ASSESSMENT OF JASON-3 AND SENTINEL-6 MF RADIATION PRESSURE MODEL

OSTST 2023
Porto Rico

Marie Cherrier[1,2,3] , Alexandre Couhert[3,4] , Flavien Mercier[3,4]

1. CELAD, Toulouse, France
2. Collecte Localisation Satellites, Toulouse, France
3. Centre National d'Etudes Spatiales, Toulouse, France
4. GET–Université de Toulouse (CNES, CNRS, IRD, UPS), Toulouse, France

Introduction

- Jason-3 (2016) and Sentinel-6 MF (2020) : two reference oceanography missions to monitor global ocean circulation, climate change and sea level rise.

- Operated in tandem (with Sentinel-6 MF flying 30 seconds behind its predecessor) between mid-December 2020 and April 2022 for calibration purposes.

- The main difference between them is their respective platform design :
  - Sentinel-6 MF solar panels are fixed on the satellite and has an almost fixed attitude,
  - Jason-3 has some yaw steering periods with rotating solar panels.

- Purpose : analyze the estimated empirical accelerations of these two satellites as a function of their beta angle, to update the Solar Radiation Pressure (SRP) models of both satellites, during the tandem phase; ultimately their empirical accelerations should be identical (if surface forces are perfectly modeled).

- Previous work / reference : Flavien Mercier – OSTST 2022, *Sentinel-6 radiation pressure model analysis* (DOI: 10.24400/527896/a03-2022.3517).

Initial SRP model implemented in the ZOOM software

Jason-3

surface / en m**2 /	normale visible en repere plate-forme			Coefs de reemission en vis. et coefs de reemission en ir, spec / diff / abs			spec / diff / abs		
0.783	-1.	0.	0.	0.341	0.646	0.013	0.	0.987	0.013
0.783	1.	0.	0.	0.149	0.851	0.	0.	1.000	0.
2.040	0.	-1.	0.	0.573	0.384	0.043	0.104	0.569	0.328
2.040	0.	1.	0.	0.539	0.424	0.037	0.089	0.627	0.283
3.105	0.	0.	-1.	0.246	0.752	0.002	0.005	0.977	0.017
3.105	0.	0.	1.	0.213	0.453	0.334	0.037	0.287	0.676

m² *normal* *visible (Ks, Kd, Ka)* *IR (Ks, Kd, Ka)*

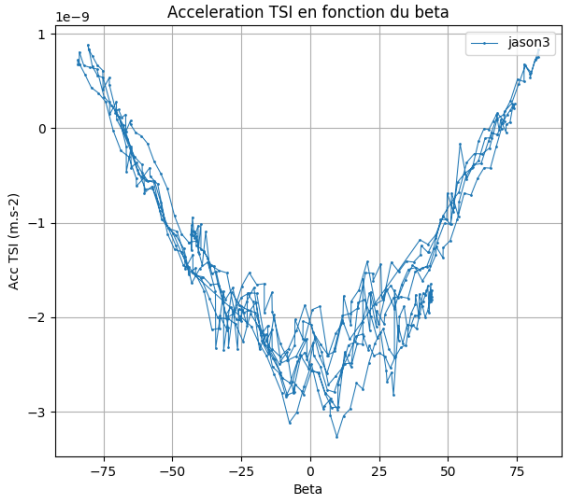
Sentinel-6 MF

surface / en m**2 /	normale visible en repere plate-forme			Coefs de reemission en vis. et coefs de reemission en ir, spec / diff / abs			spec / diff / abs		
3.500	-1.	0.	0.	0.200	0.800	0.000	0.180	0.040	0.780
3.500	1.	0.	0.	0.200	0.800	0.000	0.192	0.808	0.
8.720	0.	-0.6157	-0.7880	0.500	0.300	0.200	0.	0.615	0.385
8.720	0.	0.6157	-0.7880	0.500	0.300	0.200	0.	0.615	0.385
2.660	0.	0.	-1.	0.800	0.200	0.000	0.114	0.627	0.259
4.100	0.	0.2588	0.9659	0.100	0.700	0.200	0.066	0.724	0.210
4.100	0.	-0.2588	0.9659	0.100	0.700	0.200	0.066	0.724	0.210
3.700	0.1736	0.	0.9848	0.100	0.700	0.200	0.066	0.724	0.210
4.400	-0.1736	0.	0.9848	0.100	0.700	0.200	0.066	0.724	0.210

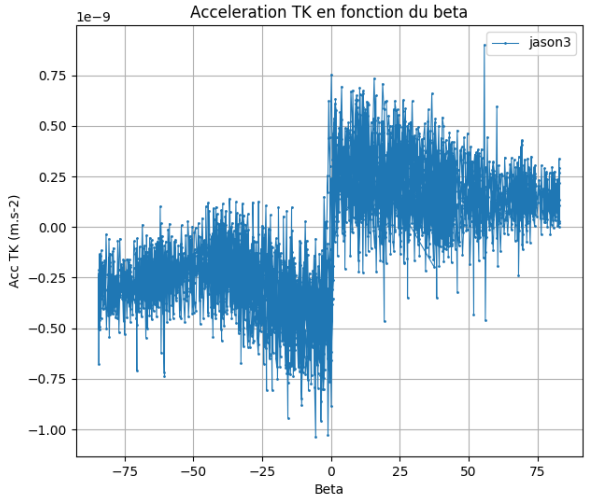
→ The idea is to update both satellites SRP models, where SRP depends only on two parameters: the orbital angle with respect to the sub-solar point and the beta angle.

