Copernicus POD Service – Model Updates and Validation of Sentinel-3 Orbit Determination

OSTST 2019, Chicago, IL
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Copernicus POD Service

esa
EUMETSAT

opernicus
Europe's eyes on Earth

Sentinel-1

Sentinel-2

Sentinel-3

- Sentinel satellites are equipped with various Earth observation instruments
- Mission requirements demand high levels of orbital accuracy (**GPS**, DORIS+SLR only S-3) → **Copernicus POD Service**

Copernicus POD Service

- Consortium led by **GMV**, Tres Cantos, Spain
- **Veripos**, external GPS orbit and clock provider (NRT, STC)
- **PosiTim**, QWG management, quality control, improvements, scientific outreach …
- **DLR, TUM, AIUB, TUD,** quality control, QWG members

PosiTIM
AIUB TU Delft Veripos
gmv

Copernicus POD Service

Sentinel-1

Sentinel-2

Sentinel-3

Mission	Category	Orbit Accuracy (RMS)
S-1	NRT (predicted)	1 m (2D)
	NRT	10 cm (2D)
	NTC	**5 cm (3D)**
S-2	NRT (predicted)	3 m (2D)
	NRT	1 m (3D)
S-3	NRT (S3PODIPF)	10 cm radial (target of 8 cm)
	STC	4 cm radial (target of 3 cm)
	NTC	**3 cm radial (target of 2 cm)**

Copernicus POD Quality Working Group

⇒ **Orbit validation and quality control**

AIUB

DLR

TU Delft

esa

TUM

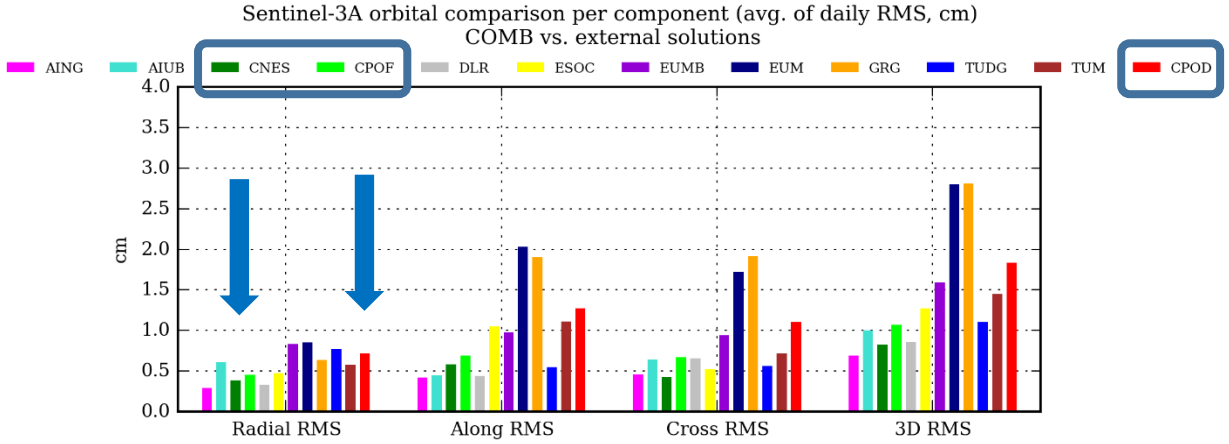
cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

