Graz in Space 2010

Graz Satellite Laser Ranging System

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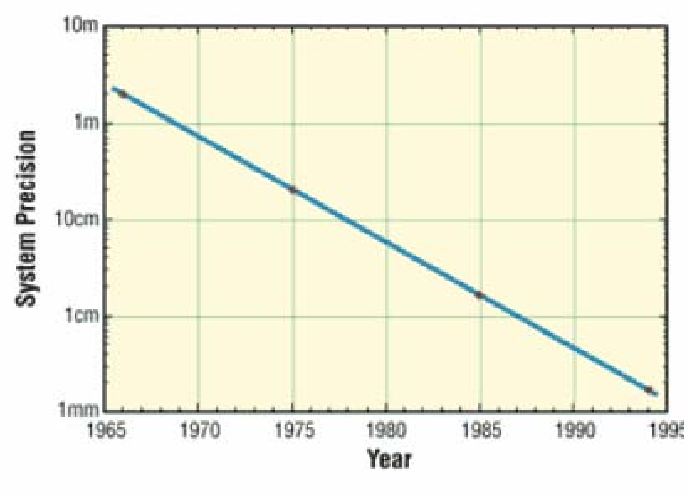
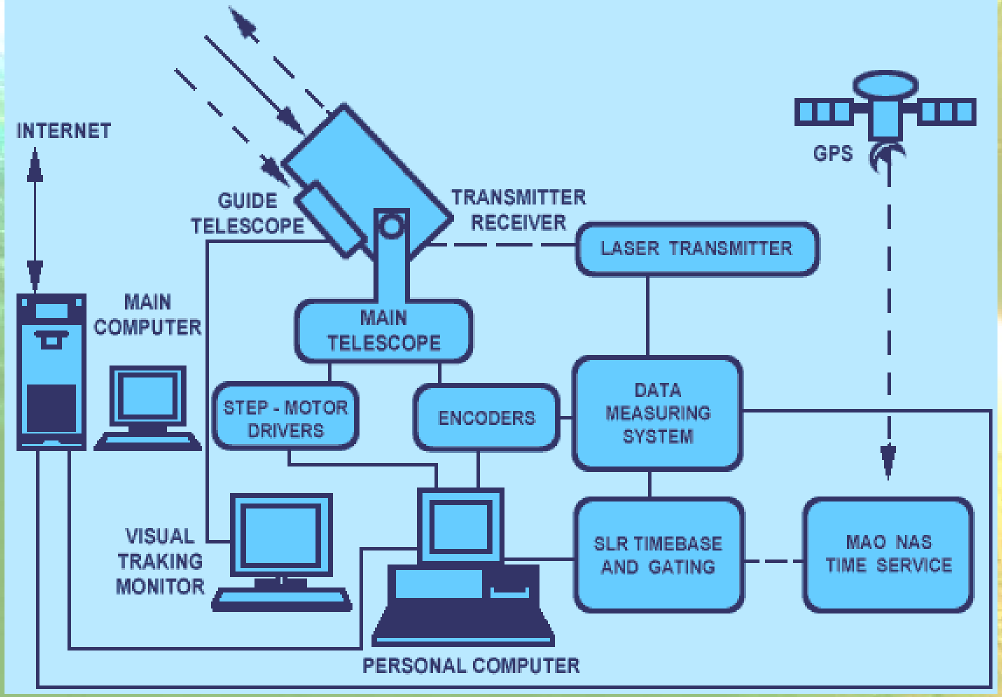
IWF / SatGeo

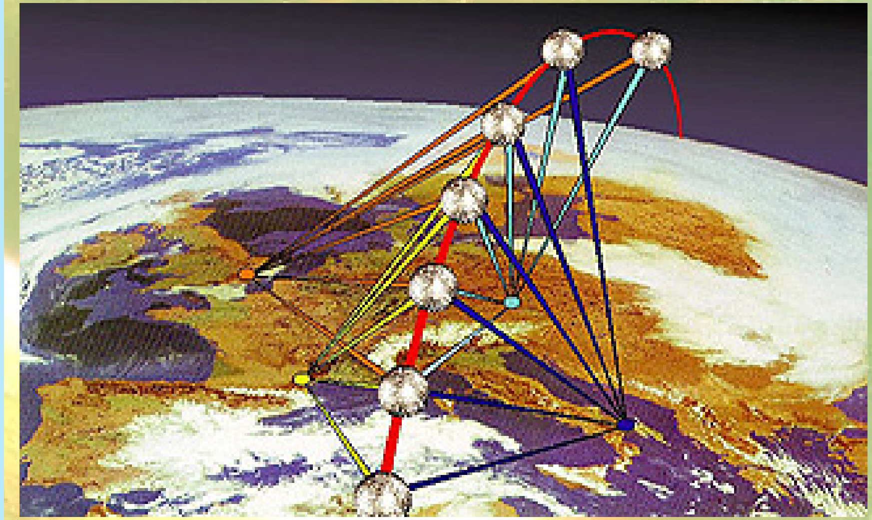
Satellite Laser Ranging

- Range measurements to the satellites
  - time of flight of the ultrashort laser pulses
  - mm precision station-satellite
  - for: POD, science



