SOLAR RADIATION PRESSURE MODEL FOR ALTIMETER SATELLITES

ANALYSIS OF SARAL SURFACE ACCELERATIONS

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IDS Workshop,
Constance, Germany

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- INTRODUCTION
- JASON 2 RESULTS
- SARAL ANALYSIS
  - OUT-OF-PLANE BEHAVIOUR
  - IN-PLANE BEHAVIOUR
- CONCLUSION

INTRODUCTION (1)

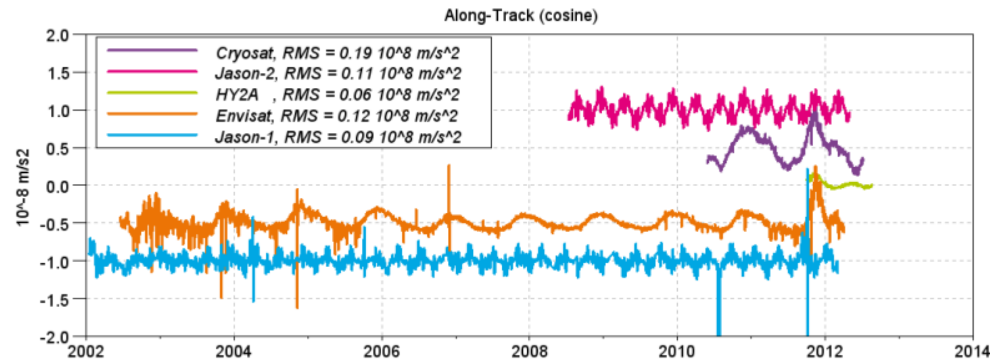
Solar Radiation Pressure (SRP) :

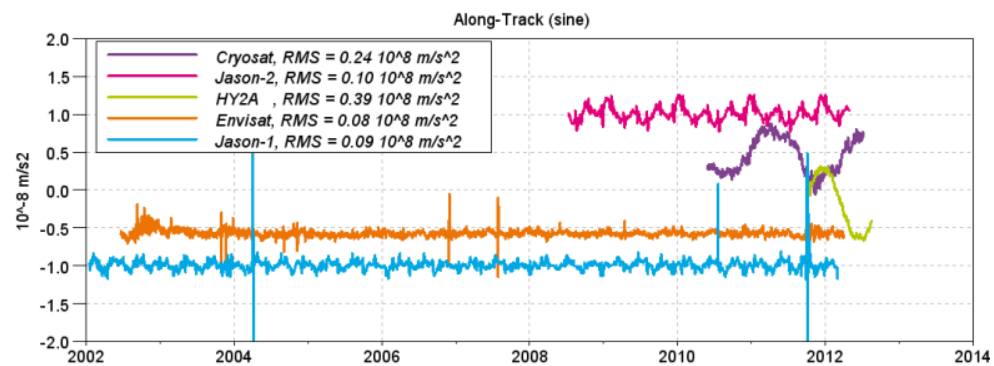
Usual approach :

- Pre-launch model : constructed using thermo-optical description of the satellite (absorptivity K_a, specular refraction K_s and diffuse refraction K_d) and thermal control
- Calibration by applying a global SRP coefficient identified during commissioning
- 1/rev empirical accelerations in T (along-track) and N (cross-track) direction (every 24h)

INTRODUCTION (2)

Empirical along-track accelerations (referenced : PSO=90°)





Objective :

- β-dependent patterns are observed[1] : probably due to SRP mismodelling
- Improve SRP model

[1] “A review of some systematic errors observed in the Precision Orbit Determination of recent DORIS satellites”, Cerri & al. IDS Workshop 2012.

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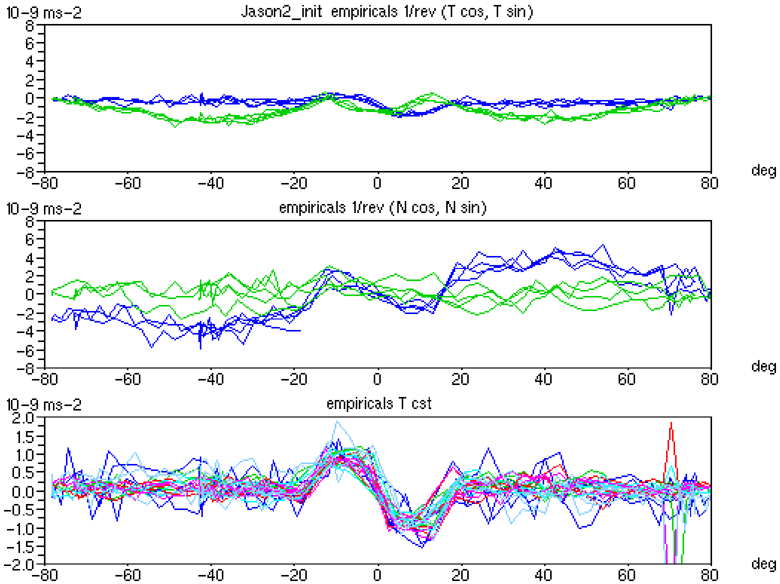
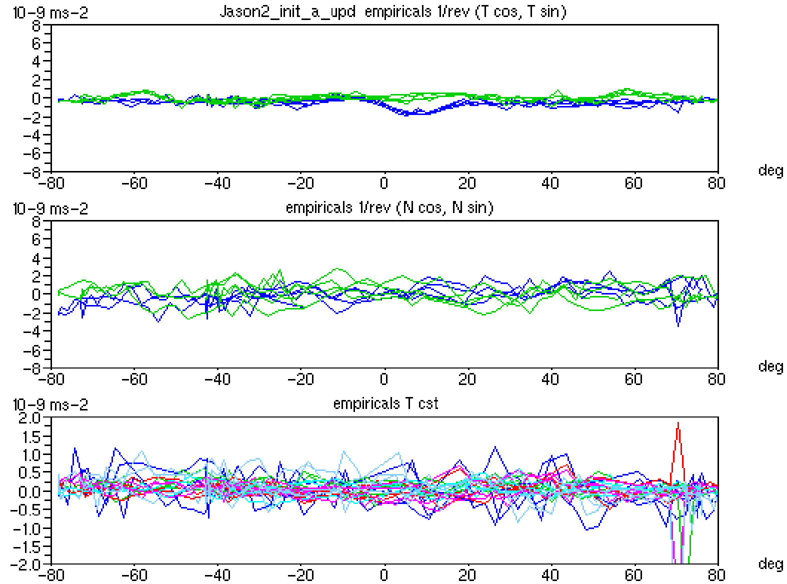
JASON 2 FINAL UPDATE

Empirical acceleration (reference : sub-solar point)





Jason 2 initial model, complete
with initial solar array model

Jason 2 updated model
with new solar array values

Courtesy of Flavien Mercier, see OSTST presentation on Wednesday (29/10/14)

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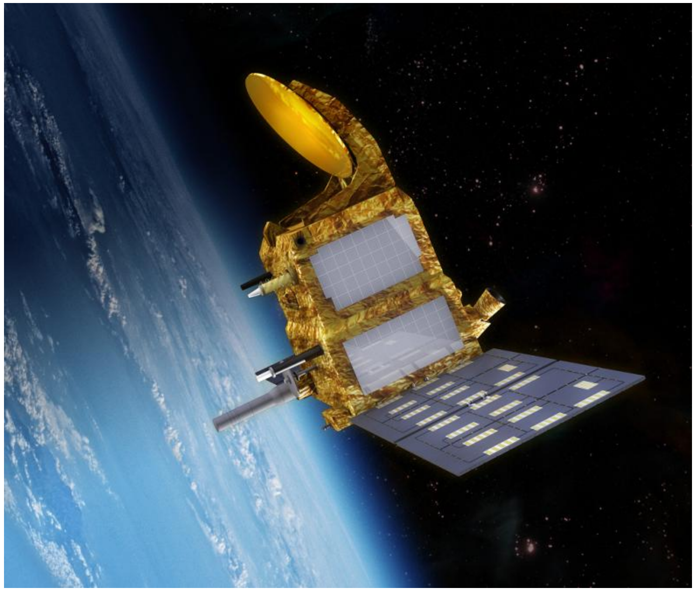
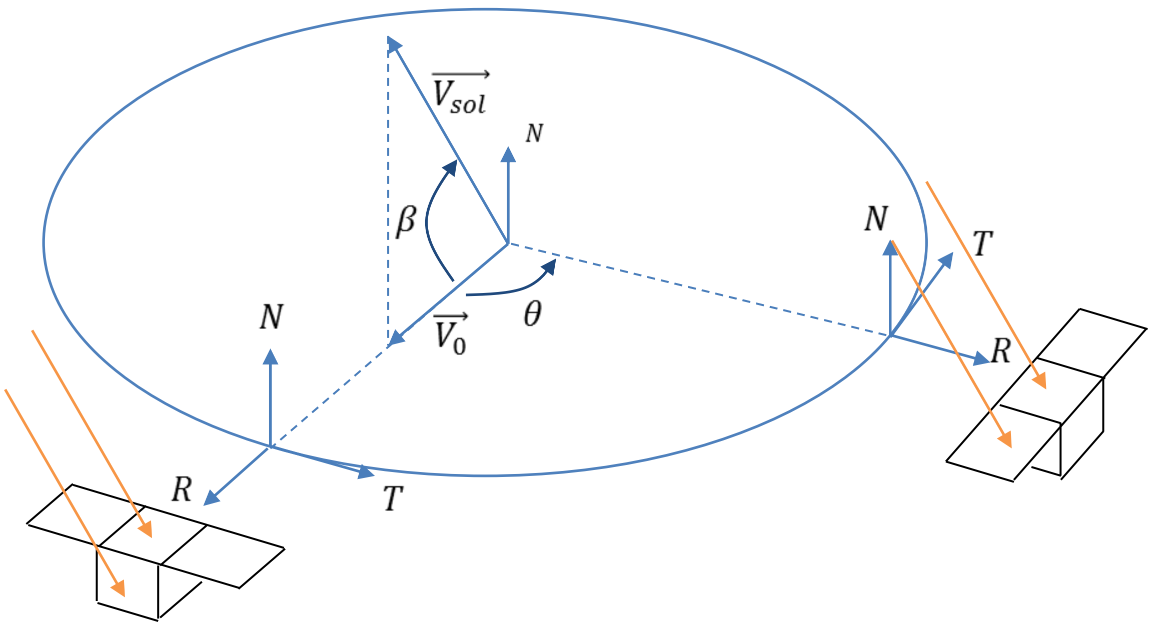
DEFINITION (1)

