Time Transfer by Laser Link

Preliminary results of the correlation between T2L2 and DORIS

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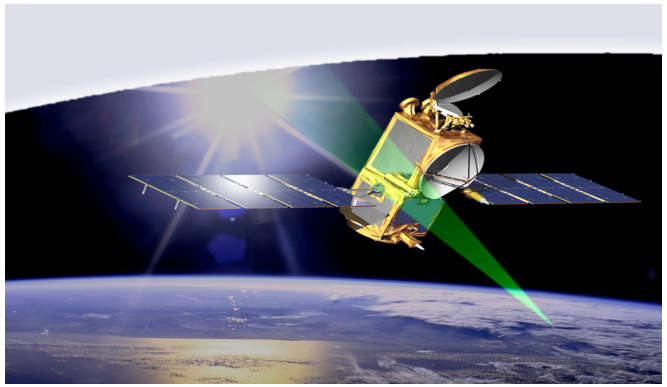


New DORIS applications & products

IDS Workshop, October, 21-22 2010, Lisbon Portugal

Scientific activities

I-Data Processing -> available on the web, see **https://t2l2.oca.eu/**

IIa-Time Transfer :

- ground-board : 50 ps @ 1 sec then 7-15 ps @ 20-30 sec
- ground-ground : common view (-> dedicated campaigns, Obs.Paris // Grasse, others...)

IIb-Time scale : OUS <-> SLR stations (UTC) => on board dates ~10nsec

IIIa-Space techniques :

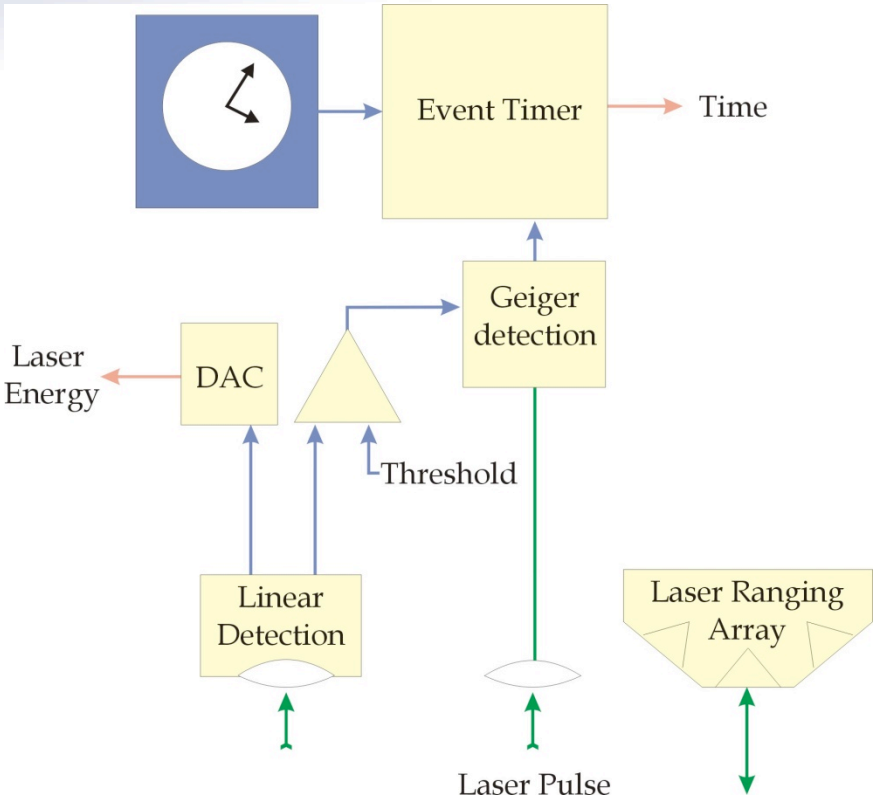
- *DORIS - T2L2 : monitoring of USO frequency $<10^{-12}$ / ±10 ps @20 sec*
- *Laser - T2L2 : re-estimation of 1-way links (t_B-t_S at 10 ps)*

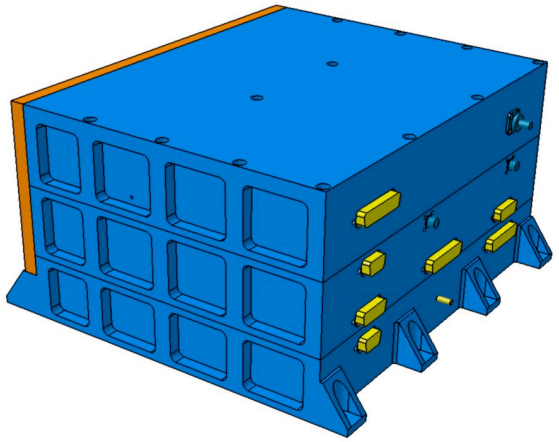
IIIb-Energy budget & atmosphere :

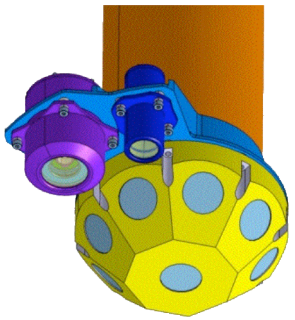
- *Laser : energy measured on board -> atmosphere and ground instrument*
- *tropospheric correction: 1-way measures < 15 deg elevation*

