

Time Transfer by Laser Link : first results



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IDS Meeting, November 14 2008, Nice



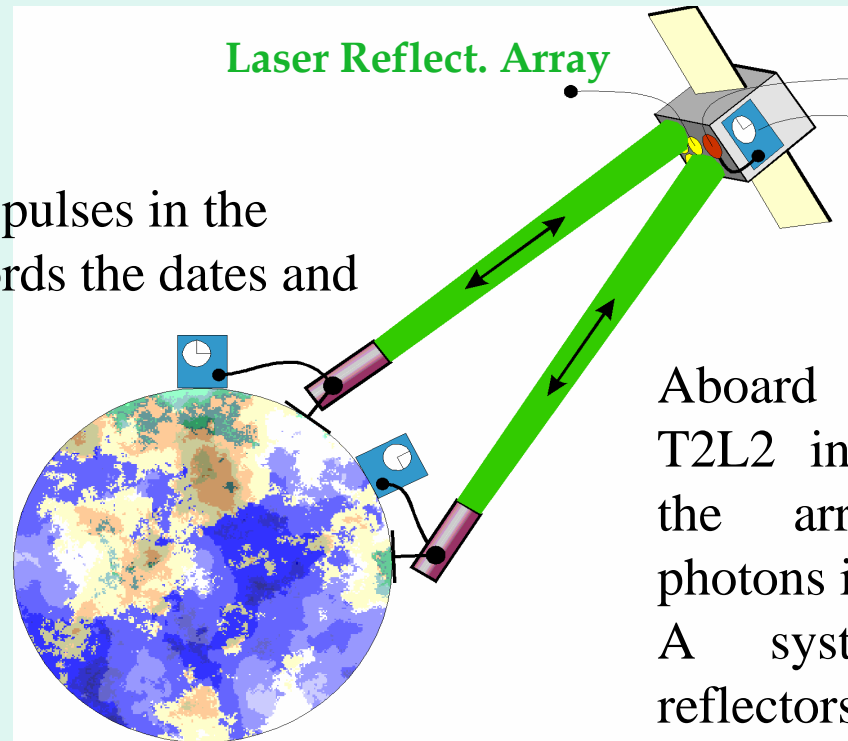
Objectives

- Time Transfer experiences :
 - » ground to board AND between ground stations in common (and non common) view
- 'Monitoring' of the DORIS USO
 - » from several 10 of seconds
 - » correlation with CARMEN-2 data (SAA area)
- Improvement of SLR data for orbitography
 - » using the on-board dates and full rate data
 - » test of 1 way pseudo-range for contributing to POD
- Fundamental physics : anisotropy of the speed of light
 - » at the level of $2,7 \cdot 10^{-9}$, but with the USO limitations
 - » fine structure constant α
 - » possibility of comparing frequencies at $5 \cdot 10^{-17}$ over 10 days of integration in common view
 - » measurement limited by ground clocks quality



Principle

A ground station fires laser pulses in the satellite's direction and records the dates and local times of the firings.

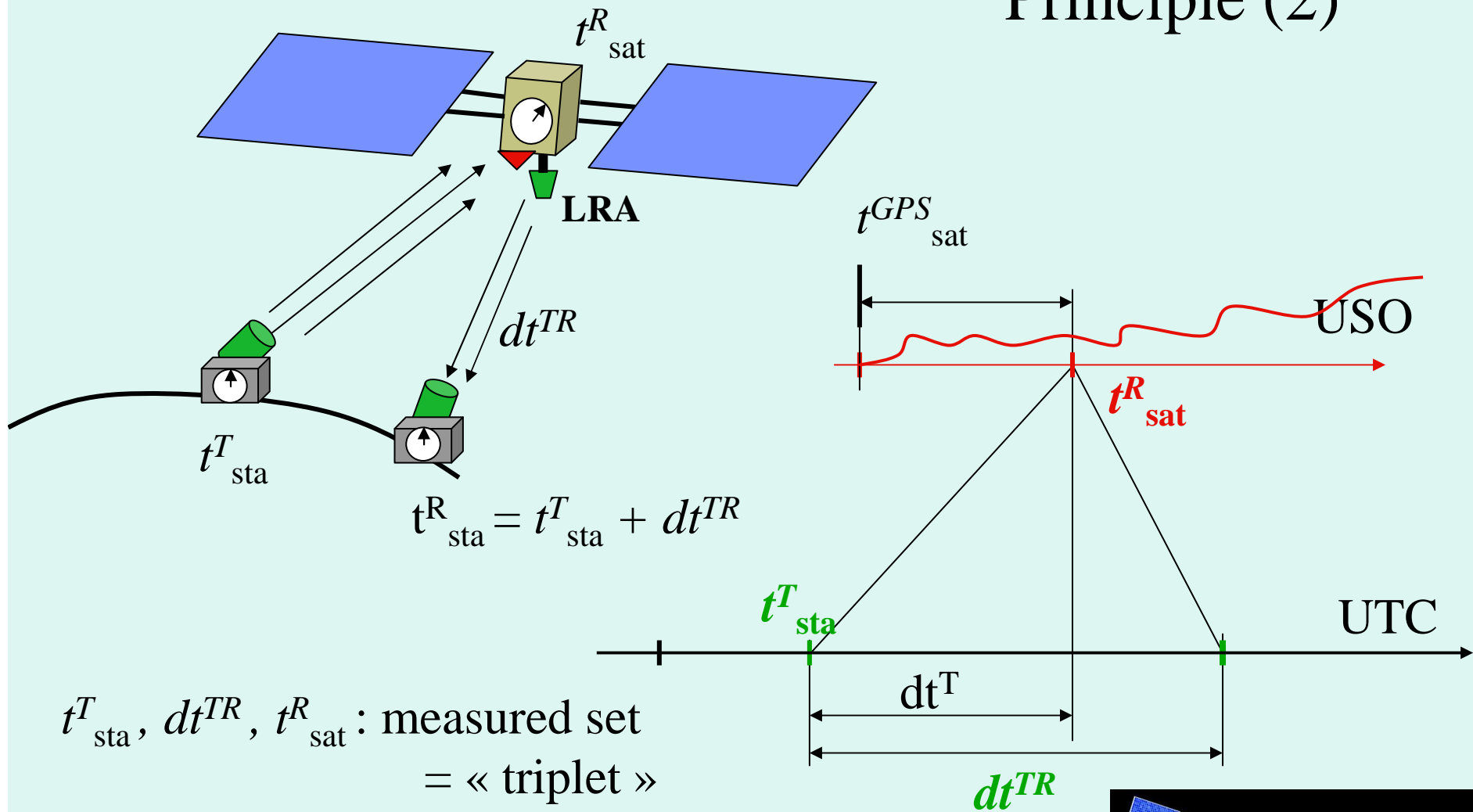


Aboard the satellite, the T2L2 instrument records the arrival dates of photons in on-board time. A system of retro-reflectors, complement to the embarked equipment, reflects some photons back toward the ground station, which records the return dates in local time.

