Identification of the satellite DORIS antenna phase map, and performances of POE-F DORIS-only orbits

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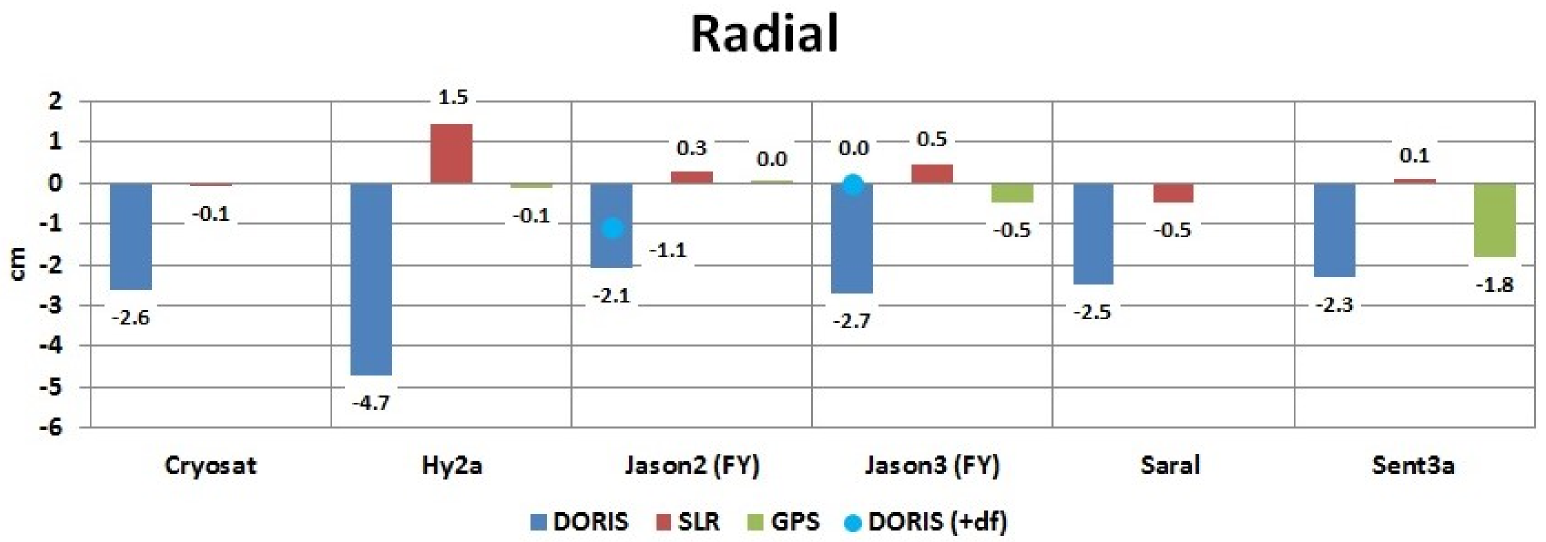
1. Identification of the satellite antenna phase map

Scope of the study

- Existing phase center corrections
  - Phase maps for the GPS receivers
  - Phase laws for the DORIS beacons
  - Phase center offset for the DORIS receivers

Offsets observed with DPOD2008 in the POE-E standards → **scale factor**



1. Identification of the satellite antenna phase map

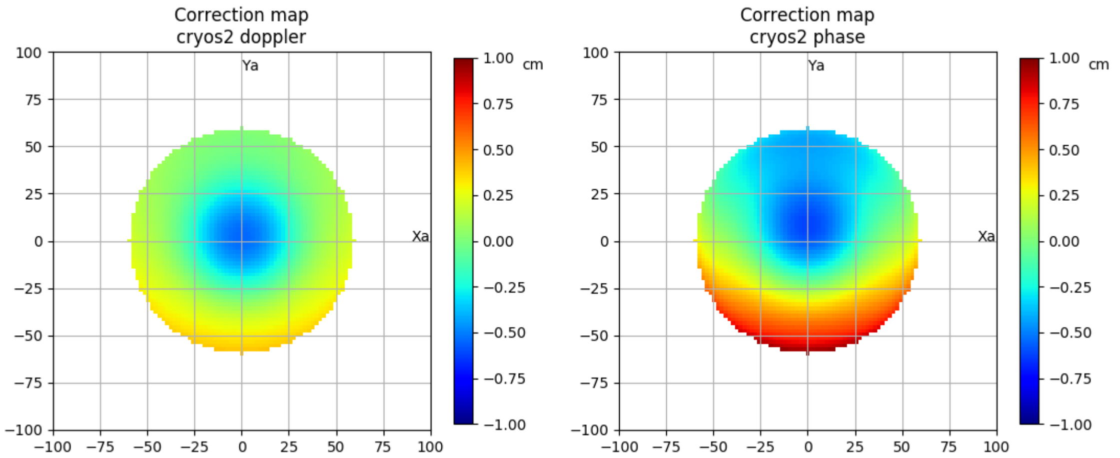
Map estimation

- Dynamic POE-F orbits from year 2017
- Modeling using an expansion in Zernike polynomials
  - 4 or 5 modes :
    - in the Z-direction: Z(2,0), Z(4,0) and Z(6,0).
    - in the XY-plane: Z(+/-1,1) according to the observability
  - Normalization angle depends on the antenna look angle
    - Cryosat-2, Saral and Sentinel-3a : around 60 degrees
    - Jason-3 : around 55 degrees
- Estimation with phase or Doppler measurements

