A MODEL FOR DORIS USO IN THE SAA

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INTRODUCTION

- DORIS measurements rely on the precise knowledge of the Ultra Stable Oscillator (DORIS USO)

- The important radiations in the South Atlantic Anomaly (SAA) perturb the USO behavior by causing rapid frequency variations

- If these variations are not modelled : systematic errors

- Goal : a model of the frequency variations due to the SAA
  So far : on Jason3 and Sentinel3a

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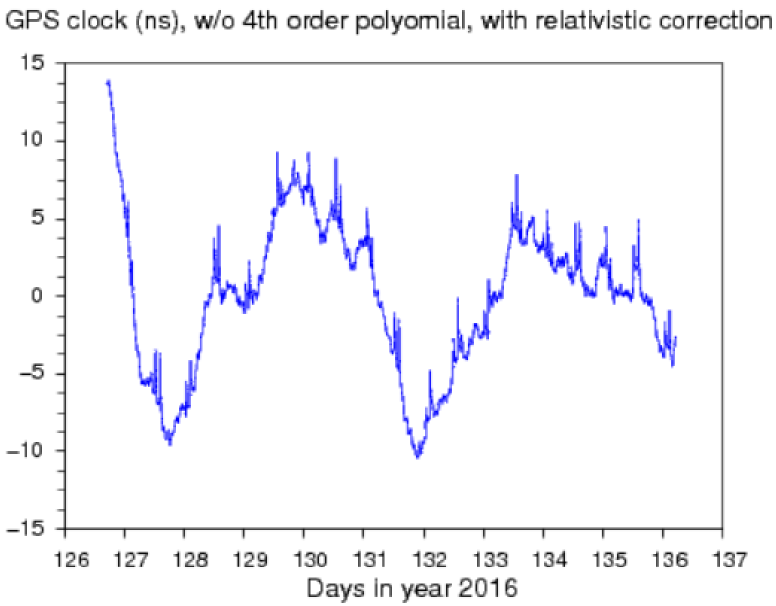
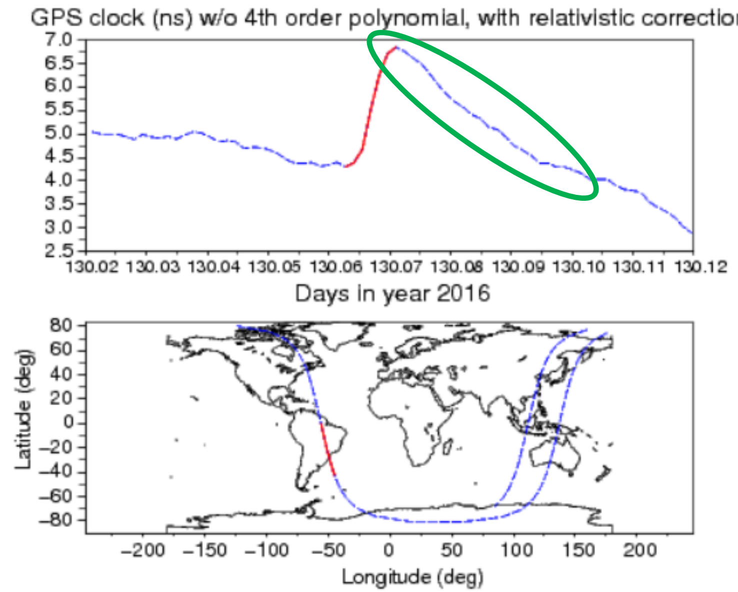
MODELLING : FREQUENCY BEHAVIOUR (1)

