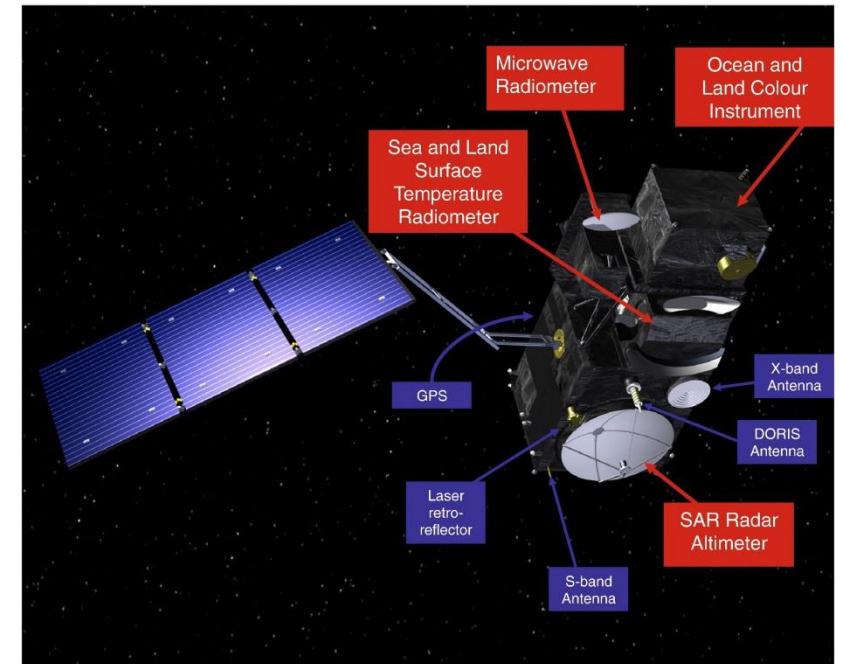


# Copernicus POD Service – Sentinel-3A orbit determination based on DORIS observations

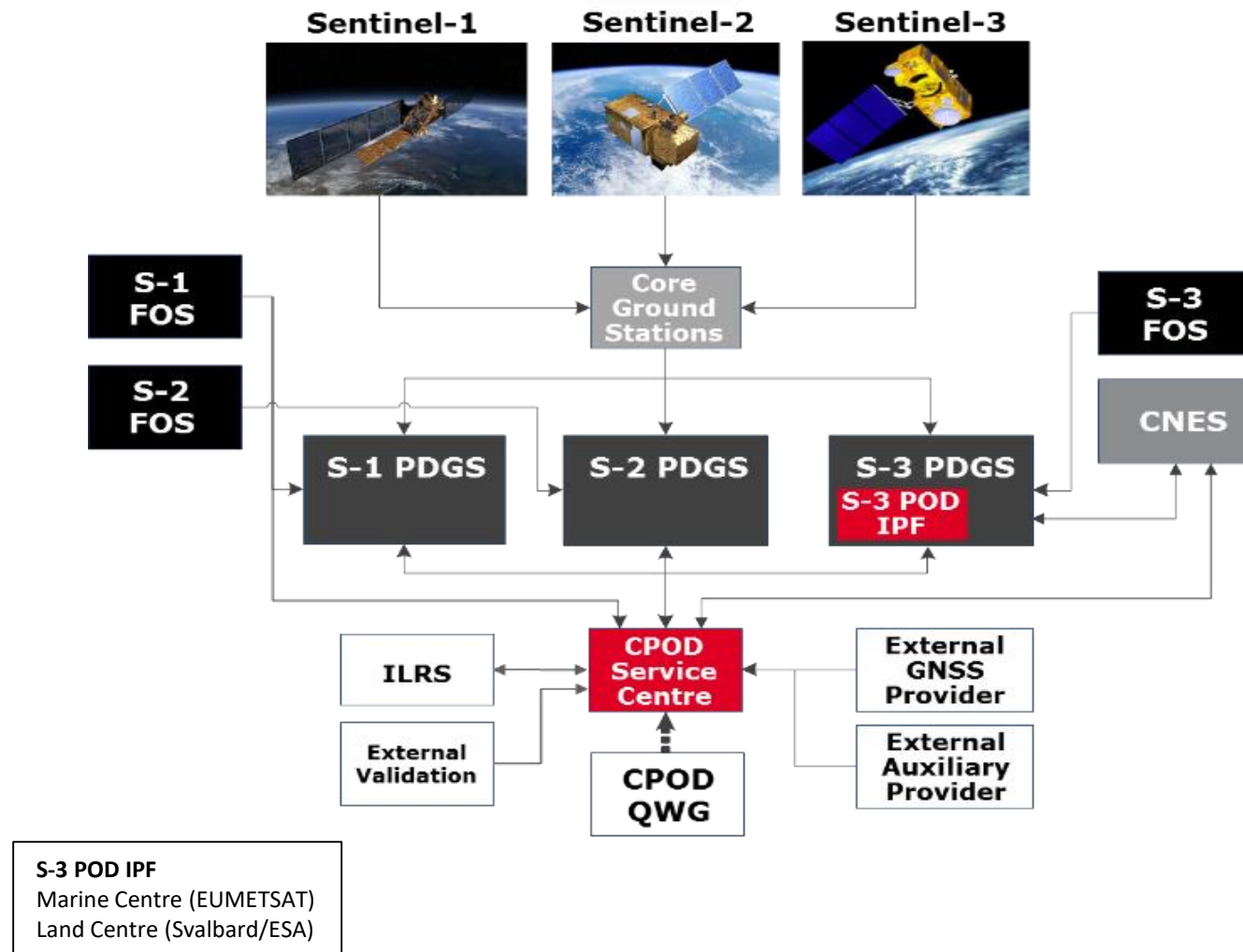
IDS AWG meeting, Toulouse  
June 11, 2018

