Time Transfer by Laser Link

P. Exertier, E. Samain, Ph. Guillemot, I. Petitbon, Ph. Berio, O. Laurain
OCA-GRGS, avenue Copernic 06130 Grasse

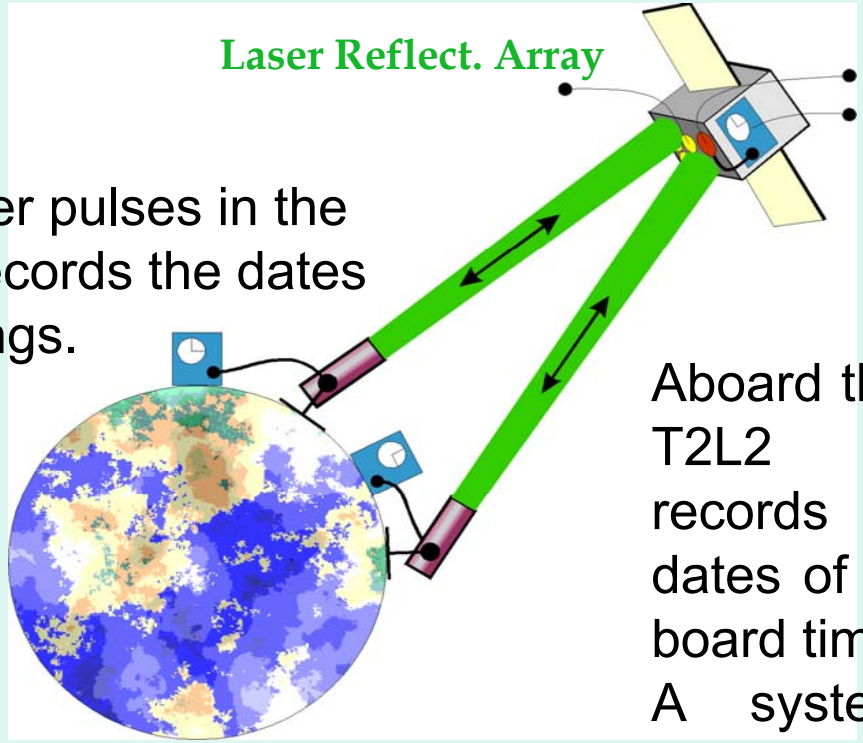
OSTST Meeting, POD September, 11 2008, Nice

Objectives

- « 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 $2{,}7.10^{-9}$, but with the USO limitations
- fine structure constant α
  - » possibiliy of comparing frequencies at $5\ 10^{-17}$ over 10 days of integration in common view
  - » measurement limited by grond clocks quality

Principle

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

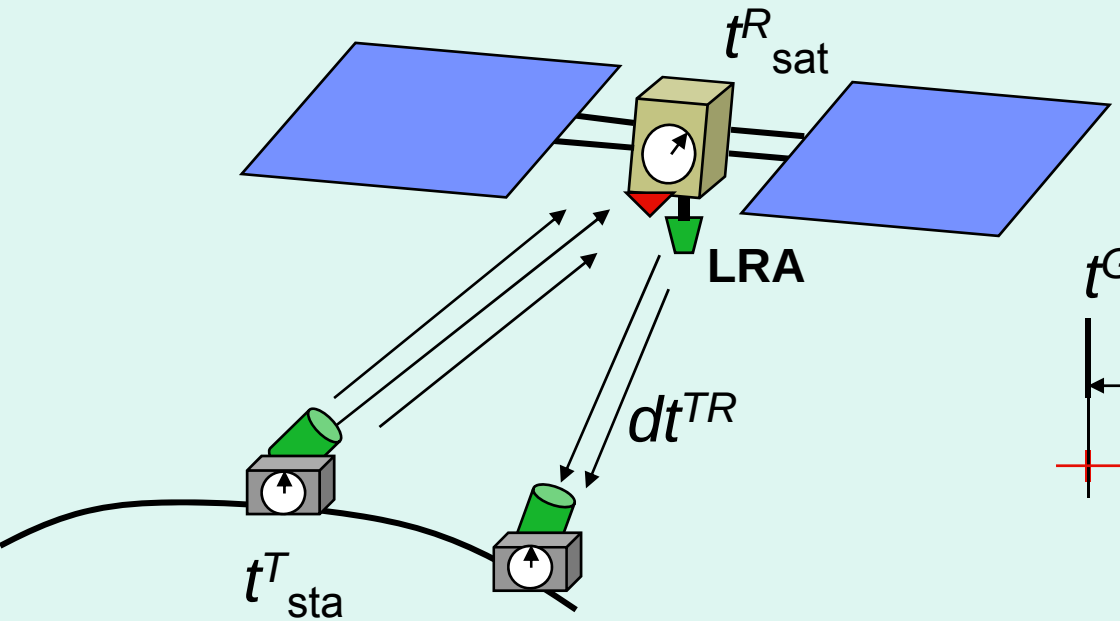


(Departure and return dates are measured in an accurate way with regard to the ground clock ; arrival dates on the satellite are given with regard to an arbitrary reference).