(Departure and return dates are measured in an accurate way with regard to the ground clock ; arrival dates on the satellite are given with regard to an arbitrary reference).



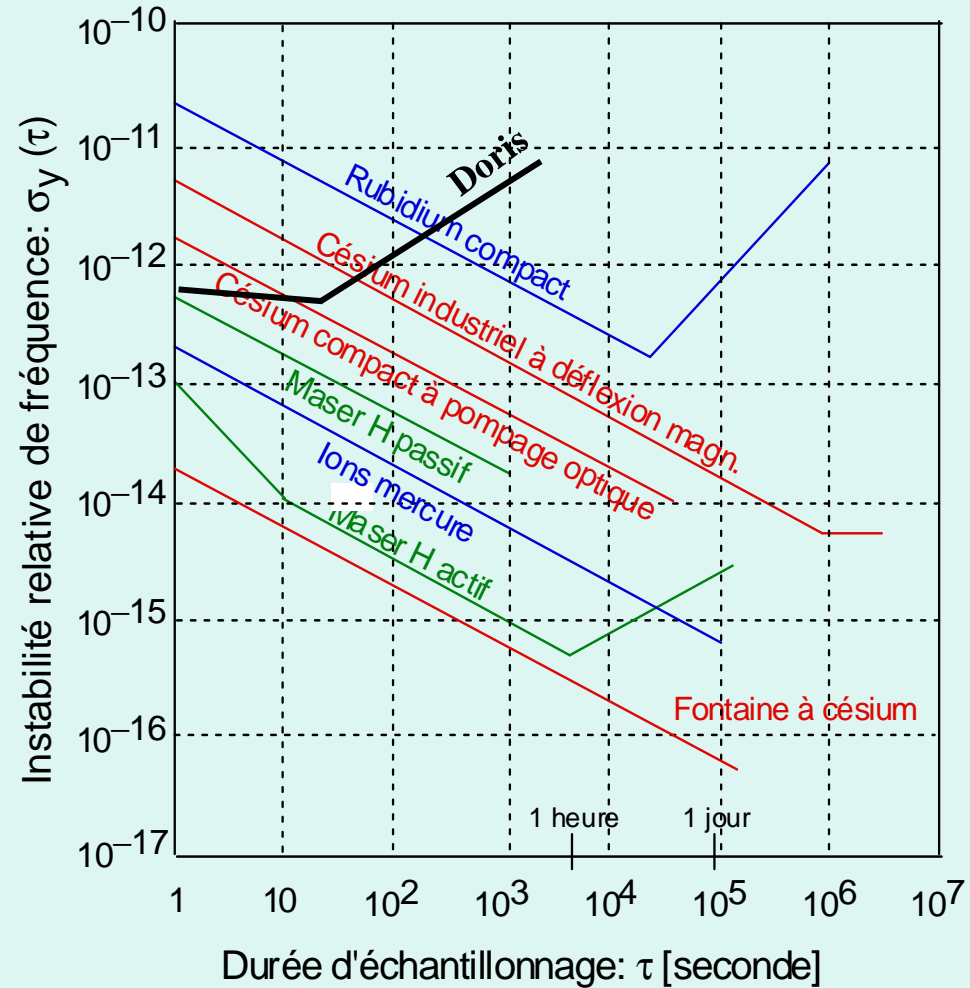
Principle (2)



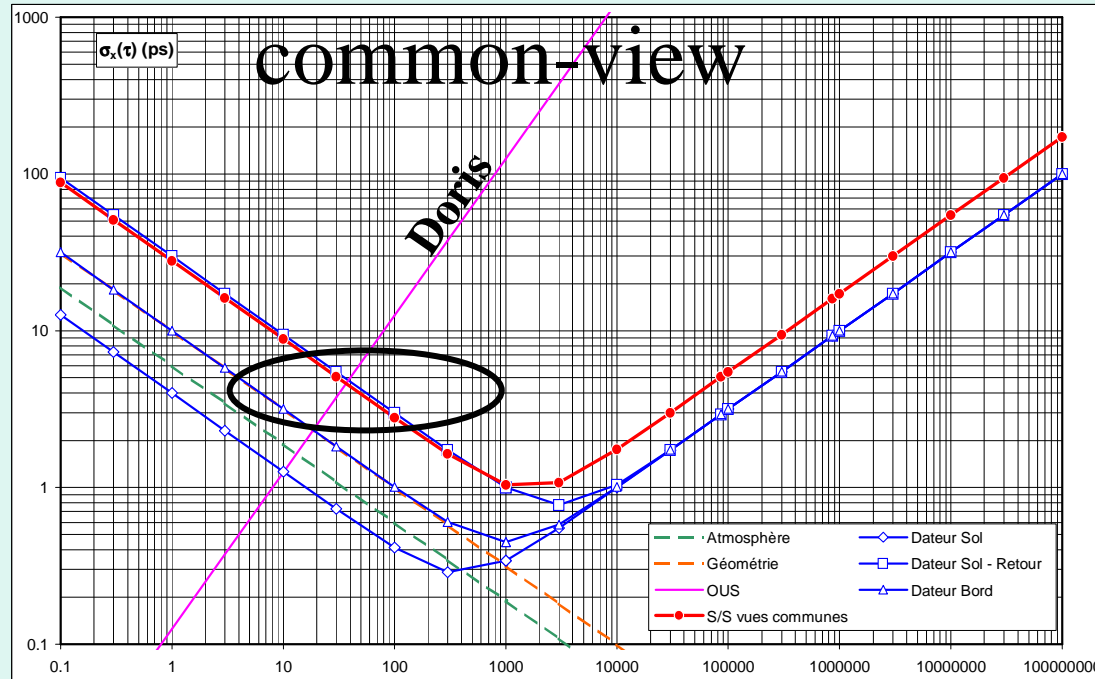
$t^T_{\text{sta}}, dt^{TR}, t^R_{\text{sat}}$: measured set
 = « triplet »
 (dt^T is computed)



