From Jason-2 to Jason-3
USO studies

Temperature, radiation and aging analysis of the DORIS Ultra Stable Oscillator by means of the Time Transfer by Laser Link on Jason-2

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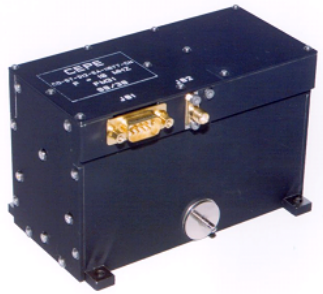
Jason-2

- Launched 20 June 2008 (~8 years of data) (17/01/16 for J-3)
- Oceanographic Satellite
- 1336 km
- 113 min
- 66°

- T2L2



- DORIS (USO)

- CARMEN-2

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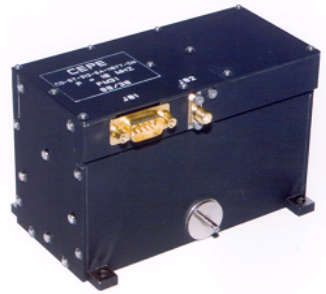
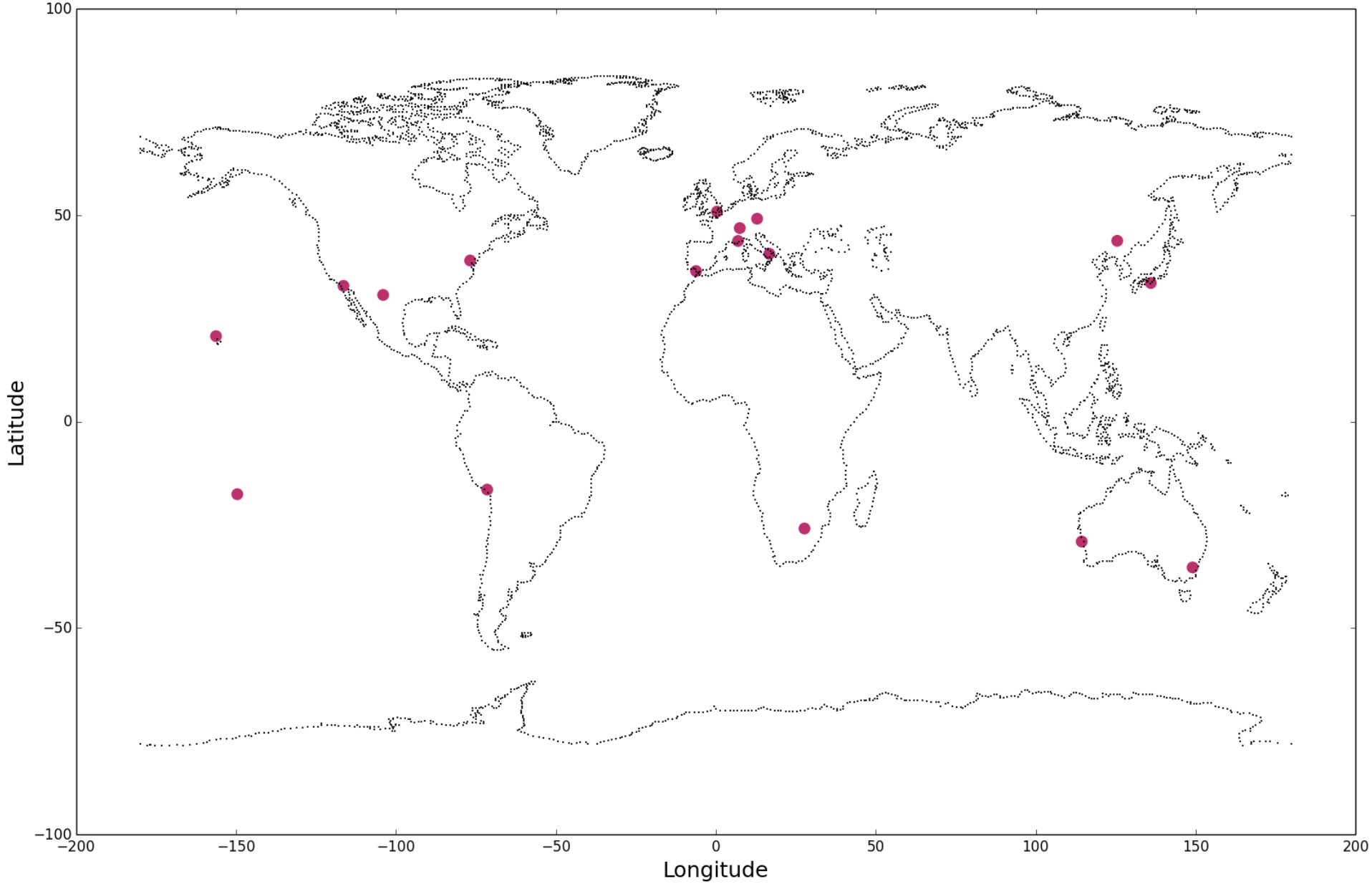


- DORIS (USO)