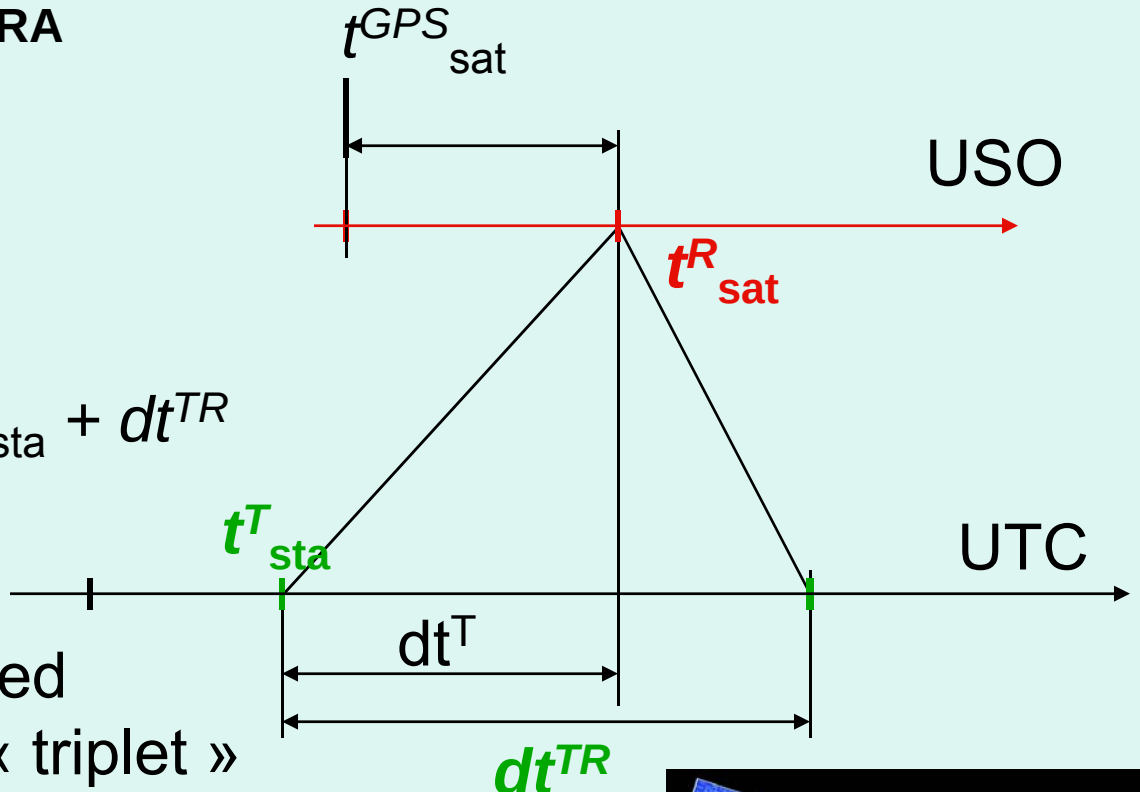
Aboard the satellite, the T2L2 instrument records the arrival dates of photons in on-board time.

A system of retro-reflectors, complement to the embarked equipment, reflects some photons back toward the ground station which records the return da... in lo... time

Principle (2)