Heike Peter  
PosiTIm UG



# 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.)



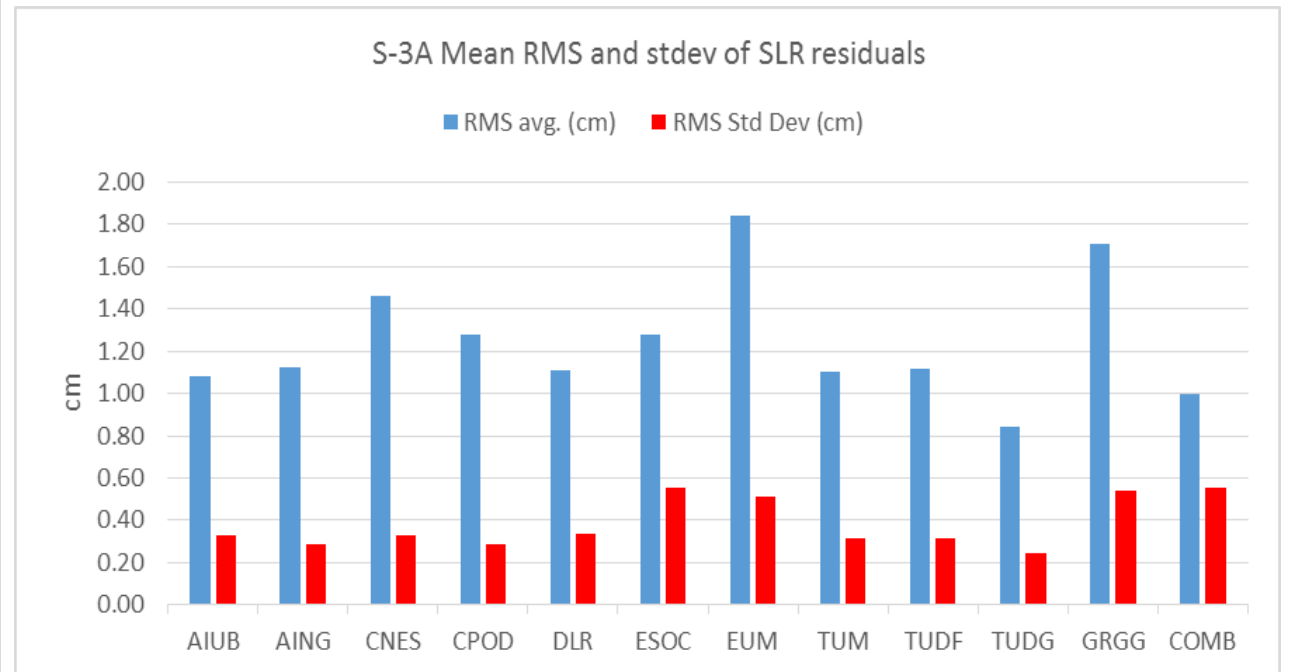
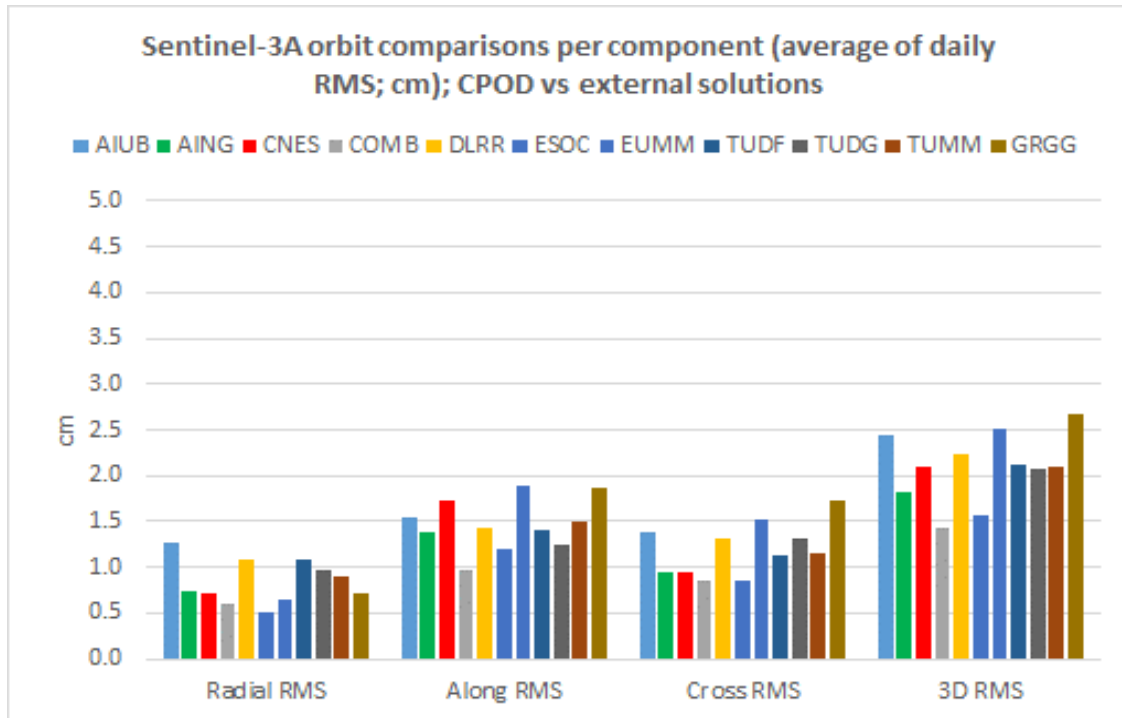
# Sentinel-3A orbit determination

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

- The official Sentinel-3A orbit products from the CPOD Service are all based on GPS observations only, SLR measurements are used for validation (NTC), no DORIS observations are used until now.
- Regular Service Reviews are done to compare the NTC orbit solutions against solutions from the POD QWG.
- Except the solution from CLS/GRGS (DORIS-only) all other orbit solutions are GPS-only as well.