SLR – geodetic technique



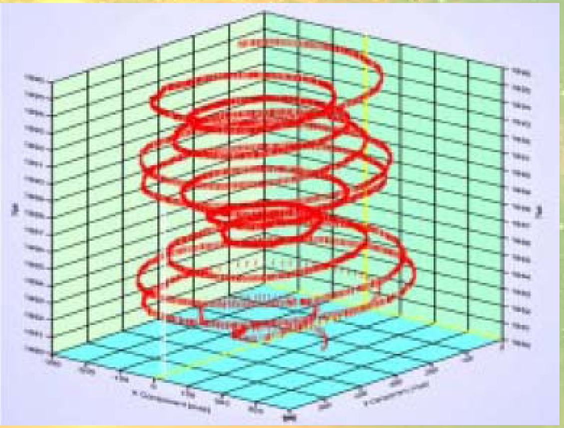


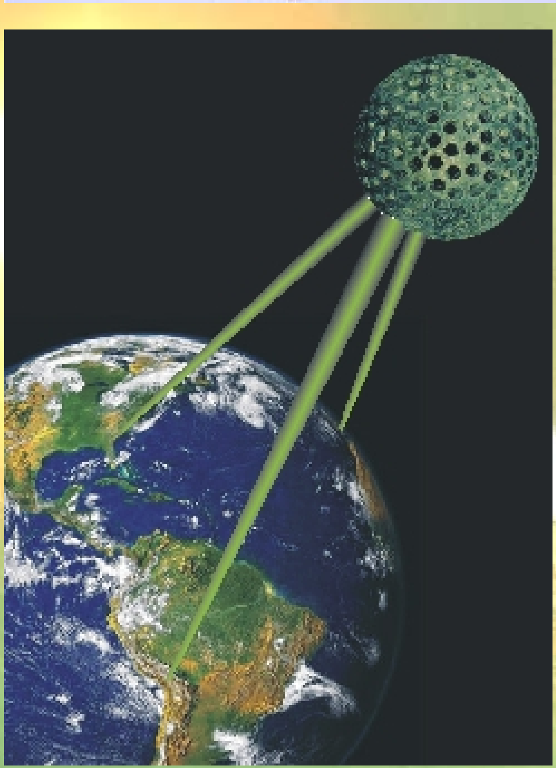
‘time of flight’ measurement of the laser pulses

SLR measurements

- scientific studies of the Earth / Atmosphere / Oceans systems, determination of the temporal mass redistribution, EOP

- determination of the geocentric position of an Earth satellite (precise calibration of radar altimeters)

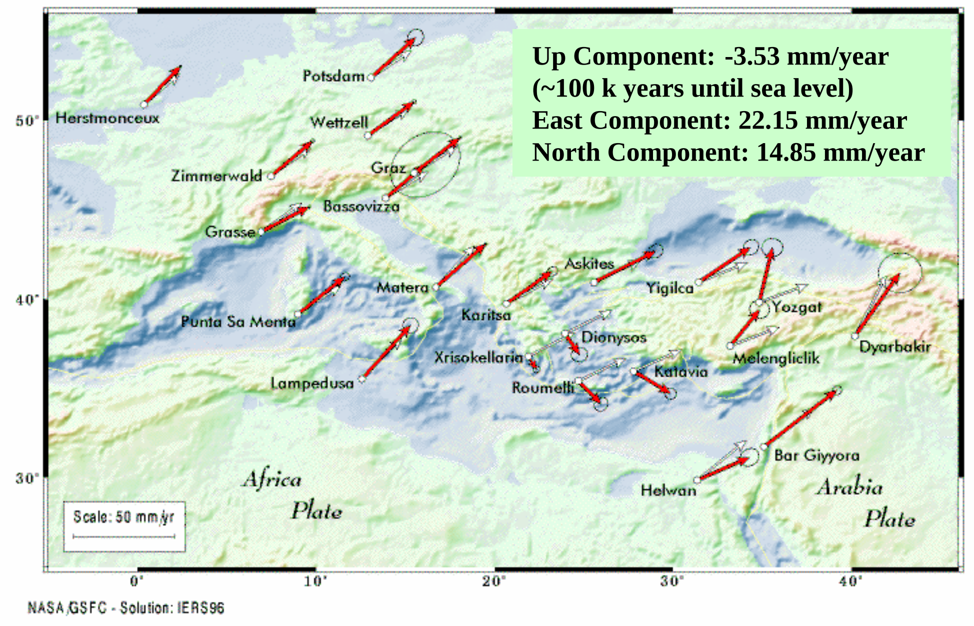




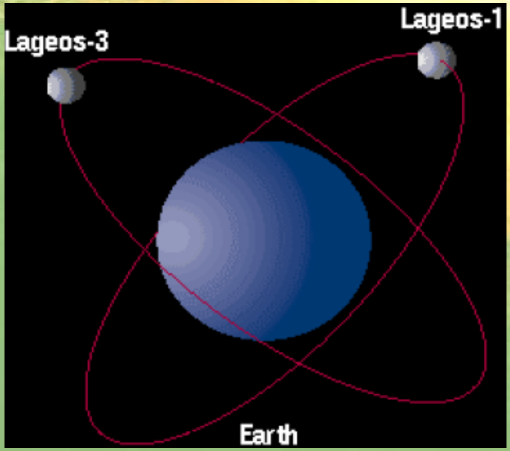
SLR measurements

- allow determination of the station position, tectonic motion with respect to the geocenter

- support research in fundamental physics. SLR measurements of LAGEOS 1 and 2 have measured the Lense-Thirring “drag” of the reference frame. A third LAGEOS-type satellite has been proposed for relativity studies.



