# The T2L2 contribution to precise orbit determination and positioning

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# Context


The relevance of an Earth observation space mission relies on its orbitography (P.O.D.), the reference frame ITRF and the link between ground and space

Link

- R-F (DORIS)
- Optical (SLR, T2L2)

P.O.D

- Essential for altimetry mission
- How improve the P.O.D ?
- The mm goal ? (E-GRASP)

Positioning

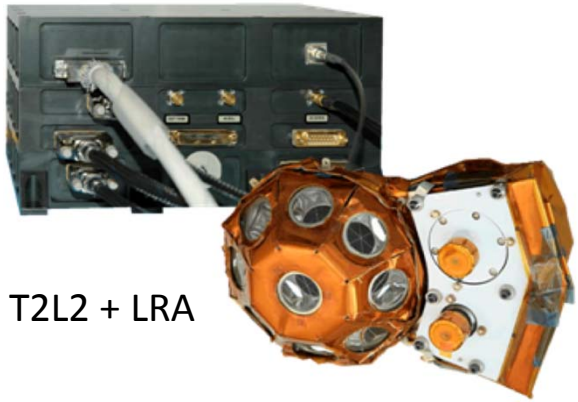
- Have a network accurate at 1 mm and stable at 0.1 mm/yr

***Plag, H.-P. and Pearlman, M. 2009**. Global geodetic observing system Meeting the requirements of a global society on a changing planet in 2020. Springer Science & Business Media.*

- DORIS (IDS)
- SLR (ILRS)

Contribution of T2L2

# T2L2 on-board Jason-2



T2L2 + LRA

T2L2 :

- Designed for remote clocks synchronization, on-ground and on-board

Time Transfer :

- Determine Time Bias in laser stations (ILRS)
- Read the frequency bias of the USO (Ultra Stable Oscillator)

Jason-2, oceanographic satellite :

- Launched the 06/20/2008
- At an altitude of 1336 km
- Orbit of 66°
- Orbital period ~110 min

Passengers :

- CARMEN-2 (High energy flux detector)

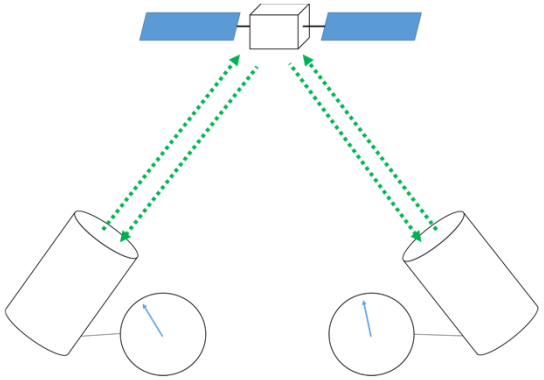
***Bezerra, F et al. 2011**. Carmen2/mex : An in-flight laboratory for the observation of radiation effects on electronic devices. In Radiation and Its Effects on Components and Systems (RADECS).*

- T2L2 (Time Transfer by Laser Link)

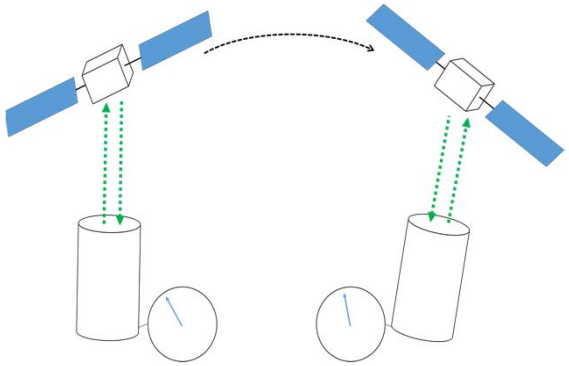
***Samain, E., et al. 2008.** Time transfer by laser link–the t2l2 experiment on jason-2 and further experiments. International Journal of Modern Physics D.*

# Time Transfer between SLR stations (i.e. TB determination)

Common View



Non Common View




Based on the integration of the frequency model of the oscillator (when T2L2 is not observed), see slides n° 8 & 9

