ASSESSMENT OF SELF-SHADOWING EFFECT ON SWOT

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07/11/2025, IDS AWG DORIS

SUMMARY

CONTEXT

Scientific requirements for future missions:

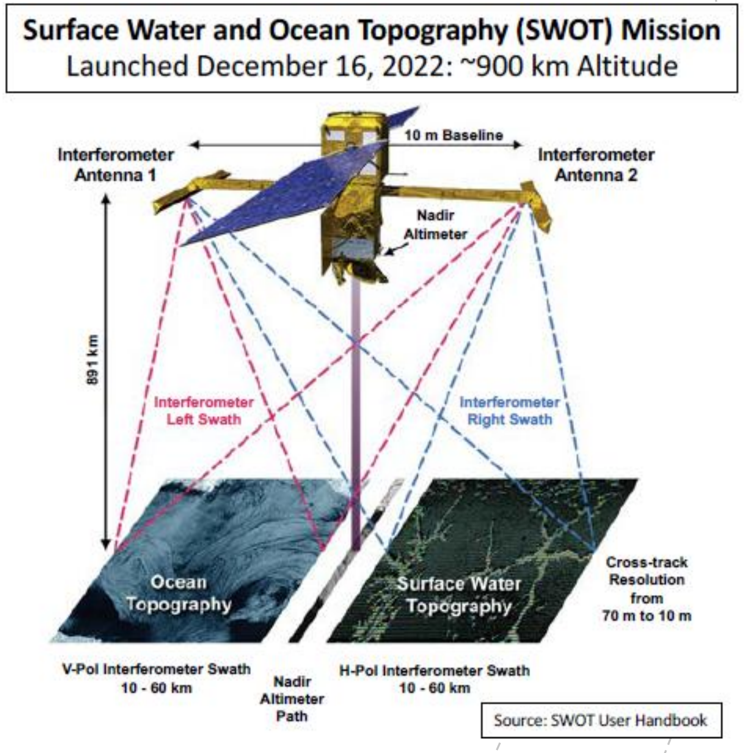
reduce the regional orbit error budget for Mean Sea Level estimation to

1 mm per decade

- Need to look into all contributors to the orbit error
- Analyze the impact of self-shadowing modelling on the orbit error budget

SWOT mission:

- launched on December 16, 2022 providing global survey of oceans and inland water surface elevations.
- Three tracking systems: GPS, DORIS, SLR
- Precise orbit determination (POD) critical to achieving SWOT's science objectives.
- 15 mm (RMS) radial orbit accuracy requirement.



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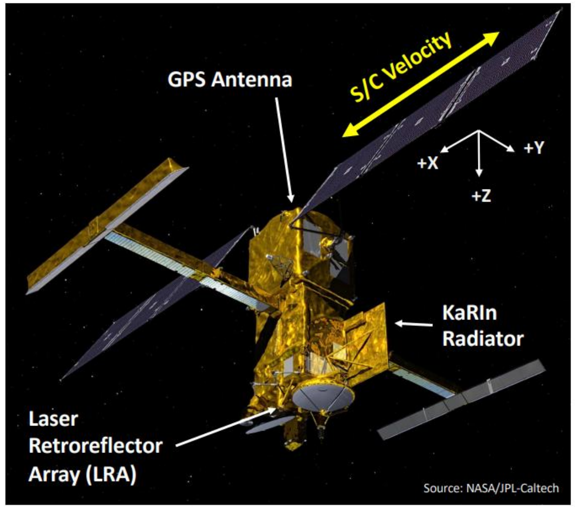
SWOT SATELLITE



Relevant elements on SWOT architecture

- S/C velocity along +/- Body X directions.
- -Y is always toward the Sun.
- Spacecraft performs yaw flips (apx. every 78 days) to keep radiator (i.e., +Y) in shade.
- One solar panel on each side of spacecraft bus along body-fixed +/- X directions.
- Radiators are located on +Y side of the spacecraft.
- Solar panels are always oriented towards –Y, taking three β-dependent positions.
- For CNES POD, the Solar Radiation Pressure (SRP) model is a cube with two solar panels