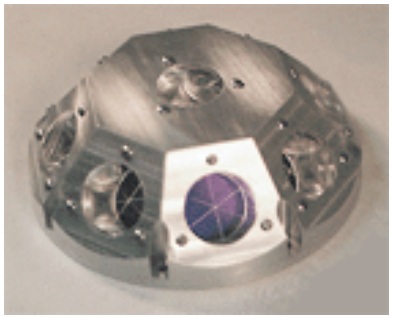
IV-Fundamental Physics

Instrumental payload on J2









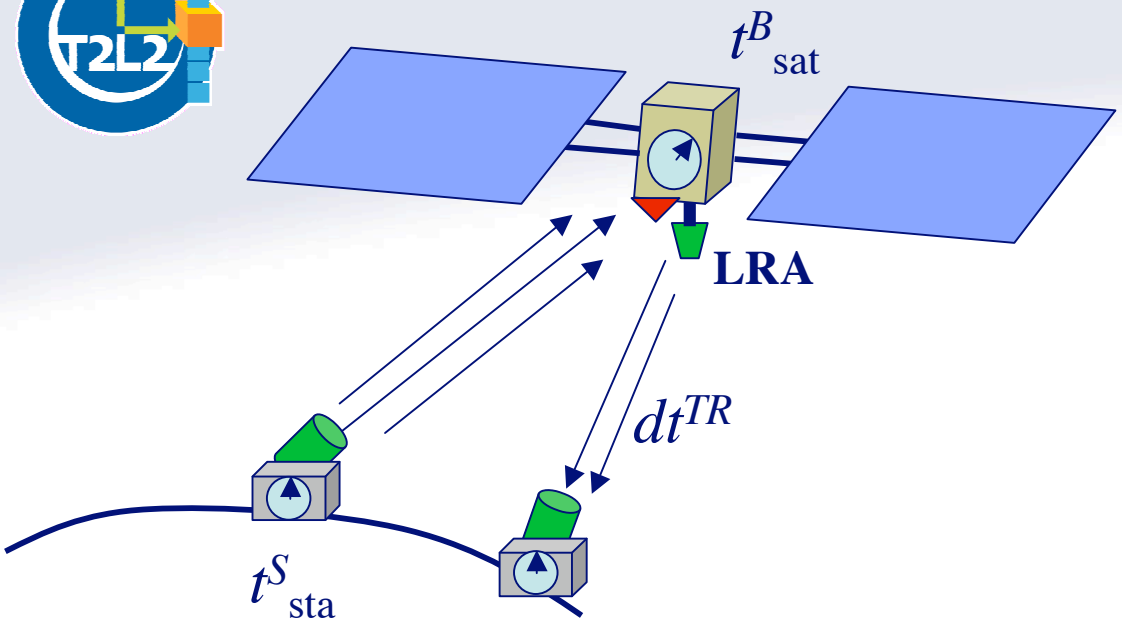
⇨ Masse : 8 kg (électronique) + 1.1 kg (optique)

⇨ Consommation : 42 W

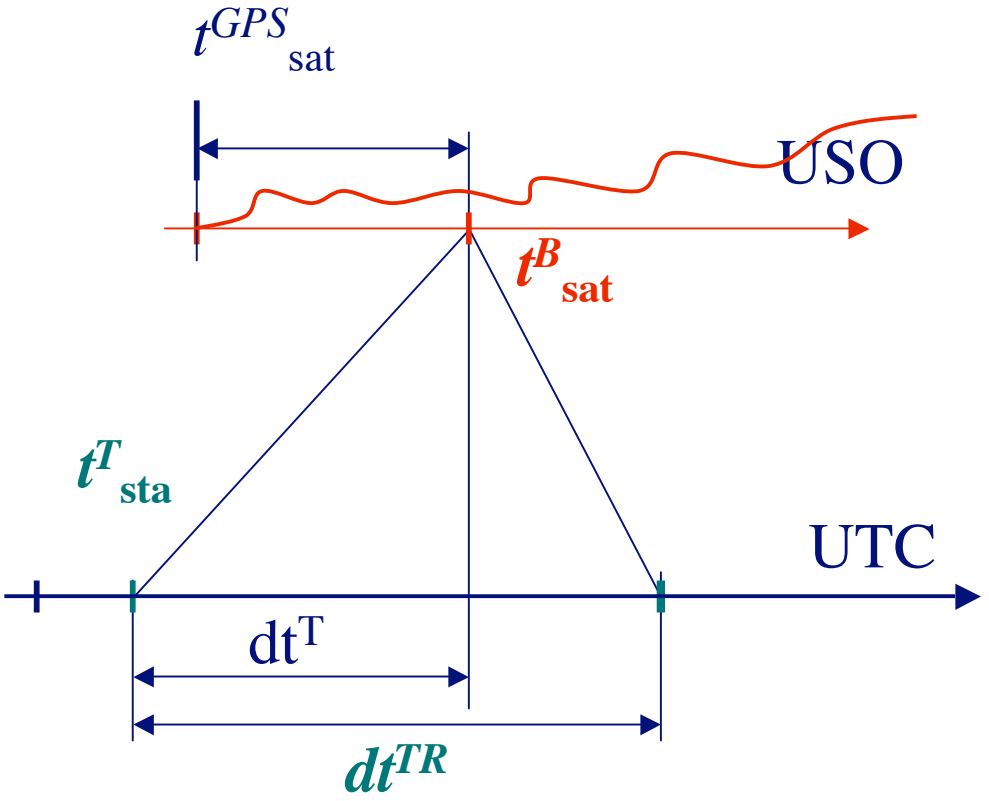
⇨ Volume : 270x280x250 mm^3 // Ø 30x95 // Ø62x100

Earth

Principle



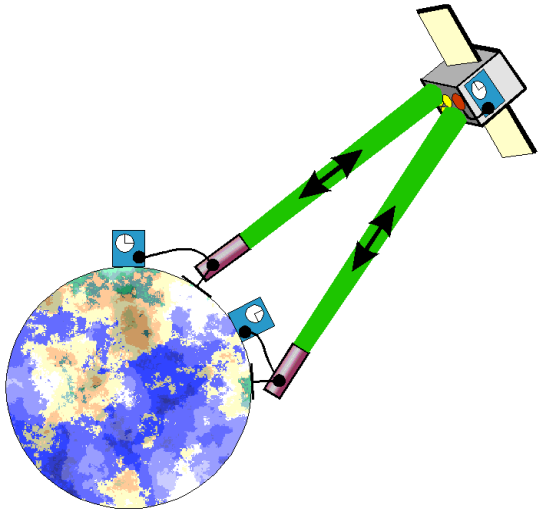
$$t^R_{sta} = t^S_{sta} + dt^{TR}$$



t^T_{sta} , dt^{TR} , t^R_{sat} : measured quantities
= « triplet »
(dt^T is computed from dt^{TR})