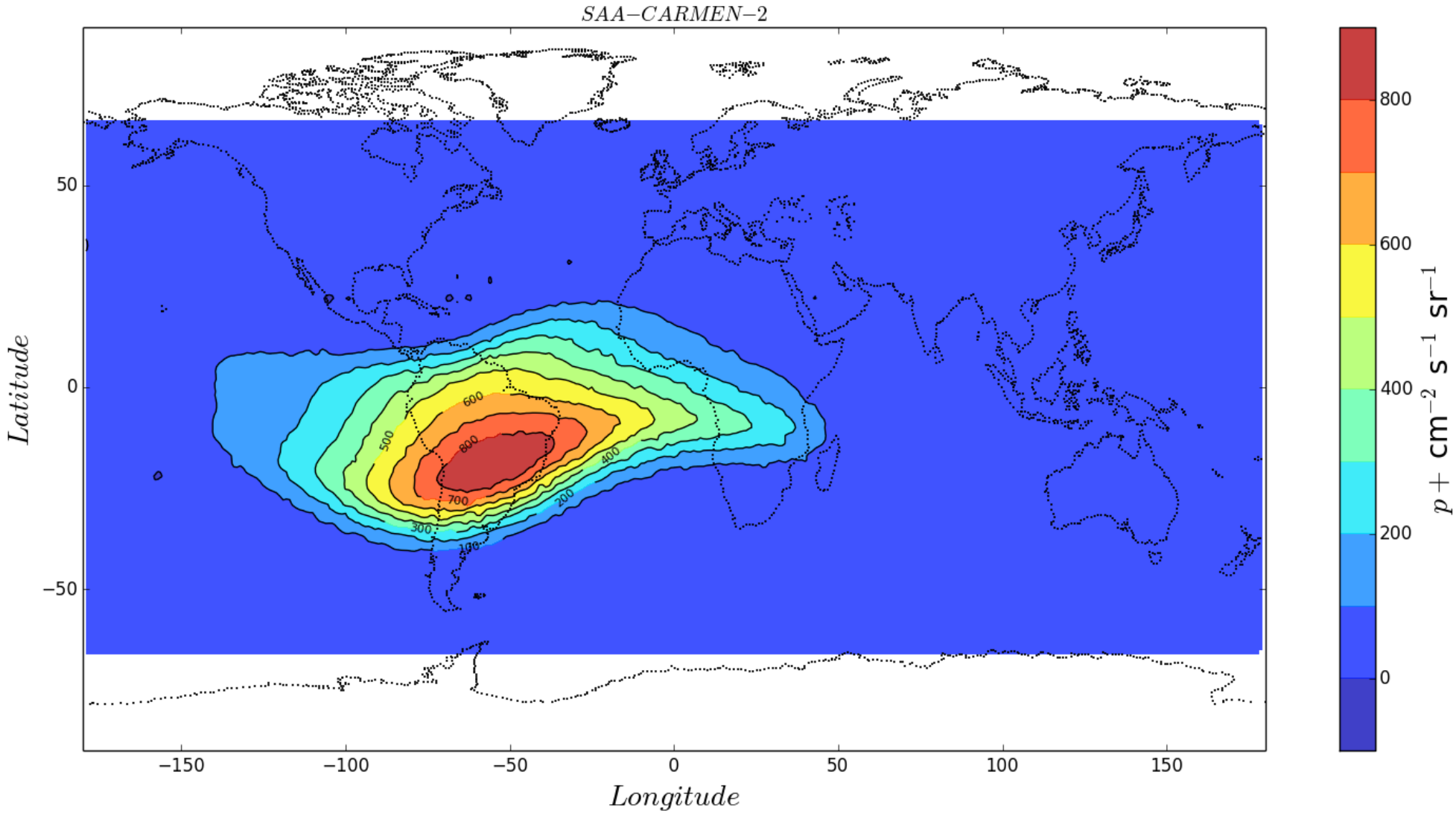
- CARMEN-2

*Jason-2 & **SLR** Stations (2015)*



Jason-2/3 & DORIS network

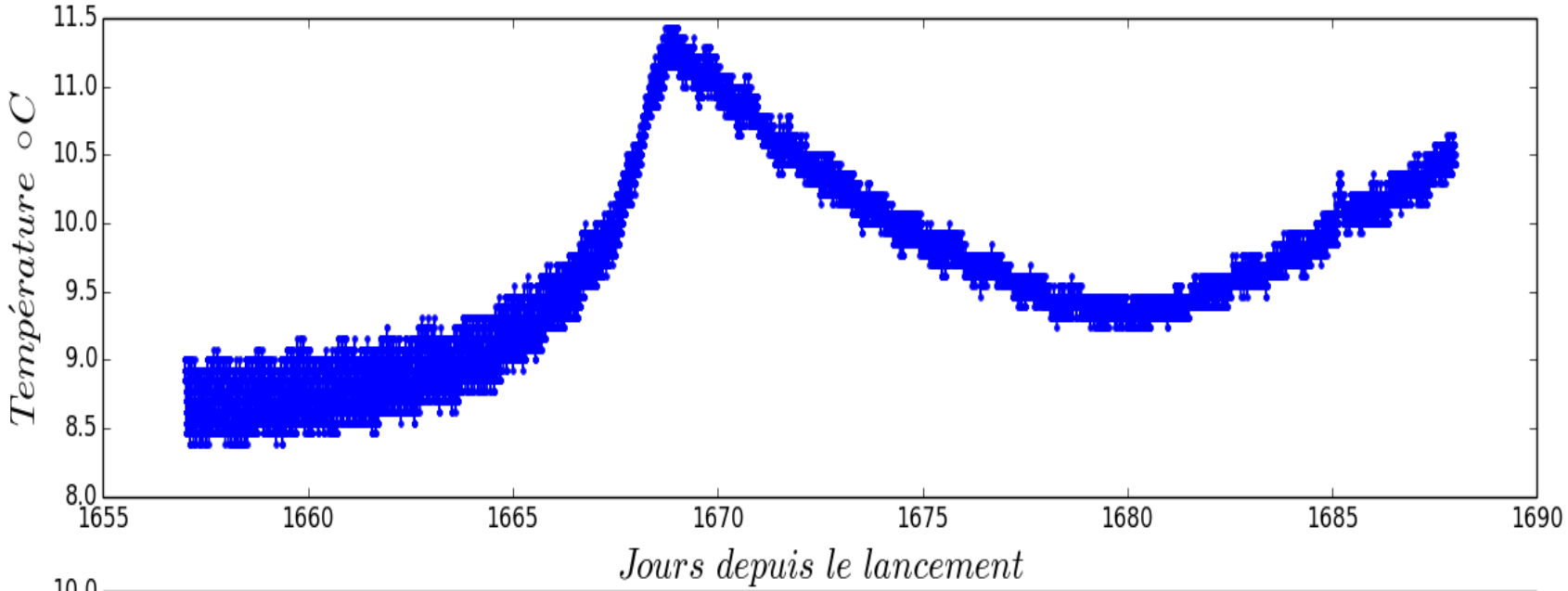
Jason-2 space environment (radiations)

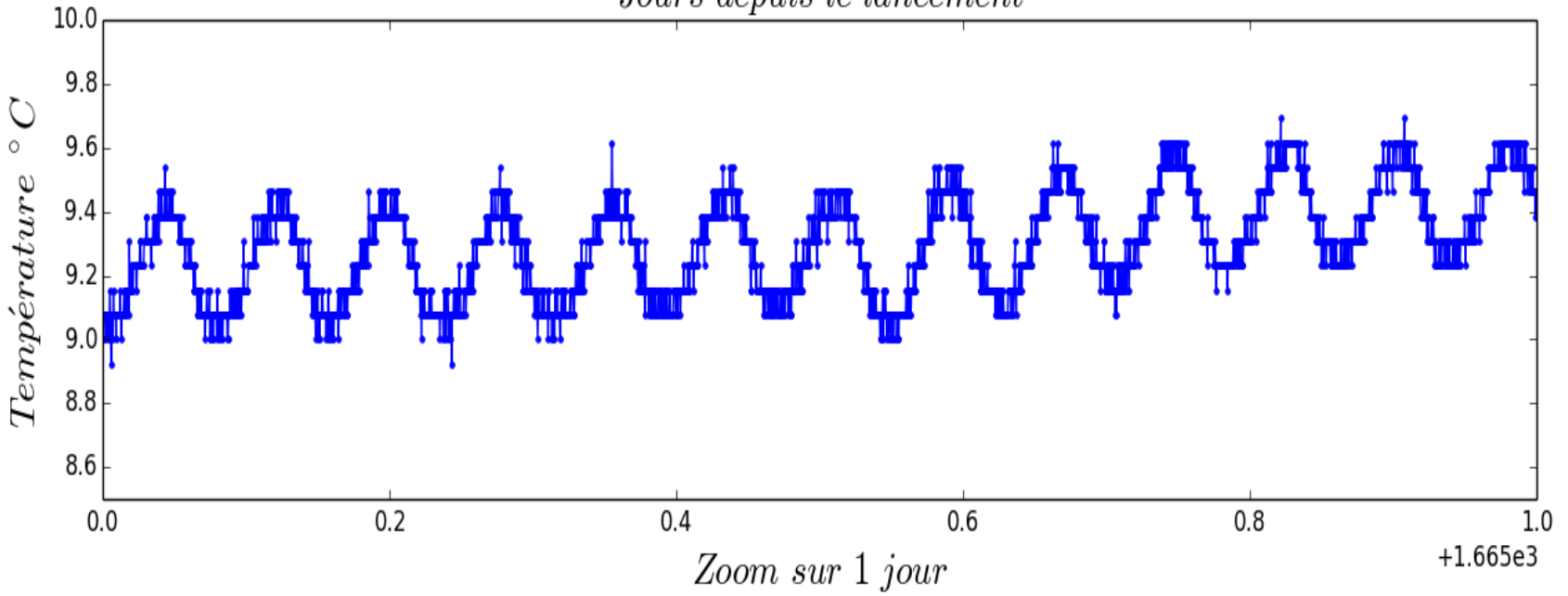


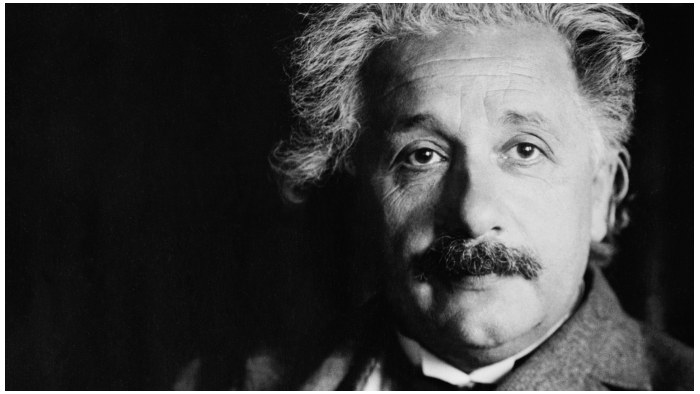
Proton flux, Carmen – 2 Calibration

[J.M. Lemoine & H. Capdeville 2006]

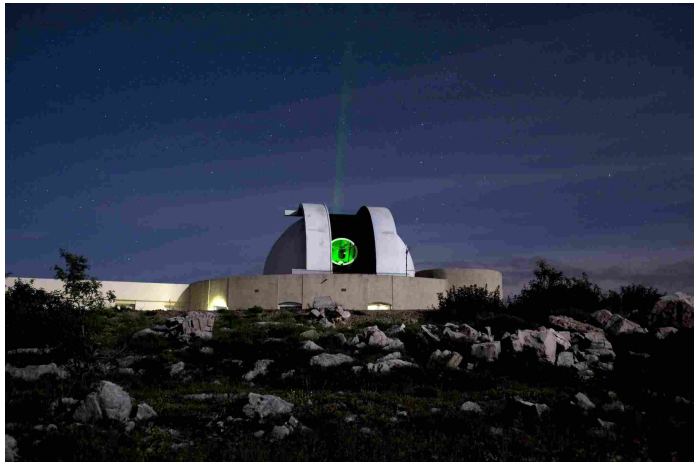
Temperature (USO)