β	Solar array angle
$[0° - 6°]$	$0°$
$[6° - 25°]$	$12°$
$> 25°$	$30°$

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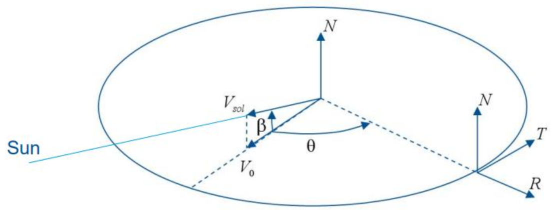
EMPIRICAL FORCES ANALYSIS

Orbit Determination using ZOOM Software, with POE-G standard for multiple beta-cycle

Analysis of once-per-revolution empirical accelerations along-track (T) and cross-track (N) computed with the reference at the subsolar point.



θ: angle between the current satellite orbital position and the subsolar point
β: angle between the orbit plane and the sun direction

Empiricals (1/rev) are written as:

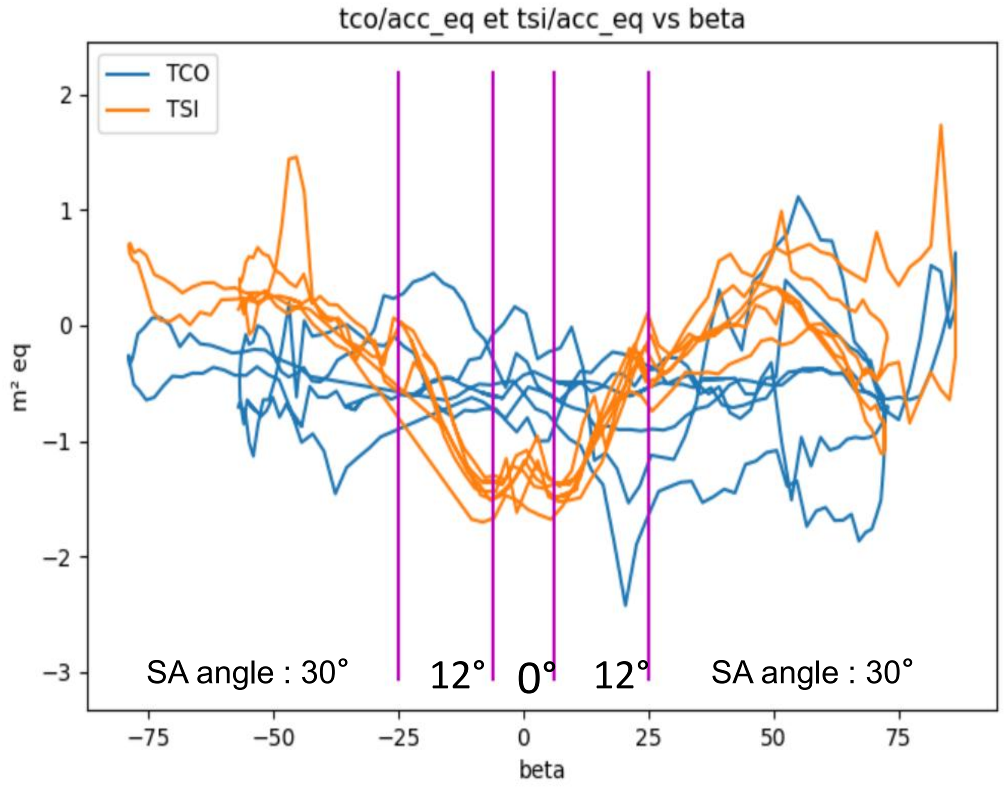
$$T = Tco.\cos(\theta) + Tsi.\sin(\theta)$$
$$N = Nco.\cos(\theta) + Nsi.\sin(\theta)$$