SARAL/AltiKa : Heliosynchronous orbit (i=98,55°)



Definition of β



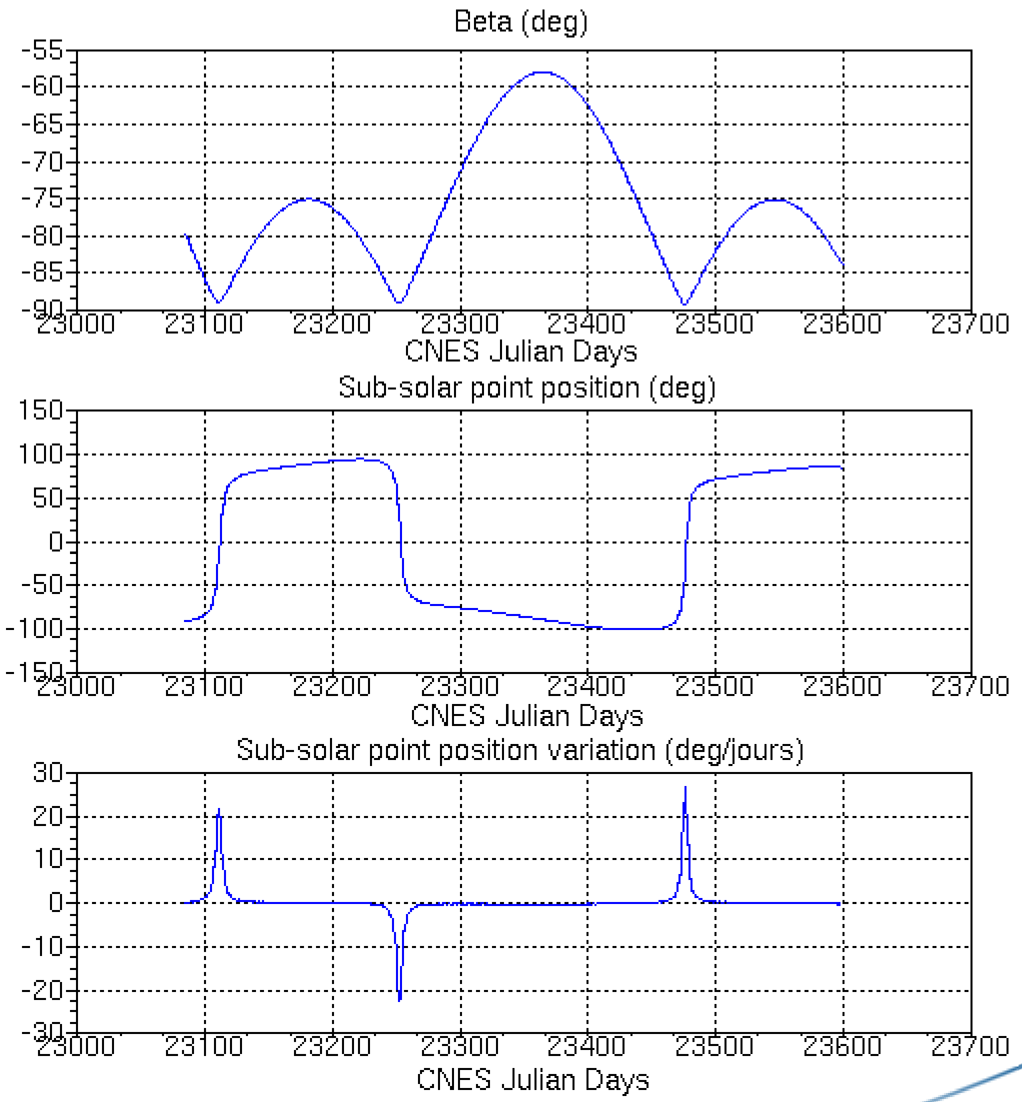
Sub-solar point

DEFINITION (2)
EVOLUTION OF THE SUB-SOLAR POINT POSITION

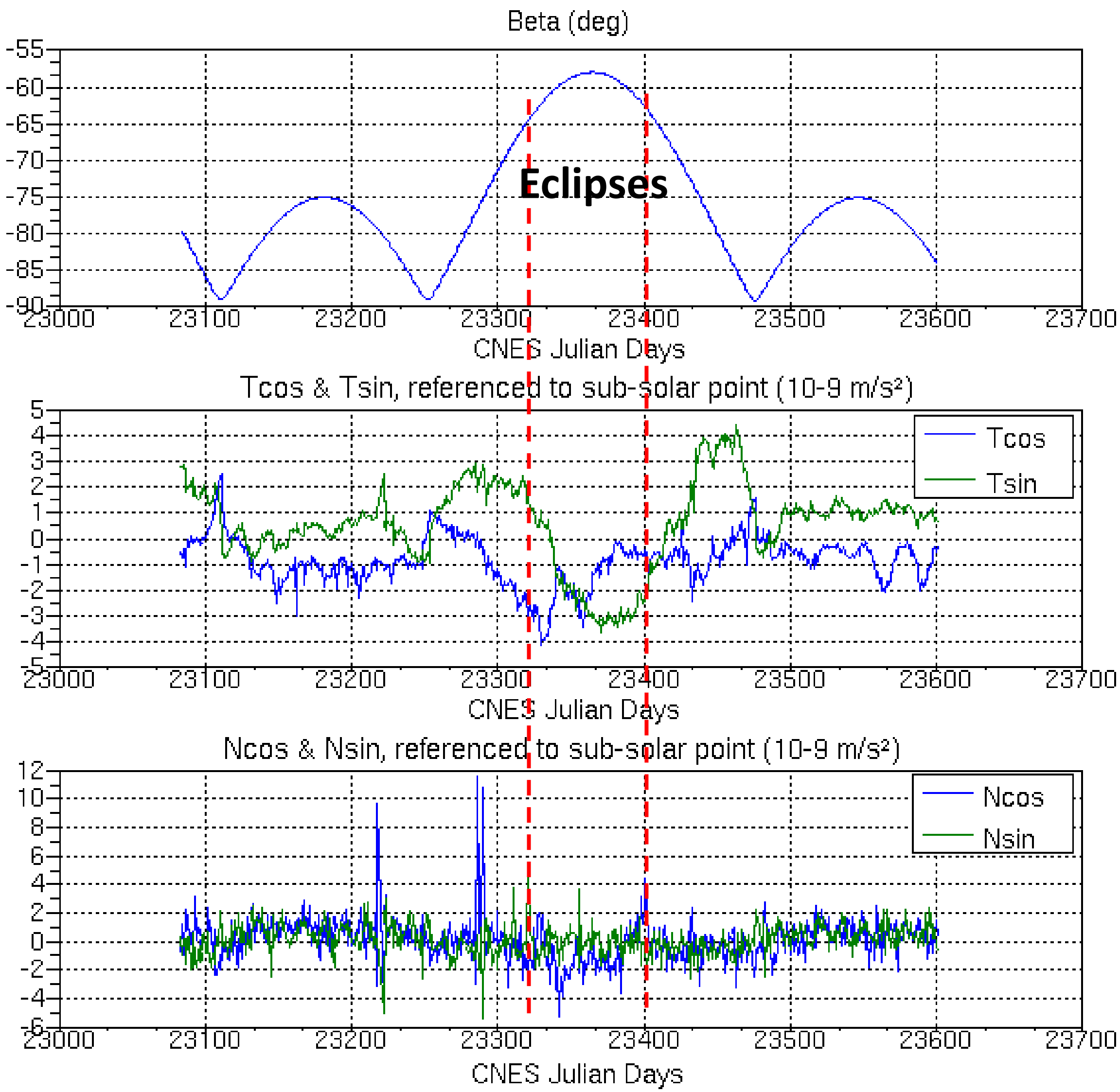
Evolution of the sub-solar point

- Steady behaviour for most values of β

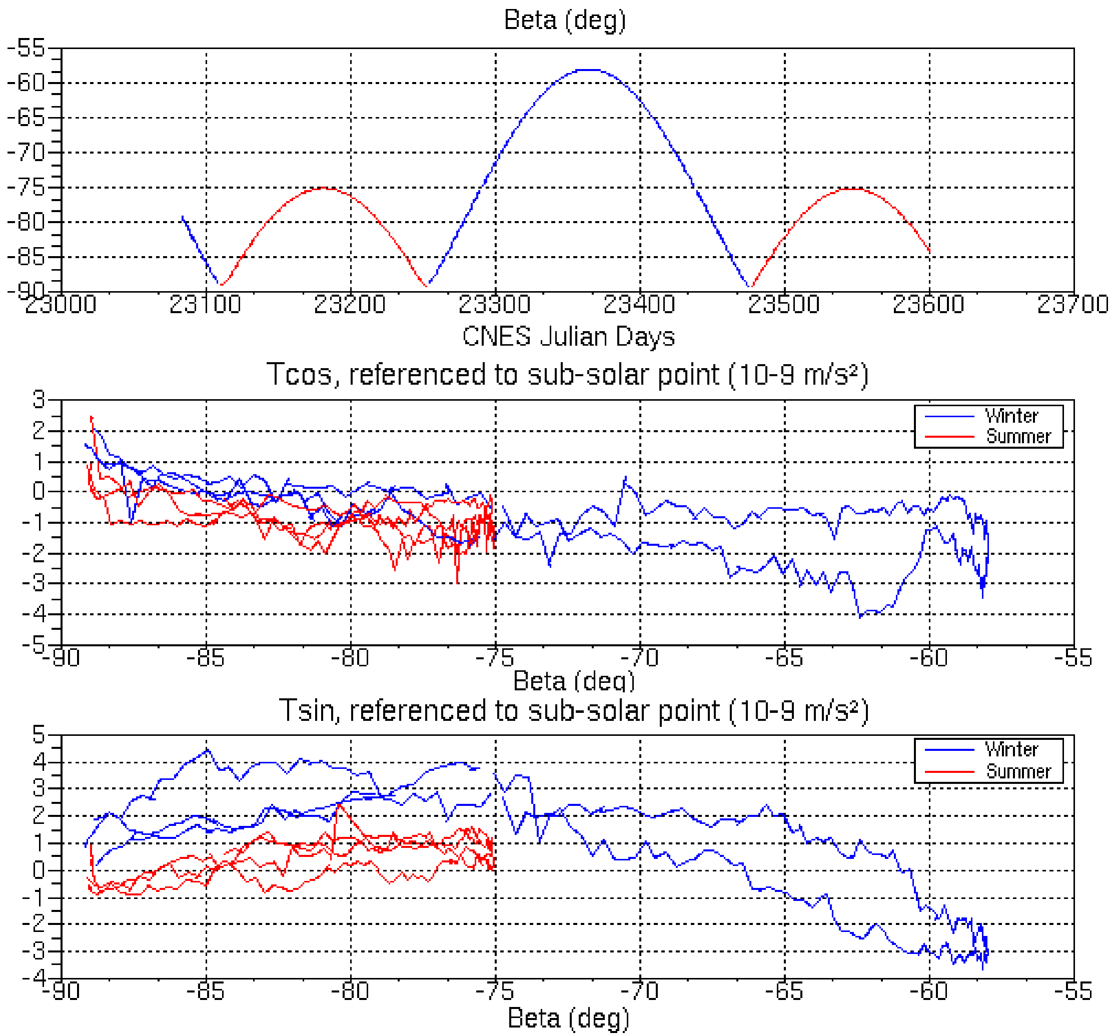
- Singularity when β close to 90°, larger values for sub-solar point variations
- But OK ← no θ dependancy for RTN frame



INITIAL RESULTS (1)
EMPIRICAL 1/REV ACCELERATION ANALYSIS



INITIAL RESULTS (2)
