OSTST 2023 – 08/11/2023

In-flight GNSS phase map calibration modelling with Zernike polynomials

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CENTRE NATIONAL D'ÉTUDES SPATIALES

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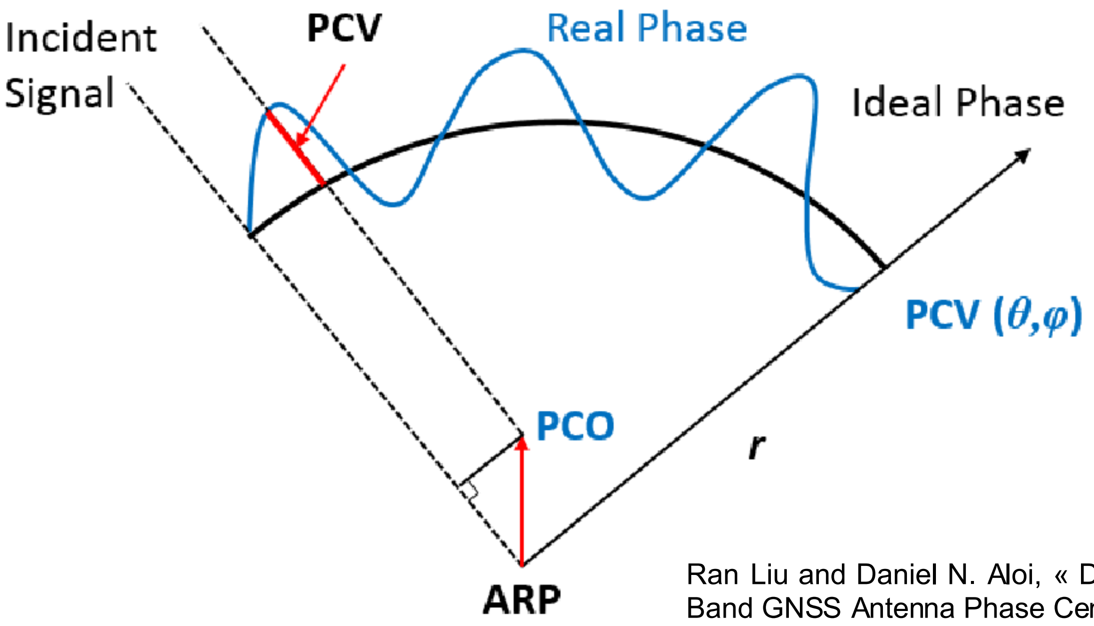
1. Antenna phase map definition. PCO & PCV

Ideally, the receiver antenna would act as a spherical phase response for GNSS signals. However, this is not true in most of cases. Instead, the electromagnetic behavior of antennas is not homogeneous and the location of its electrical phase center varies with different elevation and azimuth.

The antenna electrical phase center can be defined as the absolute mean phase center offset (PCO) with respect to the antenna reference point (ARP) and the elevation and azimuth-dependent phase center variations (PCVs), which are the differences between the real and ideal wavefront.



Ran Liu and Daniel N. Aloi, « Dual Band GNSS Antenna Phase Center Characterization For Automitive Applications »

2. Phase map modelling : common approach vs. Zernike approach

Common approach

Determine the antenna phase maps iteratively from the residuals. Unfortunately, this method leads to potential correlations with dynamic orbit models.

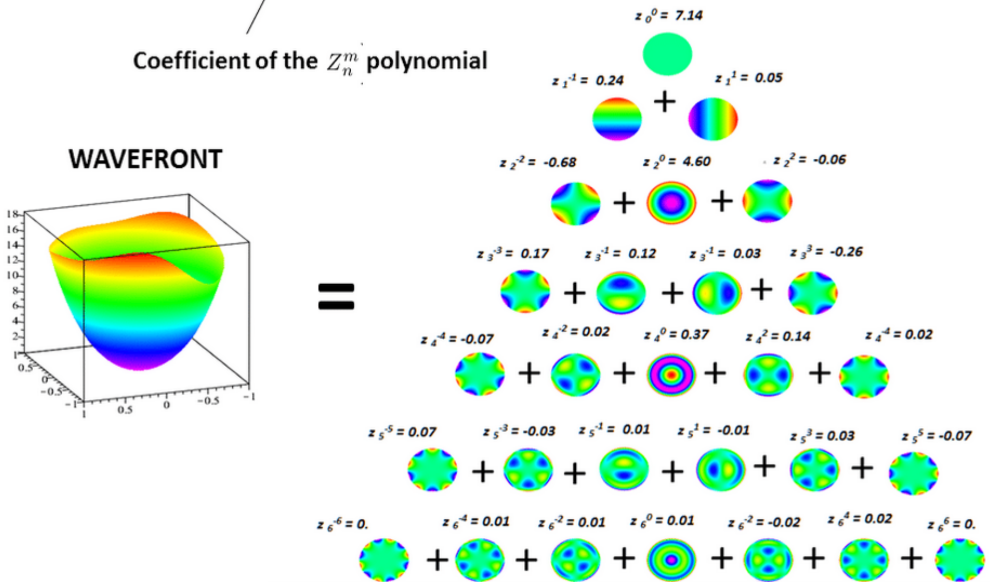
Zernike approach

Determine the antenna phase map through an expansion in well-chosen Zernike polynomials. This method is more direct and less prone to correlations.

First step is to determine the PCO, and then have it fixed for the actual Zernike estimation.

