-3C and -3D Satellites on 9th February 2016**
  - Delivery of the C and D models by end 2021, well in advance compared to the predicted lifetime of the A and B models (7 years min from start of operations)
- **With the inclusion of the C and D models to the fleet of Sentinel-3 satellite, mission continuity is ensured for at least 25 years from the launch of the first Satellite**
- **Today we will see many talks and posters on the the early results and performance of the S3A-STM…starting with Francios Boy!**


Thank You – any Questions
Contact: Craig.Donlon@esa.int

Sentinel-3 Phase E1 Results

La Rochelle – France

31 October 2016

cnes esa ThalesAlenia Space CLS COLLECTE LOCALISATION SATELLITES NOVELTIS LEGOS

Sentinel-3 Phase E1

Phase E1 = 5 months after launch

SRAL Swith-on: March, 1st

First week after Switch-On

↓

Functionnal and verification tests:

- Specific sequence to cover all data acquisition modes (LRM & SAR, CL & OL)
- CAL1/CAL2 sequences over 3 orbits to conduct a detailed calibration analysis by TAS

↓

Cycle 1 (partial) and Cycle 2

LRM Closed-loop:

- With a SAR CL mode acquisition box over Pacific Ocean to analyse the continuity between SAR Mode and LRM

↓

Cycle 3: from April, 16th, 2016

Nominal scenario: 100% SAR Mode coverage

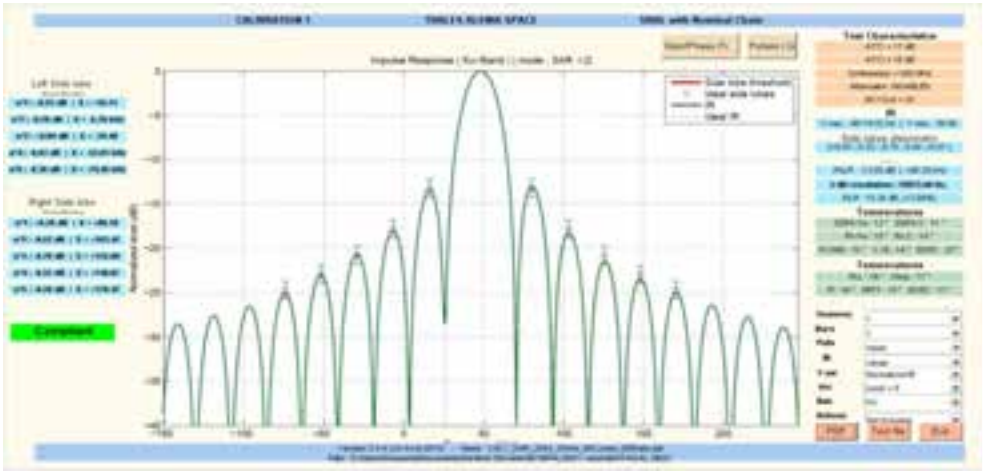
- SAR Open-Loop over ocean, coastal areas,

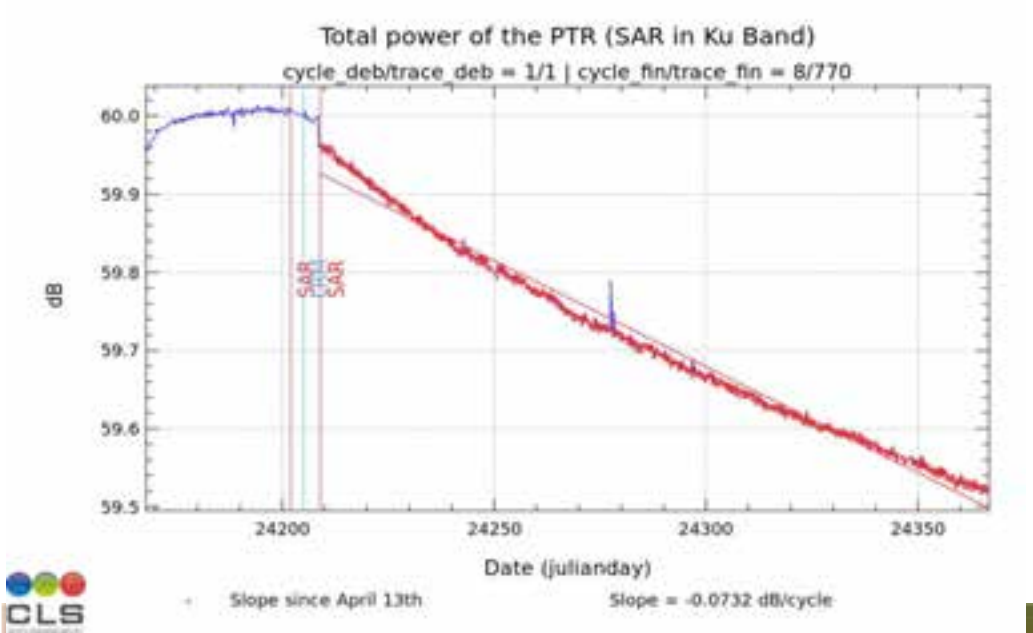
Antarctica and Arctic margins, inland waters over steep regions