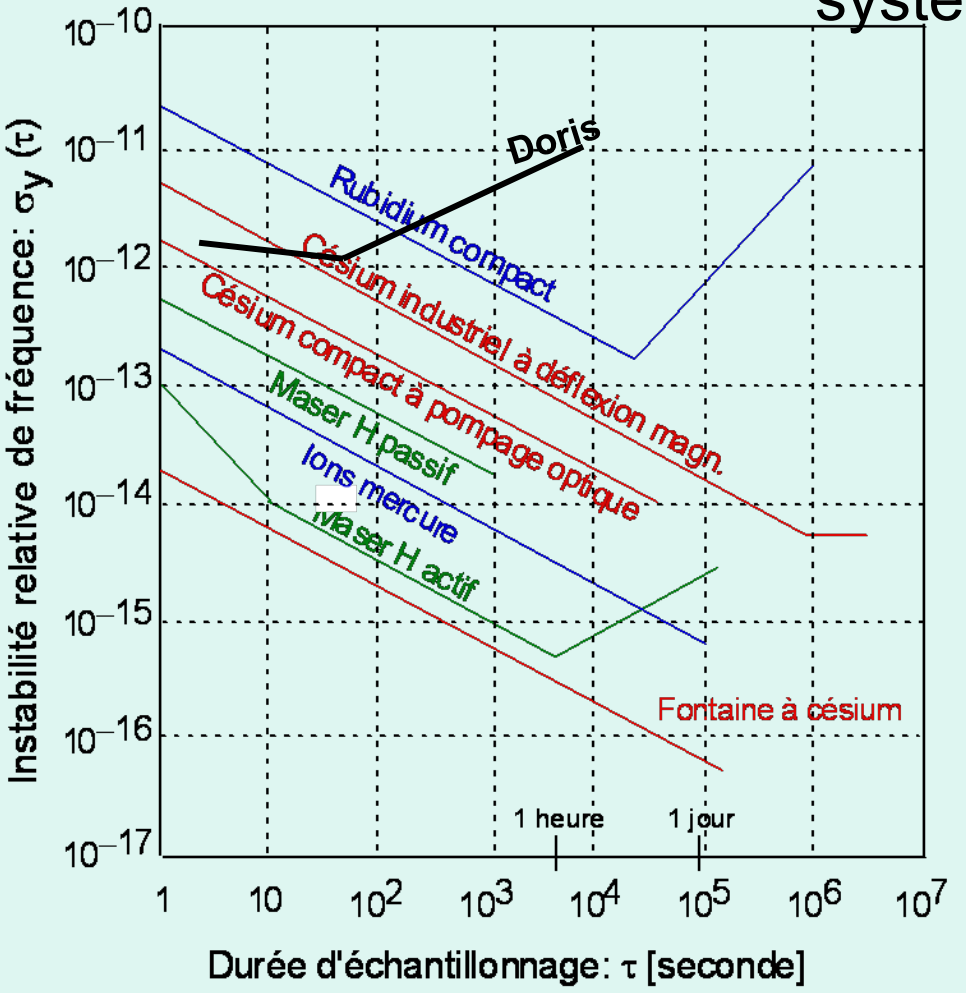
$t^R_{sta} = t^T_{sta} + dt^{TR}$



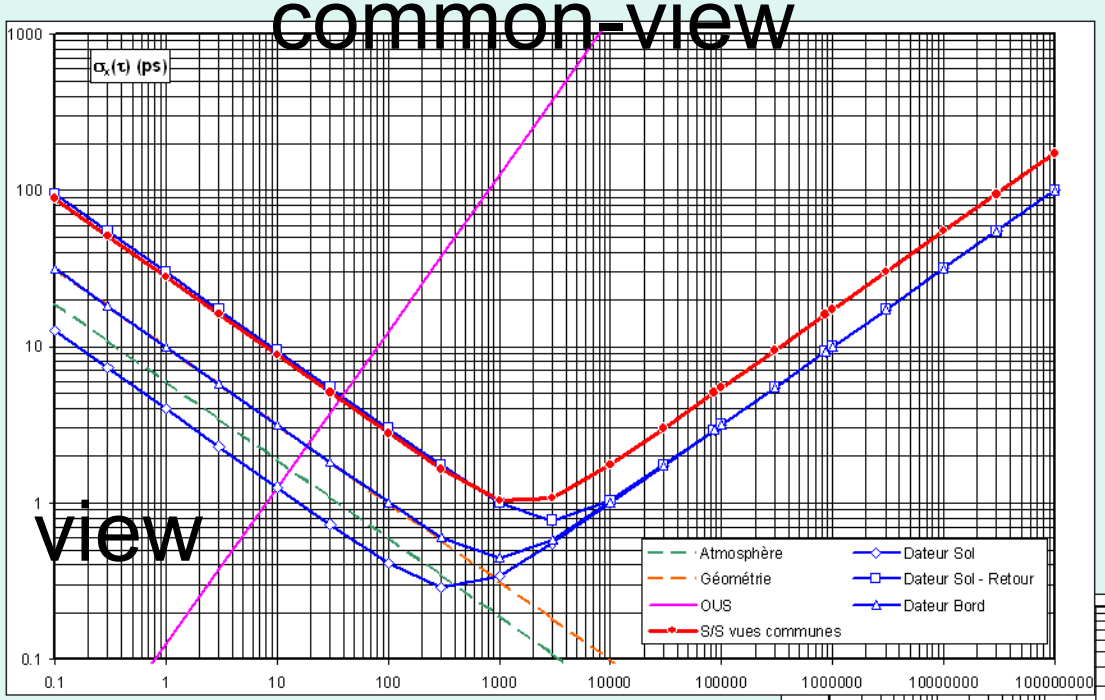
t^T_{sta} , dt^{TR} , t^R_{sat} : measured
= set of « triplet »

(dt^T is computed)

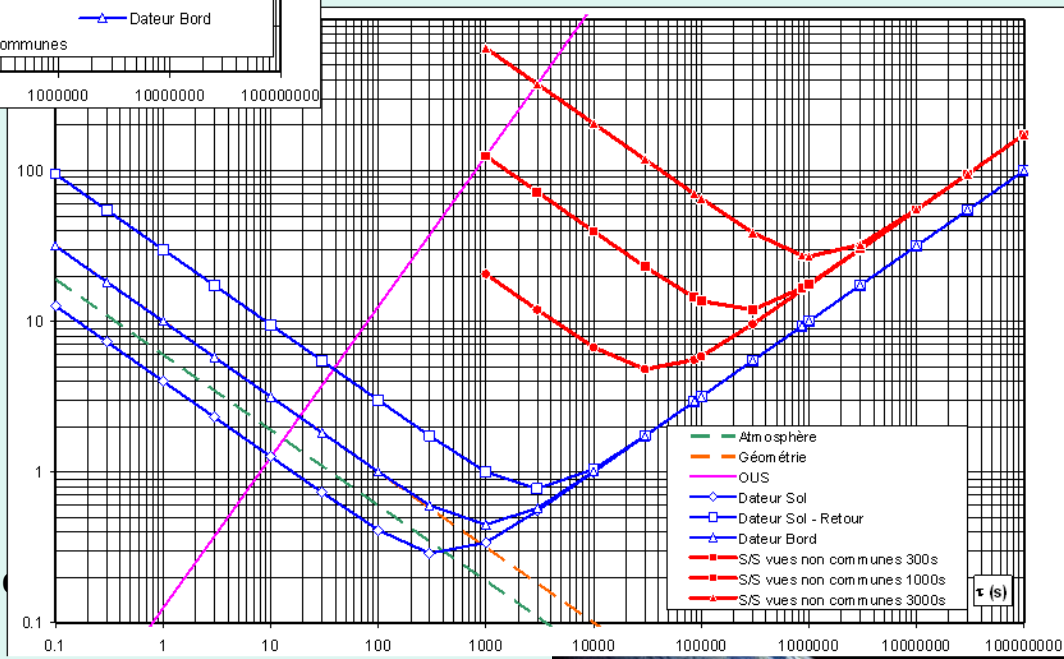
Freq stability of atomic clocks (for positioning&navigation systems)



Expected T2L2 stability : common-view



non common-view



First : monitoring 1µsec date (and less)

GPS :

on board PPS (1 sec) : 0.15 µsec and $\Delta f/f = 3.10^{-13}$

1µsec : easy

SLR stations (clocks) :

- 100ns class :
  Arequipa, Tahiti, Yaragadee, Hartebeestoek, Greenbelt, MacDonald,
  MtPeak, Wettzell