1/rev are divided by the acceleration on the satellite produced by a black square of 1m² in normal lighting.
-> better aknowledge the 1/rev amplitude wrt satellites surfaces

$$acc_{eq} = \frac{\Phi * s}{c * m} = 2.28e{-9}\ m/s^2$$

With Φ, solar flux, s, square surface, c, light velocity, m, satellite mass

BETA-DEPENDANT SIGNATURE - TANGENTIAL



- Tco signal absorbs mostly drag modelling errors. It is mostly correlated with the solar activity and not with the beta angle.
- Tsi signal absorbs mostly SRP modelling errors. A correlation both with the beta angle and with the solar array angle is visible.
- β > 25° : 1/rev flat and close to 0m² error.
- β < 25° : 1/rev peaks up to 1.5m².

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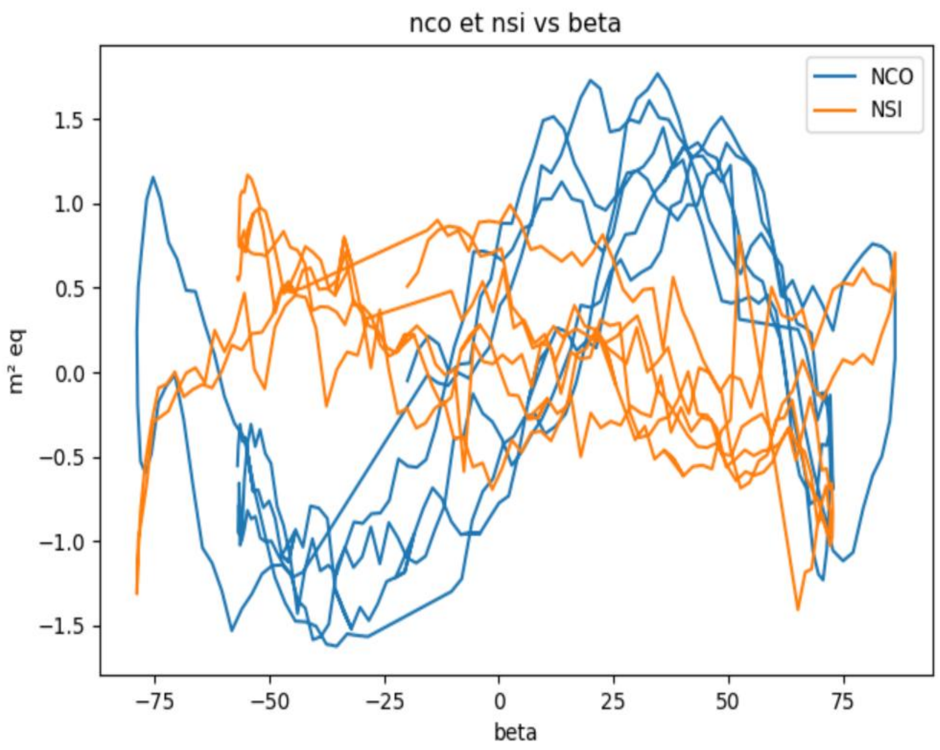
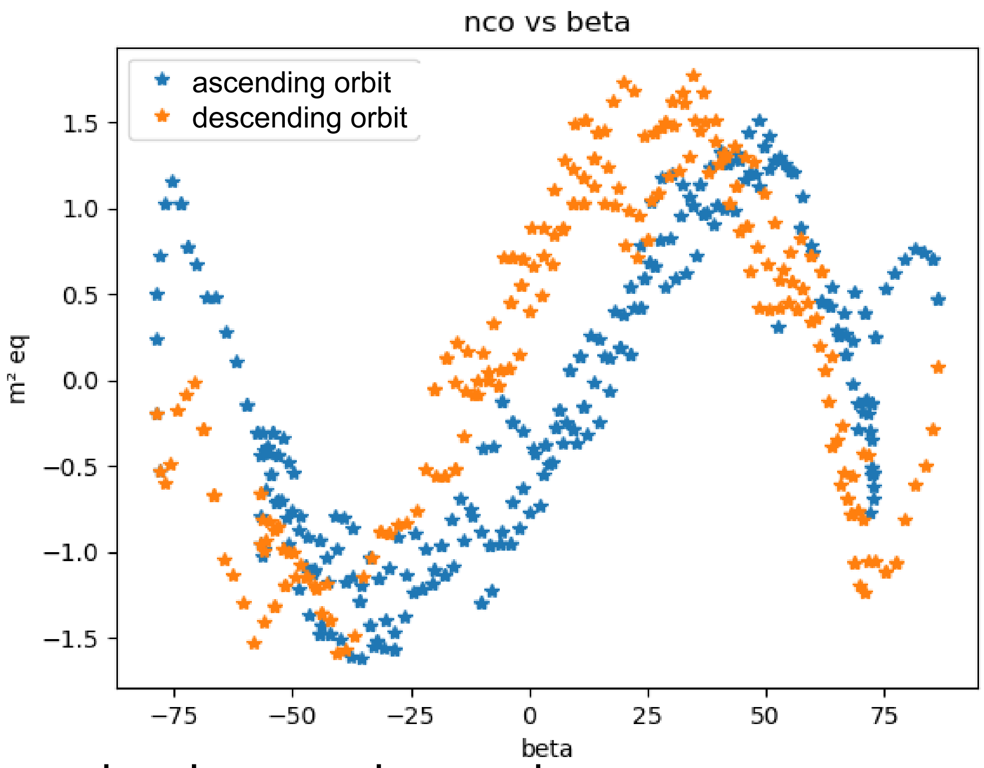
BETA-DEPENDANT SIGNATURE - NORMAL





