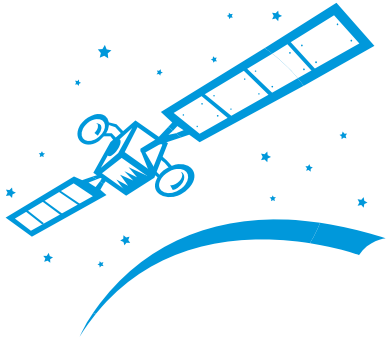

Inter Ambiguity Resolved Orbits for Sentinel-3A and Sentinel-3B

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OSTST Meeting, Ponta Delgada, Azores, 27-28 September 2018

What we do for Sentinel-1,2 and 3

- The Navigation Support Office provides a complete independent solution for validation purposes:
  - We generate our own RINEX files from the Sentinel telemetry (L0 data).
  - We use our own (ESA) NRT/IGS GPS satellite orbits and clocks (30 seconds).
  - We generate the Sentinel orbits making use of the Navigation Support Office software package NAPEOS (4.1) and use the latest state of the art models.
  - We provide both orbit solutions in NRT and in NTC mode (results presented here based on NTC products).

Data processed for Sentinel

- The following periods and Satellites have been processed so far:
  - Sentinel-1A 7th of April 2014 – current
  - Sentinel-1B 18th of June 2016 – current
  - Sentinel-2A 27th of June 2015 – current
  - Sentinel-2B 23rd of March 2017 – current
  - Sentinel-3A 16th of March 2016 – current
  - Sentinel-3B 2nd of May 2018 – current
- Orbits are available on our ftp server dgnl6.esoc.esa.int (login / password required, available on request) and on the COPPOD ftp server

Processing strategy

- NAPEOS version 4.1
- Loosely based on to the CNES POE-F standards
- Modeling according to latest standards (IERS2010)
- ESA IGS14/NRT GPS orbits and clocks (30s) introduced (kept fixed)
- For Sentinel-3A and 3B SLR data used for validation only

- Estimated parameters
  - Orbit parameter (1-day arcs)
    - SV
    - 6 CPRs (constant/sin/cos in along-track/cross-track) every 12h
    - 10 Drag parameters every 24h
  - GPS phase ambiguites (fixed ~95%)
  - Sentinel clock bias (30s)

Processing strategy

- Gravityfield
  - GRGS EIGEN.GRFS.RL03.v2 (120x120) + linear drift, annual and semi annual variation up to degree and order 80)
- Surface forces
  - box-wing model for Solar radiation, drag, Albedo and IR (UPDATED for Sentinel-1 and Sentinel-3)
- GPS antenna phase centre modeling
  - values for Sentinel-3 are taken from: “GMV-GMESPOD-TN-0027_v1.1draft”
  - ANTEX corrections are based on the latest files from the COPPOD server
  - Updated location of the PCO for ambiguity fixed orbits
- Attitude modelling
  - Nominal attitude model for all satellites

Ambiguity Fixing – Two techniques

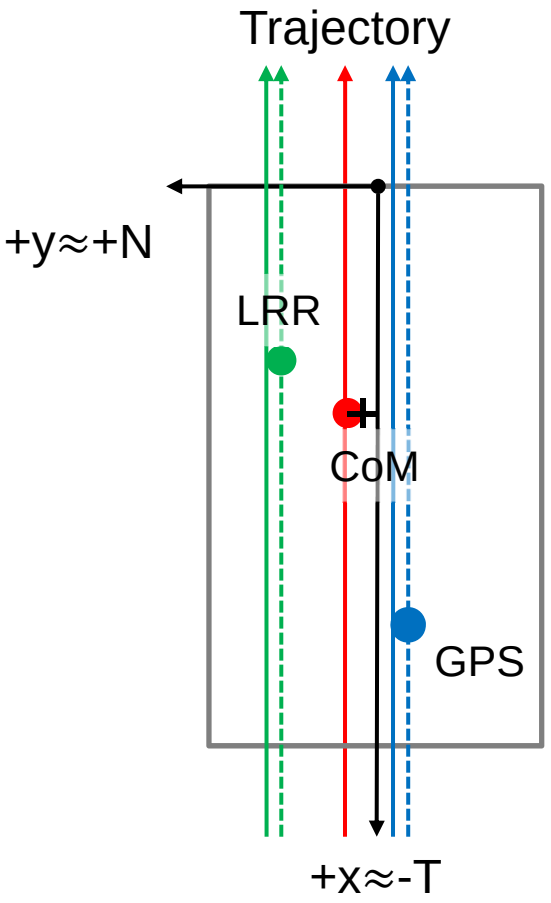
- Currently we have in our software (NAPEOS) two methods available for fixing the ambiguities of the LEO satellites:

1. The integral approach in which the LEO is included into an IGS like scenario (including GPS station data) and the LEO is treated as another (although orbiting) station and the integer ambiguities are resolved at the double difference level together with the station ambiguities.
2. In the second approach the un-calibrated phase delays (UPD) are saved from our IGS runs and later reintroduced into the LEO ambiguity resolution processing. In this processing the UPDs are used together with two single differences to resolve the integer ambiguities of the LEO.

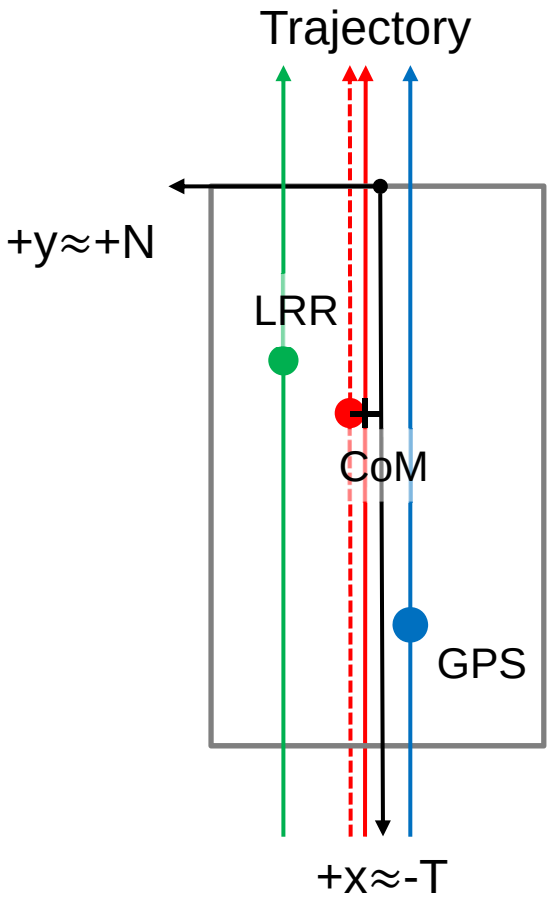
Sentinel-3A Cross-track Levelling

Taken from DLR presentation at QWG#7

float



ambfix



Montenbruck O., Hackel S., Jäggi A.; *Precise orbit determination of the Sentinel-3A altimetry satellite using ambiguity-fixed GPS carrier phase observations*; Journal of Geodesy (2017) DOI 10.1007/s00190-017-1090-2