NASA/GSFC - Solution: IERS96

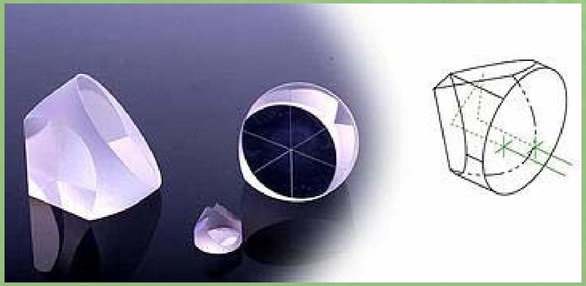


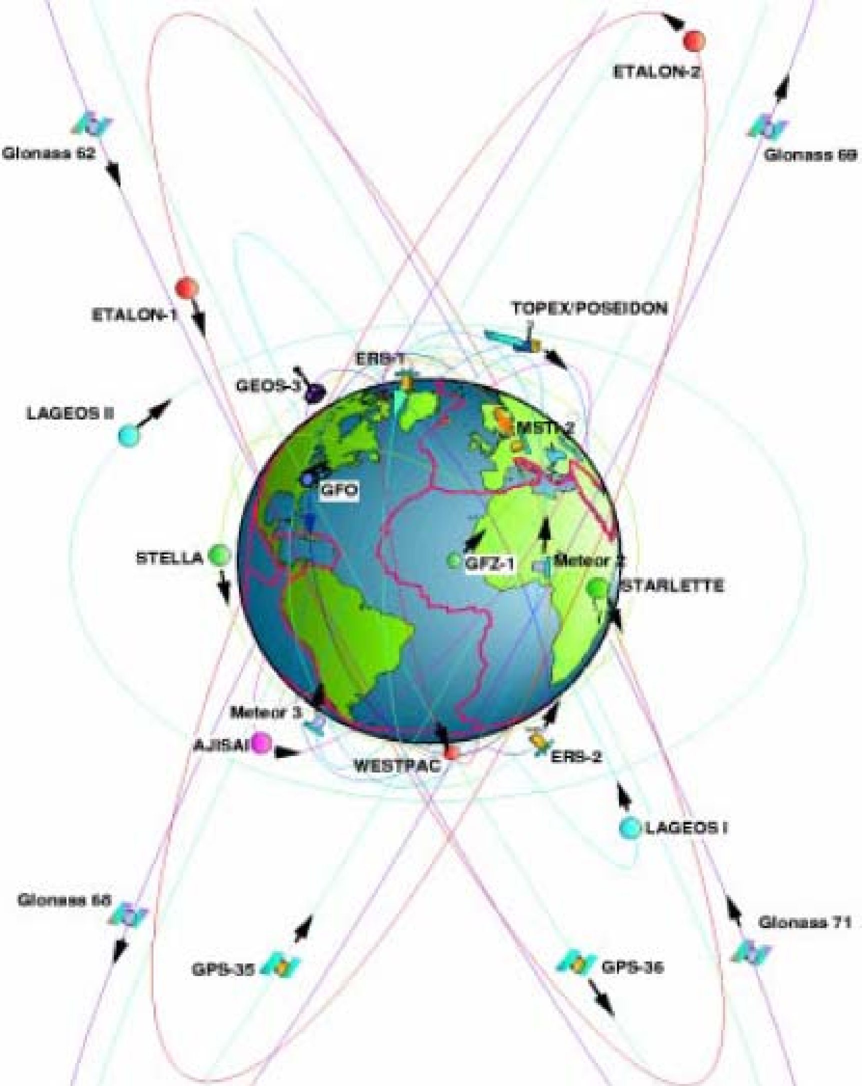
The satellites

Currently 35 objects

- active: altimetry, gravitometry, navigation

- passive: geodynamic





LAGEOS-1 i 2

426 CCRs

60 cm diameter

Mass 411 kg, 405 kg

~6000 km above the surface

Fully passive, geodesy

Ajisai

1436 CCRs + 318 mirrors