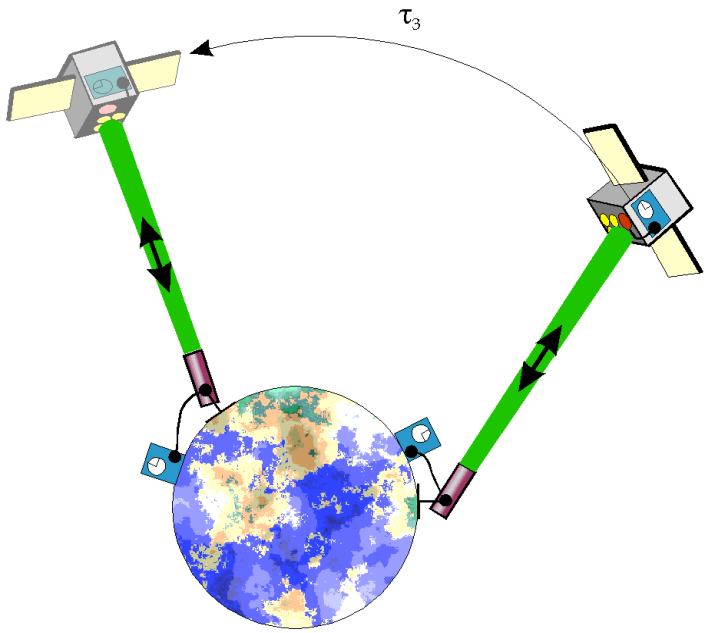
$$X_A = \frac{t_S + t_R}{2} - t_B + \tau_{\text{Relativity}} + \tau_{\text{Atmosphere}} + \tau_{Instrument}$$

Principle (2)



Common view configuration

On-board oscillator noise $\sigma_x(0.1\ s)$



Non common view configuration

On-board oscillator noise $s_x(t_3)$:

20 ps @ 100 s ; 500 ps @ 1000 s ; 20 ns @ 10 000 s

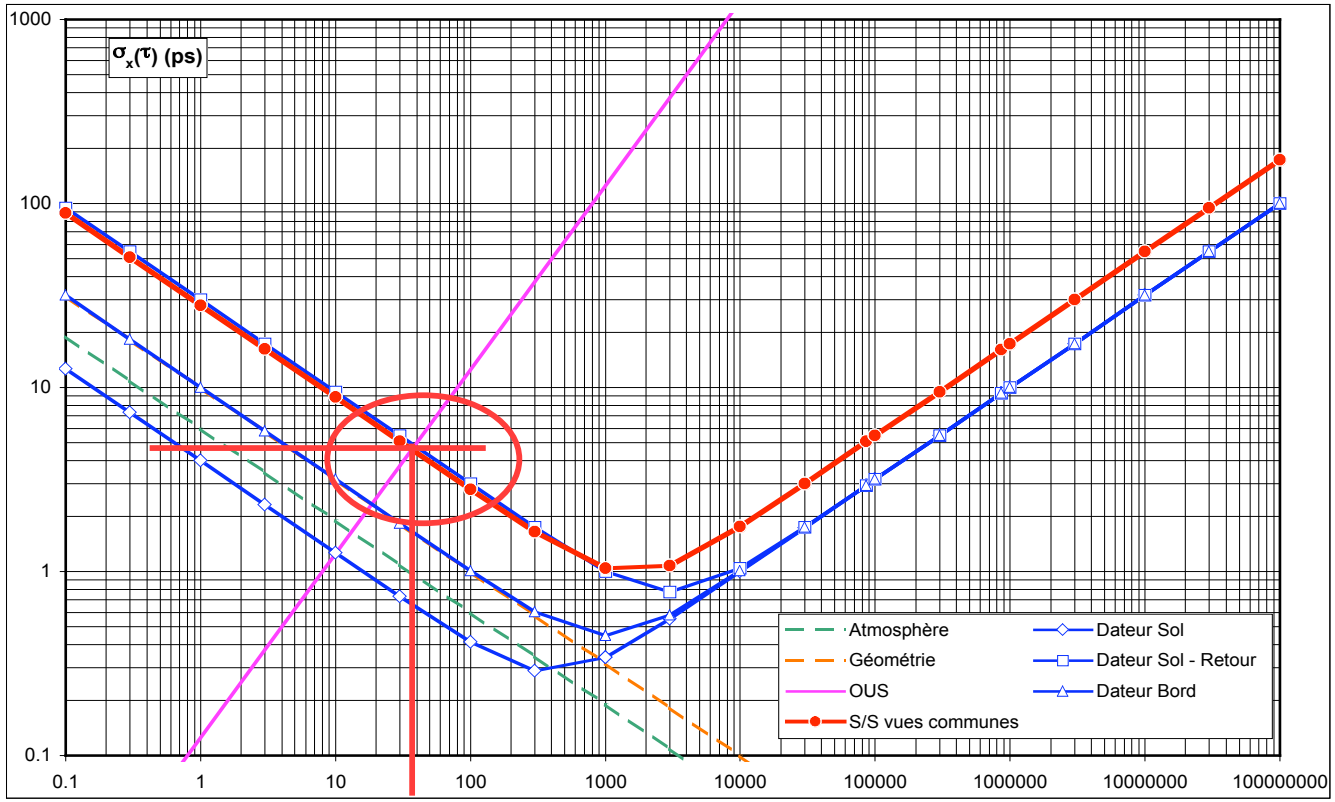
$$\sigma_x^2(\tau) = \left(2.10^{-14} \times \tau^{+3/2}\right)^2$$