- Model based on observations of Sentinel3A USO

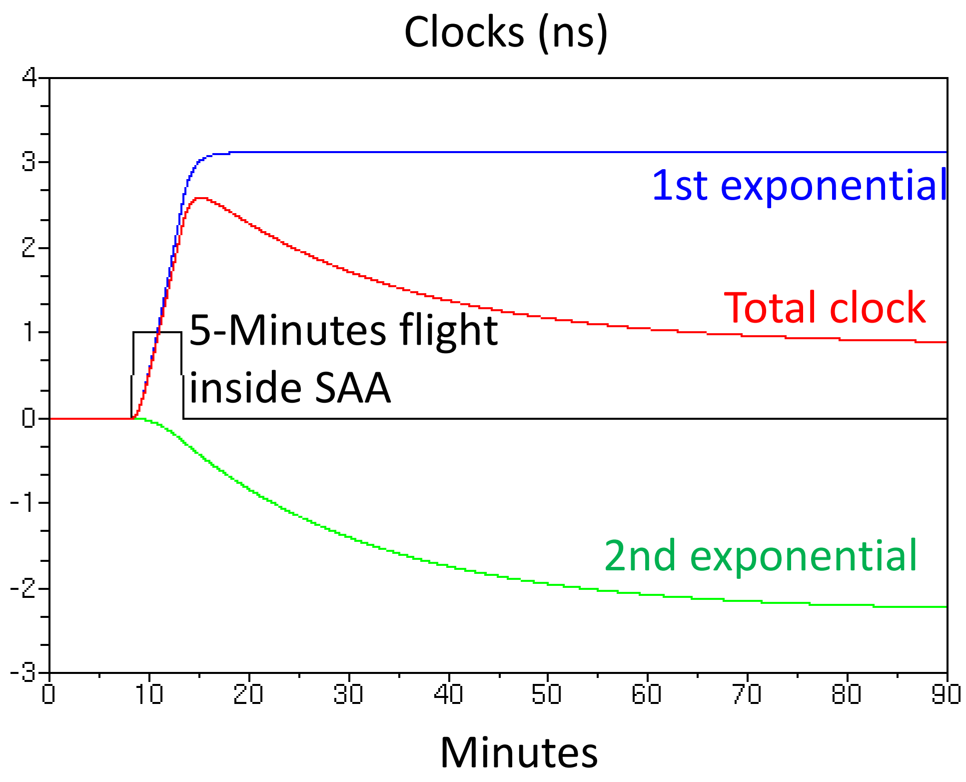




- Two phenomenon :
  - Drift when entering the SAA
  - Relaxation aftern exiting the SAA

MODELLING : FREQUENCY BEHAVIOUR (2)

- In order to reproduce the behaviour observed on Sentinel3A USO, two exponentials are added :
  - One describing the drift when the satellite enters the SAA
  - One describing the relaxation of the USO



MODELLING : FREQUENCY BEHAVIOUR (3)

- Model : USO frequency f is the sum of two exponentials

$$df_1 = -\alpha_1 f_1 + \beta_1 a(t)$$
$$df_2 = -\alpha_2 f_2 + \beta_2 a(t)$$

With :

- $\alpha_i = {}^1/_{\tau_i}$: inverse of the time constant of the exponentials
- a(t) : the radiation exposure due to the SAA at time t
- β_i : gain linked to the exposure

MODELLING : PARAMETERS (1)

- α_i : cannot be estimated
  depends on the USO device

- Sentinel3a : the USO behaviour is known, and so are the time constants. (see « Analysis of South Atlantic Anomaly perturbations on Sentinel-3A Ultra Stable Oscillator. Impact on DORIS phase measurement and DORIS station positioning. » Jalabert and Mercier)
  - $\alpha_1 = 1$ minute
  - $\alpha_2 = 20$ minutes

- Jason3 : the hypothesis is that the time constants are similar to those of Jason1. The values are read on the plot of the article « A corrective model for Jason-1 DORIS Doppler data in relation to the South Atlantic Anomaly », JM Lemoine and H. Capdeville
  - $\alpha_1 = 1$ minute
  - $\alpha_2 = 90$ minutes

MODELLING : PARAMETERS (2)

- β_i : estimated during the orbit determination process

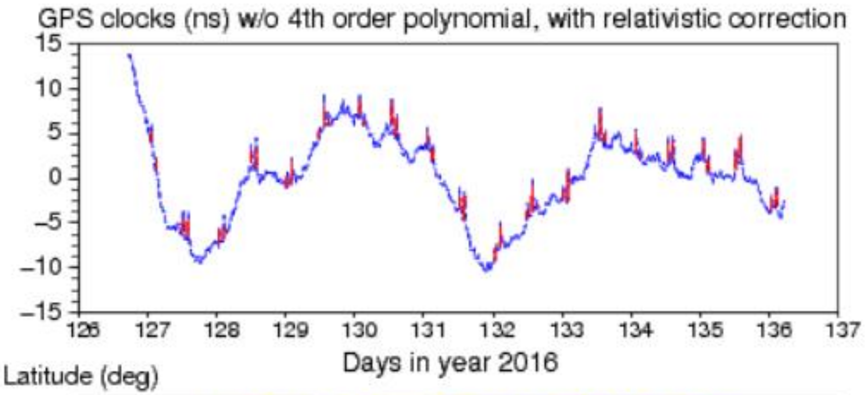
- a(t) : geographical grid from the article « A corrective model for Jason-1 DORIS Doppler data in relation to the South Atlantic Anomaly », JM Lemoine and H. Capdeville

