COPERNICUS POD SERVICE

GLOBAL MONITORING FOR ENVIRONMENT AND SECURITY

SENTINEL-3 CPOD SERVICE

POD OF SENTINEL-3A AND PREPARATIONS FOR SENTINEL-3B

S3VT Meeting 2018, 13 – 15 March; EUMETSAT, Darmstadt

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AGENDA

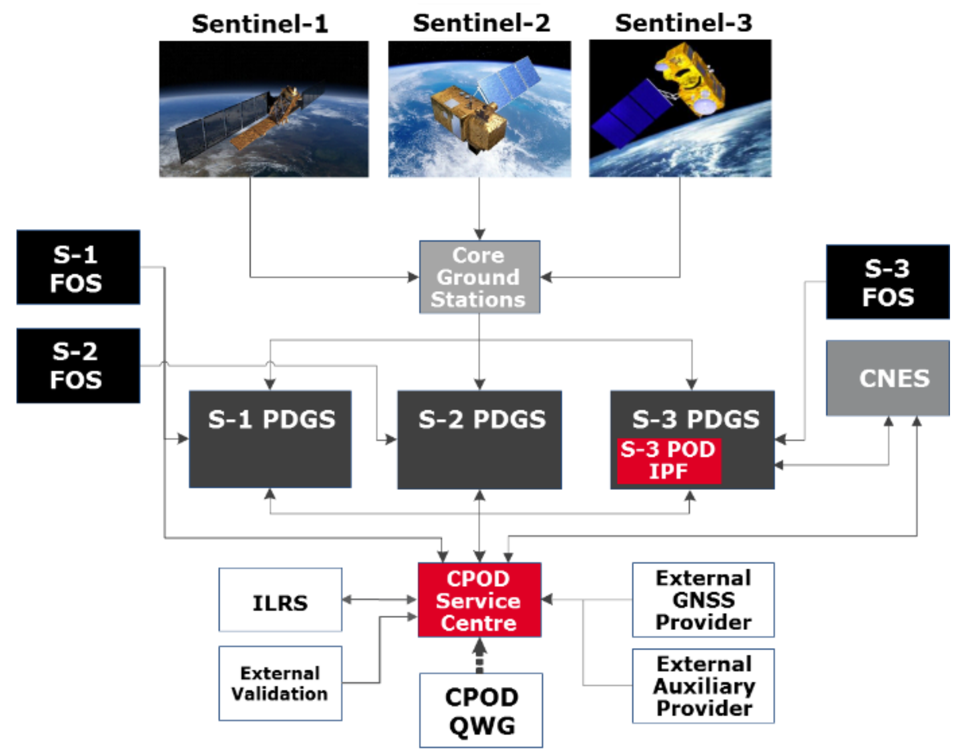
- Overview of Copernicus POD Service
- Overview of Sentinel-3 POD sensors and requirements

- Methods to assess the orbital accuracy
- S-3 orbital accuracy assessment of CPOD products

- Future steps to improve accuracy
- S-3B preparations

OVERVIEW OF COPERNICUS POD SERVICE

- **Payload Data Ground Segment (PDGS):**
  - Processing the scientific data
  - Provider of GPS and attitude data to the CPOD Service
  - User of the orbits and platform files from the CPOD Service
- **Sentinels Flight Operations Segment (FOS):**
  - Orbits, manoeuvre and satellite mass evolution
  - ESOC for S1 and S2; EUMETSAT for S3
- **Centre National d'Études Spatiales (CNES):**
  - S-3 orbital and attitude products, DORIS data
- **ILRS - SLR data provider:**
  - International Laser Ranging Service –ILRS- centres
- **External Validation:**
  - AIUB, CNES, DLR, ESOC, TU Delft, TUM, EUM, CLS, (JPL)
  - provision of independent orbital products
- **External GNSS data Provider (EGP):**
  - VERIPOS; provider of high accurate GPS orbits and clocks products
  - ***magicGNSS***: in-house back-up GPS provider
- **External Auxiliary providers:**
  - Atmospheric gravity models, EOPS and leap seconds, etc.
- **CPOD Quality Working Group (CPOD QWG):**
  - Monitoring the quality of CPOD products
  - Definition of enhancements (algorithms, standards, etc.)

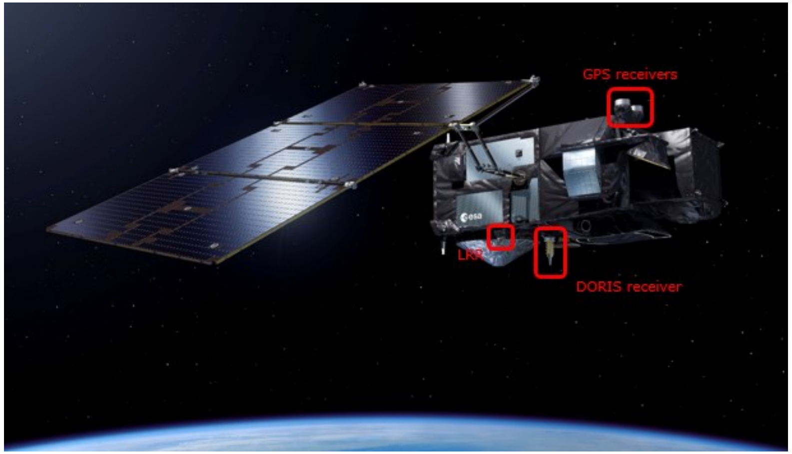


S-3 PDGS

Marine Centre (EUMETSAT)
Land Centre (Svalbard/ESA)

OVERVIEW OF S-3 POD SENSORS AND REQUIREMENTS

- 814.5 km / 98.65 deg. / 1250 kg
- 2 dual frequency **GPS** receivers
- A **DORIS** receiver
- A Laser Retro-Reflector (**LRR**)



SENTINEL-3 Payloads (Credit: ESA)