Initial SRP model : Jason-3 empirical forces

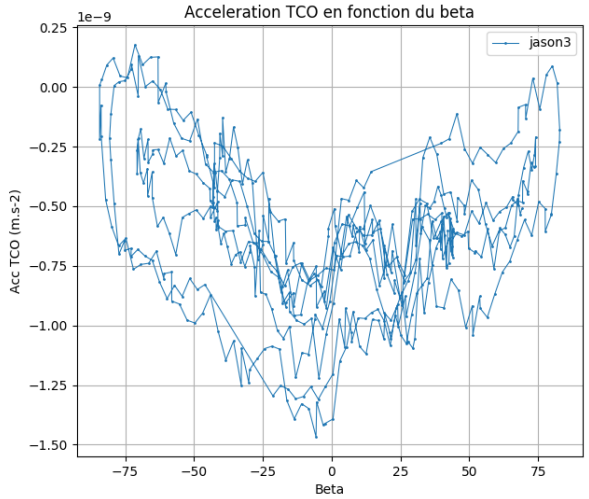
TSI : 1/rev along-track sine term



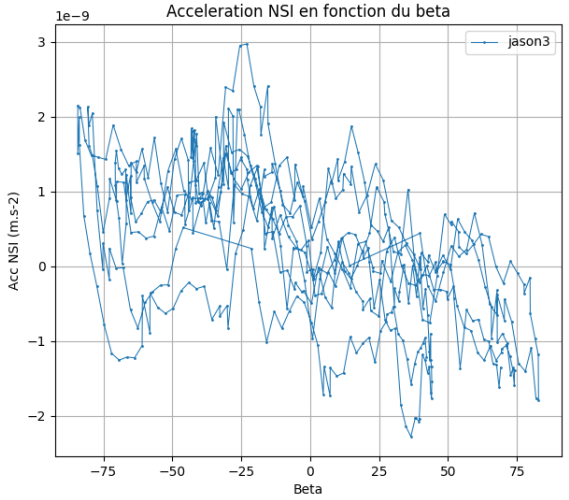
TK : constant along-track term



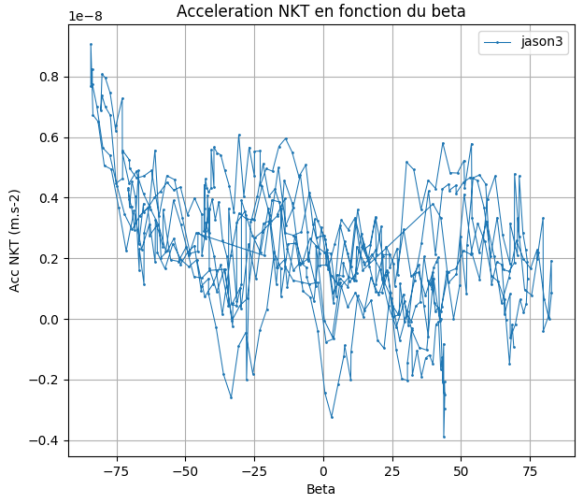
TCO : 1/rev along-track cosine term



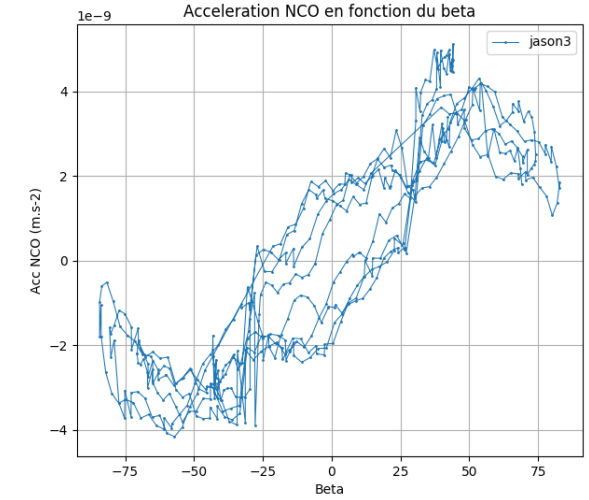
NSI : 1/rev cross-track sine term



NKT : constant cross-track term

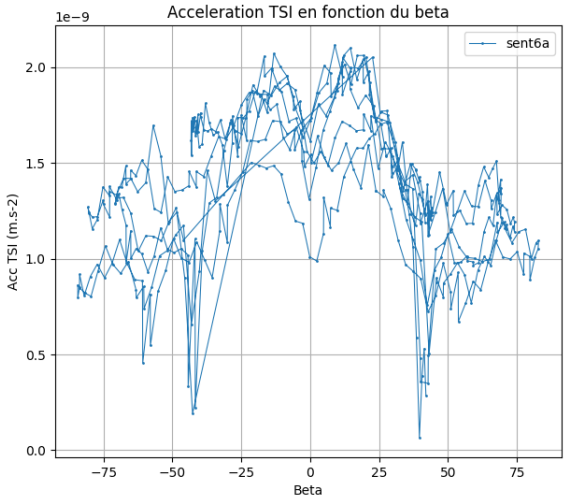


NCO : 1/rev cross-track cosine term

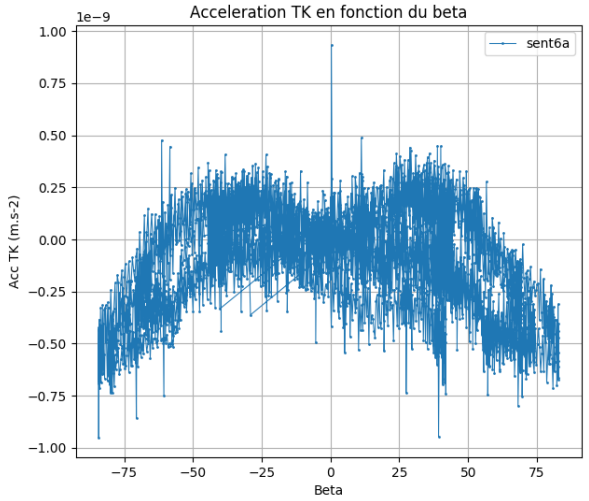


Initial SRP model : Sentinel-6 MF empirical forces

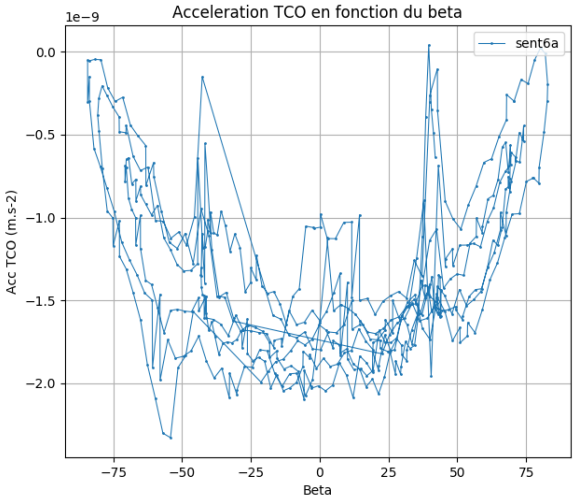