ILRS recommendations are +/- 100 ns of the UTC

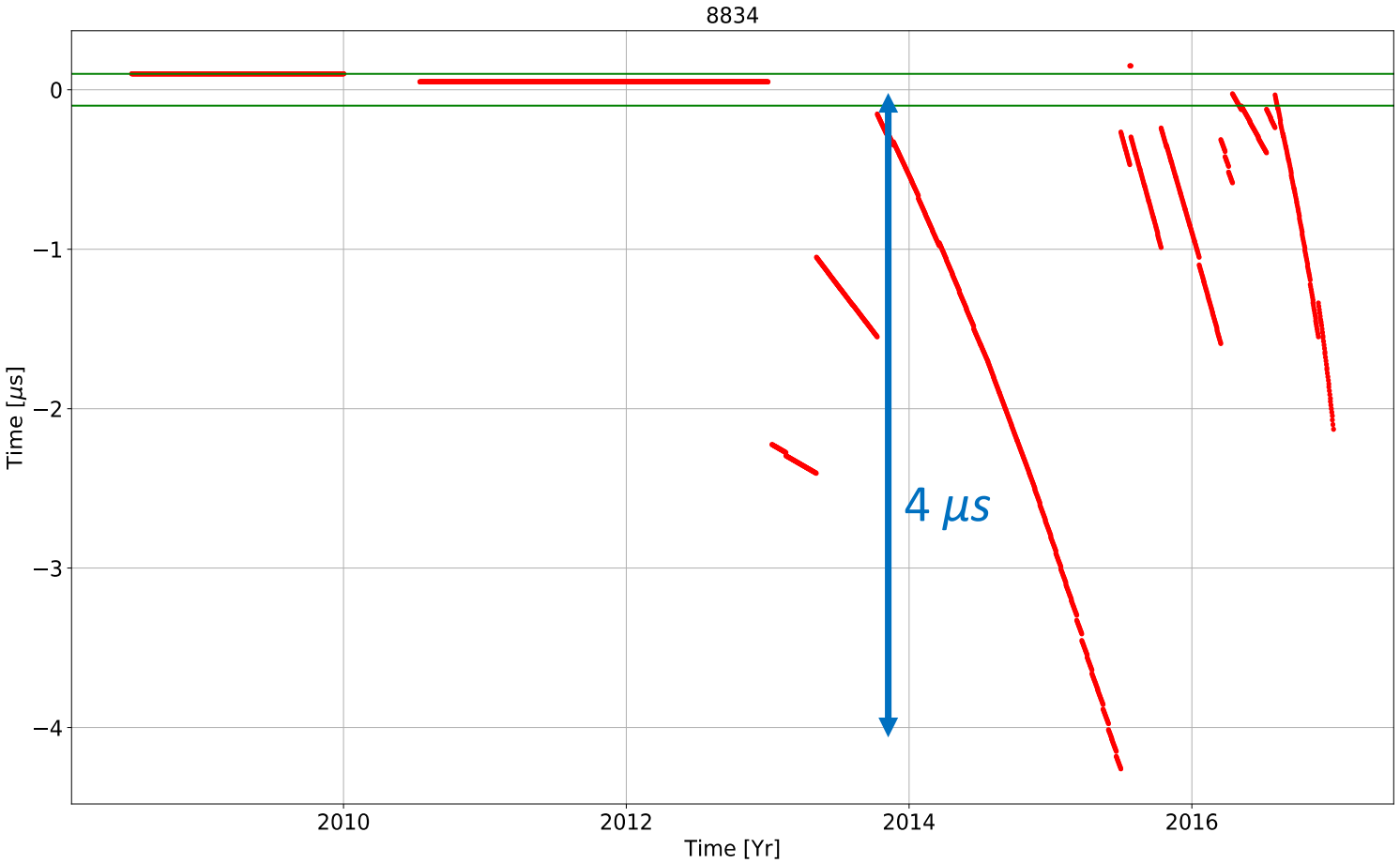
Accuracy +/- 15 ns to 5 ns (using Grasse as master station)

Compared to GPS at 0.2 ns

***Exertier, P., et al. 2017. Time biases in laser ranging observations: A concerning issue of Space Geodesy. Advance in Space Research,*** *Volume 60, Issue 5, 1 September 2017, Pages 948-968*

***Samain E., et al., 2017, (****submitted), Time Transfer by Laser Link (T2L2) in non common view between Europe and China.*