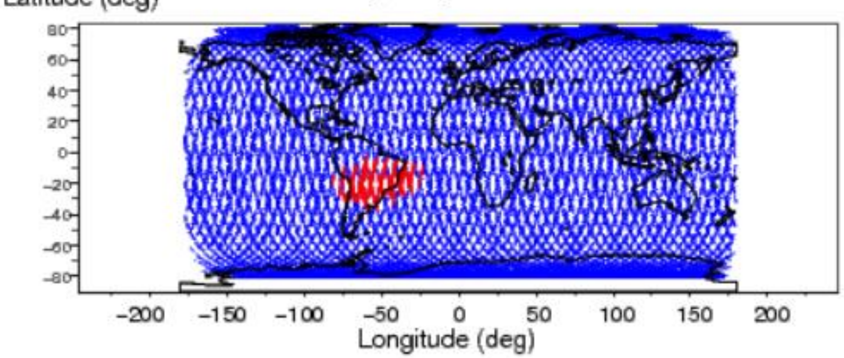
$$\exp\left(-\frac{1}{2}\left[\frac{lat - lat_{SAA}}{SAA\_lat\_extend}\right]^2\right) * \exp\left(-\frac{1}{2}\left[\frac{lon - lon_{SAA}}{SAA\_lon\_extend}\right]^2\right)$$

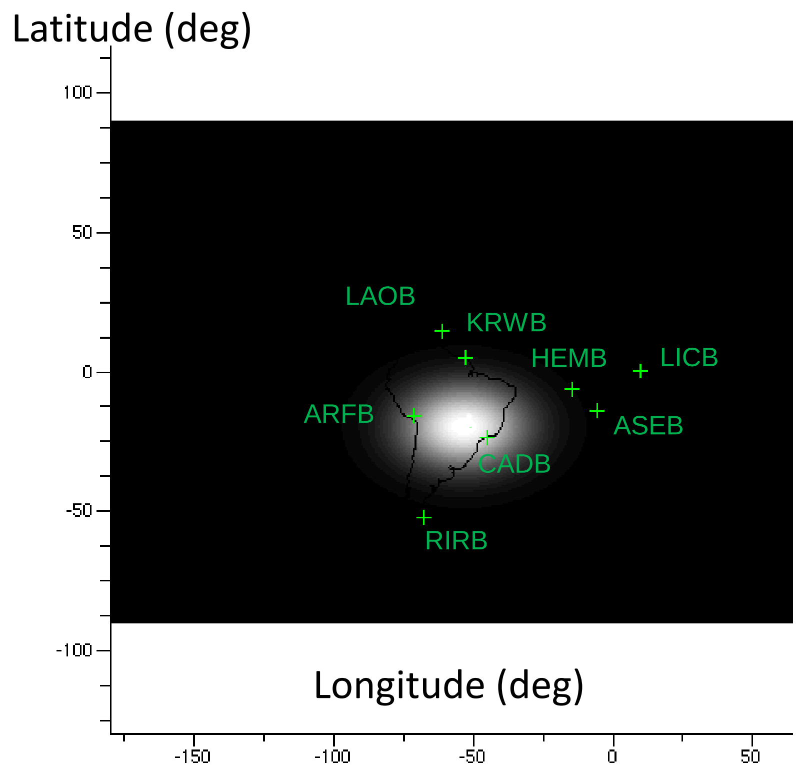
- The difficulty is to properly place the SAA on the Earth.
  - For Sentinel3a, the USO behaviour being known, it is straightforward.
  - But for Jason3, the SAA was placed empirically.

MODELLING : SENTINEL3A SAA GRID (1)

- The area where the drift in the USO occurs can be plotted.