TSI : 1/rev along-track sine term



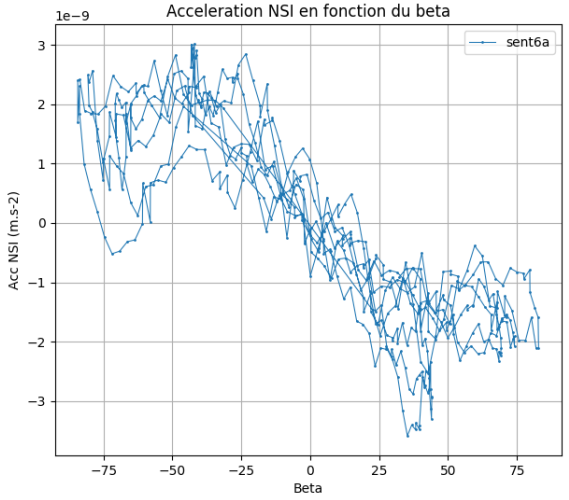
TK : constant along-track term



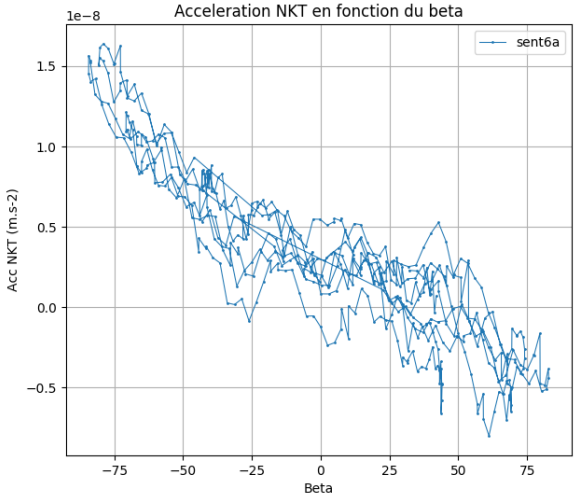
TCO : 1/rev along-track cosine term



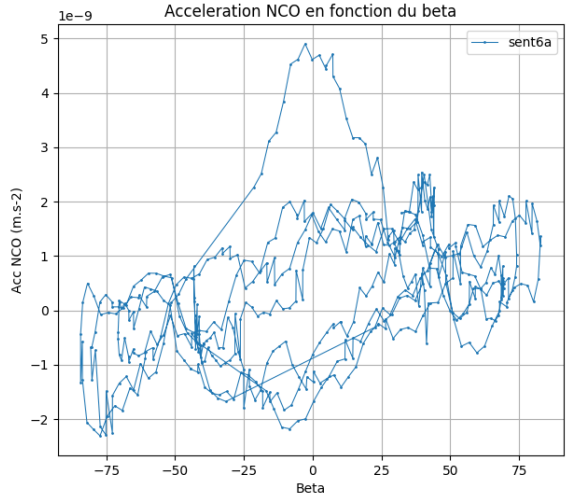
NSI : 1/rev cross-track sine term



NKT : constant cross-track term



NCO : 1/rev cross-track cosine term



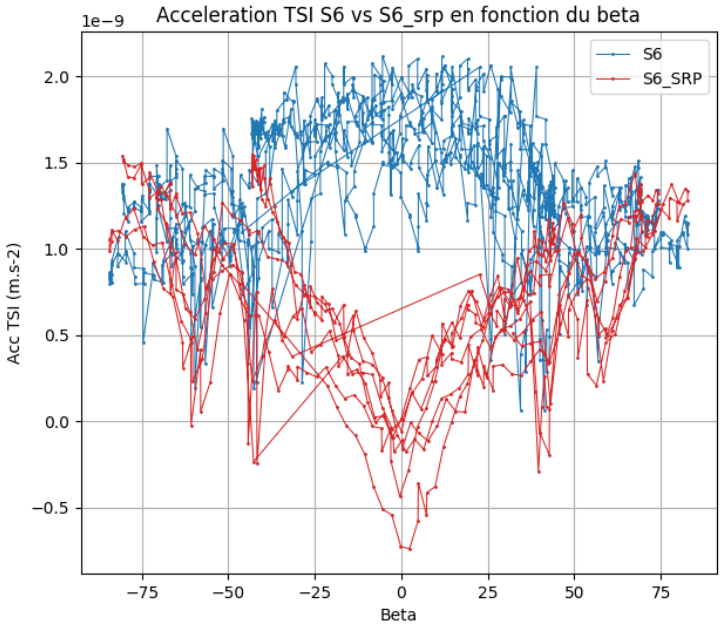
Updated model by F. Mercier

- Analyze by F. Mercier, thanks to new in flight information on Sentinel-6 MF:
  - Temperatures variations along the orbit, for different sun orbital angle cases,
  - Energy production of the array.