50 ns : possible

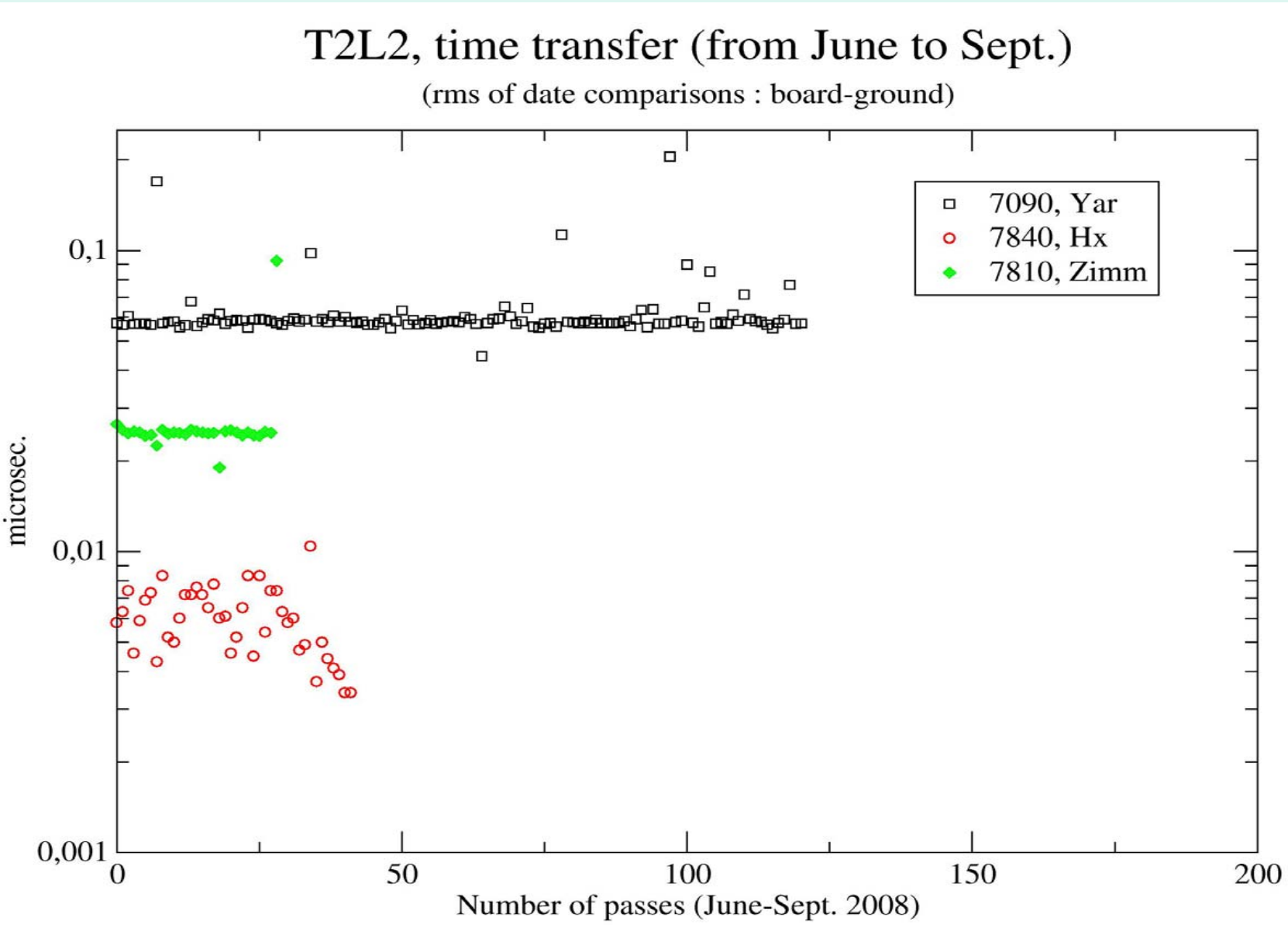
- 1-2ps class :
  Grasse, Herstmonceux, Matera (soon), Wettzell (soon)

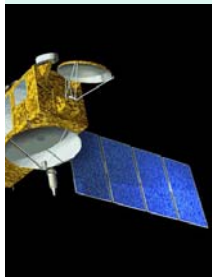
< 10ps : soon...