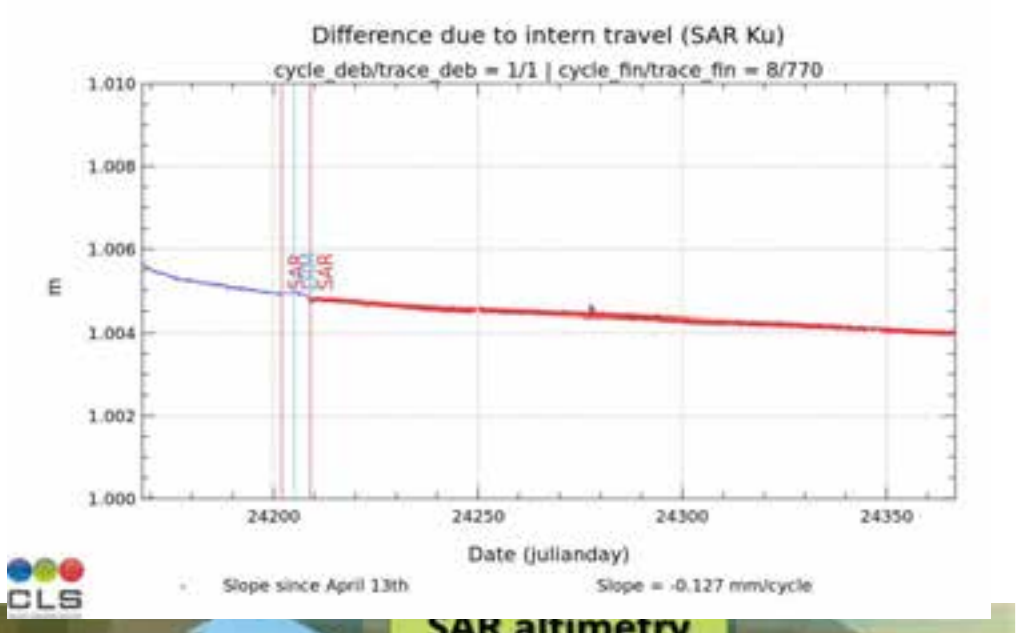
- SAR Closed-Loop elsewhere

SRAL Monitoring

- All T°, V, power consumption are nominal
- LRM & SARM SNR in line with requirements.
- Tracking Commands (gain and range) behave as expected
- Nominal CAL1 SAR Ku (and C)
  - Very stable Internal Path Delay, phase and gain variation
  - PTR Total Power decreases with a 0,06dB/cycle slope
- Nominal CAL2