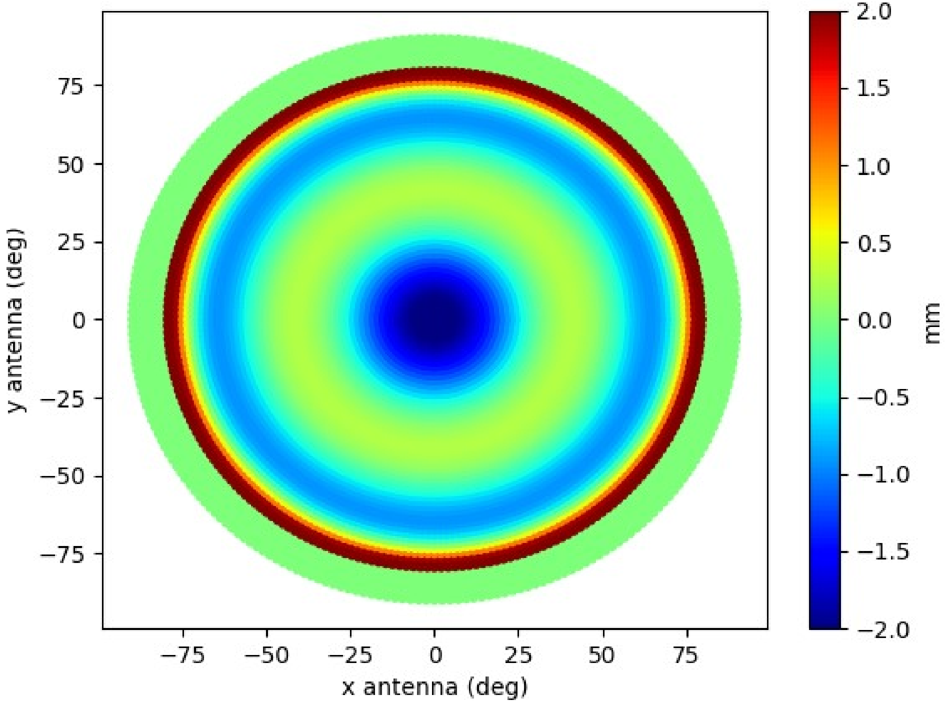
$$f = \sum_{n \in \mathbb{N}} \left(\sum_{m \in I_n} z_n^m(f)\, Z_n^m \right) = \sum_{m \in \mathbb{Z}} \left(\sum_{n \in J_m} z_n^m(f)\, Z_n^m \right)$$

Coefficient of the Z_n^m polynomial

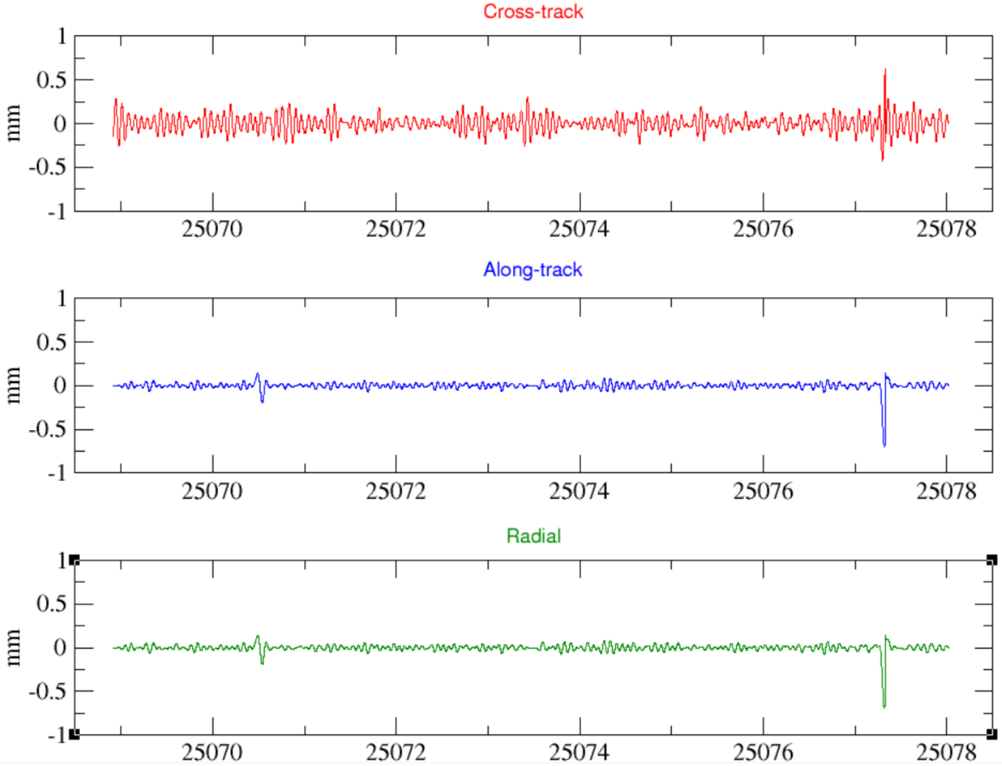


3. GPS phase map modelling for Sentinel-3A – Current solution

Current POE-F S3A GPS antenna phase map



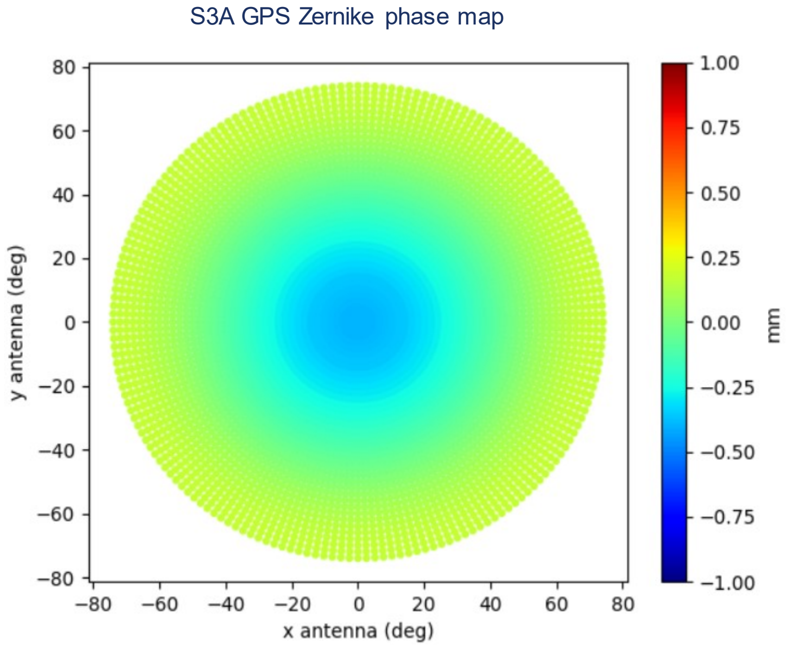
Orbit differences wrt. POE-F solution with no phase map