- Thermal model constructed using thermal coefficients adjusted on these in flight data.
- New SRP model applicable for Sentinel-6 MF but not for Jason-3.

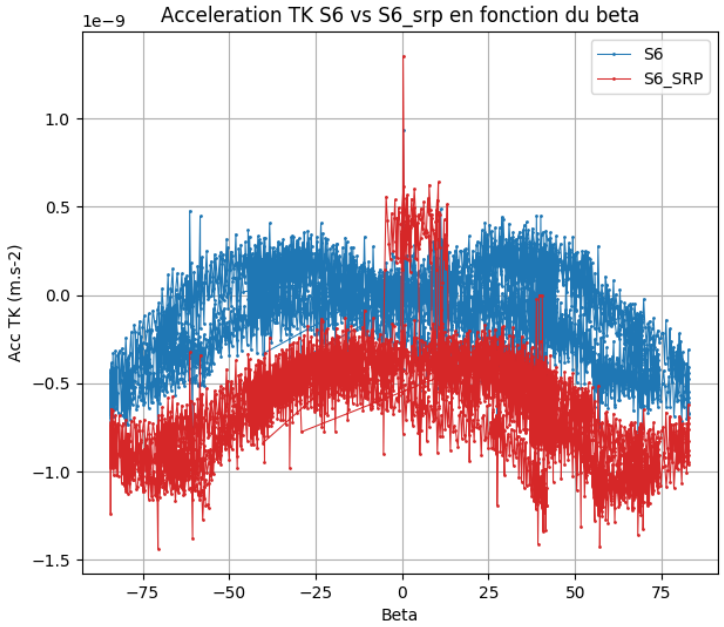
	surface / en m**2 /	normale visible en repere plate-forme			/ Coefs de reemission en vis. et coefs de reemission en ir, / spec / diff / abs /			spec / diff / abs /		
-x	3.35	-1.	0.	0.	0.20	0.80	0.	0.21	0.79	0.
+x	2.99	1.	0.	0.	0.80	0.20	0.	0.21	0.79	0.
Gsa	8.65	0.	-0.6157	-0.7880	0.30	0.50	0.20	0.	1.0	0.
GSb	8.65	0.	0.6157	-0.7880	0.30	0.50	0.20	0.	1.0	0.
-z	2.61	0.	0.	-1.	0.45	0.55	0.	0.16	0.84	0.
+z	15.48	0.	0.	1.	0.	1.00	0.	0.	1.00	0.