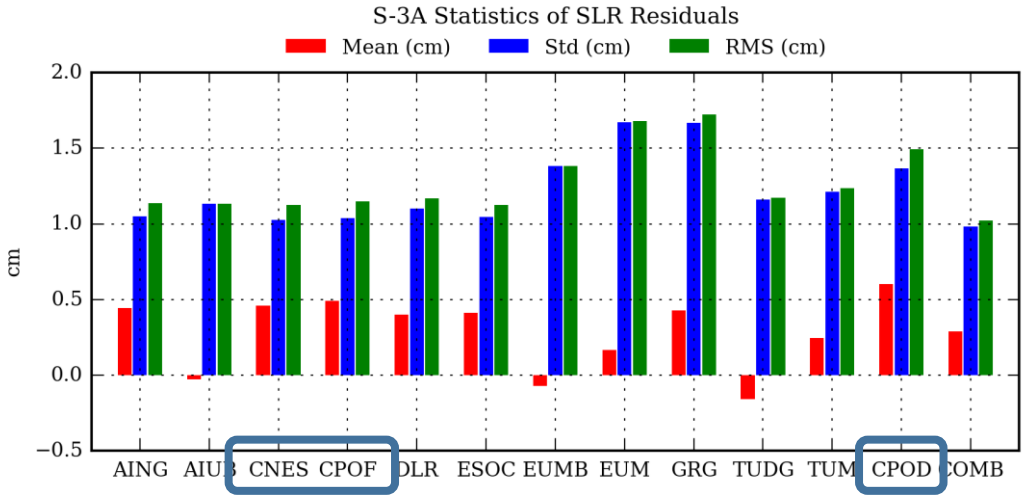
CLS
COLLECTE LOCALISATION SATELLITES

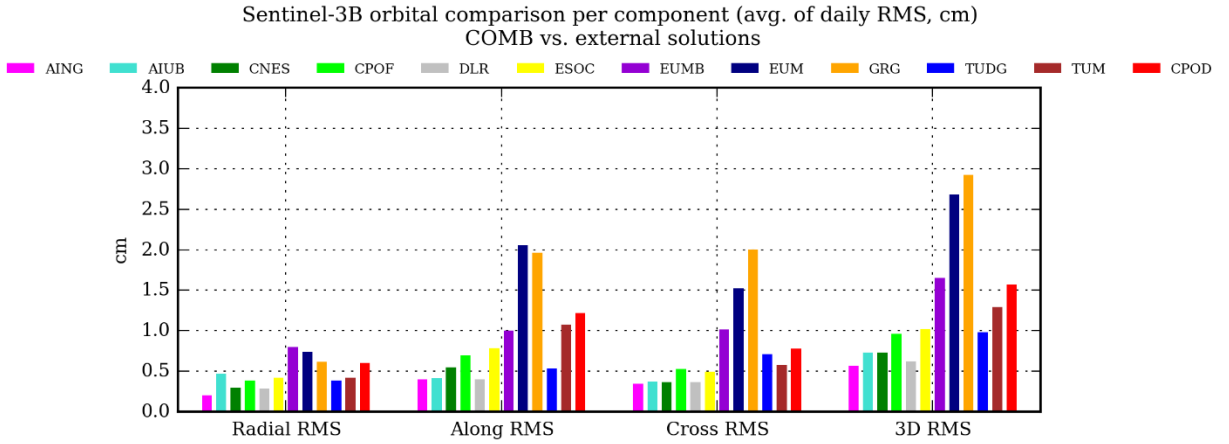
EUMETSAT

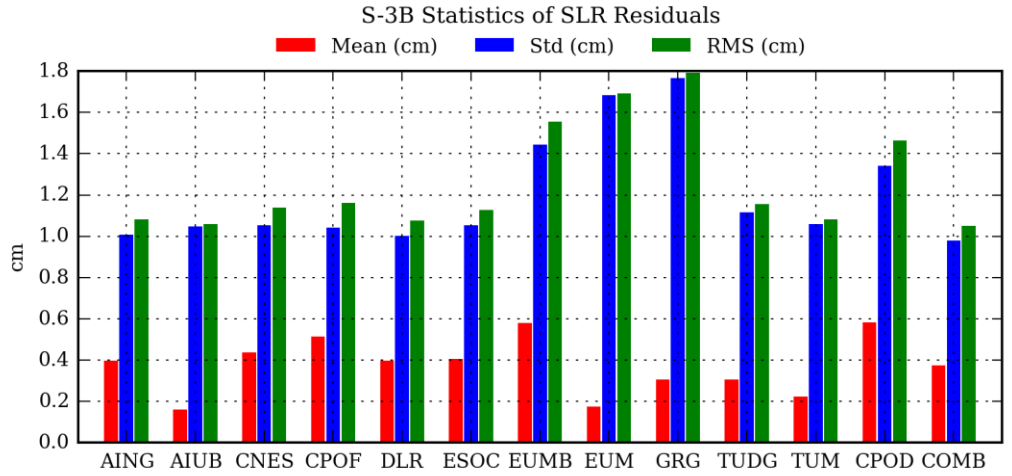
Official orbit provider for S-3 is CNES, Copernicus POD Service delivers backup solutions.