β - DEPENDANCY OF ALONG-TRACK EMPIRICAL ACCELERATION



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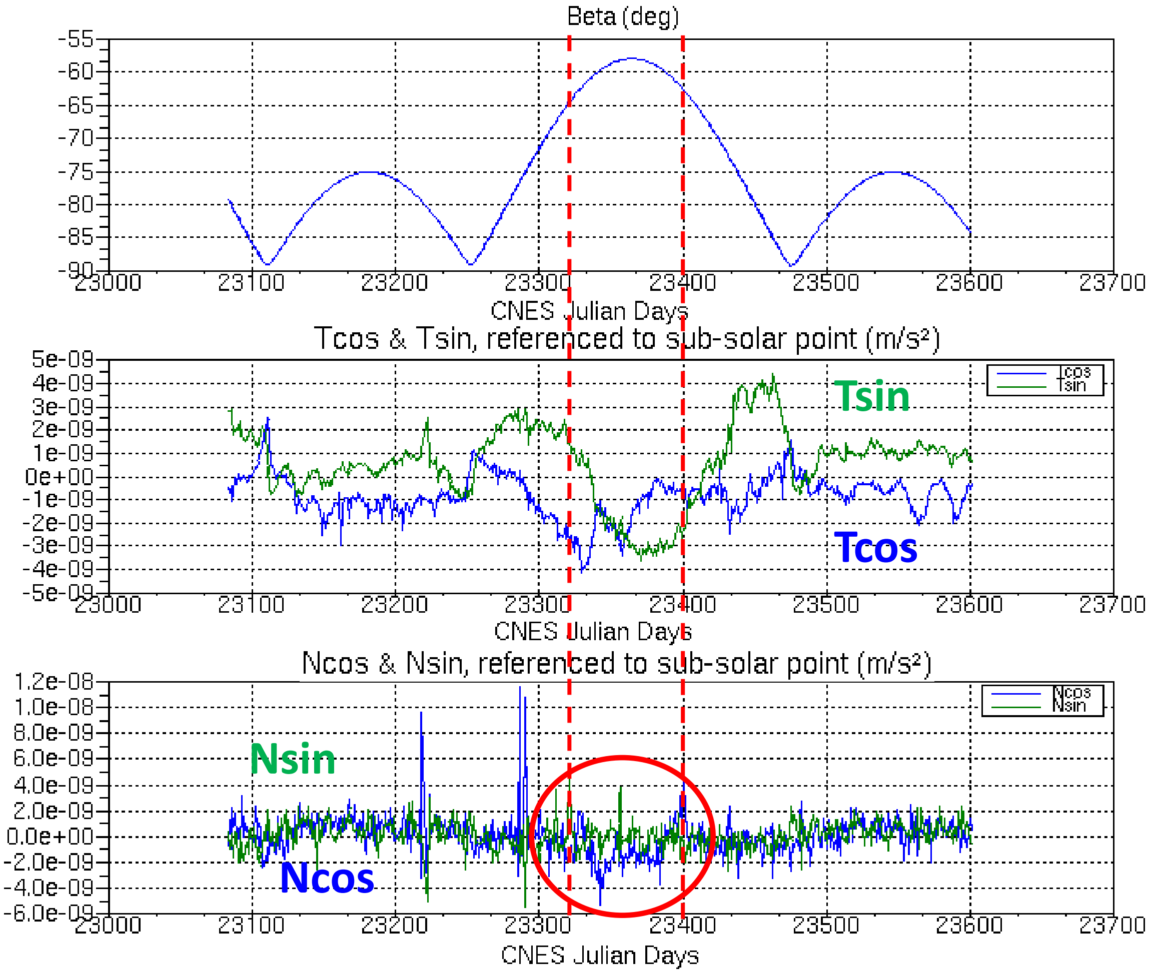
OUT-OF-PLAN BEHAVIOUR (1)
NORMAL BIAIS

Normal bias :

A normal bias of 5 cm has been observed (equivalent magnitude : 5.10^{-8} m/s² *)
May be due to CoM misalignment or SRP mismodelling
Corresponds to half of the cross-track SRP acceleration

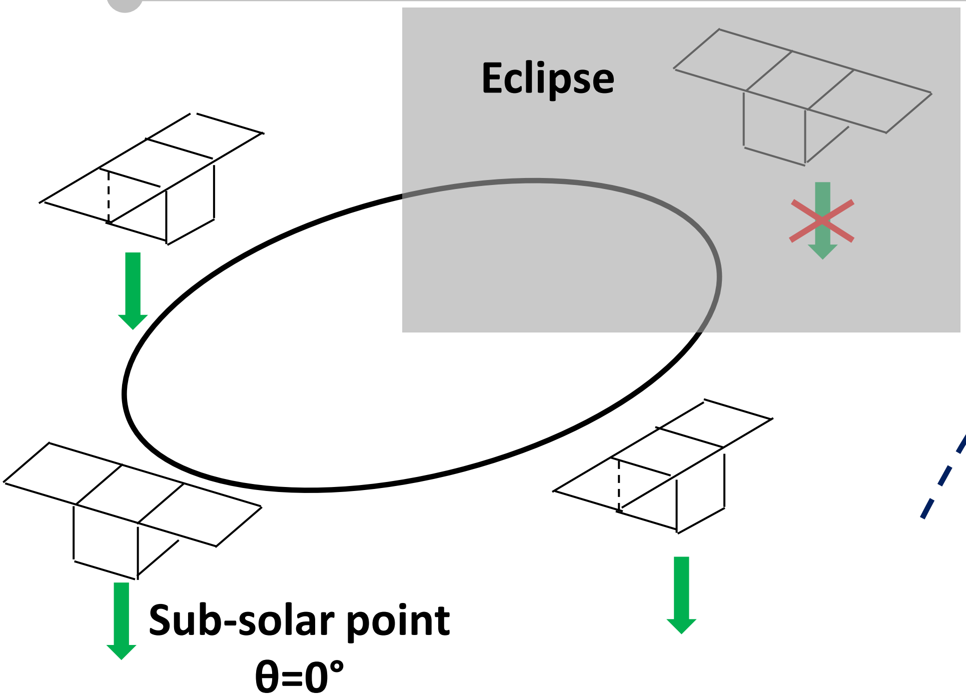
* « *Status of GDR orbites for ocean topography missions and prospects for future improvements* » (Cerri & al., OSTST 2013)