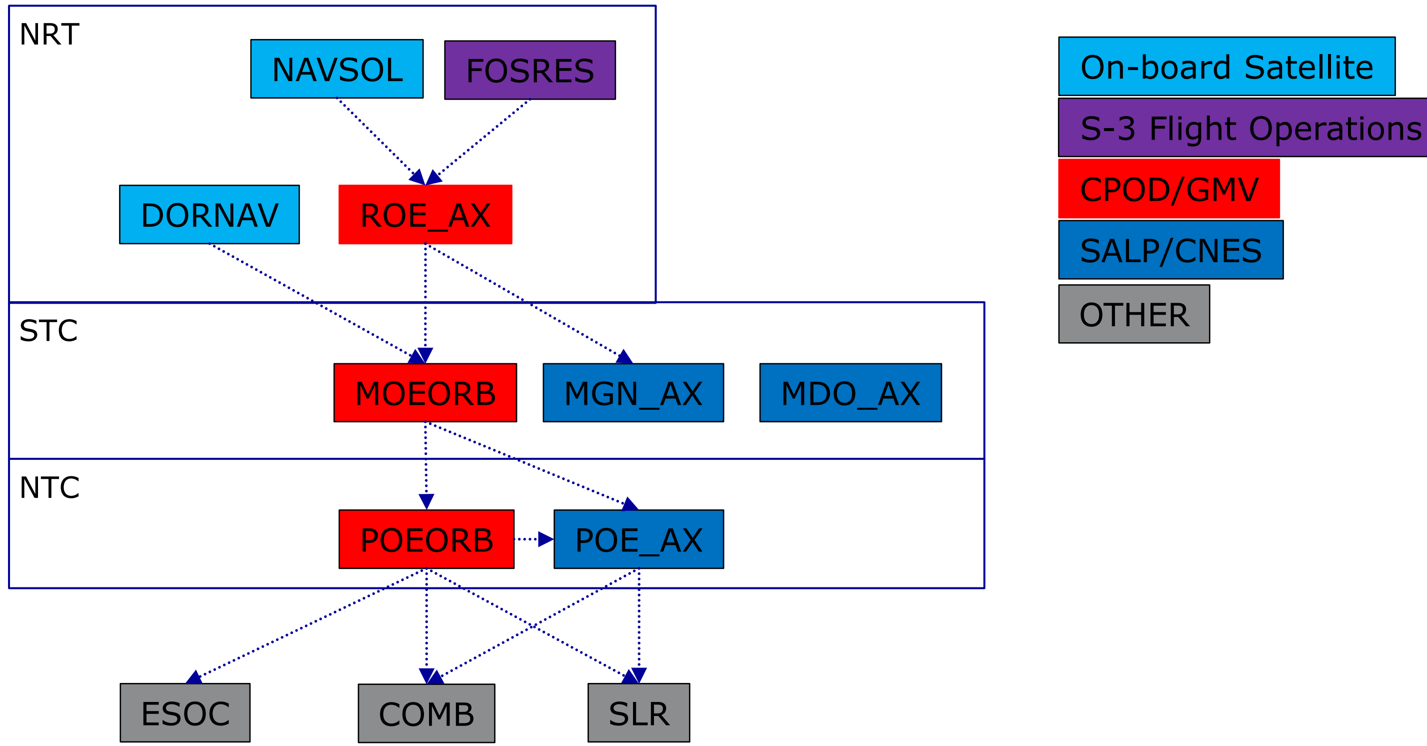
REQUIREMENTS OF POD PRODUCTS			
Category	**Latency**	**Orbit Accuracy**	**SOLUTIONS**
RT	RT	N/A	DORIS on-board Navigation solution GPS on-board Navigation solution
NRT	30 min	10 cm radial RMS 1-sigma (target of 8 cm)	CPOD (@ Marine and Land PDGS)
STC	1.5 days	4 cm radial RMS 1-sigma (target of 3 cm)	CPOD (@ GMV) CNES
NTC	25 days	3 cm radial RMS 1-sigma (target of 2 cm)	CPOD (@ GMV) CNES

METHODS TO ASSESS ORBITAL ACCURACY

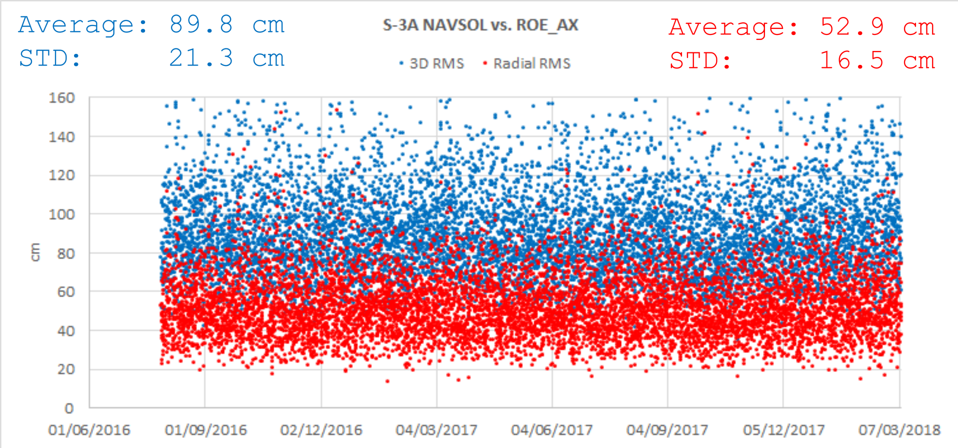
- Direct comparison between two orbits computed independently (different SW, processing scheme, etc.)
  - It provides consistency between methods
- Analysis of SLR residuals
  - It provides an external, independent, assessment

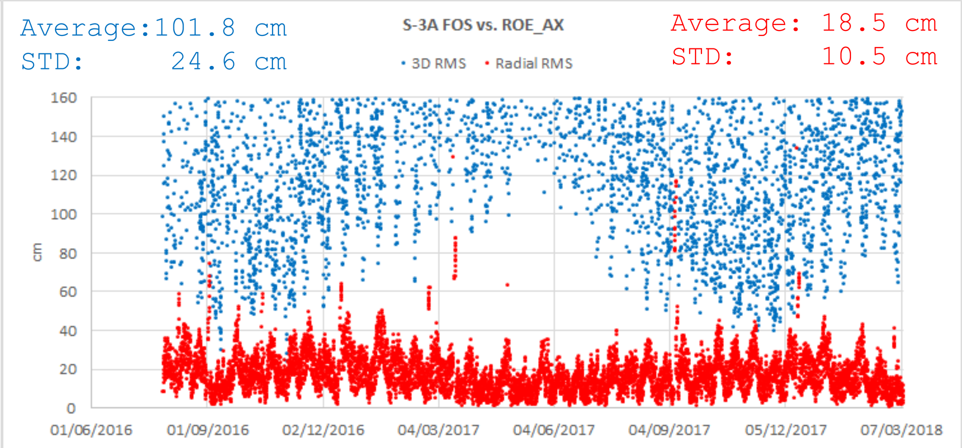
- Overlaps comparisons between consecutive orbits
- Analysis of residual
- Covariance analysis
- Cross-overs analysis (S-3)
- InSAR analysis (S-1)