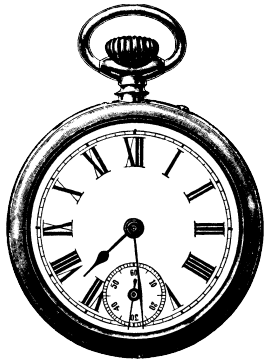






Relativity





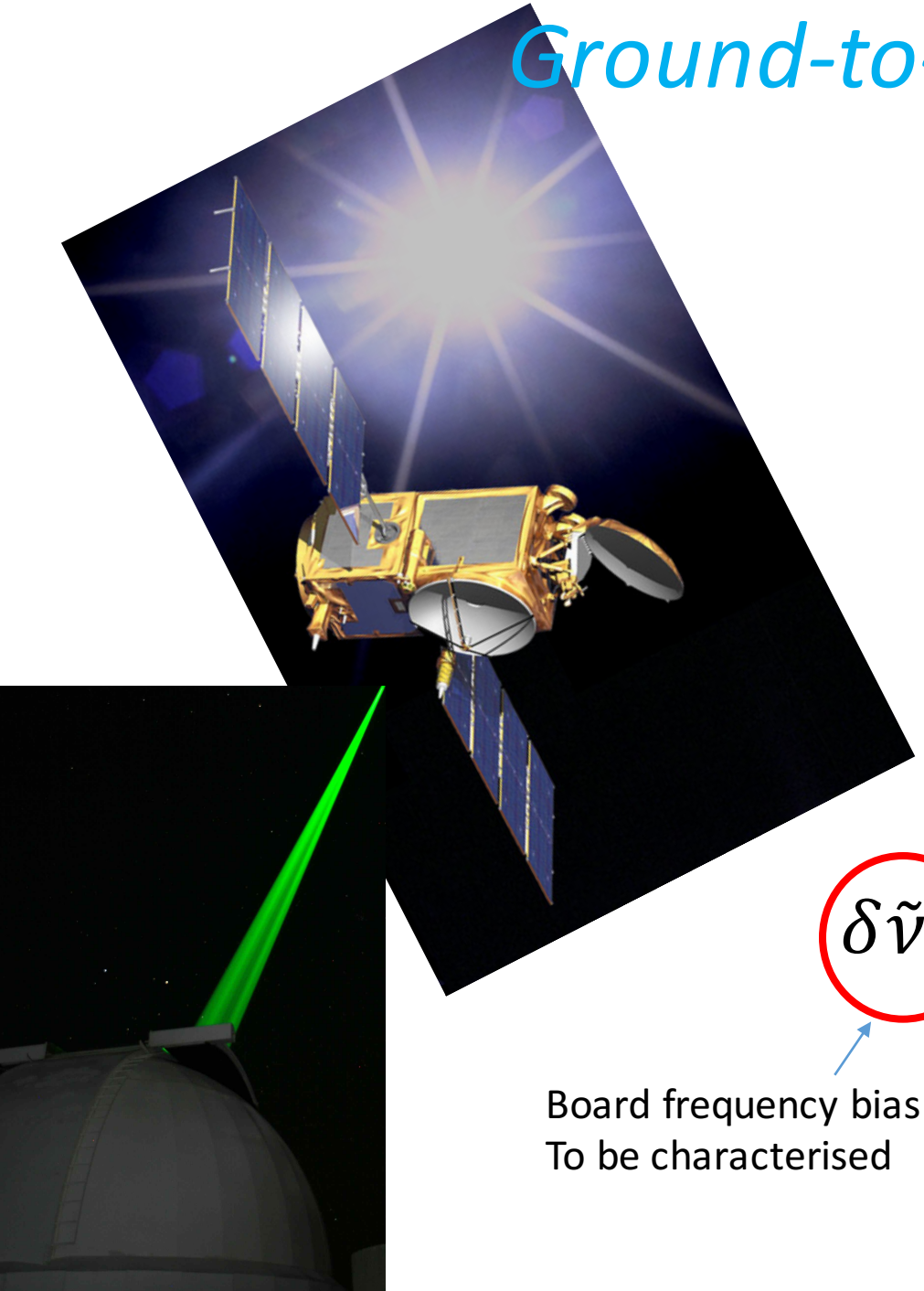
Global Drift and Aging

Effects on USO

Effects	Frequency Bias 10^{-12}	Time Period	Sources	T2L2 / DORIS
Noise	0.35	10 s à 100 s	Auriol & Tourain 2010	DORIS
Global drift	< 10.0 / day	Long term	Guillemot et al. 2009	DORIS & T2L2
Temperature	0.65 /°C	Orbit (113 min) to 60 days	Galliou et al. 2007	T2L2 (short term) DORIS & T2L2 (Long term)
Radiations	6.7 / rad	~20 min to long term	Lefèvre et al. 2009	T2L2 (short term) DORIS & T2L2 (Long term)
Relativity	0.1-0.2	Orbit (113 min)	Petit & Wolf 1994	T2L2
Total Drift	< 22.0 / day	Long term		DORIS & T2L2

Ground-to-space time transfer to a frequency bias seen by T2L2

[Exertier et al. 2010]



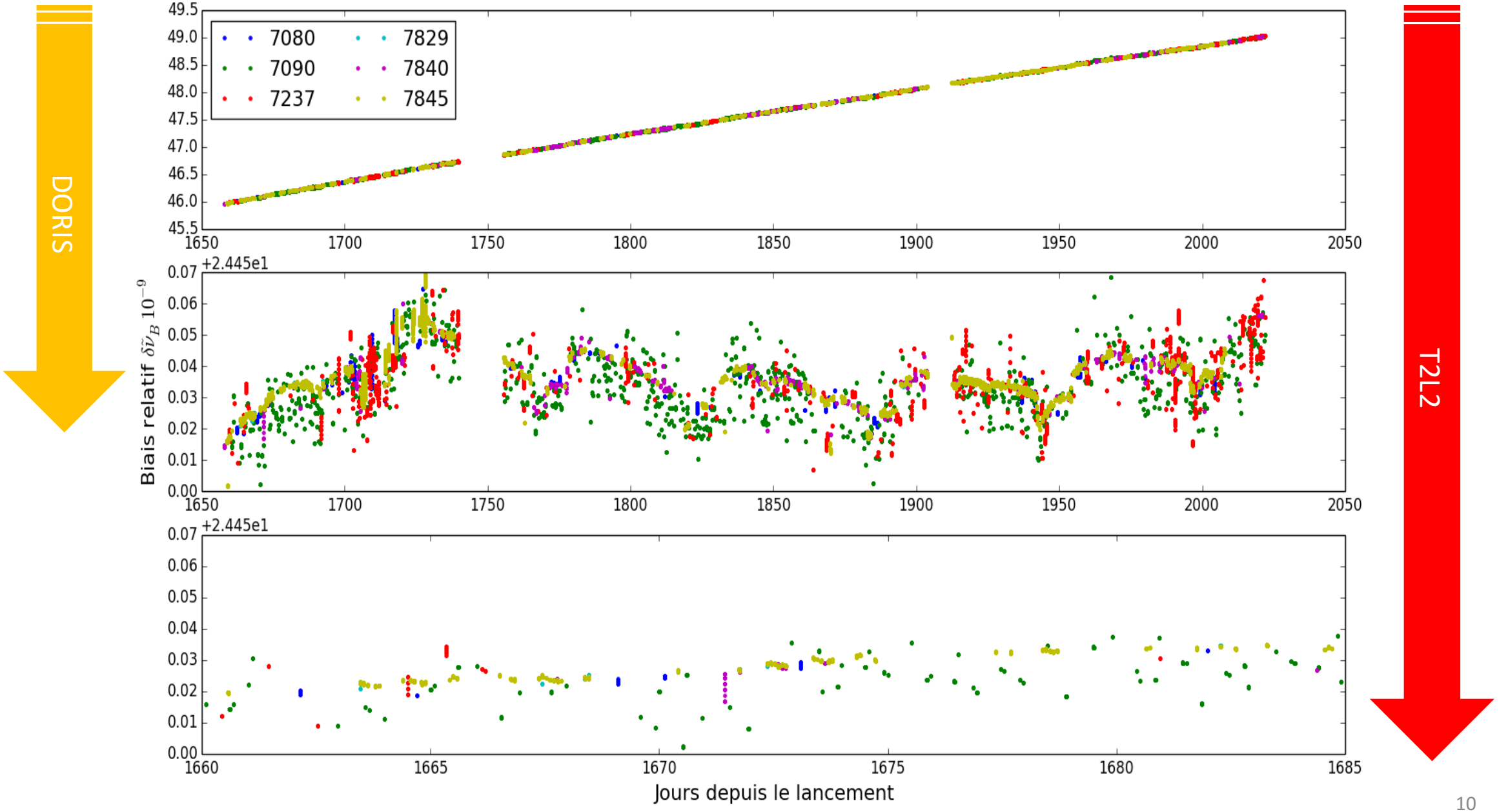
$$\Delta_S^B(t) = t_b - [t_e + D(t)] + \Delta_S^B(t_0)$$