# Sentinel-3A orbit determination

Comparison results from the last RSR#10 (Oct 2017 – Jan 2018)



# Key data of DORIS processing

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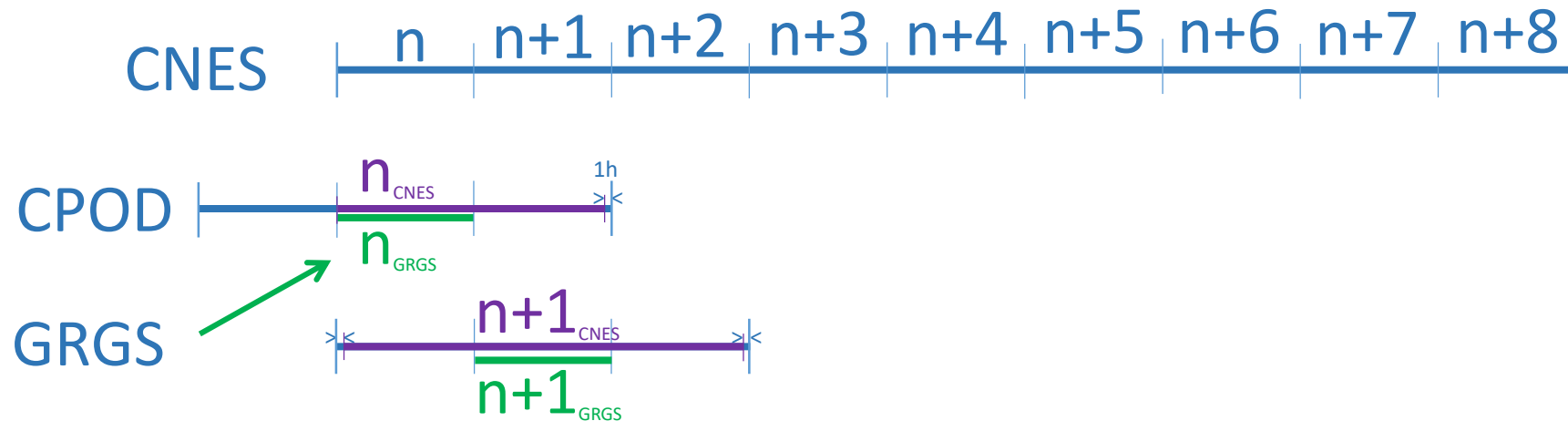
- At first, the DORIS phase observables (from the DORIS RINEX files) are converted to Doppler observations, so that the data processing can be done in the same way as for other DORIS satellites in NAPEOS.

The key data of the DORIS processing for **Solution A** are:

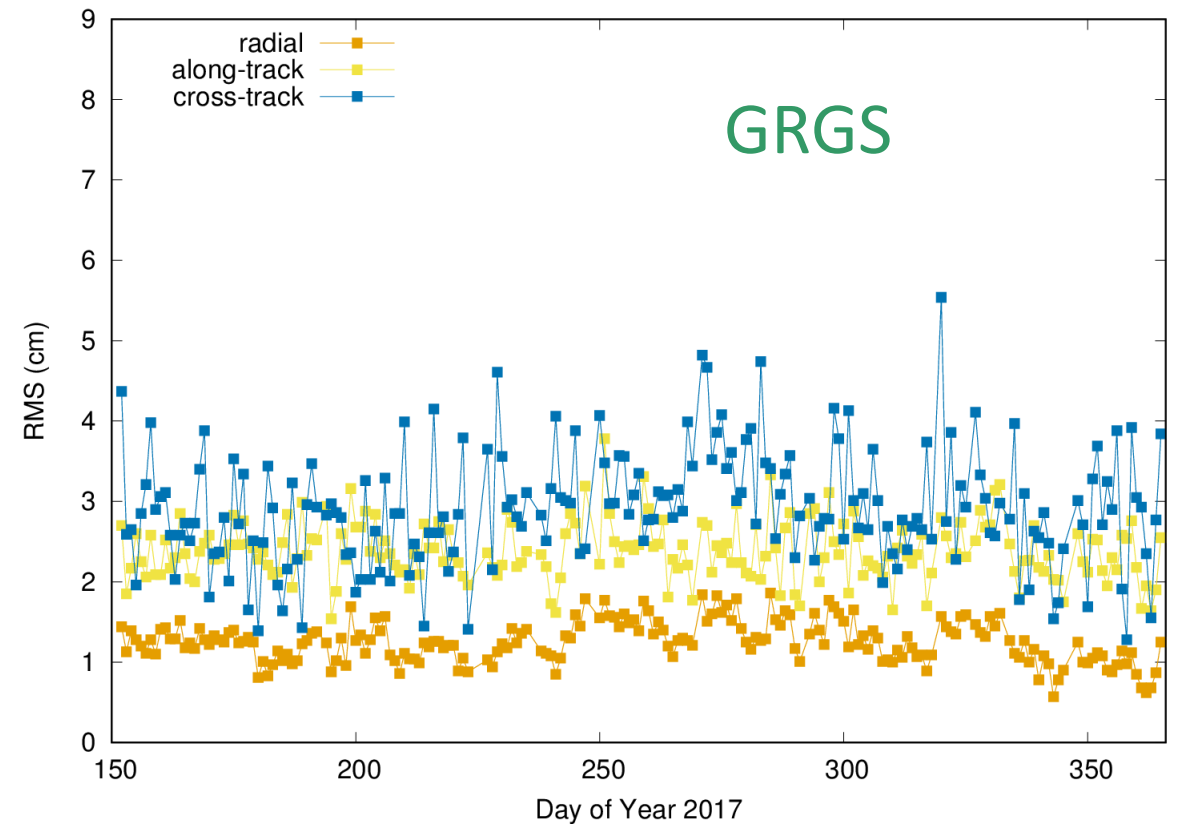
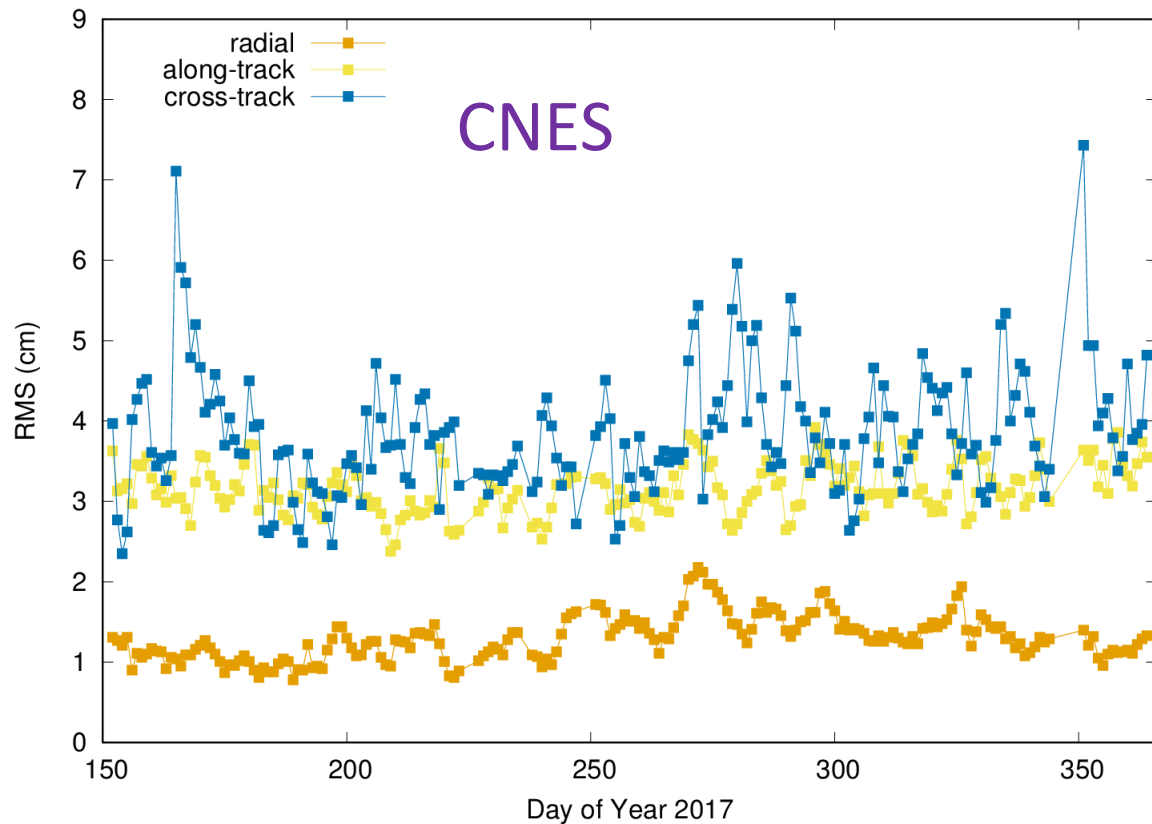
- Three-day arc length (72 hours)
- Estimation of
  - 1 radiation pressure coefficient
  - 10/24h atmospheric drag scale factors
  - 2/24h sets of CPR along-track sine+cosine and cross-track sine+cosine parameters
- Elevation cut-off angle of  $10^\circ$  for DORIS observations, no elevation-dependent weighting

# DORIS-only orbits

- DORIS-only orbits from CNES and CLS/GRGS are available for comparison
- Arc length: CNES 9 days, GRGS 1 day (extracted from 3,5 days), CPOD 3 days
- Orbit comparison is done for 1 Jun – 31 Dec 2017 based on different arc lengths