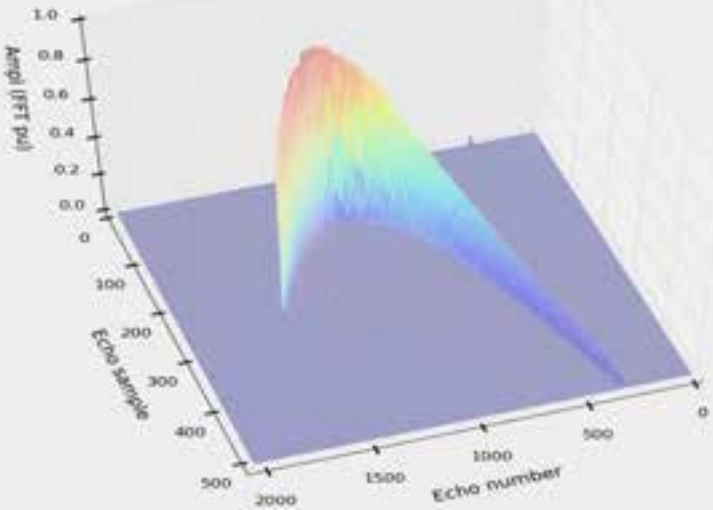




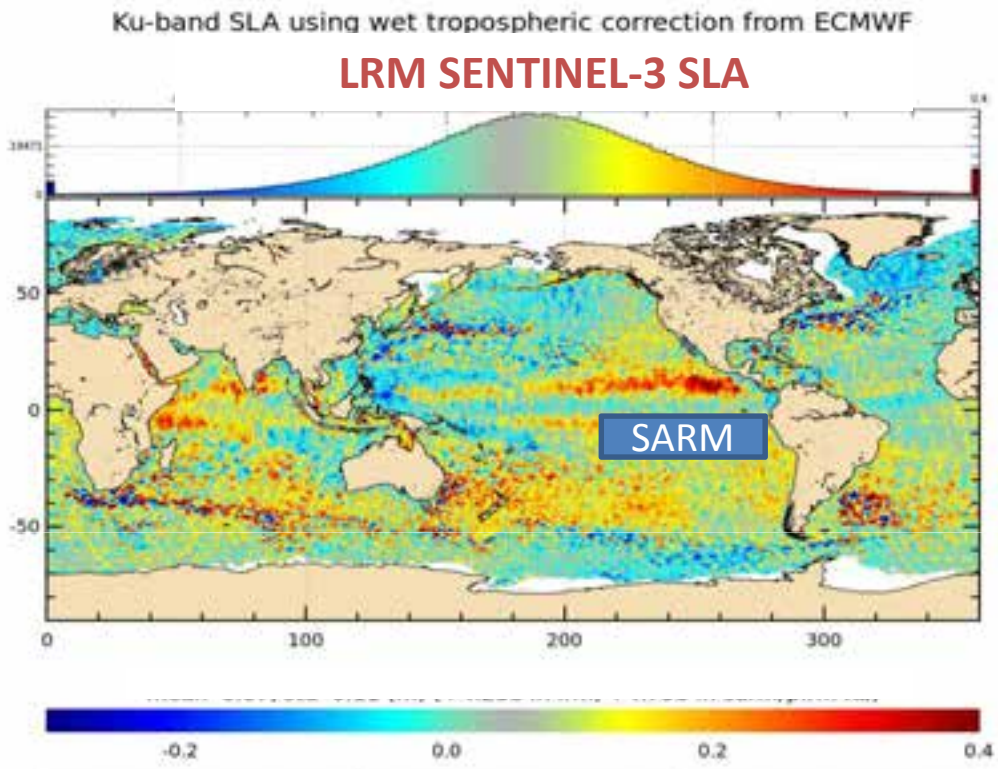
Transponder Calibration

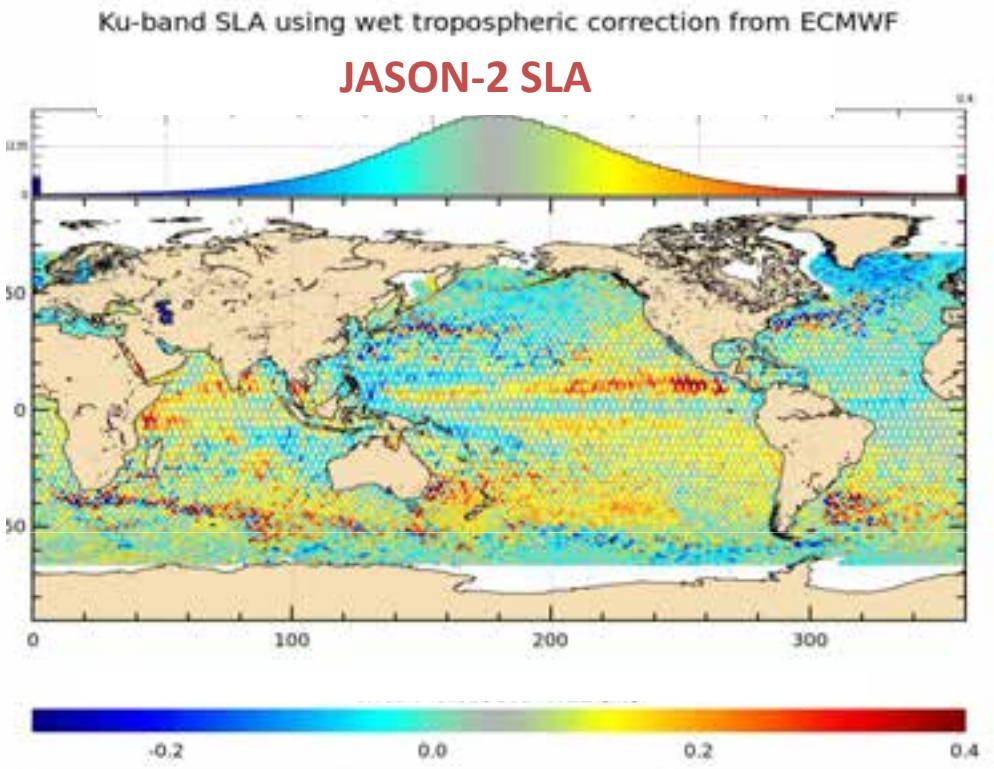
- Ku-Band Transponder developed by the TUC (Technological University of Crete) and GeoMatLab.
- Installed in Crete on a S3A, S3B, Jason-2/3 crossover points.
- First overflights give promising results:
  - Clean echoes during acquisitions
  - Good bias stability over the 7 passes
  - SRAL Range bias
    - -10,5cm in SARM (minus means too long)
    - -12,3cm in PLRM
  - Absolute bias not in line with in-situ CALVAL results (refer P. Bonnefond SAW presentation) – To be investigate