$$\delta\tilde{\nu}_B - \delta\tilde{\nu}_S = \delta\tilde{\nu}_B - \left[\mathrm{d}\tilde{\Psi}_S + \frac{1}{c^2}U_S\right] + \delta\tilde{\nu}_N$$

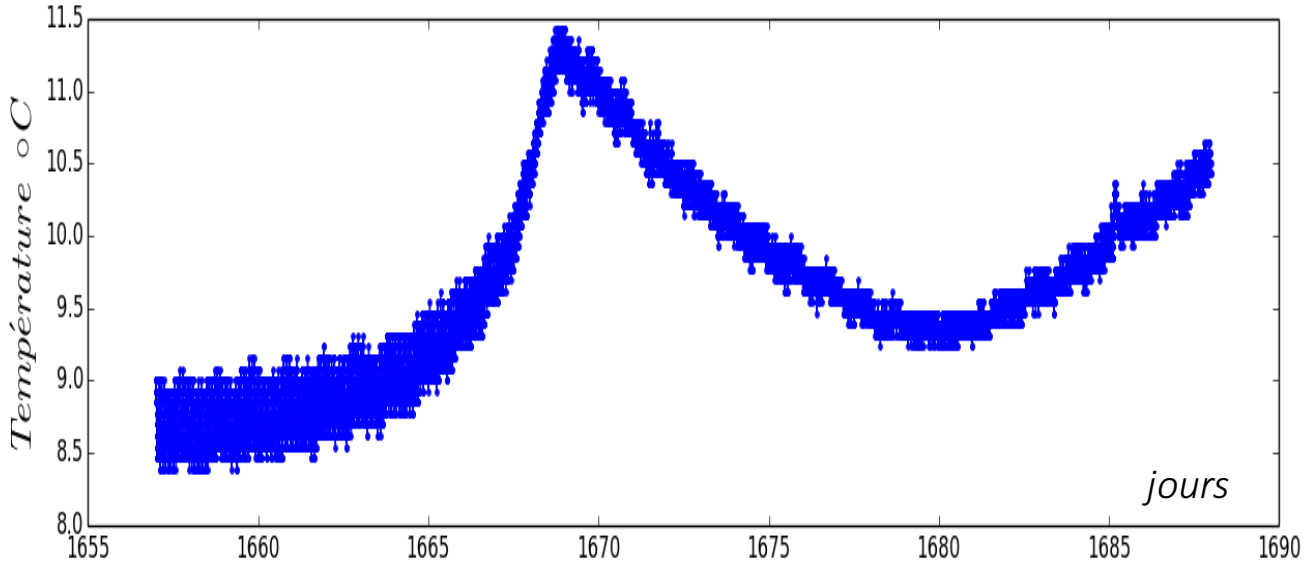
Ground frequency bias

Board frequency bias (unknown)
To be characterised

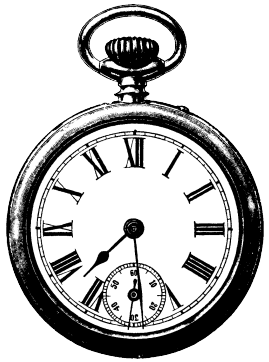
relativity (Einstein effect)


DORIS
T2L2
7080
7090
7237
7829
7840
7845
+2.445e1
+2.445e1
Biais relatif $\delta\tilde{\nu}_B\ 10^{-9}$
Jours depuis le lancement

Temperature (USO)



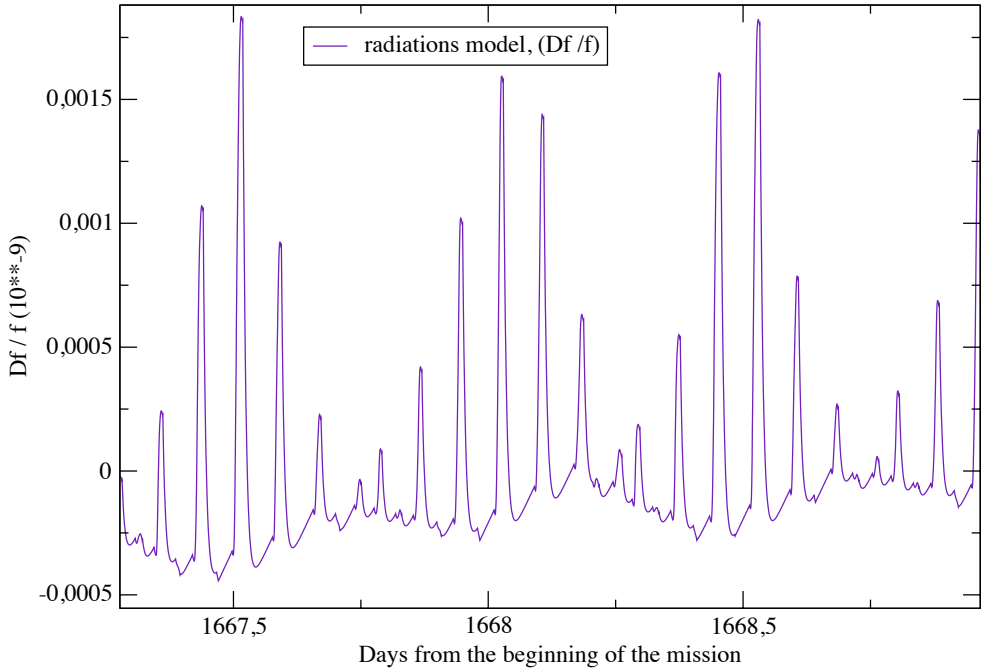
Polynomial, 3 coefficients to be ajusted
Ground studies [Galliou et al. 2007]