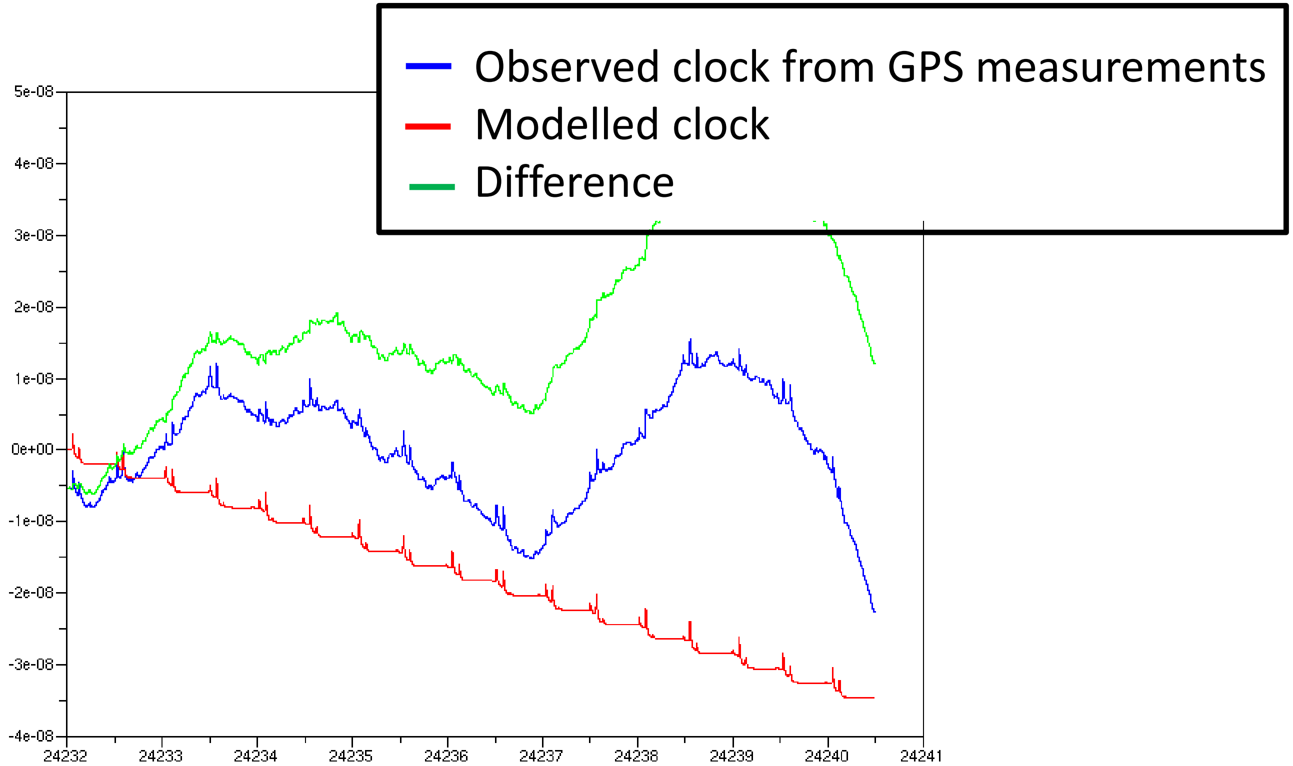





```
milieulongSAA=-53 ;
milieulatSAA=-20  ;
envergurelong=15  ;
envergurelat=10  ;
A=0*%pi/180;
```

MODELLING : SENTINEL3A SAA GRID (2)