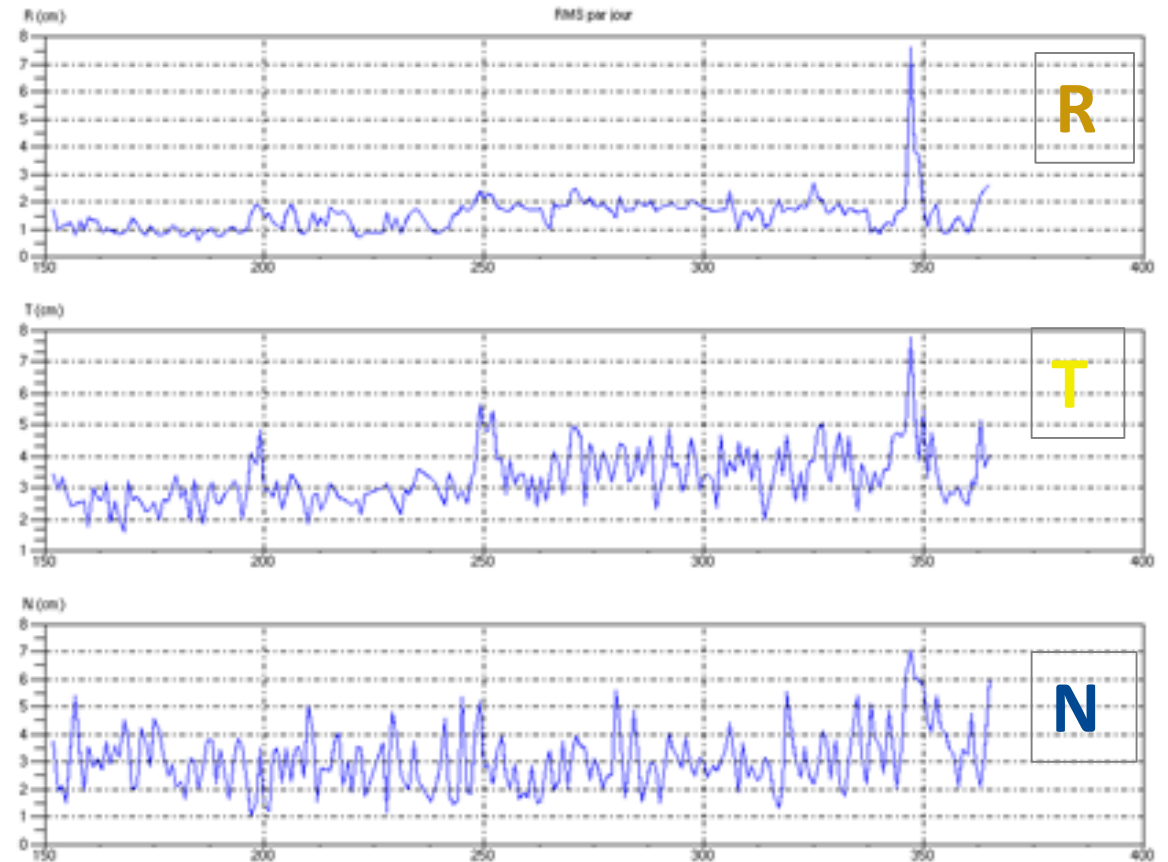
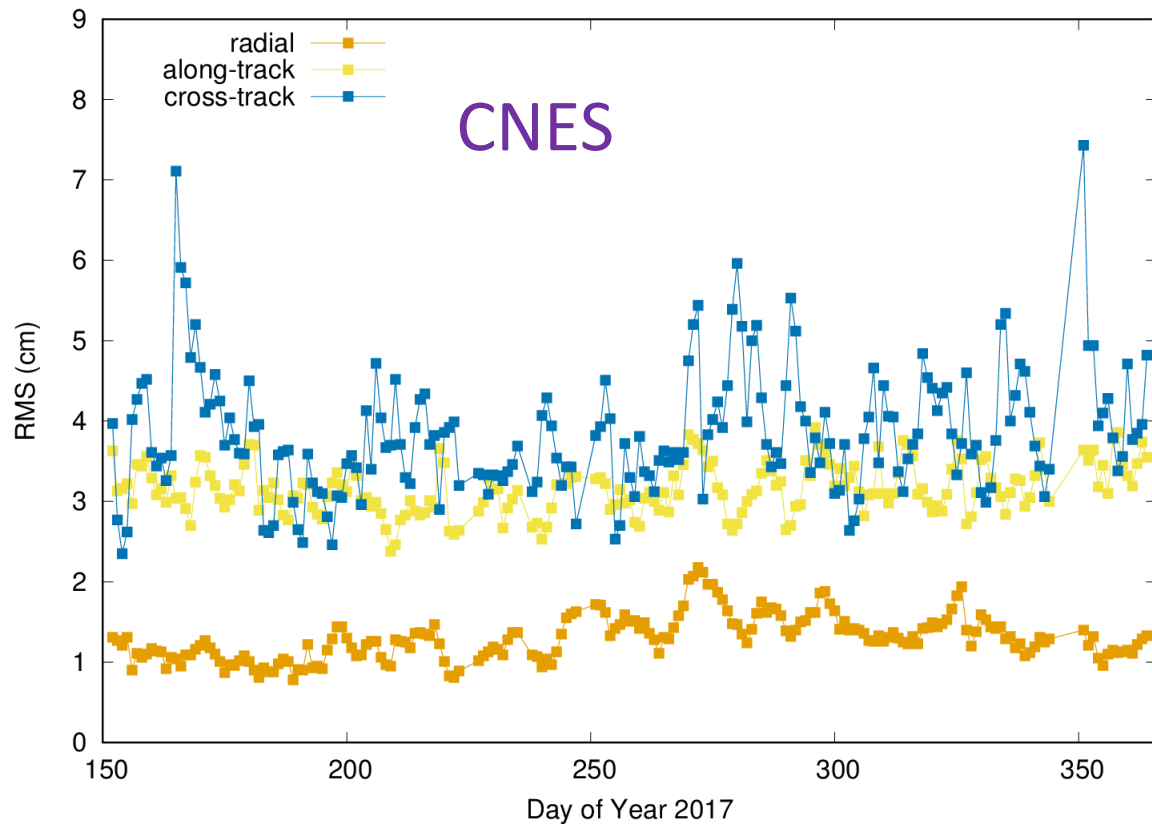


# DORIS-only orbits



Daily RMS (cm) of Solution A orbits w.r.t. CNES DORIS (left) and GRGS DORIS (right) orbits; outliers >10 cm excluded