Global Drift and Aging

Polynomial, 3 coefficients to be ajusted

Radiations



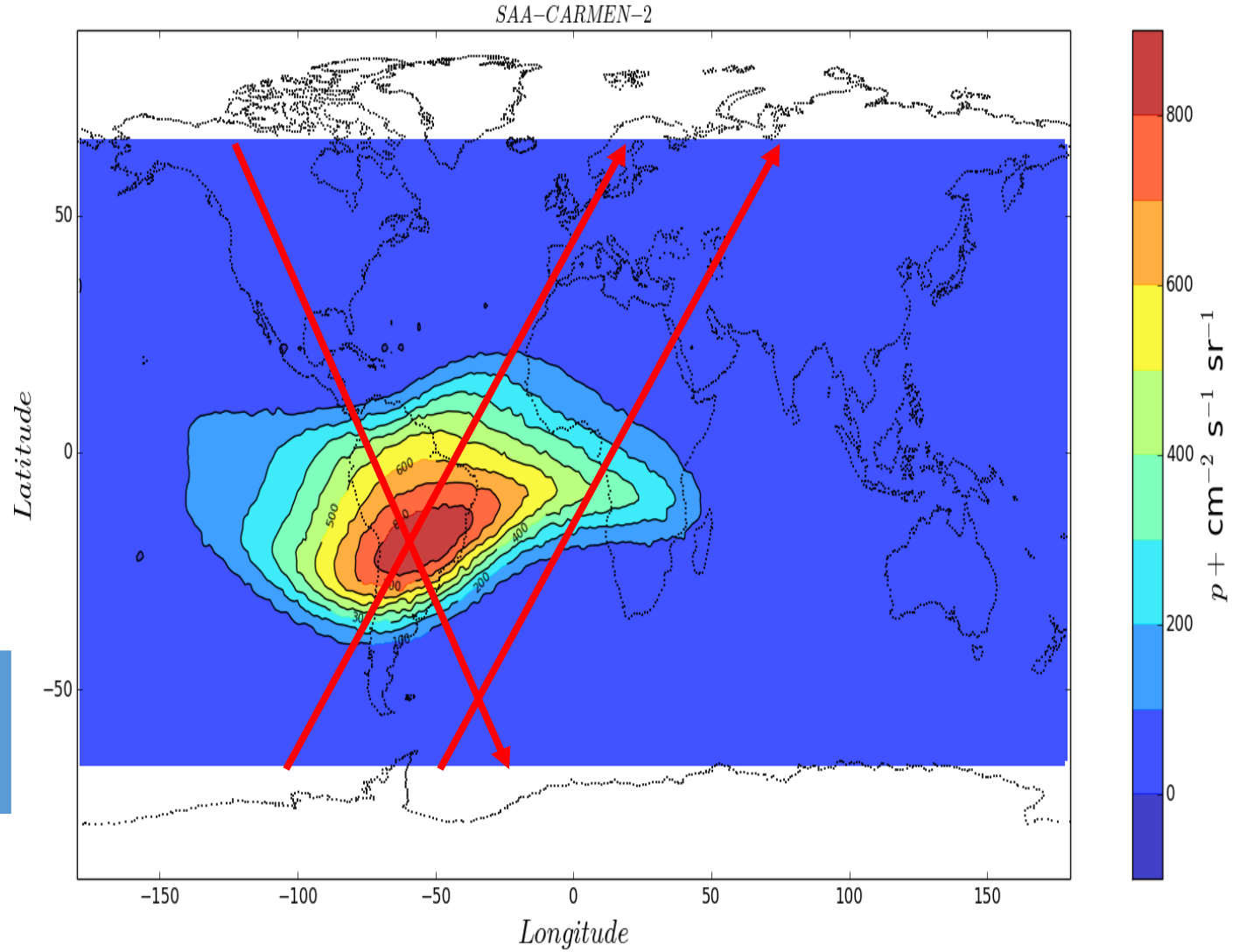
$$\delta\tilde{\nu}_{SAA}(t) = \gamma_1 \int_{t_0}^{t_{SAA}} \gamma_Q D(t)$$

4%

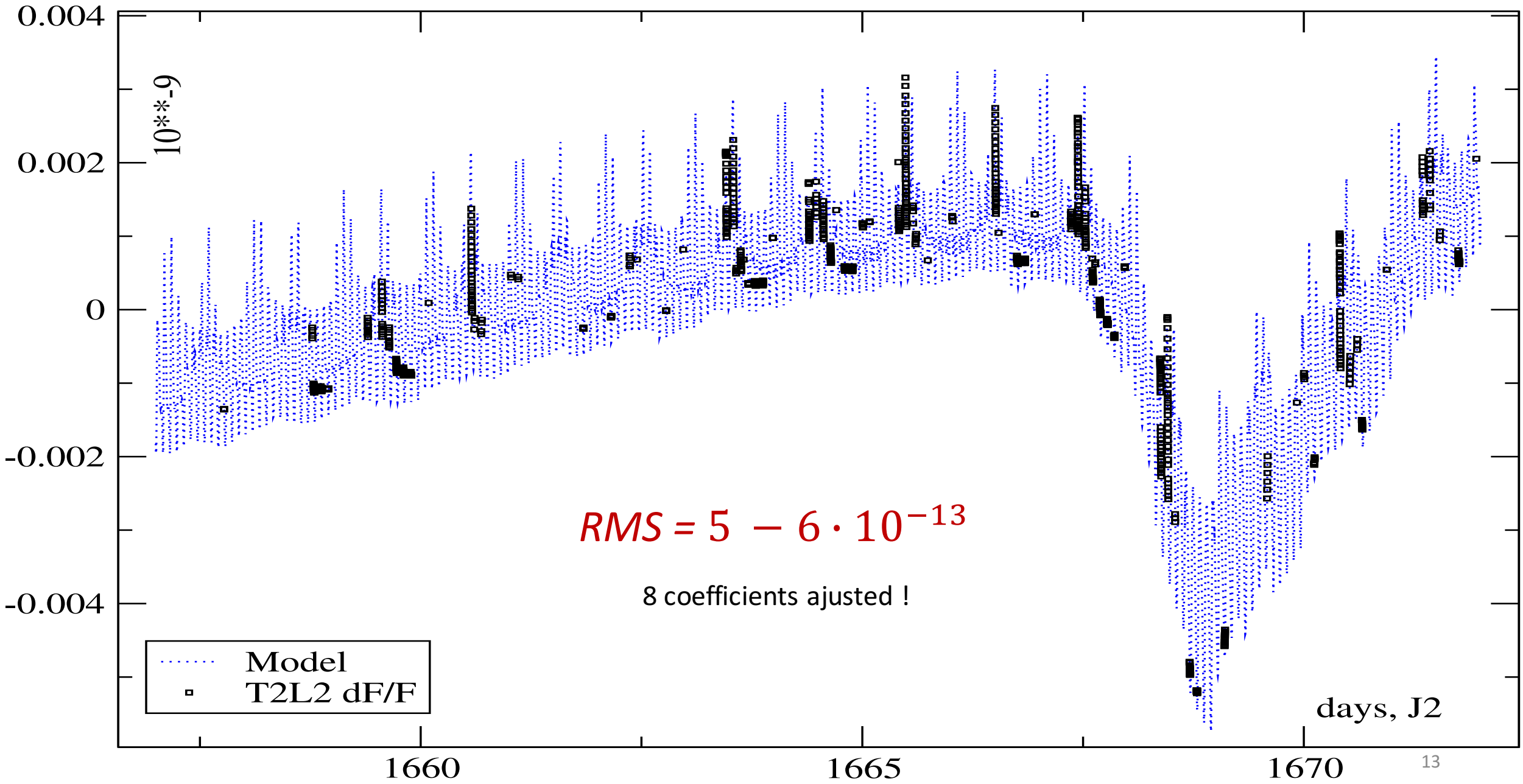
$6.5 \cdot 10^{-12}/rad$	$0.0016\ d^{-1} \cdot 10^{-12}/rad$
A priori	**A posteriori**

$$\delta\tilde{\nu}(t > t_{SAA}) = \delta\tilde{\nu}_{SAA}[\exp^{-\frac{(t-t_{SAA})}{\tau}} + \gamma_2\, t]$$