Regular Service Reviews – RSR#14 Feb – May 2019

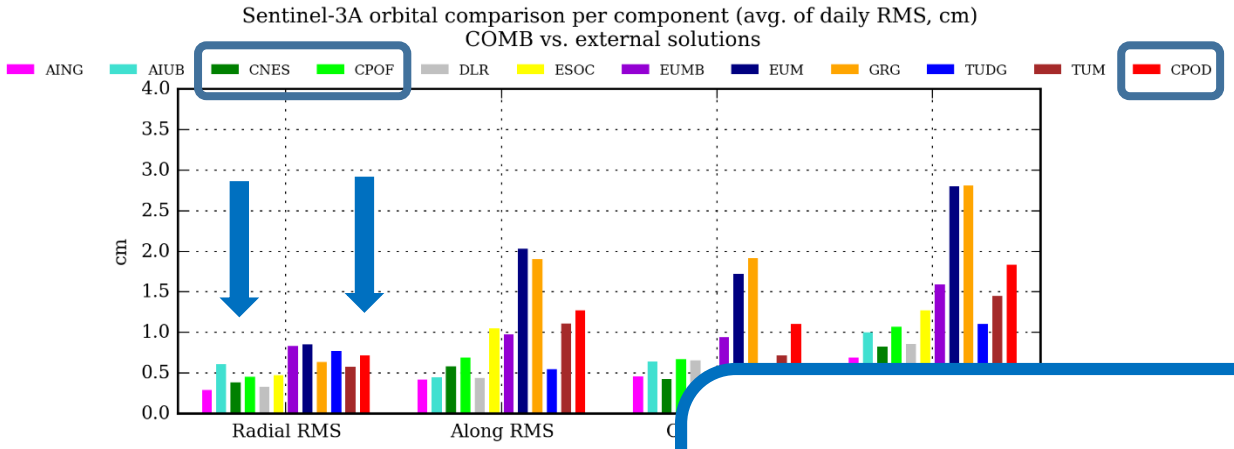


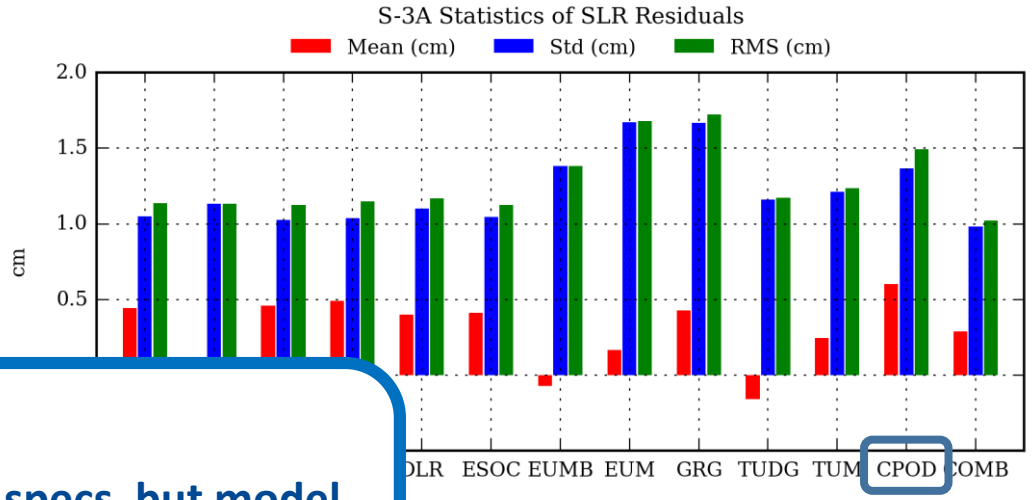




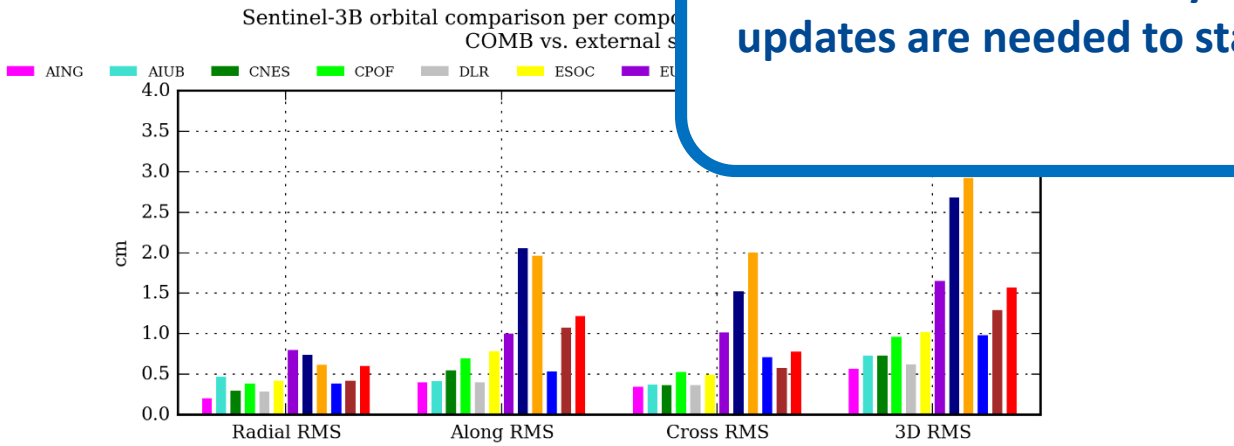


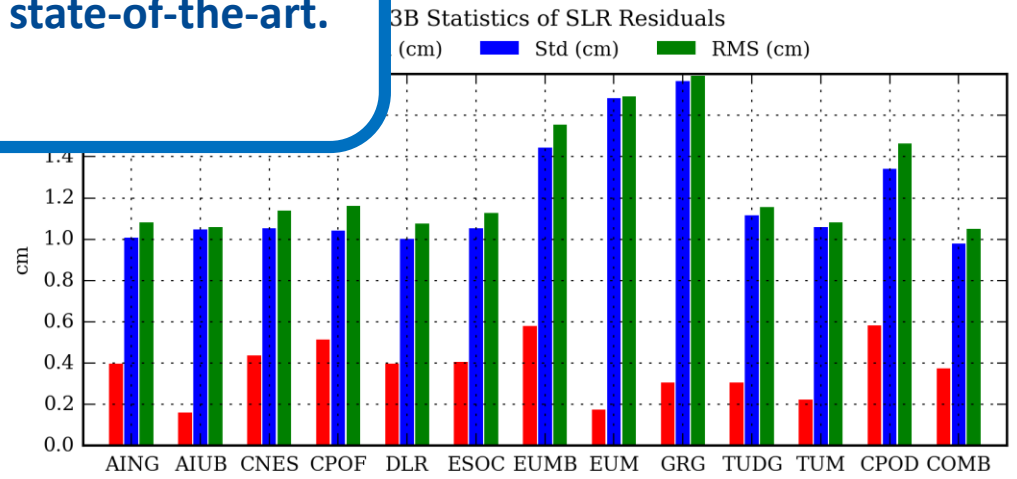
Regular Service Reviews





CPOD solution is totally in specs, but model updates are needed to stay state-of-the-art.





Operational Sentinel-3 POD settings

- NAPEOS (NAvigation Package for Earth Orbiting Satellites)
- IERS2010 conventions
- IGS Final orbits and clocks (30 s), igs14.atx
- 10 s S-3 GPS data, 1^o x 1^o PCVs, ambiguity-float solution
- 32 h arc; 19:00 (day-1) – 03:00 (day+1)

- EIGEN.GRGS.RL03 gravity field (120 x 120), time-variable coefficients (50 x 50)
- EOT11a ocean tides (50 x 50)
- Atmosphere gravity product from massloading.net, atmosphere tides (Ray-Ponte, 2003)

- Satellite macro model for non-gravitational force modelling
- Atmosphere model MSISE90 + HWM93, 15 drag coefficients per arc
- Earth albedo and IR radiation
- One solar radiation pressure coefficient per arc

- Empirical CPR (cycle-per-revolution) parameters: three sets/arc
  - along-track sine + cosine, cross-track sine + cosine

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Planned / Future Sentinel-3 POD settings

- NAPEOS (NAvigation Package for Earth Orbiting Satellites)
- IERS2010 conventions
- *GRGS* Final orbits and clocks (30 s), igs14.atx
- 10 s S-3 GPS data, 1° x 1° PCVs, ambiguity-fixed solution
- 32 h arc; 19:00 (day-1) – 03:00 (day+1)

- EIGEN.GRGS.RL04 gravity field (120 x 120), time-variable coefficients (50 x 50)
- *FES2014 ocean tides (50 x 50)*