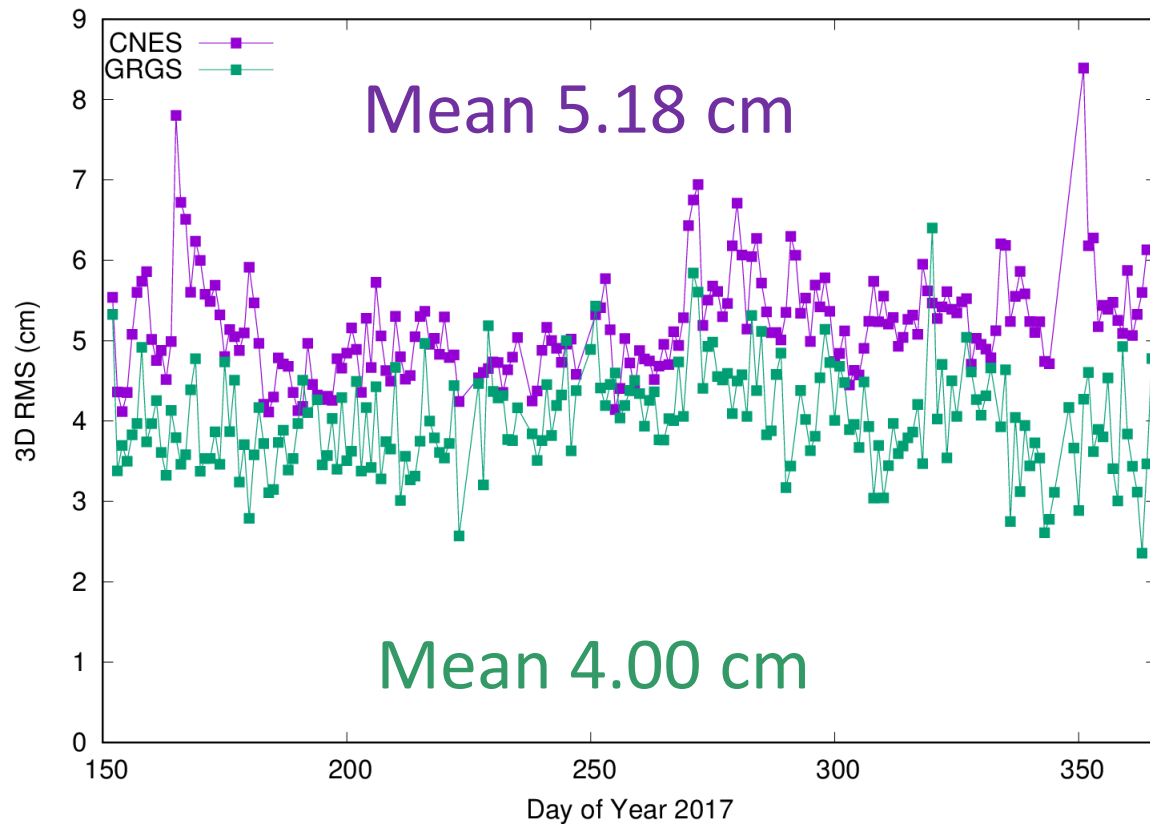
# DORIS-only orbits



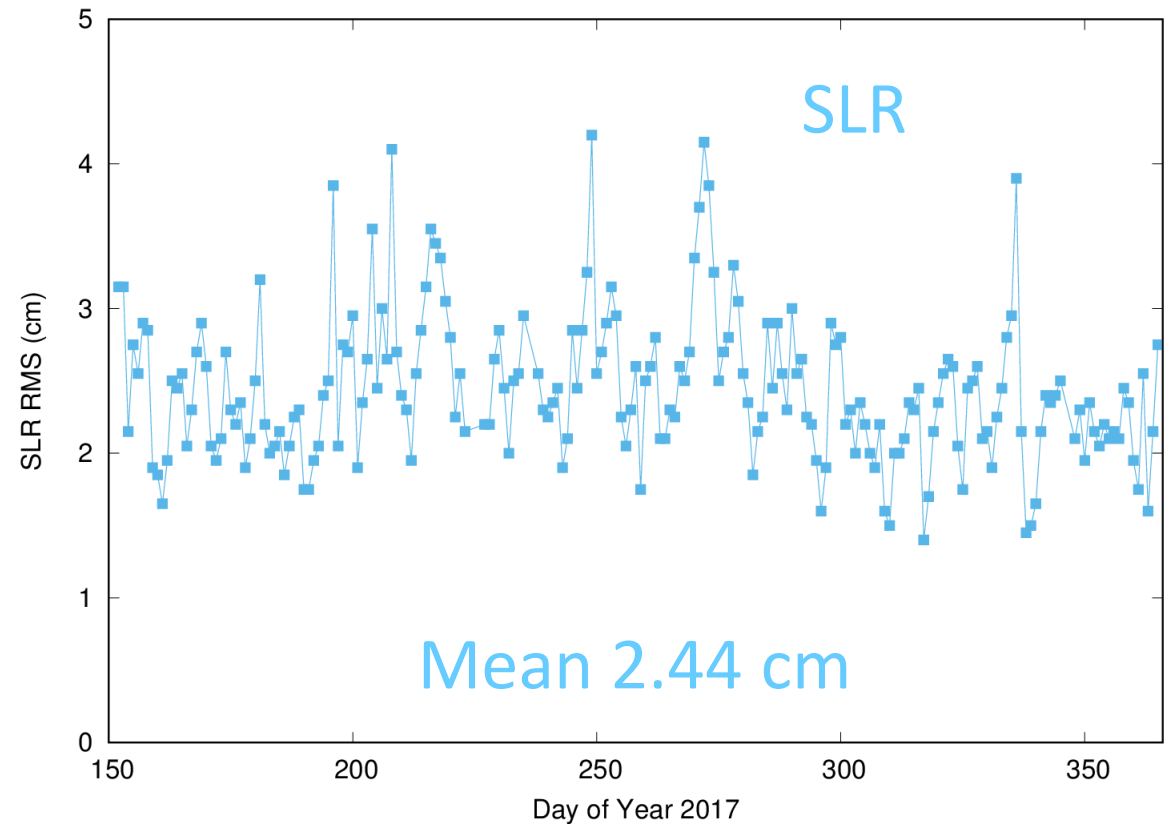
**Daily RMS (cm) of Solution A orbits w.r.t. CNES DORIS (left) and CNES DORIS correct EOP handling (right) orbits; outliers >10 cm excluded**



# DORIS-only orbits



Daily 3D RMS (cm) of Solution A orbits w.r.t. CNES DORIS (left) and GRGS DORIS (right) orbits; outliers >10 cm excluded