# Time Biases in Laser Ranging Station

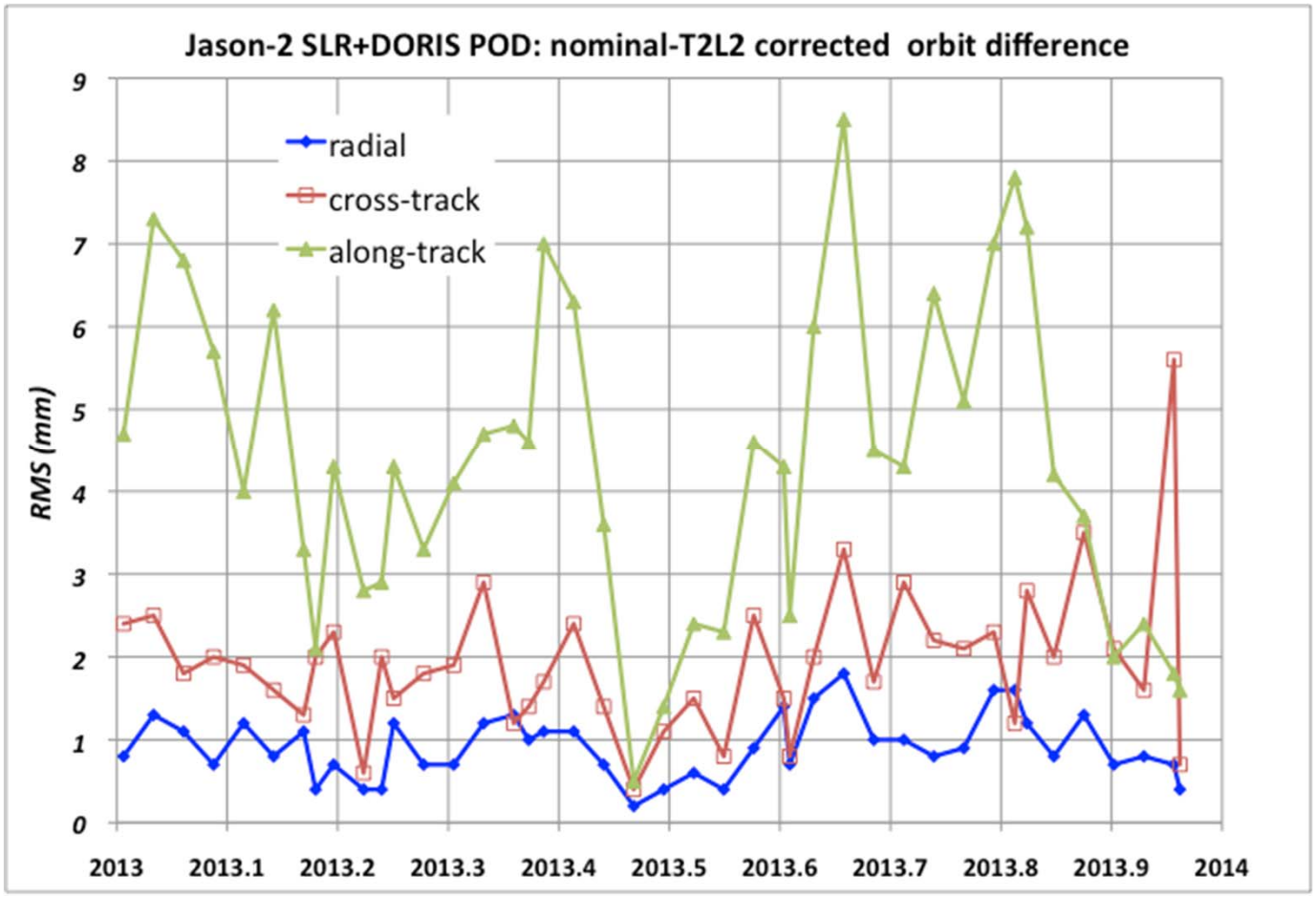



Time Bias for Wettzell (8834) SLR station (2008-2017)

- Accuracy 15 ns
- ILRS recommendations
- Available for 8 years ! (ILRS community & others) for 32 SLR stations

**What kind of impacts did we expect on the P.O.D ?**

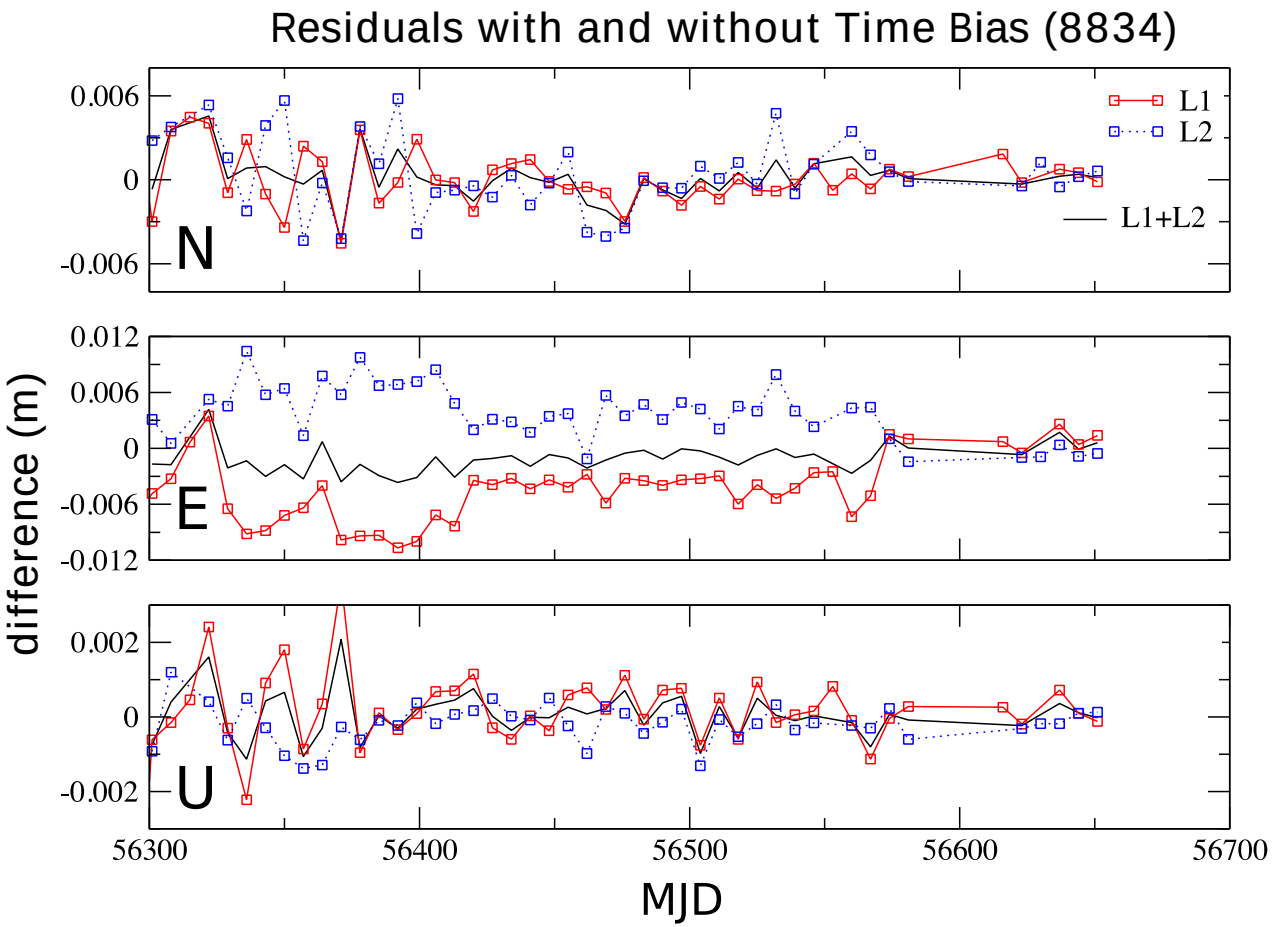
# Impact of Time Biases on the P.O.D




**Impact on Jason- 2 P.O.D for 2013 (due to Time Biases in SLR stations)**

- Main impact on the along-track component
- The orbit is slightly improve (4 mm mean in *along-track*, i.e. 15% of the global *along-track* error !)