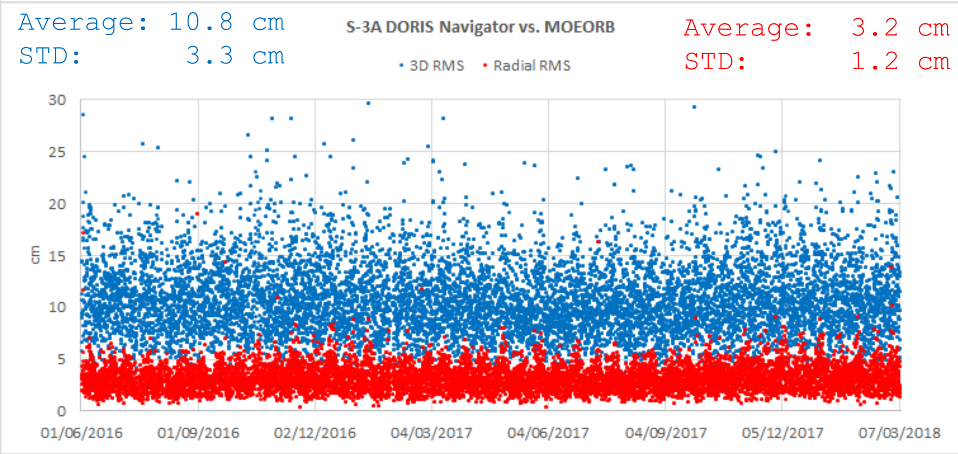
S-3 ORBITAL ACCURACY ASSESSMENT OF CPOD PRODUCTS

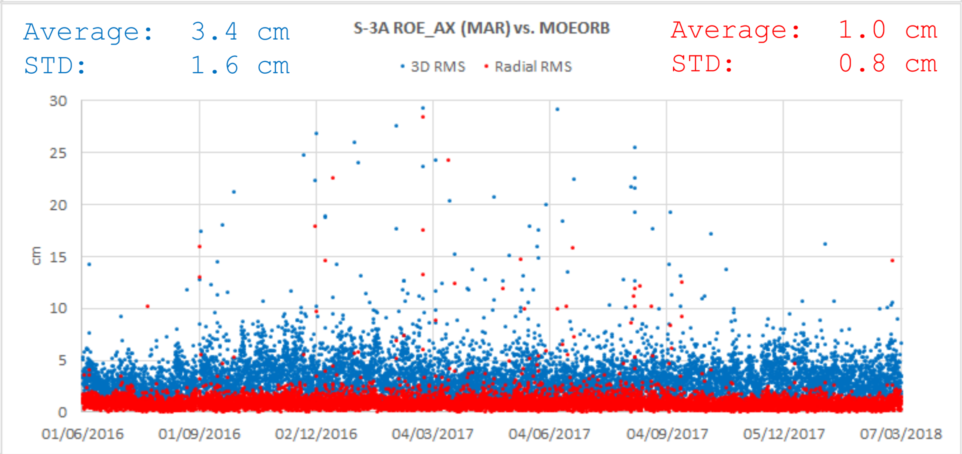


S-3A NRT ORBITAL SOLUTIONS

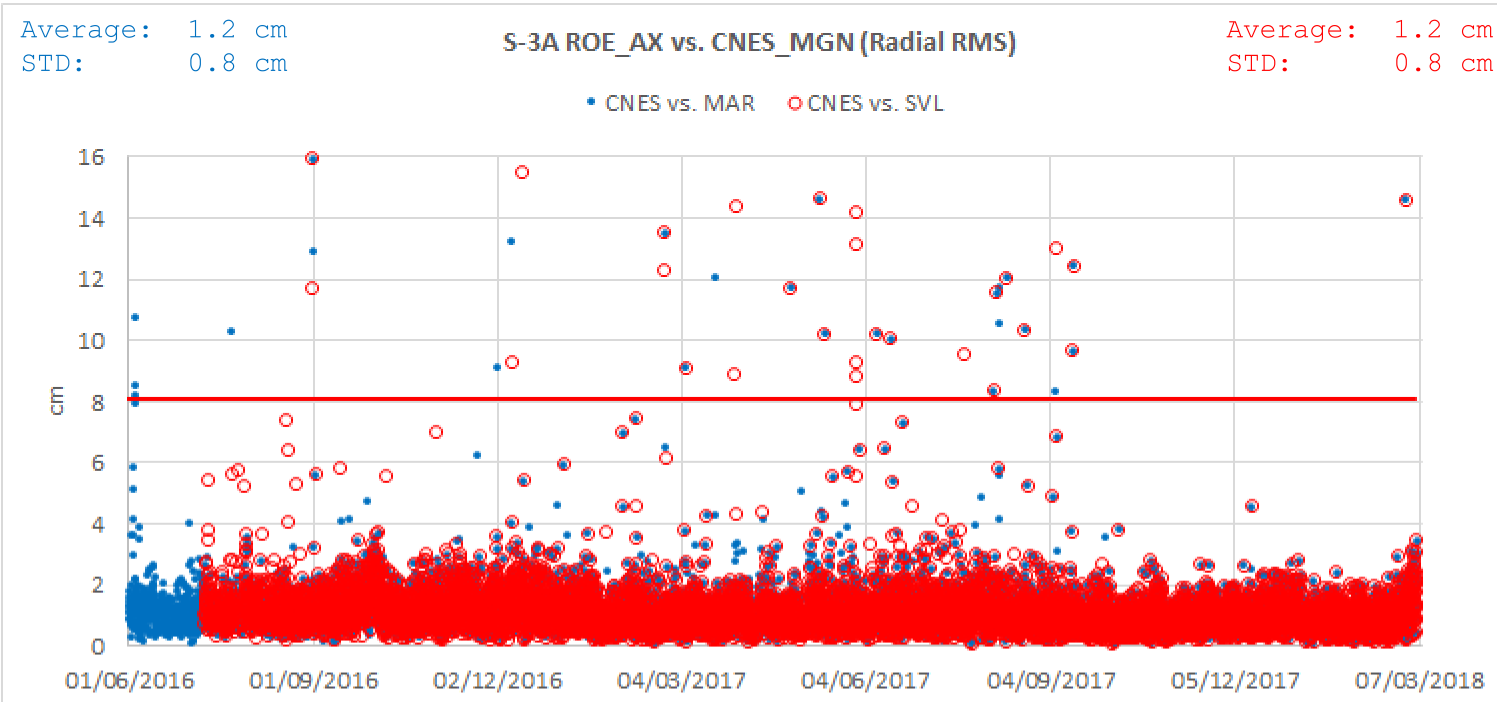