3. GPS phase map modelling for Sentinel-3A – Scenarios

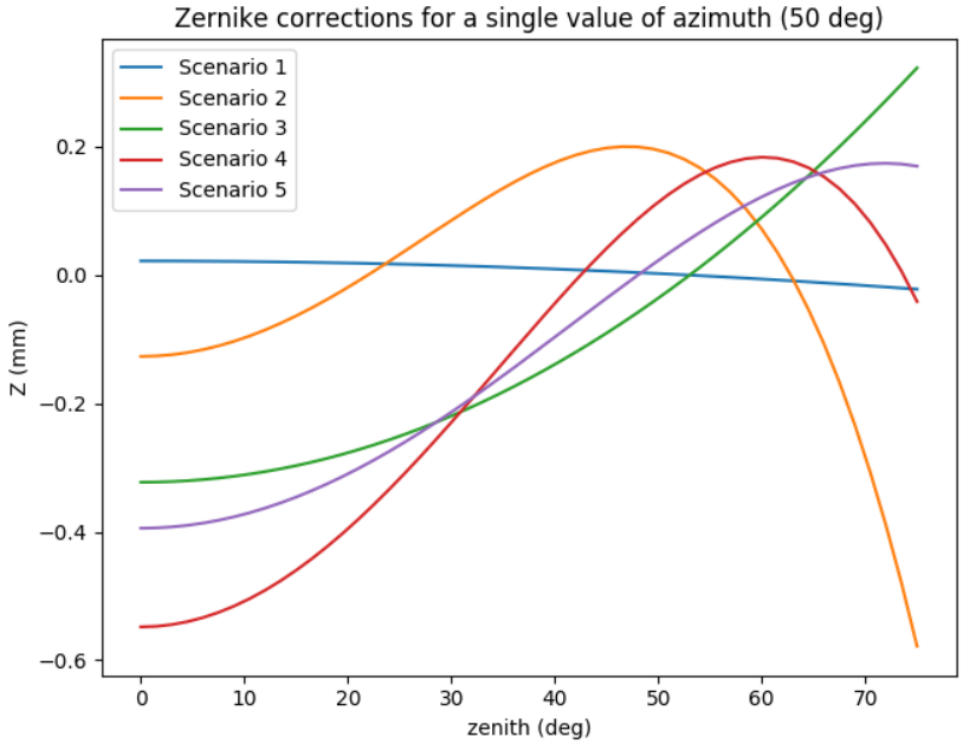
	Input orbit	Estimated Zernike coefficients
Scenario 1	DORIS dynamic	Z-11, Z11, Z-22, **Z02**, Z22
Scenario 2	DORIS dynamic	Z-11, Z11, Z-22, **Z02**, Z22, Z-33, Z-13, Z13, Z33, **Z04**
Scenario 3	GPS reduced-dynamic	Z-11, Z11, Z-22, **Z02**, Z22
Scenario 4	GPS reduced-dynamic	Z-11, Z11, Z-22, **Z02**, Z22, Z-33, Z-13, Z13, Z33, **Z04**
Scenario 5	-----	Z-22, **Z02**, Z22, Z-33, Z-13, Z13, Z33, **Z04**

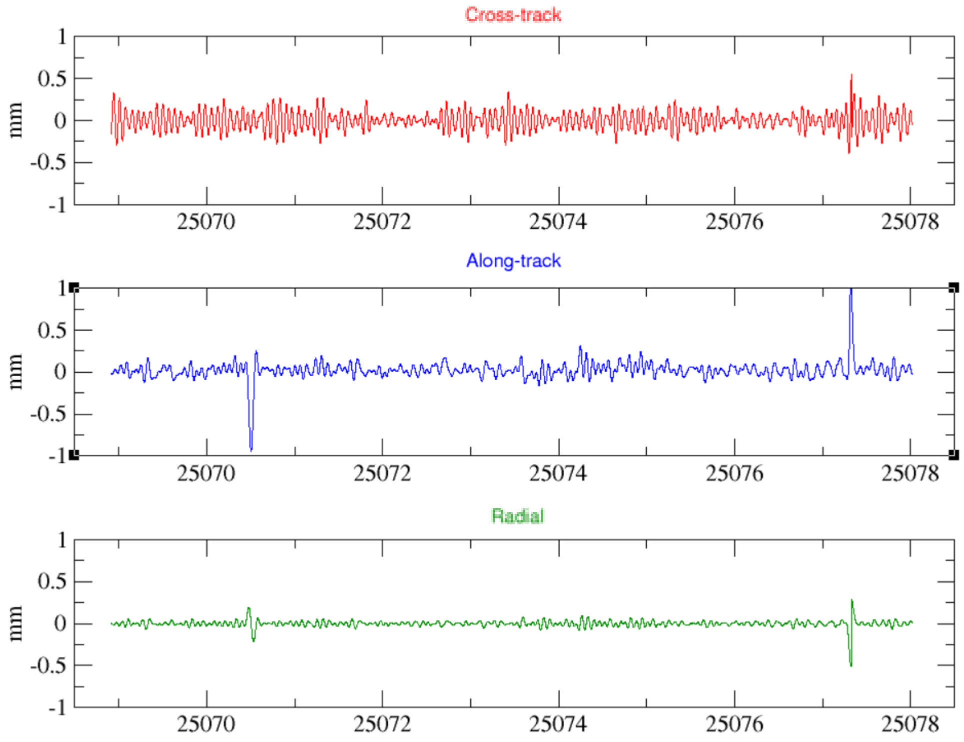
Constellation	Current PCO-Z	Identified PCO-Z
GPS	79,4 mm	79 mm



