GLOBAL MONITORING FOR ENVIRONMENT AND SECURITY

COPERNICUS POD SERVICE – ORBIT VALIDATION OF SENTINEL-3 MISSION

Jaime Fernández Sánchez / GMV
Heike Peter / POSITIM
Emilio José Calero / GMV
Javier Berzosa / GMV
Luis Javier Gallardo / GMV
Pierre Féménias / ESA

AGENDA

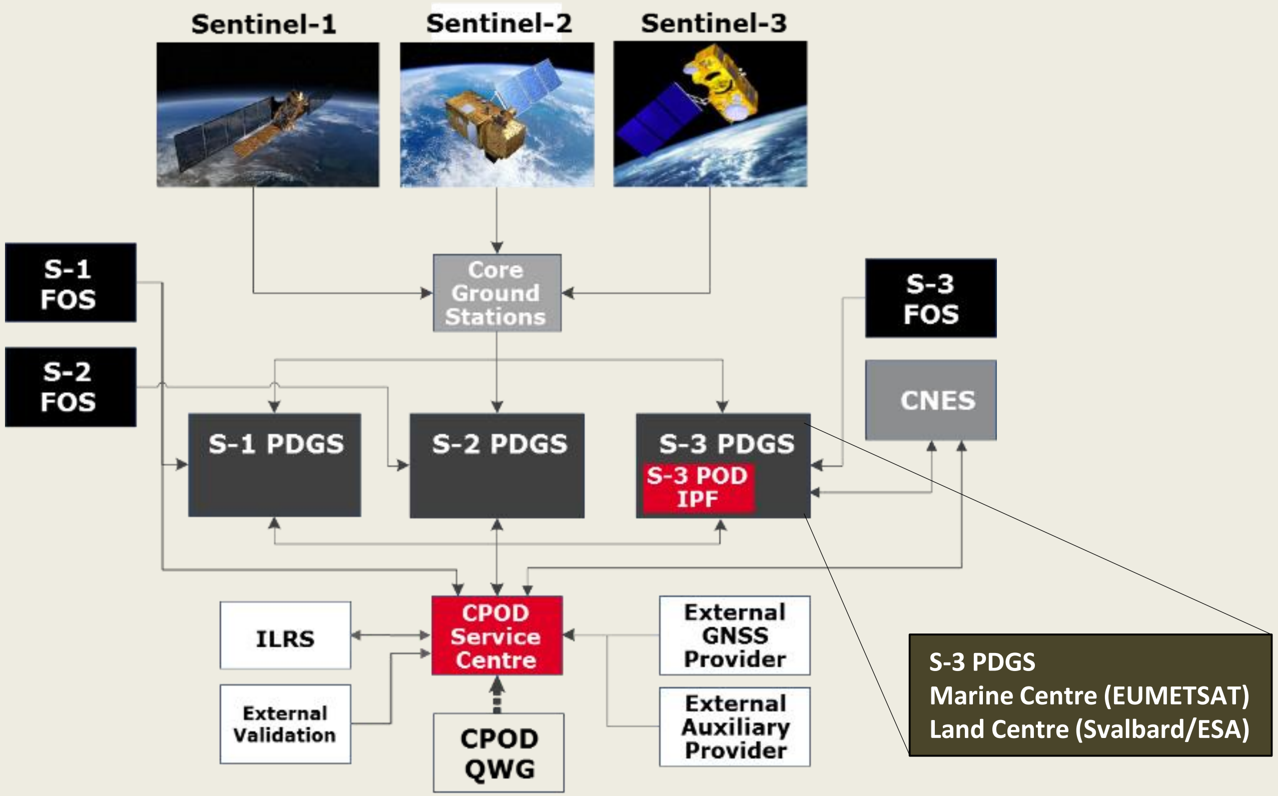
- Overview of Copernicus POD Service
- Overview of Sentinel-3 POD sensors and requirements

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

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

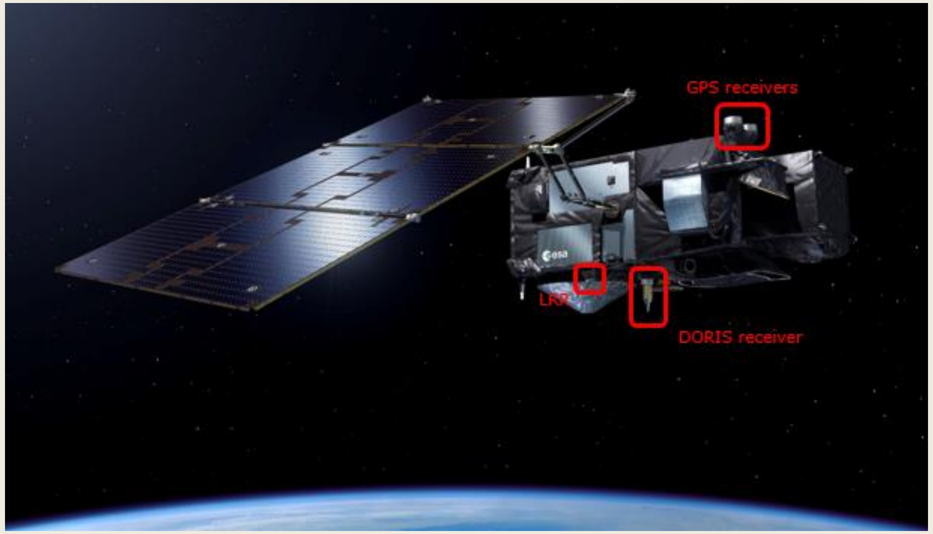
OVERVIEW OF COPERNICUS POD SERVICE

- **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.)



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)

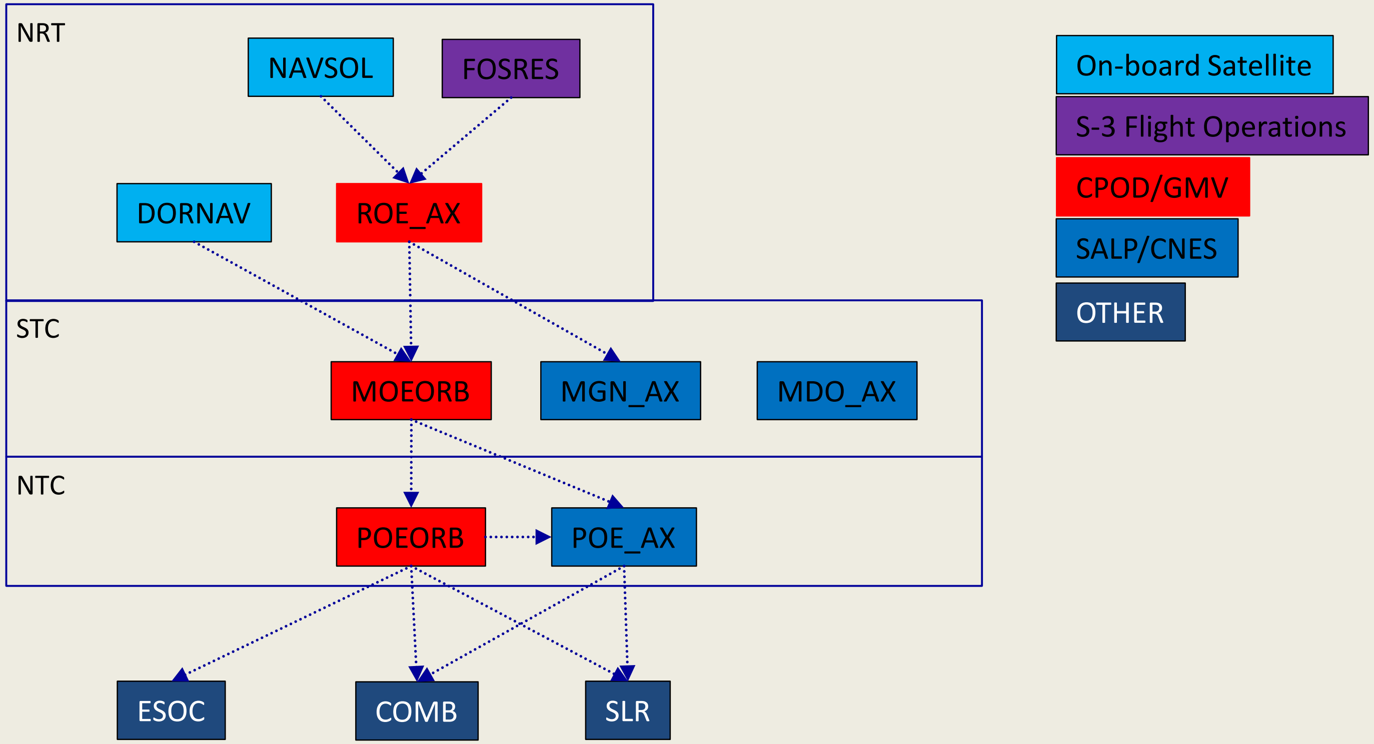
REQUIREMENTS OF POD PRODUCTS			
Category	**Latency**	**Orbit Accuracy**	**SOLUTIONS**
RT	RT	N/A	DORIS on-board Navigation solution GPS on-board Navigation solution
NRT	30 min	10 cm radial RMS 1-sigma (target of 8 cm)	CPOD (@ Marine and Land PDGS)
STC	1.5 days	4 cm radial RMS 1-sigma (target of 3 cm)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

METHODS TO ASSESS ORBITAL ACCURACY

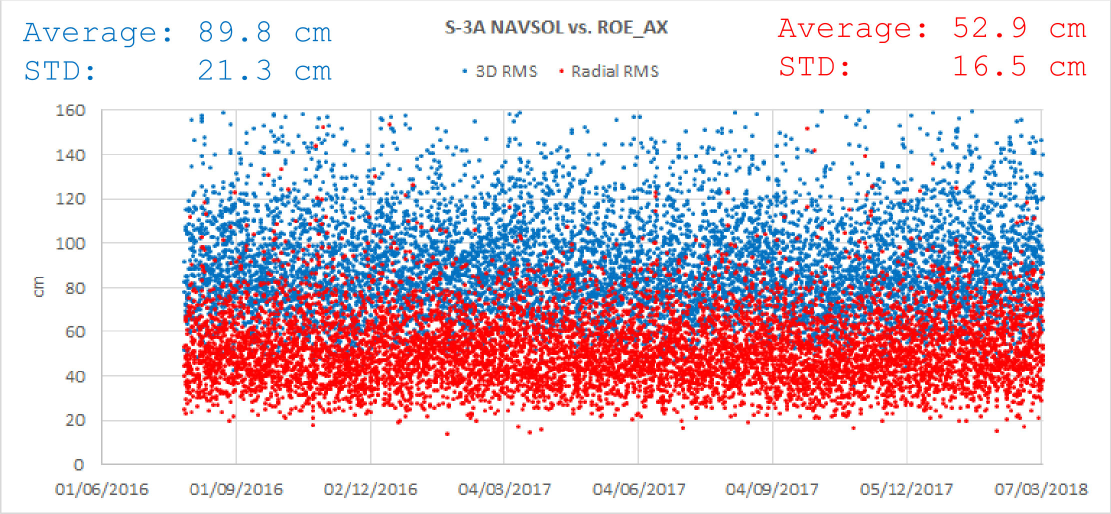
- Direct comparison between two orbits computed independently (different SW, processing scheme, etc.)
  - It provides consistency between methods
- Analysis of SLR residuals
  - It provides an external, independent, assessment