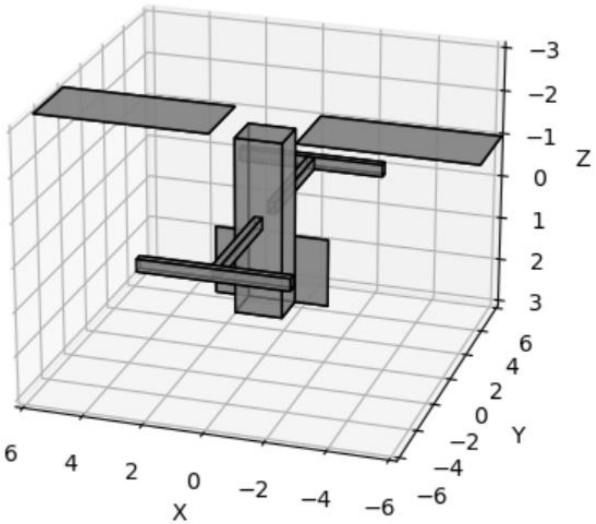
- Nsi signal is flat w.r.t. β, no relevant dependencies are observed.
- Nco signal shows a sinusoidal dependency w.r.t. β, up to 1.5m².
- There is a dependency between ascending or descending orbits when viewed from the sun direction. It could be correlated to the heat flow from the radiators on face –Y.