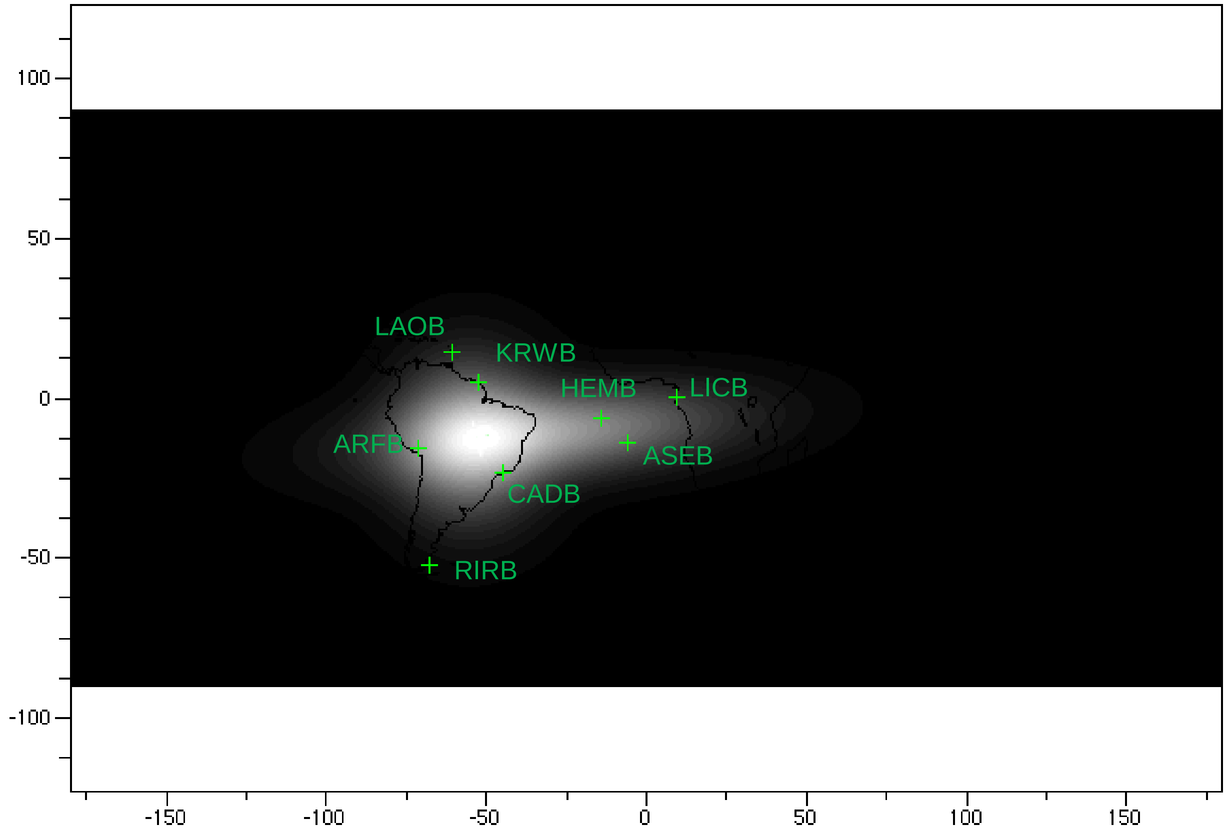
- The chosen positioning of the area is satisfying because it corrects the SAA peaks in the DORIS USO.



- Note : the drift coming from the integration of the model is small enough not to perturb the time tagging. ($3\ 10^{-8}$ sec / 9 days, i.e 7mm over 1 pass)

MODELLING : JASON3 SAA GRID

- The positioning of the SAA area is empirical.
- Two ellipse are necessary to better represent the area.