# Impact of Time Biases on the Positioning

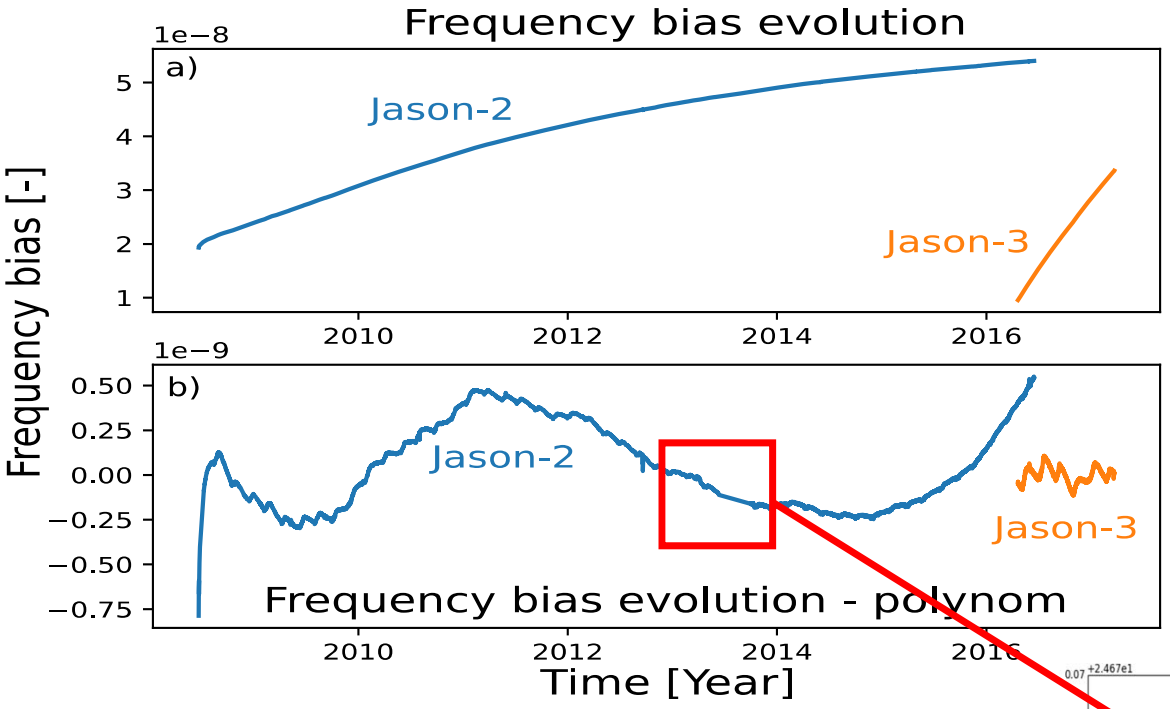



Time Bias effect on SLR coordinates

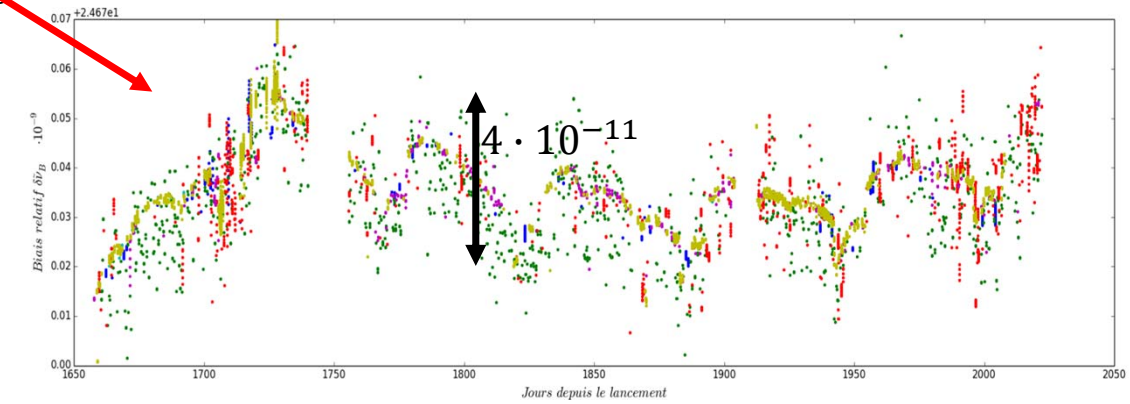
- 2013, SLR station 8834
- N-E component more affected
- **Microsecond biases lead to mm effects !**

*Exertier, P., et al. 2017. **Time biases in laser ranging observations: A concerning issue of Space Geodesy. Advance in Space Research,** Volume 60, Issue 5, 1 September 2017, Pages 948-968*