685 kg

Diameter 215 cm

1500 km above the Earth

Fully passive, geodesy

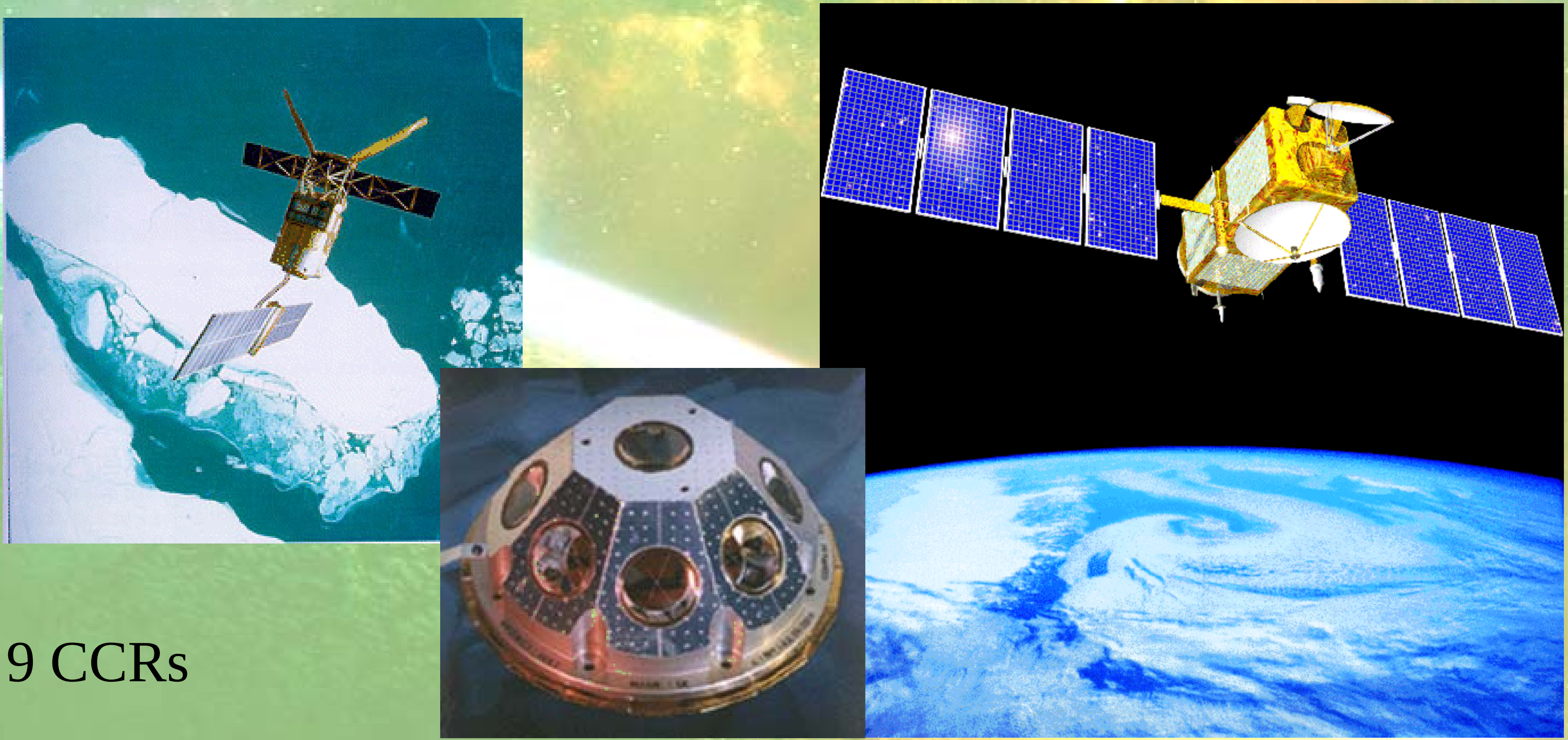
GPS-35 i 36

Panels with 32 CCRs

Navigation system,

time transfer

ERS-2, Envisat



9 CCRs

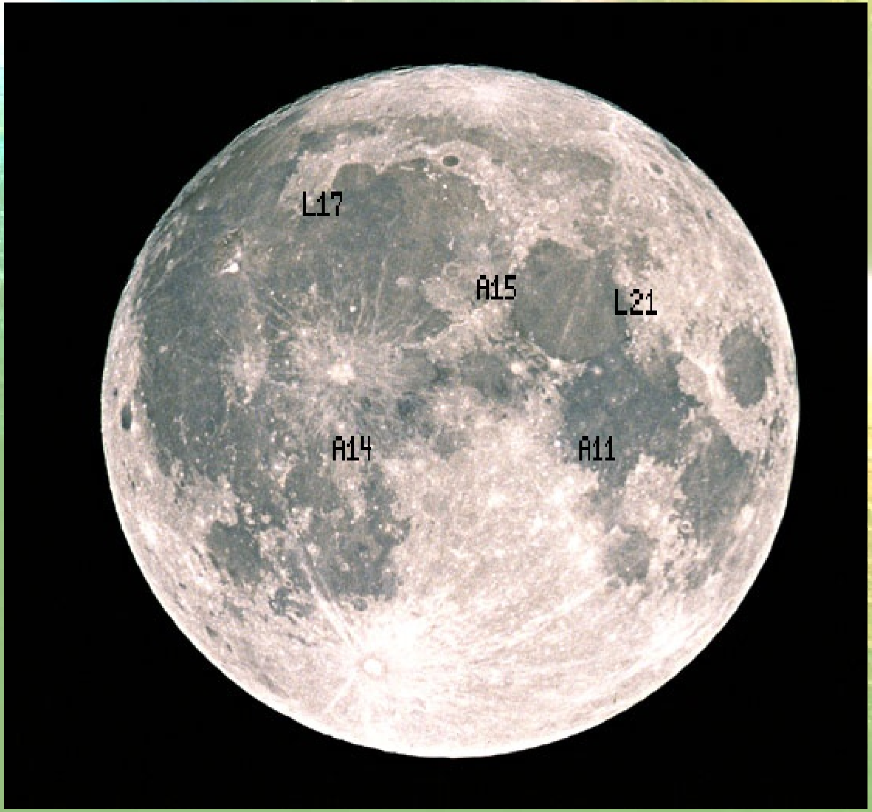
800 km above the ground

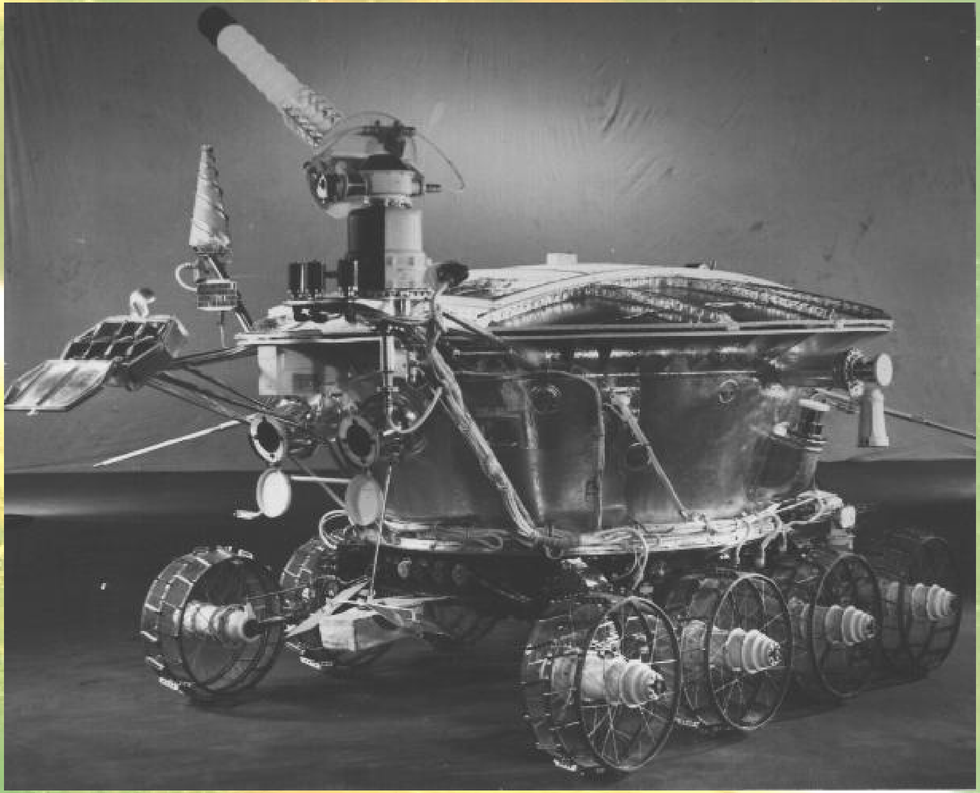
remote sensing and environmental monitoring