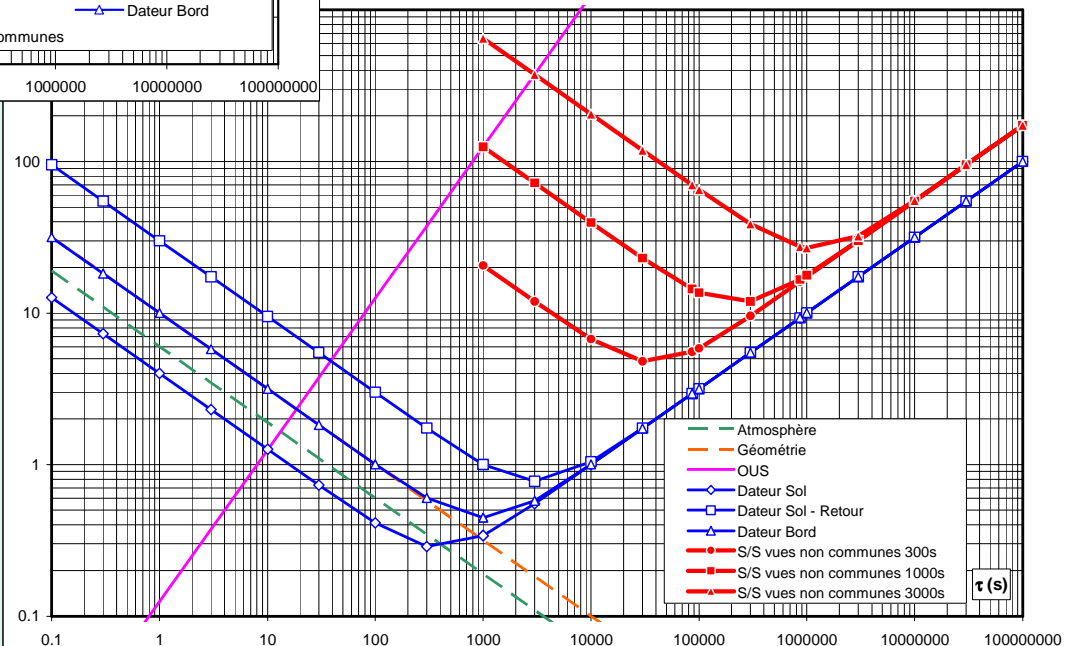
Freq stability of atomic clocks (for positioning & navigation systems)



Expected T2L2 stability :



non common-view



monitoring $<1\mu\text{sec}$ date of T2L2 events

T2L2 events

GPS :

1 μsec : easy

on board PPS (at 1 sec) : $0.15\ \mu\text{sec}$ and $\Delta f/f = 3.10^{-11}$

SLR stations (clocks) :

- 100ns class :

50 ns : ok now

Arequipa, Tahiti, Yaragadee, Hartebeestoeck, Greenbelt, MacDonald, MtPeak, Wettzell

- 1-2ps class :

Grasse, Herstmonceux, Matera (soon), Wettzell (soon)

< 10ps : soon...

- intermediary class :

Changchun, FTLRS(Ajaccio), Zimmerwald, Mt Stromlo

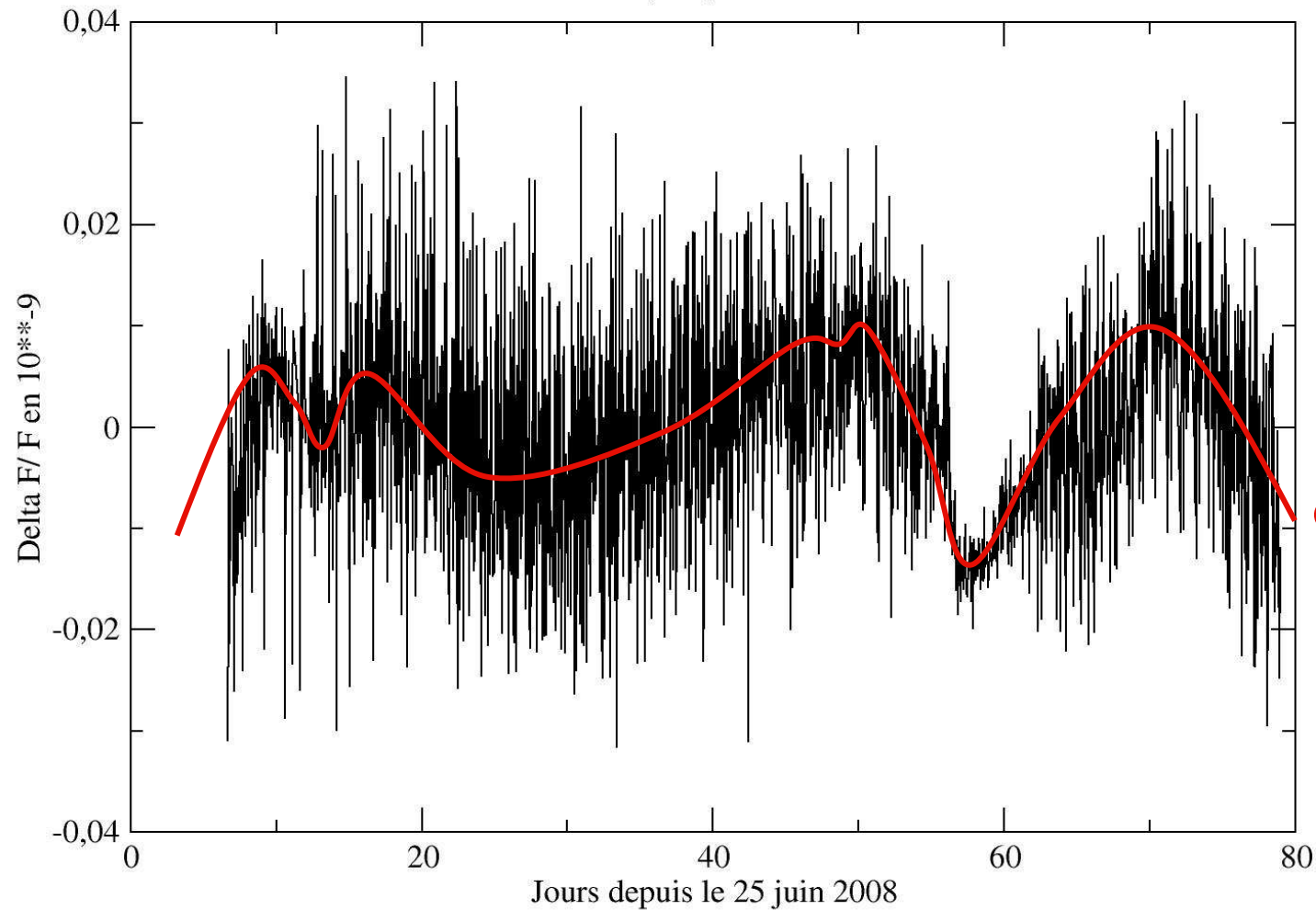
$\pm < 1\ \text{ns}$



USO along time

CMS T2L2 OUS bord versus PPS-Gps

(suivi juin juillet aout)