# The USO on-board Jason-2



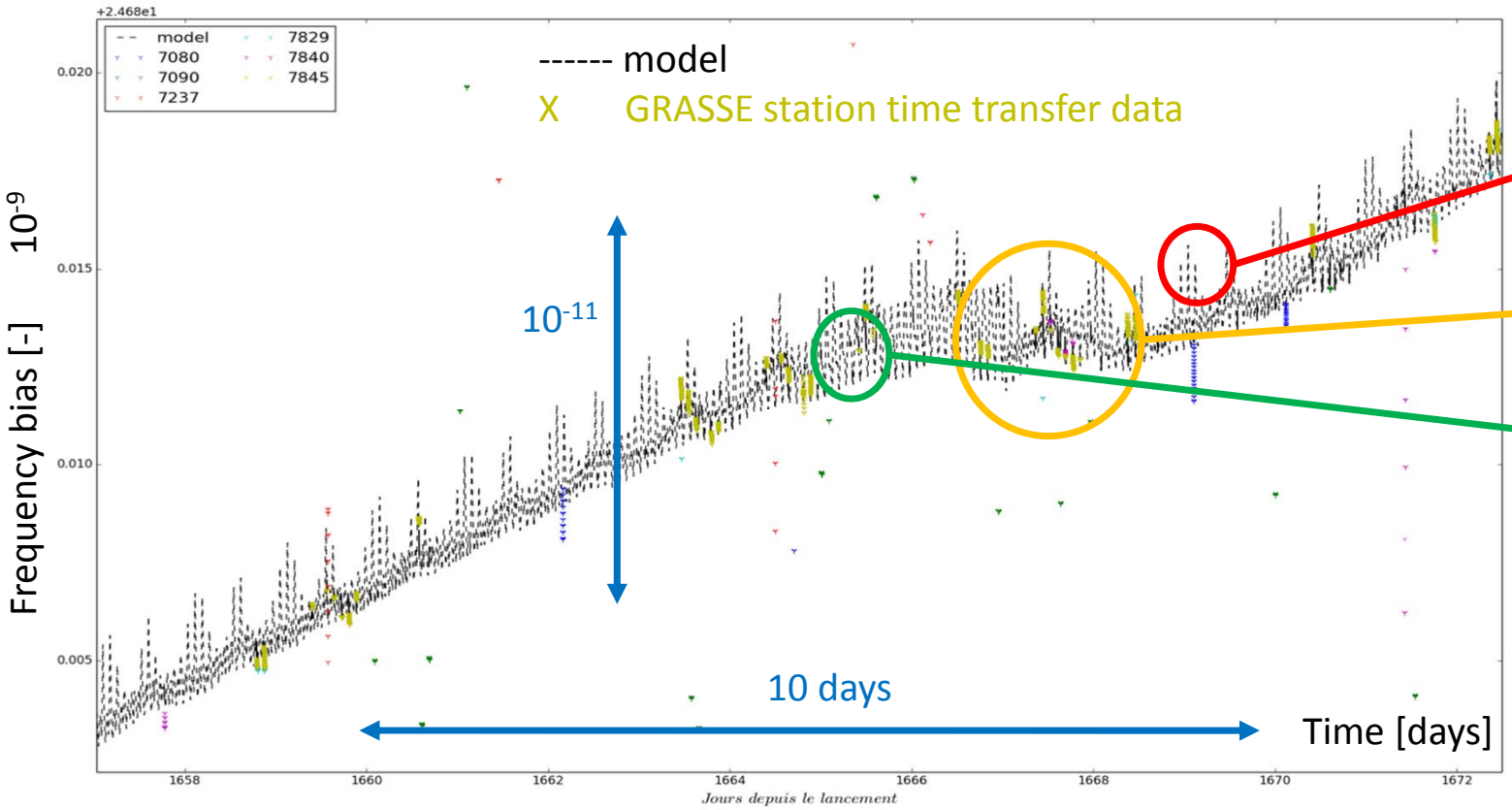

| Effects | Frequency bias/effect | Bibliography |
|---|---|---|
| Global drift | $< 10^{-11}$/d | Guillemot, P., et al. 2009. Fisrt application of the t2l2 ground to space time transfer : Characterisation of the doris uso. IEEE International. |
| Temperature | $6.5 \cdot 10^{-13}/°C$ | Galliou, S., et al. 2007. A program to analyse the origin of noise in ultra-stable quartz crystal resonators. IEEE International. |
| Radiation SAA | $2 - 3 \cdot 10^{-12}/rad$ | Lefèvre, J., et al. 2009. Characterization of unswept and swept quartz crystals for space applications. Journal of Applied Physics. |




DORIS MOE $10^{-12}$ T2L2 $10^{-13}$

**USO model !**

# The USO model




SAA effect

Attitude change (temperature)