- GFZ AOD L1B, *atmosphere tides from GFZ AOD product*

- Satellite macro model for non-gravitational force modelling
- Atmosphere model MSISE00 + HWM14, 15 drag coefficients per arc
- Earth albedo and IR radiation
- One solar radiation pressure coefficient per arc

- Empirical CPR (cycle-per-revolution) parameters: three sets/arc
  - along-track sine + cosine, cross-track sine + cosine

Stepwise validation of model updates

Update of gravity field RL03 => RL04

- **RL04:** Time-variable gravity field coefficients are based on data until end of 2016, afterwards the coefficients are extrapolated
- First available model was limited to degree and order 90

Time series up to end of 2016:

Mean carrier phase RMS (mm)

	Sentinel-3A
RL03/120	6.17
RL04/90	**6.07**

Mean overlaps (4 h) (mm)

SENTINEL-3A	radial	along-track	cross-track	3D
RL03/120	3.42	9.58	4.25	11.20
RL04/90	**2.95**	**7.70**	**3.75**	**9.20**

SLR validation (mm)

SENTINEL-3A	Mean	RMS
RL03/120	3.5	13.8
RL04/90	**2.6**	**13.0**

Time series up to end of 2017:

Mean carrier phase RMS (mm)

	Sentinel-3A
RL03/120	6.21
RL04/90	**6.18**

Mean overlaps (4 h) (mm)

SENTINEL-3A	radial	along-track	cross-track	3D
RL03/120	3.66	10.87	5.98	13.15
RL04/90	**3.31**	**8.77**	**5.00**	**10.80**

SLR validation (mm)

SENTINEL-3A	Mean	RMS
RL03/120	3.7	13.4
RL04/90	**2.9**	**12.8**

=> Clear improvement of the results

Different atmosphere gravity field products

1. atm_grav20 from GSFC/NASA, 20x20, 6h resolution
2. atm_geosfpit from massloading .net, 64x64, 3h resolution <= old
3. GFZ AOD L1B product, 180x180, 3h resolution (max. 100x100 used) <= new