SRP WITH AND W/O SHADOW

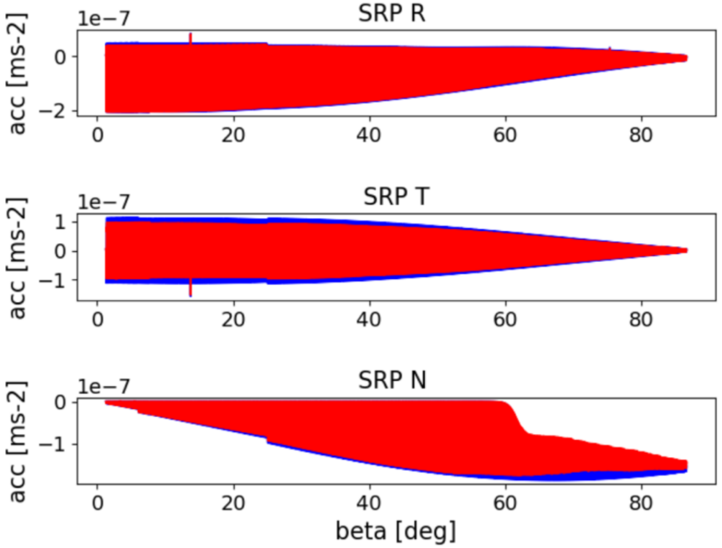
- Acceleration computation using GINS software
- Three models, one for each solar array position
- Satellite modelled with a main body, solar arrays, Karin and radiators

Main shading effects on:

- The tangential acceleration, for beta <~ 40°
- The normal acceleration, for beta >~ 60, with a bias

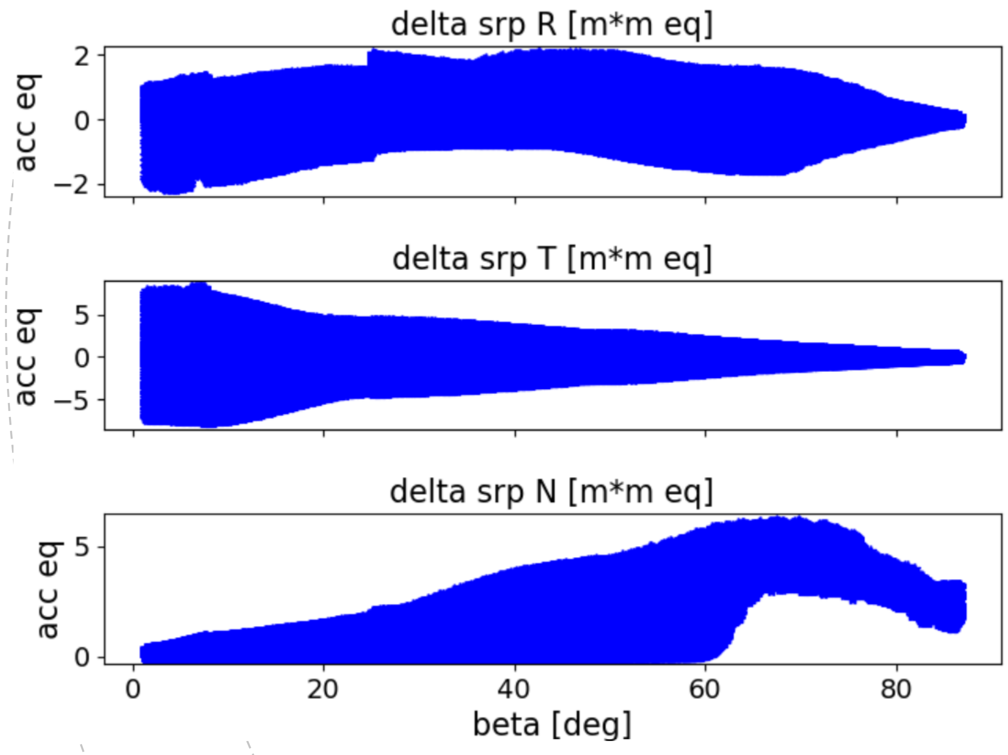


3D model for beta < 6°



SRP in RTN, blue without self shadow, red, with self shadow

SRP DIFFERENCE WITH AND W/O SHADOW



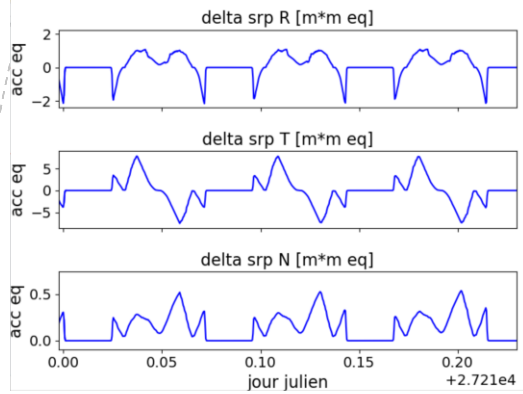
Tangential :