Comparaison between initial and updated SRP models 1/2

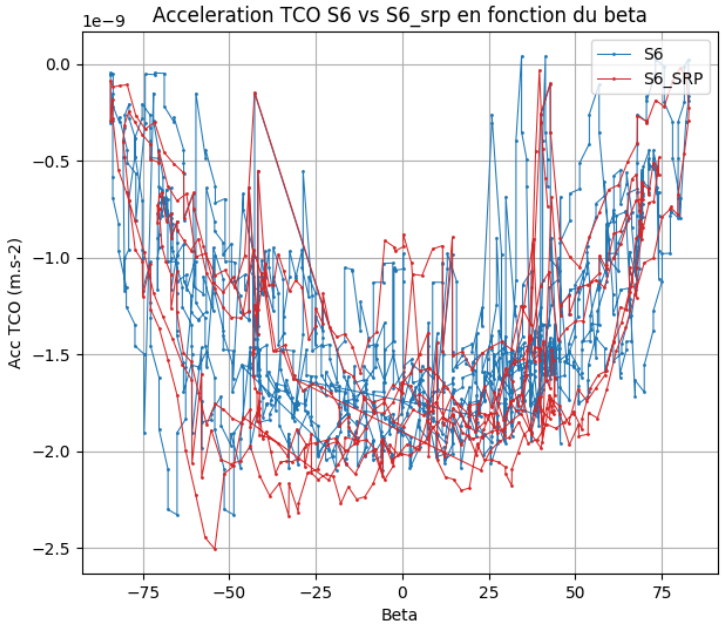
TSI : 1/rev along-track sine term



TK : constant along-track term



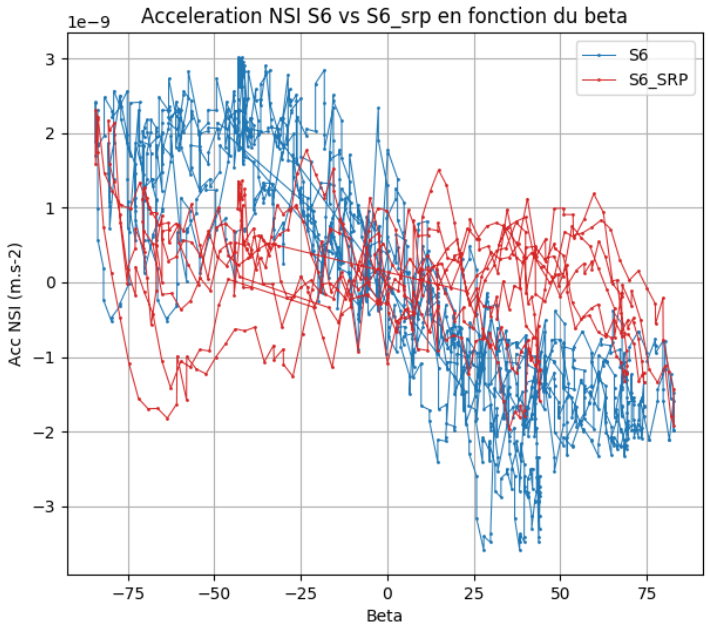
TCO : 1/rev along-track cosine term



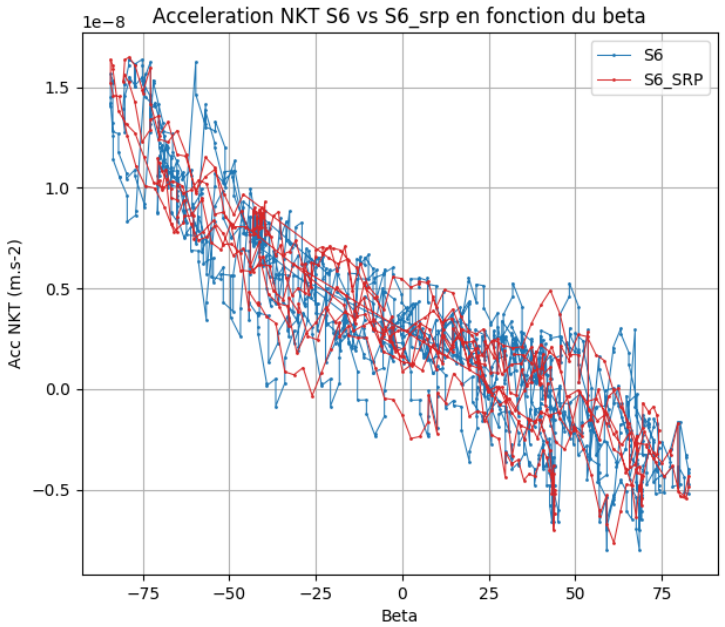
→ For TSI and TK, the initial model shows no beta-dependency. On TCO, both models are equivalent. The red peak on TK corresponds to the period when Sentinel-6 MF flew backwards.

Comparaison between initial and updated SRP models 2/2

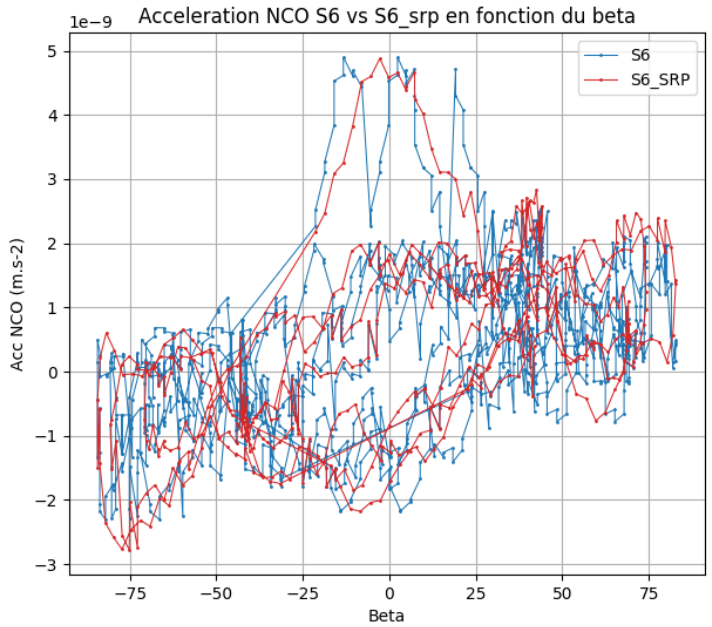
NSI : 1/rev cross-track sine term



NKT : constant cross-track term



NCO : 1/rev cross-track cosine term



→ For NKT and NCO, both models are equivalent. But for the NSI acceleration, the new SRP model seems to show no beta-dependency.