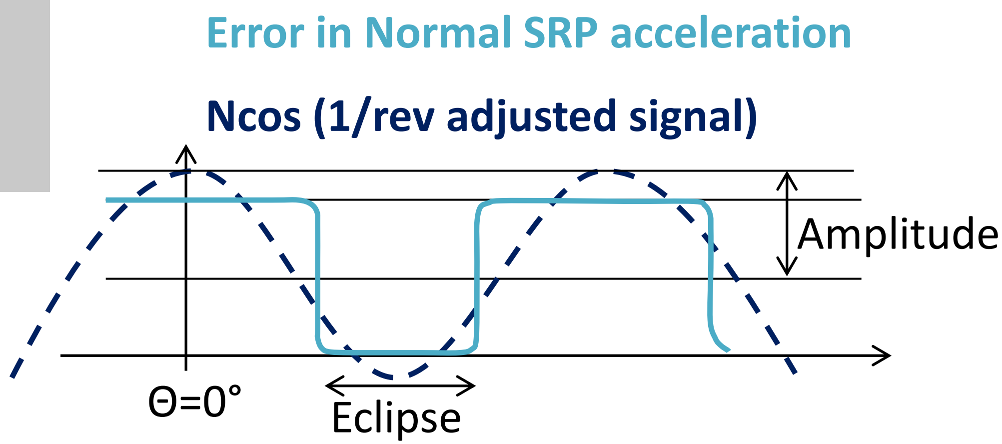
OUT-OF-PLAN BEHAVIOUR (2)
EMPIRICAL 1/REV ACCELERATION ANALYSIS



Eclipse Periode

OUT-OF-PLAN BEHAVIOUR (3)
NORMAL BIAIS





Estimation of bias

- Estimation of the bias that causes 2.10^{-9} m/s² acceleration

$$Bias \cong amplitude/0.6 / omega^2 = 2.10^{-9}/0.6/10^{-6} = 3.2\,\text{mm}$$

- Error due to SRP mismodelling can be up to 4 mm maximum :
  → observed bias comes from CoM mismodelling, not SRP mismodelling

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IN-PLANE BEHAVIOUR (1)
THEORETICAL SHAPE OF ALONG-TRACK ACCELERATION

Along-track SRP acceleration :

Tsin

- Nominal Tsin is a sinus
- Actual Tsin is mostly made of sinus

Tcos

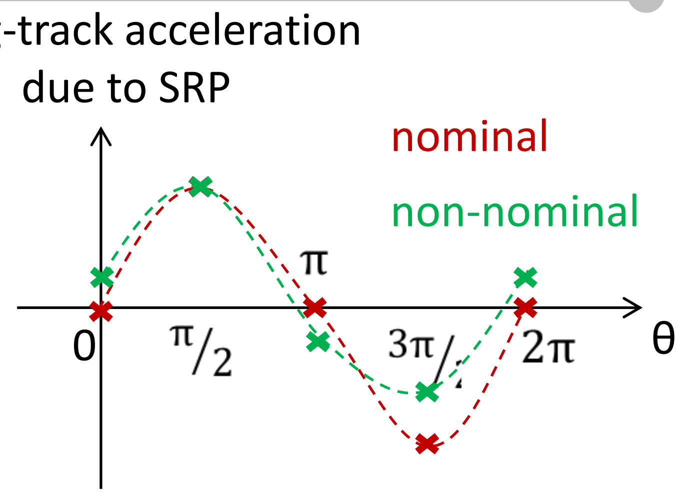
- Nominal Tcos is equal to 0
- Actual Tcos is small

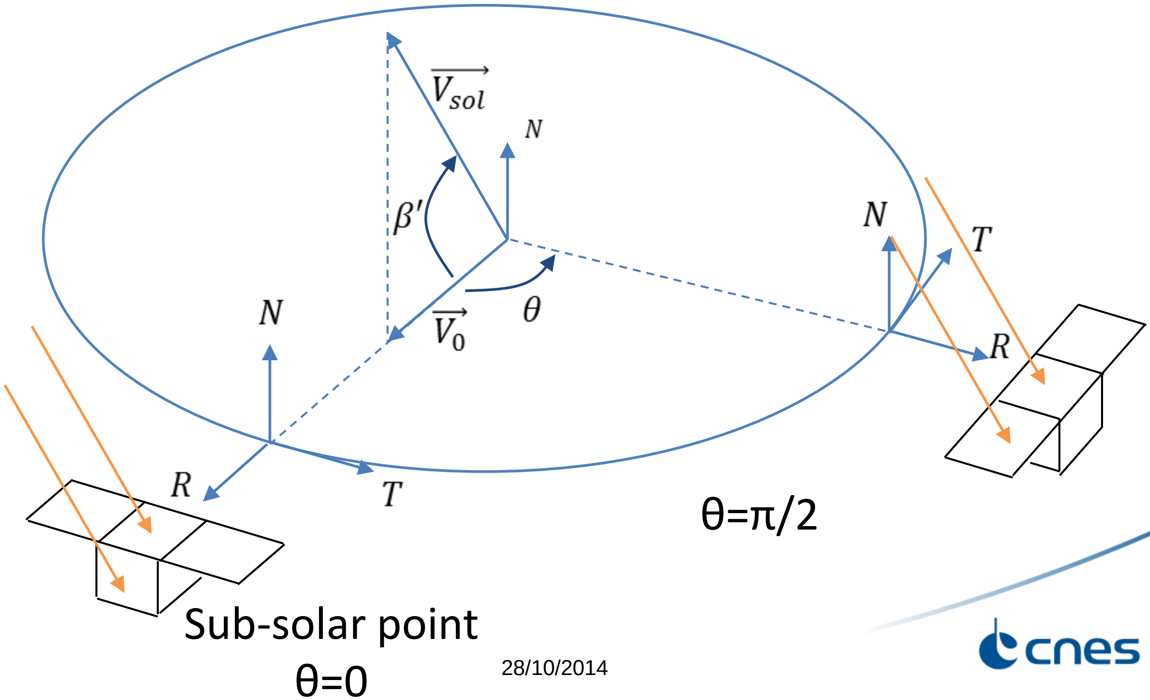
Radial SRP acceleration :

Similarly : mostly made of cosinus,
with a small sinus

Empirical 1/rev along-track acceleration :