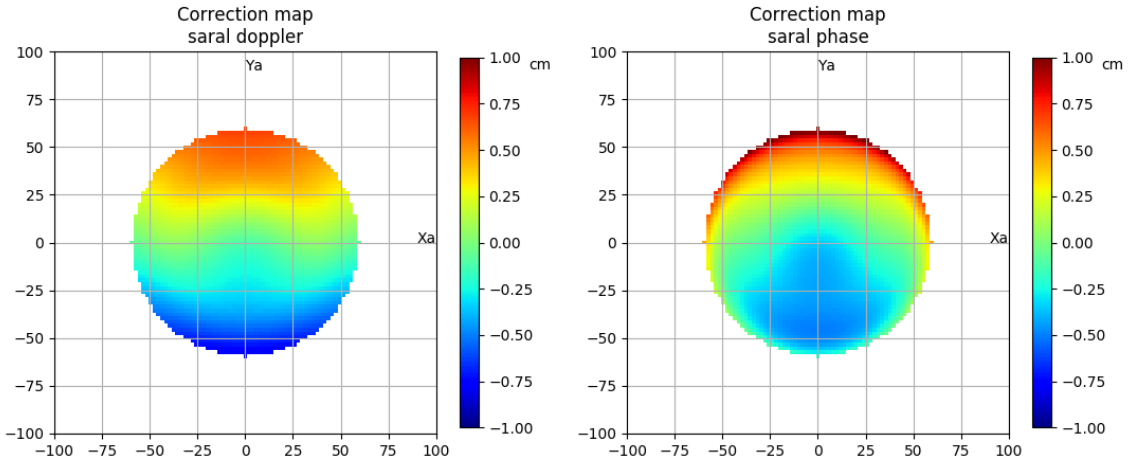
1. Identification of the satellite antenna phase map