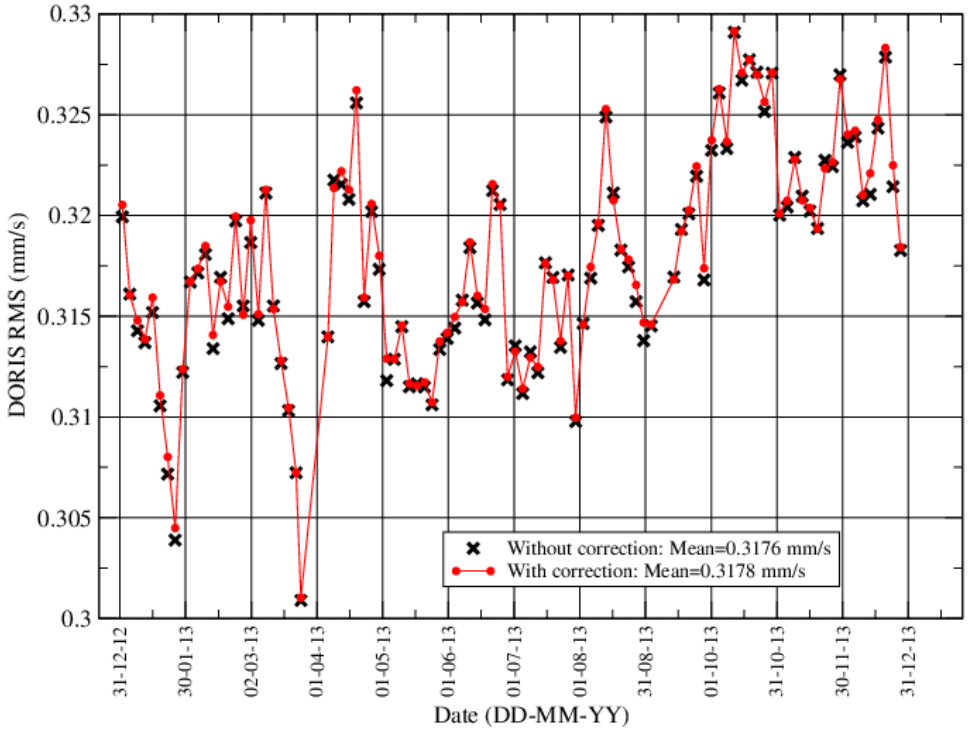
Orbital period (temperature)

- Radiation + temperature + aging
- Precision around 5-7 x $10^{-13}$
- Accuracy $10^{-12}$

***Belli, A., et al. 2015**. Temperature, radiation and aging analysis of the doris ultra stable oscillator by means of the time transfer by laser link experiment on jason-2. Advances in Space Research. Scientific Applications of DORIS in Space Geodesy.*

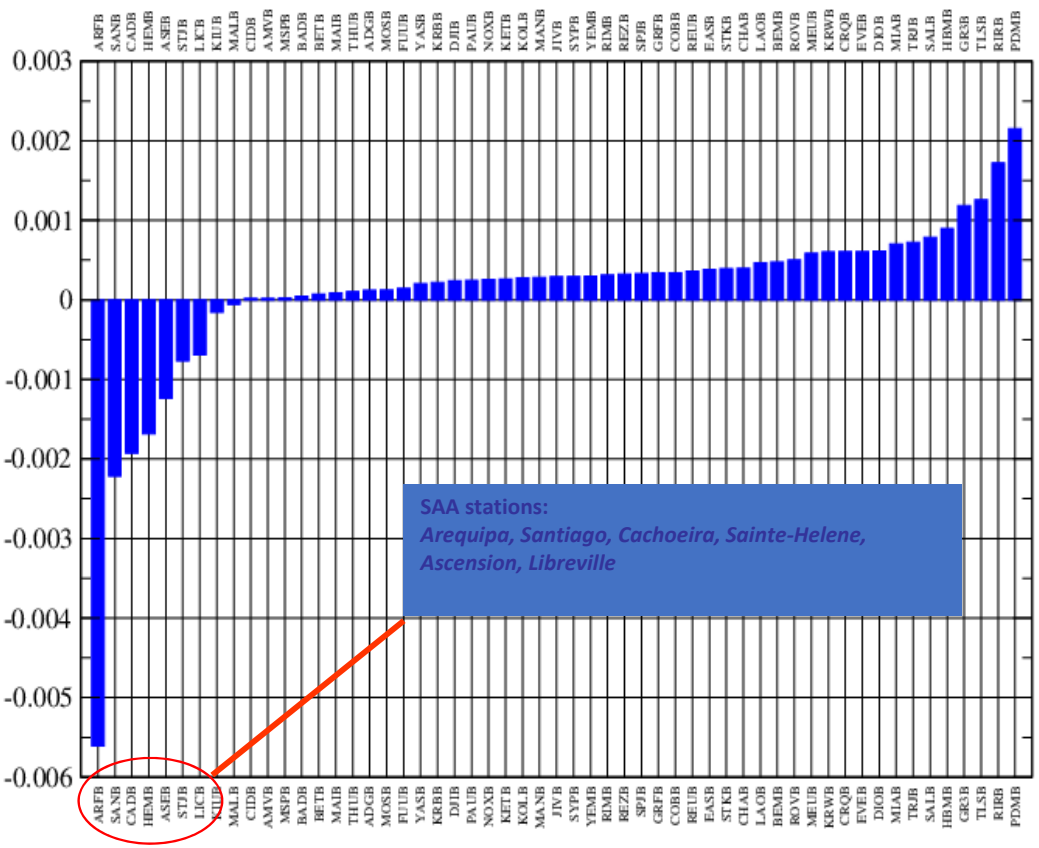
# Impact on P.O.D (1 year corrected files)

**DORIS RMS of fit**




**DORIS RMS of fit differences by station**

(with correction – without correction)




