A model for DORIS USO in the SAA

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Introduction

• DORIS measurements processing relies on a precise knowledge of the Ultra Stable Oscillator (USO)

• The important radiations in the South Atlantic Anomaly (SAA) produce rapid variations of the USO frequency

• If these variations are not modelled: systematic errors

Objective: construct a model of the frequency variations due to the SAA developed for Sentinel3a application on Jason 3
Introduction

Modelling

Impact on Doris measurements and station positioning

Sentinel3B results (tandem phase)

Conclusion
• Model based on observations of Sentinel3A USO

• Two phenomena:
  • Drift when entering the SAA
  • Relaxation after exiting the SAA
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
Model: USO frequency 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:

- \( \alpha_i = \frac{1}{\tau_i} \): inverse of the time constant of the exponentials
- \( a(t) \): the radiation exposure due to the SAA at time \( t \)
- \( \beta_i \): gain linked to the exposure
MODELLING: parameters (1)

- \( \alpha_i \): 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 obtained from:
  «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
- $\beta_i$ : estimated during the orbit determination process

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

\[
\exp \left( -\frac{1}{2} \left[ \frac{\text{lat} - \text{lat}_{\text{SAA}}}{\text{SAA}_{\text{lat}_{\text{extend}}}} \right]^2 \right) \times \exp \left( -\frac{1}{2} \left[ \frac{\text{lon} - \text{lon}_{\text{SAA}}}{\text{SAA}_{\text{lon}_{\text{extend}}}} \right]^2 \right)
\]

- The difficulty is to properly represent the SAA area.
  - for Sentinel3a, the USO behaviour is directly observed : OK
  - for Jason3, the SAA area was placed empirically.
• The area where the drift in the USO occurs can be observed.
• Validation: the observed SAA peaks in the clock are correctly removed.

• Note: the drift produced the integration of the model doesn’t impact the time tagging ($3 \times 10^{-8}$ sec effect on 9 days)
The positioning of the SAA area is empirical. Two ellipses are necessary to correctly represent the effects.
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• During the orbit determination process, only $\beta_i$ are estimated. The other parameters for the model are fixed.

• $\beta_2$ (relaxation) : stable with time
• $\beta_1$ (short term) : small variations, drift for Jason 3
Residuals rms

Sentinel3A: Mean of the DORIS phase measurement RMS over \(\sim 40\) cycles (cm)

Jason3: Mean of the DORIS phase measurement RMS over \(\sim 40\) cycles (cm)
• OSTST 2016: estimation of a drift in frequency for each pass of stations inside the SAA area.

• Similar results, depends on station
Results on station positioning (Jason3)

- Model: improves the vertical positioning, but not as efficient as the freq. drift (OSTST 2016).

- However, the model represents better the actual behaviour of the USO, rather than just estimating a parabolic parameter on each pass, to minimise signatures.
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Sentinel3B USO observation (tandem phase)

Conclusion
Sentinel 3A and 3B tandem phase, USO frequency observed by GPS

STC orbits observed USO df/f (added offset for se3b plot)

120 s average frequency receiver clock relativity term not removed

Long term evolution removed (deg. 1 for se3a, deg. 2 for se3b)
Perturbations due to SAA observed also on se3b

USO sensitivity of opposite sign
Direct comparison of the clock frequency

- GNSS observation
  (120 s average frequency)
- Doris USO frequency file
  (long term average frequency)

0.2 mm error on altimeter

\( \pm 10^{-10} \) for \( df/f \)

A precise observation of the frequency for the altimeter processing is possible using the GNSS measurements.
Conclusion

The model improves the Doris processing

The model parameters are adjusted simultaneously with orbit determination

Difficulties to determine a correct SAA area, specifically for Jason 3

Sentinel 3B has similar behaviour as Sentinel 3A, but opposite sign of the sensitivity.

To do:
• Improve the SAA area definition on Jason3
• Tests on Jason 1