- intermediary class :
  Changchun, FTLRS(Ajaccio), Zimmerwald, Mt Stromlo

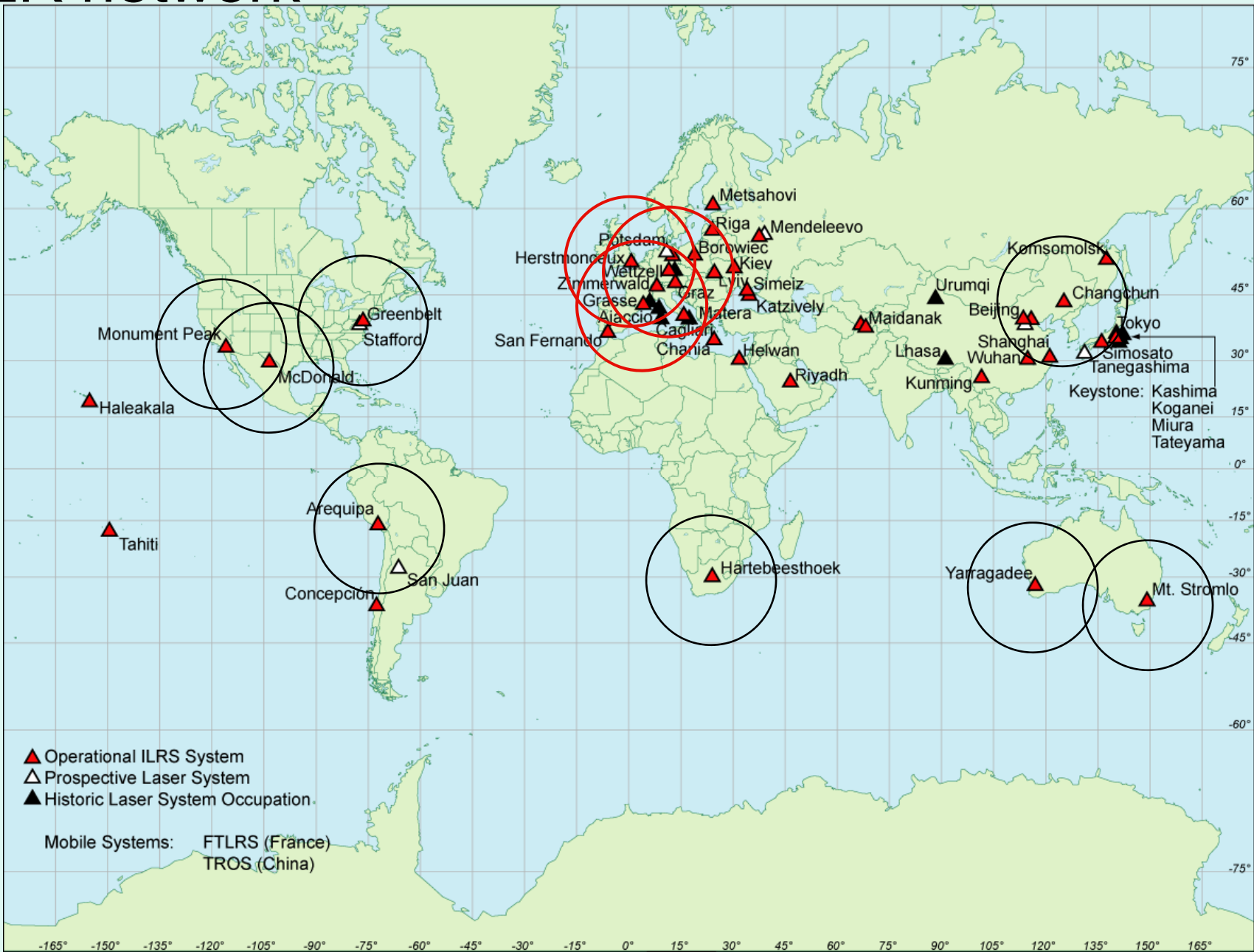
± < 1 ns

exemple of Time Transfers

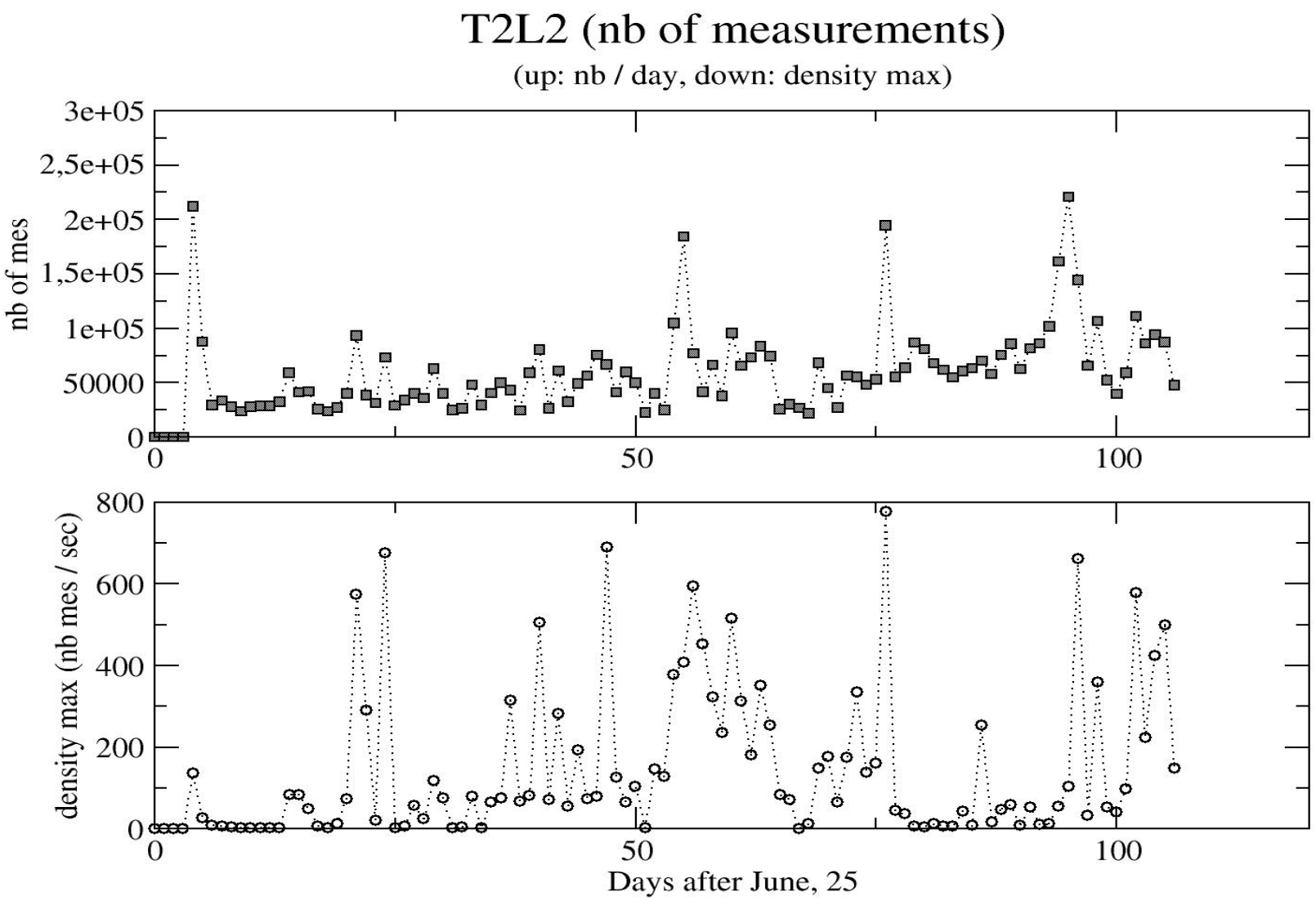


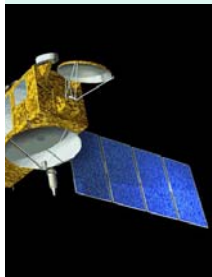


SLR network

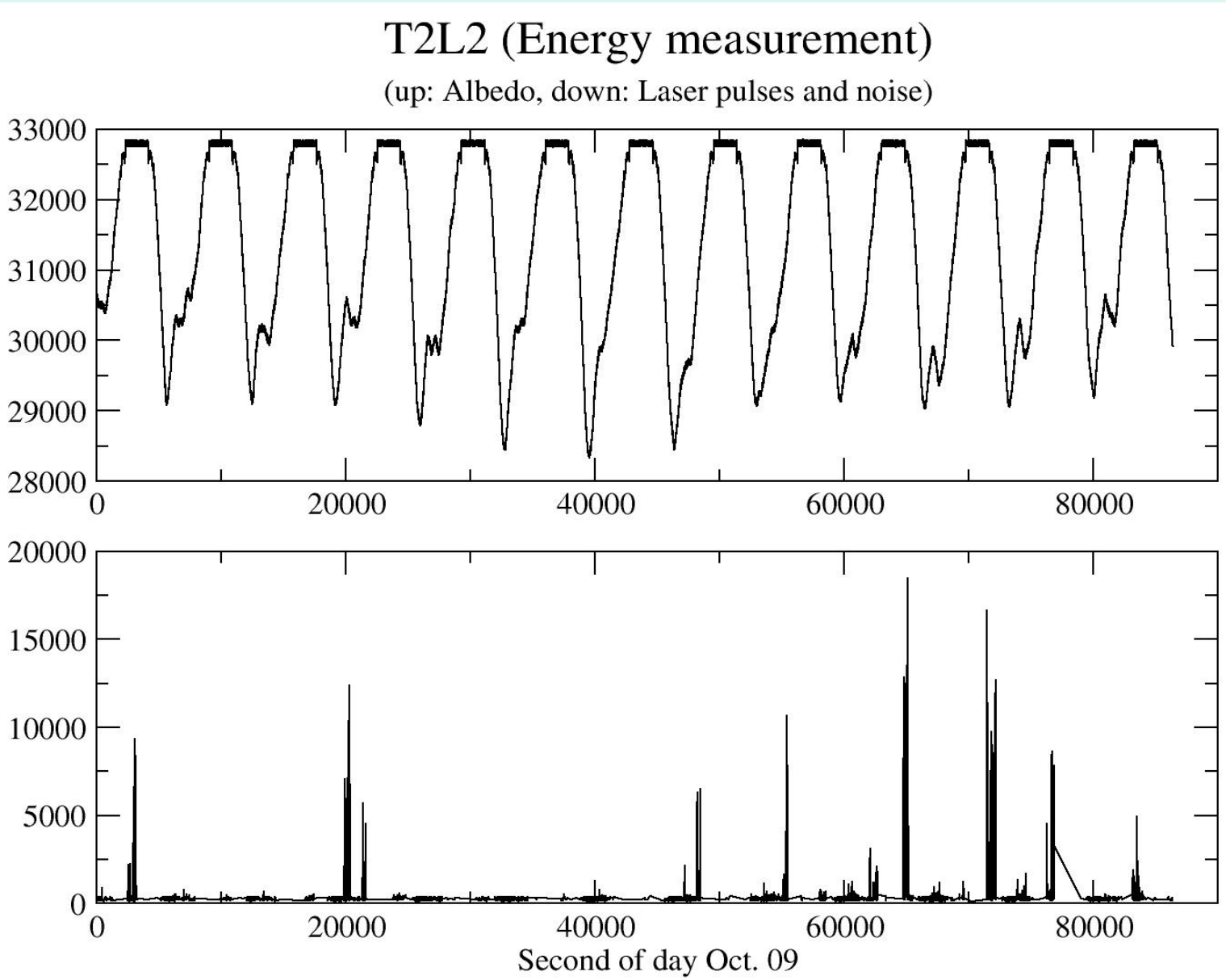

Metsahovi
Riga
Mendeleevo
Potsdam
Borowiec
Herstmonceux
Kiev
Wettzell
Zimmerwald
Lviv
Simeiz
Graz
Grasse
Katzively
Ajaccio
Matera
Cagliari
San Fernando
Chania
Helwan
Riyadh
Maidanak
Urumqi
Komsomolsk
Changchun
Beijing
Tokyo
Shanghai
Wuhan
Lhasa
Kunming
Simosato
Tanegashima
Keystone: Kashima
Koganei
Miura
Tateyama
Greenbelt
Stafford
Monument Peak
McDonald
Haleakala
Arequipa
Tahiti
San Juan
Concepción
Hartebeesthoek
Yarragadee
Mt. Stromlo
Operational ILRS System
Prospective Laser System
Historic Laser System Occupation
Mobile Systems: FTLRS (France)
TROS (China)
75°
60°
45°
30°
15°
0°
-15°
-30°
-45°
-60°
-75°
-165° -150° -135° -120° -105° -90° -75° -60° -45° -30° -15° 0° 15° 30° 45° 60° 75° 90° 105° 120° 135° 150° 165°

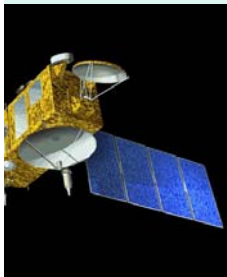
Statistics


T2L2 (nb of measurements)
(up: nb / day, down: density max)
nb of mes
3e+05
2,5e+05
2e+05
1,5e+05
1e+05
50000
0
0
50
100
density max (nb mes / sec)
800
600
400
200
0
0
50
100
Days after June, 25