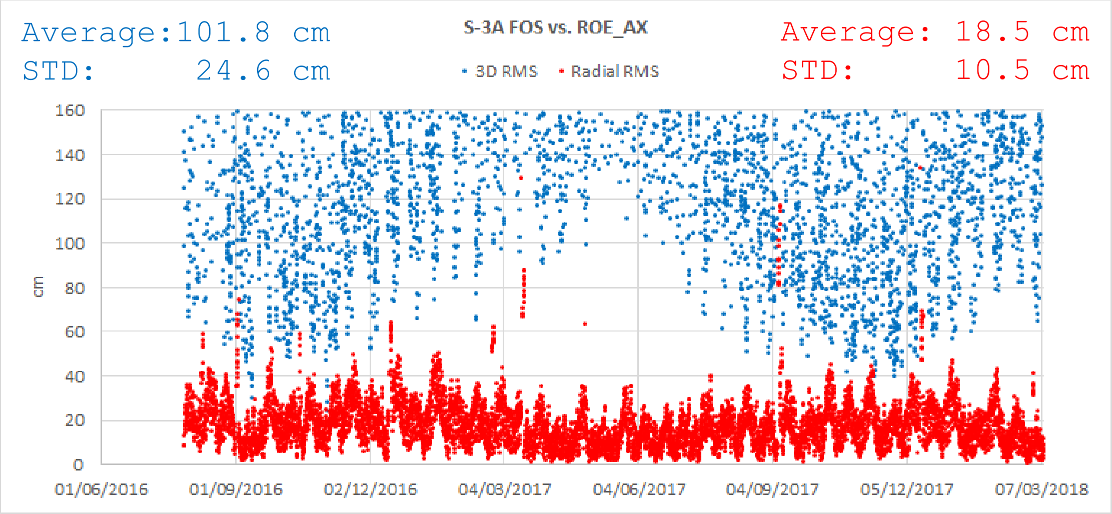
- Overlaps comparisons between consecutive orbits
- Analysis of residual
- Covariance analysis
- Cross-overs analysis (S-3)
- InSAR analysis (S-1)