SRAL echoes over the transponder



LRM Performances over ocean

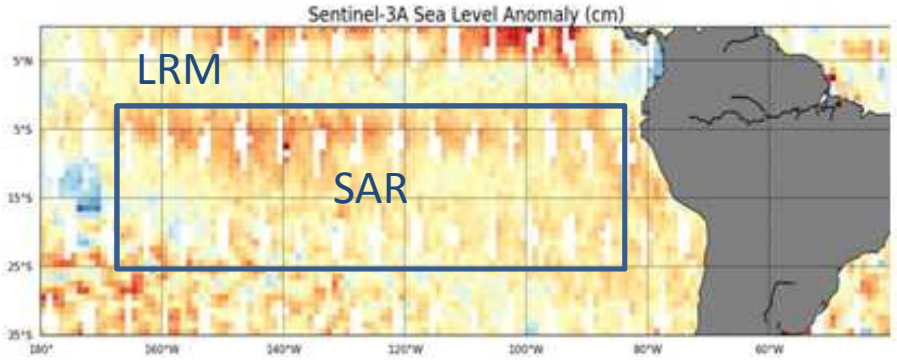


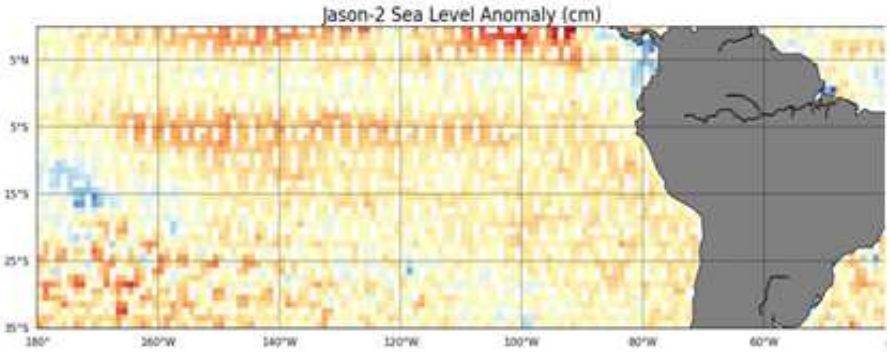


- **Excellent agreement between Sentinel-3a and Jason-2 Sea Level Anomaly and SWH (not shown)**

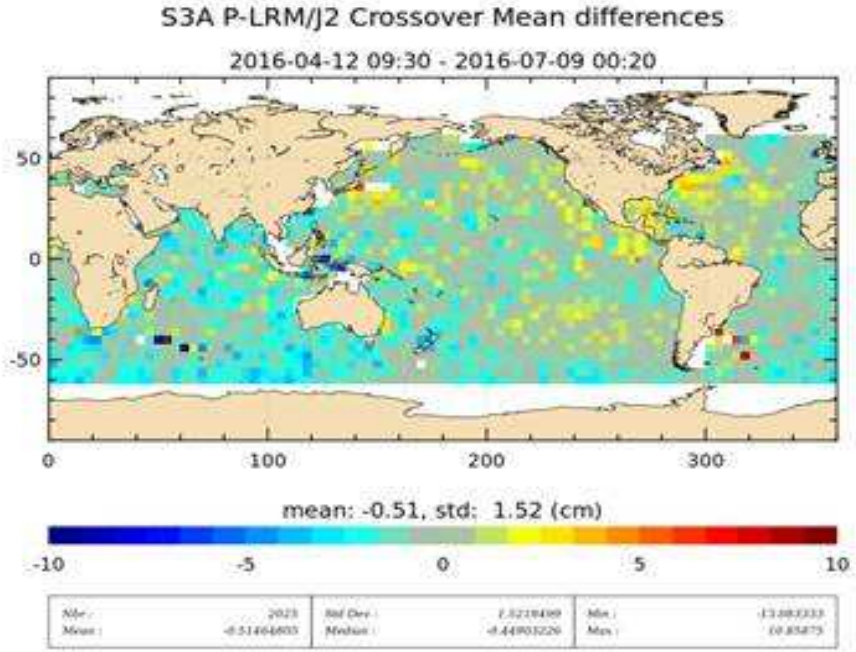
- **Same level of performances than J2/J3 (@SWH=2m)**
  - **Range @1Hz = 1,45 cm RMS**
  - **SWH @1Hz = 11 cm RMS**

LRM to SARM continuity





& PLRM Validation

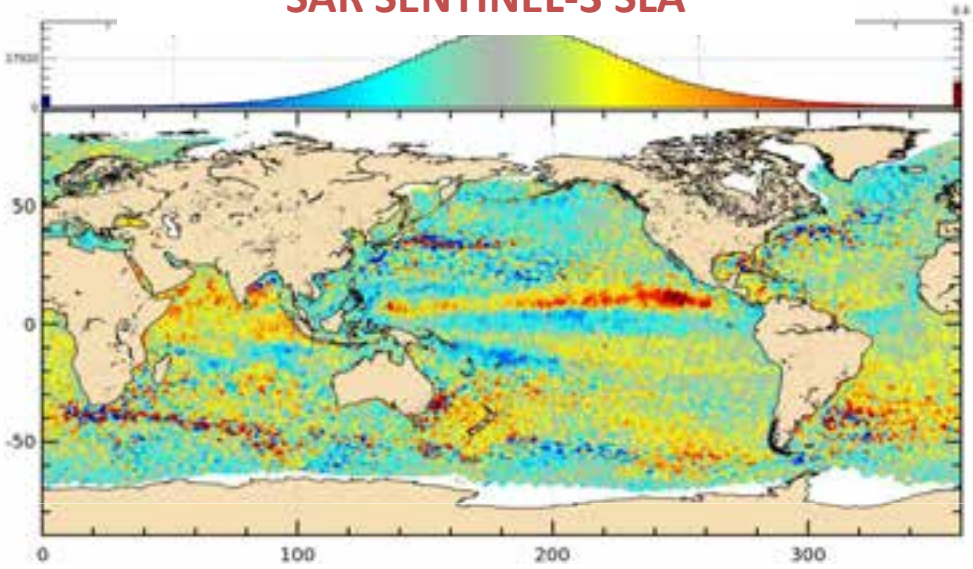


- **Seamless transition between SARM and LRM over the pacific box**
- **PLRM fully validated using several diagnoses (PLRM/LRM continuity , mono&multi-mission Xover)**
  Reference to calibrate and validate SARM