$dF/F \pm 8 \cdot 10^{-12}$

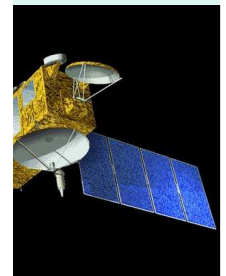
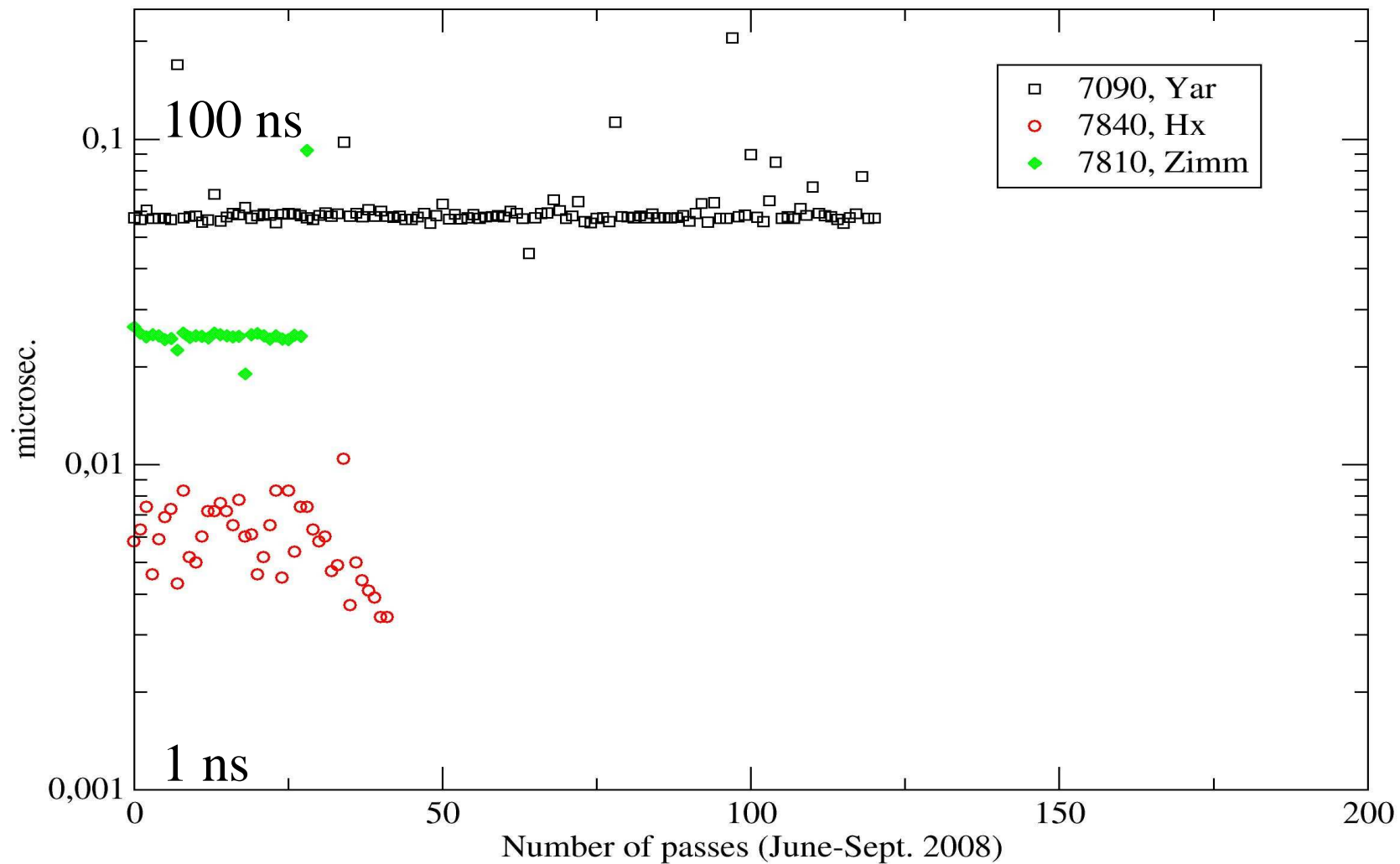
$\rightarrow dt \pm 70 \text{ ns}$