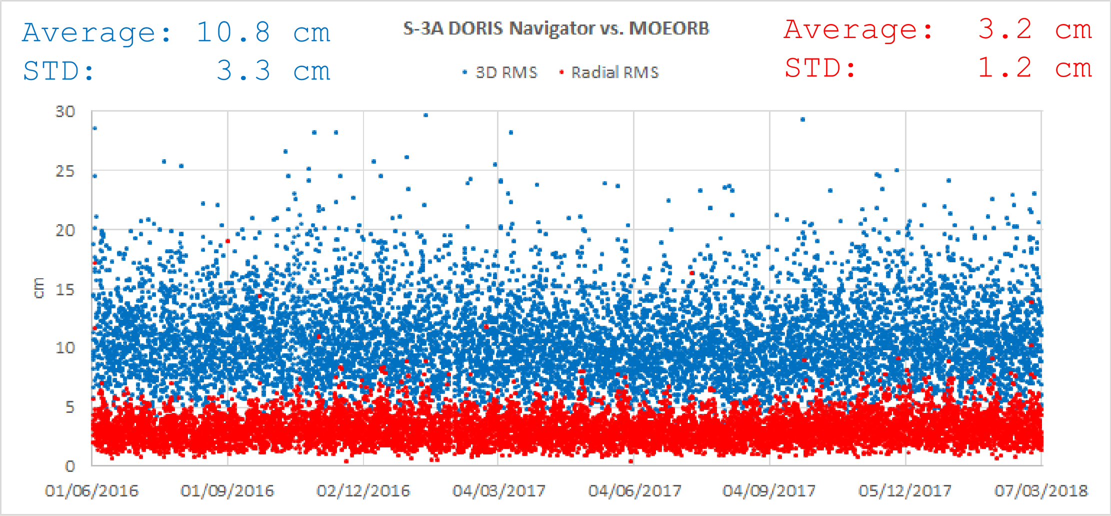
S-3 ORBITAL ACCURACY ASSESSMENT OF CPOD PRODUCTS

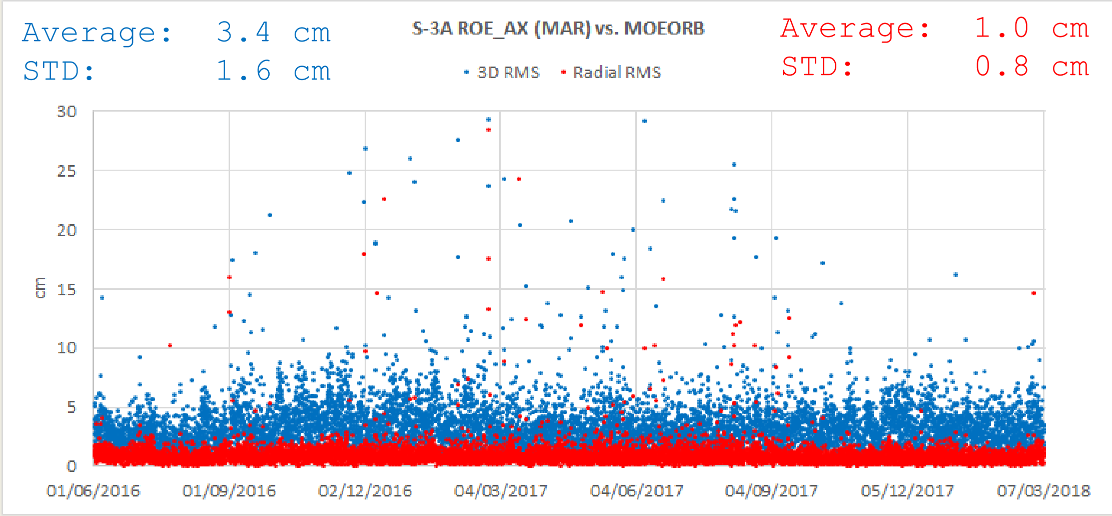


S-3A NRT ORBITAL SOLUTIONS

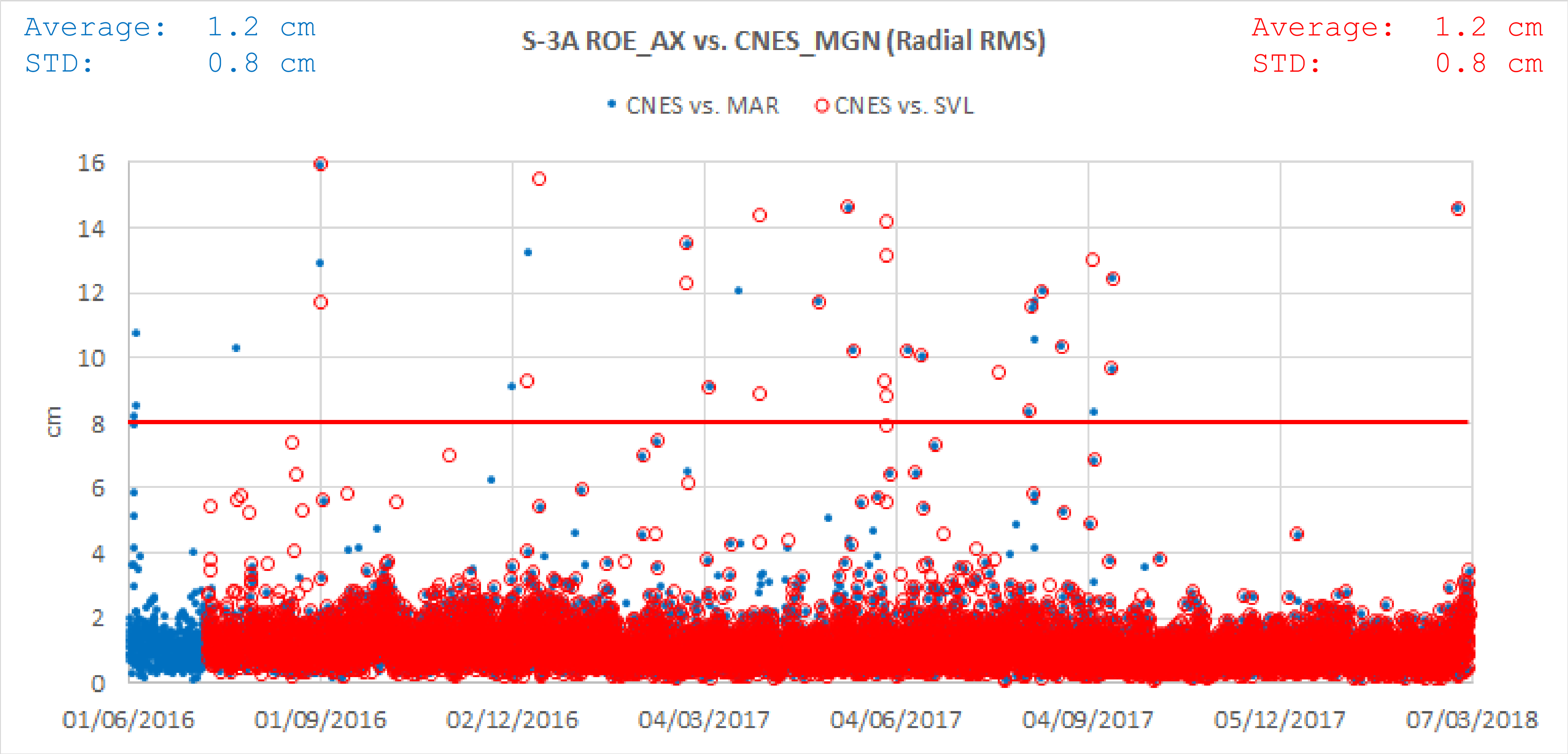




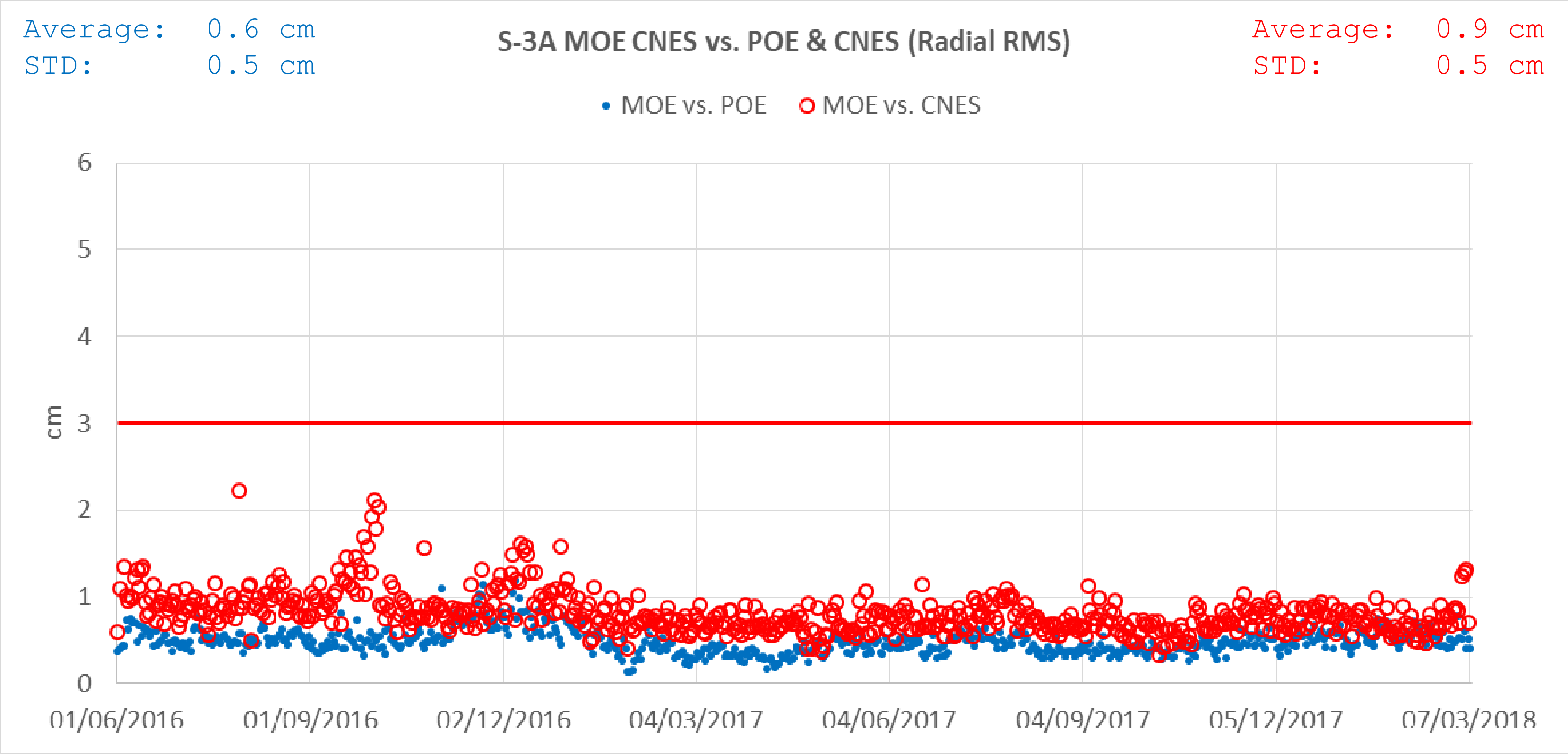




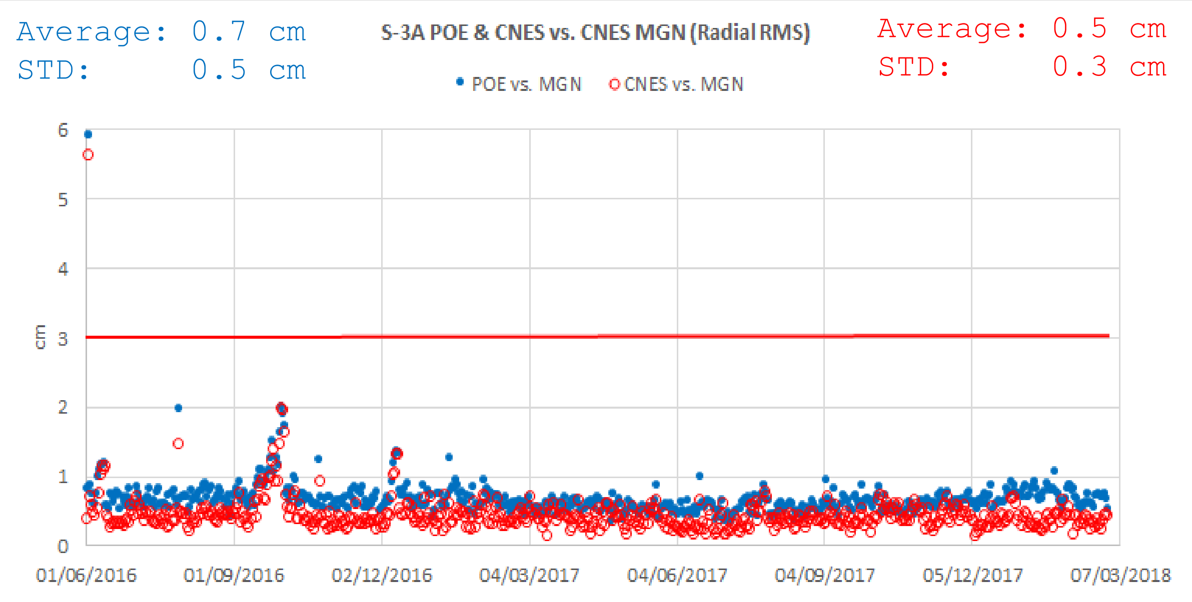