**DORIS residuals are reduced by the use of the model for SAA stations**

**No orbit differences significantly**

# Impact of the model on the Positioning

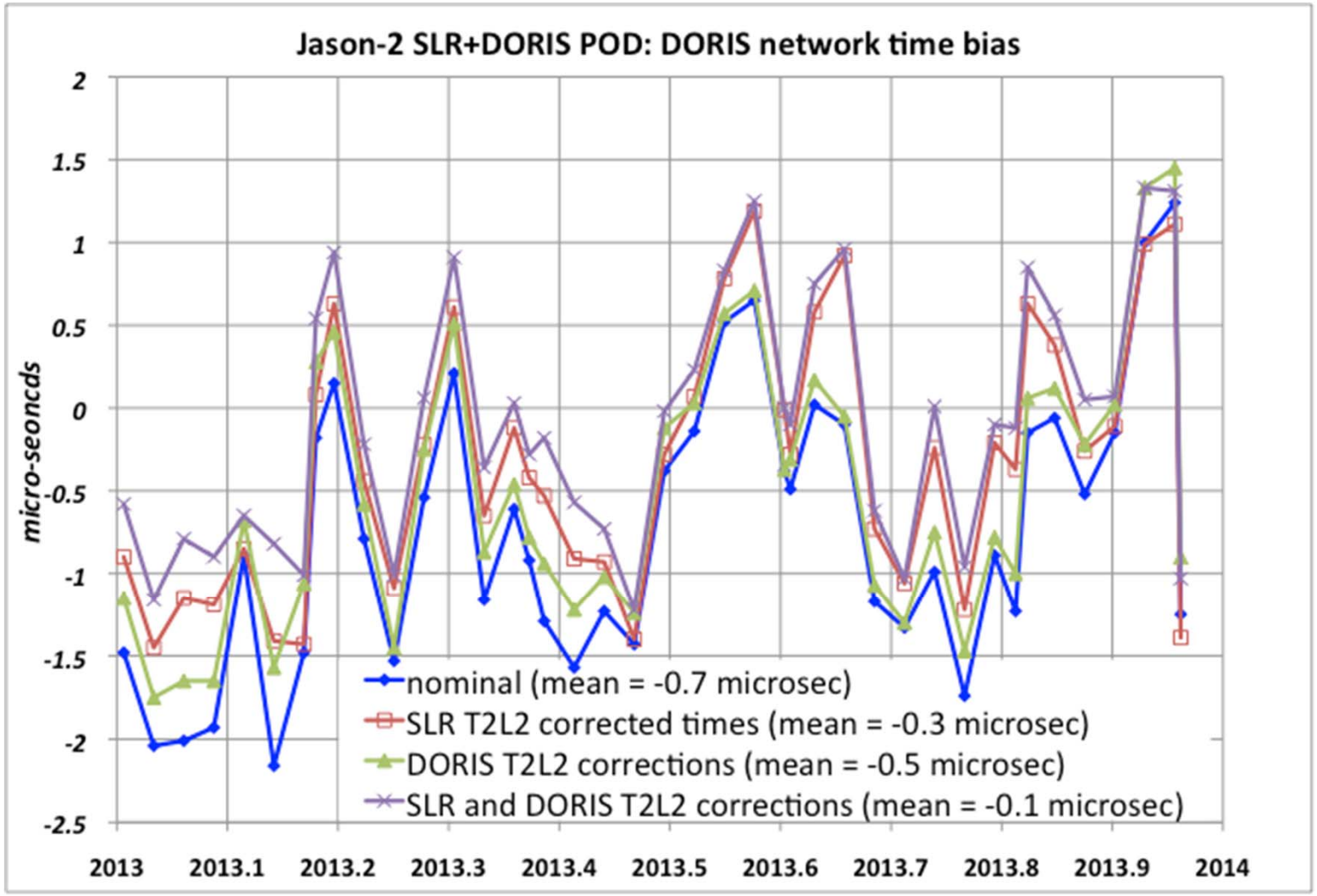
| Station | Jason-2 (in cm) North | East | Up | Jason-2 corrected (in cm) North | East | Up |
|---|---|---|---|---|---|---|
| Cachoeira | 4.3 | 2.2 | **7.4** | 2.8 | 3.3 | 4.1 |
| Arequipa | -2.0 | 2.4 | **8.8** | -1.6 | 1.9 | 3.4 |
| Santiago | **8.2** | -0.3 | 1.8 | **6.1** | 0.2 | -0.7 |
| Ascension | 0.7 | -1.7 | **5.3** | -0.1 | -0.4 | 3.2 |
| Saint Helene | **5.2** | 0.3 | 2.9 | 3.9 | 0.5 | 1.2 |
| Libreville | -2.7 | -1.0 | 2.9 | -2.1 | -0.6 | 1.4 |
| Kourou | -2.2 | -0.4 | 1.9 | -1.4 | -0.7 | 0.9 |
| *Yarragadee* | *0.3* | *-0.8* | *0.5* | *0.1* | *-0.8* | *0.6* |
| *Thule* | *-0.3* | *-0.9* | *-2.0* | *-0.4* | *-1.1* | *-1.8* |

Impact on the station position estimation

- Jason-2 with or without USO model
- Cryosat-2 as reference (not affected by the SAA)
- Single satellite solution
- 2013