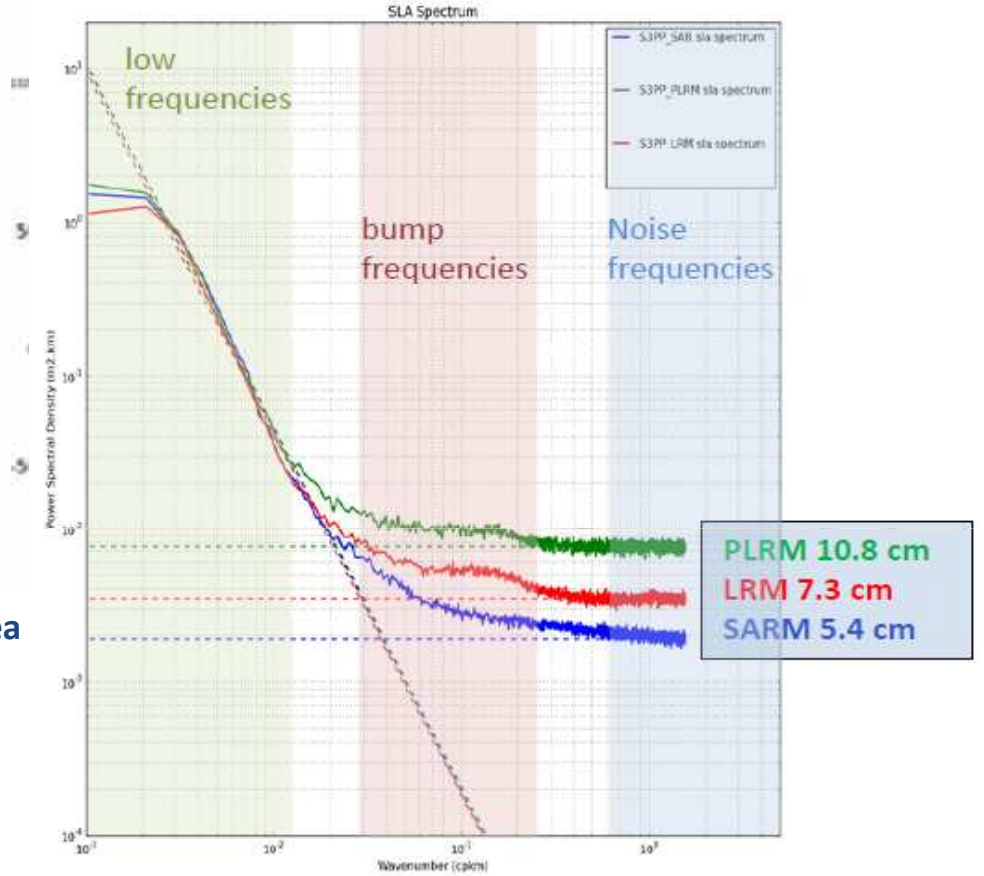
SARM Performances over ocean

Ku-band SLA using wet tropospheric correction from ECMWF

SAR SENTINEL-3 SLA



Ku-band SLA using radiometer



- **Excellent agreement between S3a SARM and Jason-2 Sea**

- **Same level of performances than Cryosat-2**
  - **Range @1Hz = 1,1 cm RMS**
  - **SWH @1Hz = 9cm RMS**
  - **Clean SLA/SWH spectra**