S-3A ROE_AX (NRT) RADIAL ACCURACY

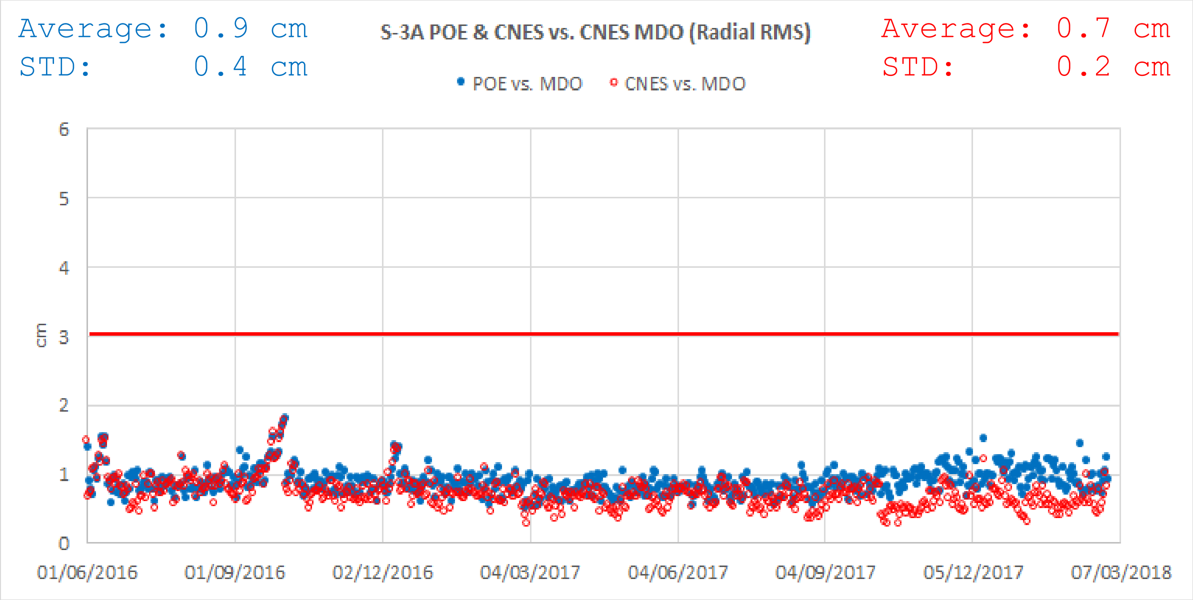


S-3A MOEORB (STC) RADIAL ACCURACY

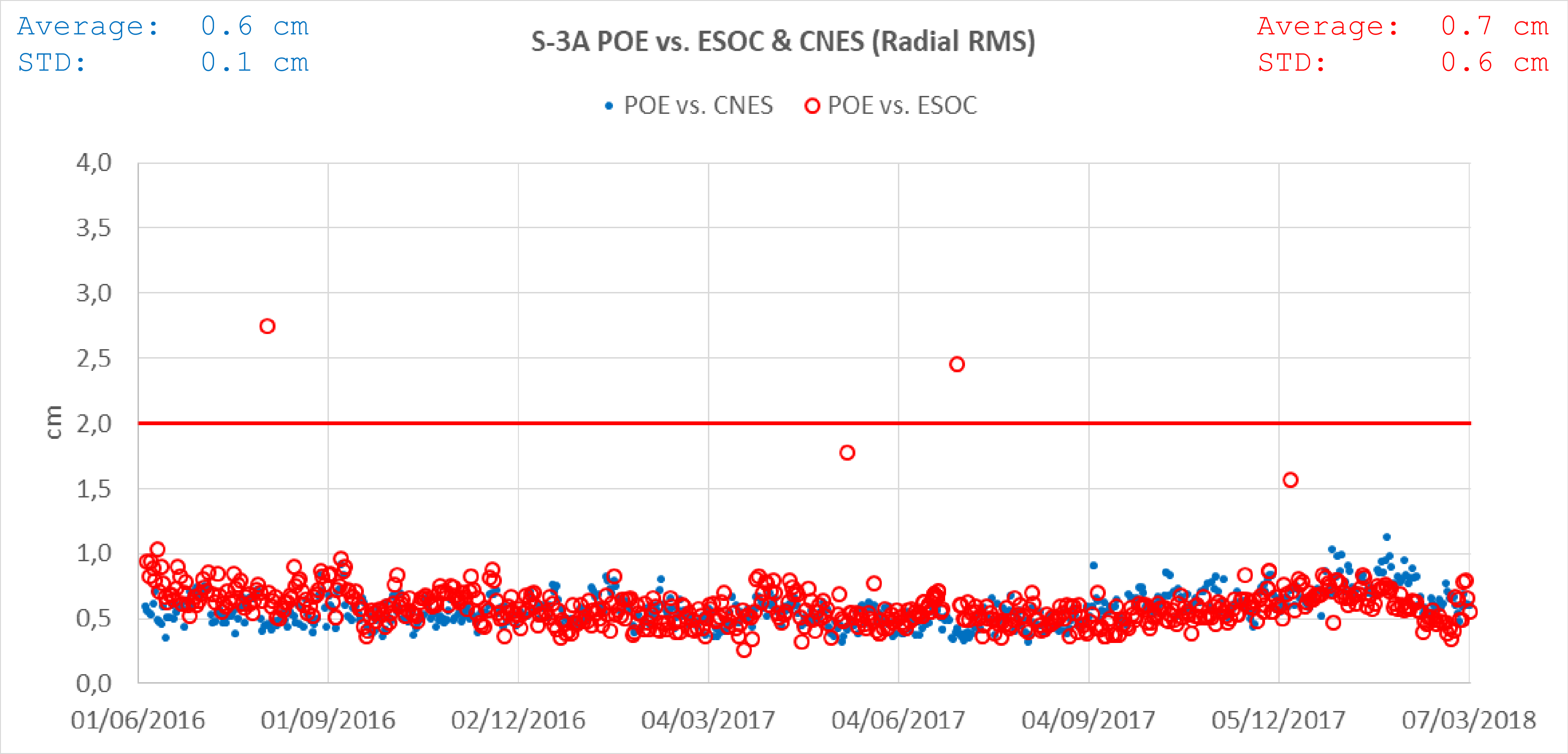


S-3A MGN & MDO (STC) ACCURACY

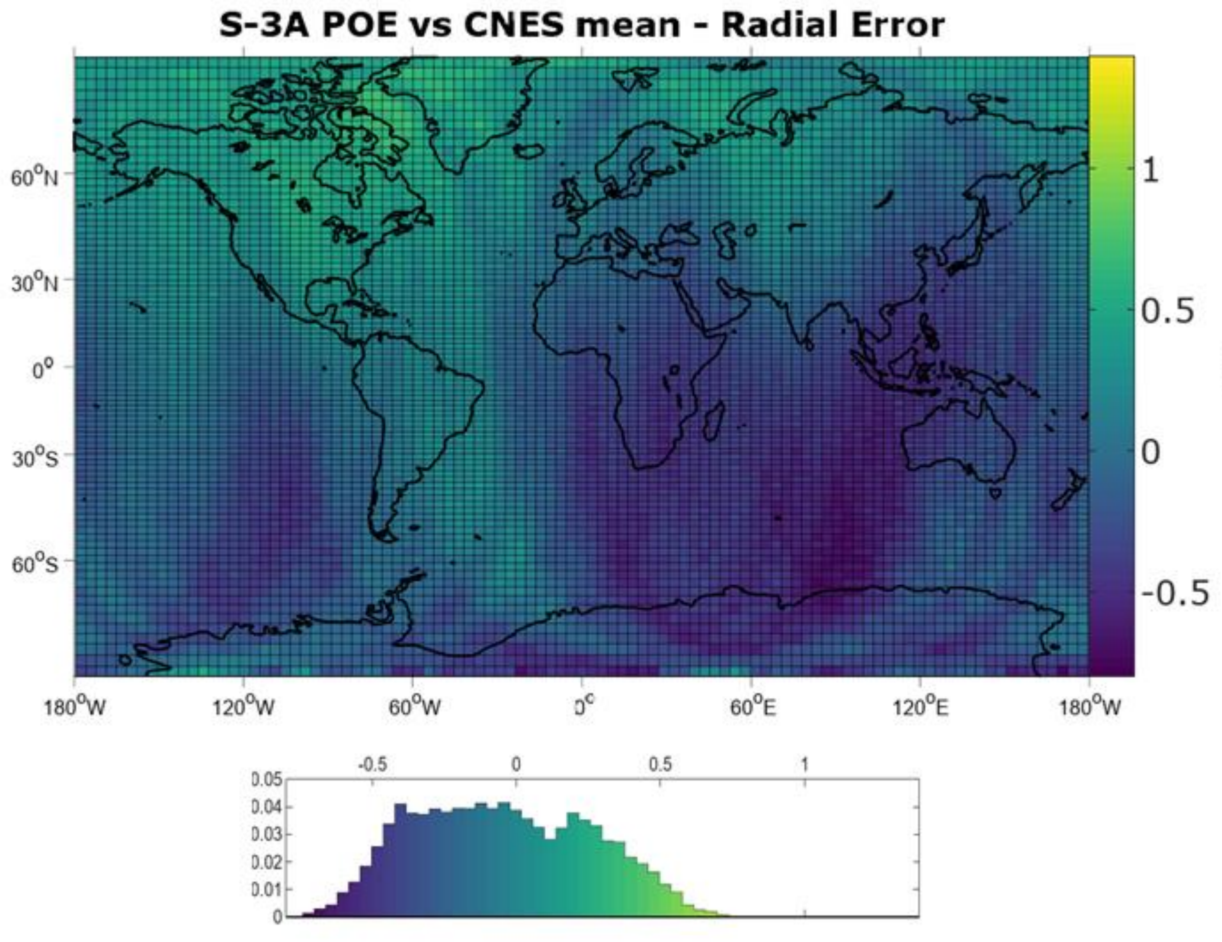


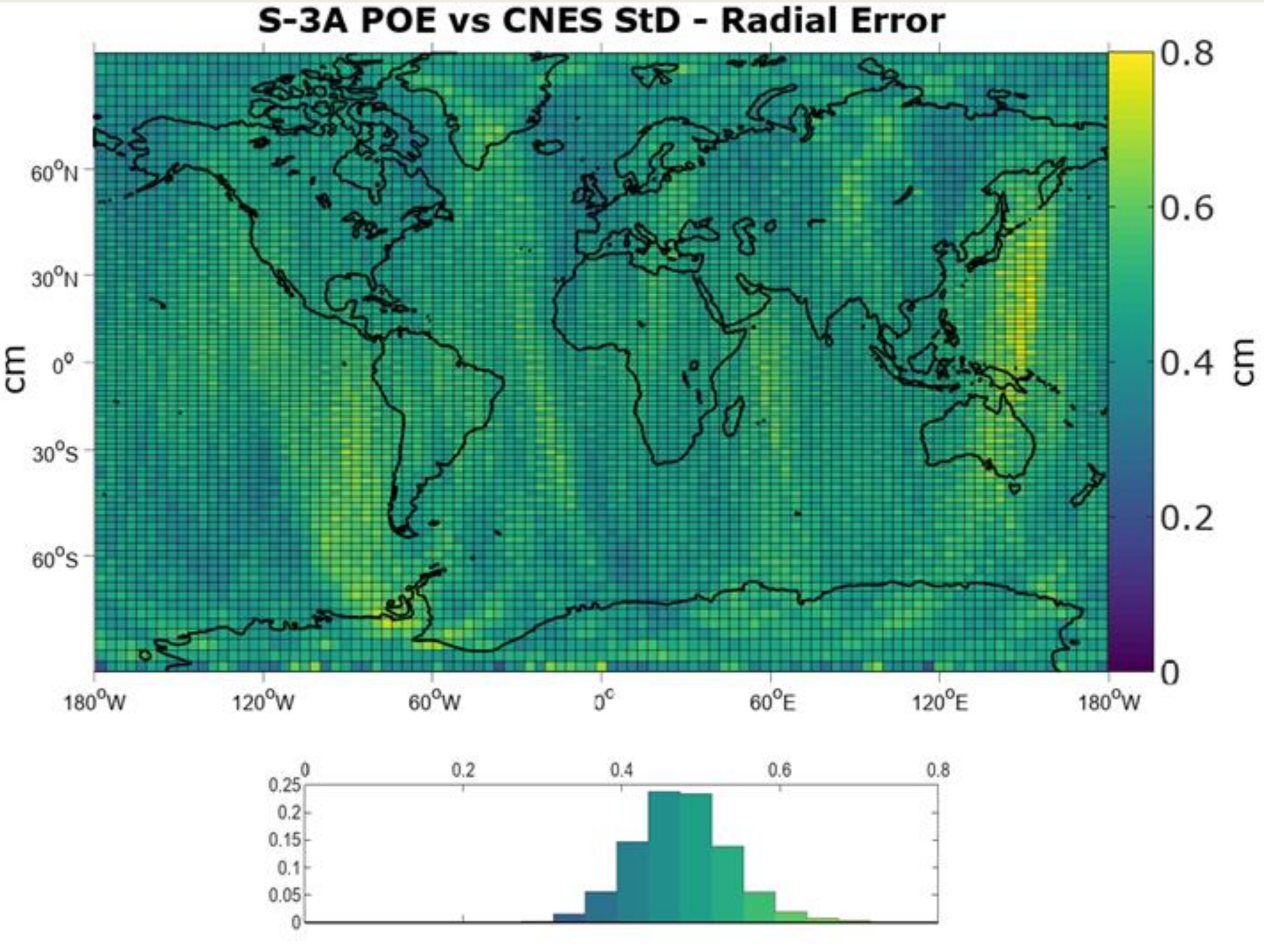


S-3A POEORB (NTC) RADIAL ACCURACY