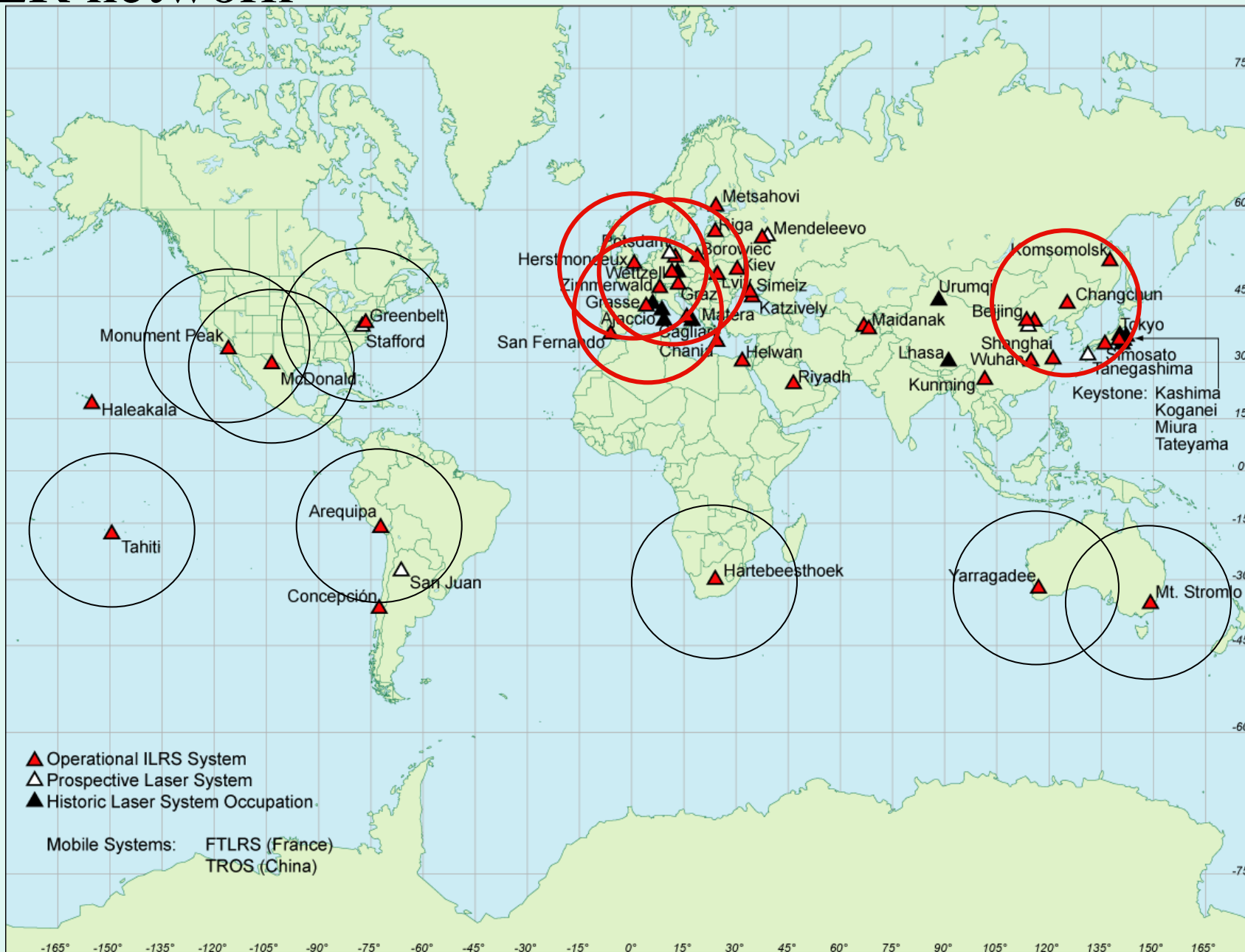
exemple of Time Transfers

T2L2, time transfer (from June to Sept.)

(rms of date comparisons : board-ground)



SLR network



SLR data

mois en 2008	MERIT-II	CRD
juin	11 (_a)	0
juillet	72 (_a)	55
	04 (_b)	
août	63 (_a)	117
	03 (_b)	
septembre	82 (_a)	210
	06 (_b)	
octobre	64 (_a)	48
	04 (_b)	

Format CRD, mois en 2008	06	07	08	09	10	11	12
7237 Changchun		0	4	56			
7810, Zimmerw., CH		13	84	50	40		
7829, FTLRS Calern		5	0	0			
7825, Mt Stromlo, AUS		0		24	5		
7840, Hx, RU		28	25	55	3		
7845, MeO, F		3	0	2			
7848, FTLRS, Ajaccio		6	4	23	**		

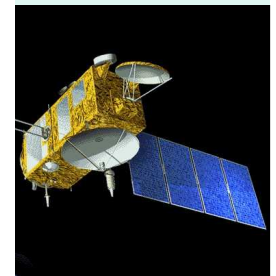
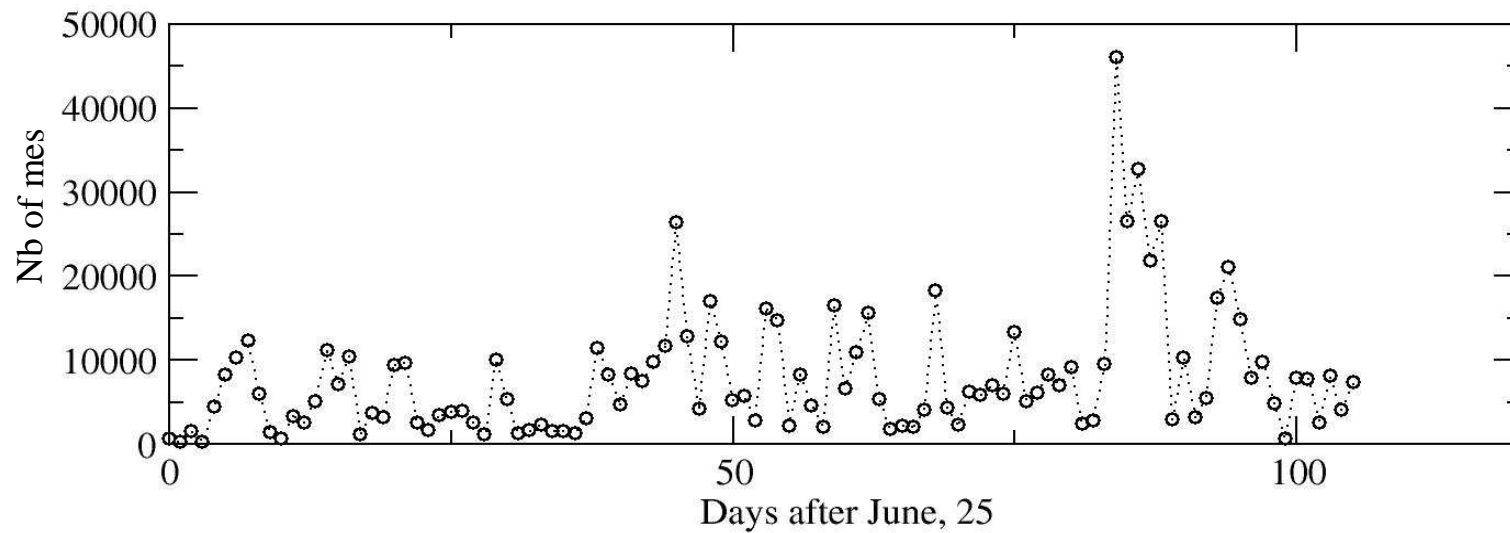
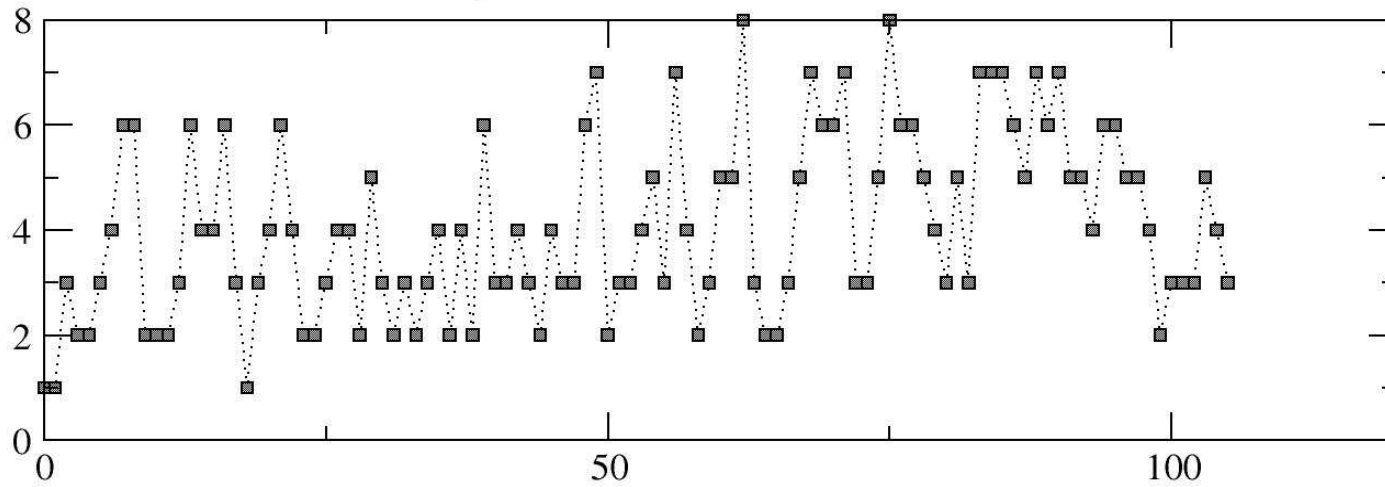
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SLR data