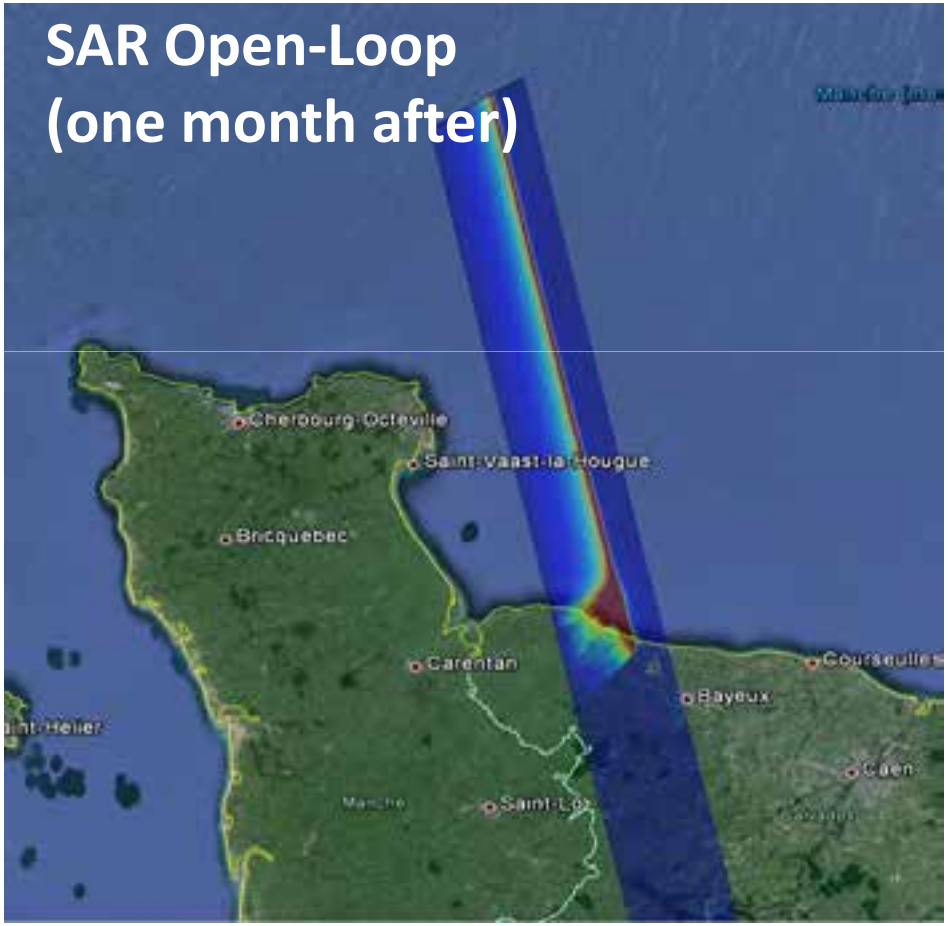
Sentinel-3a Delay Doppler Processing: Assessment over the Global Ocean. (M.Raynal, SAR Workshop)
Results over ocean of the SAR Mode processing in Sentinel-3A Products (S. Labroue, SAR Workshop)

- **SAR Sensitivity to swell conditions have been identified and a first assessment is provided**:

Does Swell Impacts Wave Height Measurements from SAR altimetry (S. Abdalla, SAR Workshop)
Effects of swell on the altimeter-derived estimates: analyzing real and simulated data (T. Moreau, OSTST/Error Session/Thursday morning)

Acquisition approaching the coast

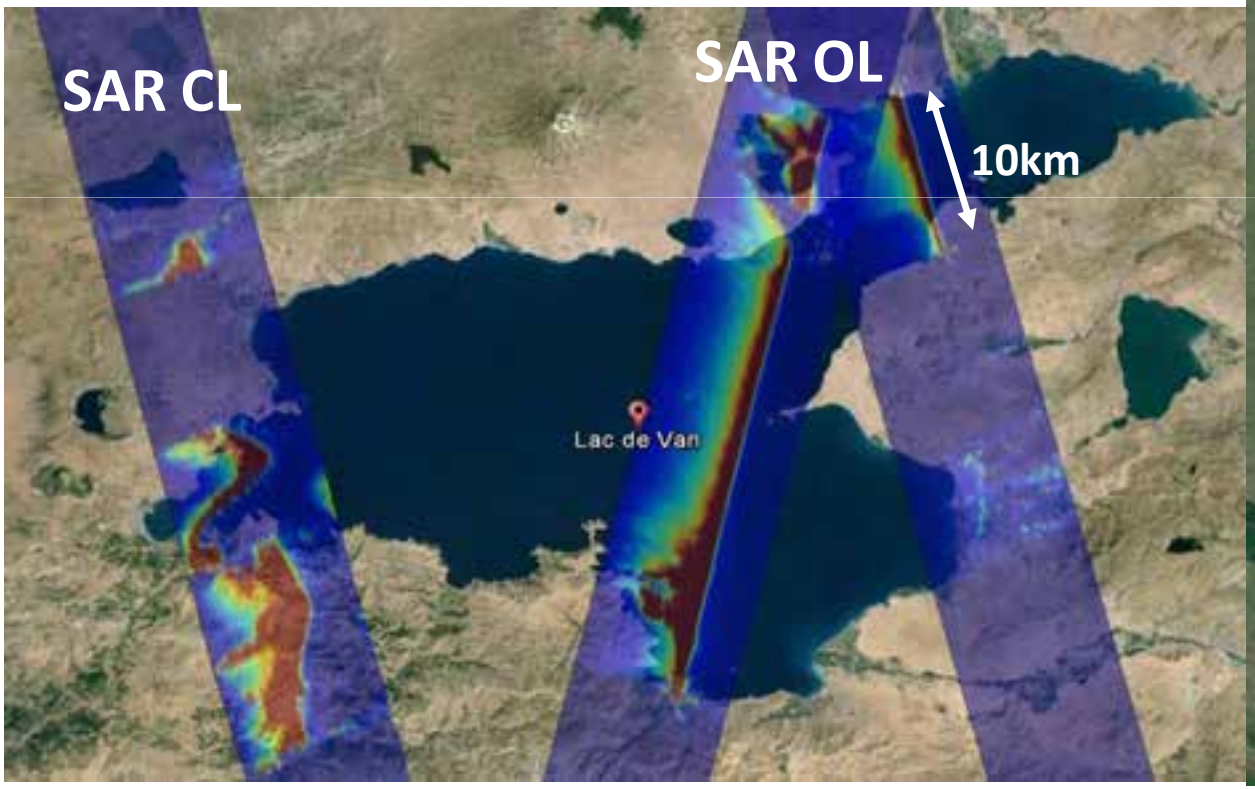
SRAL Altimeter, using **SAR Mode** driven with the **Open-loop tracking mode** provides measurements **closer to the coast**