Map estimation

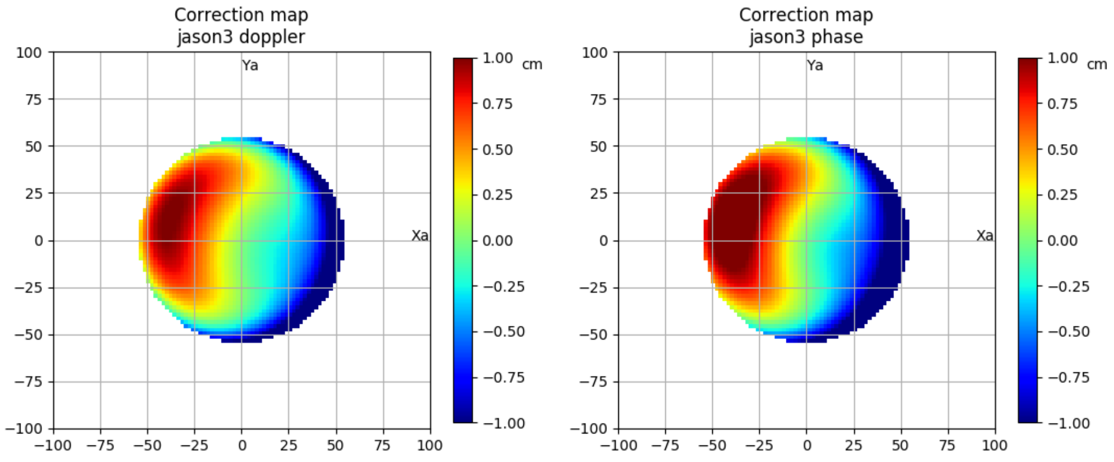
Cryosat-2



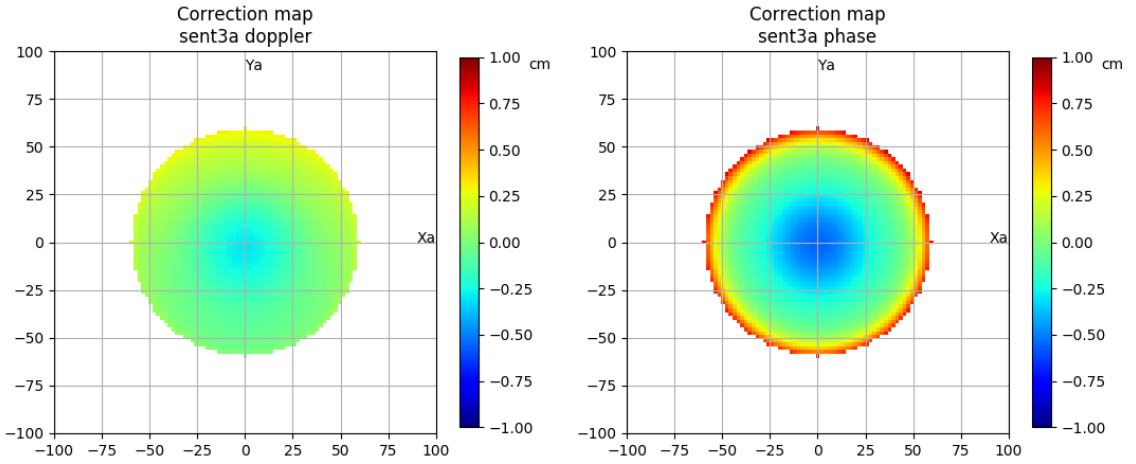
Saral



Jason-3



Sentinel-3a



1. Identification of the satellite antenna phase map

Corrected phase center location

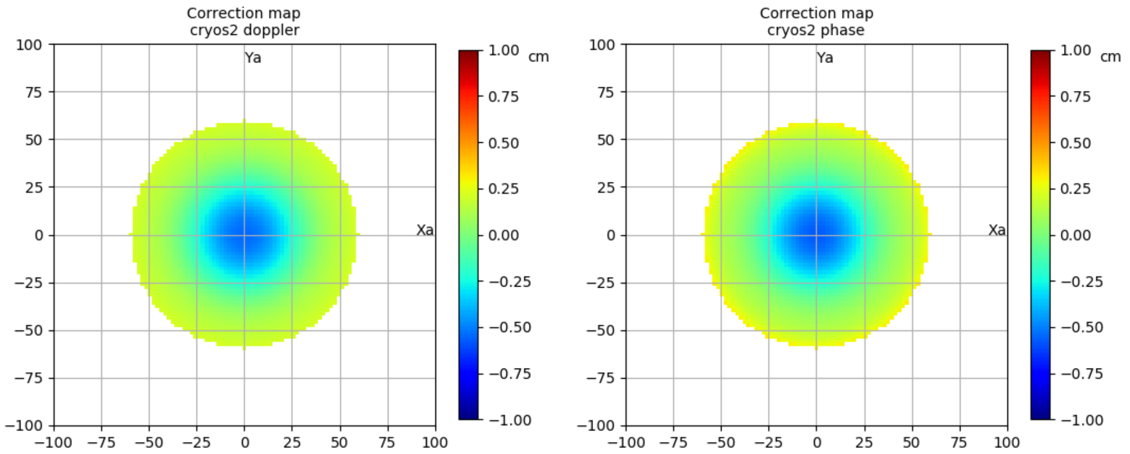
- Jason-3 : effects of the Xa-offset on orbits
  - It implies a T-bias of +/- ~1.5 cm in fixed yaw and in-between biases in R/T in yaw steering regime
  - Orbit difference w.r.t GPS dynred orbit :

(in cm)	GPS reddyn - DORIS doppler reddyn **without map**				GPS reddyn - DORIS doppler reddyn **with map**			
	fixed yaw		yaw steering		fixed yaw		yaw steering	
	mean	RMS	mean	RMS	mean	RMS	mean	RMS
Radial	0.00	0.76	0.00	0.74	0.00	0.76	0.00	0.69
Along-track	**-0.99**	**2.52**	**-0.68**	**2.49**	**-0.83**	**2.43**	**-0.60**	**2.34**
Cross-track	0.00	2.14	0.00	2.34	0.00	2.13	0.00	2.25

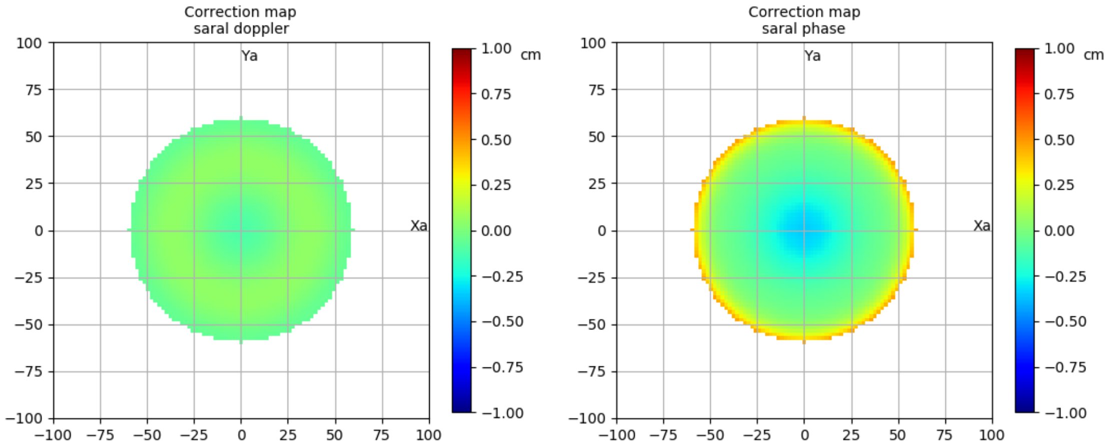
1. Identification of the satellite antenna phase map