Expected stability & noises

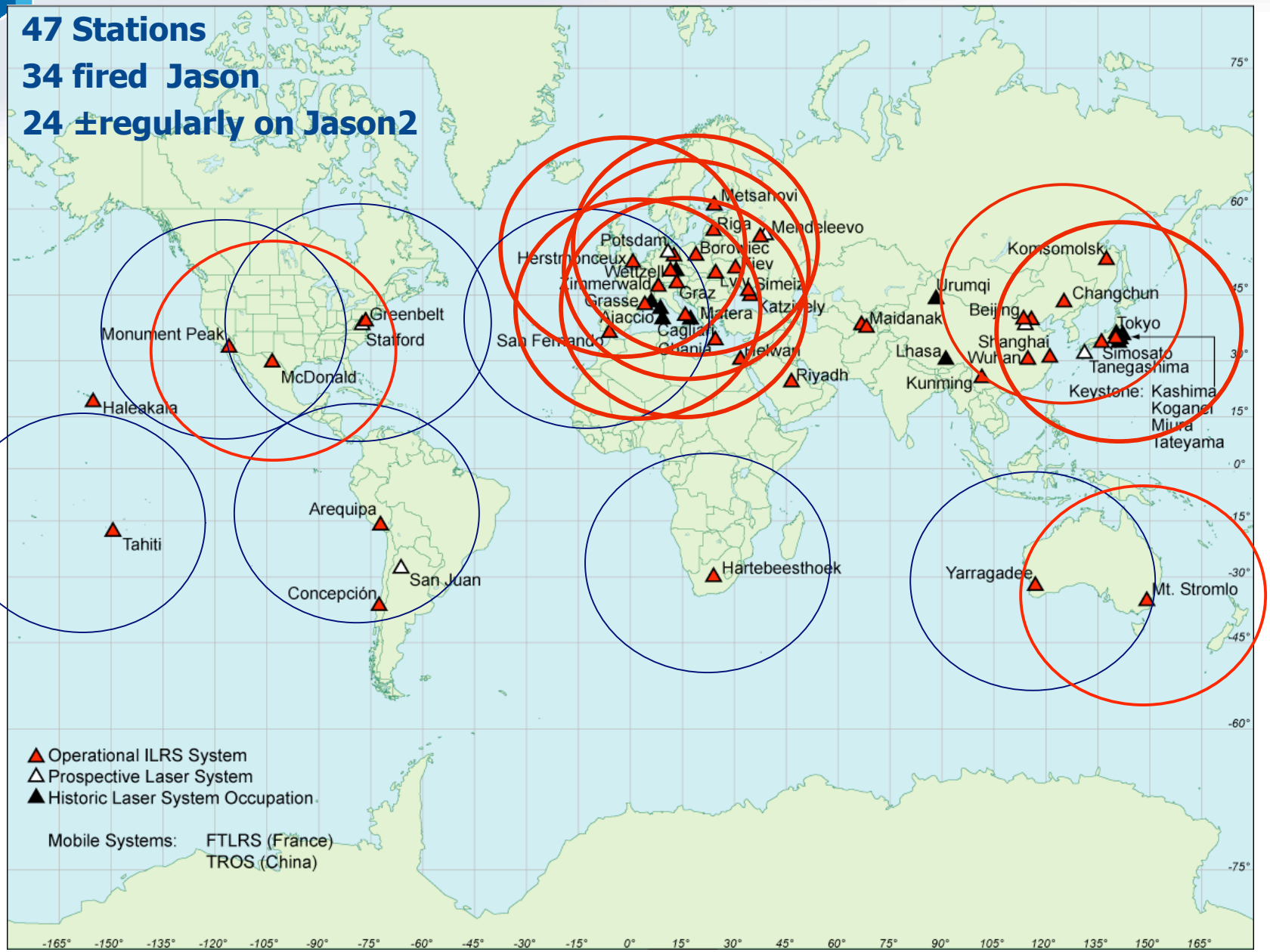
_ **Validation of the optical link :**

- $\sigma_x^2(\tau) = \left(28.10^{-12} \times \tau^{-1/2}\right)^2 + \left(17.10^{-15} \times \tau^{+3/2}\right)^2 \qquad \tau_0 = 0.1\ \mathrm{s}$
- $\sigma_y(\tau) = 0.4\ 10^{-13} \tau^{-1/2}$ **for τ > 10000 s**