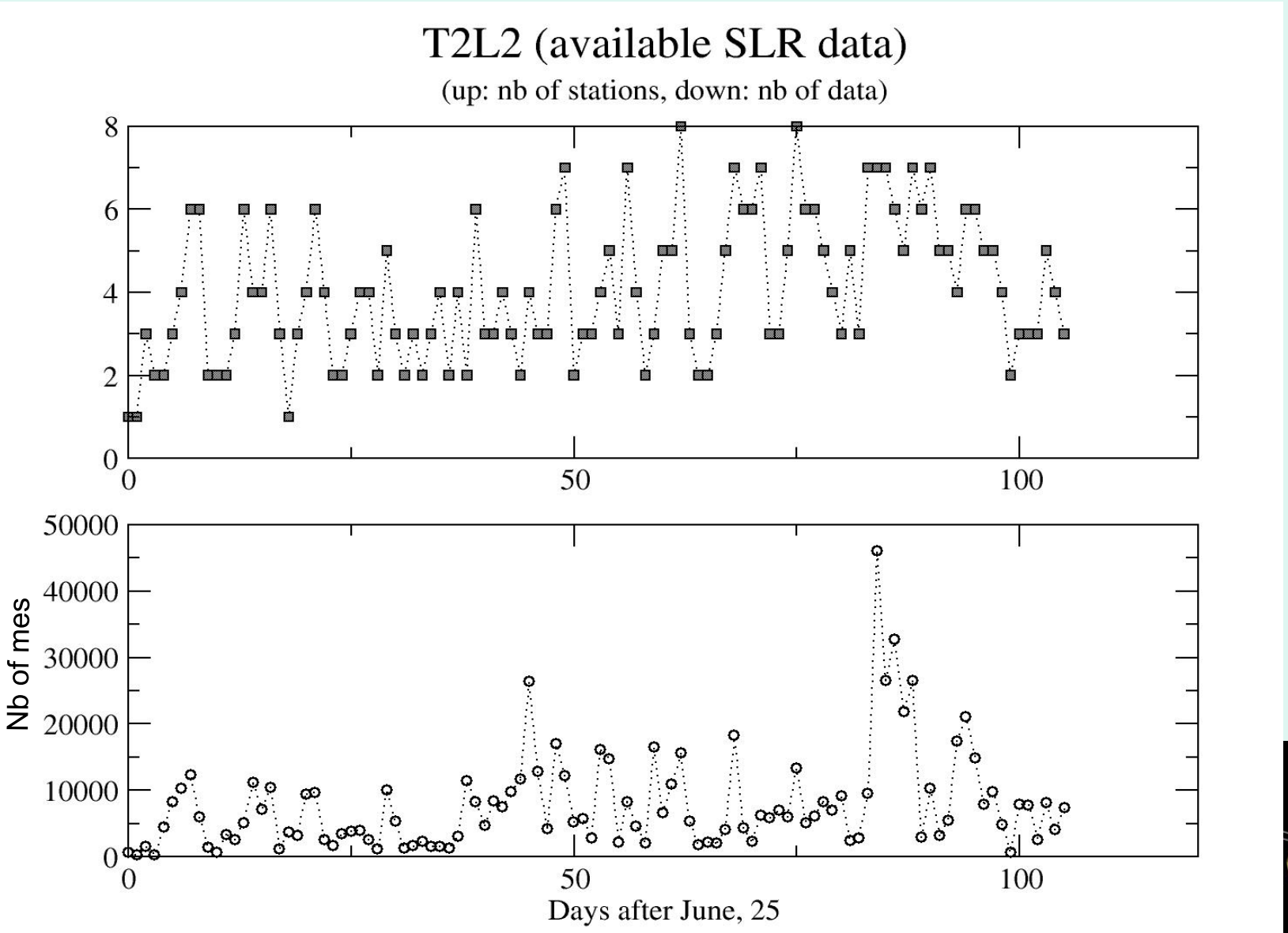


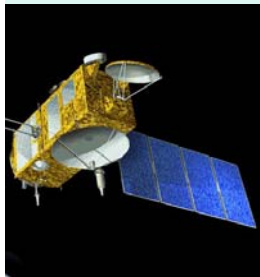
Energy


T2L2 (Energy measurement)
(up: Albedo, down: Laser pulses and noise)
33000
32000
31000
30000
29000
28000
0
20000
40000
60000
80000
20000
15000
10000
5000
0
0
20000
40000
60000
80000
Second of day Oct. 09