Updated SLR Phase Centre

Sentinel-3A – ESOC presentation at QWG#7

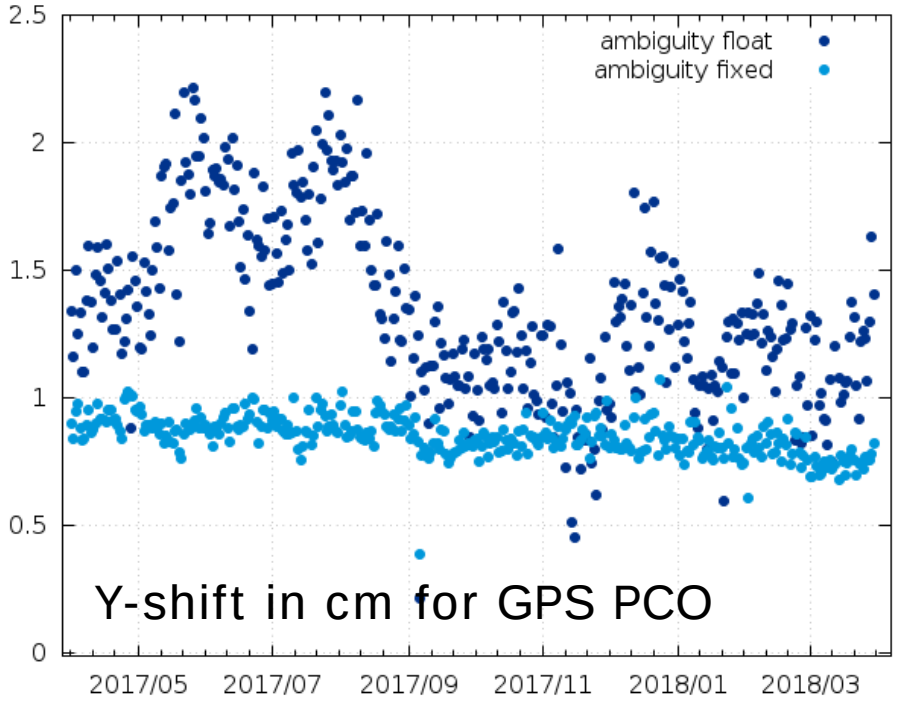
- Ambiguity fixed solution for Sentinel more sensitive to centre of mass or phase centre errors compared to float solution.
- For the SLR location we applied the DLR updated value for the y-direction (+10 mm)

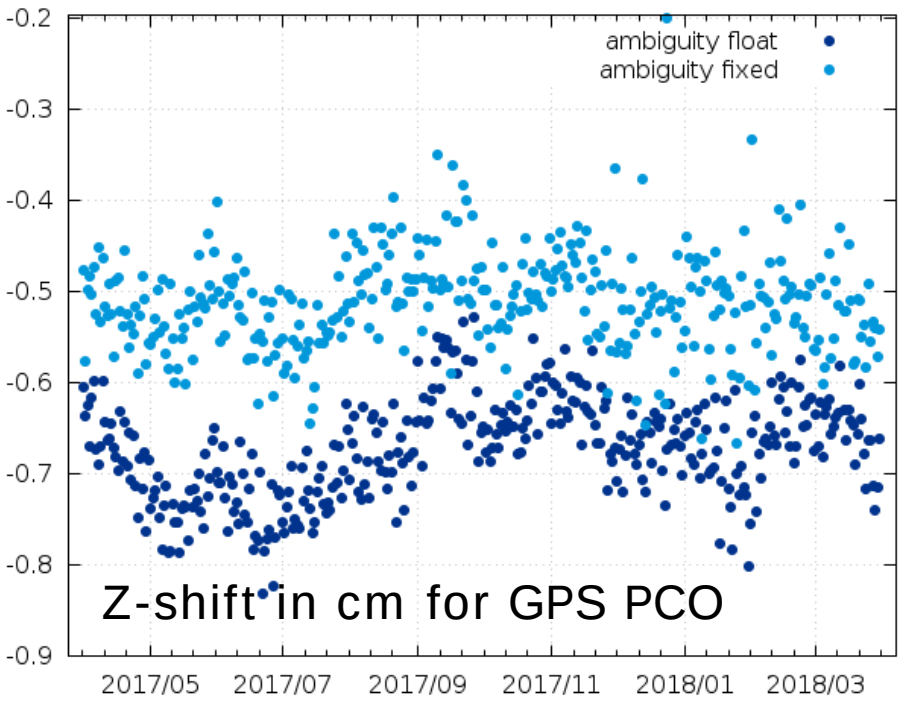
SLR location	>10°	>30°	>60°
original	0.0/13	-0.5/12	-1.0/10.5
updated	0.0/12.5	0.0/11	-0.5/10.0

Sentinel-3A SLR residuals for RSR#10, mean and *rms* in mm (fixed solution, method-2).

