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SINGLE-RECEIVER AMBIGUITY RESOLUTION FOR SENTINEL-3 PRECISE ORBIT DETERMINATION AT COPERNICUS POD SERVICE

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ABSTRACT

Single-receiver GPS ambiguity resolution methods are beneficial for the precise orbit determination results of the Copernicus Sentinel satellites as proven by DLR (Montenbruck et al. 2017), CNES (Mercier et al. 2018), TUD (Simons et al. 2018) and ESOC (Otten et al. 2018). The availability of so-called bias products for the GPS satellite is, however, mandatory to do the ambiguity-fixing with a single receiver. The GPS wide-lane bias product from CNES/CLS (Laurichesse et al. 2009) is widely used but also other products recently became available, e.g., the CODE bias products (Arnold et al. 2019) and the ESOC undifferenced phase delays.

The continuous availability and reliable latency of such bias products is essential for operational orbit determination as it is done at the Copernicus POD Service for the Sentinel-1, -2, and -3 satellites.

The impact of the ambiguity-fixed carrier phases on the resulting Sentinel-3 orbit products is analysed. Different bias products are also compared based on Sentinel-3 orbit results. Due to the different latencies of the orbital products, it is carefully investigated for which product lines dedicated bias products might be available in time.

This study will give an overview of the work done at the Copernicus POD Service to follow up recent developments in the frame of single-receiver ambiguity resolution for POD of the Copernicus Sentinel-3 satellites.

COPERNICUS POD SERVICE

CPOD Service products & requirements for Sentinel-3:

Category	Orbit Accuracy (RMS)	Latency
NRT (S3PODIPF)	10 cm radial (target of 8 cm)	30 min.
STC	4 cm radial (target of 3 cm)	1.5 days
NTC	3 cm radial (target of 2 cm)	25 days

Because of timeliness of GPS biases, orbits and clocks, ambiguity-fixing algorithms can only be applied for the NTC products

CPOD operational ambiguity-fixing:

- New inputs required
  - CNES/CLS routinely provides **wide-lane satellite biases (WSB)** with a timeliness of 5-12 days → **Ambiguity-fixing only applicable for NTC products**
  - CODE generates phase biases internally. These products are not routinely circulated to external users yet.
  - ESOC generates undifferenced phase delays (UPDs) internally. These products are not routinely circulated to external users yet.

PROCESSING AND TRIAL DATA SETS

Daily reduced-dynamic POD solutions for Sentinel-3A and Sentinel-3B based on 10s-rate GPS observations and 32h-length determination arc

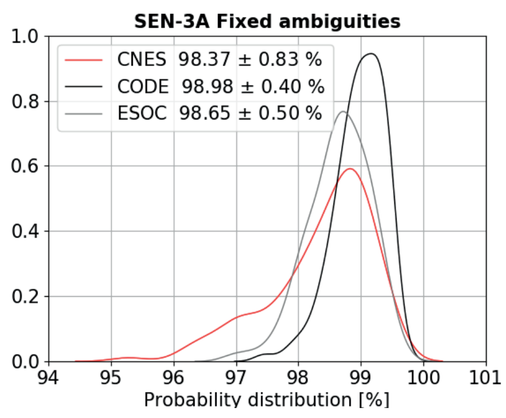
Gravity model	EIGEN.GRGS.RL04 (120x120)	**Atmosphere gravity**	AOD1B RL06 (100x100)
Radiation pressure model	Box-wing model with instantaneous re-radiation	**Estimated radiation pressure coefficients**	One per arc
Earth radiation model	Albedo and infra-red applied	**Estimated drag coefficients**	15 per arc
Atmospheric density model	Msise00	**Empirical accelerations**	Three sets per arc (along-+cross-track, sine+cosine)

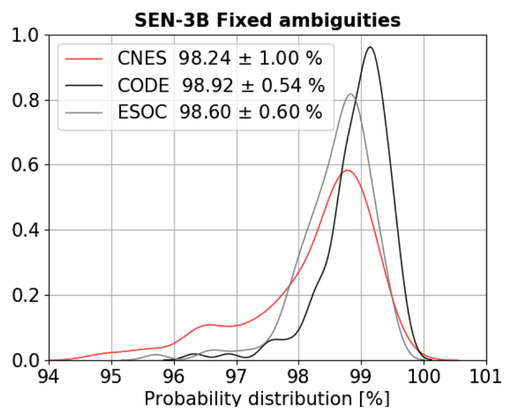
- CNES/CLS WSB products retrieved from IGS archive

- CODE and ESOC have provided a trial data set of phase bias products and UPDs, respectively, from **23/09/2018** to **26/01/2019** (126 days)

- Float (FA) and integer (IA) ambiguity solutions generated for each provider:
  CNFA: FA solution using CNES/CLS products
  CNIA: IA solution using CNES/CLS products
  COFA: FA solution using CODE products
  COIA: IA solution using CODE products
  ESFA: FA solution using ESOC products
  ESIA: IA solution using ESOC products