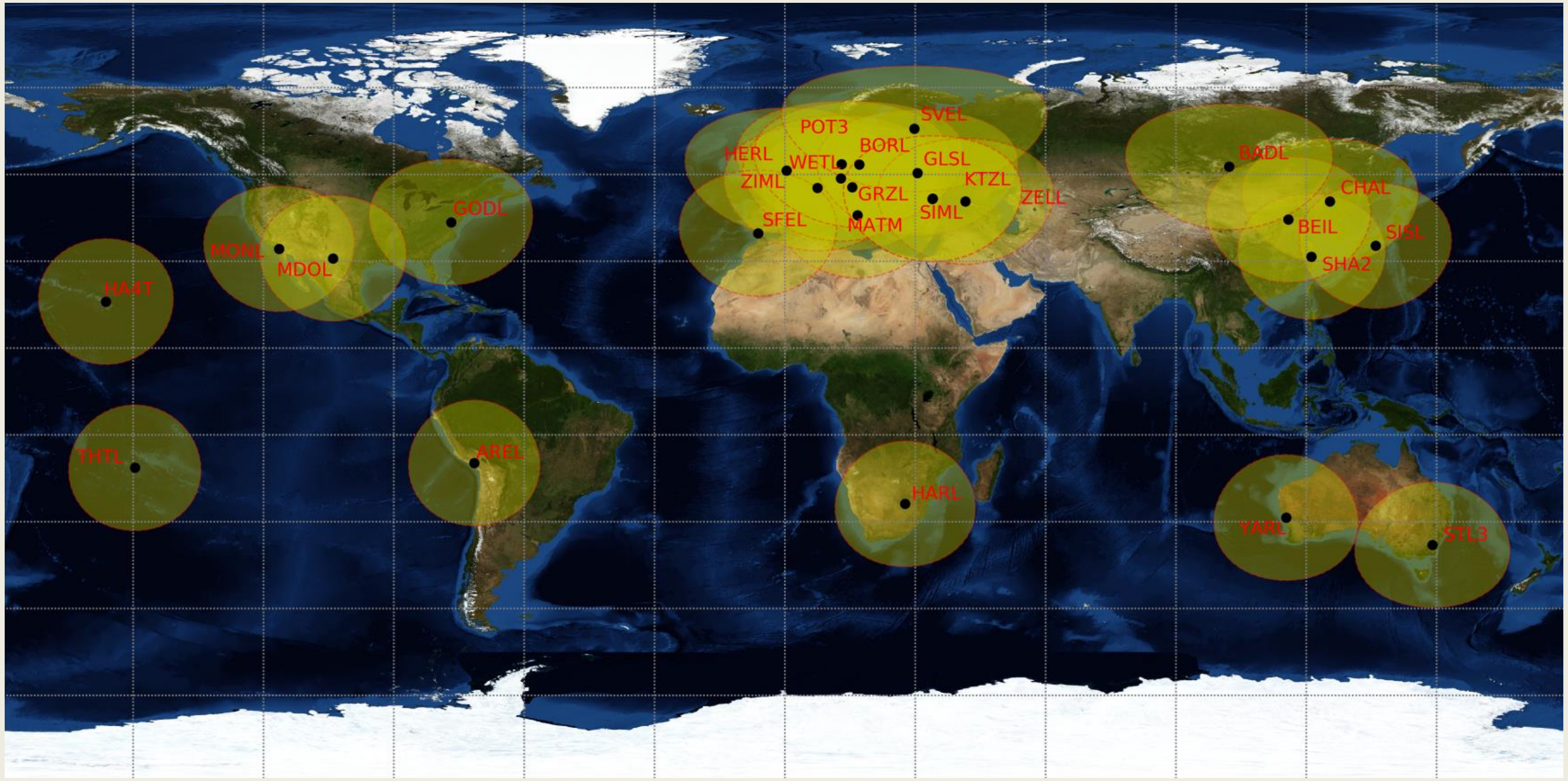


S-3A POEORB vs. CNES (NTC) - WORLD MAP RADIAL ERROR

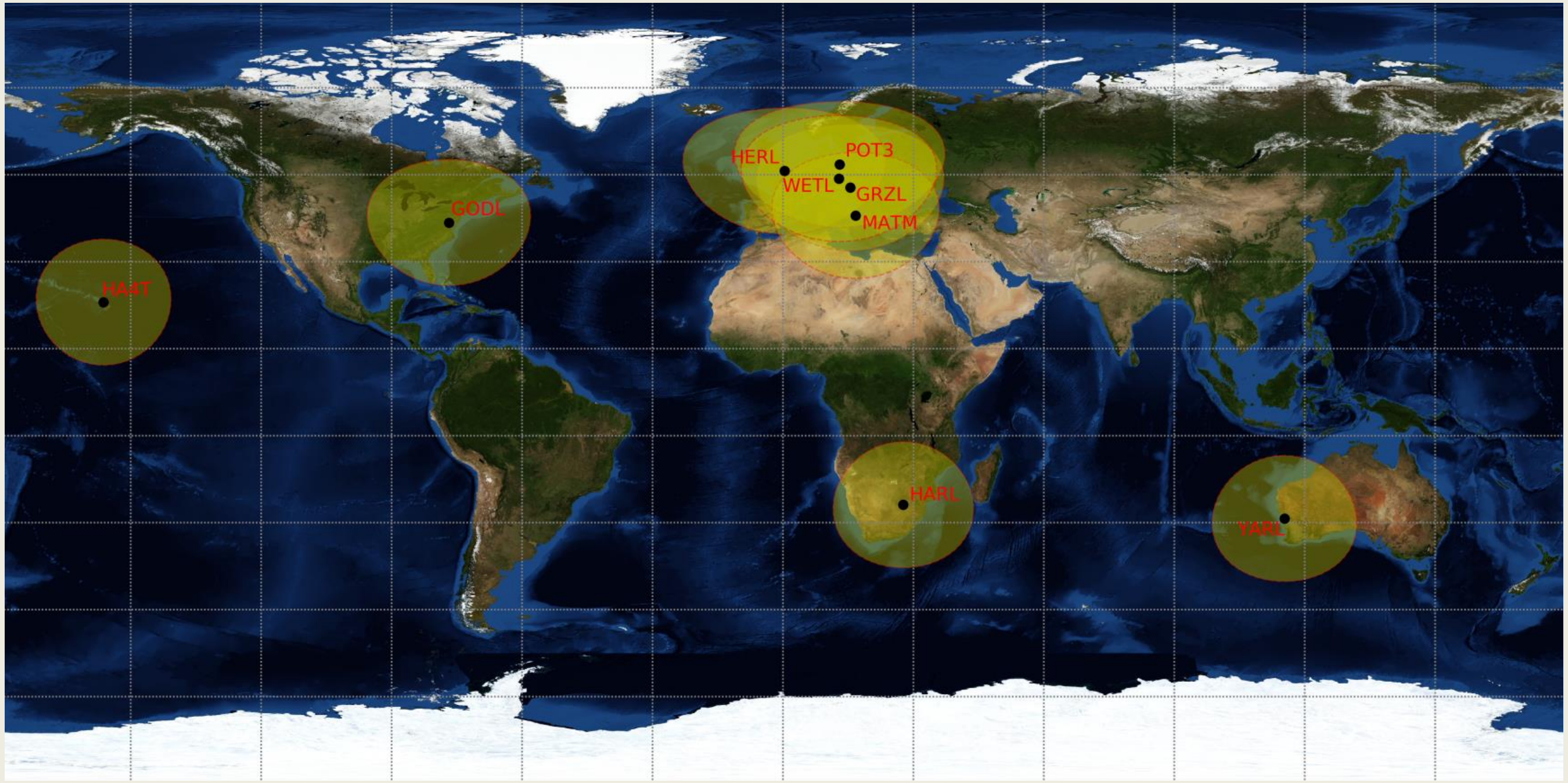




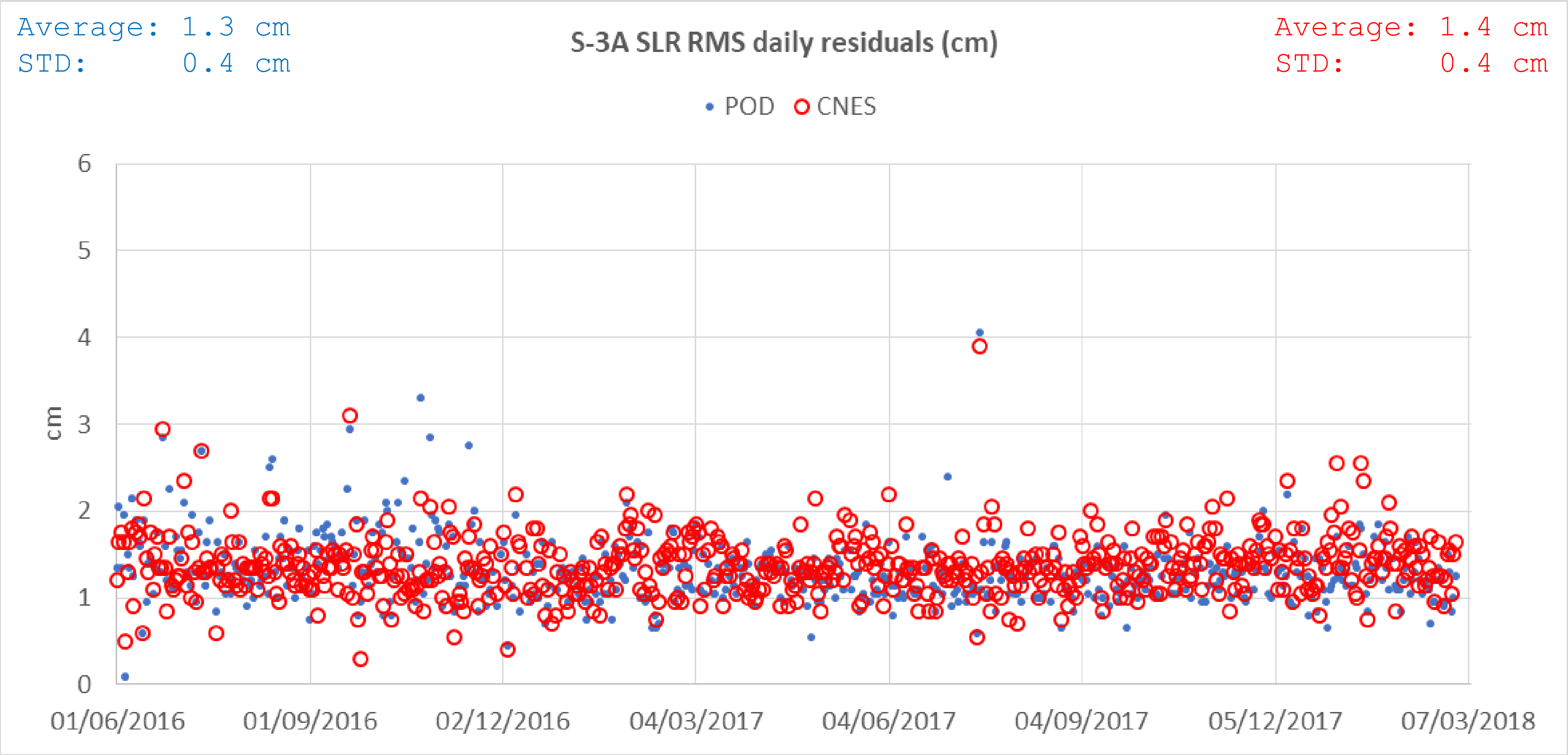
S-3A POEORB (NTC) SLR VALIDATION



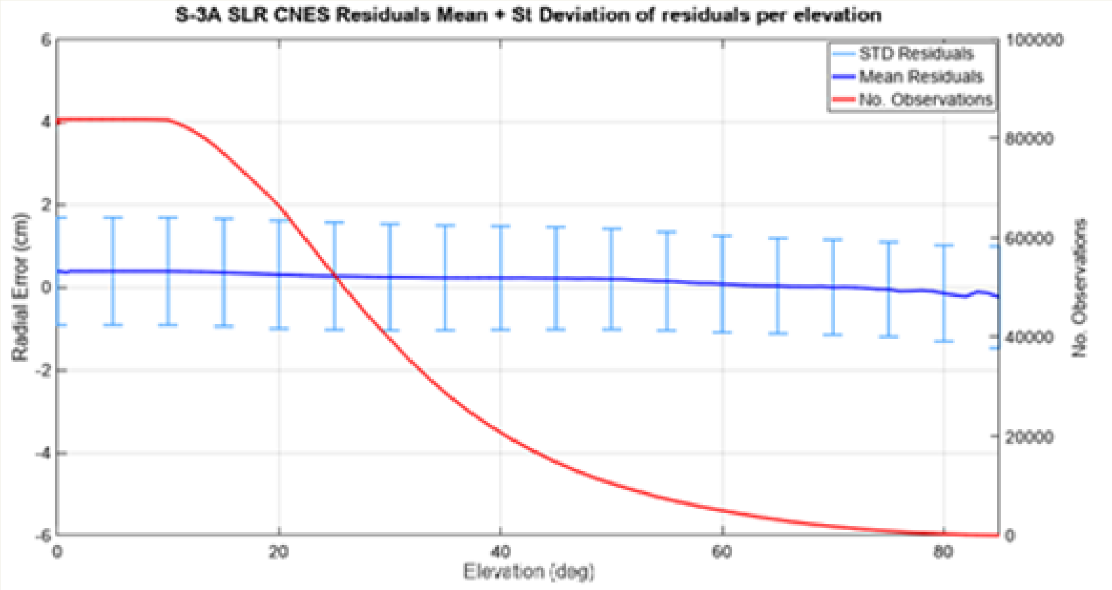
S-3A POEORB (NTC) SLR VALIDATION

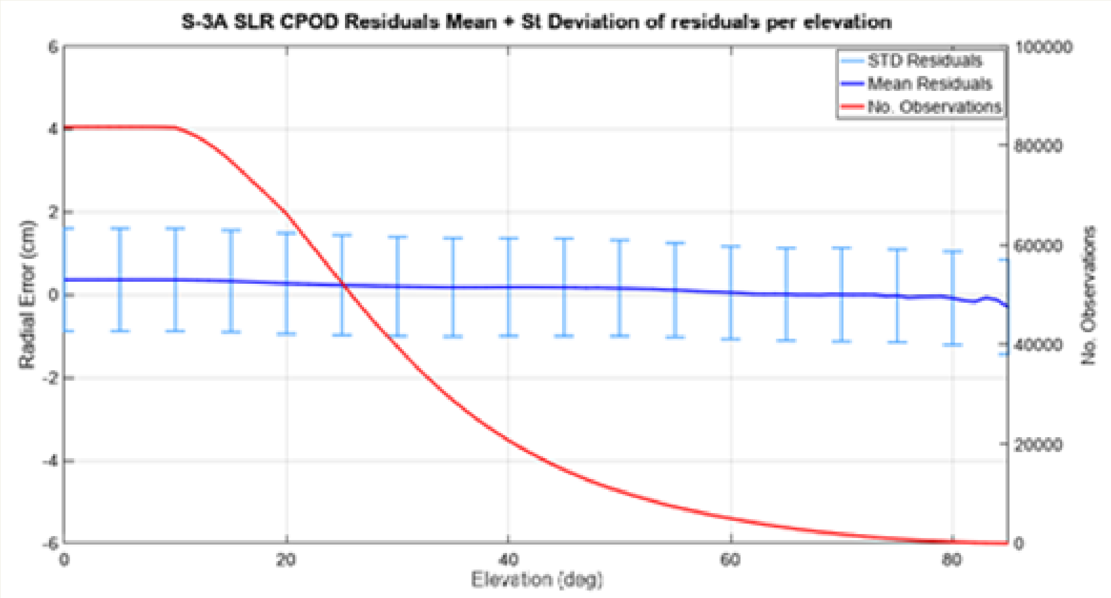