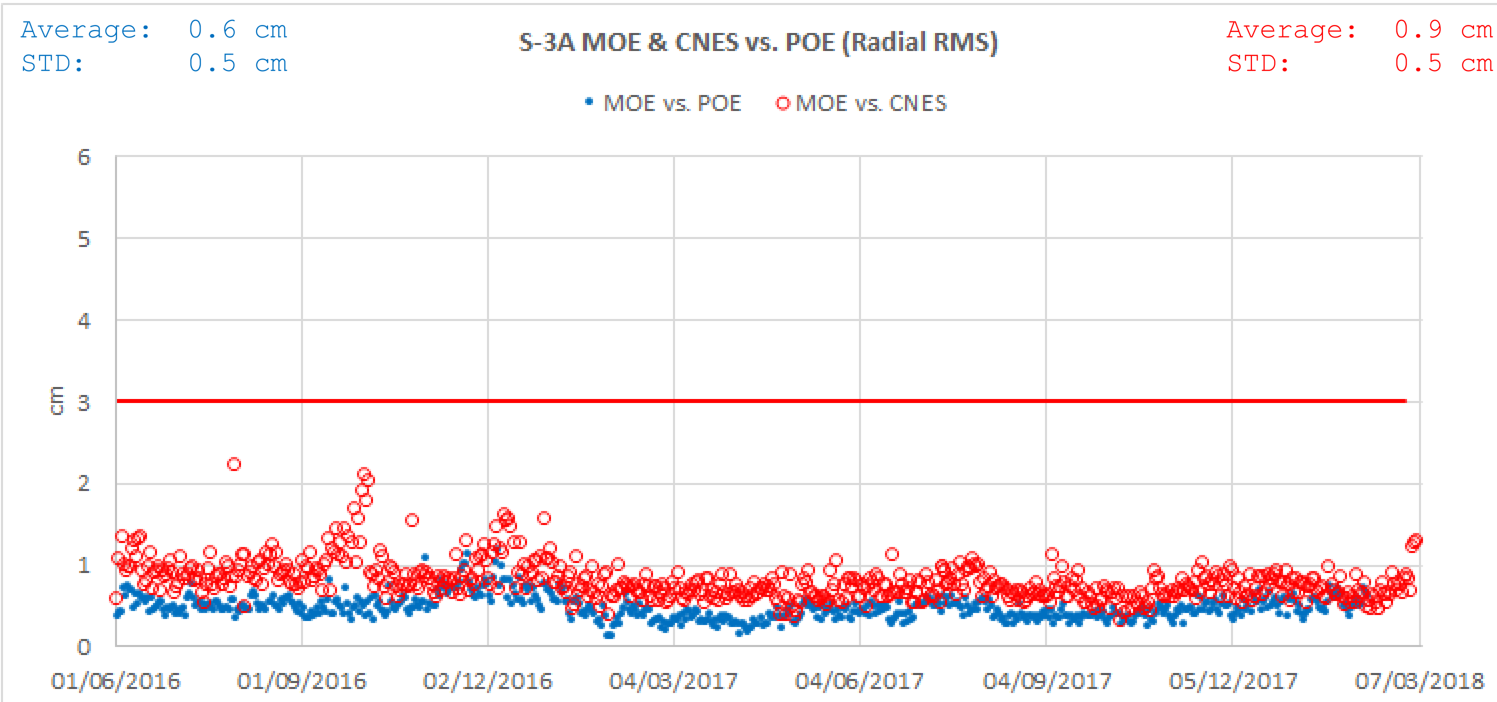




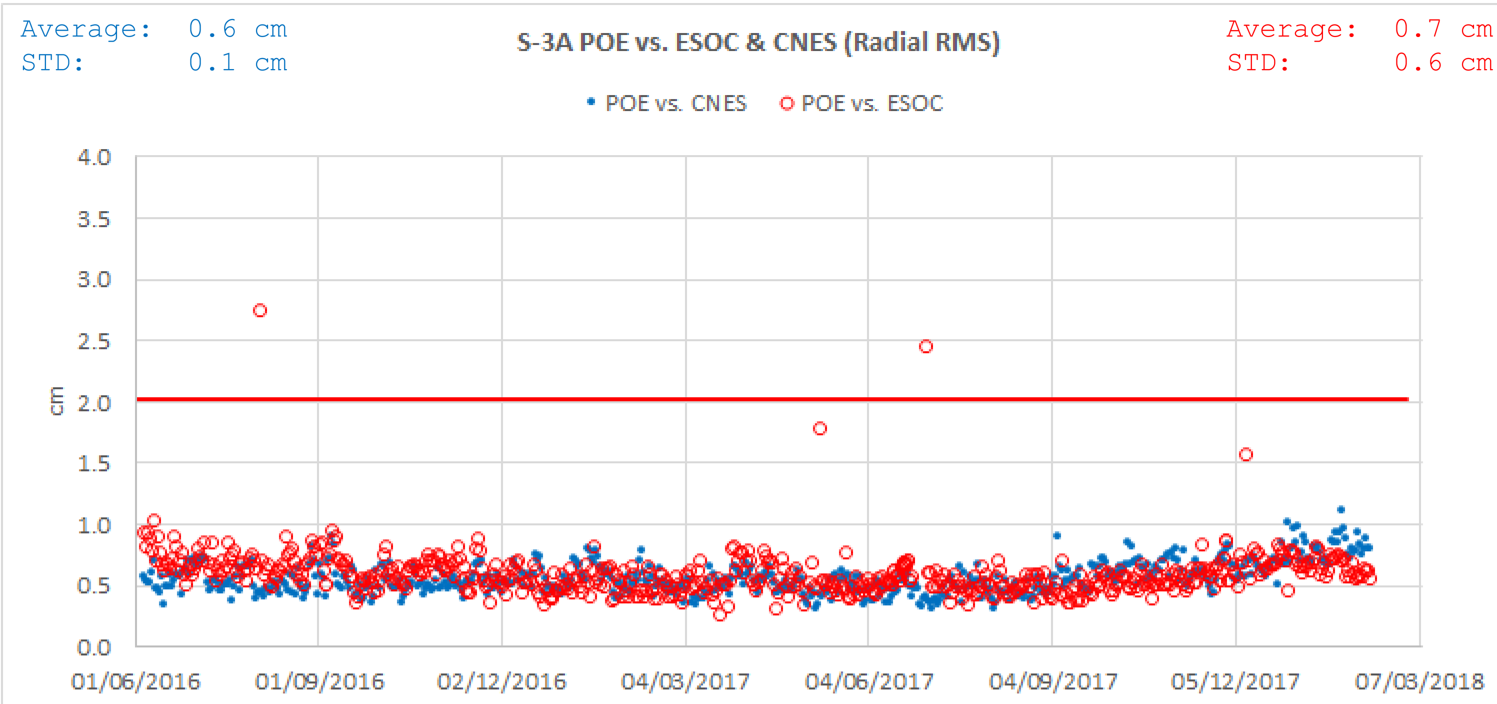
S-3A ROE_AX (NRT) RADIAL ACCURACY



S-3A MOEORB (STC) RADIAL ACCURACY

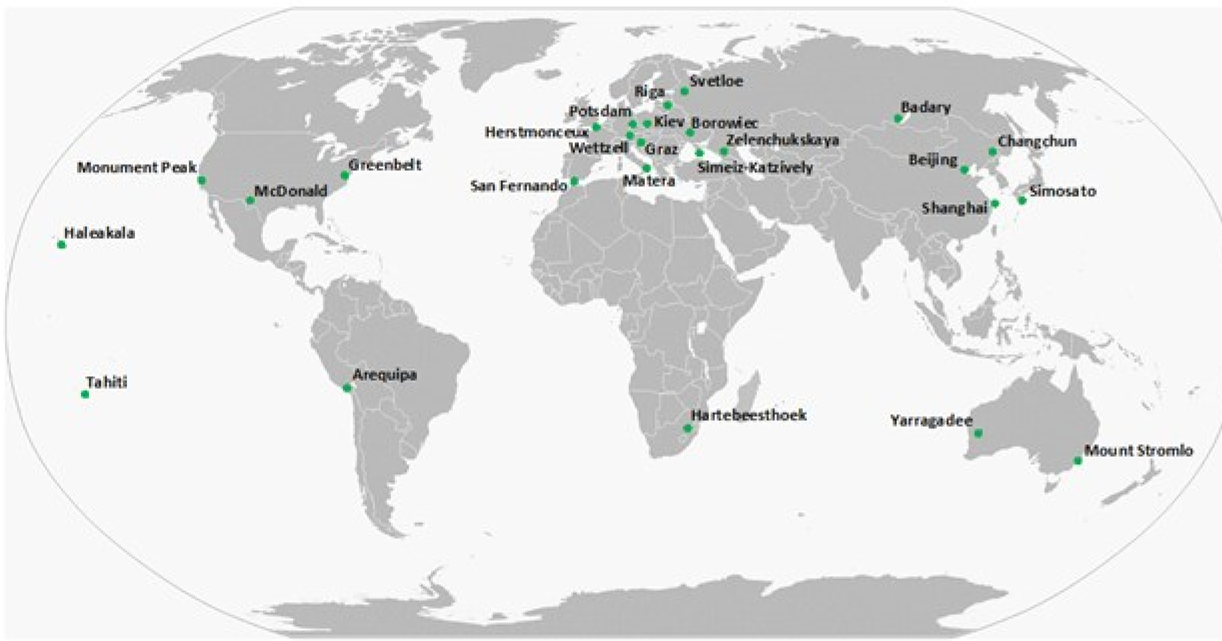