- Strongest effect occurs at low beta angles, with the shadow of the panels on the ±X faces (5.4 m²).
- Shadows from the central body and the KaRIn reflector on the ±X faces of the KaRIn boom as beta increases (up to 2.3 m²).
- From around beta ~70°, the impact is less than 1 m².

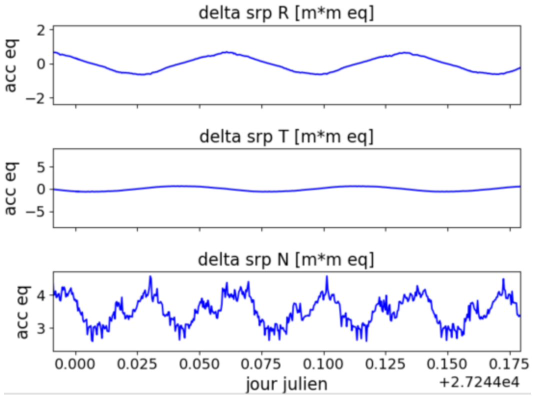
Normal:

- <1m² for beta < 20°.
- The central body casts a shadow on the radiators (up to 3.4 m²).
- A bias appears at high beta angles: part of the -Y surfaces are always in the shadow of another face.

ACCELERATION DIFFERENCE WITH AND W/O SHADOW



Beta ≅ 0 degré

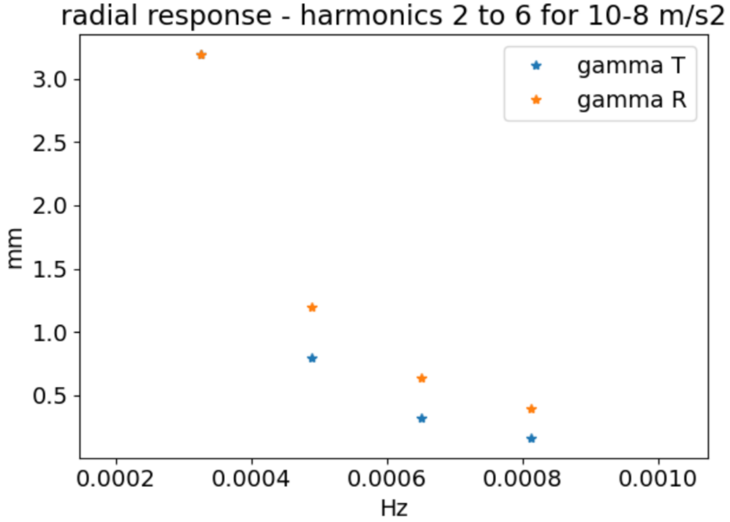


Beta ≅ 75 degré

the signature of the acceleration difference is mainly at the orbital period, along with a bias in some cases.

The empirical terms at the orbital period will absorb the first-order harmonic errors caused by the lack of modeling of shadowing effects.