3. GPS phase map modelling for Sentinel-3A – Scenarios and orbit differences

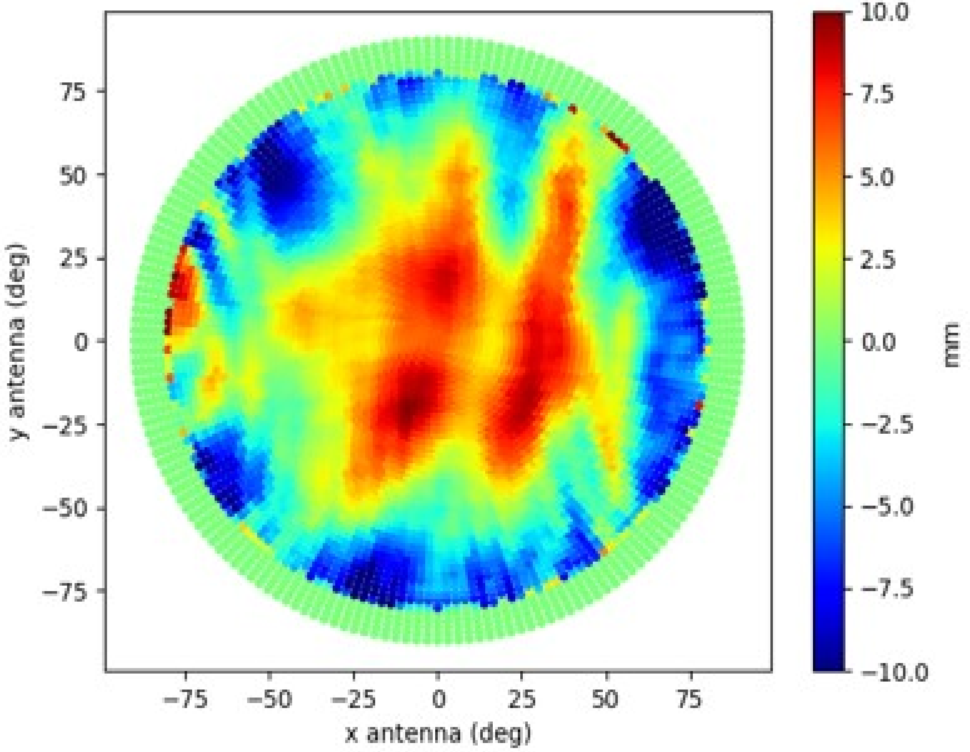
All phase maps have rather similar corrections (not bigger than 1 mm) regardless of the input orbit, which makes sense because the idea is that the parameterization used for adjusting the phase map should not depend on the input orbit.