1200 km

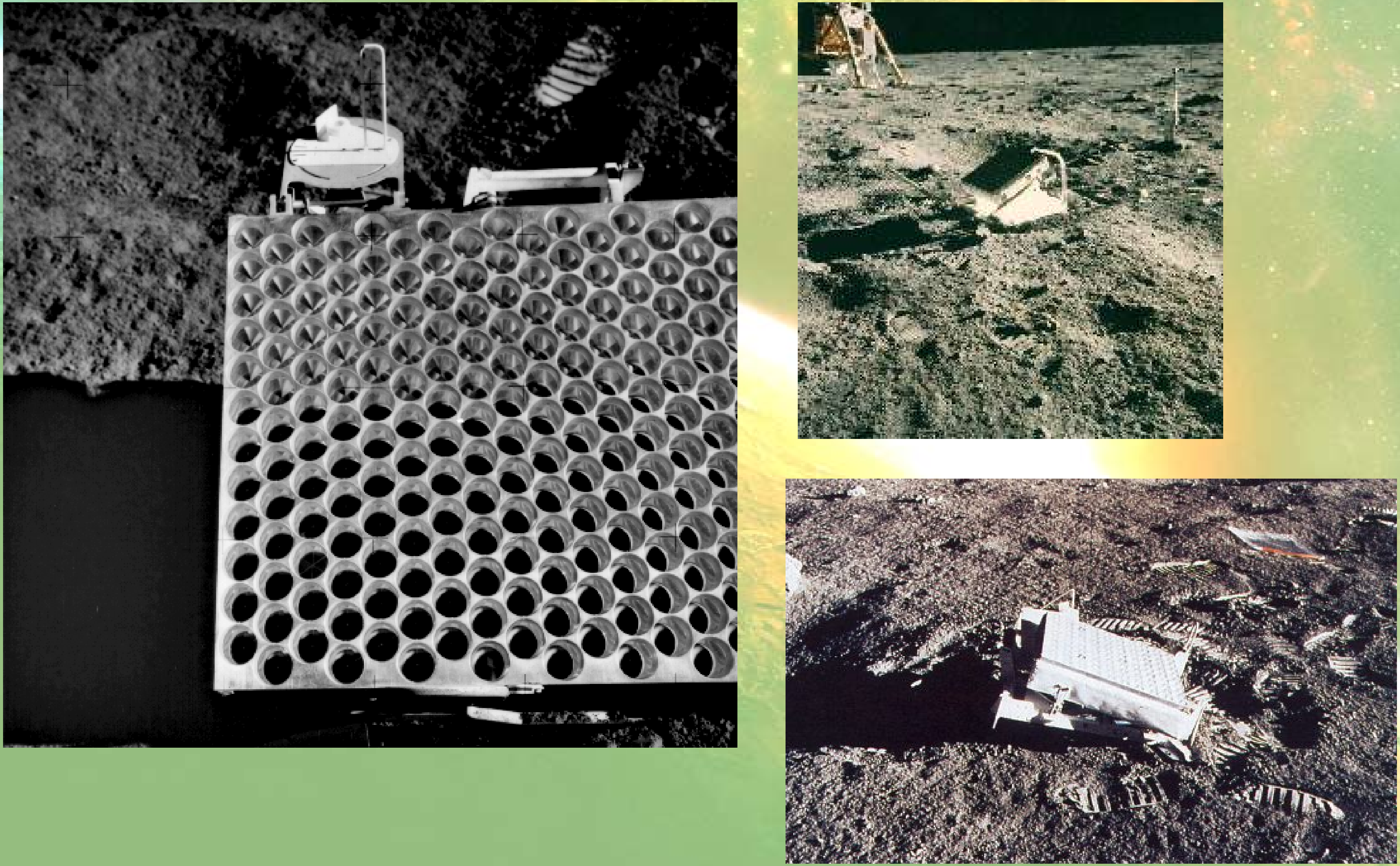
altimetry, oceanography

The Moon

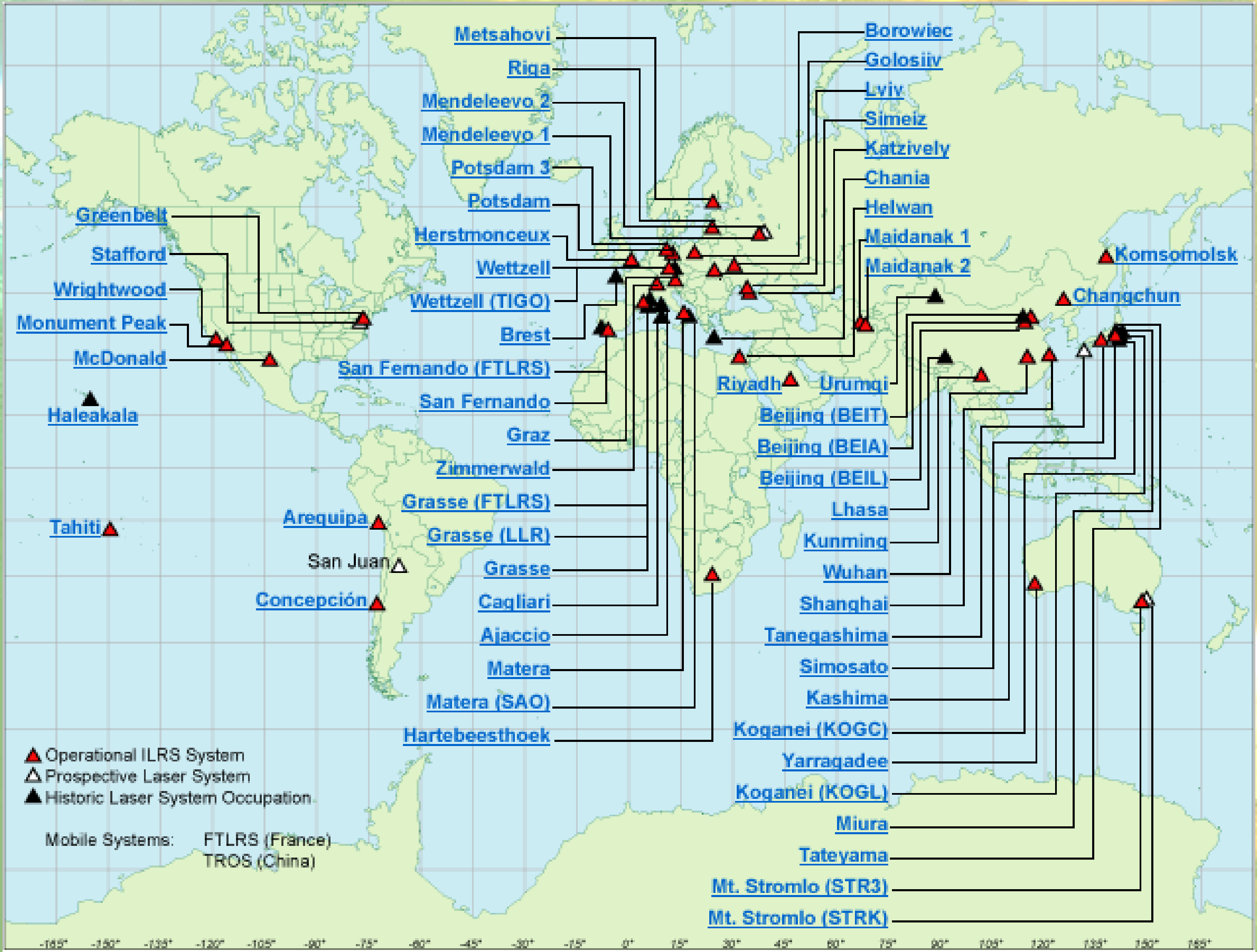




The Moon



SLR stations on the world



Graz SLR station

	GRAZ	The other stations
Laser pulse	2 kHz	5 - 10 Hz
Energy / puls	0.4 mJ	35 – 200 mJ
Puls width	10 ps	35 – 200 ps
Wavelength	532 nm	532 nm