S-3A POEORB (NTC) RADIAL ACCURACY

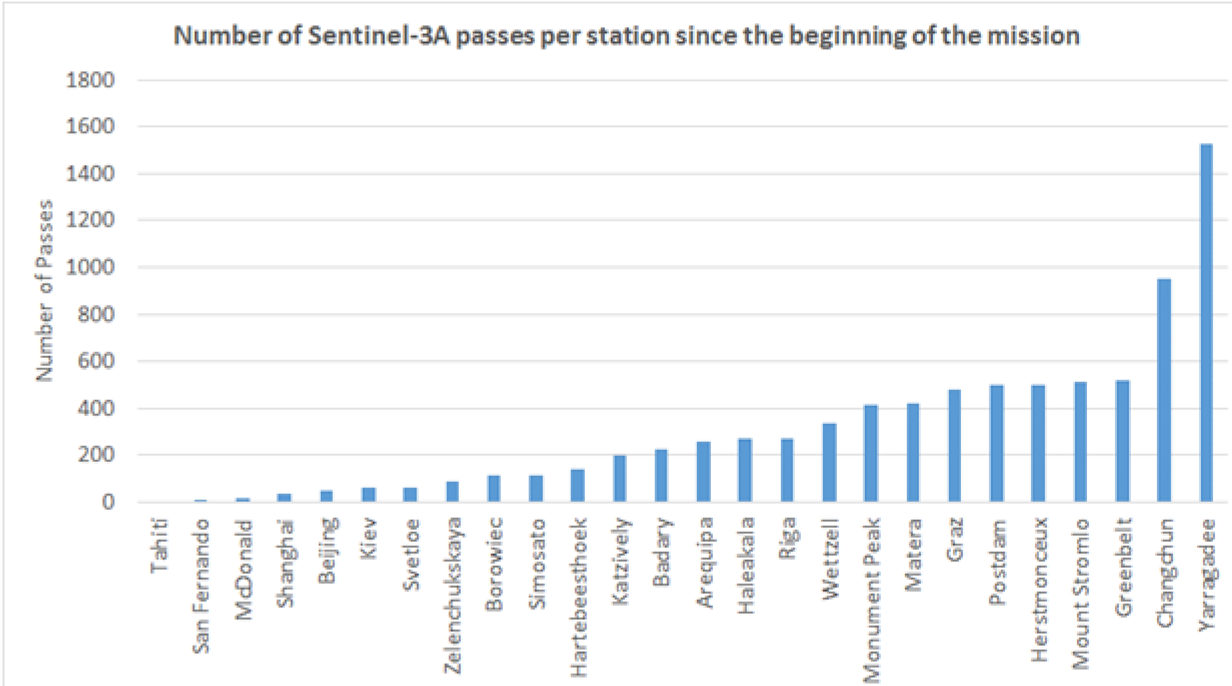


S-3A POEORB (NTC) SLR VALIDATION

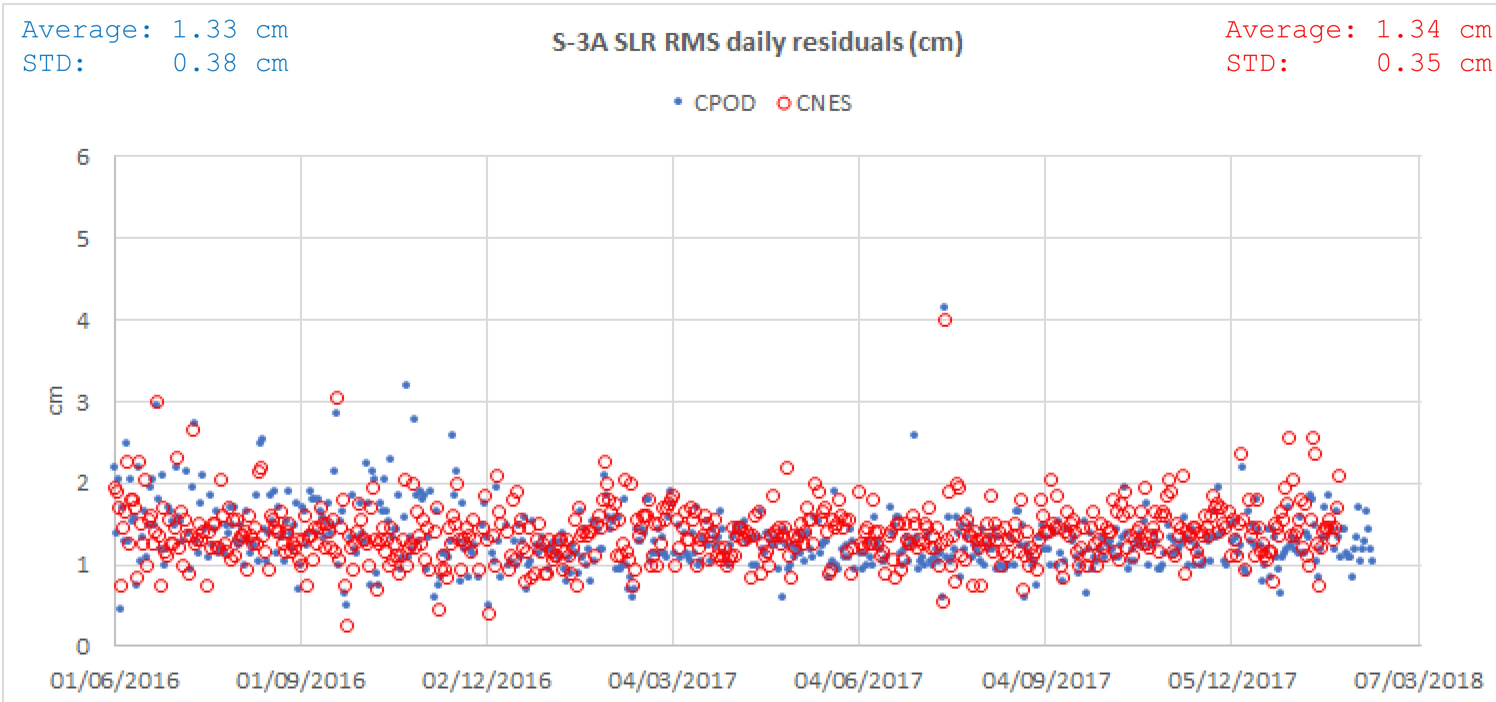
ILRS Stations willing to track Sentinel-3