S-3A POEORB & CNES (NTC) SLR VALIDATION

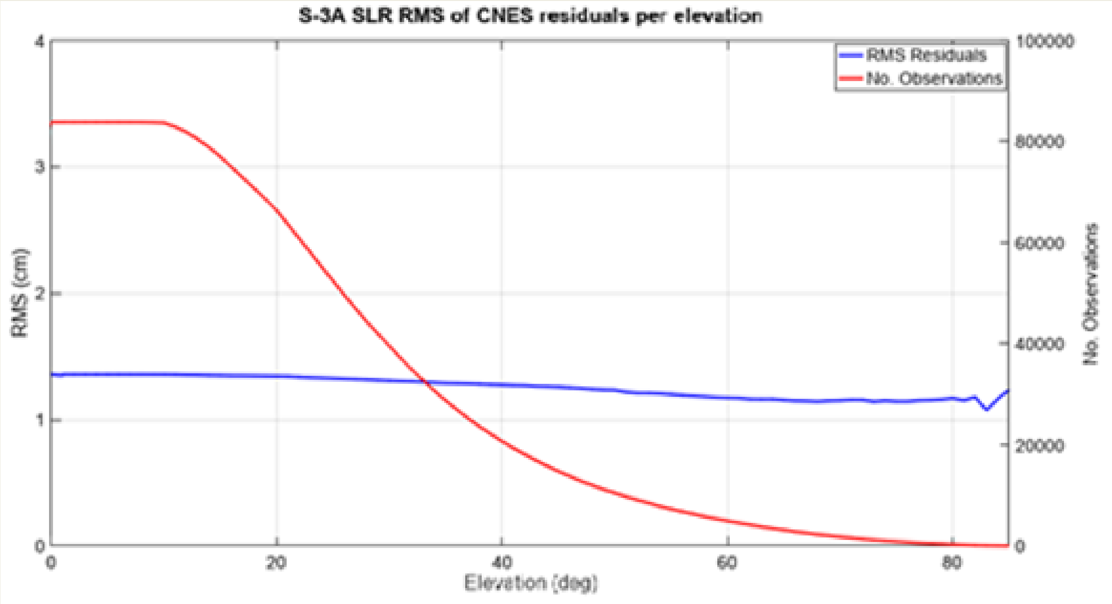


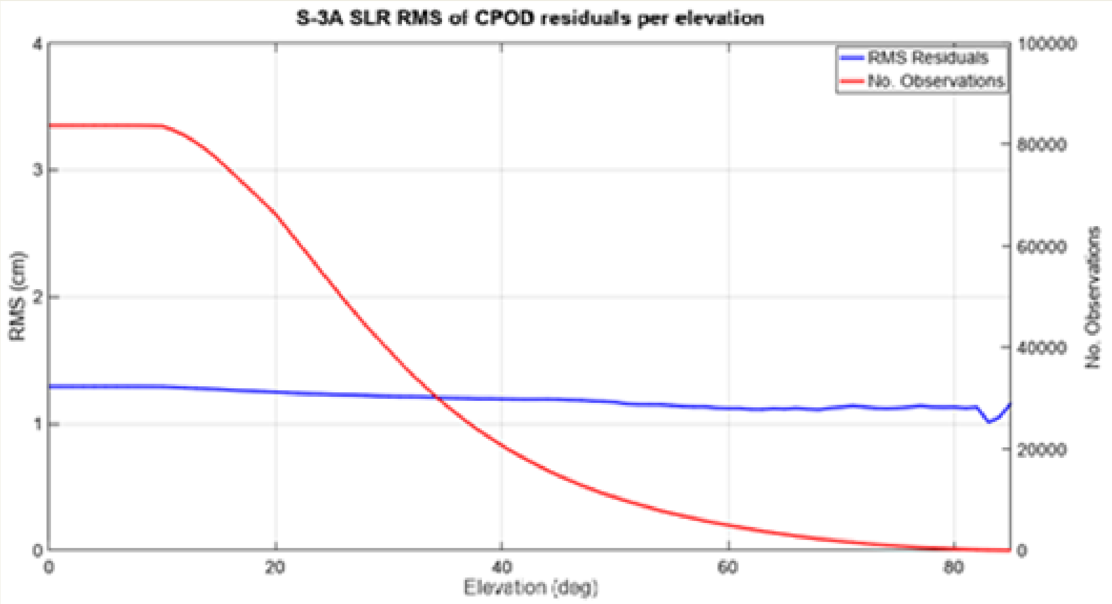
S-3A POEORB & CNES (NTC) SLR VALIDATION – MEAN RESIDUAL vs. ELEV.



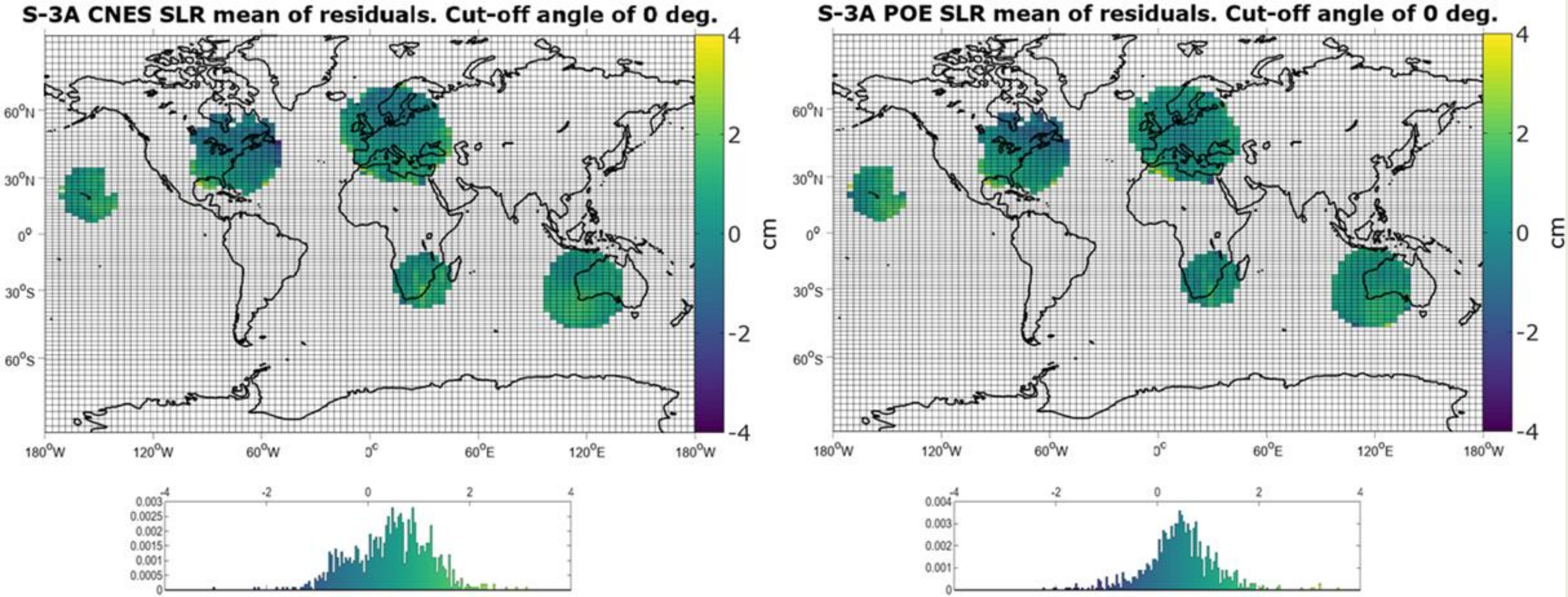


S-3A POEORB & CNES (NTC) SLR VALIDATION – RMS RESIDUAL vs. ELEV.