High accuracy (~3mm) of the distance measurements

200 times more measurements per second

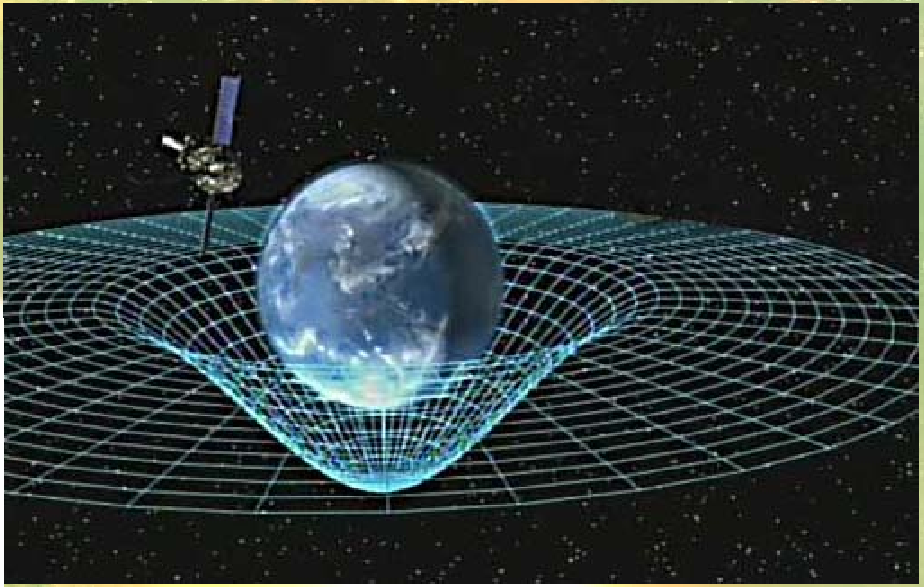
Graz kHz SLR – new applications

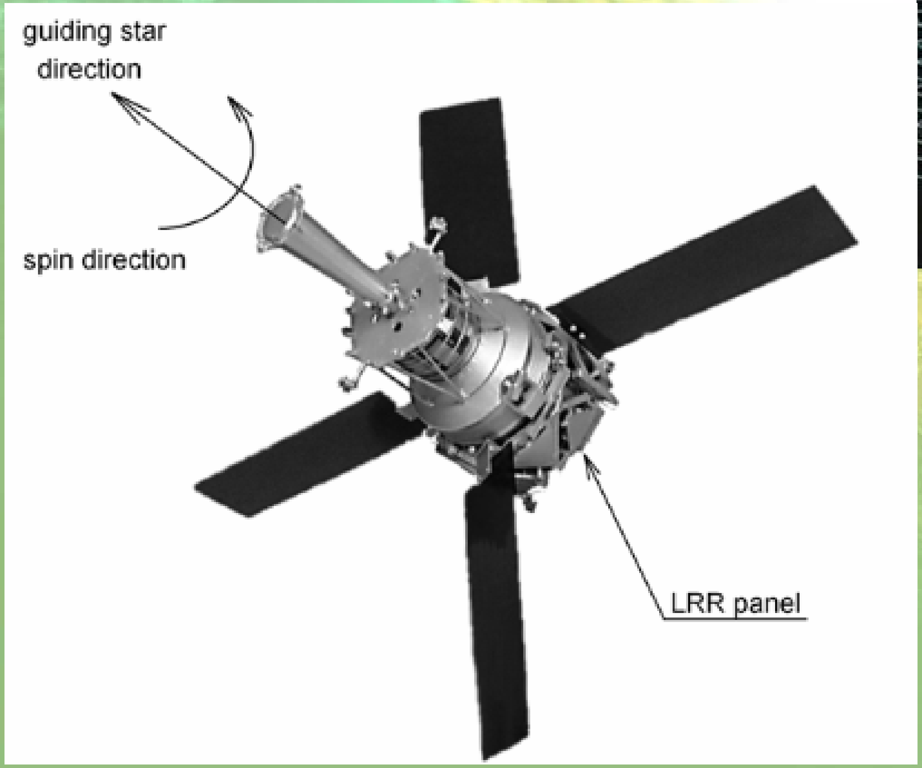
- Satellite spin measurements
  - Gravity Probe – B, 650 km, 75 s
  - Ajisai, 1500 km, 2.11 s
  - LAGEOS – 1, 2, 6000 km, 5000 s, 600 s
  - ETALON –1 , 2, 19000 km, 65 s