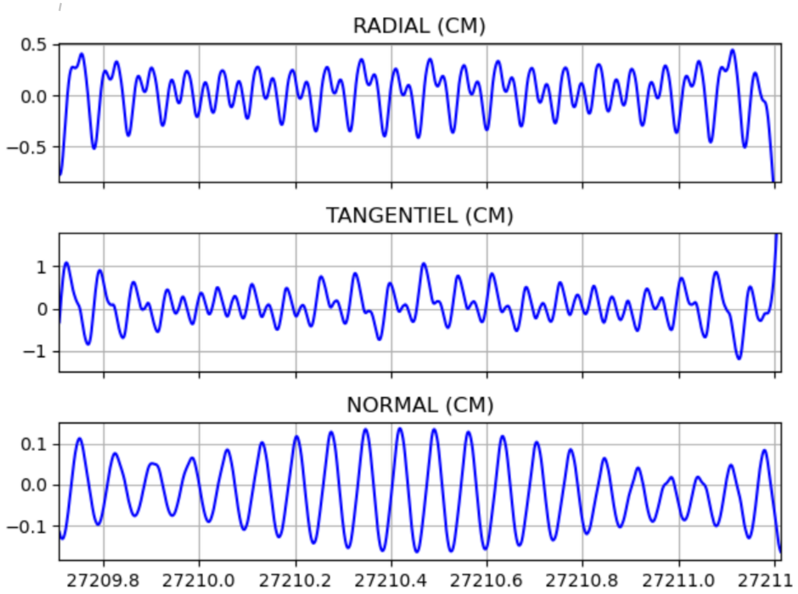
Higher order errors will not be compensated by the 1/rev and will participate in the orbit error.



For a maximum harmonic of 5 m² (in T, $\beta = 0$), we obtain an acceleration of approximately 10^{-8} m/s², corresponding to a second-order harmonic with an amplitude of 3 mm.

ORBIT DIFFERENCE WITH AND W/O SHADOW - ZOOM

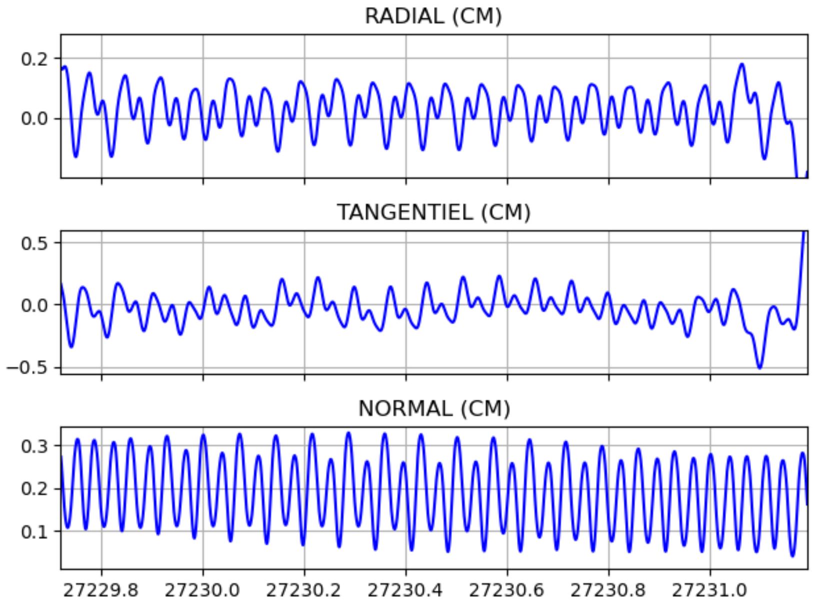
Preliminary work using ZOOM software and the acceleration from GINS instead of the ZOOM nominal SRP model.



β close to 0°:

1cm error on T, with signatures at 1/rev, 2/rev

0,1cm error on N, unbiased



β close to 60°:

0,2cm error on T, with signatures at 1/rev, 2/rev

0,1cm error on N, 0,2cm bias

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CONCLUSION

Validation of the amplitude of the self-shadowing effect on the satellite SWOT

Preliminary testing in ZOOM

Futur work:

Re run SWOT orbits on a few beta cycles in ZOOM and analyse the results

Remarks:

This analysis doesn't take into account multiple reflexion, for instance the corner main body-radiators

The normal dependancy to ascending/descending orbits, remains to be investigated, starting by looking into thermal effects