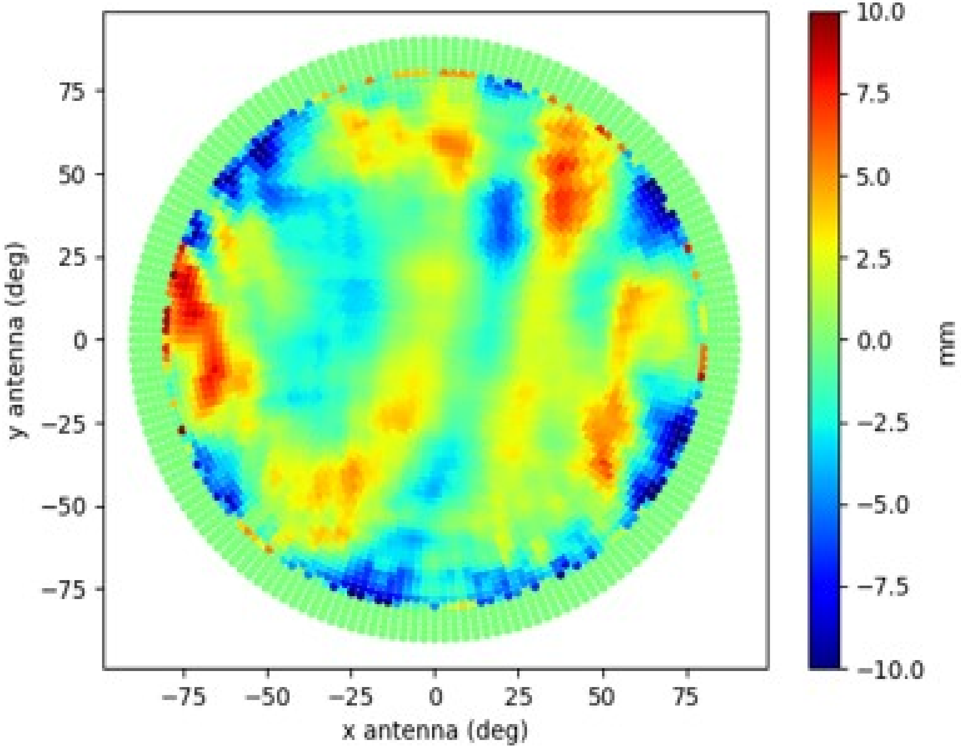


4. GPS & Galileo phase map modelling for Sentinel-6A – Current solution

Current POE-F S6A GPS antenna phase map



Current POE-F S6A GAL antenna phase map

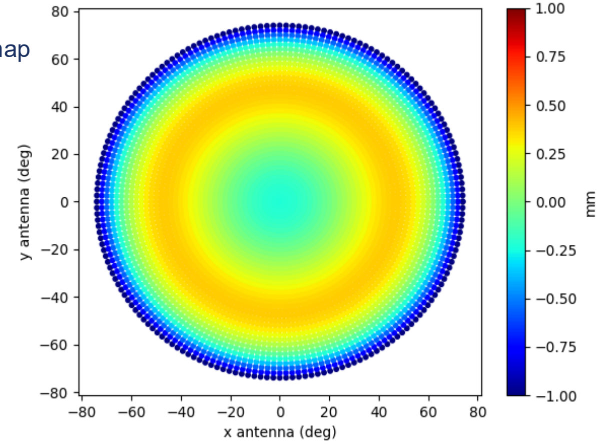


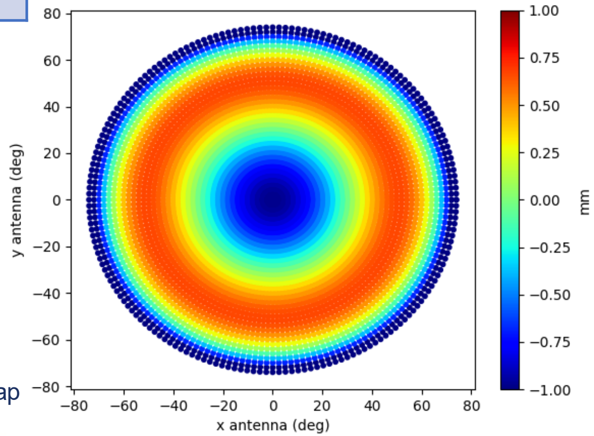
4. GPS & Galileo phase map modelling for Sentinel-6A - Scenarios

	Input orbit	Estimated Zernike coefficients
Scenario 1	DORIS dynamic	Z-11, Z11, Z-22, **Z02**, Z22
Scenario 2	DORIS dynamic	Z-11, Z11, Z-22, **Z02**, Z22, Z-33, Z-13, Z13, Z33, **Z04**
Scenario 3	GPS reduced-dynamic	Z-11, Z11, Z-22, **Z02**, Z22
Scenario 4	GPS reduced-dynamic	Z-11, Z11, Z-22, **Z02**, Z22, Z-33, Z-13, Z13, Z33, **Z04**
Scenario 5	----	Z-22, **Z02**, Z22, Z-33, Z-13, Z13, Z33, **Z04**