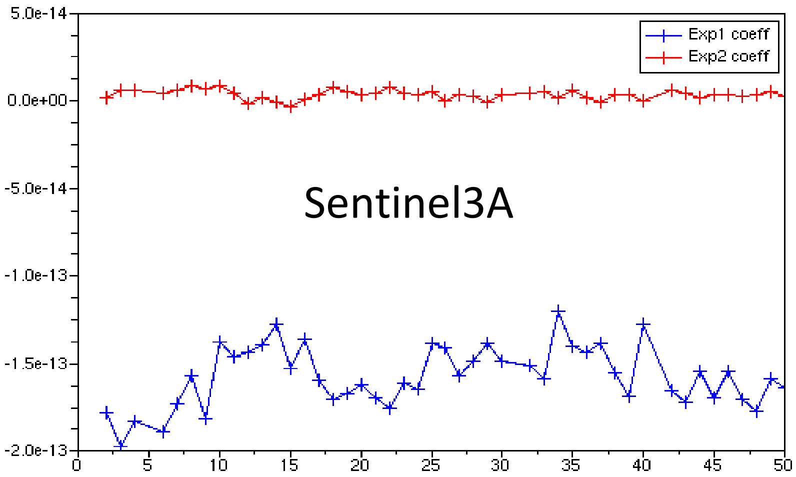


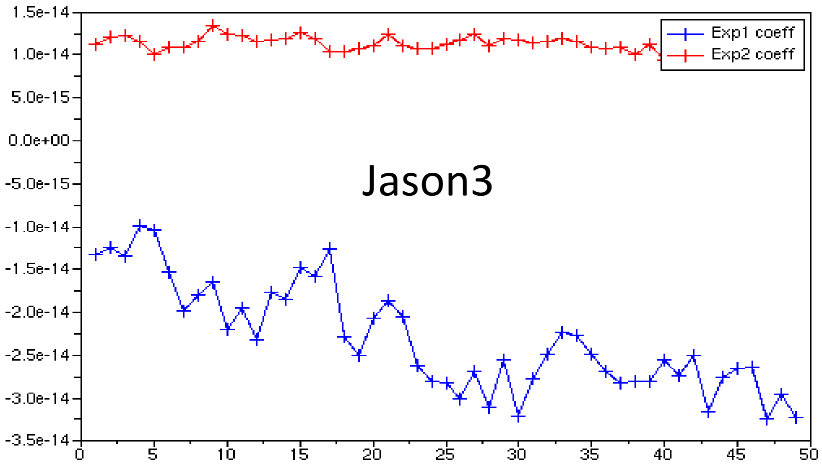

```
// 1er patch
milieulongSAA=-29 ;
milieulatSAA=-11  ;
envergurelong=36  ;
envergurelat=9  ;
A=-5*%pi/180;

// 2e patch
milieulongSAA2=-55 ;
milieulatSAA2=-13 ;
envergurelong2=15  ;
envergurelat2=17  ;
B=0*%pi/180;
```

MODELLING : GAIN ON EXPOSURE

- During the orbit determination process, only β_i are estimated. The other parameters for the model are fixed.

- Stable in time for β_2 (relaxation)
- Small and long term variations for β_1(drift when entering the SAA)