S-3A POEORB (NTC) SLR VALIDATION



S-3A POEORB (NTC) SLR VALIDATION



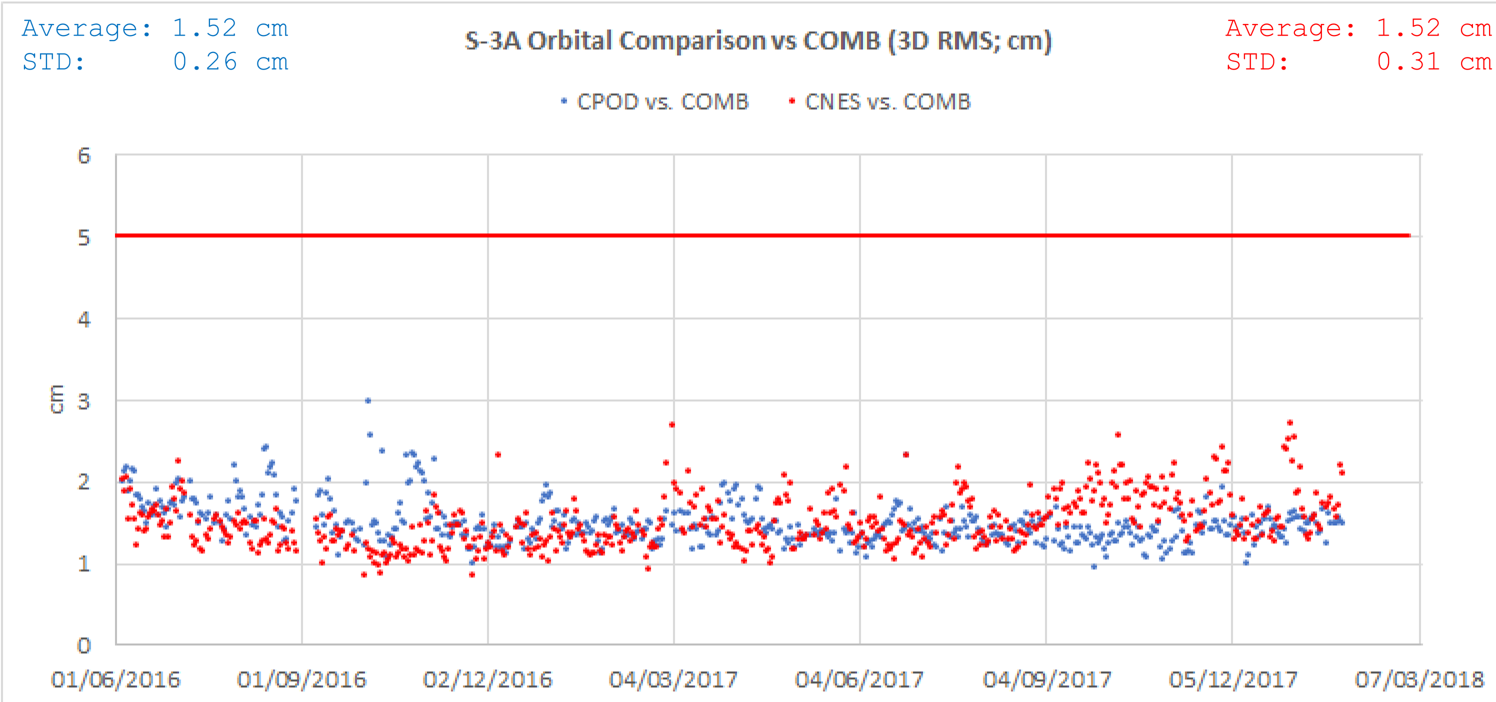
S-3A POEORB (NTC) – 3D ACCURACY vs. COMBINED SOLUTION

- Using orbital solutions from independent centres, a combined solution is generated using a weighted average (IGS like approach).

- During the last review, covering Oct' 17 to Jan' 18, the centres used came from:
  - AIUB: Two solutions: One more kinematic, another more dynamic; using Bernese
  - CNES: One solution; using ZOOM
  - CPOD: One solution; using NAPEOS
  - DLR: One solution; using GHOST
  - ESOC: One solution; using NAPEOS
  - EUM; One solution; using NAPEOS
  - Delft: Two solutions; Using GHOST and Gipsy
  - TUM: One solution; Using Bernese
  - CLS (GRG); One solution; Using GINS/DYNAMO

- Advantage: A simple way to evaluate the consistency among different solutions
- Disadvantage: Solutions are penalized (with the weights) just because they are away of the mean solution. This could just happens due to the usage of different location of receivers.