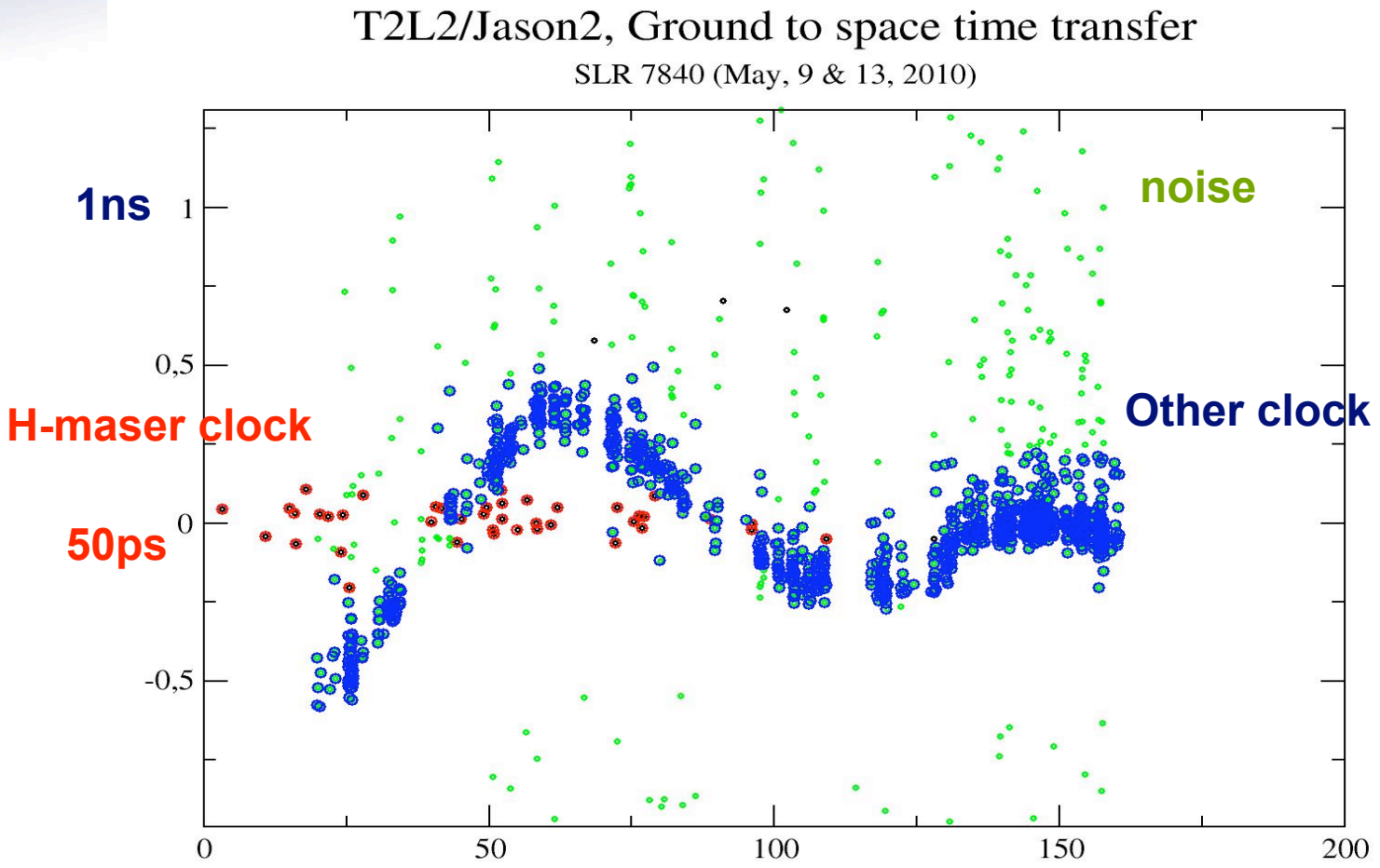
- **accuracy < 100 ps**



ILRS laser network



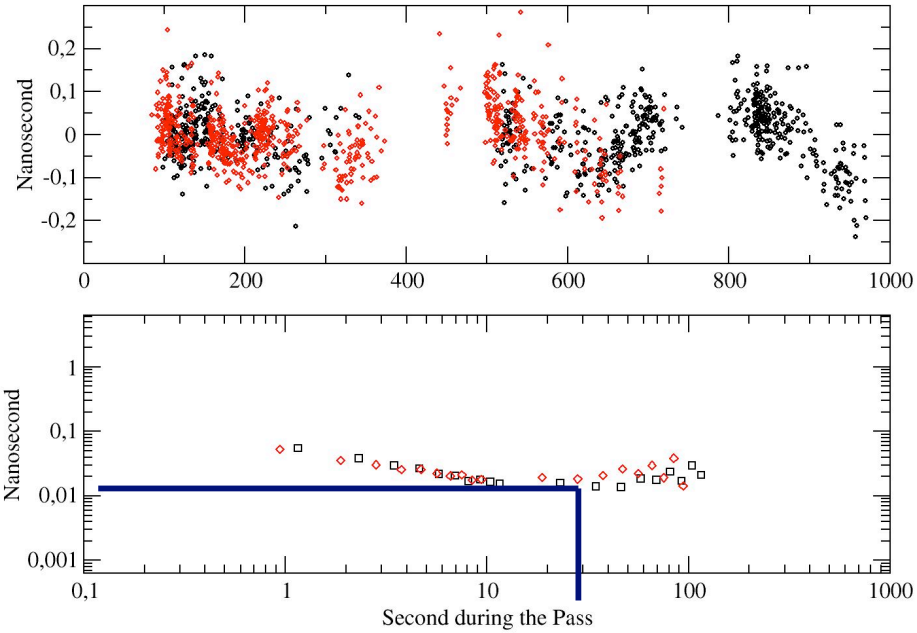
Ground to space TT (*outliers and ref. clocks*)



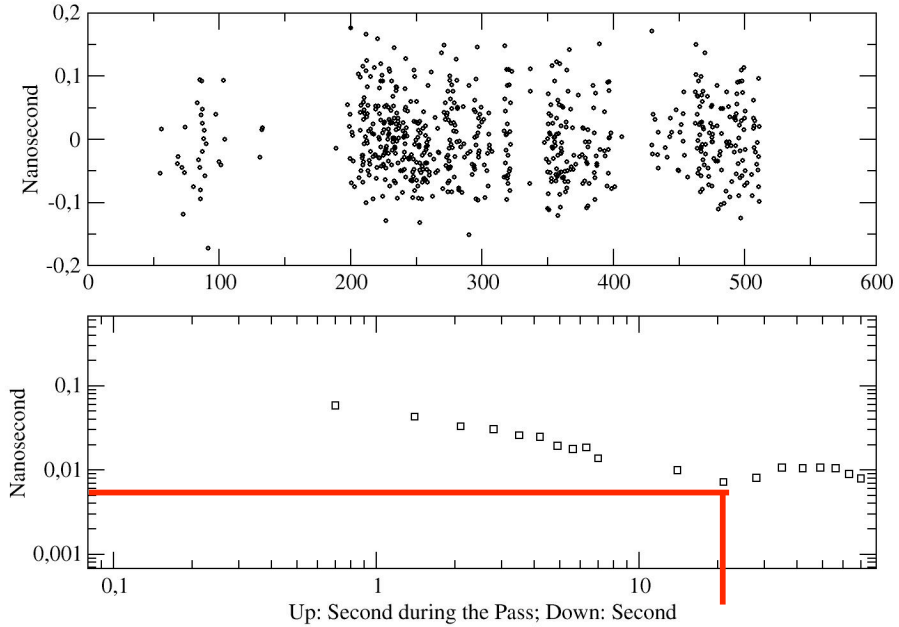
Ground to space TT (Grasse, *Cesium and H-maser*)

Cesium clock (-> May 2010)