- Mostly sinus

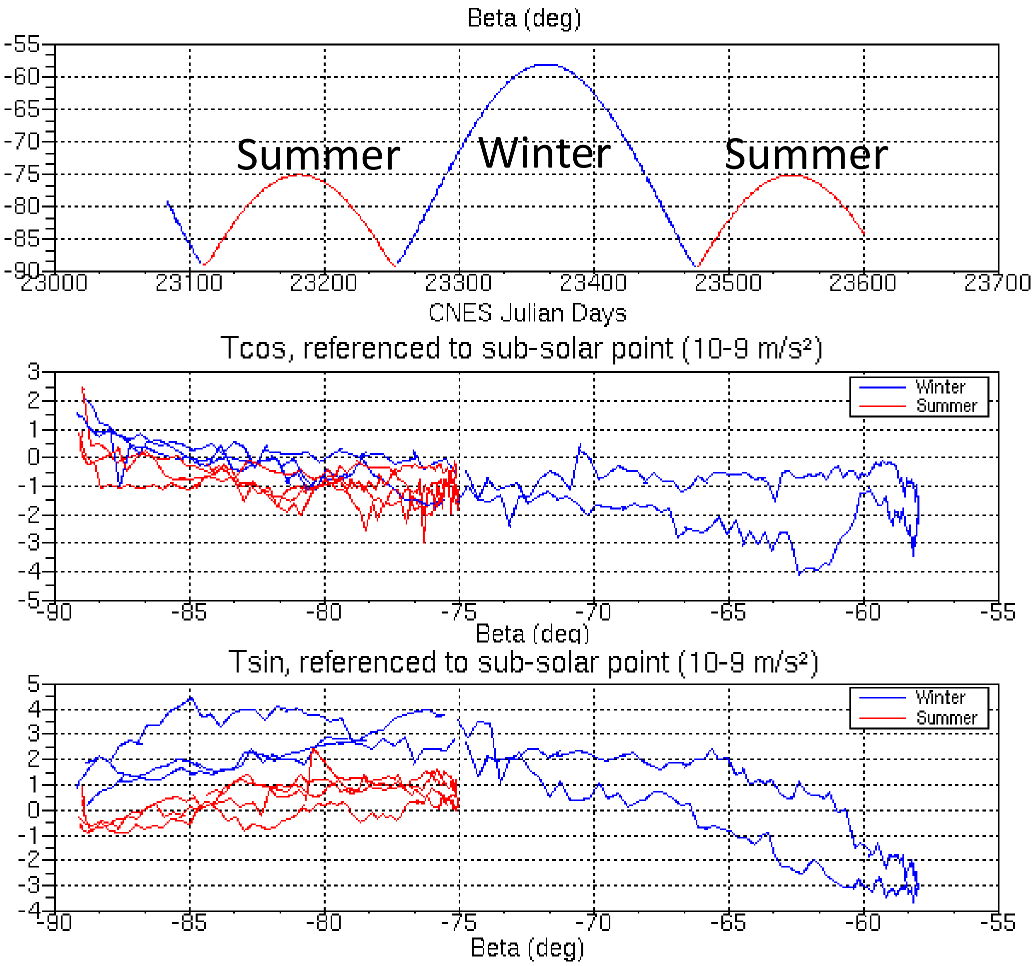




IN-PLANE BEHAVIOUR (2)
β- DEPENDANCY

No systematic behaviour

- Different behaviour in winter and summer



Tcos :

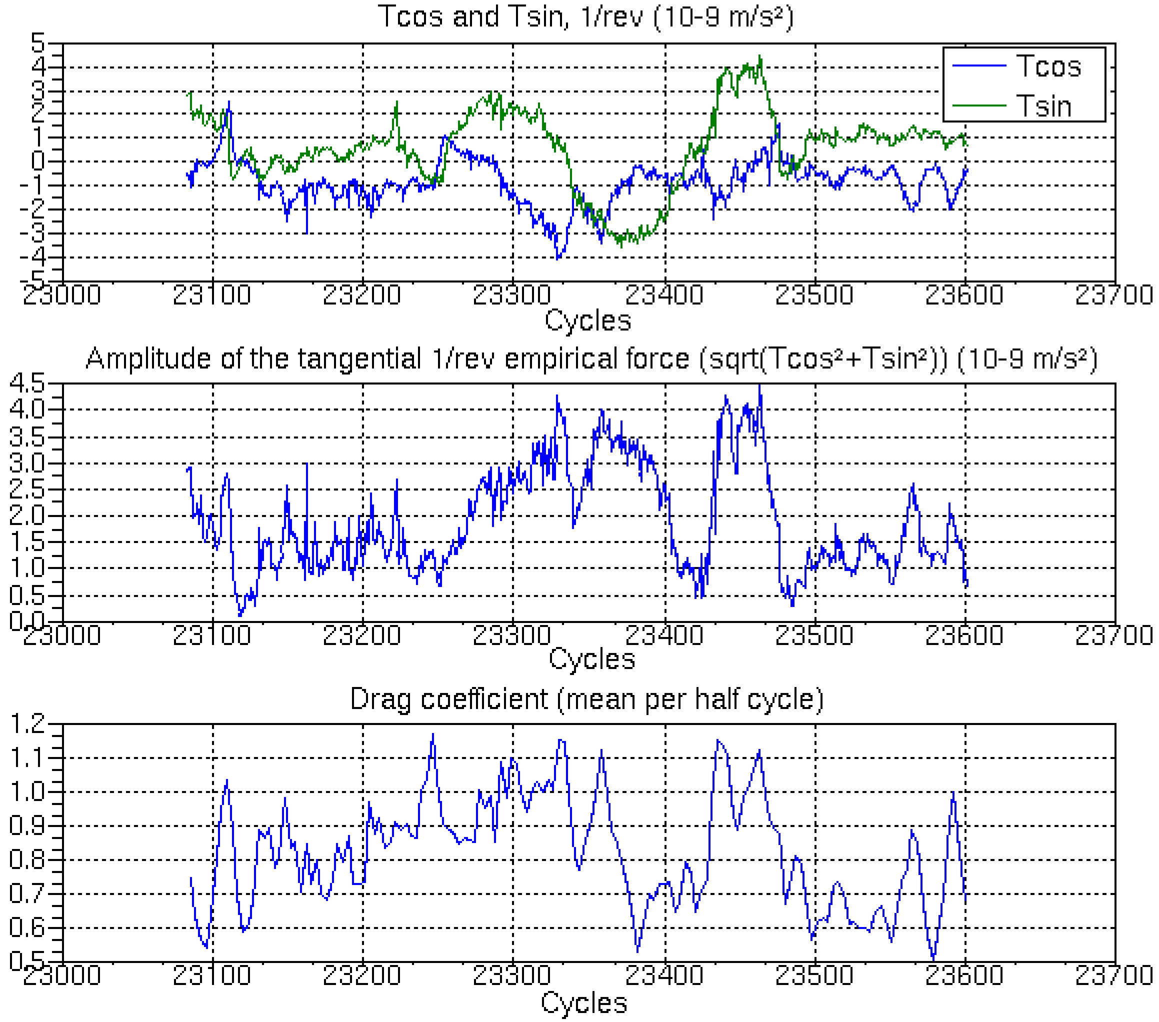
- Should be small due to the symmetry of the satellite attitude

Tsin :

- β<75° : summer and winter curves don't superimpose
- β >75°: lack of data and dispersion

IN-PLANE BEHAVIOUR (3)
INFLUENCE OF THE ATMOSPHERIC DRAG

- Similar signatures on drag values and empirical along-track amplitude
- Atmospheric drag may contribute to T empirical 1/rev acceleration
- Other effect? (attitude)



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CONCLUSION

JASON 1 and JASON 2

→ See OSTST presentation on Wednesday, 12:00

SARAL CROSS-TRACK BEHAVIOUR

- Observed cross-track bias cannot come from SRP model
- Cross-track current SRP model OK

SARAL IN-PLANE BEHAVIOUR

- Summer and winter behaviour inconsistent
- Model ok during summer (precision 10-9)
- During winter : important discrepancies in acceleration for the same beta value (high dispersion) and only one set of data

The current SRP model is satisfactory for GDR products

Possible improvement using more β cycles to mitigate drag effect

Thank you for your attention

Any questions?

Back-up slides

BACK UP SLIDES (1)
COMPUTATION OF THE OPTICAL COEFFICIENTS

- Computation of the optical coefficients from the material property and the amount of each material on each side of Saral [2]
- New hypothesis : MLI doesn't absorb solar flux. All the incoming flux is reemitted in IR, (diffuse reemission)

smaller values of K_a

Faces (ISRO frame)	Initial values (GDRD)			New values		
	K_s	K_d	K_a	K_s	K_d	K_a
+X	0.4000	0.2450	0.3550	0.3370	0.3810	0.2820
-X	0.5450	0.1690	0.2860	0.4840	0.4890	0.0280
+Y	0.5170	0.1720	0.3040	0.5280	0.4290	0.0430
-Y	0.5200	0.1840	0.3020	0.5400	0.4130	0.0470
+Z	0.2940	0.0760	0.6230	0.2940	0.1750	0.5310
-Z	0.0780	0.0760	0.8370	0.0780	0.1580	0.7640

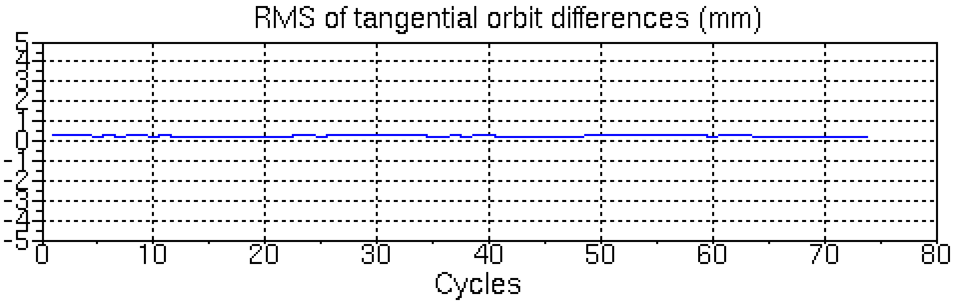
same values of K_s for +Z side

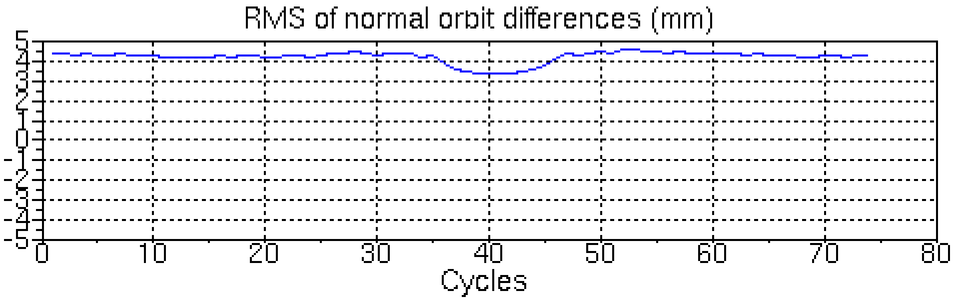
[2] « *Saral characteristics for DORIS calibration plan and POD processing*», Cerri & al