S-3A POEORB (NTC) – 3D ACCURACY vs. COMBINED SOLUTION



SUMMARY OF ORBITAL ACCURACY ASSESSMENT

- NRT: ROE_AX has a radial consistency with respect to MGN_AX (CNES MOE) of ~1.2/0.8 cm (average/sigma)

- STC: MOEORB has a radial consistency with respect to POE_AX (CNES) of ~1.0/0.5 cm

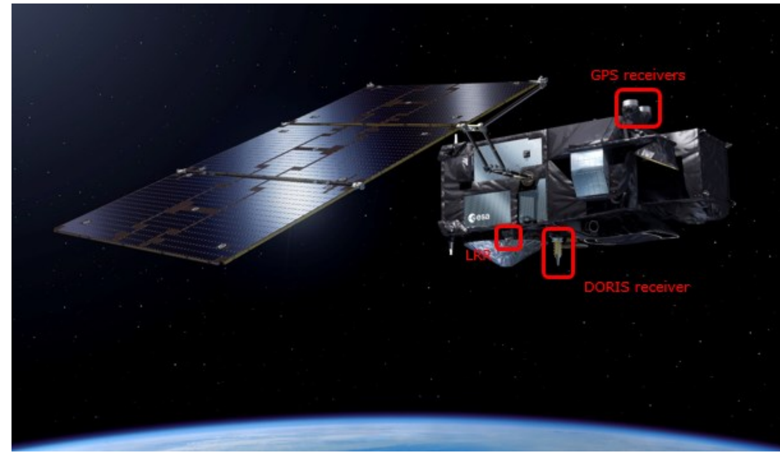
- NTC: POEORB has a radial consistency with respect to POE_AX (CNES) of ~0.6/0.1 cm

- NTC: POEORB has SLR residuals of 1.33/0.38 cm
- NTC: POE_AX has SLR residuals of 1.34/0.35 cm

- NTC: POEORB has a 3D consistency of 1.52/0.26 cm
- NTC: POE_AX has a 3D consistency of 1.52/0.31 cm

ISSUES WITH ORBITAL ACCURACY ASSESSMENT

- Need to agree on a number of parameters:
  - Location of Centre of Gravity (CoG)
  - Location of GPS antenna reference point (ARP)
  - Location of GPS antenna phase centre (APC)
  - Location of SLR reference point
  - SLR azimuth/elevation corrections
  - Location of DORIS antenna reference point (ARP)
  - Location of DORIS antenna phase centre (APC)



- Orbit comparison is done wrt. CoG, but observations just measure the distance between APCs, not CoG.
- Vector APC – CoG is typically assumed constant.

FUTURE STEPS TO IMPROVE ACCURACY

- Final calibration and agreement on several parameters: CoG, ARP, APC, SLR, …
  - Lesson learnt: To measure the location of ARP, to mm accuracy once installed. This was done for DORIS and SLR, but not with GPS antennas.
  - Lesson learnt: To properly document the meaning of ARP (S-1 documentation contained two different set of values without a proper description)

- Apply GPS integer ambiguity resolutions:
  - This has the potential to reach sub-cm accuracy in radial direction
  - Already tested by several members of CPOD QWG, including CNES, DLR and ESOC

- Generate a GPS+DORIS solution:
  - Already done by CNES; on testing mode by GMV.

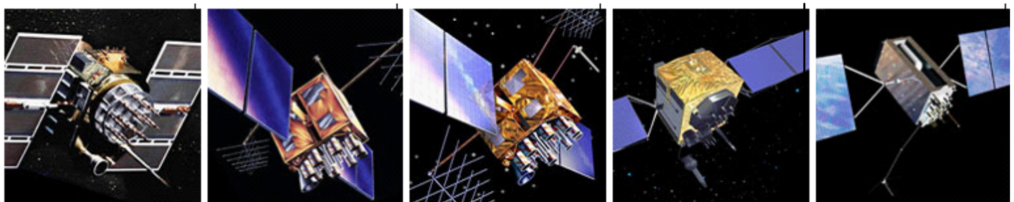
- Improve dynamical models for drag and solar radiation.

SENTINEL-3B PREPARATIONS

- Sentinel-3A & 3B tandem configuration allows to:
  - Validation of GPS receiver
  - Calibration of Antenna Phase Delays (PCO/PCV)
  - Capability to perform combination of signals (double differences) between S-3A and S-3B satellites
  - SLR tracking in tandem configuration: assess different satellite LRR biases

- Sentinel-3B GPS receivers will generate data simultaneously. This allows to:
  - Calibrate both antennas
  - Validate the L2C tracking capabilities

SENTINEL-3B PREPARATIONS – L2C TRACKING



Block IIA	Block IIR	Block IIR(M)	Block IIF	GPS III
0 operational	12 operational	7 operational	12 operational	In production
- Coarse Acquisition (C/A) code on L1 frequency for civil users - Precise P(Y) code on L1 & L2 frequencies for military users	- C/A code on L1 - P(Y) code on L1 & L2	- All legacy signals - 2nd civil signal on L2 (L2C)	- All Block IIR(M) signals - 3rd civil signal on L5 frequency (L5)	- All Block IIF signals - 4th civil signal on L1 (L1C)
- Launched in 1990-1997	- Launched in 1997-2004	- Launched in 2005-2009	- Launched in 2010-2016	- Available for launch in 2018

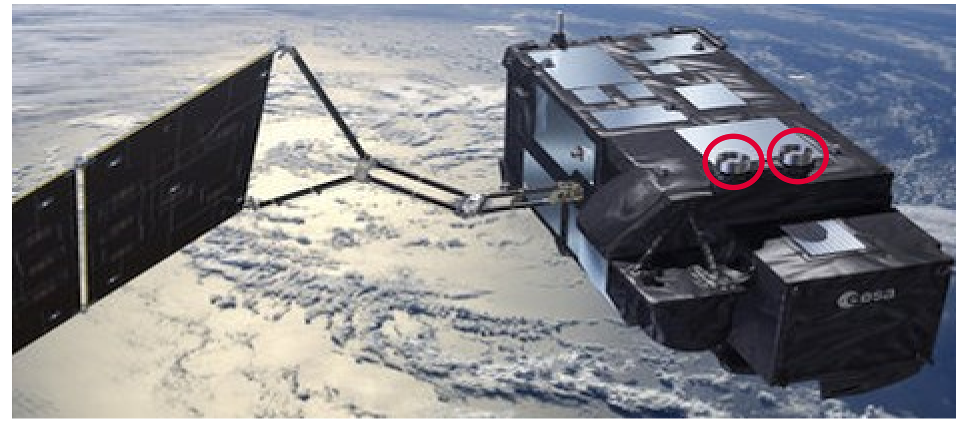
Signal	# sats
C/A	31
P1/P2	31
L2C	19
L5	12
L1C	N/A

*The USG commits to maintaining the existing GPS L1 C/A, L1 P(Y), L2C, and L2 P(Y) signal characteristics that enable codeless and semi-codeless GPS access until at least **two years after there are 24 operational satellites broadcasting L5**. … Twenty-four satellites broadcasting the L5 signal is estimated to occur in **2024**.* (https://www.gps.gov/technical/codeless)