12 ps @ 30sec

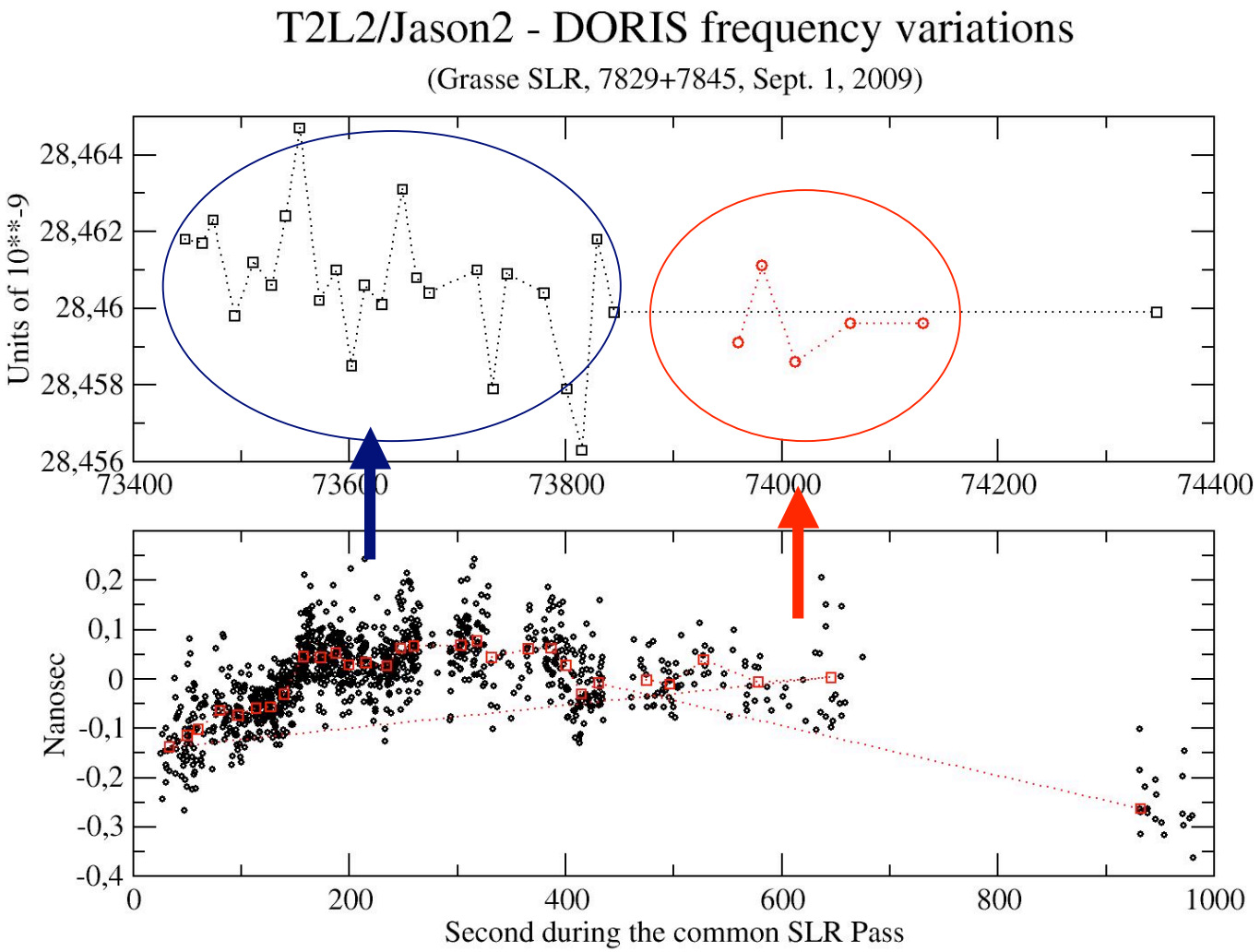


H-maser clock (May 2010 -> ...)