August 2018 is processed for all six satellites

Atmosphere tides => Ray-Ponte, 2003

Mean carrier phase RMS (mm)

	S-1A	S-1B	S-2A	S-2B	S-3A	S-3B
1	6.02	5.86	6.19	6.16	6.40	6.12
2	6.04	5.88	6.23	6.19	6.43	6.15
3	**6.00**	**5.85**	**6.18**	**6.14**	**6.39**	**6.11**

Mean midnight overlaps (mm) – only one point

SENTINEL-3A	radial	along-track	cross-track	3D
1	14.67	**20.95**	15.65	33.82
2	**14.51**	21.74	15.94	34.59
3	15.20	21.25	**13.23**	**33.60**

SENTINEL-3B	radial	along-track	cross-track	3D
1	**12.26**	**22.86**	10.79	**31.11**
2	12.33	23.42	11.12	32.08
3	12.75	24.36	**9.17**	32.72

⇒ No clear improvement but results are on the same level

⇒ Atmosphere tides still have to be adopted

Comparison to S-3 CNES orbits

S-3 CNES orbit solutions are based on POE-F standards since beginning of Nov 2018. This includes the EIGEN.GRGS RL04 gravity field model and the GFZ AOD 1B product.

Orbit comparison for Dec 2018 (mm):

S-3A	radial	along-track	cross-track	3D
RL03_agra	7.24	14.45	10.74	19.45
RL03_AOD	7.28	14.44	10.39	19.25
RL04_agra	6.28	12.47	9.83	17.12
RL04_AOD	**6.12**	**12.09**	**9.42**	**16.54**

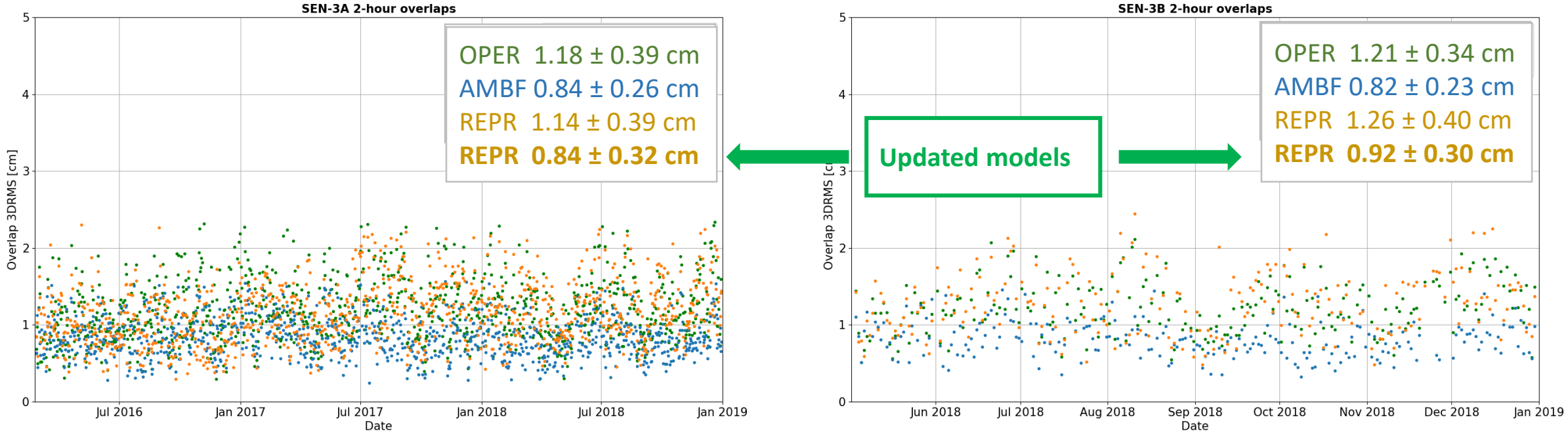
S-3B	radial	along-track	cross-track	3D
RL03_agra	5.57	13.16	8.48	16.66
RL03_AOD	5.63	13.20	8.19	16.56
RL04_agra	4.32	10.82	7.38	13.84
RL04_AOD	**4.21**	**10.59**	**6.93**	**13.38**

=> Consistency with CNES orbits improved

Ambiguity-fixed vs. ambiguity-float solution

- Single-receiver ambiguity-fixing is possible since the half-cycle ambiguities have been corrected in L0 => RINEX file generation.
- GRGS Final GPS orbit and clock solutions together with widelane satellite biases are used.
  (see poster "Single-receiver ambiguity resolution for Sentinel-3 precise orbit determination at the Copernicus POD Service", Calero et al.)

- REPR solutions are ambiguity-float solutions based on reprocessed GPS orbits and clocks.