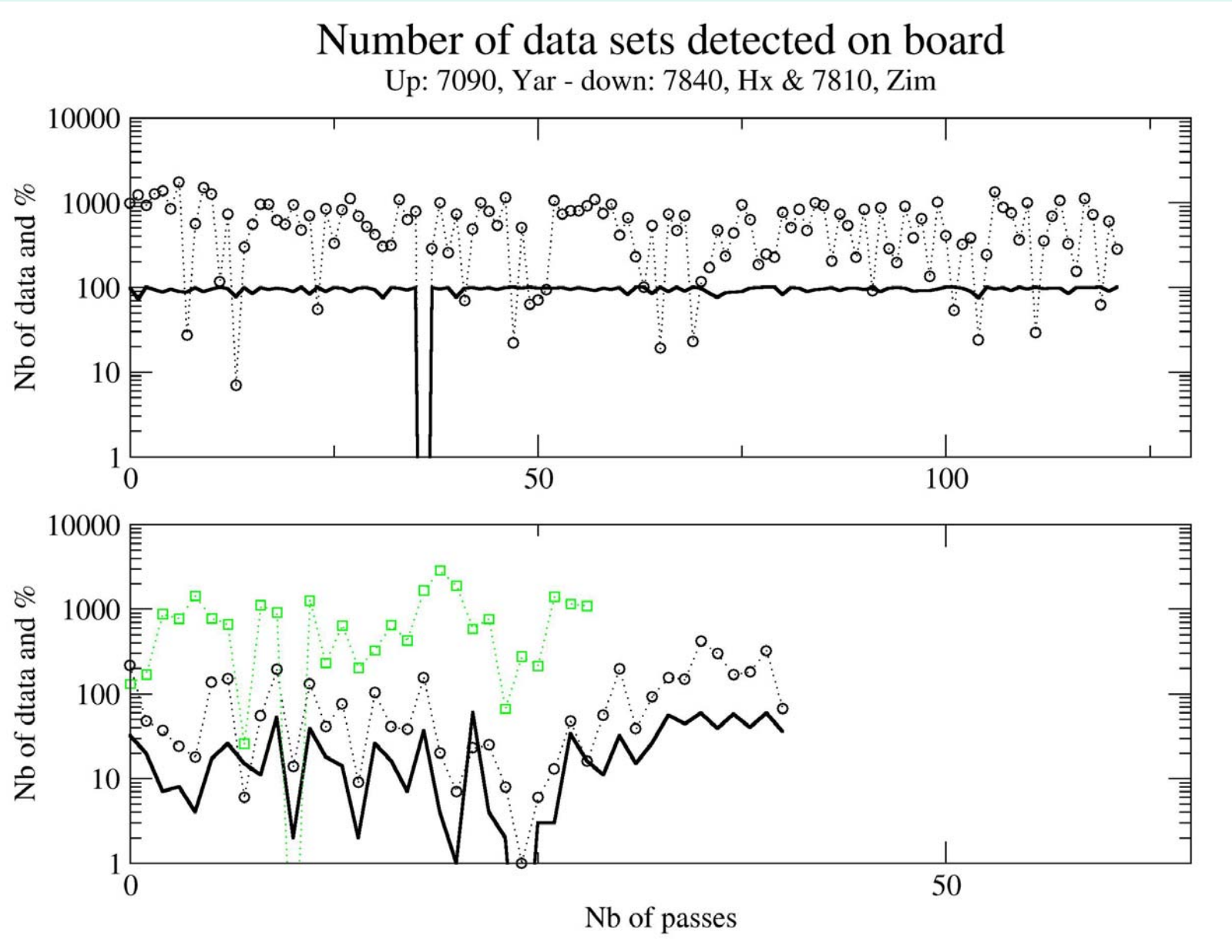


SLR data

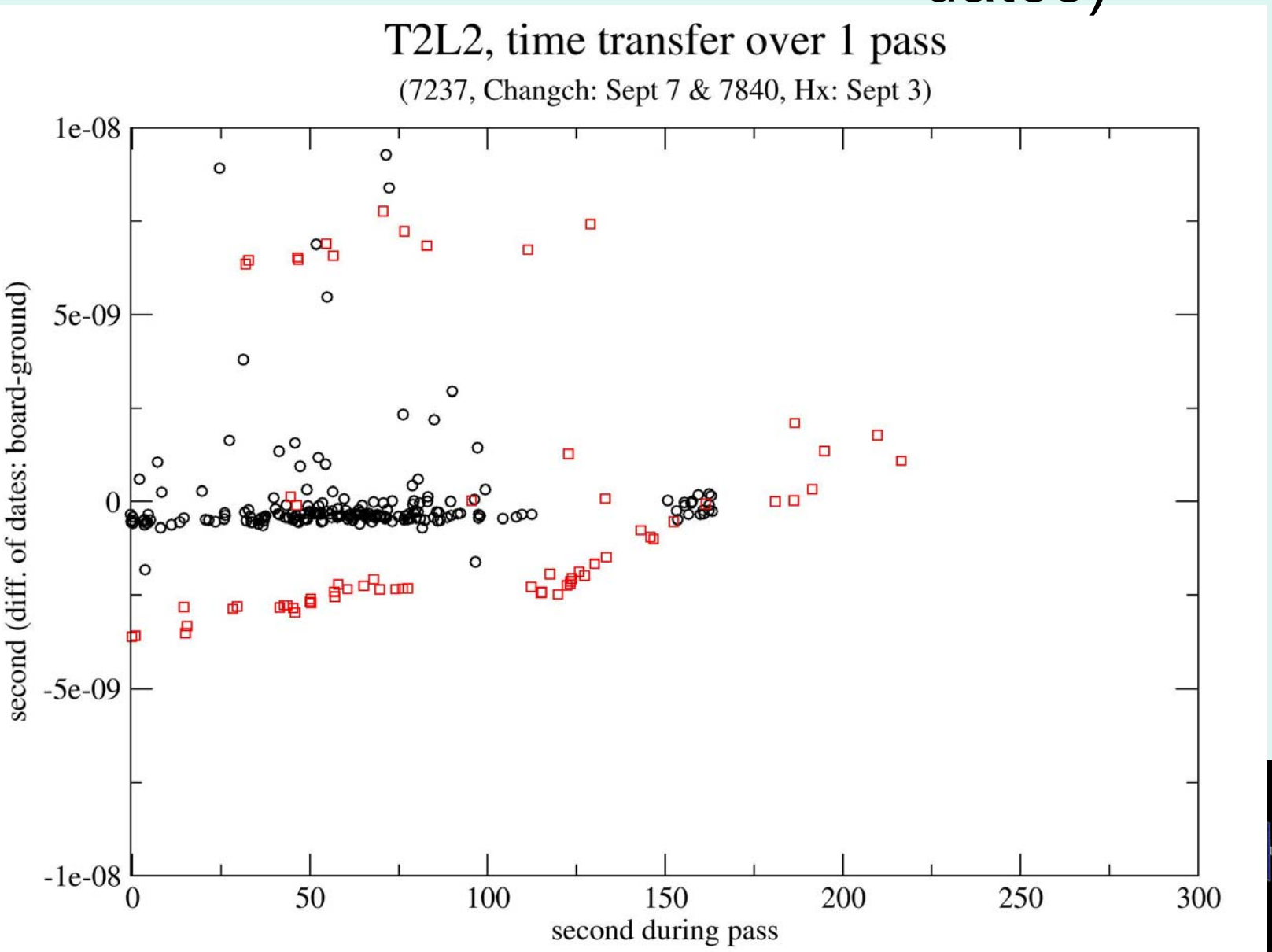

T2L2 (available SLR data)
(up: nb of stations, down: nb of data)
0
2
4
6
8
0
50
100
Nb of mes
0
10000
20000
30000
40000
50000
0
50
100
Days after June, 25



SLR vs T2L2 data



Sets of « triplet » (3 dates)



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 campaings in 2009 with :

- **SLR** :
  - FLTRS (in Paris)
  - Grasse
  - Hx, Wettzell
- **Atomic clocks** (Cesium, Maser-H, mobile fontain)
- **DORIS** (new beacon at Grasse SLR station)

Calibrations (stations, energy,...)

Futur analyses of Time Transfers