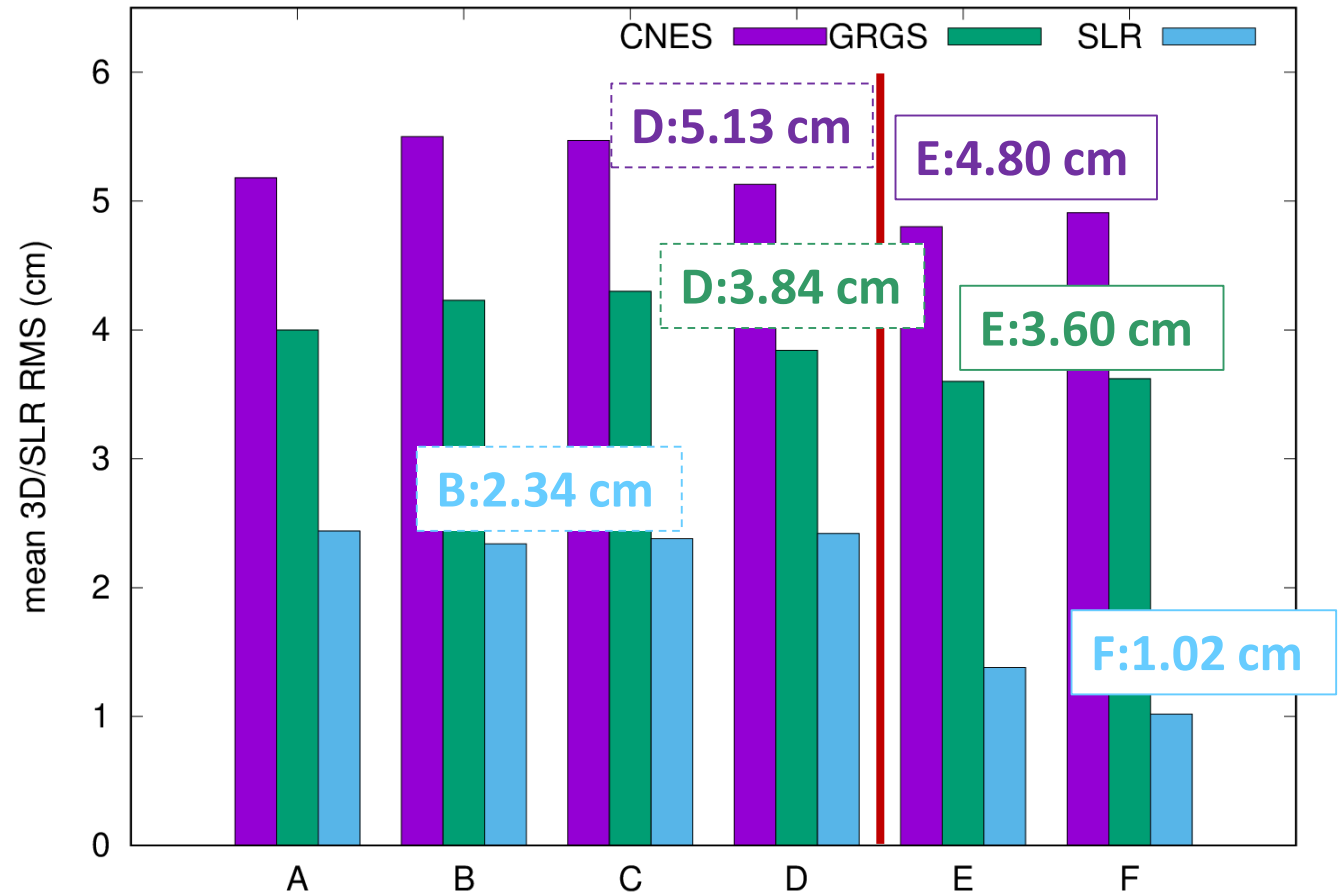


SLR RMS (cm) of Solution A orbits; outliers > 5 cm excluded

# DORIS-only and DORIS+SLR orbits

Different CPOD solutions are generated based on different parametrizations and observation models (differences to **Solution A** are noted):

- **Solution B:** elevation cut-off angle of  $7^\circ$ , elevation dependent weighting with  $\sigma=1/\sin(\text{elev})$
- **Solution C:** radiation pressure coefficient is fixed to 1, CPR cross-track constant parameters are estimated
- **Solution D:** elevation cut-off angle of  $12^\circ$
- **Solution E:** combined DORIS+SLR solution
- **Solution F:** combined DORIS+SLR solution, DORIS elevation cut-off angle of  $7^\circ$ , elevation dependent weighting with  $\sigma=1/\sin(\text{elev})$