With corrected phase center location

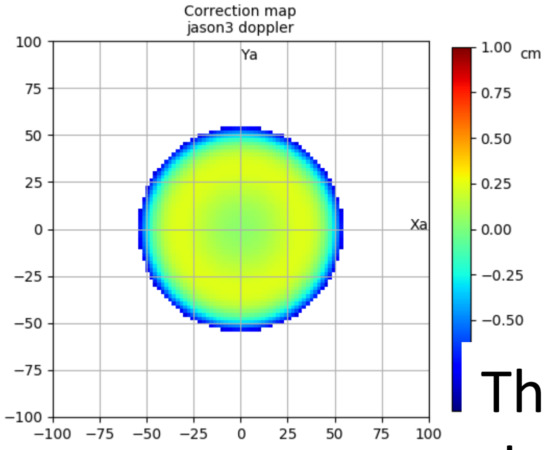
Cryosat-2

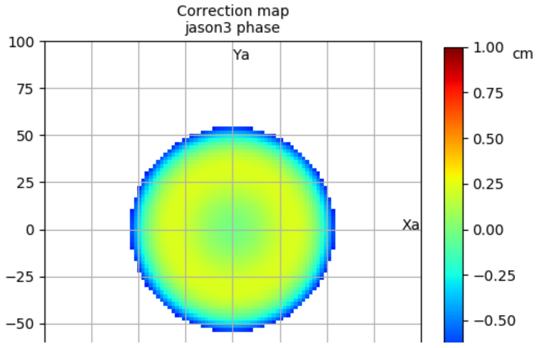


Saral

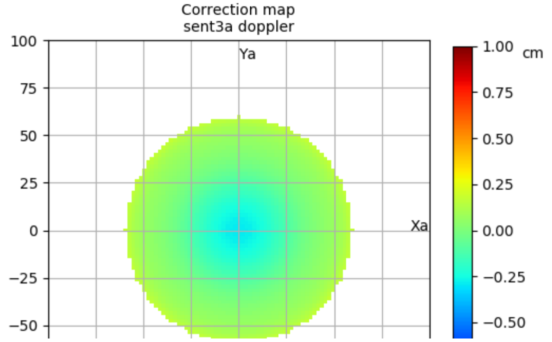


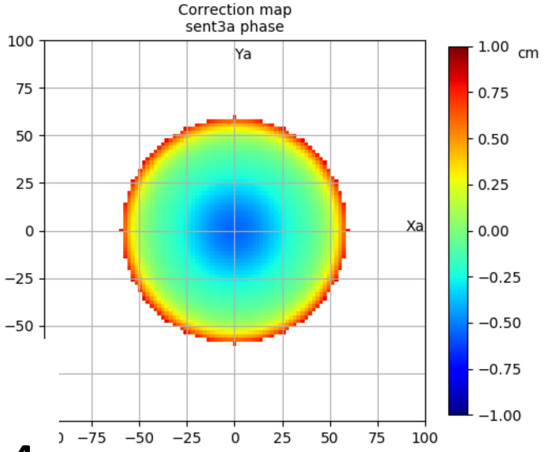
Jason-3





Sentinel-3a





The radial offset is significantly reduced, showing the improvement of the scale factor with DPOD2014

1. Identification of the satellite antenna phase map

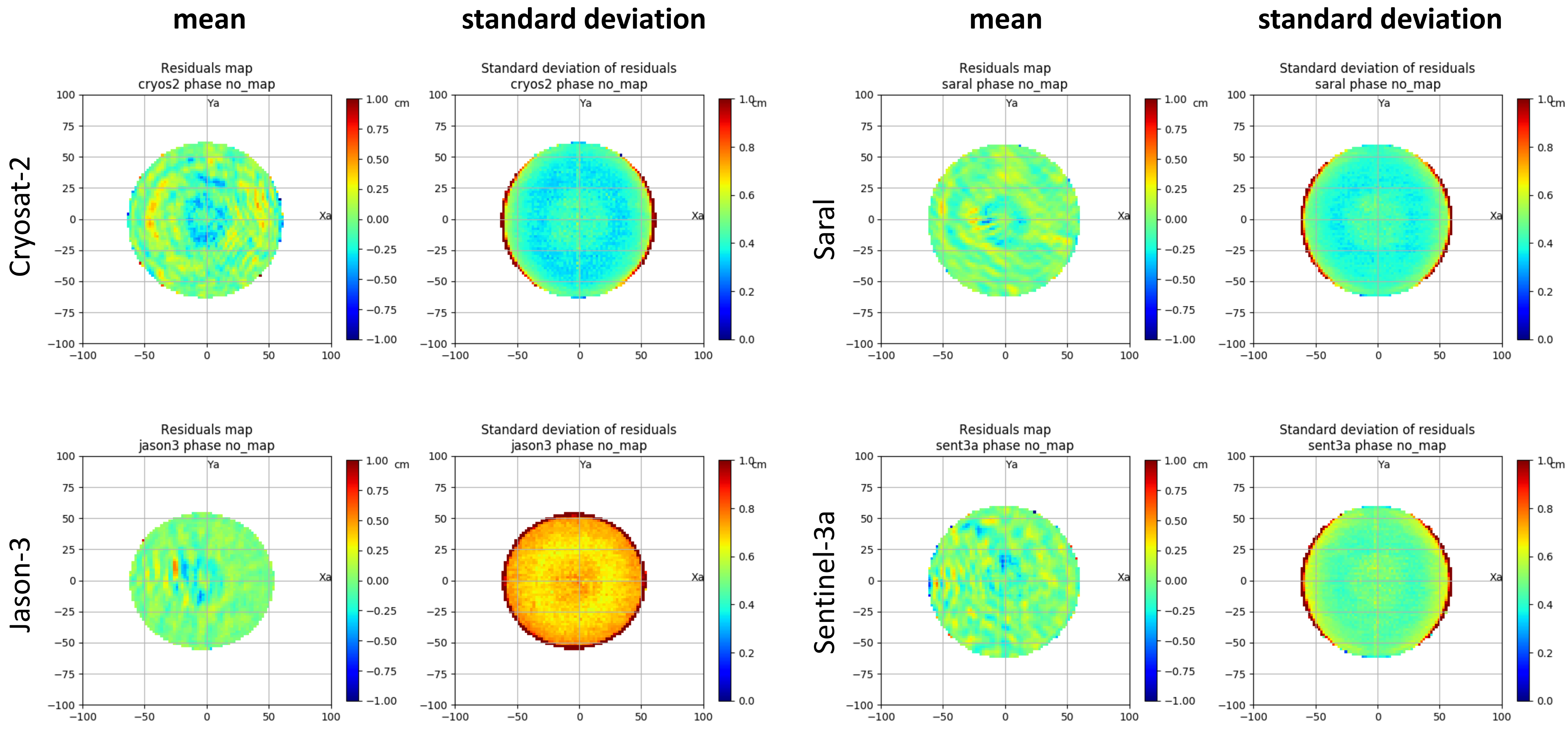
Effects on orbits performances

- The orbit performances are similar as seen by SLR residuals.
- There is no effect on Doppler residuals.