Constellation	Current PCO-Z	Identified PCO-Z
GPS	97 mm	73 mm
Galileo	97 mm	93 mm

S6A GPS Zernike phase map

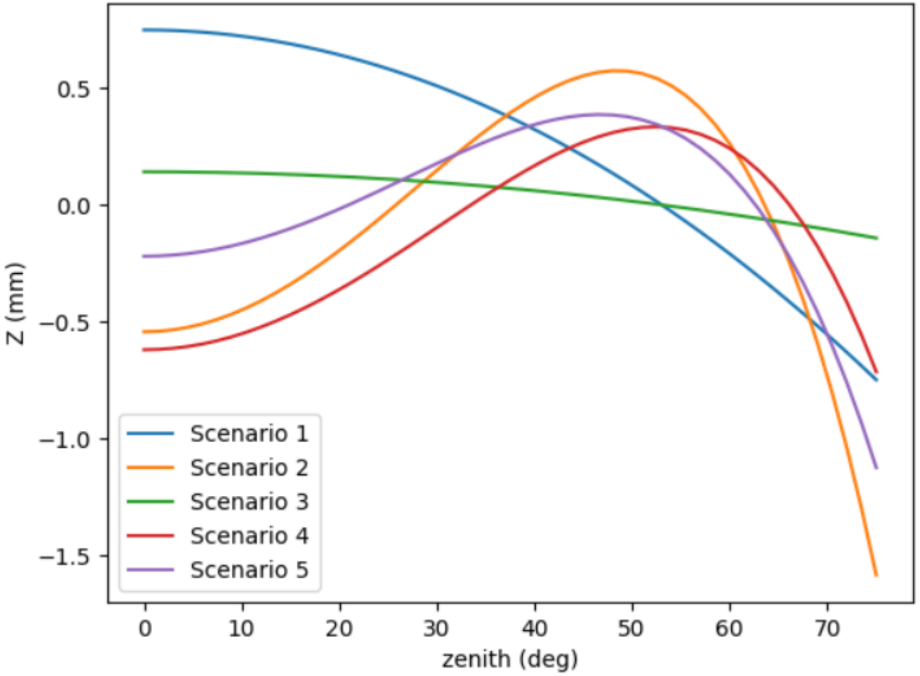


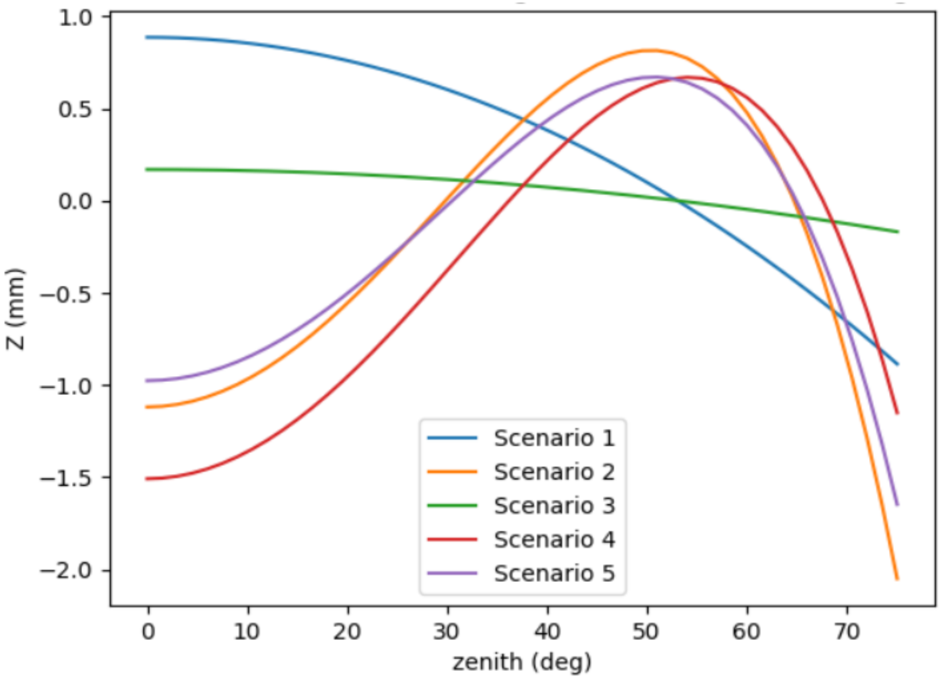


S6A GAL Zernike phase map

4. GPS & Galileo phase map modelling for Sentinel-6A - Scenarios

Zernike corrections for a single value of azimuth (50 deg) for GPS (left) and Galileo (right)

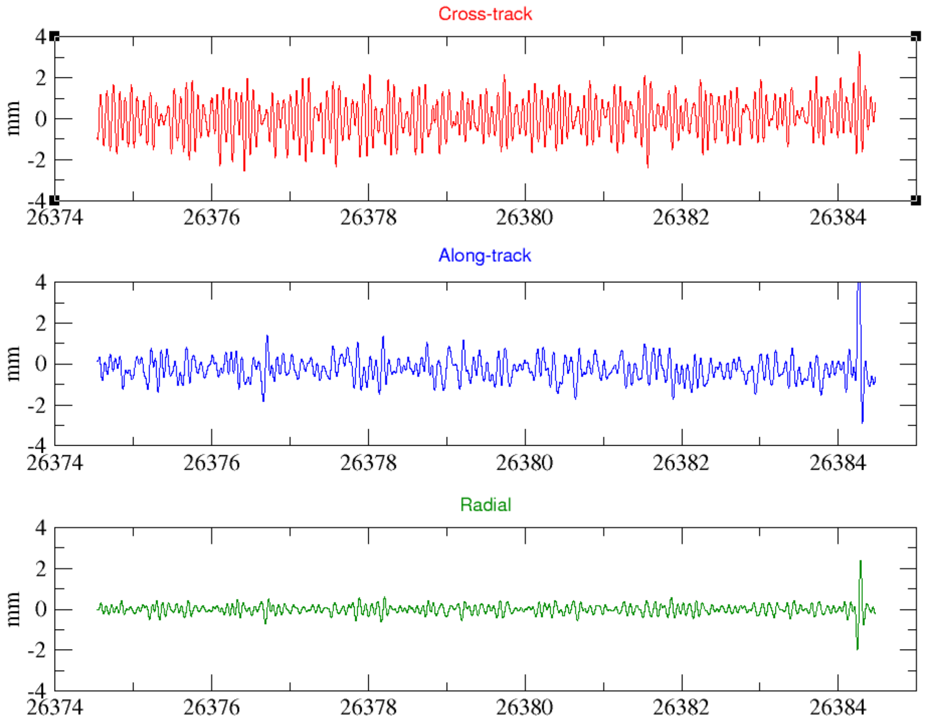


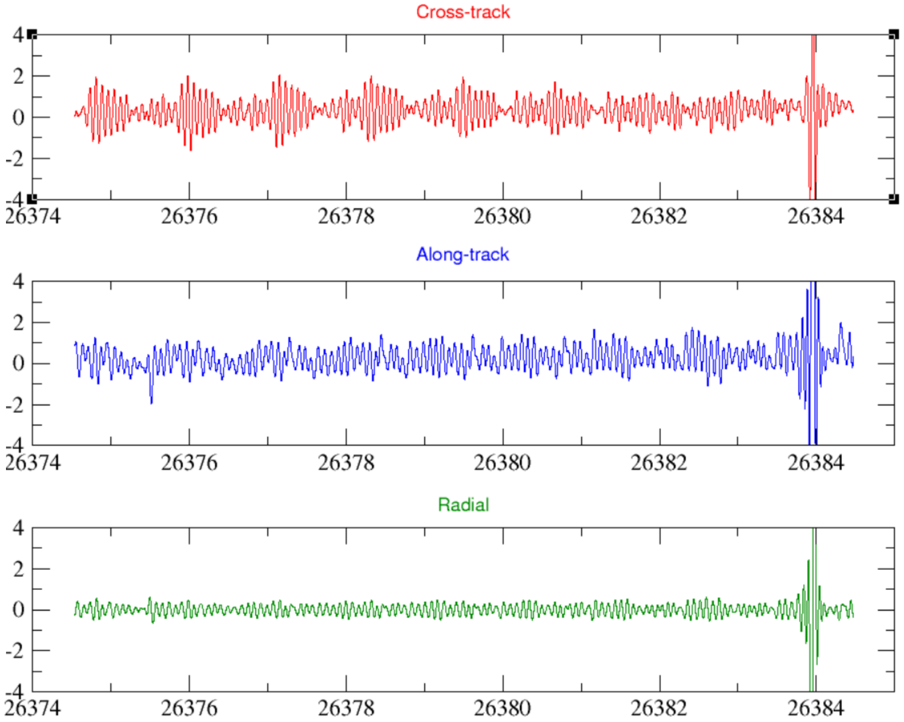


- Very good agreement between DORIS and GPS for both constellations, specially between scenarios 2 and 4
- No coupling between the Zernike coefficients and the orbit