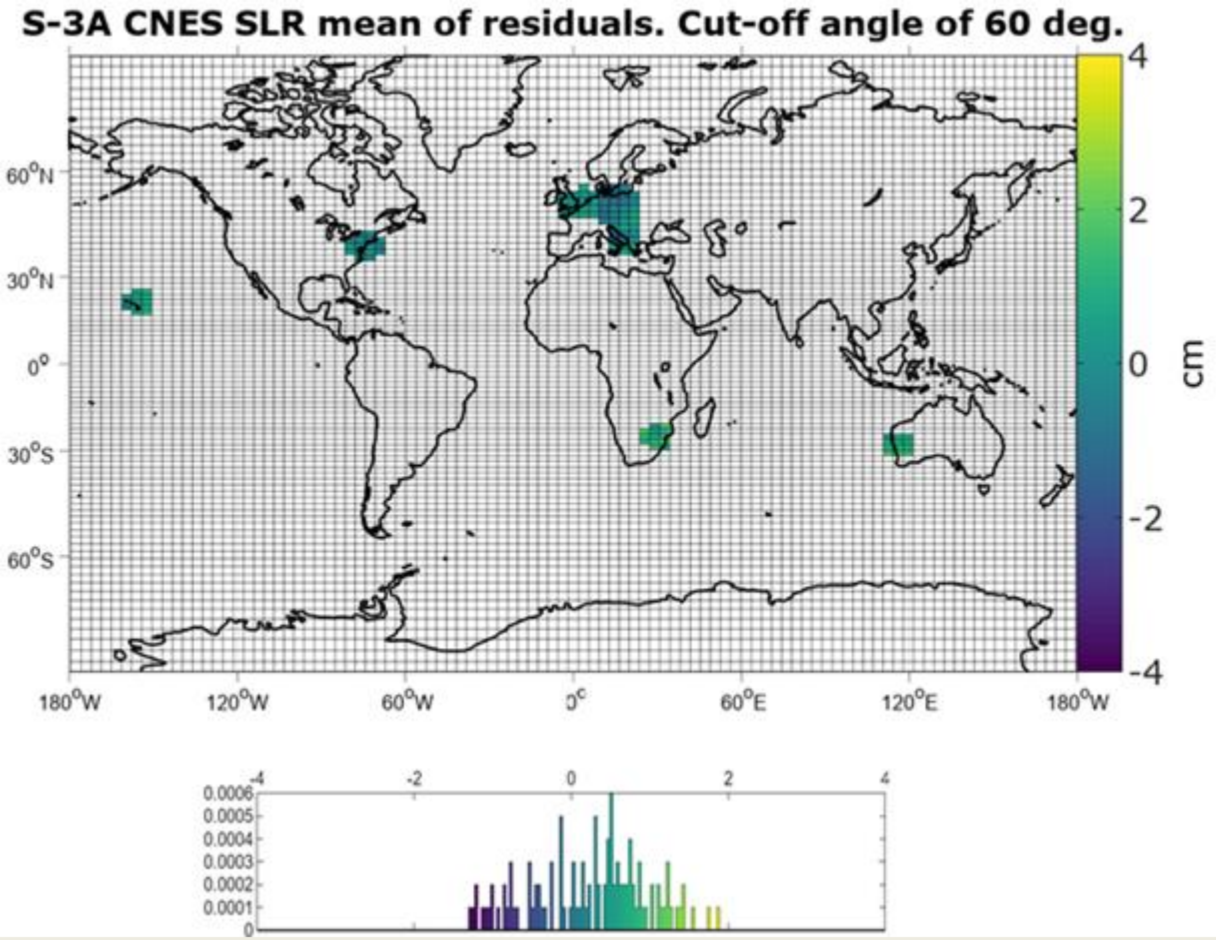


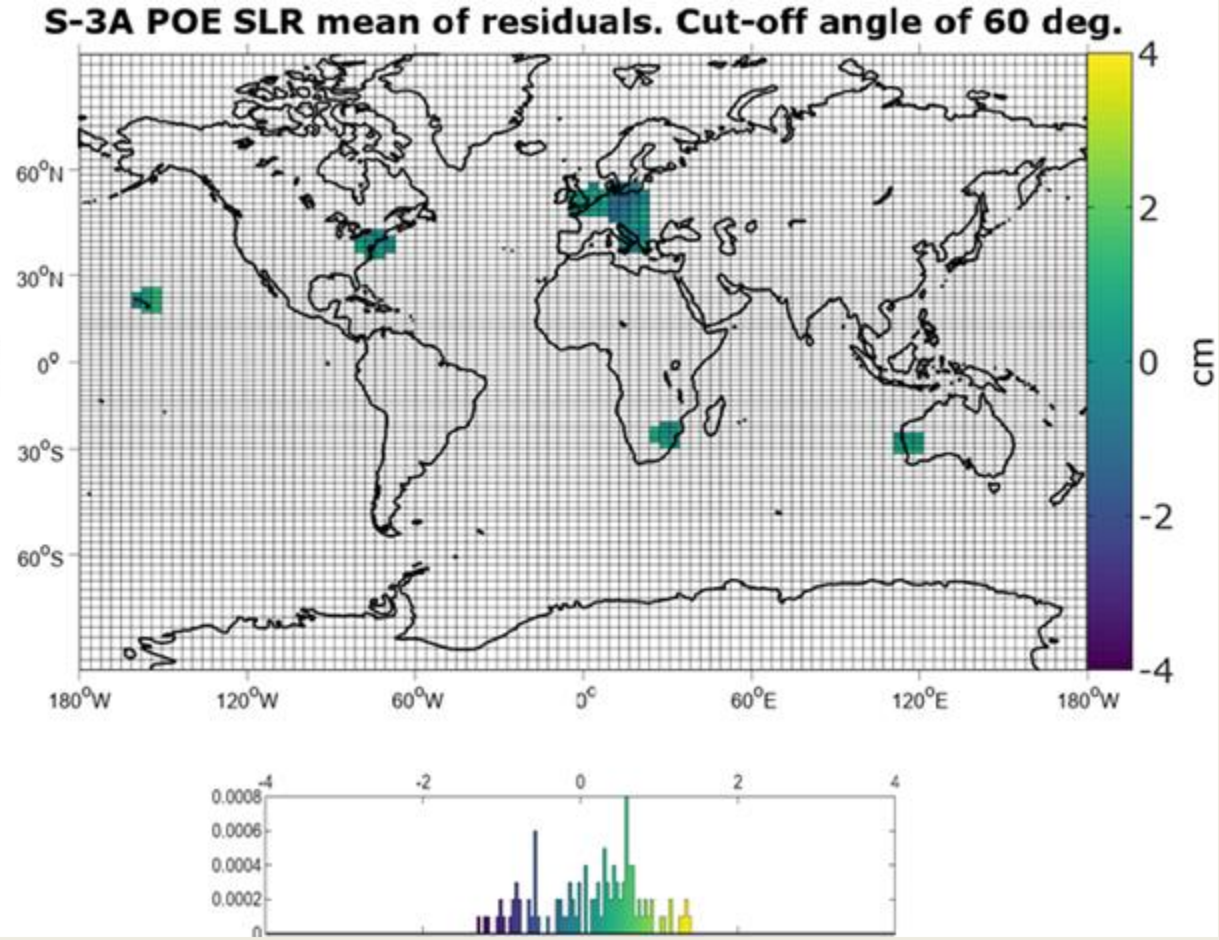


S-3A POEORB & CNES (NTC) SLR - WORLD MAP RESIDUALS. CUT-OFF ELEVATION ANGLE OF 0^o



S-3A POEORB & CNES (NTC) SLR - WORLD MAP RESIDUALS. CUT-OFF ELEVATION ANGLE OF 60º

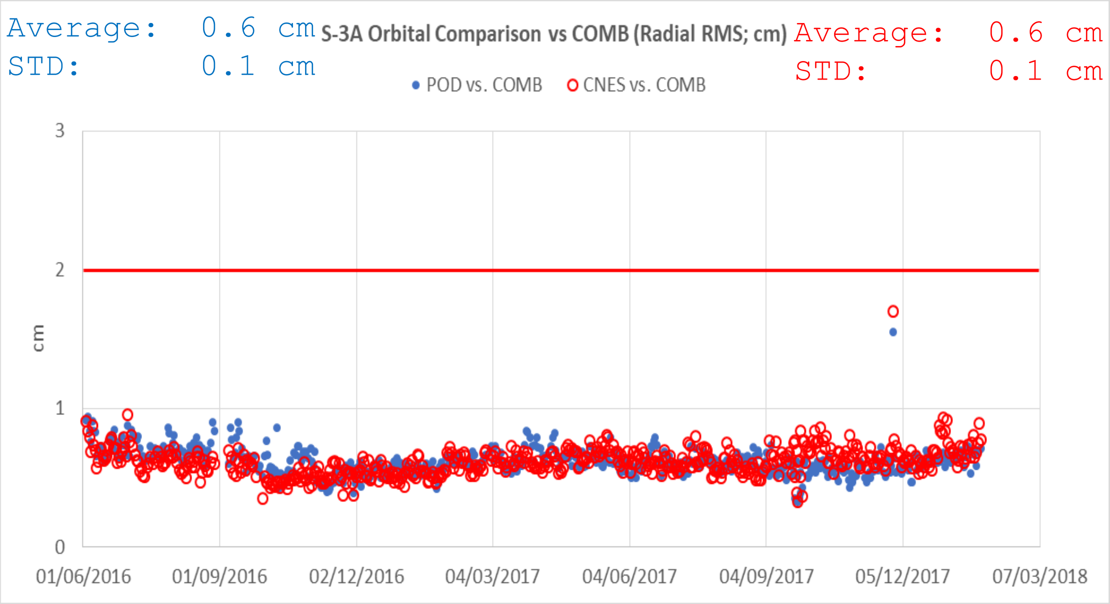


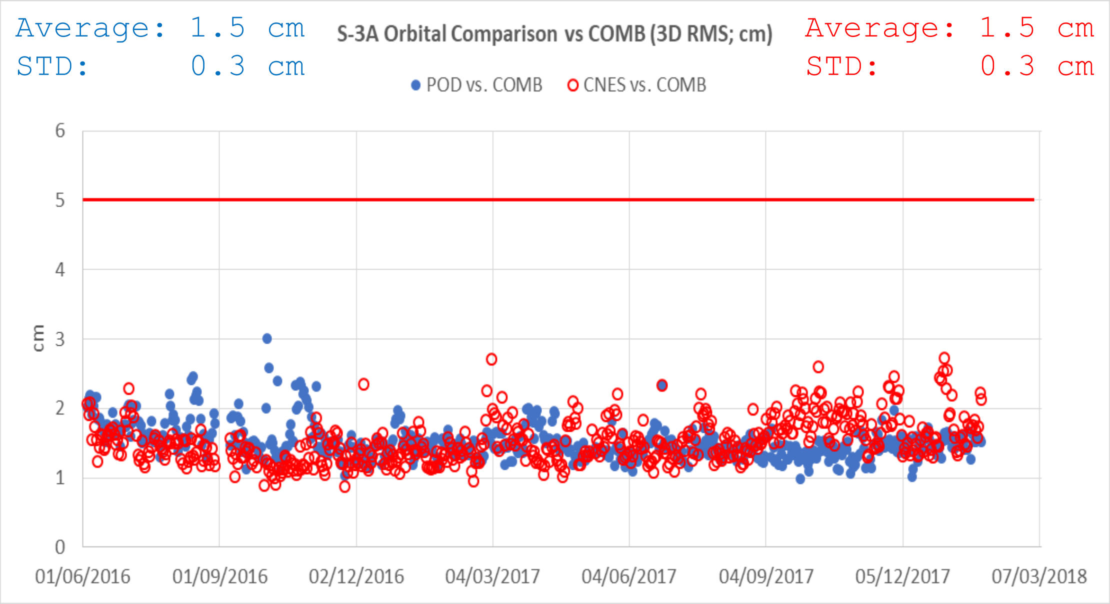


S-3A POEORB (NTC) – 3D ACCURACY vs. COMBINED SOLUTION

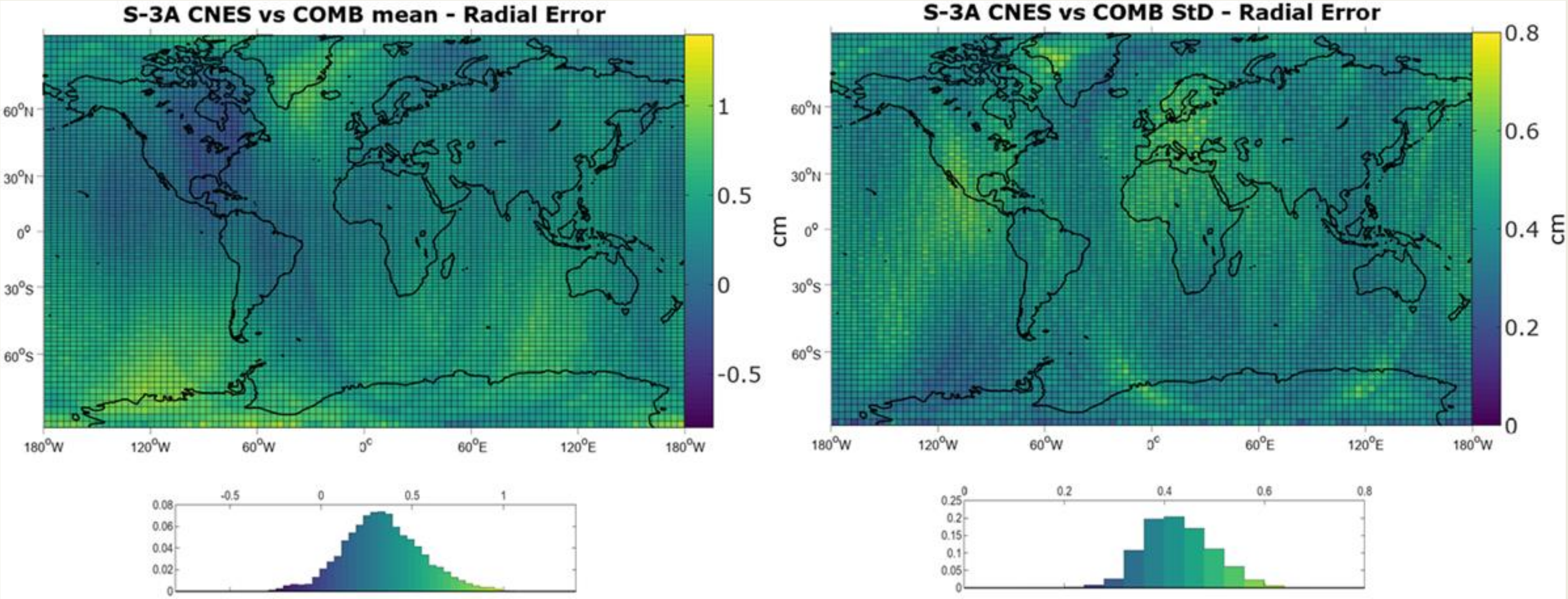
- Using orbital solutions from independent centres, a combined solution is generated using a weighted average (IGS like approach).
- During the last review, covering Oct' 17 to Jan' 18, the centres used came from:
  - AIUB: Two solutions: One more kinematic, another more dynamic; using Bernese
  - CNES: 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 & CNES (NTC) vs. COMBINED SOLUTION