T2L2 (available SLR data)

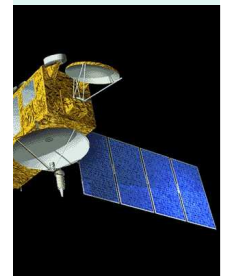
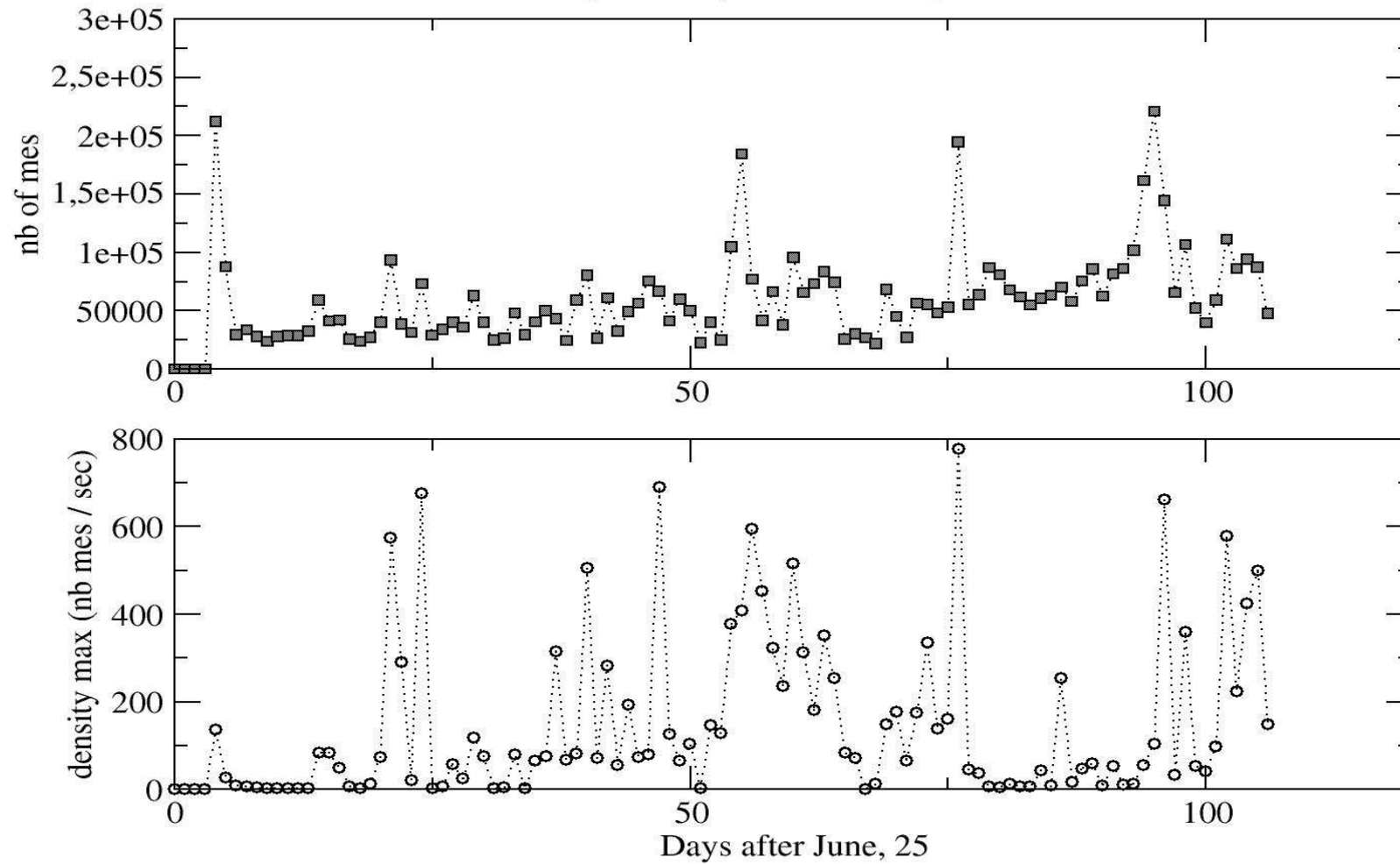
(up: nb of stations, down: nb of data)