Sentinel-3 POD settings

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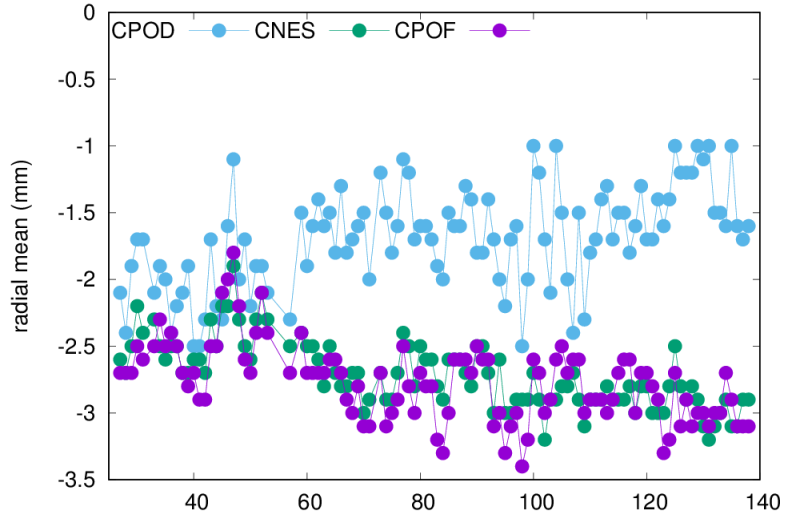
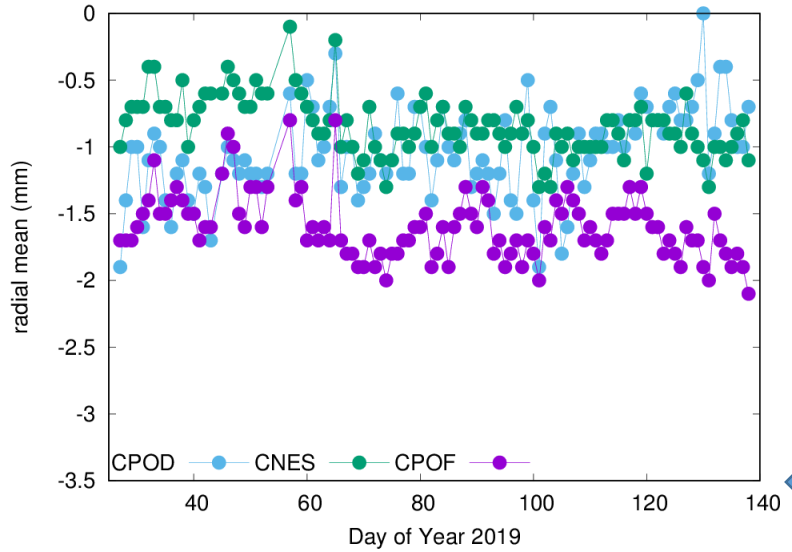
Updates and validation still to be done

CPOF - ambiguity-fixed solutions with updated models

S-3A



S-3B



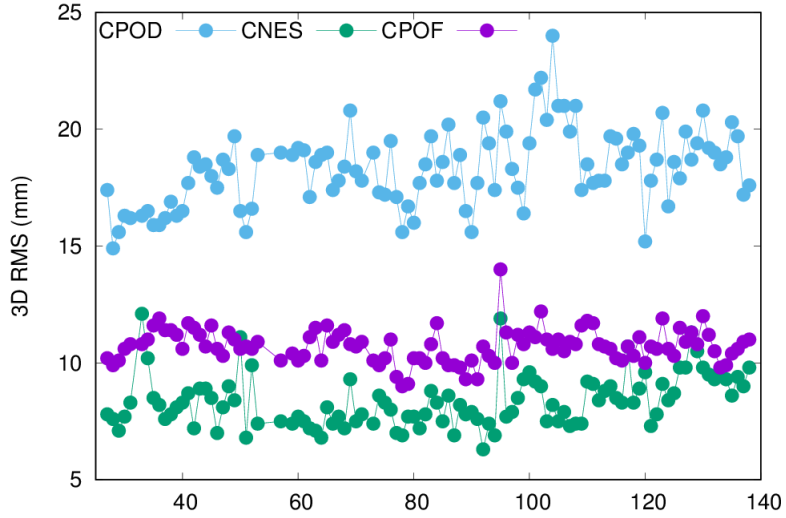
- 27 Jan – 18 May 2019
- Comparison of **CPOD**, **CNES**, and **CPOF** solution against QWG combined orbit solution
- SLR validation (mm)