- **Similar fixing performance for each provider (fixing rate ~98%)**





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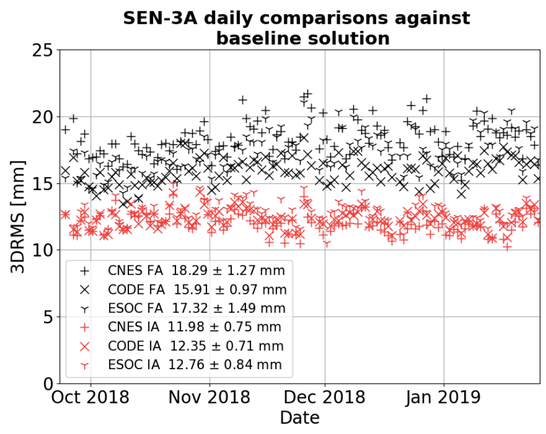
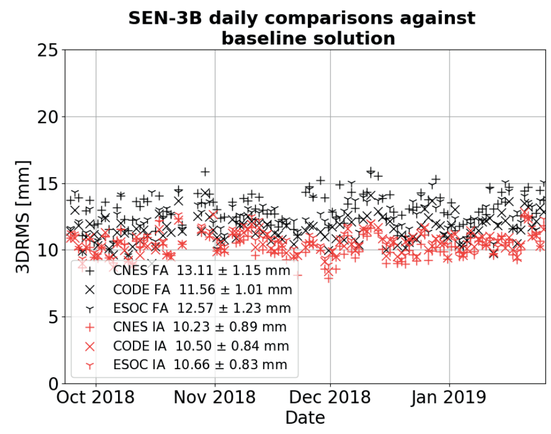
Finally, IGS, and, particularly, CNES/CLS Analysis Center, CODE and ESOC, are greatly appreciated and acknowledged for the provision of the GPS products

RESULTS AND CROSS-VALIDATION OF THE IA POD AT THE CPOD SERVICE





Baseline solution generated from combining the **POD QWG** orbits (Fernández et al., 2019)

IA solutions are closer to the baseline solution: **improvement in accuracy**

Similar performance for each provider

1-point overlaps at midnight [mm]

	SEN-3A	SEN-3B
CNFA	6.33 ± 3.48	6.15 ± 2.77
COFA	6.14 ± 3.40	5.65 ± 2.87
ESFA	6.08 ± 3.08	5.99 ± 3.09
CNIA	4.44 ± 2.09	4.32 ± 1.99
COIA	4.24 ± 1.90	4.13 ± 1.79
ESIA	4.37 ± 1.84	4.14 ± 1.81

Smaller overlaps for IA solutions: **improvement in repeatability**

Similar performance for each provider

SLR residuals after removing a common constant bias per station* [mm]

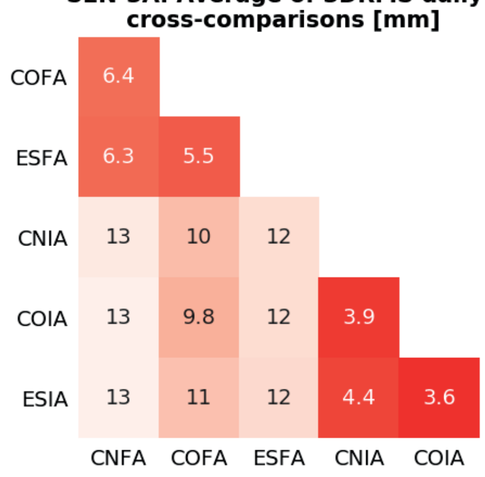
	SEN-3A	SEN-3B
CNFA	-0.33 ± 10.12	-0.43 ± 8.77
COFA	0.11 ± 9.13	-0.42 ± 7.87
ESFA	0.11 ± 9.13	-0.42 ± 7.87
CNIA	0.08 ± 7.19	0.02 ± 7.22
COIA	0.05 ± 7.30	0.13 ± 7.52
ESIA	-0.07 ± 7.26	0.03 ± 7.31

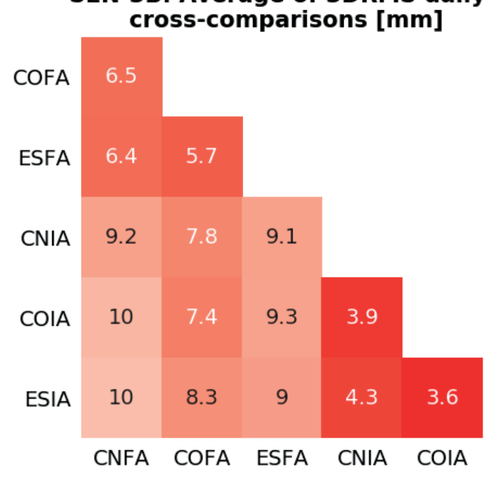
***Bias per SLR station**

Yarragadee	5.13 mm
Greenbelt	6.79 mm
Haleakala	8.00 mm
Hartebeesthoek	10.17 mm
Graz	11.23 mm
Herstmonceux	6.59 mm
Potsdam	-4.45 mm
Matera	-1.66 mm
Wettzell	-17.90 mm

Lower SLR dispersion for IA solutions: **improvement in accuracy**

Similar performance for each provider





Higher synergy/correlation between IA solutions: **improvement in consistency**

CONCLUSIONS

- Ambiguity fixing capabilities have been implemented in the tools of the CPOD Service, handling different products.
- A first analysis of the trial data set provided by CODE and ESOC has been presented and compared against the CNES/CLS solutions, showing a promising performance.
- Improvements in accuracy, repeatability and consistency have been proven for the IA solutions.
- Similar figures have been found using the CNES/CLS, CODE and ESOC products.