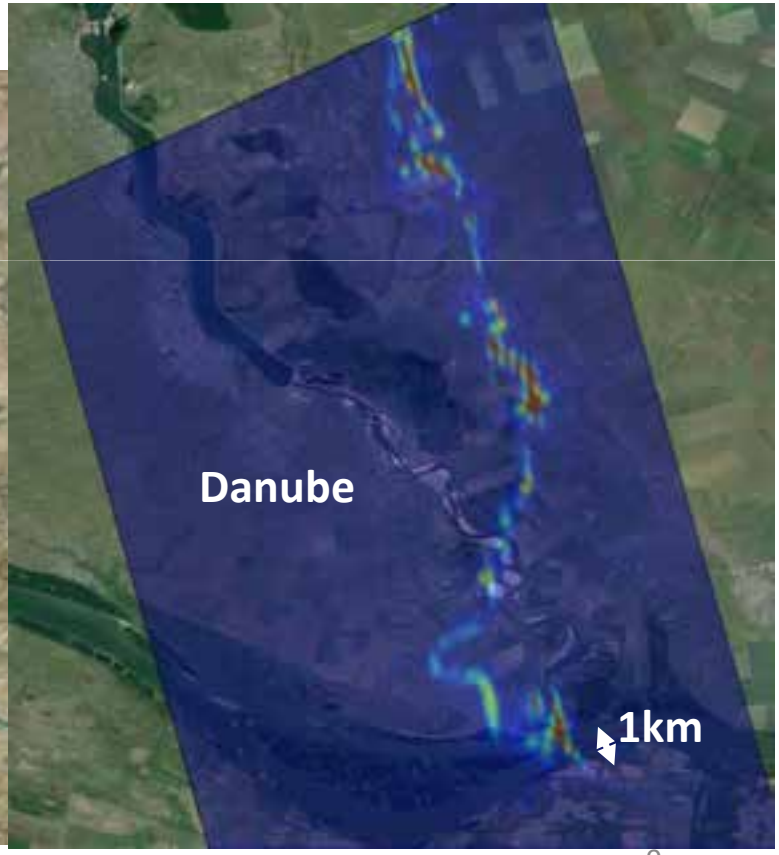


Acquisitions over in-land waters

- **SAR Open-Loop** over rivers and lakes gives better measurements (where SAR CL sometimes failed or is disturbed by surrounding relief)

- **Requires an accurate a-priori elevation** information to build the **on-board DEM** (Hydroweb, GLWD database, …)