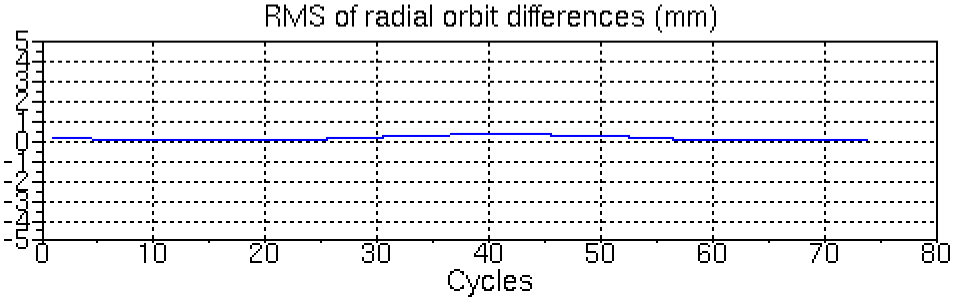
BACK UP SLIDES (2)
RMS OF ORBIT DIFFERENCES

- RMS of orbit differences for the two sets of (K_s, K_d, K_a) parameters

- Very small in-plane orbit differences (absorbed by empiricla 1/rev acceleration)
- Normal bias (not absorbed by parameterization)

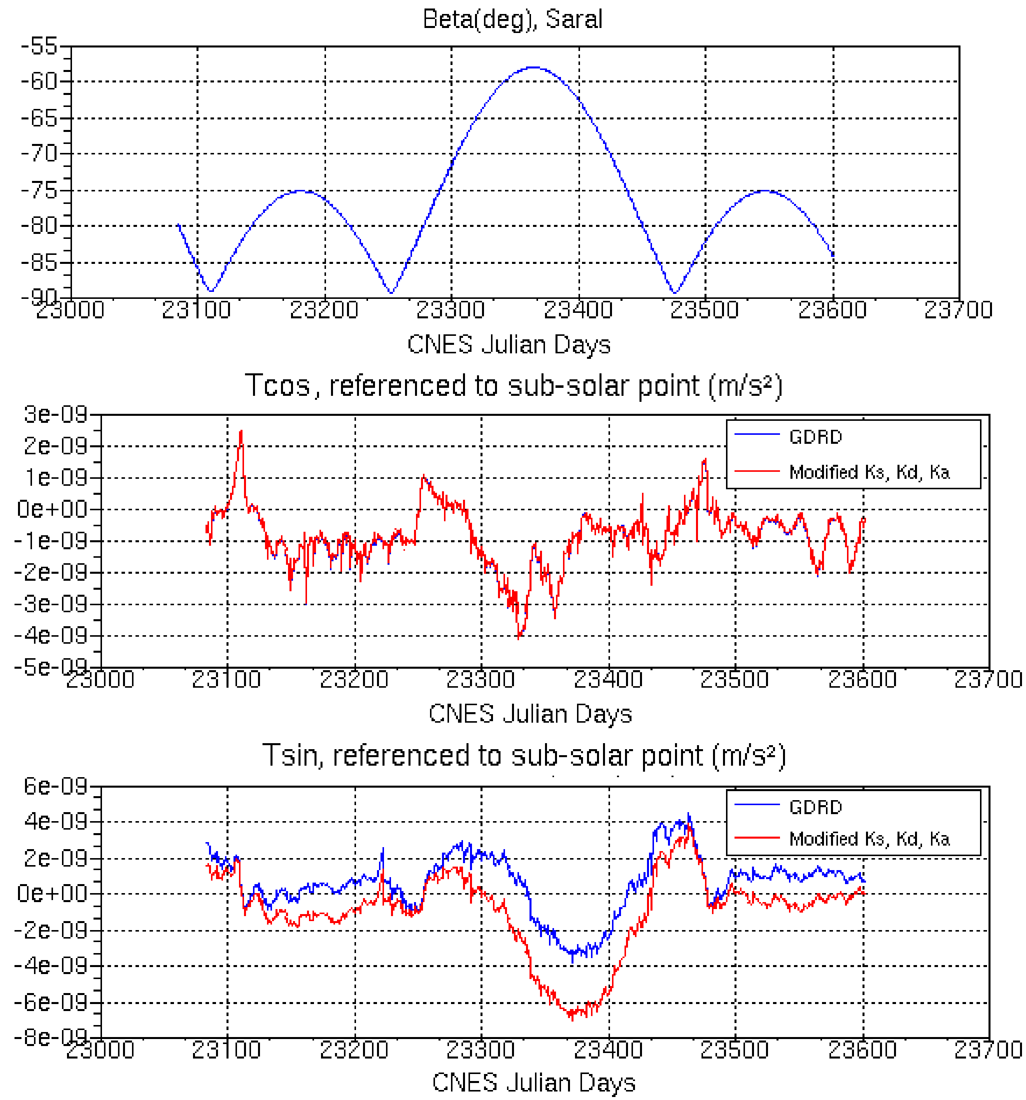






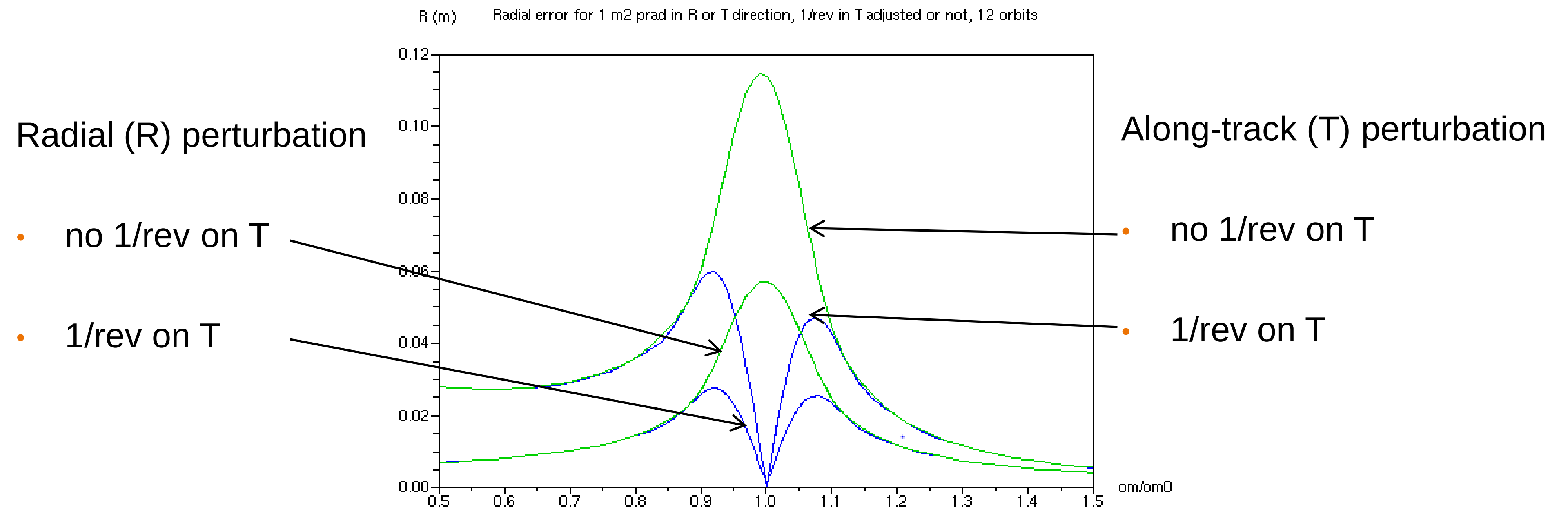
BACK UP SLIDES (3)
1/REV EMPIRICAL COEFFICIENTS

- Tcos
  - K_s, K_d and K_a have no influence on Tcos (because Tcos cannot be SRP)
- Tsin
  - Same values around β=90° (because for β=90°, there are no in-plane SRP accelerations, Tsin and Tcos are then only made of unmodelled forces)
  - Tsin still not a function of β



BACK UP SLIDES (4)
RESPONSE TO A PERTURBATION

Dynamic response to a periodic perturbation



- For frequencies close to the orbital period f_0 : radial error due to the perturbation is very small
- For frequencies far from the orbital period ($0{,}9f_0$ and $1{,}1f_0$) : radial error due to the perturbation is maximum

- SRP force spectrum : close to the orbital period.