(in cm)		Cryosat-2		Jason-3		Saral		Sentinel-3a	
		no map	with map	no map	with map	no map	with map	no map	with map
Doppler	SLR core network, 3D	1.18	1.18	1.59	1.64	1.14	1.14	1.25	1.25
	SLR core network, radial	0.68	0.68	0.89	0.89	0.66	0.67	0.64	0.64
	DORIS	0.45	0.45	0.43	0.43	0.39	0.39	0.45	0.45

1. Identification of the satellite antenna phase map

Residuals maps without map

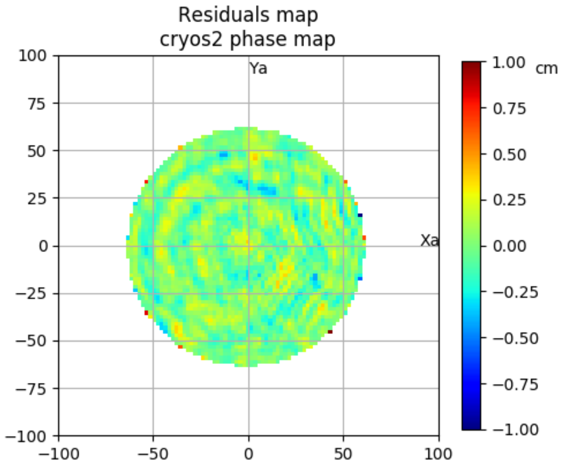


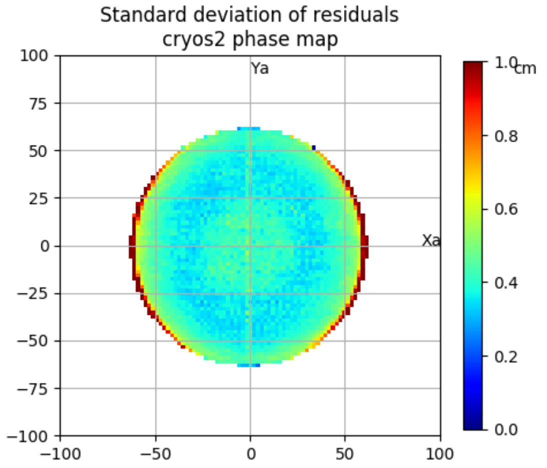
1. Identification of the satellite antenna phase map

Residuals maps with map

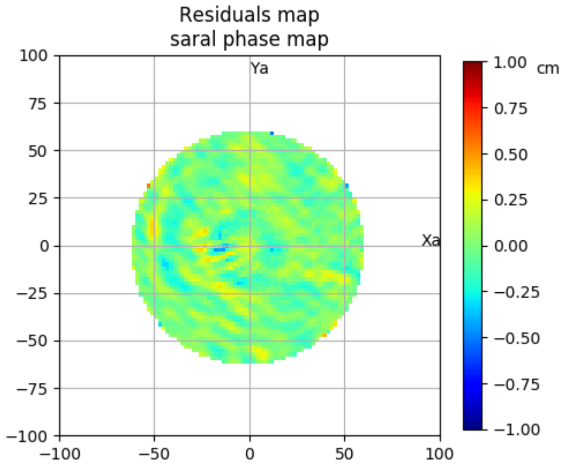
mean | **standard deviation** | **mean** | **standard deviation**