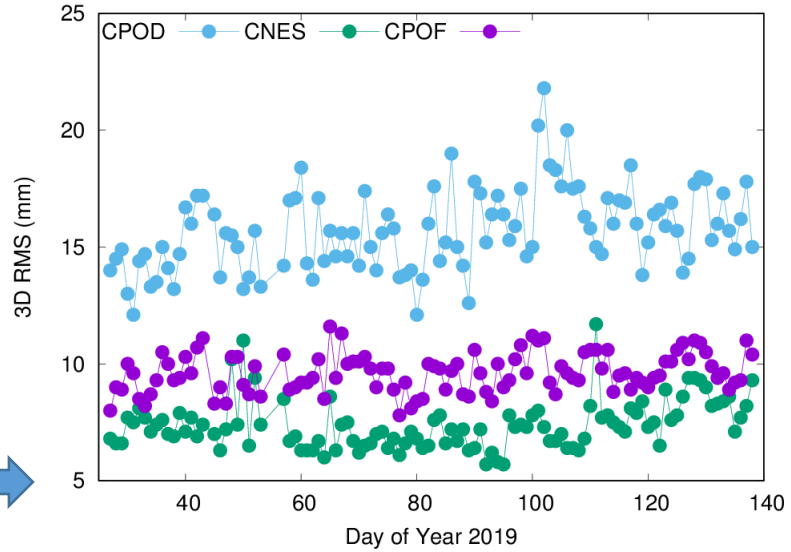
SENTINEL-3A	Mean	RMS
CPOD	6.0	14.9
CNES	4.6	11.3
CPOF	4.9	11.5