τ	A priori 10 min	A posteriori 8 min

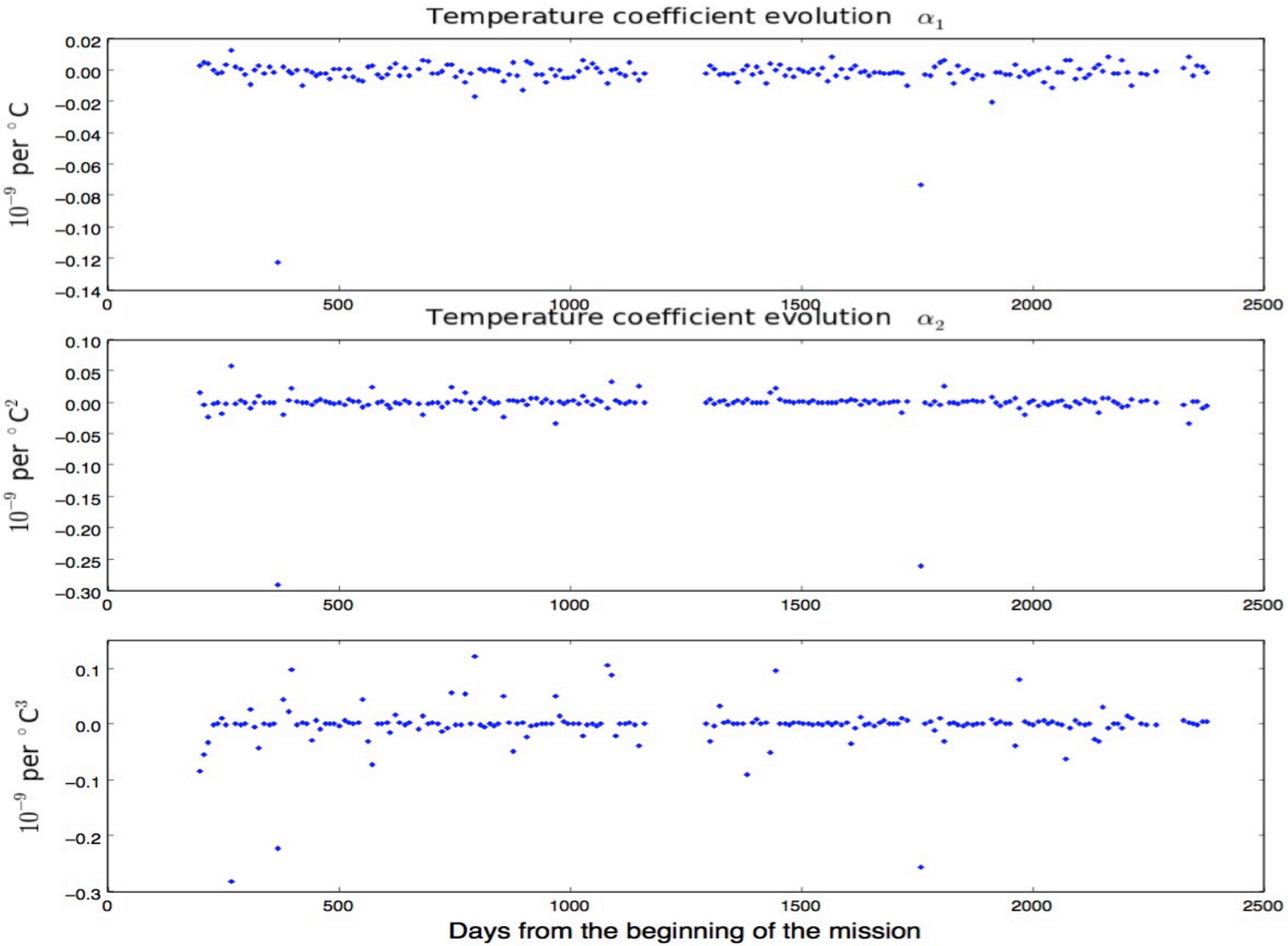


Model



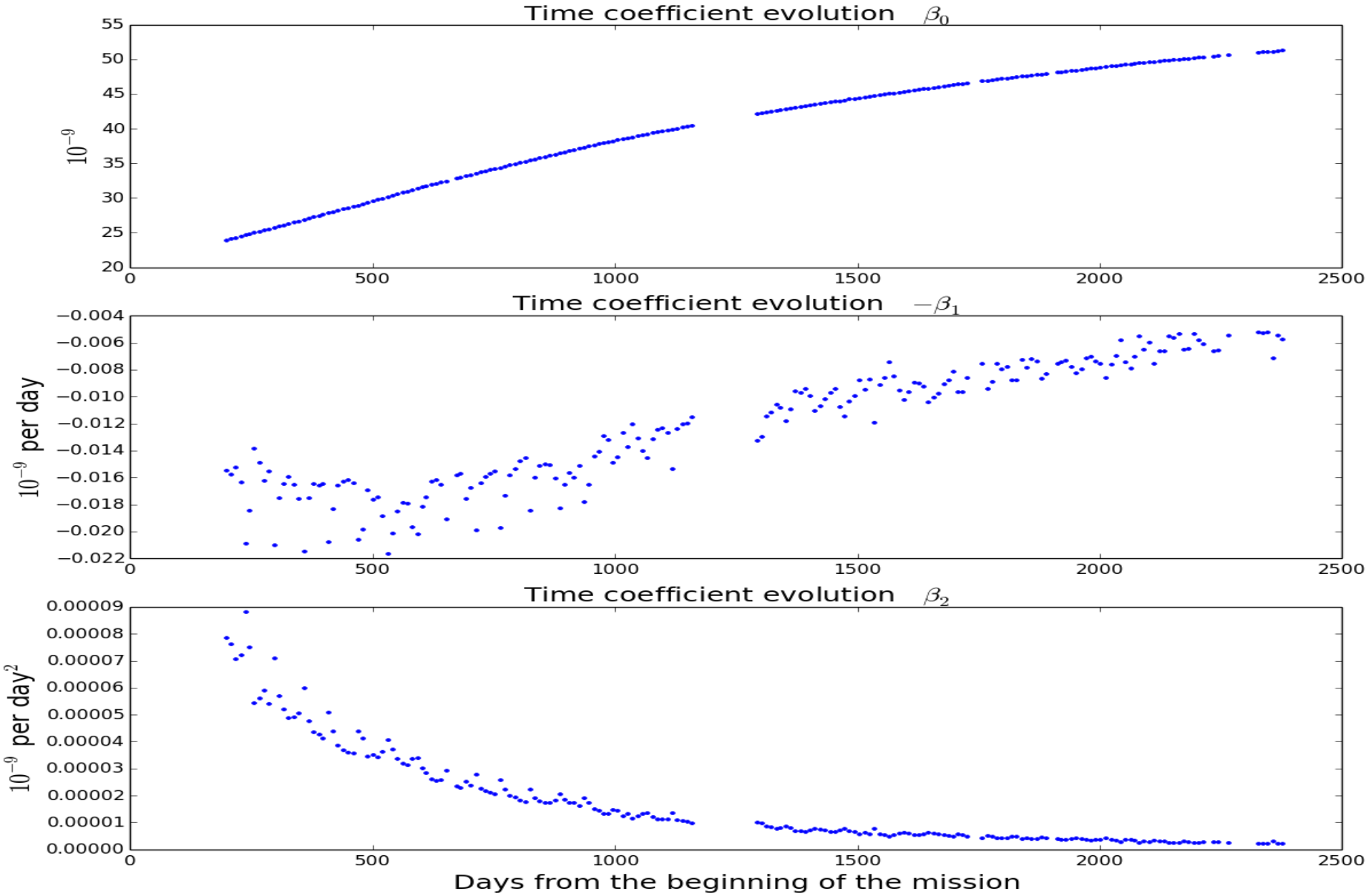
$RMS = 5 - 6 \cdot 10^{-13}$

8 coefficients ajusted !