Analyzing the impact of the Earth Radiation Pressure (ERP) model

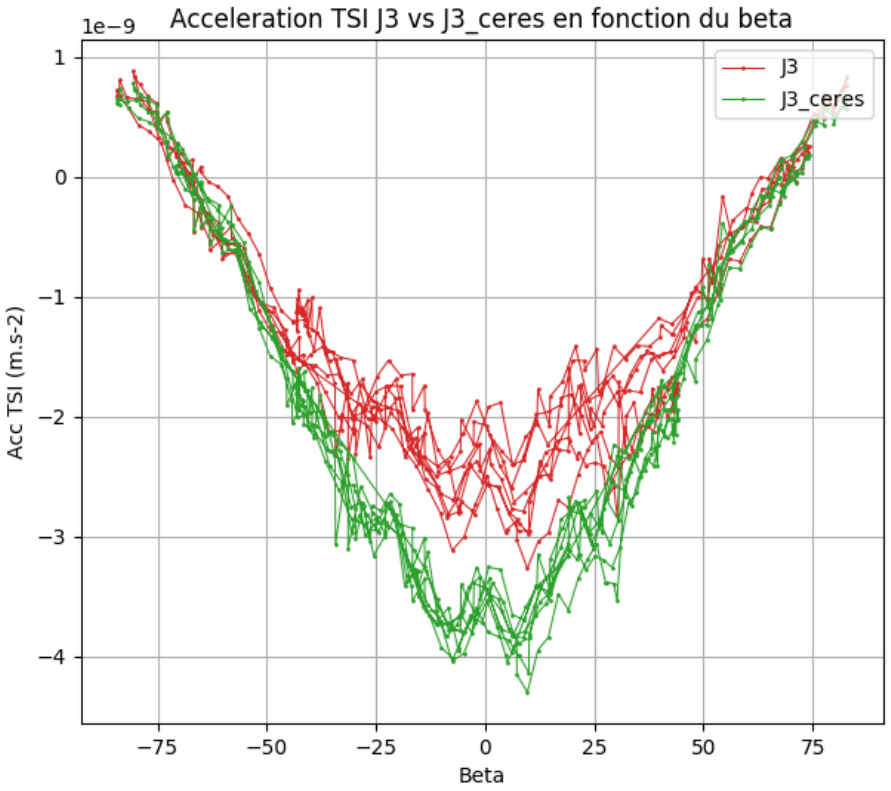
- Model implemented in the CNES Precise Orbit Determination software (ZOOM) is based on the Knocke et al (1988) ERP model.

- Knocke ERP model :
  - Depends on reflected/emitted radiation as a function of latitude and time,
  - Does not take into account the spatial and temporal complexity of reflection phenomena.

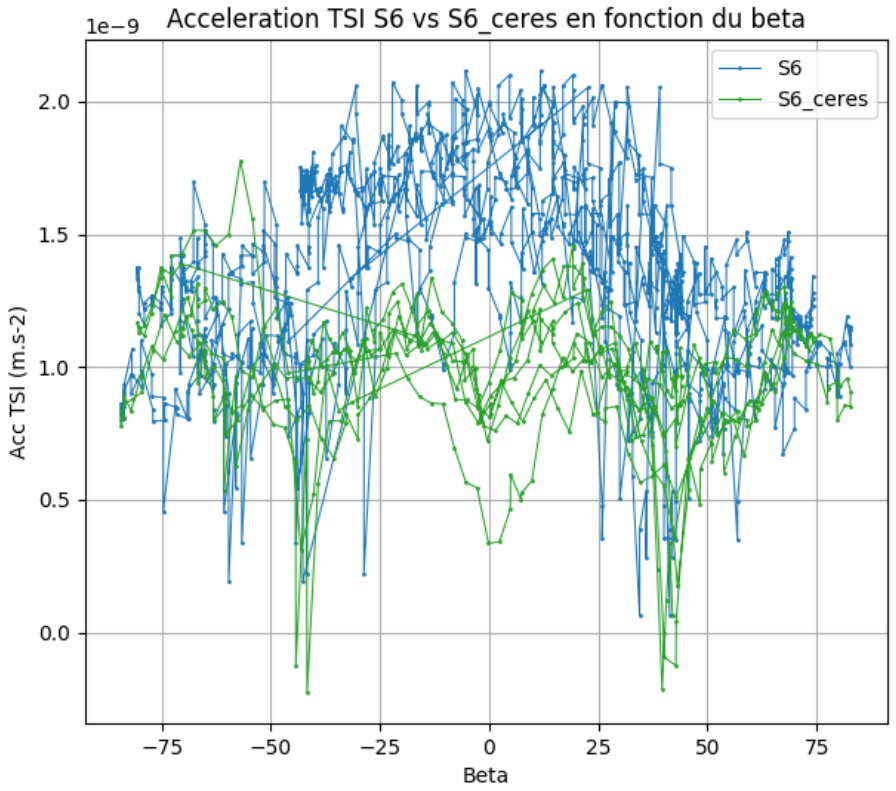
- Updated Earth Radiation Pressure model (see *"Enhancing satellite orbit accuracy for sea level monitoring through Earth radiation pressure modeling"* - Nocet-Binois et al.) → approach based on the use of observations from Earth radiation fluxes (CERES and ERA5 ECMWF).