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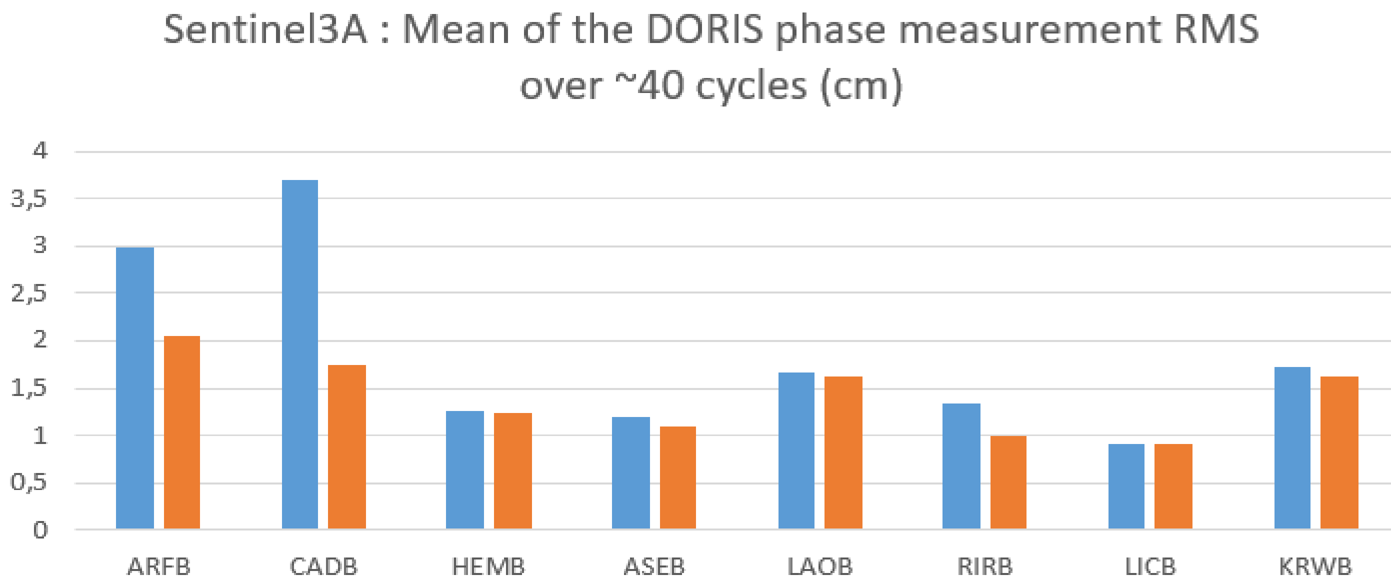
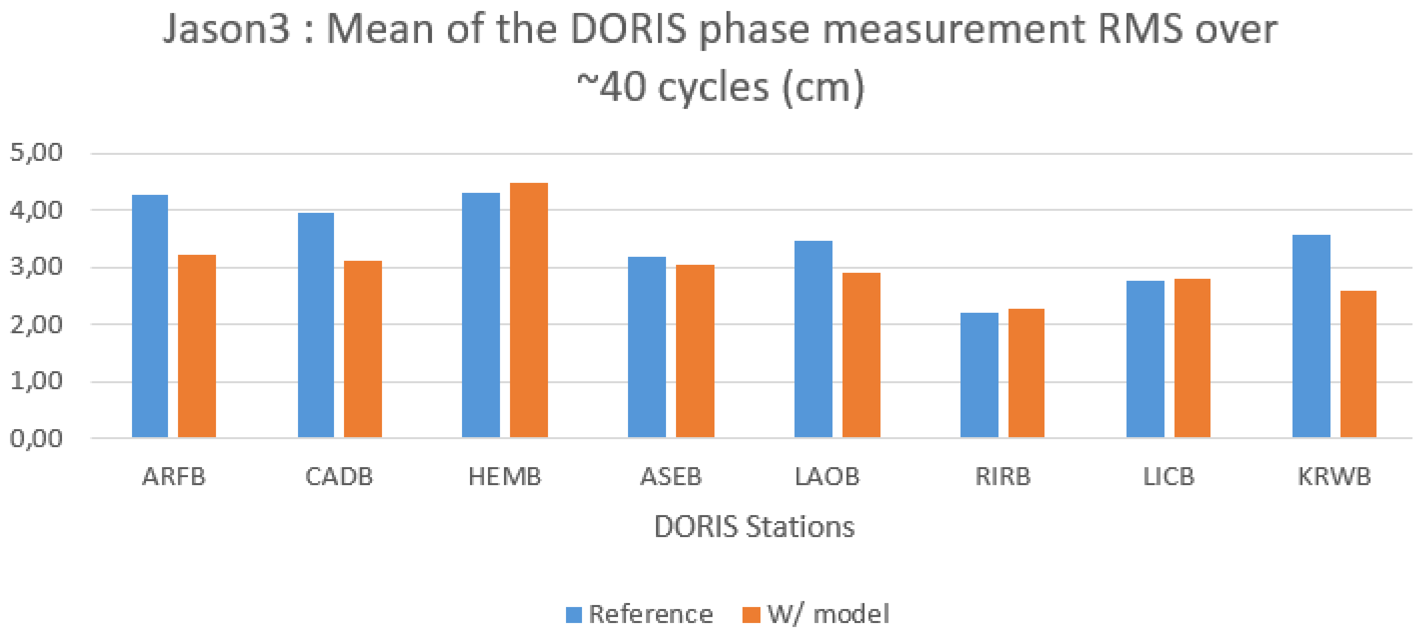
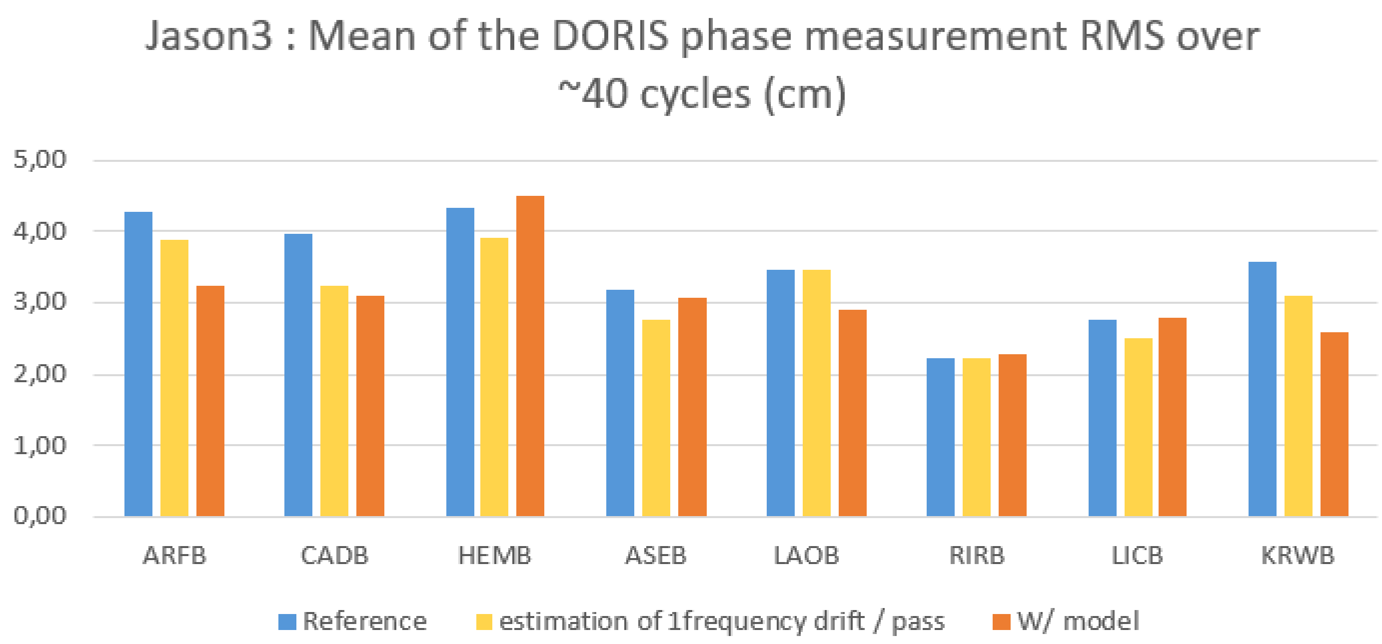
RESULTS ON RMS