Updated GPS Phase Centre (1)

Sentinel-3A





- From our analysis both the SLR and GPS phase center benefit from a +10mm shift in the y-direction -> CoM should be shifted by -10mm
- From the GPS phase centre estimation the orbit overlaps benefits from a shift in the z-direction of -5mm as well

Processing strategy Ambiguity fixing

- The first method that we tested was the combined processing (method 1) and results were presented at the 2016 OSTST meeting.
- For this presentation results of both methods will be presented.
- For this presentation we processed 1 year of orbits for Sentinel-3A (April-2017 until April 2018) and now routinely compute for both Sentinel-3A and Sentinel-3B ambiguity fixed orbits.
- This presentation focuses on the Sentinel-3A results.
- We computed 24hr arcs without overlap.
- For the fixed solutions we estimate the same number of orbit parameters as in the float solution.

Processing strategy of Method-1

- We included 60 globally well distrusted stations and use 30 second sampling for the ground stations and Sentinel-3A/B.
- We first generate a solution in which all the ambiguities are estimated as float together with all the other parameters
- From this solution we then resolve for both the stations and Sentinel-3A/B the integer ambiguities at the double difference level. **Requires the LEO data to have the same epoch as the ground network tracking data (zero second!)**
- We generate then again a new solution identical to the first step but now we keep all the ambiguities fixed that could be resolved in the previous step (95-97%)
- We do this last step to be able to edit out wrongly fixed ambiguities

Orbit overlap and SLR statistics

Sentinel-3A – Method-1

Solution	Radial	Along	Cross	Typical
Float	12.62	12.00	5.60	11.93
Fixed	9.06	8.31	5.17	8.75

Sentinel-3A orbit overlap point from 24hr arc (mm) for test year.

Solution	>10°	>30°	>60°
Float	0.5/9.0	1.0/9.0	1.5/9.0
Fixed	1.0/8.0	1.5/7.5	2.0/8.0

Sentinel-3A SLR residuals from core-sites for test year, mean and *rms* in mm.

Processing strategy of Method-2

- We take the results from the standard Sentinel solution (float)
- At the ambiguity fixing step we introduce the wide-lane and narrow-lane GPS (UPD) biases from the global IGS solution and resolve the LEO ambiguities (GFZ/CNES approach)
- This method does not require the orbiting receiver to track at the same time (zero second) as the ground network so can be used for all Sentinel satellites
- Rest the same as method-1:
  - We generate then again a new solution identical to the first step but now we keep all the ambiguities fixed that could be resolved in the previous step (95-97%)
  - We do this last step to be able to edit out wrongly fixed ambiguities

Orbit overlap and SLR statistics

Sentinel-3A – Method-2

Solution	Radial	Along	Cross	Typical
Float	12.62	12.00	5.60	11.93
Method-1	9.06	8.31	5.17	8.75
Method-2	10.99	6.41	5.62	9.07

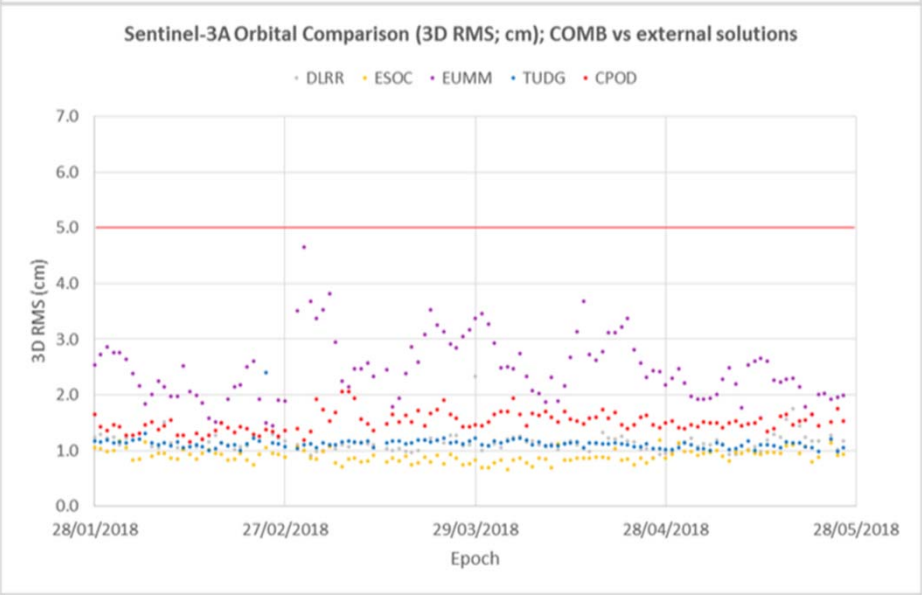
Sentinel-3A orbit overlap point from 24hr arc (mm) for test year