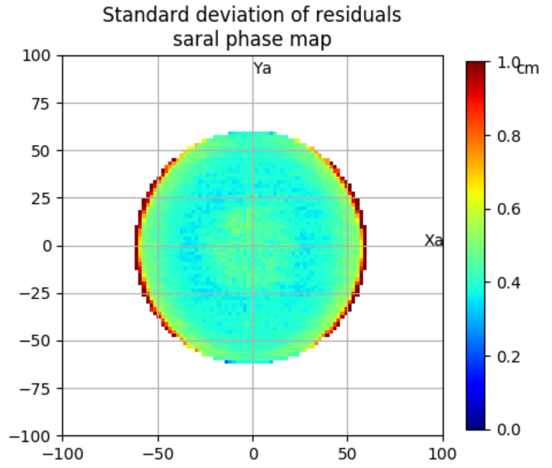
Cryosat-2



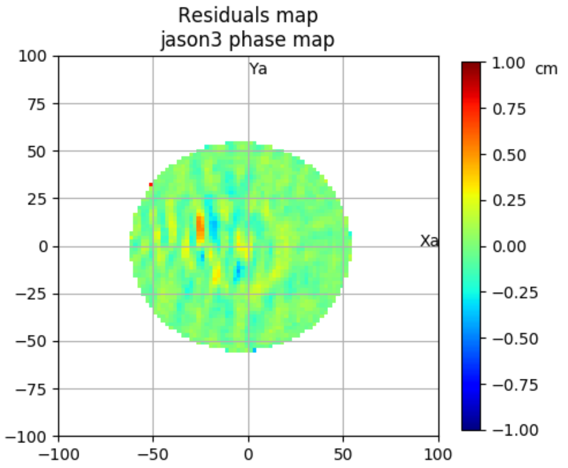


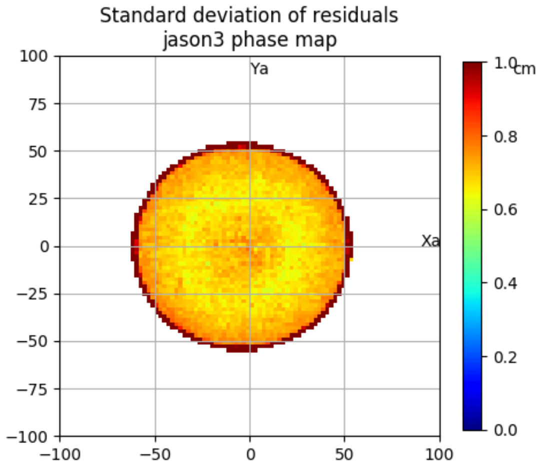
Saral



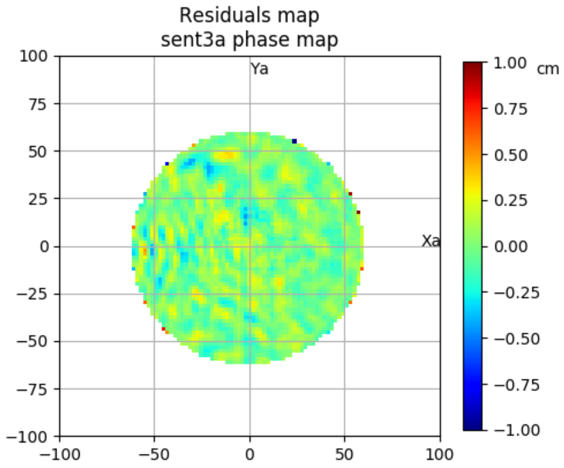


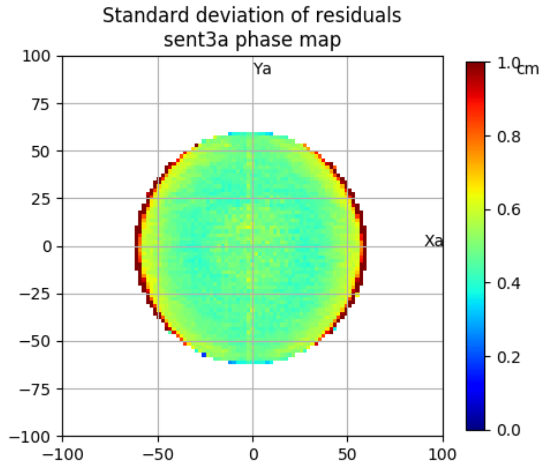
Jason-3





Sentinel-3a

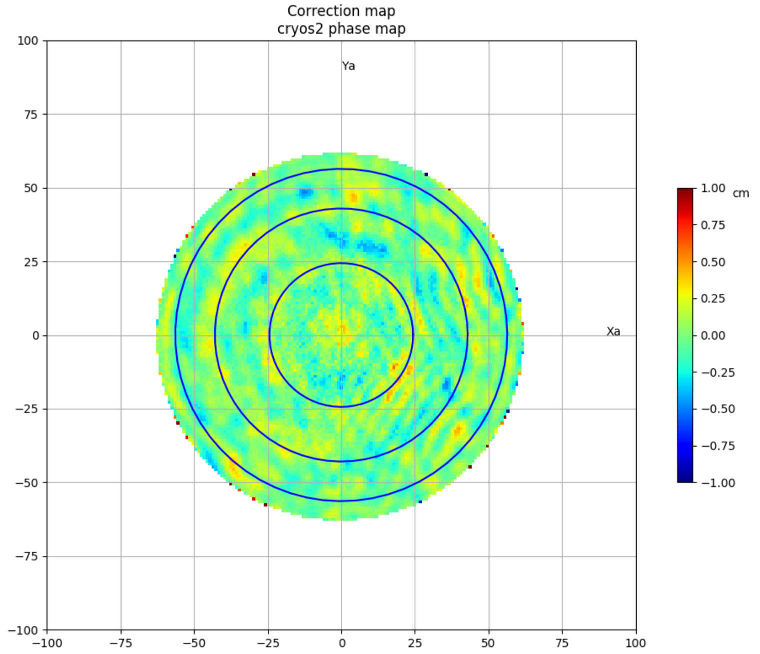


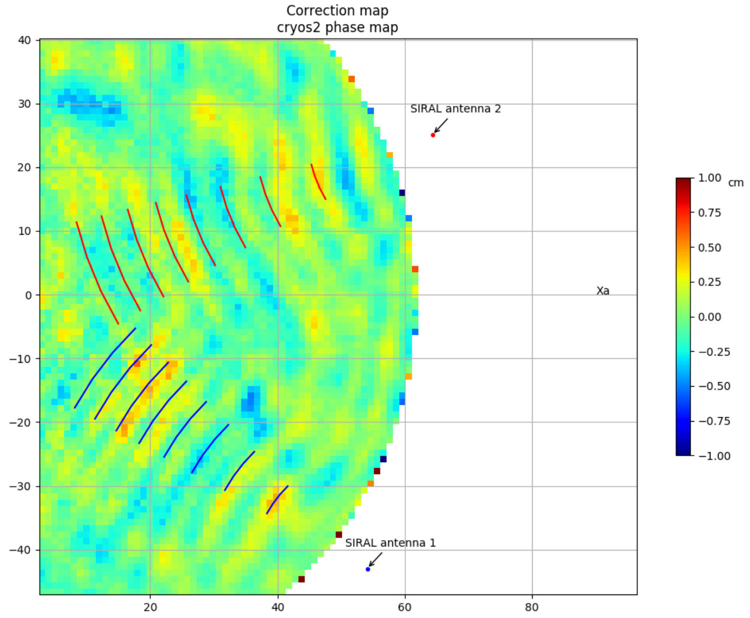


1. Identification of the satellite antenna phase map

Interference sources – case of Cryosat

- The central rings seem to correspond to a reflection of the 2GHz signal on a surface located ~10 cm below the antenna.
- Rings coming from the right may coincide with a reflection on the SIRAL antennas.





1. Identification of the satellite antenna phase map

Conclusions

- The phase center locations are OK.
  - There is a Xa-offset for Jason-3, but it does not degrade the orbits.
  - The common -2.5cm phase center Za-offset disappears (effects of DPOD2014)
- The DORIS phase map is rather flat (as stated by the constructor) and less than 1cm (once the phase center correctly located).
  - By comparison :
    - For the GPS receiver antenna, the phase map correction is around 3 cm.