$a\ priori\ 7 \cdot 10^{-13}/°C$

$a\ posteriori\ -1.2 \cdot 10^{-12}/°C$



$a\ priori\ 20 \cdot 10^{-9}$

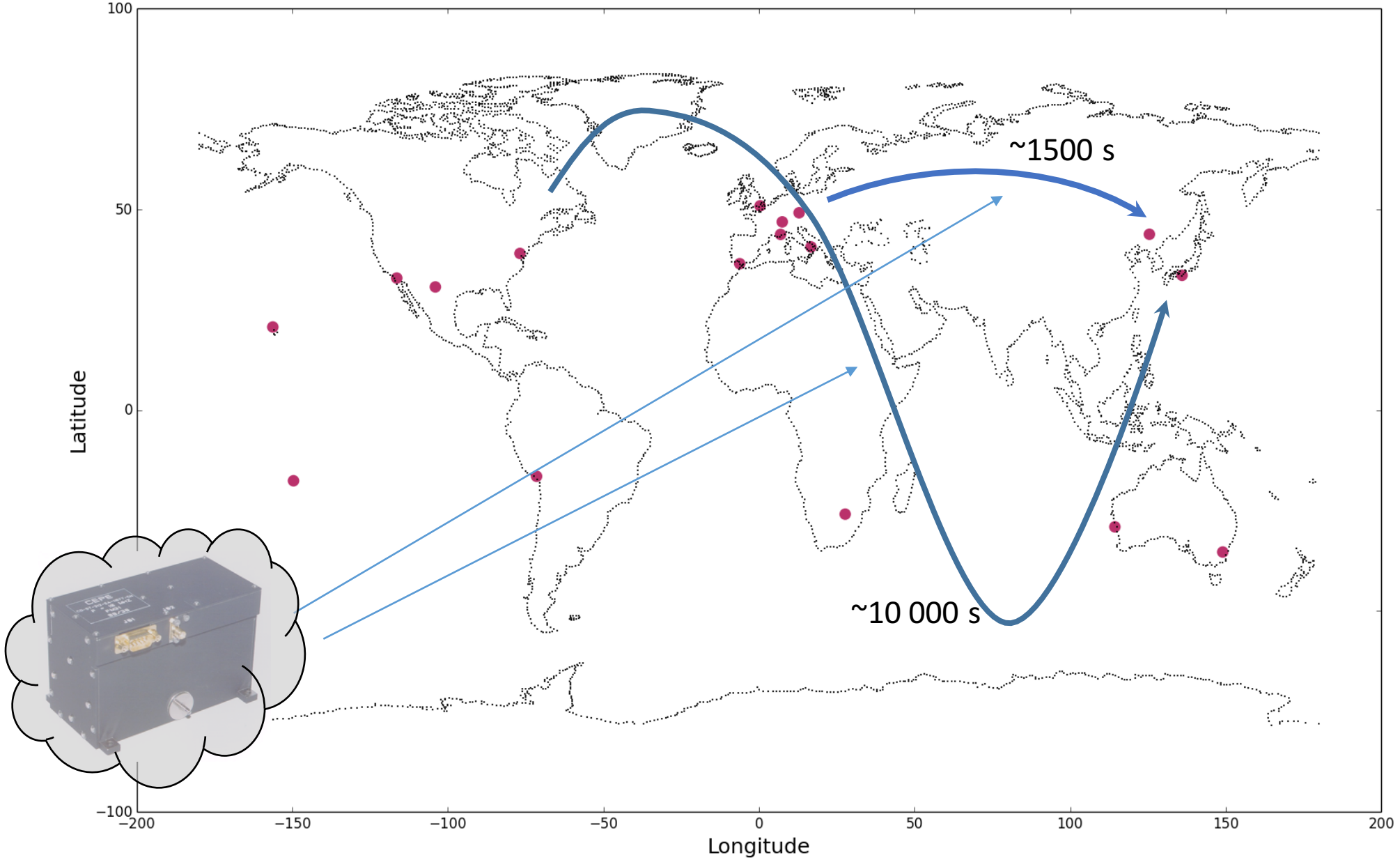
$a\ priori\ 1.9 \cdot 10^{-11}/d^{-1}$

Conclusions…

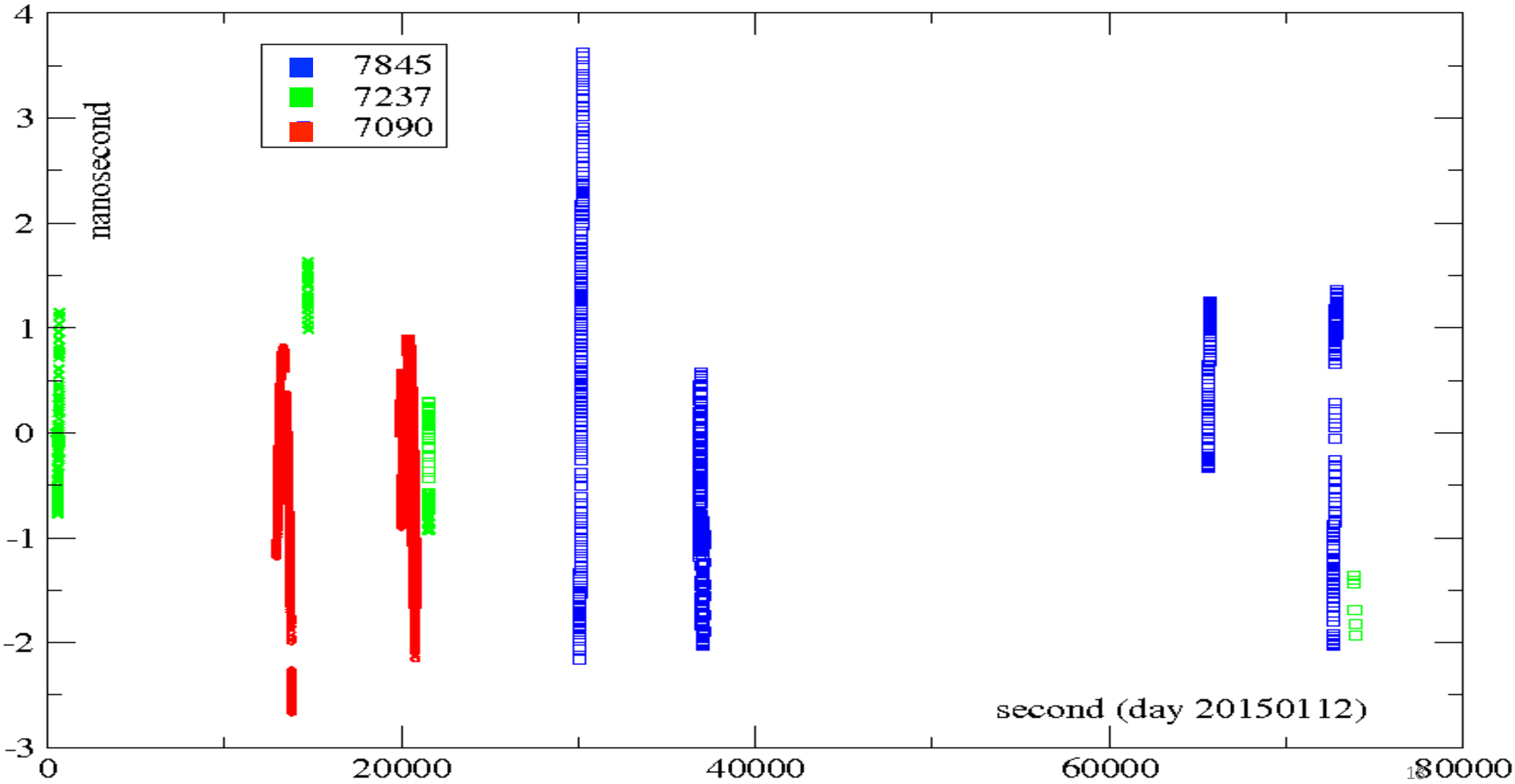
Jason-2

- Model available
- Study of the space environment through the frequency changes on USO
- Comparison and complementarity T2L2/DORIS [Jayles et al. 2016]
- Comparison and complementarity T2L2/CARMEN-2 [Capdeville et al. 2016]
- JASON-2 is sensitive to radiation but not only !!!
- To the non common view !
- To time bias in SLR stations and DORIS beacon positionning !

Non common view



Non common view



Jason-3

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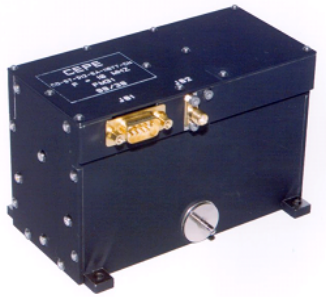
- DORIS (USO)



- CARMEN-3

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Total Drift	< ?? / day	Long term

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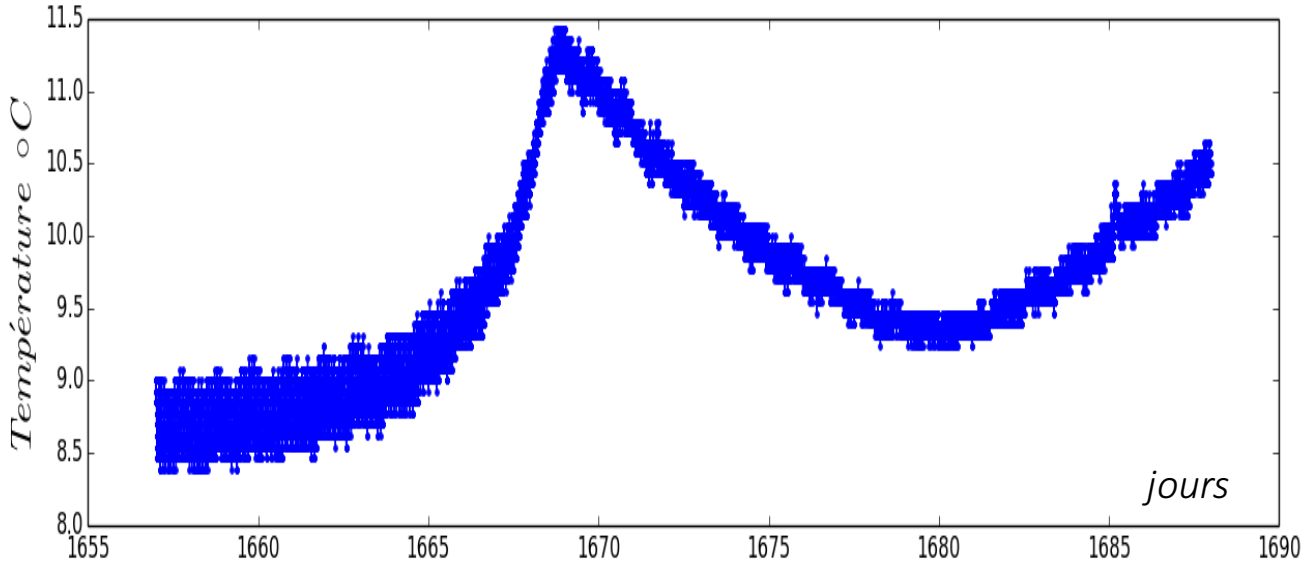