- Atmospheric seeing measurements
  - monitoring the atm. condition of the way of a laser pulse
- Lidar (Light Detection And Ranging)
  - clouds detection

Graz kHz SLR – spin of GP-B

Lense-Thirring “drag”

650 km

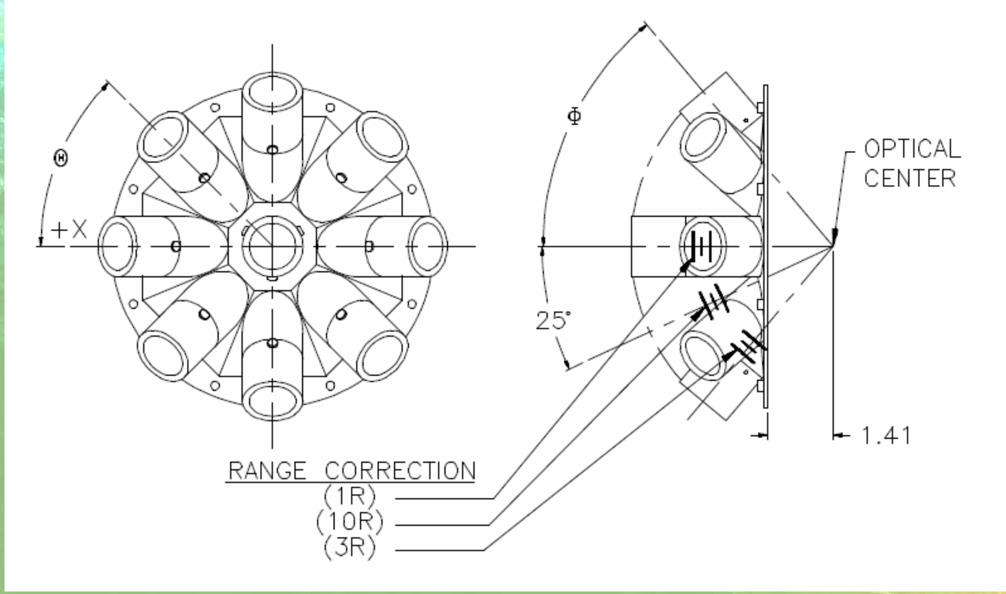


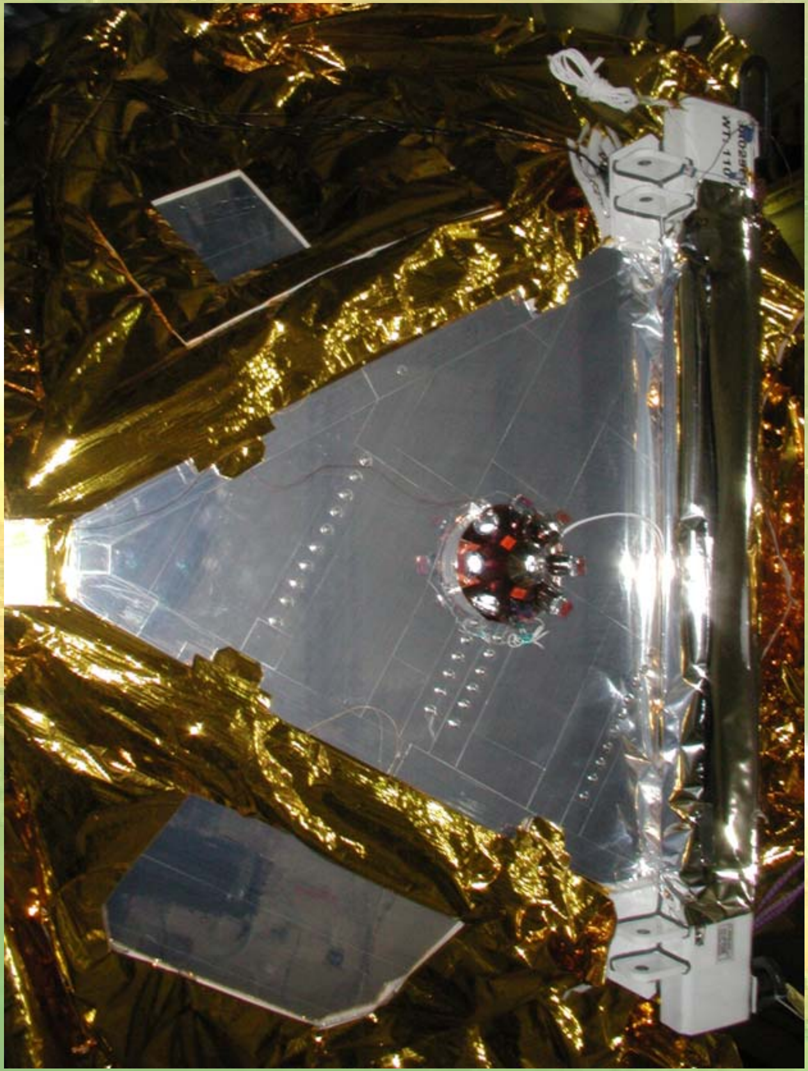


Only Graz kHz SLR station was able to measure the spin of the spacecraft.