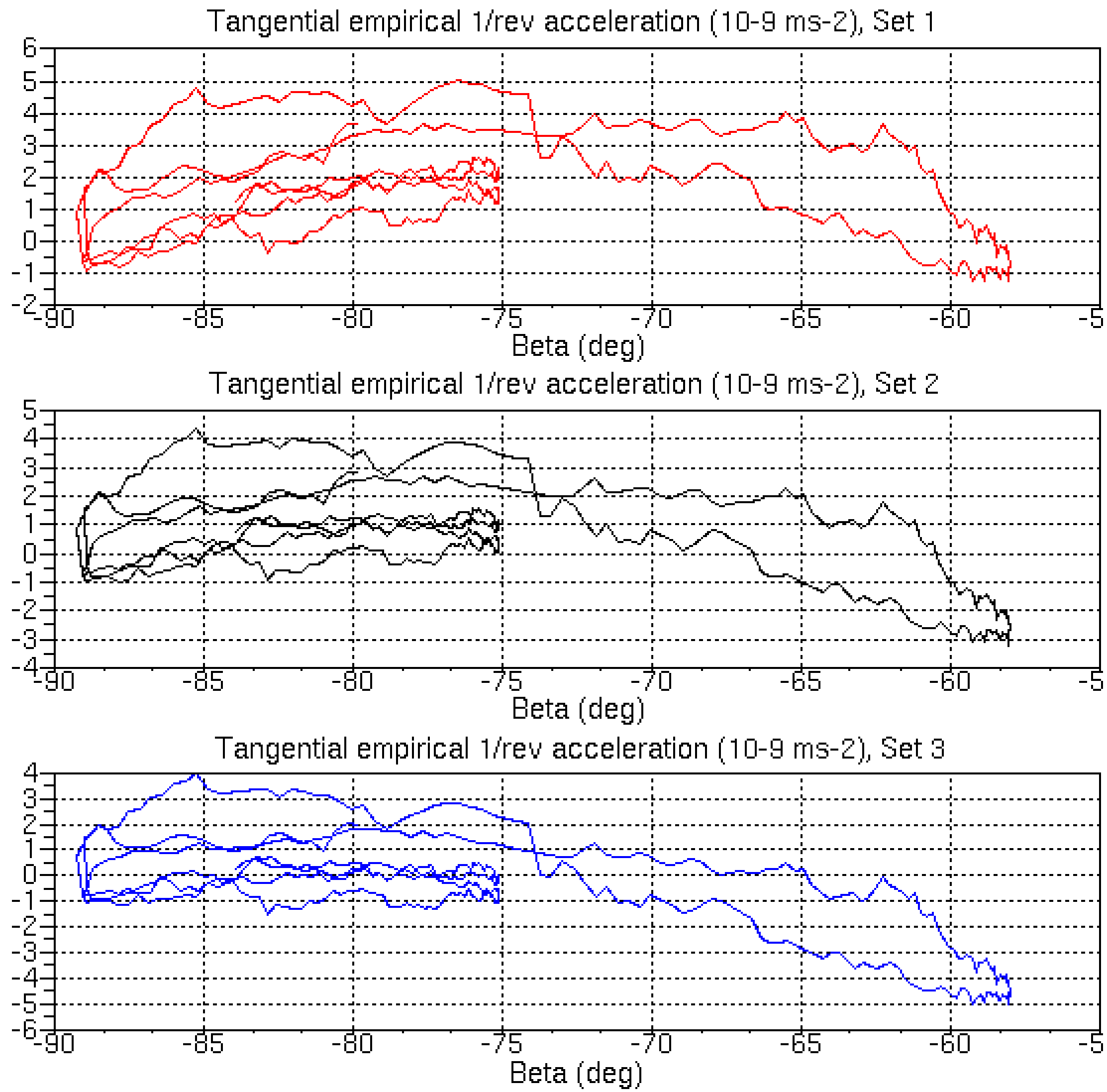
→ That's why the orbit comparison of the two different models has very small RMS in radial and along-track directions.

BACK UP SLIDES (5)
SENSITIVITY ANALYSIS, THERMO-OPTICAL COEFFICIENTS

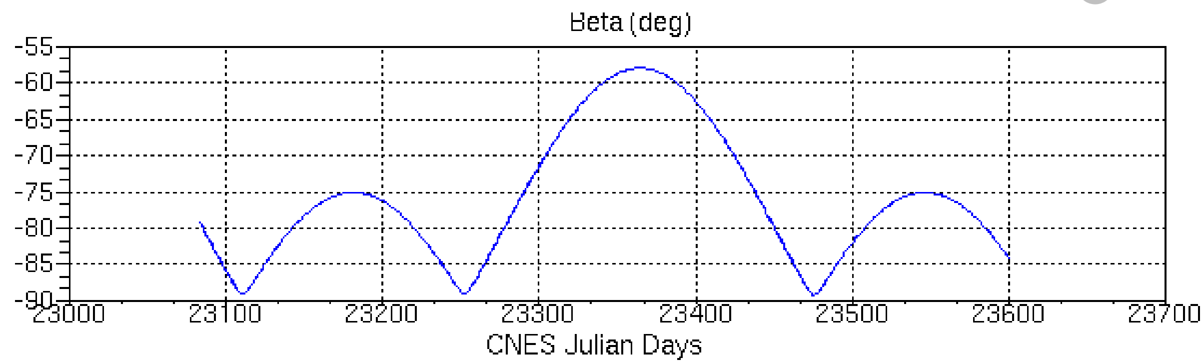
- Different sets of (K_s, K_d, K_a) are considered

- Difference between GDRD coefficients and sets coefficients :