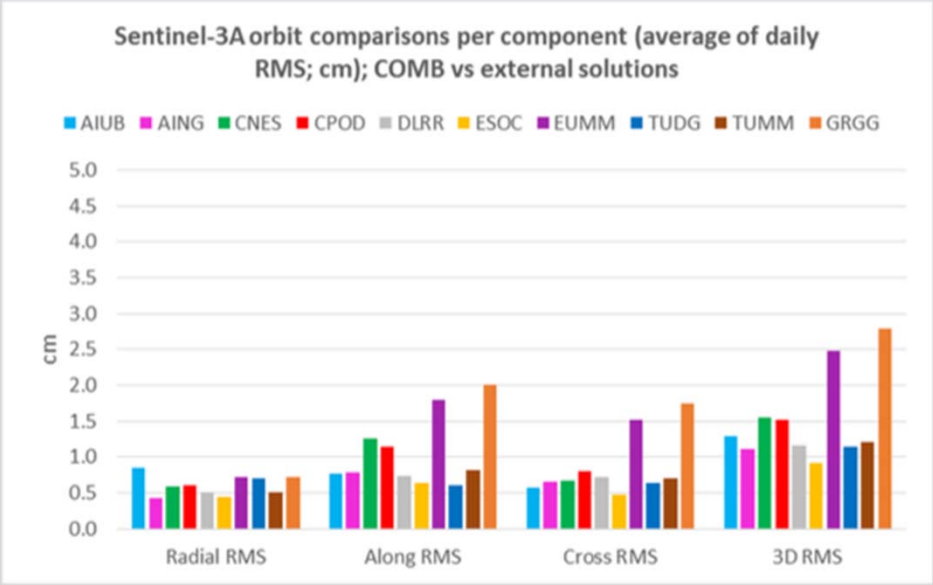
Solution	>10°	>30°	>60°
Float	0.5/9.0	1.0/9.0	1.5/9.0
Method-1	1.0/8.0	1.5/7.5	2.0/8.0
Method-2	0.5/9.0	1.0/9.0	1.5/9.0

Sentinel-3A SLR residuals from core-sites for test year, mean and *rms* in mm.

Orbit Comparison for RSR#11

Sentinel-3A – Method-1





- The figures above show for (RSR#11) from February until June 2018 for Sentinel-3A the orbit comparison of the various solutions against the combination solution (the combination is generated from the individual solution in the same way as done for the IGS solutions).
- The values for the ESOC solution are (R/A/T/3D in cm): 0.44 / 0.64 / 0.47 / 0.91cm

Difference between the two methods

Sentinel-3A

- Minimal orbital differences between the Sentinel-3A orbit using the two methods (3D *rms* ±3mm for daily solutions)
- Some outlier days present using Method-2 which are not present in Method-1 (cause under investigation)
- Orbit overlap performance slightly better for Method-1 (except along-track) both methods outperform the float
- Independent SLR residuals show a very small preference for Method-1 and Method-1 has slightly lower residuals compared to the float solution (Method-2 has identical SLR residuals compared to float)

Summary

- Ambiguity fixed solutions for Sentinel-3A (and Sentinel-3B) are being routinely generated at ESOC using two different methods. Both methods give nearly similar performance (slightly better performance for Method-1) and result in more consistent solution compared to our float solutions
- Need to update the CoM position for Sentinel-3A. Both SLR and GPS indicate a change in the y-direction of +10mm
- For the GPS location a further adjustment of the PCO / reference point in the z-direction of -5mm is recommend as well.
- Similar CoM analysis to be performed for Sentinel-3B currently using the Sentinel-3A adjustment

Orbits available on COPPOD ftp server
or on request: michiel.otten@esa.int

Thank you

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