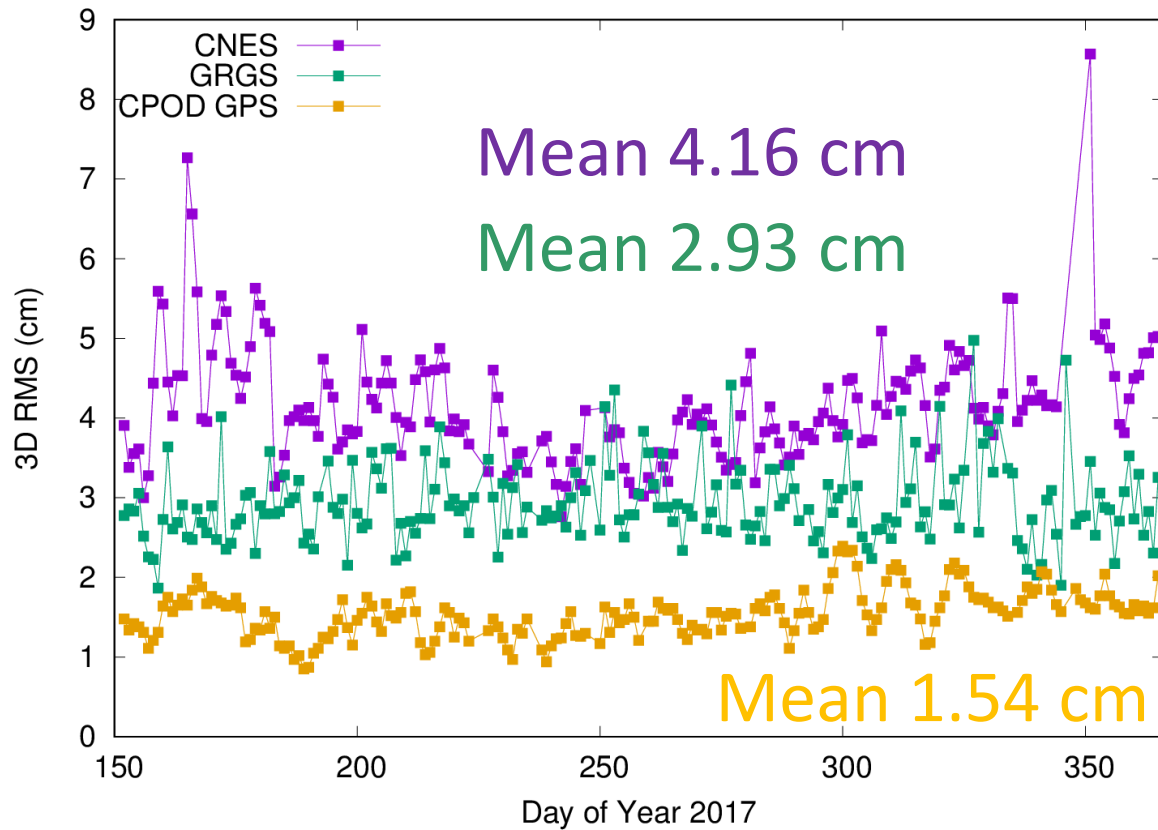
# GPS+DORIS(+SLR) orbits

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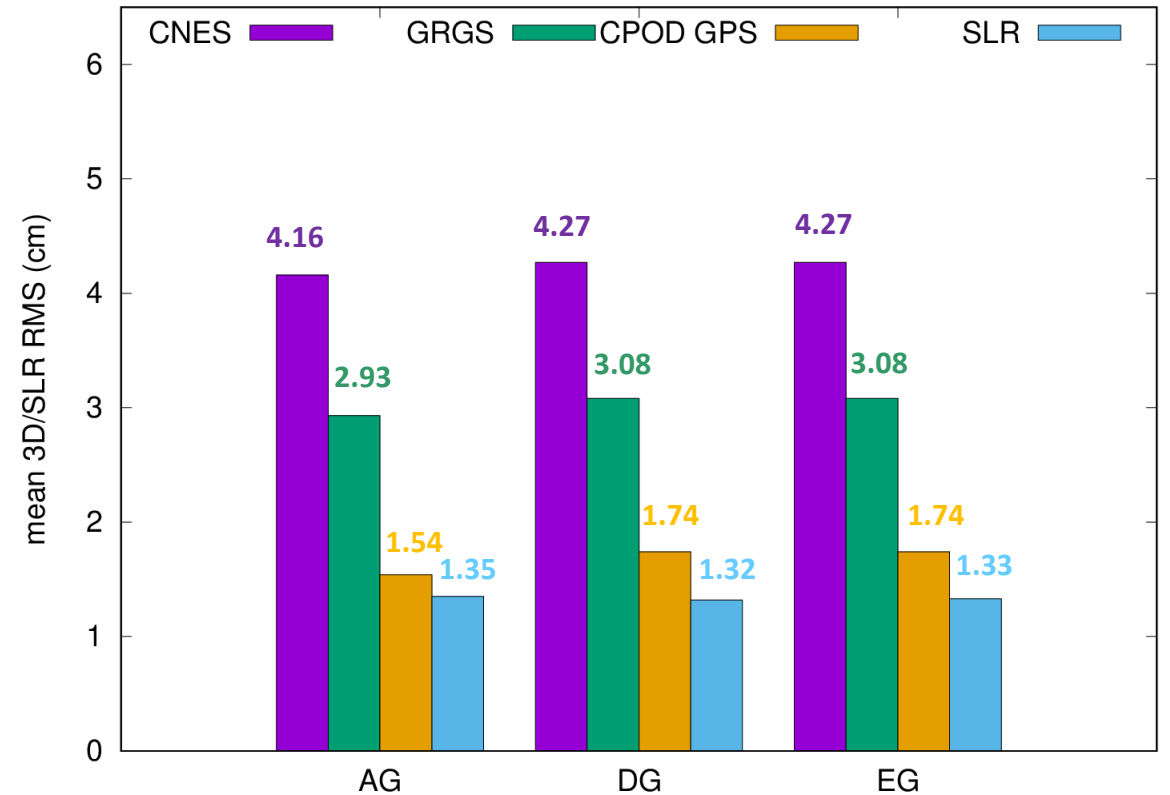
The following combined GPS+DORIS(+SLR) orbits are generated:  
(GPS observation modelling is the same as for the GPS-only orbits)

- **Solution AG:** DORIS: elevation cut-off angle of  $10^\circ$ , no elevation dependent weighting
- **Solution DG:** DORIS: elevation cut-off angle of  $12^\circ$ , no elevation dependent weighting
- **Solution EG:** DORIS: elevation cut-off angle of  $10^\circ$ , no elevation dependent weighting + SLR

# GPS+DORIS(+SLR) orbits



Daily 3D RMS (cm) of Solution AG orbits w.r.t. CNES and GRGS DORIS orbits and CPOD GPS only orbits; outliers >10 cm excluded



Mean 3D RMS (cm) values and mean SLR RMS (cm) values for different solutions

# Summary and future plans

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- The performance of the CPOD orbits based on DORIS observations is already good and promising.
- The comparison results of the combined **CPOD GPS+DORIS(+SLR)** orbits (**AG, DG, EG**) are, however, better than for the **CPOD DORIS(+SLR)** orbits (**A-F**). One reason for this is the strength of the GPS observations but the DORIS processing should also be analysed again to improve the comparisons to DORIS-only orbit solutions.

Further investigations will be done to

- find the best elevation cut-off angle and the best elevation-dependent weighting scheme
- check the conversion of the DORIS phase observables to Doppler
- find the optimal a priori sigma for the DORIS observations
- find the optimal relative weighting scheme between the different observation techniques for a combined orbit solution

One goal is to have DORIS-only and combined S-3 orbit solutions available for a proper internal CPOD comparison of the three observation techniques. Focus will also be given to biases between the different orbit solution types.

Sentinel-3B will be included as soon as DORIS observations will be available.

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Thank you for your attention!