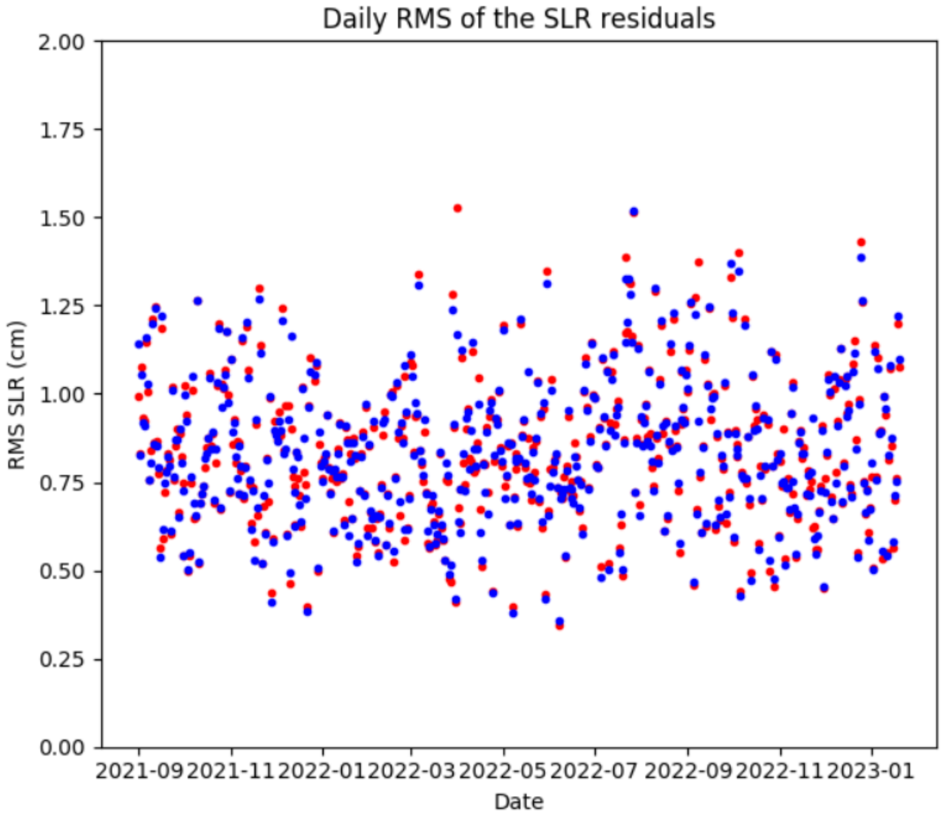
4. GPS & Galileo phase map modelling for Sentinel-6A - Orbit differences

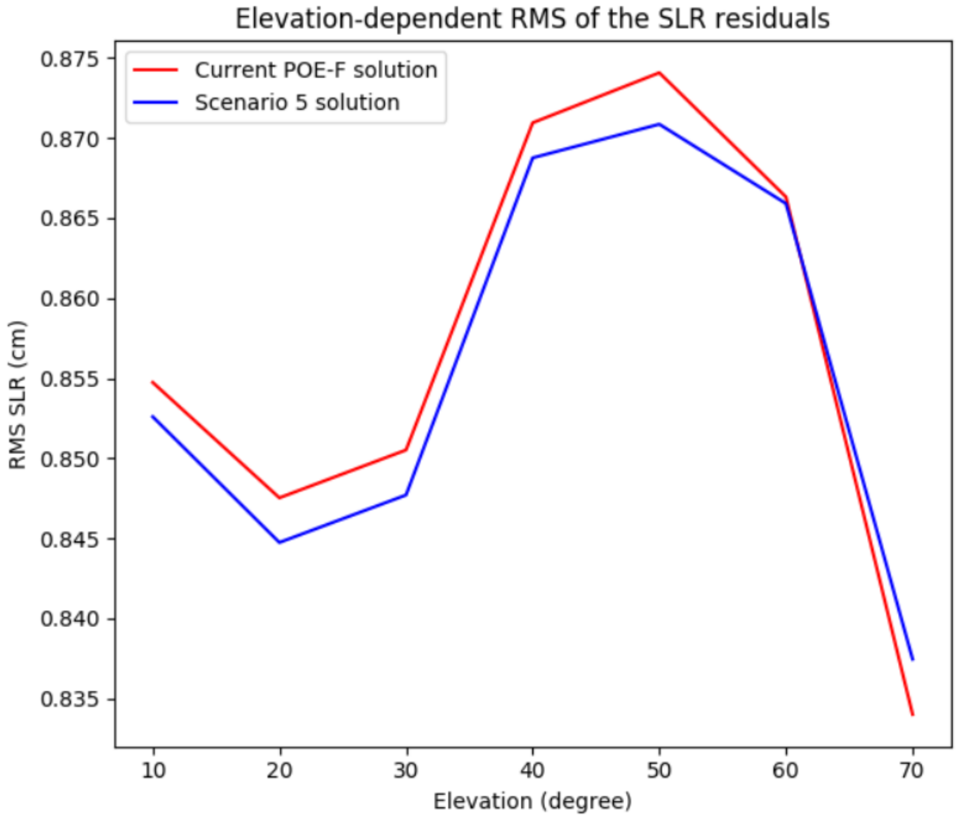
What are the orbit differences then between Scenario 5 and the current POE-F solution ? GPS (left) and Galileo (right)