RESULTS ON RMS

- OSTST 2016 : « band-aid » solution for SAA impact on Jason3 : estimation of a drift in frequency for each pass of stations inside the SAA area.
- Similar results, depends on station



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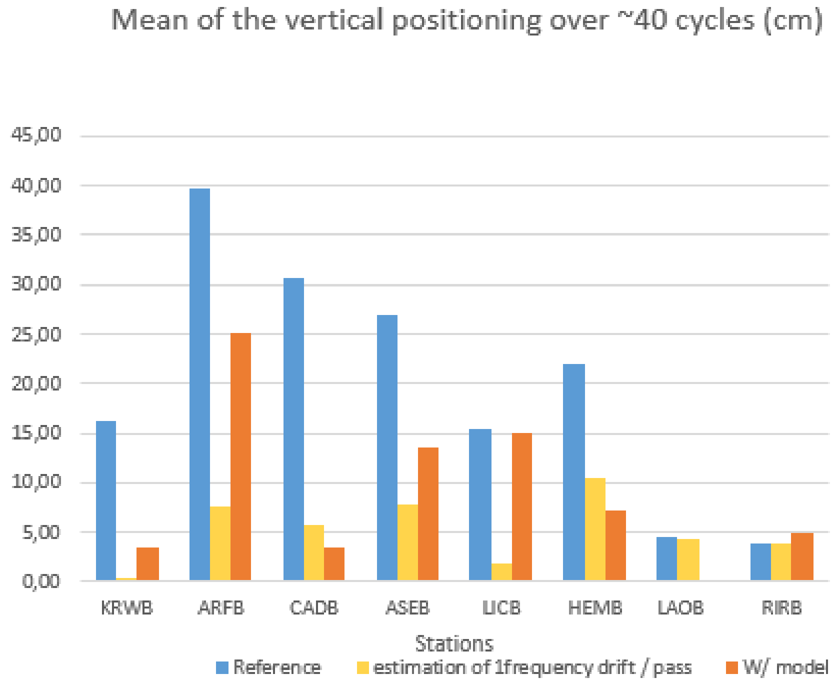
RESULTS ON STATION POSITIONING (JASON3)

- The model enables to overall improve the vertical positioning. But it does not improves it as much as the « band-aid » solution presented at OSTST 2016.

- However, the model represents better the actual behaviour of the USO, rather than just estimating parabolic parameter on the clock, each pass, to minimise signatures.



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CONCLUSION

The modelling of SAA frequency variations enables to improve DORIS phase measurement RMS for stations in the SAA for SentinelA3 and Jason3.

It also improves station positioning for Jason3.

To do :

- Improve the SAA area definition on Jason3
- Apply the model on Jason 1