SENTINEL-3B	Mean	RMS
CPOD	5.8	14.6
CNES	4.4	10.5
CPOF	5.1	10.4

⇐ radial mean

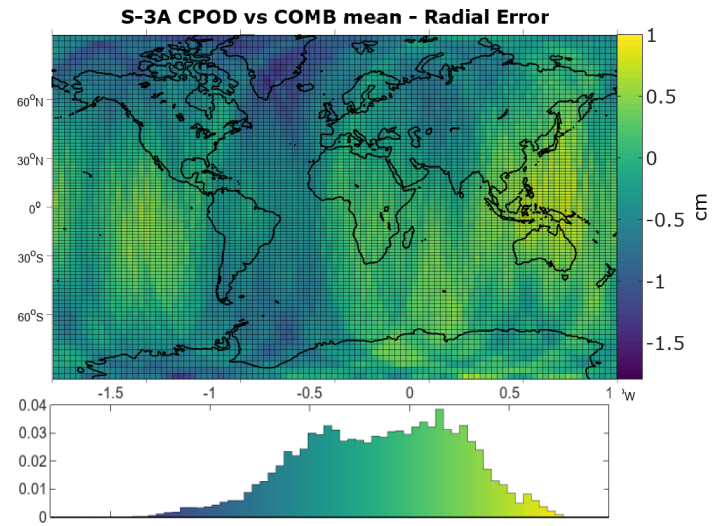
3D RMS ⇒

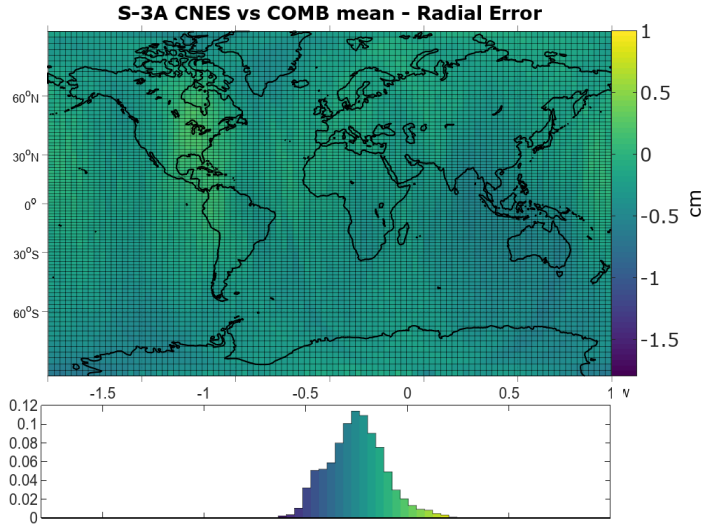


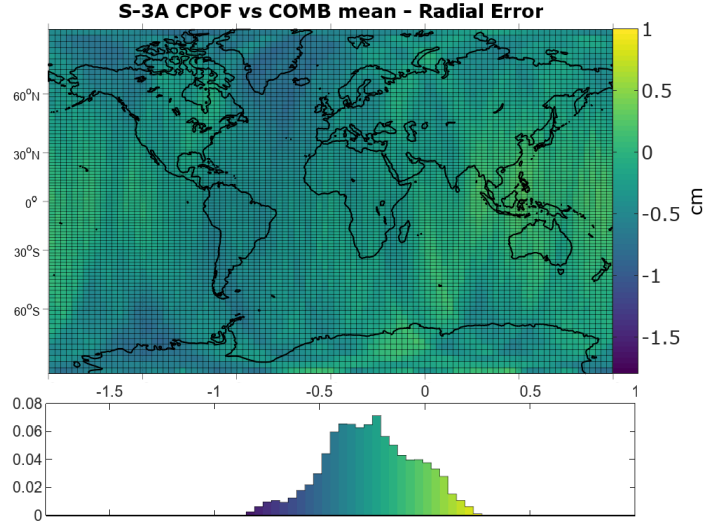


Geographically distributed radial mean differences

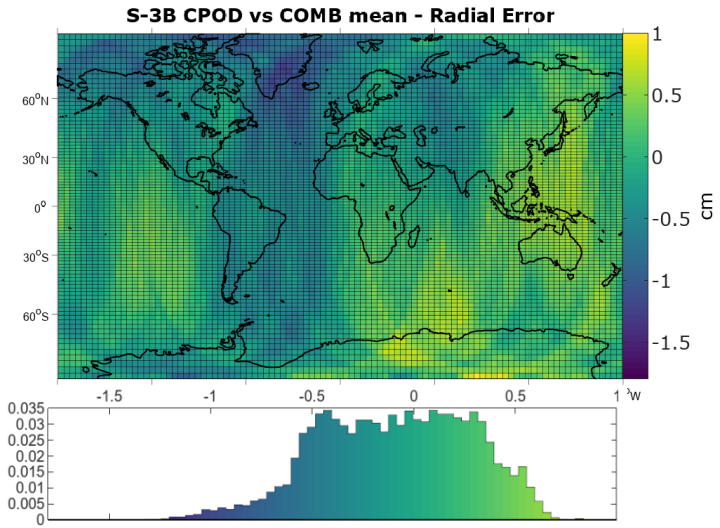
S-3A

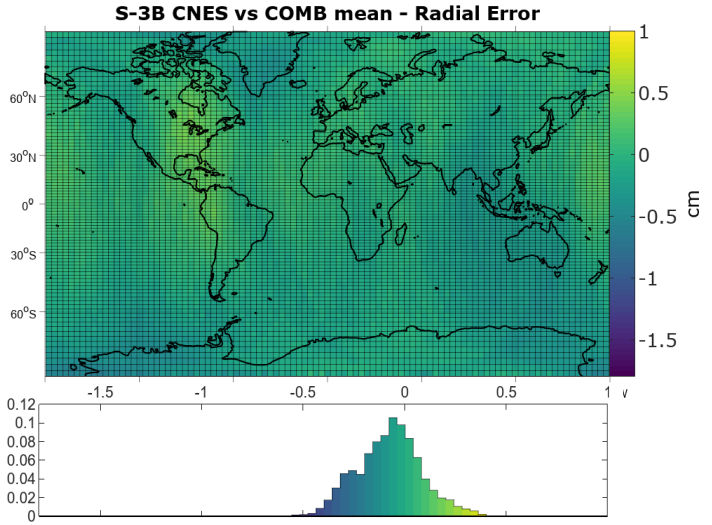


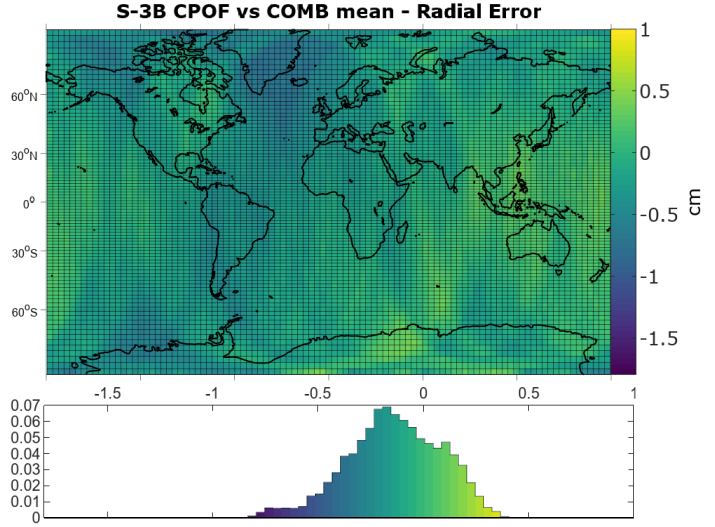




S-3B







Summary

- The Copernicus POD Service is responsible for Sentinel-1, -2, and -3 POD processing.
- POD setup has to be regularly reviewed to stay up-to-date.
- Step-wise validation of several model updates has successfully been performed for all three missions.
- Implementation of FES2014 ocean tide model and GFZ AOD atmosphere tidal contribution is still pending.
- Different GPS bias products for the single-receiver ambiguity resolution are still tested.
- Copernicus POD QWG has to approve the new POD setup for all three Sentinel missions before the switch can be done.
- Reprocessing of entire missions can be done.

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