Set	ΔK_s	ΔK_d	ΔK_a
1	0.25	0.0	-0.5
2	0.0	0.0	0.0
3	-0.25	0.0	0.5

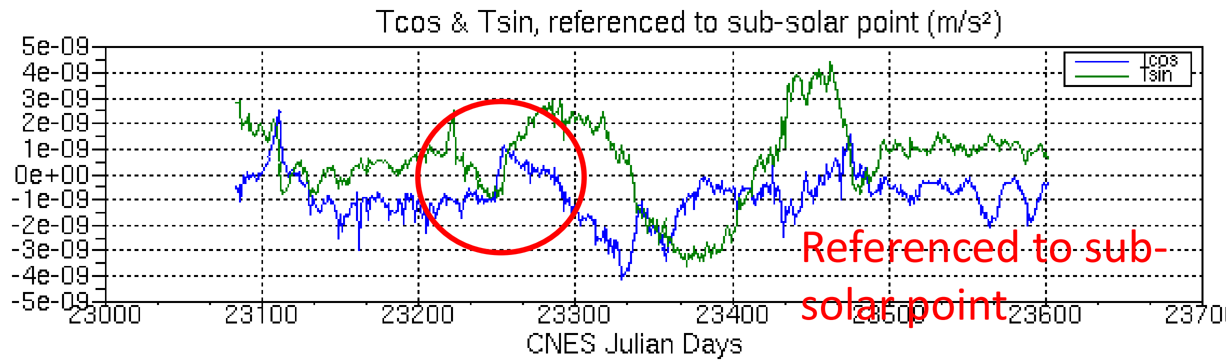


BACK UP SLIDES (6)
ANALYSIS OF 1/REV EMPIRICAL ACCELERATION COEFFICIENTS



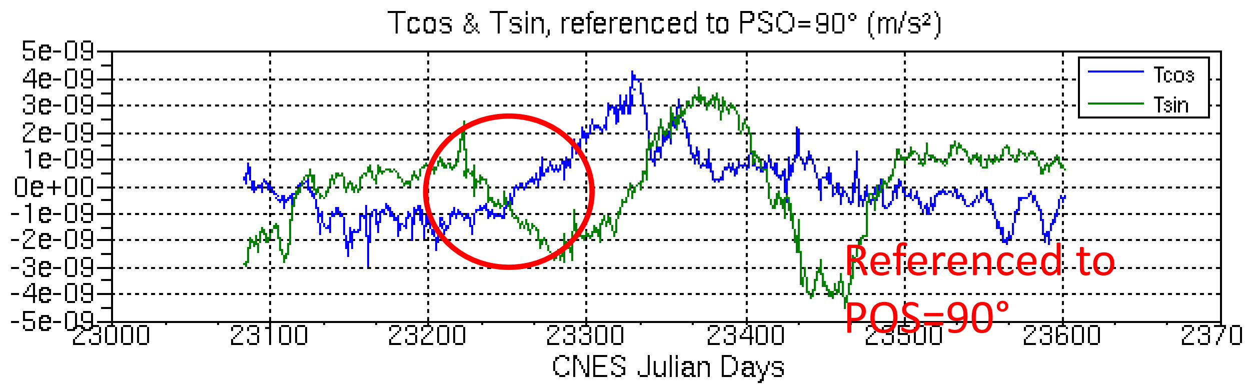
When β close to 90°

- Tsin and Tcos bias : jumps when β close to 90



Tcos

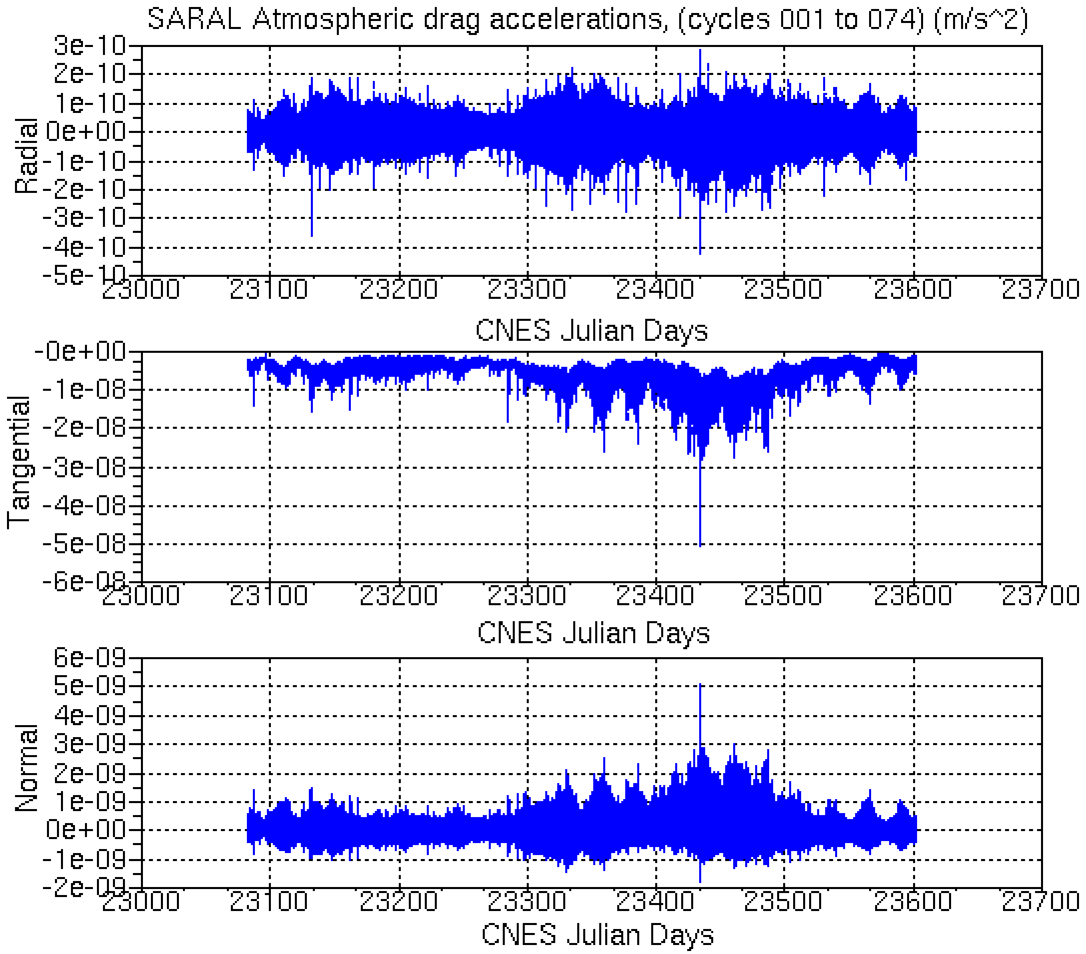
- can't come from nominal SRP : something else is absorbed



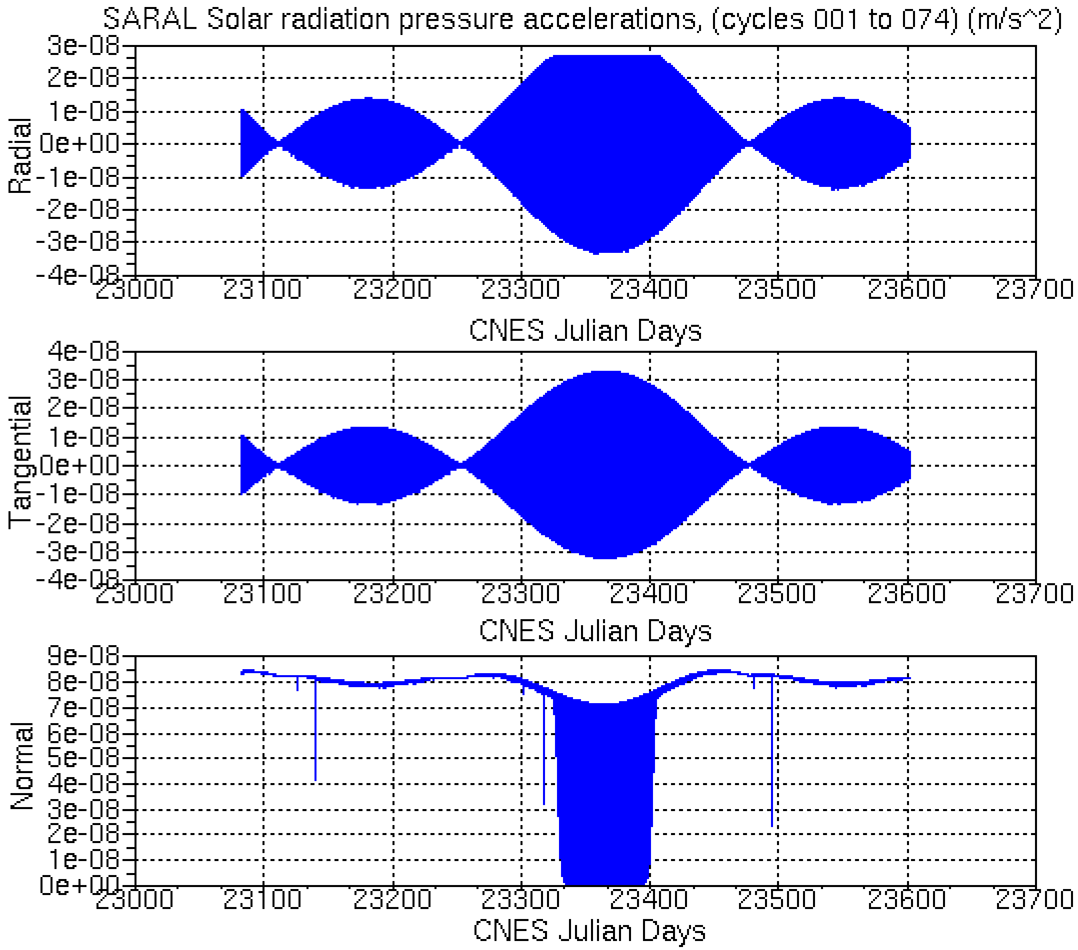
Tsin

- not a function of β

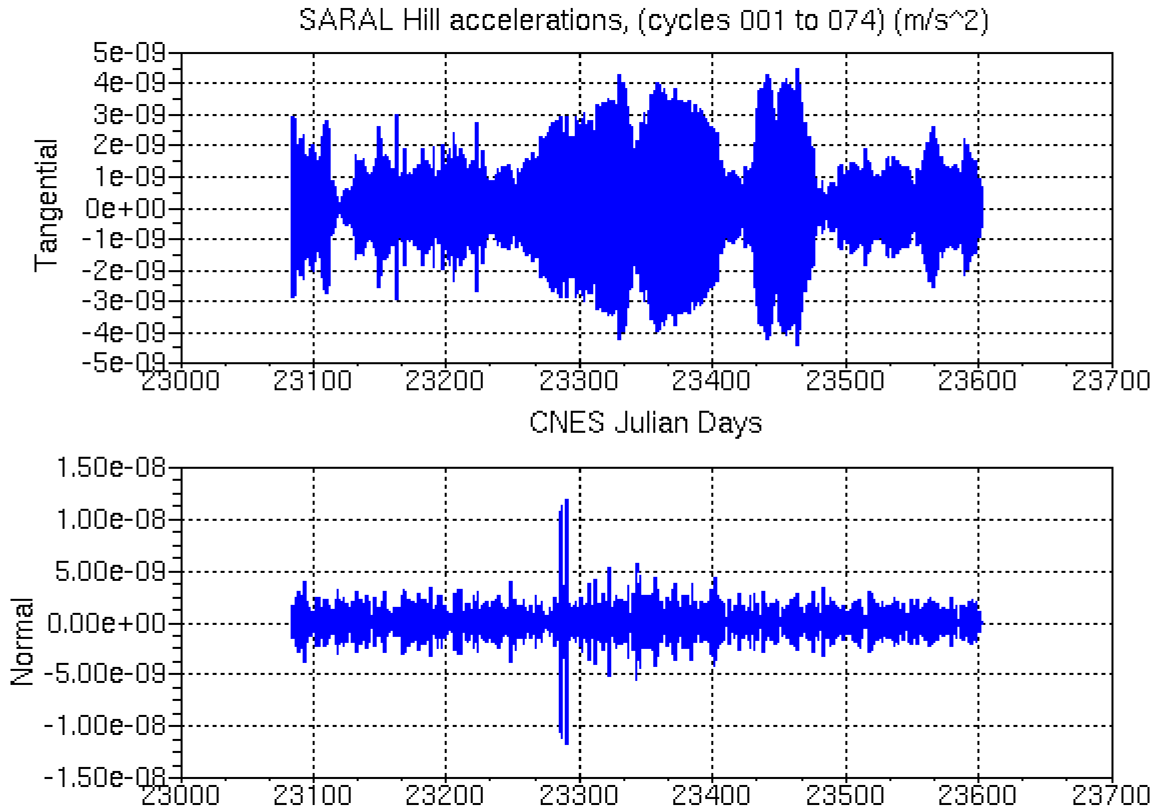
BACK UP SLIDES (7)
ESTIMATED ACCELERATION : DRAG, GDRD ORBITS



BACK UP SLIDES (8)
ESTIMATED ACCELERATION : SRP, GDRD ORBITS



BACK UP SLIDES (10)
ESTIMATED ACCELERATION HILL: DRAG, GDRD ORBITS



BACK UP SLIDES (11)
EVOLUTION OF β