SENTINEL-3B PREPARATIONS – L2C

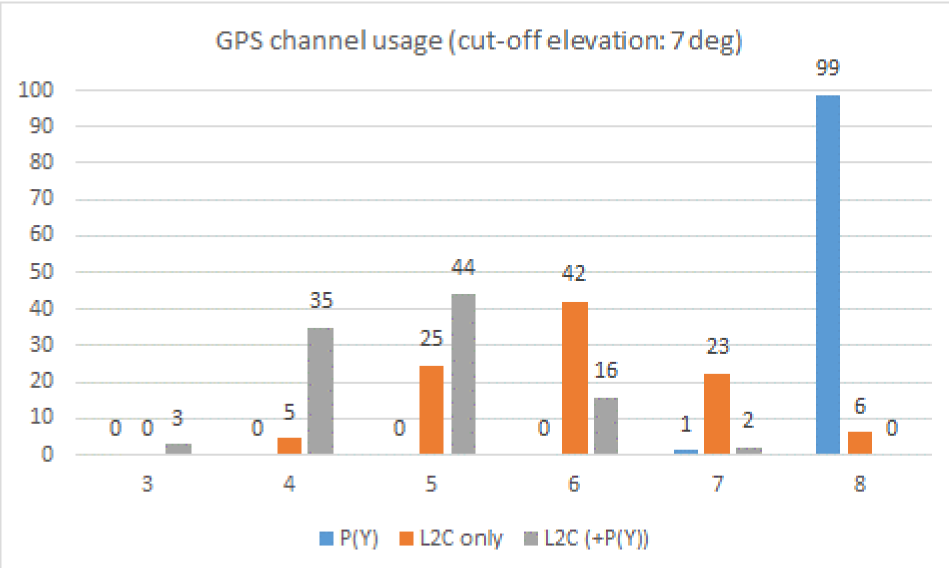
- GPS nominal:
  - Tracking C/A, P1, P2

- GPS redundant:
  - Tracking C/A, L2C if available
  - Tracking C/A, P1, P2 otherwise



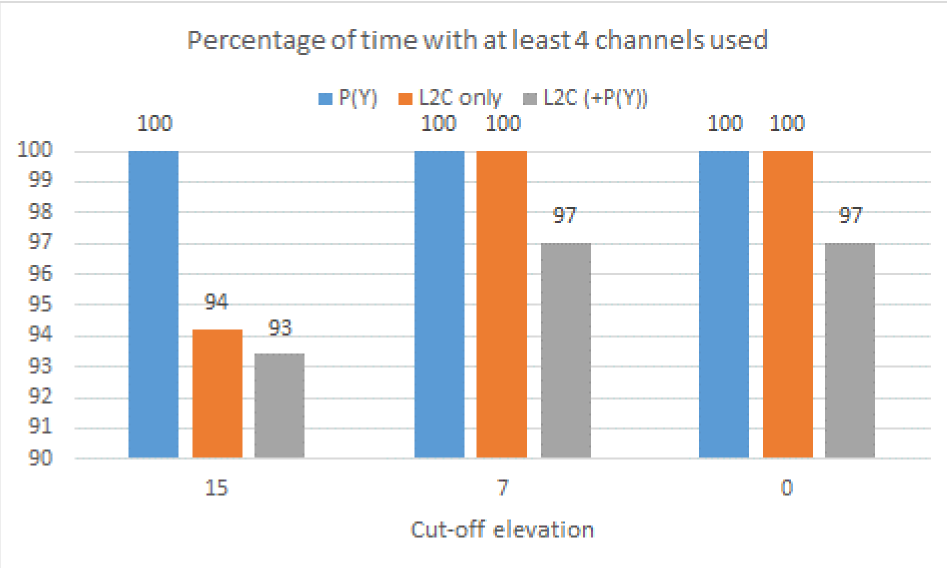
- GPS redundant can also be configured to track only satellites with L2C, despite of not filling all channels.

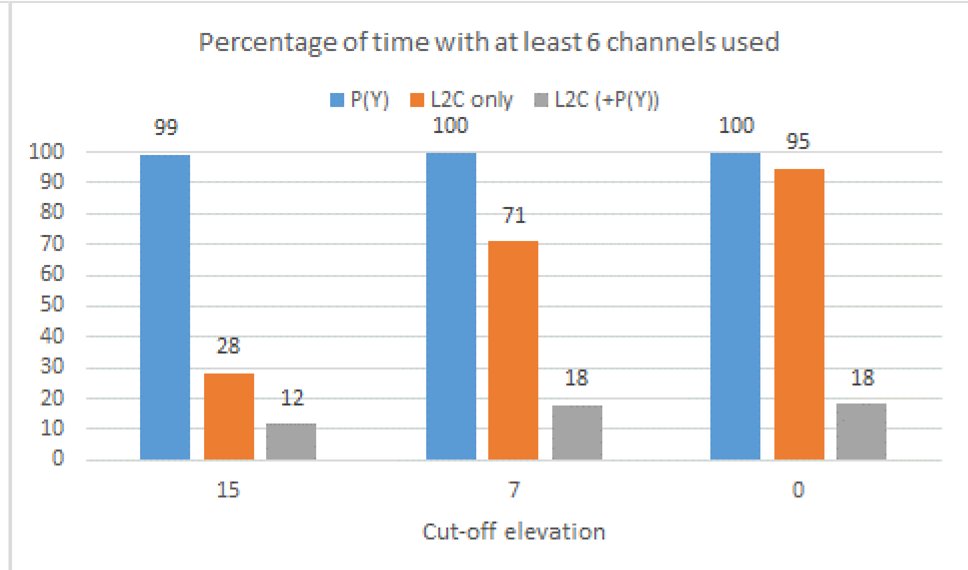
SENTINEL-3B PREPARATIONS – L2C



- Distribution of channel usage depending on the tracking strategy used:
  - P(Y): used by nominal receiver. It track all available GPS satellites
  - L2C only: tracks only GPS satellites with L2C
  - L2C (+P(Y)): track all satellites, but in case of having L2C, this signal is used; otherwise tracks P(Y). Figure shows only the satellites with L2C.

SENTINEL-3B PREPARATIONS – L2C





- While the strategy of tracking only satellites with L2C implies not using all channels available in the receiver (8), it increases the number of satellite with L2C which are tracked, and do not risk the on-board navigation.

A FINAL NOTE – DATA AVAILABILITY

- S-3A GPS data is now available on the Copernicus Data Hub:
- S-3A information to do POD will soon be available on the Sentinels On-Line webpage
  - Manoeuvres, mass history file, attitude model, properties of satellite, etc.
- S-3A quality information about orbital accuracy will be available on-line in the Sentinels On-Line webpage.

- S-3A orbital products (mainly NTC) availability on-line is under discussion:
  - Need for NRT products availability?

CONCLUSIONS

- CPOD is generating S-3 orbital products equivalent to those of CNES for STC and NTC, and for NRT, it is the best solution available within a timeliness of 30 min.
- ILRS provides an invaluable support to the S-3 mission to validate the orbital accuracy independently.
- CPOD QWG provides a strong support to the validation of S-3 products.
- GMV, CNES and the members of the CPOD QWG continues improving the orbital accuracy by the introduction of new techniques (integer ambiguity resolution, DORIS, better models, etc.)
- S-3B provides a test-bed scenario to not only validate the routine generation of orbital products, but to test the capabilities of the L2C tracking.