7-8 ps @ 20 sec

From phase to frequency



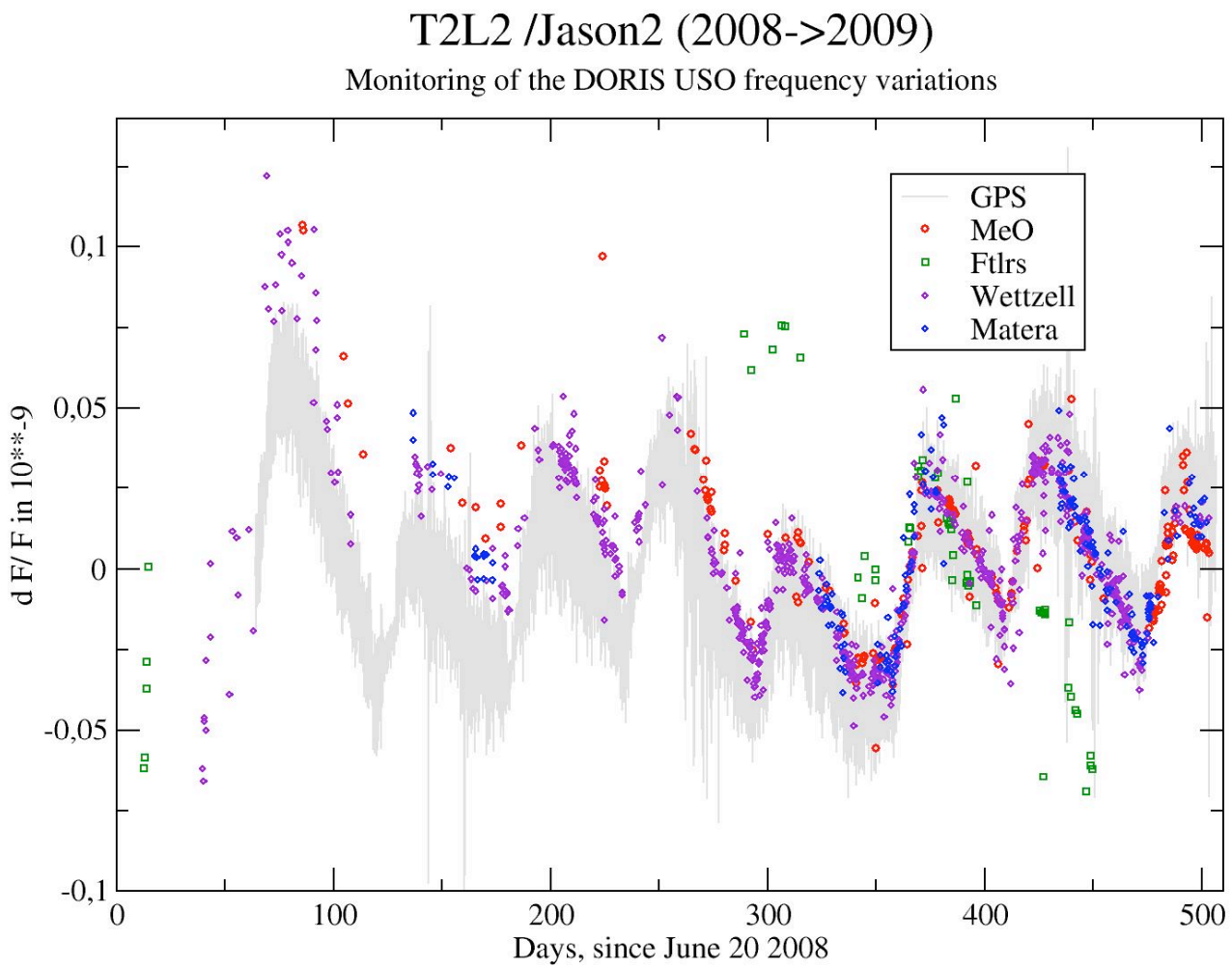
SLR 7845

FTLRS 7829

~5.10^{-13}

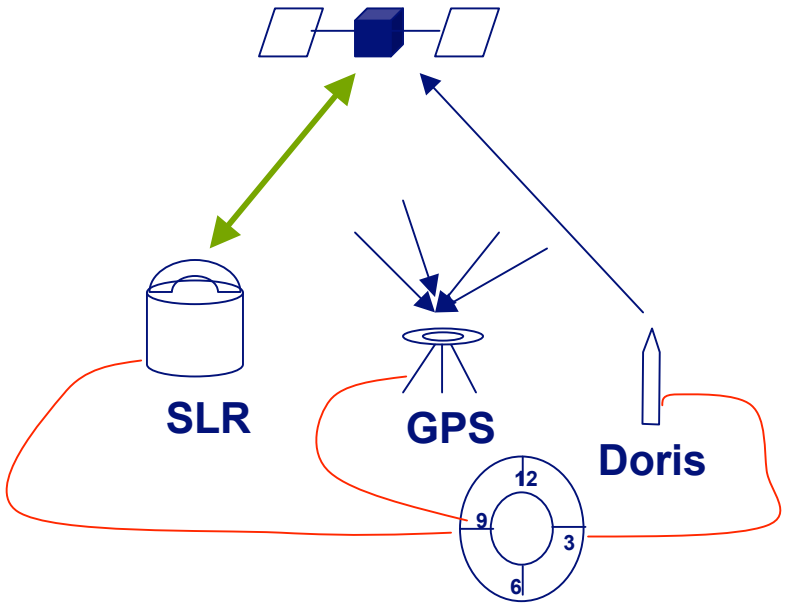
~10ps @ 20 sec

First T2L2 estimates of DORIS USO

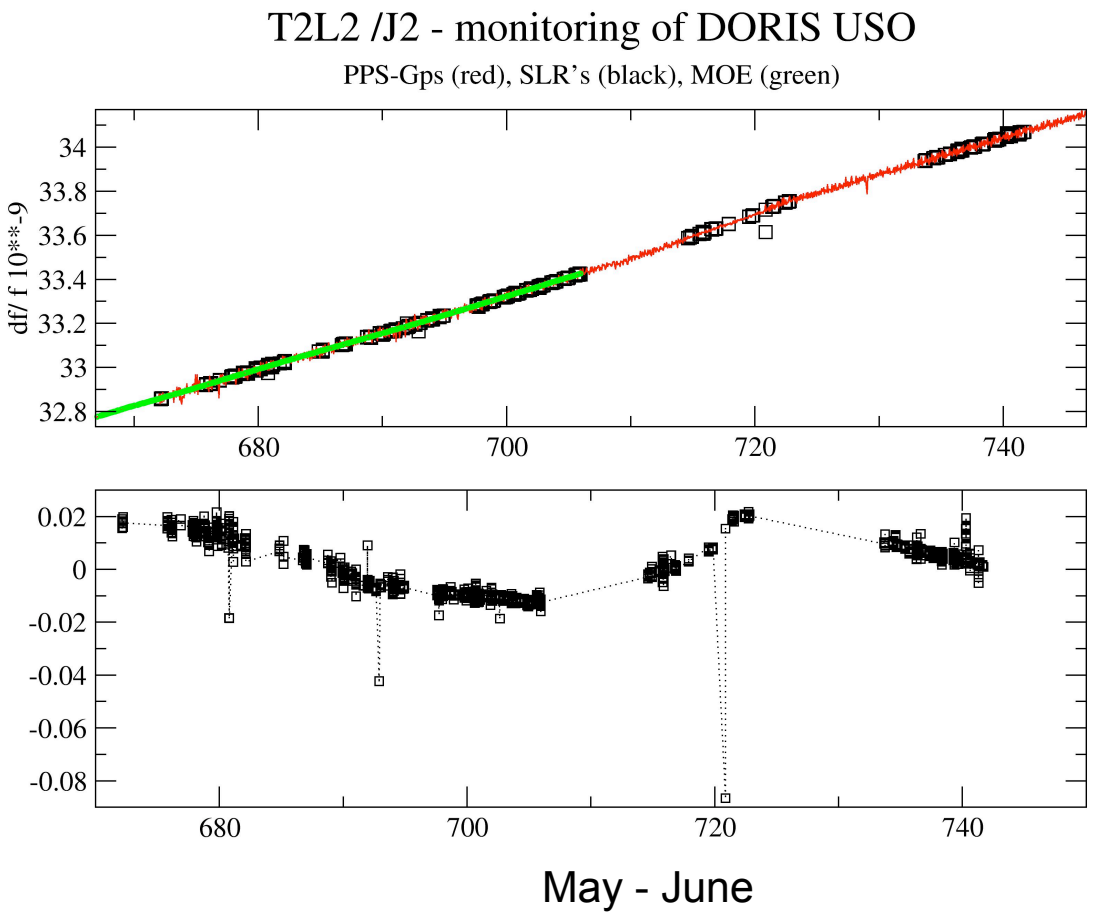


T2L2 estimates (2)