    - For the DORIS ground beacon antenna, the phase law correction is about 1cm.
  - The residuals maps may be slightly improved in the Za direction.
  - There is no effect on Doppler- or phase-based orbits.

2. Performances of POE-F DORIS-only orbits

Center of mass for Saral – background

- Configuration used for the dynamic POE orbit : empirical forces
  - Periodic 1/rev acceleration in along-track and cross-track, estimated /24h
  - Along-track constant acceleration, estimated every 2 orbits

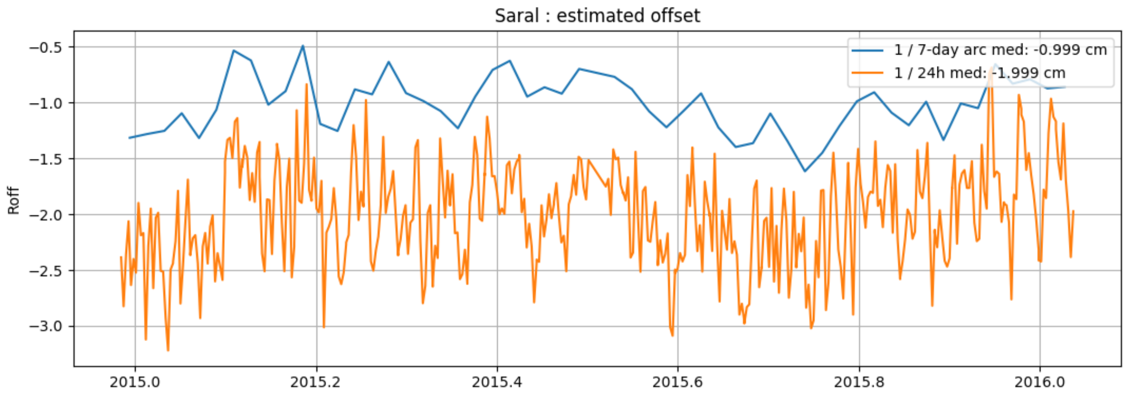
- The center of mass location was already shifted by 47.8mm in cross-track.

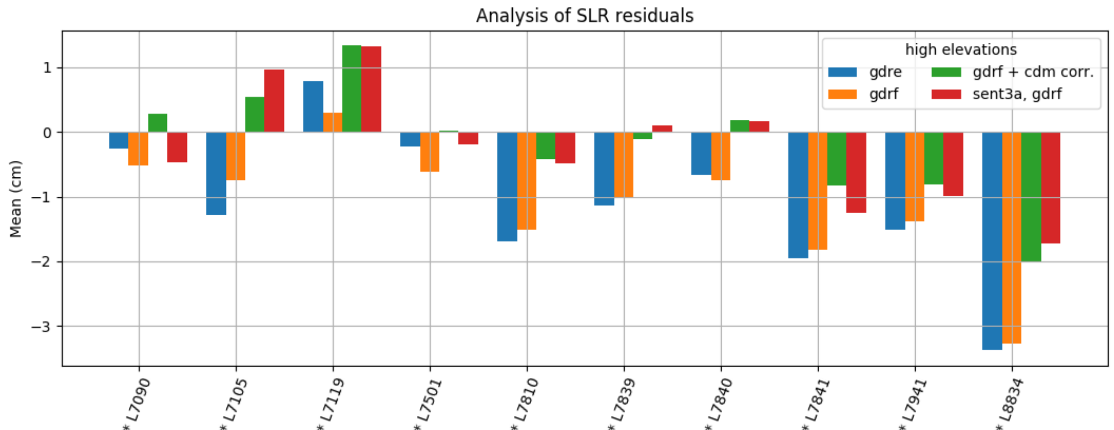
- Potential perturbations due to propellant sloshing (??) and how can they be retrieved ?
  - Periodic along-track empirical acceleration ?
    - The radial errors are not fully recovered by the along-track forces
  - Periodic radial empirical acceleration ?
    - The estimation is not possible due to observability issues with DORIS measurements
  - Constant radial empirical acceleration ? → **approach used in this analysis**