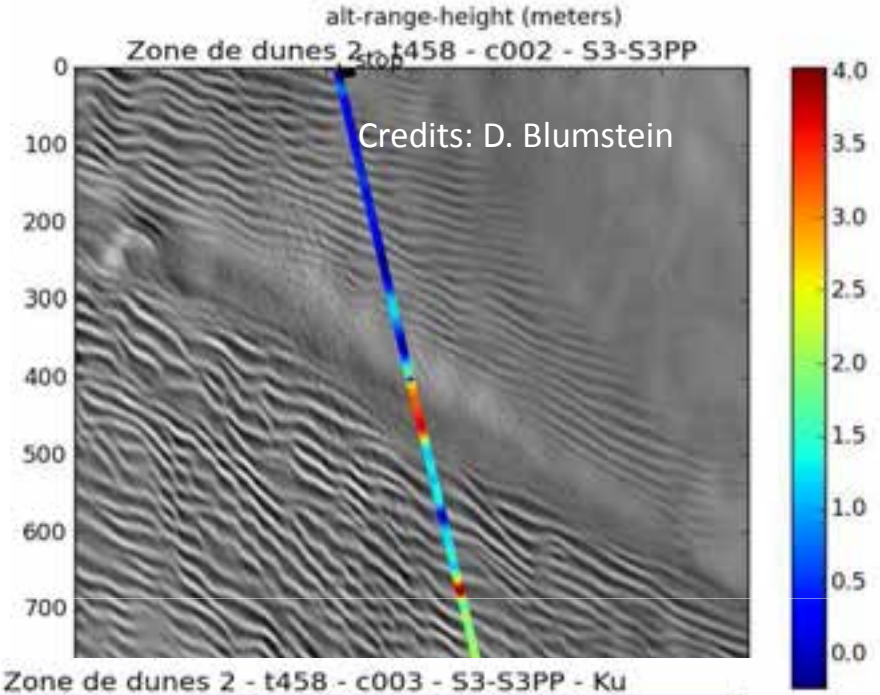


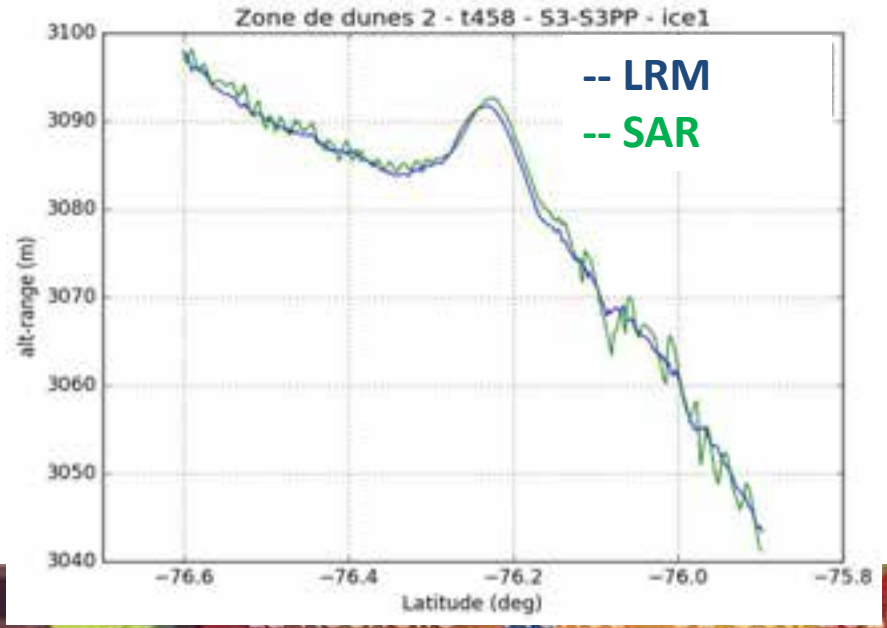
Acquisitions over Land Ice

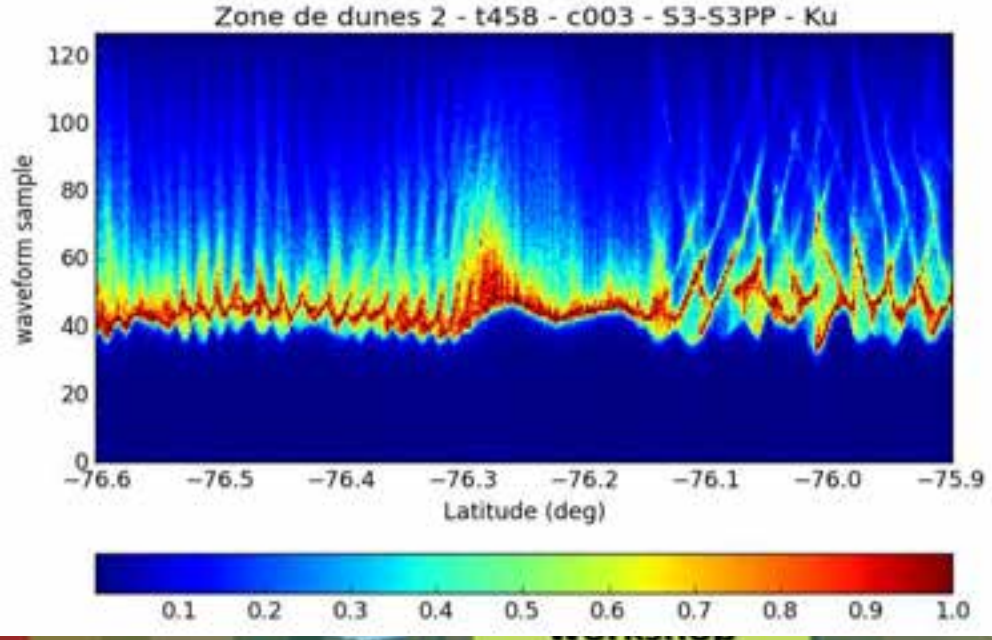
- **First results confirm observations from CryoSat-2**
- **SAR mode strongly improve the quality and the resolution of ice elevation computation.**

SAR-mode altimetry performance over the Antarctic ice sheet (J. Aublanc)

- **OLTC commands not accurate enough over the margins. Switch back to closed-loop commanding over land ice in the coming weeks.**







Conclusion

Sentinel-3 SRAL altimeter is operating nominally 100% in SAR Mode

Very high quality measurements are already provided over ocean:

- **LRM performances** over ocean are comparable to **Jason-2&3**
- **SARM performances** are in line with expectations and with **Cryosat-2 experience:**
  - **Lower noise in SLA and SWH**
  - **Clean SLA and SWH Spectra (no hump)**

Over all surfaces, SARM will open new perspectives, providing high resolution data.

A lot of results from the Sentinel-3 mission already presented today by the user experts at the SAR Altimetry Workshop

Altimetry Satellites Constellation