From May to Oct. 2010



Grasse ground clock: H-maser

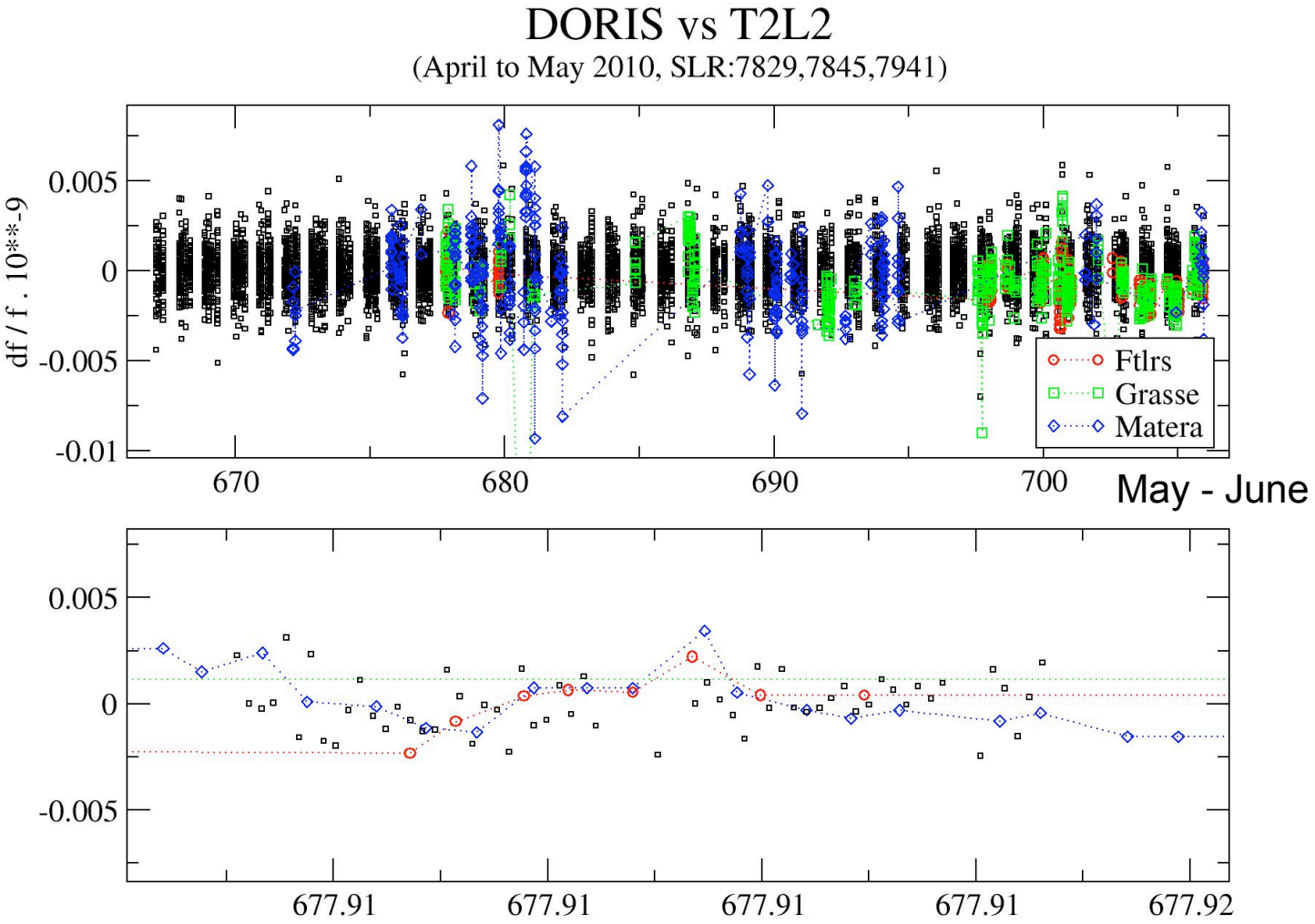


May - June

T2L2 estimates (3)

Doris orbit residuals (from MOE ephem.) are converted to *df/f* (via *dv/c*):

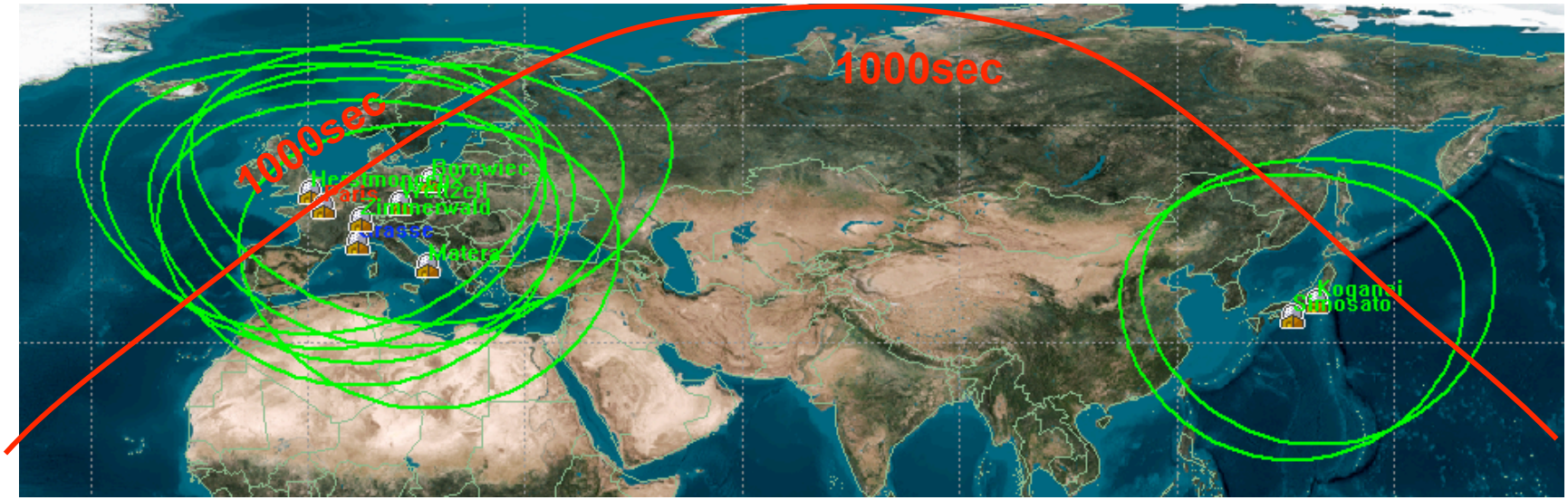
0.3mm/sec ~ 10^{-12}



Campaigns

Second international T2L2 Campaign (June->Oct. 2010) :

- **8 stations involved, in Europe (with FTLRS in Paris) and Asia**
- **Observation planning : 4-5 pass per day above each station**
  - In commun view configuration above Europe or Asia
  - On common orbit between Europe and Asia per day
- **Campaign from June to October :**
  - About 1.000 passes from the 8 stations involved,
  - 450 passes in common view between at least 2 stations
  - % of laser shots detected / identified on board from 10 to 90%, depending on the station



Conclusion

T2L2 performances have been verified; they are in agreement with expected quantities:

-> ground to space : 7-8ps @ 20 sec

-> ground to ground : 20ps @ 45 sec and accuracy < 100ps

ILRS stations (20-24 stations) are participating to T2L2 in sending full rate data:

-> 9-10 stations have the potentiality of TT (stability of a few ps over 1000sec)

-> from which, 7 stations are currently OK

T2L2 data are able to « measure » the on board USO at 10^{-12} and less

Fine comparison of DORIS and T2L2 at Grasse (with H-maser clock) has to be confirmed (an atomic clock is monitoring our H-maser)

TT in non common view has to be improved (model of USO, ...)

Calibration (1-way) of SLR equipments should be realized to permit UTC diffusion (including for on-board dates)