Impact of the uptaded ERP model on the inital SRP model

TSI : 1/rev along-track sine term



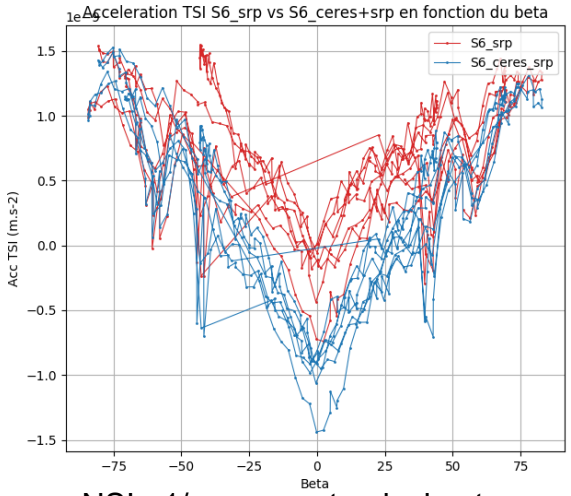
TSI : 1/rev along-track sine term



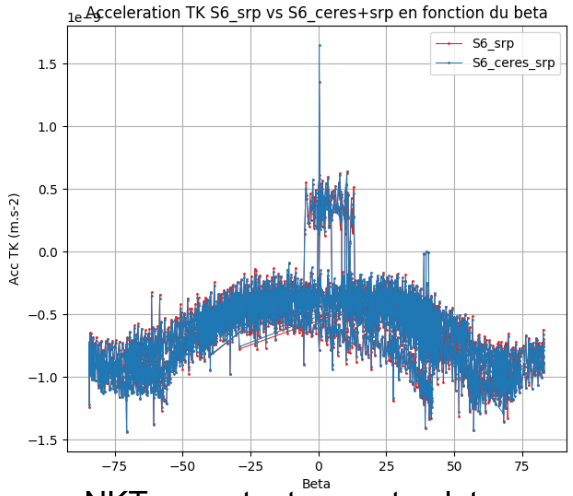
→ Nothing noticeable for the empirical accelerations, except for TSI. For Sentinel-6 MF, the introduction of the new ERP model tends to improve the data. But for Jason-3, it tends to degrade them. However, Knocke ERP modeling errors were erroneously interpreted as SRP modeling errors for Jason-3 when it was calibrated in the past. This work should be redone now with the updated ERP model.

Test when adding both updated SRP and ERP models (for Sentinel-6 MF)