T2L2 event statistics

T2L2 (nb of measurements) / day

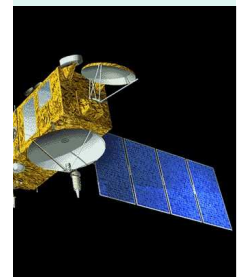
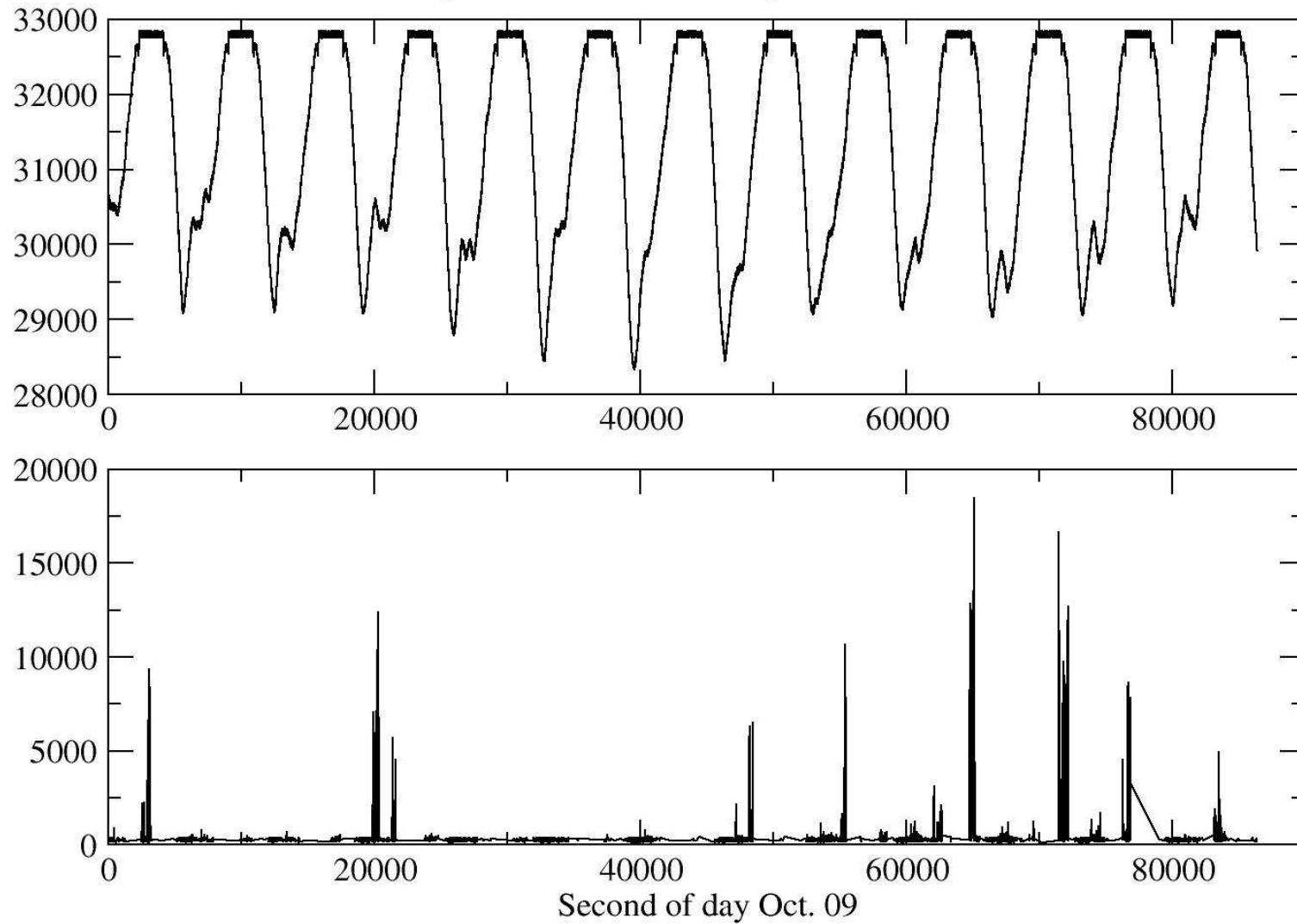
(up: nb / day, down: density max)



Energy

T2L2 (Energy measurement)

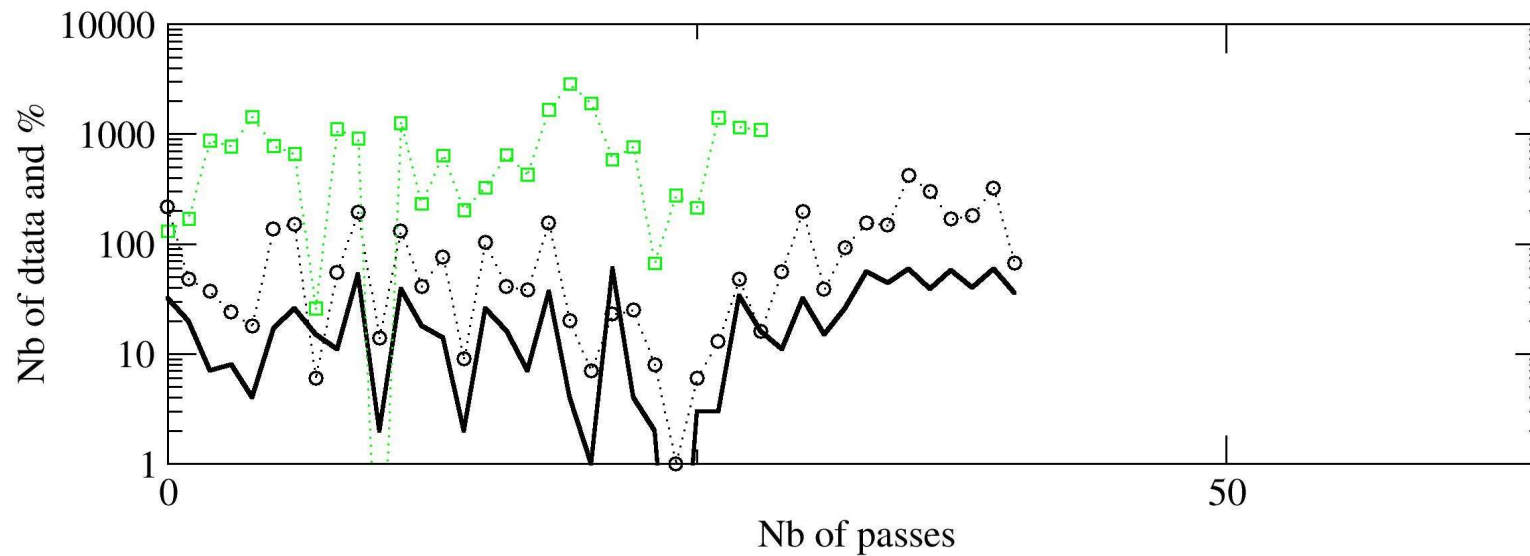
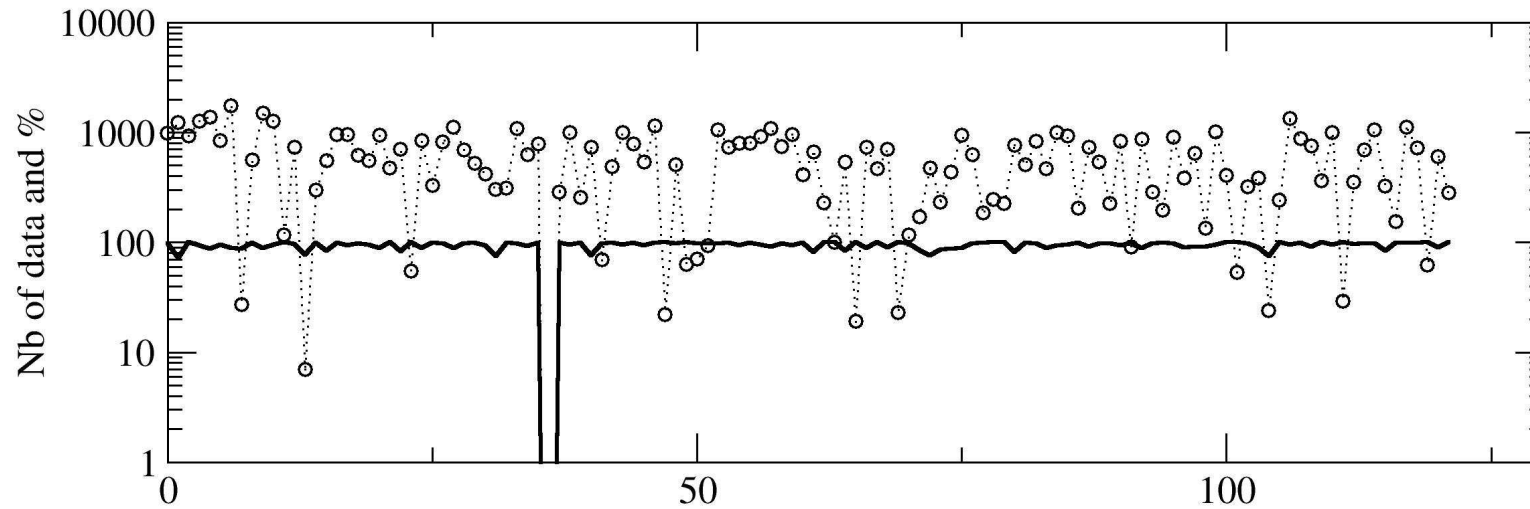
(up: Albedo, down: Laser pulses and noise)