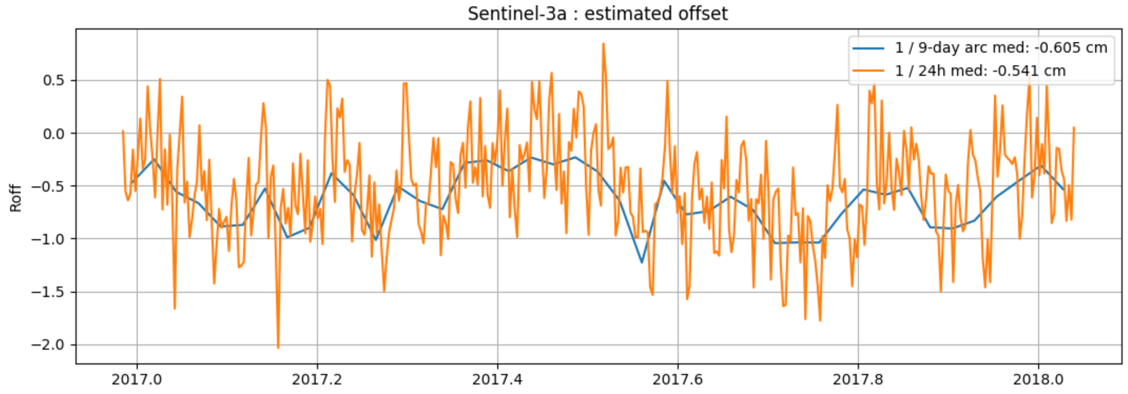
2. Performances of POE-F DORIS-only orbits

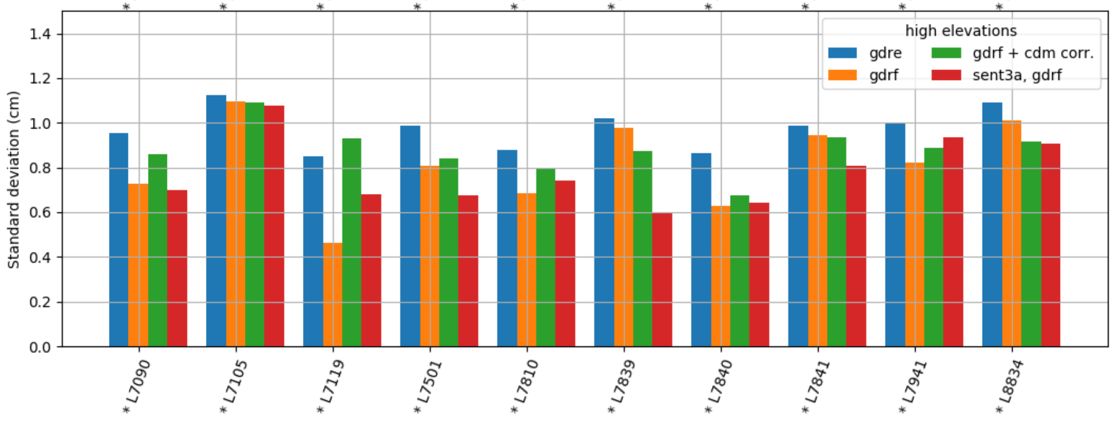
Center of mass for Saral

- For Saral, a +1cm-shift of the center of mass can be observed by DORIS and SLR measurements









2. Performances of POE-F DORIS-only orbits

SLR performances on reduced-dynamic orbits

- The radial performances are about 5-7 mm.
- The POE-F DORIS-only orbit performances approach those of Jason-3 GPS-based orbits.

Mean of RMS over 2017 (in cm)		Cryosat-2	Jason-3		Saral	Sentinel-3a	
		DORIS-only	DORIS-only	GPS-only	DORIS-only	DORIS-only	GPS-only
SLR core network, 3D	POE-E	1.66		1.62	1.77		1.10
	POE-F	1.18	1.59	1.06	1.14	1.25	0.85
SLR core network, radial	POE-E	**0.98**		**0.90**	**0.78**		**0.72**
	POE-F	**0.68**	0.89	**0.70**	**0.66**	0.63	**0.54**
DORIS	POE-F	0.45	0.43		0.39	0.45	

3. Recap of the identified offsets and map coefficients

(in cm)		Cryosat-2		Jason-3 **(a)**		Saral		Sentinel-3A	
		doppler	phase	doppler	phase	doppler	phase	doppler	phase
Phase center offset	Z(1,1) Xa **(b)**			- 1.12 - 1.83	- 1.43 - 2.34				
	Z(-1,1) Ya **(b)**	- 0.19 - 0.29	- 0.68 - 1.02	0.35 0.57	0.39 0.64	0.75 1.13	0.65 0.98	0.15 0.23	0.05 0.08
	Z(0,2) = Za	0.33	0.36	- 0.39	- 0.34	- 0.02	0.30	0.19	0.53
Phase map coefficients	Z(0,4)	- 0.16	- 0.13	- 0.40	- 0.35	- 0.08	0.07	- 0.06	0.12
	Z(0,6)	0.05	0.09	- 0.05	0.00	0.04	0.11	0.05	0.15
Center of mass						R = +1 cm			

(a) For Jason3, the values in the XY-plane are the means over the domain where it is observable
(b) Phase center offsets computed from the Zernike coefficients

Thank you for you attention