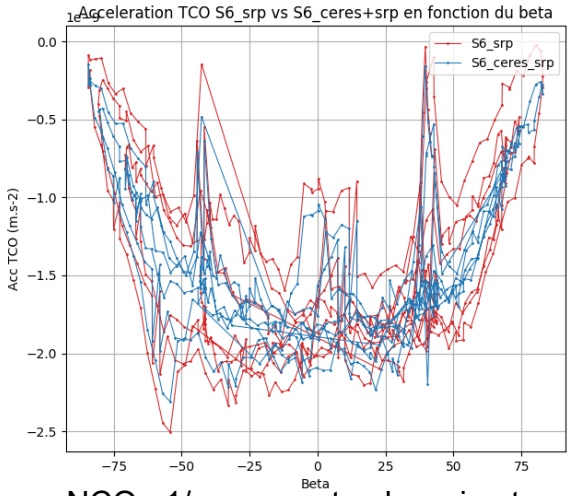
TSI : 1/rev along-track sine term



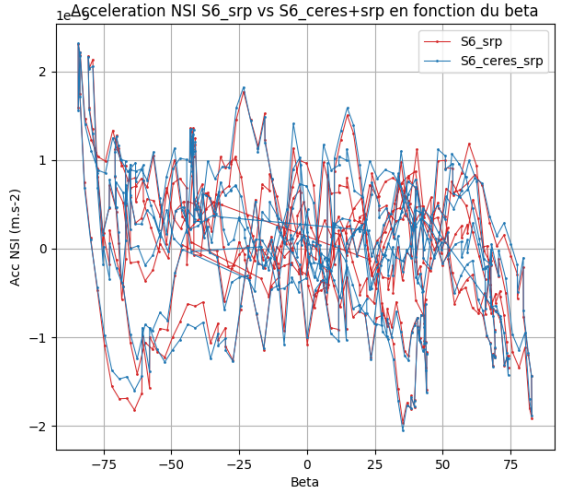
TK : constant along-track term



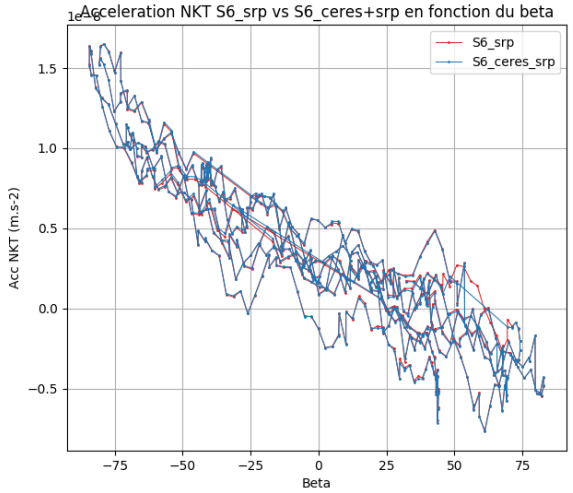
TCO : 1/rev along-track cosine term



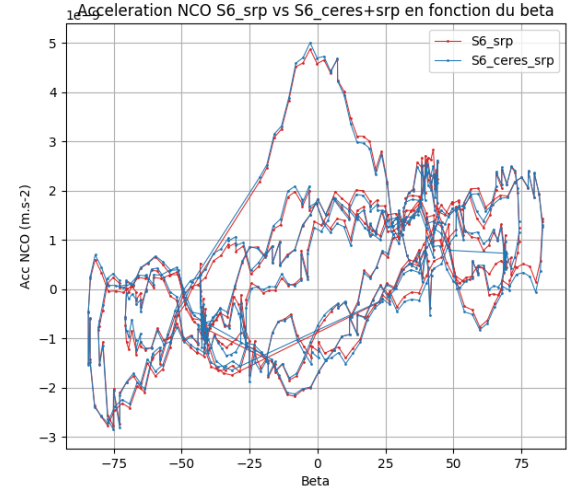
NSI : 1/rev cross-track sine term



NKT : constant cross-track term



NCO : 1/rev cross-track cosine term



→ Adding both updated models has no effect on most accelerations, except for TSI (updated SRP model alone is more adjusted). Also for TCO, which seems even less scattered with the new ERP model.

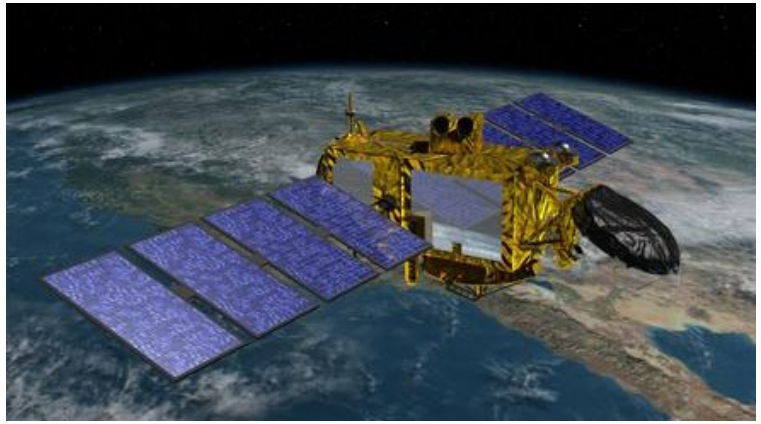
Conclusions on preliminary results

	1/rev along-track sine term	Constant along-track term	1/rev along-track cosine term	1/rev cross-track sine term	Constant cross-track term	1/rev cross-track cosine term
Jason-3 initial SRP model	=	=	=	+	Acceleration biases for Jason-3 and Sentinel-6 MF : modeling problem of the geocenter in the Z direction (*)	+
Sentinel-6 MF initial SRP model	=	+	=	-		+
Sentinel-6 MF updated SRP model	=	=	=	+		=
Jason-3 initial SRP model + updated ERP model	-	=	+	=		=
Sentinel-6 MF initial SRP model + updated ERP model	+	=	+	=		=
Sentinel-6 MF updated SRP and ERP models	+	=	+	=		=

+ : configuration improving the accelerations
- : configuration degrading the accelerations
= : has no effect whatsoever

** will be eliminated with the new POE-G standard and the ITRF 2020 geocenter model*

What's next ?



- *Correcting the along-track sine acceleration (TSI)* : we want first to readjust the direct solar radiation pressure coefficient (CR) on Jason-3 and Sentinel-6 MF (with the updated SRP), using the updated ERP model for terrestrial radiation on both satellites. As mentioned previously, for this acceleration, the new ERP model will also correct the SRP modeling errors for Jason-3.
- *Correcting the constant cross-track acceleration* : we want to try to adjust the diffuse and specular coefficients of the solar panels.
- *Correcting the constant along-track acceleration, only on Jason-3* : we will calibrate Xsat and Ysat accelerations during Yaw Steering periods to compensate for the thermal effects of radiators.

BACK-UP SLIDE

Detailed explications on preliminary results

For each accelerations, the differents models tested had various effects :

- TSI : the updated ERP model tend to degrade the acceleration for Jason-3, but has the reverse effect on Sentinel-6 MF. Combining both ERP and SRP updated models improves the TSI acceleration.
- TK : slight improvement in scattering with the intial SRP model for Sentinel-6 MF. One can visualize the period when it flew backwards. For Jason-3, a strange jump between positive and negative data is observed at β=0 (thermal effect of the radiators ?).
- TCO : less scattered with the new ERP model, more noticeable effect with Jason-3.
- NSI : better with Jason-3 and more stable with the updated SRP model for Sentinel-6 MF.
- NKT : bias on Jason-3 and Sentinel-6 MF accelerations, but it comes from a modeling problem of the geocenter in the Z direction (will be eliminated with the new POE-G standard and the ITRF 2020 geocenter model).
- NCO : negligible effect of the two updated models.