**The use of the corrective model improves slightly the single satellite station position estimation**

# DORIS Time Bias



# Conclusions

| T2L2 | TIME | FREQUENCY |
|---|---|---|
| Determine Time Biases in laser stations | X | |
| Read the USO on-board Jason-2 | | X |
| Effect of TB on positioning and P.O.D | X | |
| USO model (available for IDS community) **including new study for Jason-3 USO** | | X |
| Effects of the USO model on positioning and P.O.D | | X |
| DORIS TB estimation | X | |
| No major effects on the P.O.D (Jason-2) | | |
| BUT mm effects on the positioning of the SLR stations due to Time Biases | X | |
| BUT cm effects on the positioning for DORIS Beacons under the SAA due to the USO instability | | X |
| To be continued, i.e. Jason-3 (USO much more sensible than Jason-2) | | X |
| Time as an supplementary independent observable | X | |

*Thank you for you attention !!*

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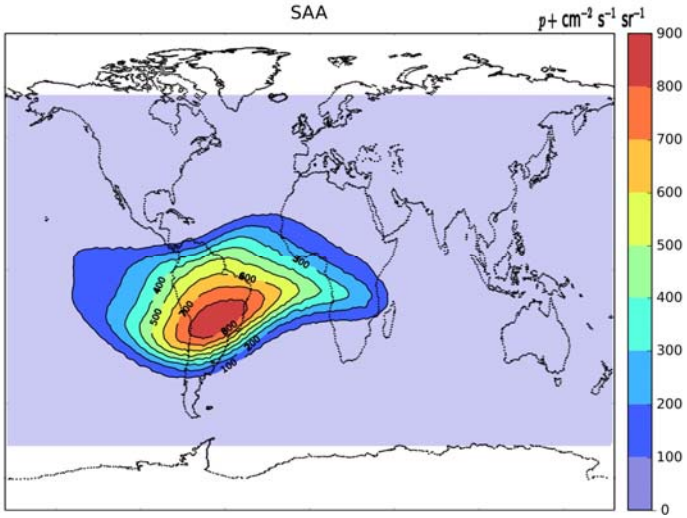
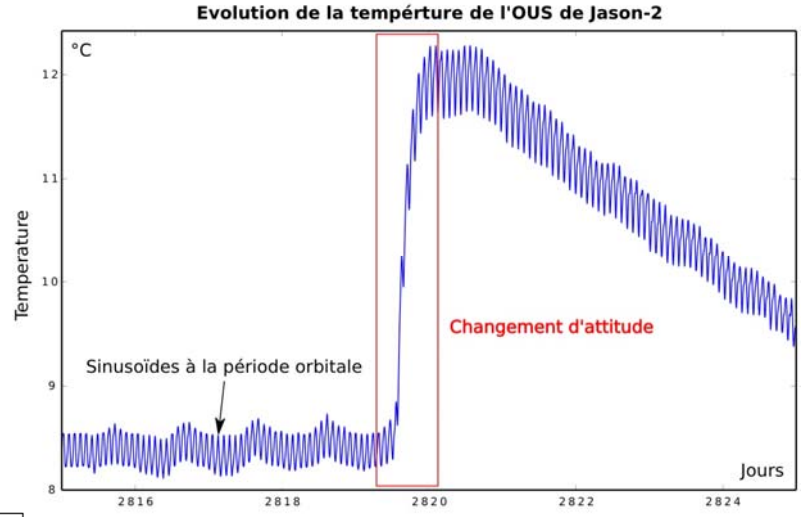
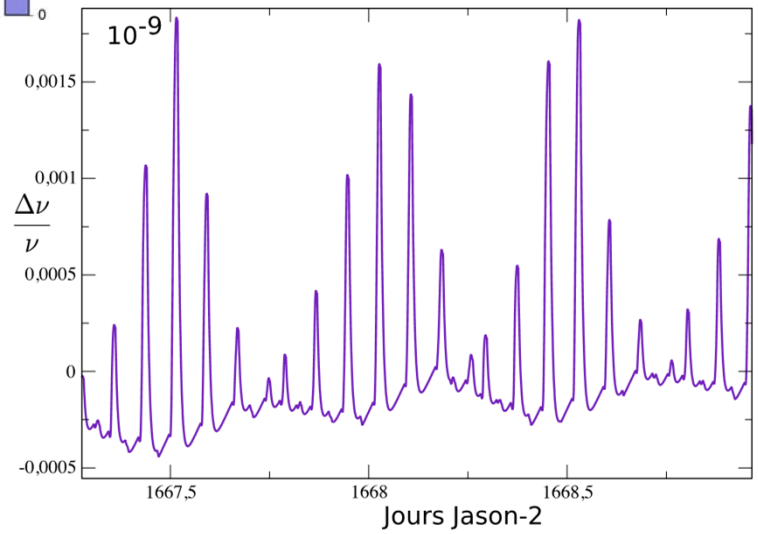
# backup


SAA
p+ cm⁻² s⁻¹ sr⁻¹
900
800
700
600
500
400
300
200
100
0


Evolution de la tempérture de l'OUS de Jason-2
°C
Temperature
Sinusoïdes à la période orbitale
Changement d'attitude
Jours
12
11
10
9
8
2816
2818
2820
2822
2824


10⁻⁹
0,0015
0,001
Δν/ν
0,0005
0
-0,0005
1667,5
1668
1668,5
Jours Jason-2