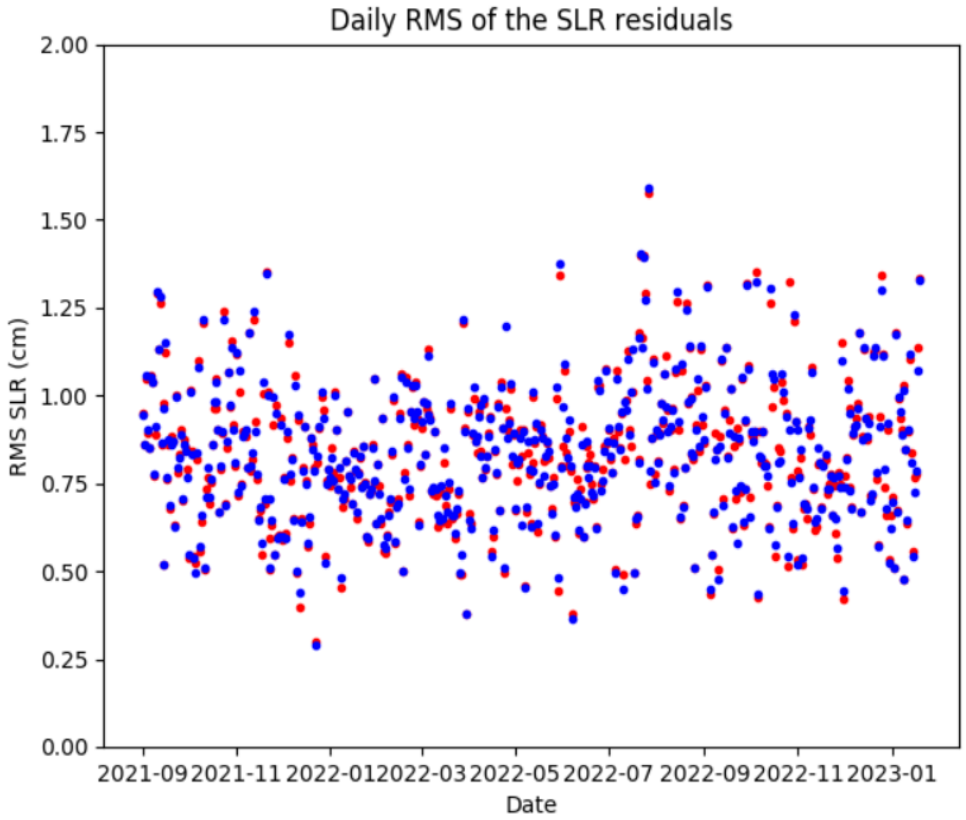
4. GPS & Galileo phase map modelling for Sentinel-6A – GPS SLR residuals

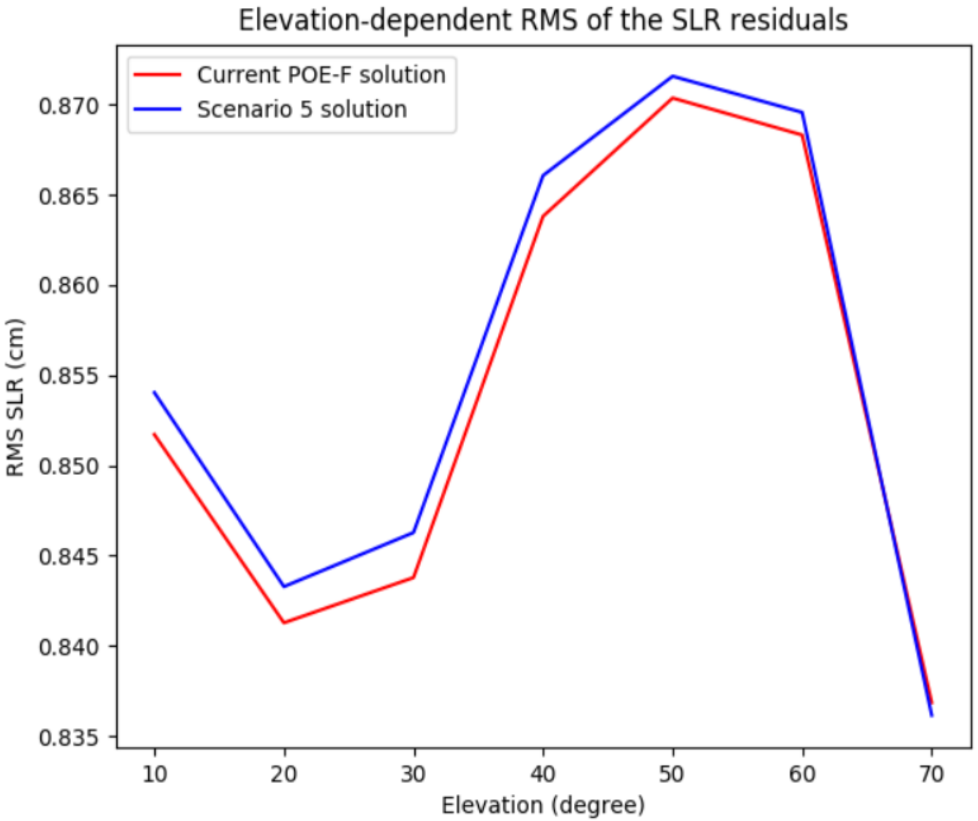




RMS = 8.366 mm RMS = 8.348 mm

4. GPS & Galileo phase map modelling for Sentinel-6A – GAL SLR residuals





RMS = 8. 337 mm RMS = 8.35 mm

5. Conclusions & Perspectives

Conclusions

- Overall, we obtain the same orbit performances in terms of orbit differences and SLR residuals with the Zernike phase maps as with the residuals phase maps, but with two important advantages :
  - Zernike-derived antenna phase maps are a lot simpler, specially for S6A.
  - Unlike phase maps obtained through the residuals, Zernike phase maps aren't correlated with the dynamic modelling.
- There is no coupling between the Zernike coefficients and the orbit, which allows us to estimate both simultaneously or independetly.

Perspectives

- SWOT GPS phase map modelling.
- Re-do the estimation with the new CNES POE-G standard, following the IGS20 directives.