SLR vs T2L2 data

Number of data sets detected on board

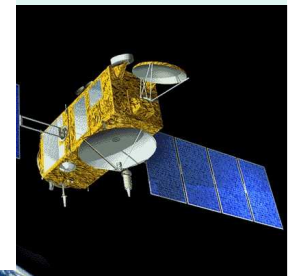
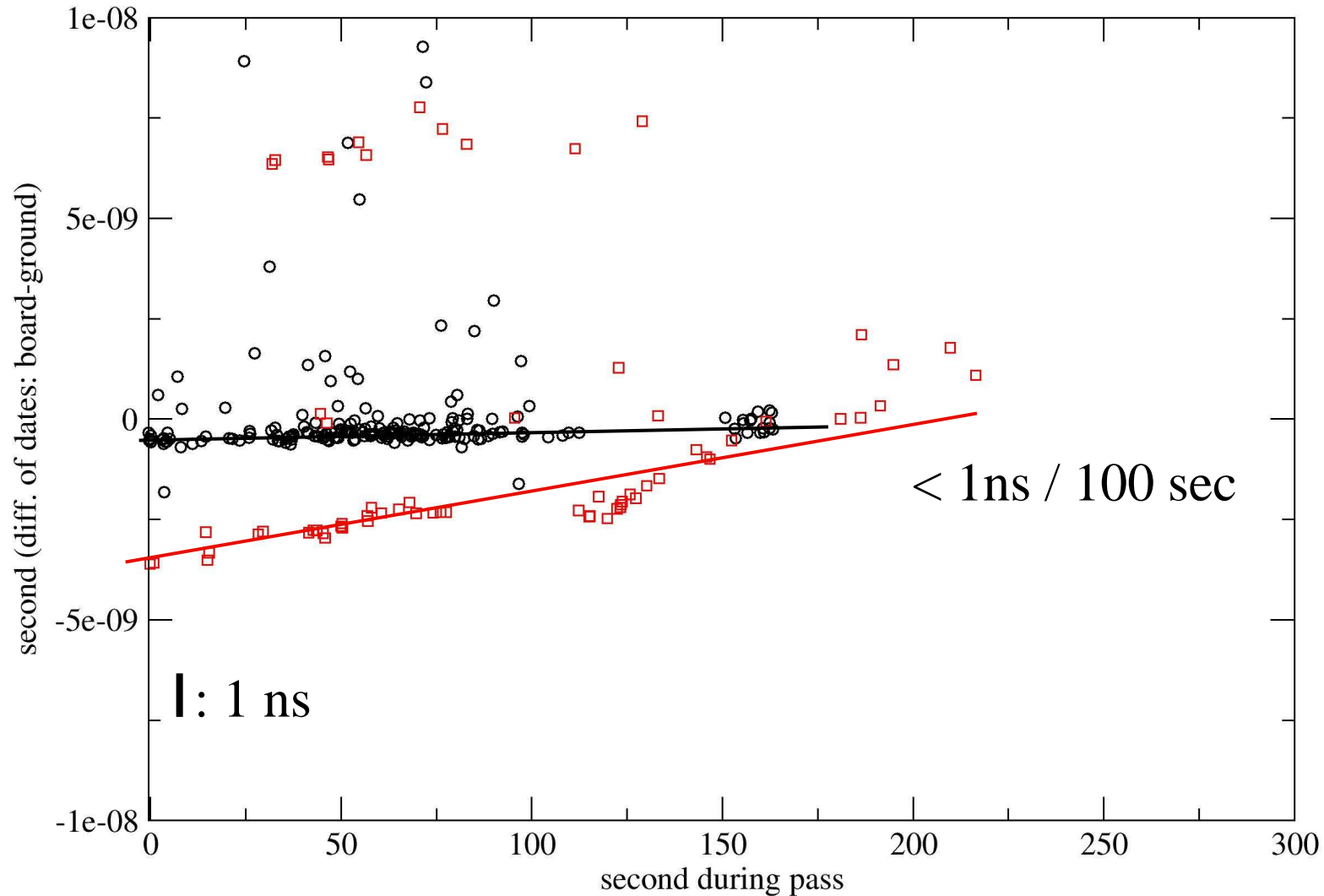
Up: 7090, Yar - down: 7840, Hx & 7810, Zim



Sets of « triplet » (3 dates)

T2L2, time transfer over 1 pass

(7237, Changch: Sept 7 & 7840, Hx: Sept 3)



Effects and limitations

Effects not (currently) modeled :

- On-board :
 - calibration of received energy
 - (non linear) detector time walk
 - attitude (LRA - T2L2 optics)
 - relativity
- SLR-station(s) :
 - calibration (telemetry vs clock)
 - bias (?)
- Limitations :
 - on-board OUS
 - proper error budget of telemetry, and calibrations
 - non-common view



Conclusion

Improving corrections

Performing campaigns in 2009 with :

SLR :

FLTRS (in Paris)

Grasse

Hx, Wettzell

Atomic clocks (Cesium, Maser-H, mobile fountain)

DORIS (new beacon at Grasse SLR station)

Calibrations (stations, energy,...)

Futur analyses of Time Transfers

Comparisons with the 2-way μ wave technique