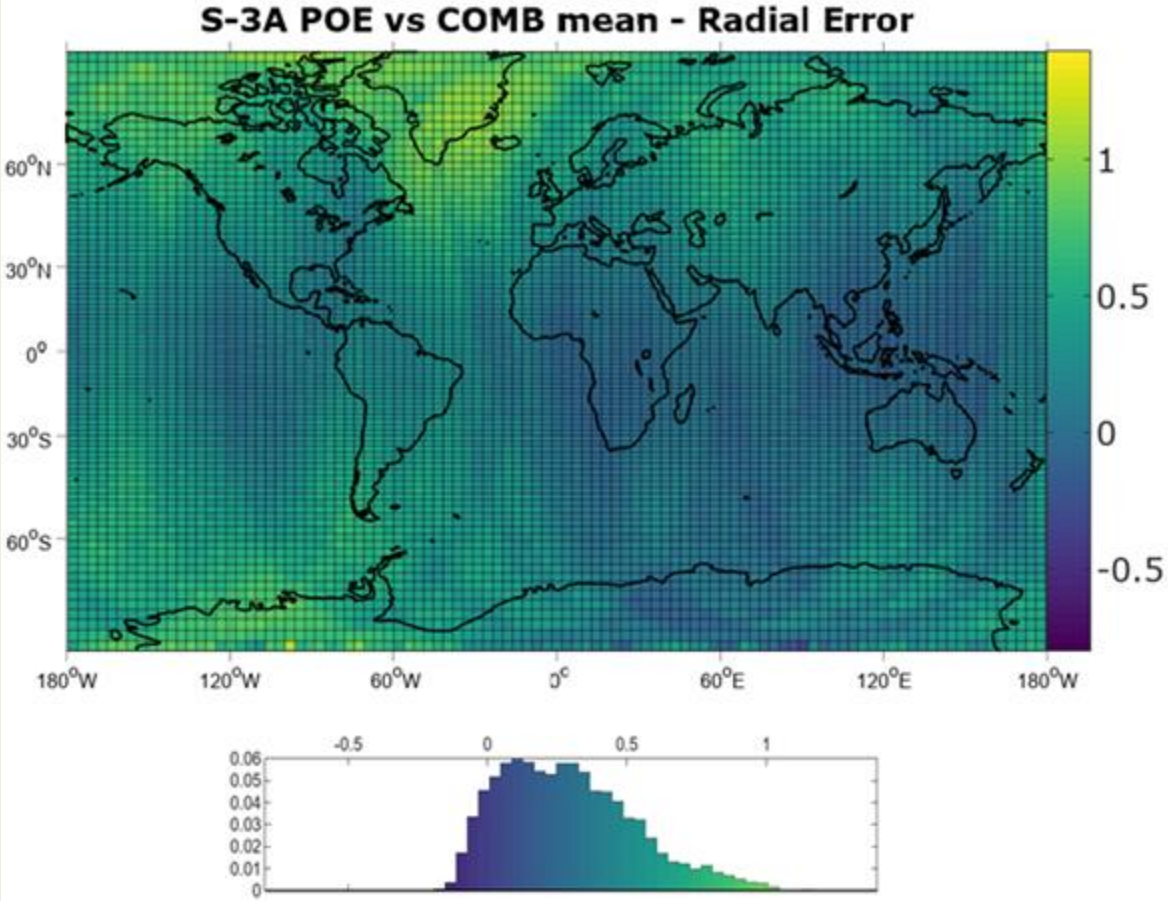


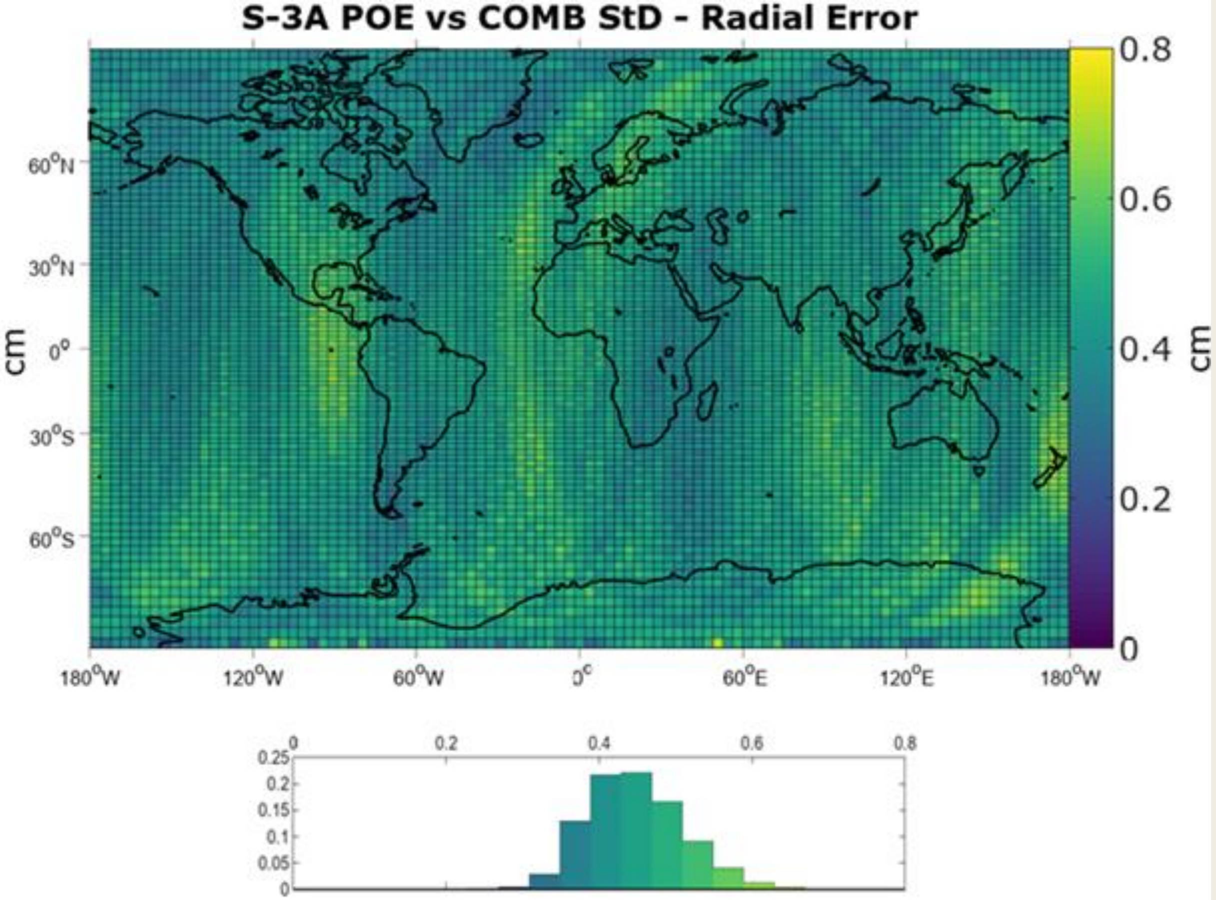


S-3A CNES (NTC) vs. COMBINED - WORLD MAP RADIAL ERROR



S-3A POEORB(NTC) vs. COMBINED - WORLD MAP RADIAL ERROR





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 ~0.9/0.5 cm

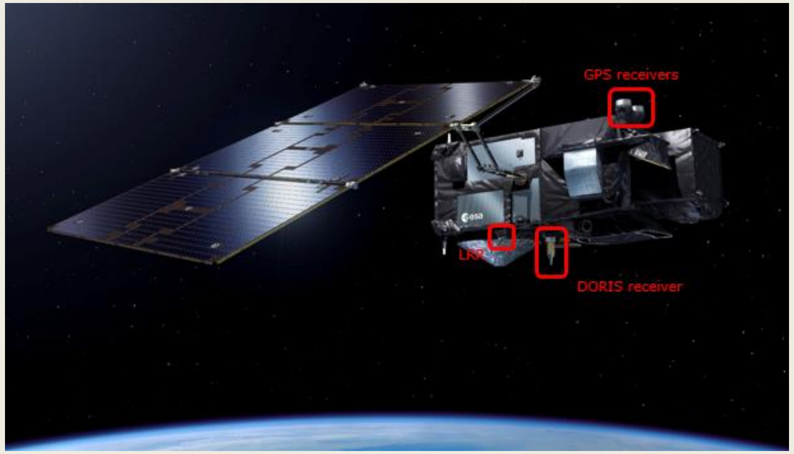
- NTC: POEORB has a radial consistency with respect to POE_AX (CNES) of ~0.6/0.1 cm

- NTC: POEORB has SLR residuals of 1.3/0.4 cm
- NTC: POE_AX has SLR residuals of 1.4/0.4 cm

- NTC: POEORB has a radial consistency with respect to COMB of 0.6/0.1 cm
- NTC: POE_AX has a radial consistency with respect to COMB of 0.6/0.1 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-3B will be launch on 25th of April

- 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

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.