Polynomial, 3 coefficients to be ajusted
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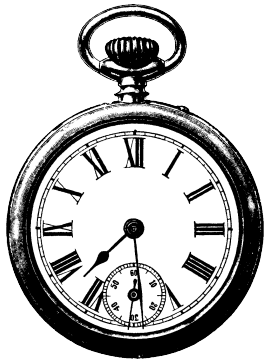


Global Drift and Aging

Polynomial, 3 coefficients to be ajusted

Jason-3 ?

Temperature ? Same, measured on-board
Not a problem, we can use the same analytical representation

Aging ? Same behavior, wait after the heating process or use a logarithm representation at first

Radiations Jason-3

Evolution of the SAA (0.3°/y to west)

~~4%~~ ?

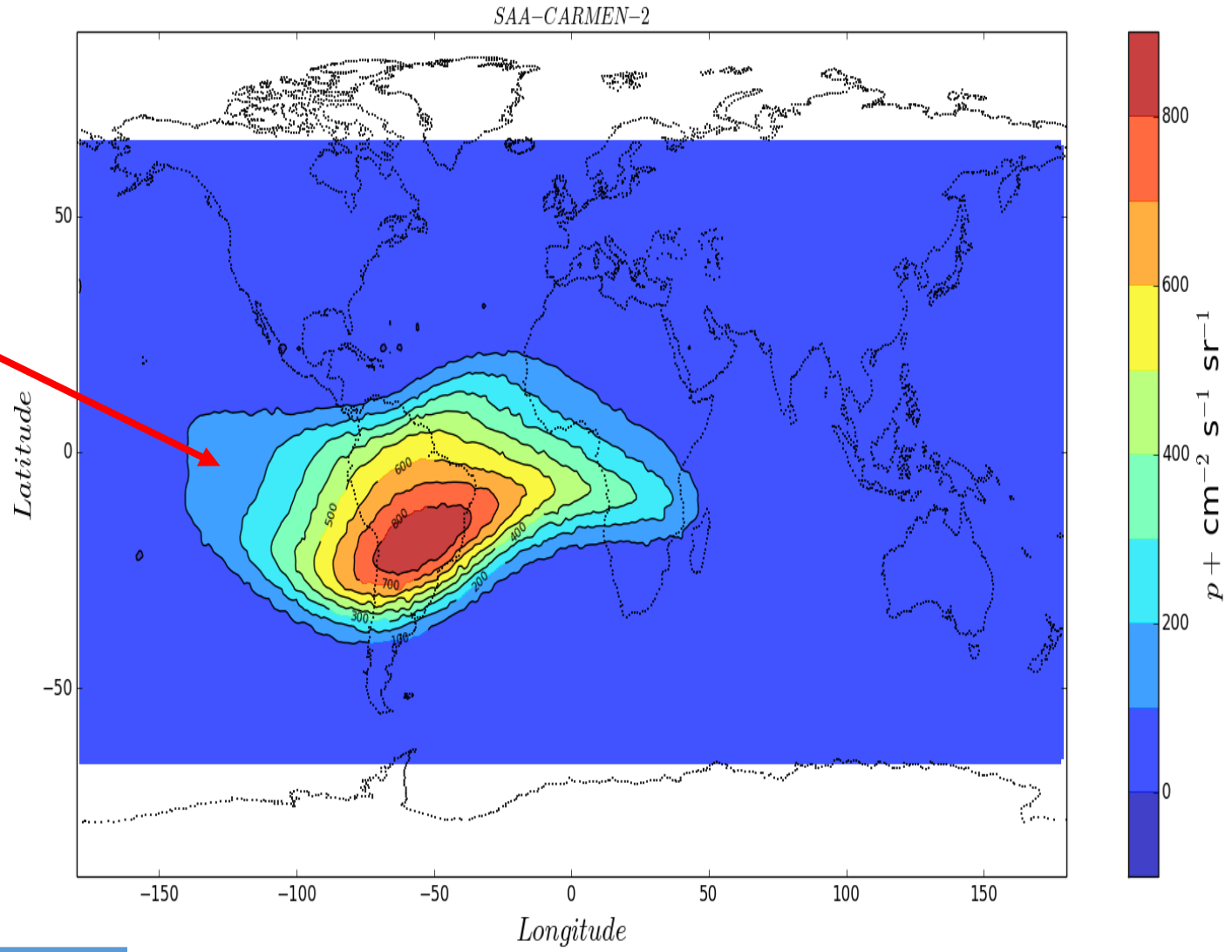
$$\delta\tilde{\nu}_{SAA}(t) = \gamma_1 \int_{t_0}^{t_{SAA}} \gamma_Q D(t)$$

$6.5 \cdot 10^{-12}/rad$

A priori ???? Could change ?

$$\delta\tilde{\nu}(t > t_{SAA}) = \delta\tilde{\nu}_{SAA}[\exp^{-\frac{(t-t_{SAA})}{\tau}} + \gamma_2 t]$$

τ	**A priori 10 min ? Same as J-2 ???**



Jason-3

New studies on Jason-3, knowing Jason-2

But new questions :

- same OUS ?
- same shielding ? → radiations
- same space environment ? Quite the same differents coefficients !! But same process

Merci
Thank you

Looking for a Post-Doc position ! For 2017

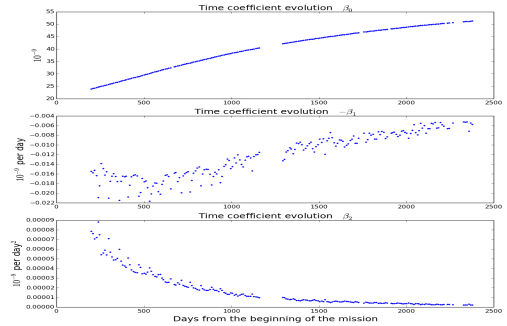
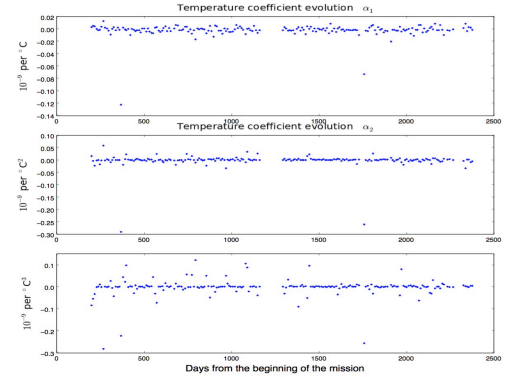
Temperature, radiation and aging analysis of the DORIS Ultra Stable Oscillator by means of the Time Transfer by Laser Link on Jason-2

Alexandre Belli, Pierre Exertier, Etienne Samain, Clément Courde, François Vernotte, Christian Jayles et Albert Auriol

Advance in Space Research 2015

belli@geoazur.unice.fr

http://www.geoazur.fr/t2l2/en/data/v4/

Modèle	coefficients	A priori	A posteriori	commentaires
Dérive	β_0	$20 \cdot 10^{-9}$		ajusté
	β_1	$1.9 \cdot 10^{-11}/d^{-1}$		ajusté
	β_2	0.0		ajusté
Température	α_1	$7 \cdot 10^{-13}/°C$		ajusté
	α_2	0.0		ajusté
	α_3	0.0		ajusté
Radiations	γ_1	$6.5 \cdot 10^{-12}/rad$	$0.0016\ d^{-1} \cdot 10^{-12}/rad$	ajusté
	γ_2		0.0	fixé
	γ_3		0.05%	fixé
	τ	10 min	8 min	ajusté