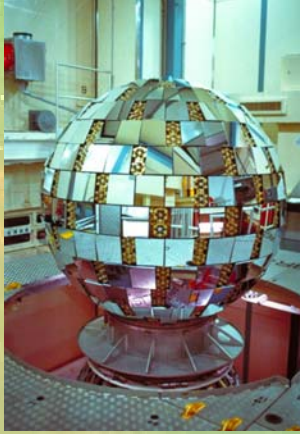
Graz kHz SLR – spin of GP-B

8 CCRs, 10cm dia.



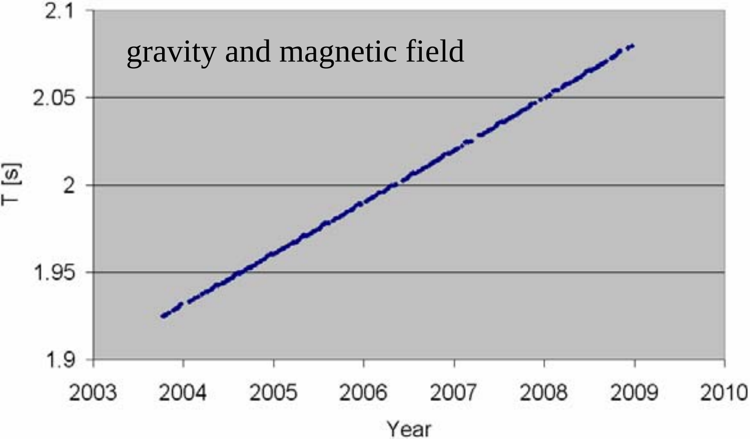


Graz kHz SLR – spin of Ajisai



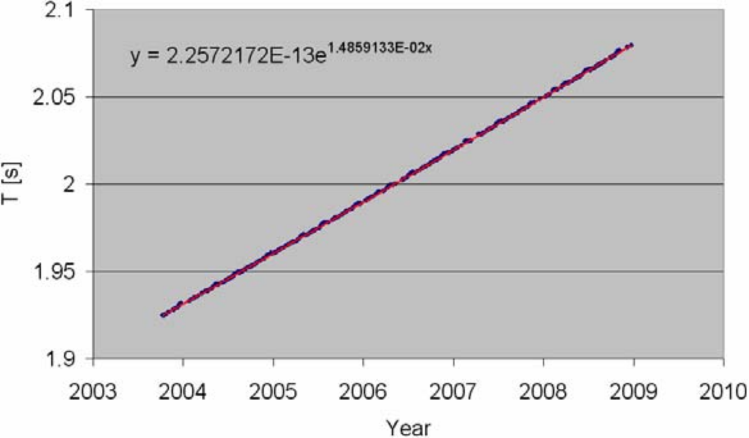
Results: 877 AJISAI kHz SLR passes
more than 5 years of observation with Graz 2 kHz system

1. Spin period – increasing with time

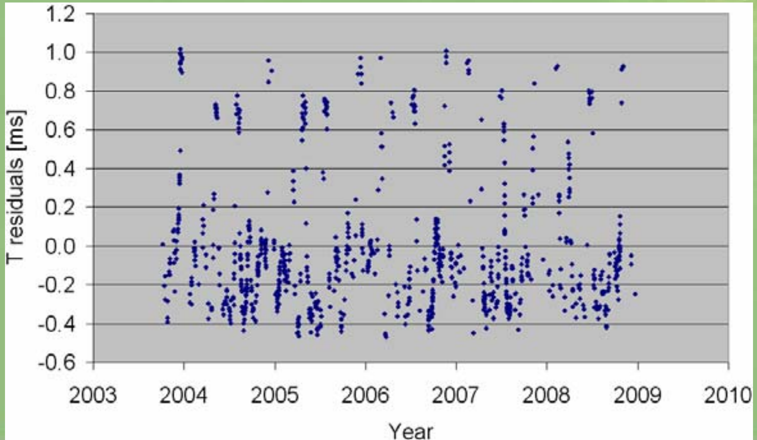


gravity and magnetic field

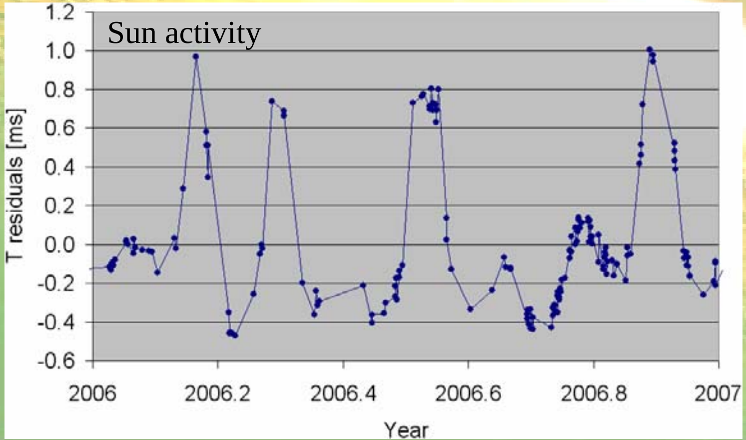
2. An exponential approximation



3. Spin period residuals



4. Spin period residuals – year 2006

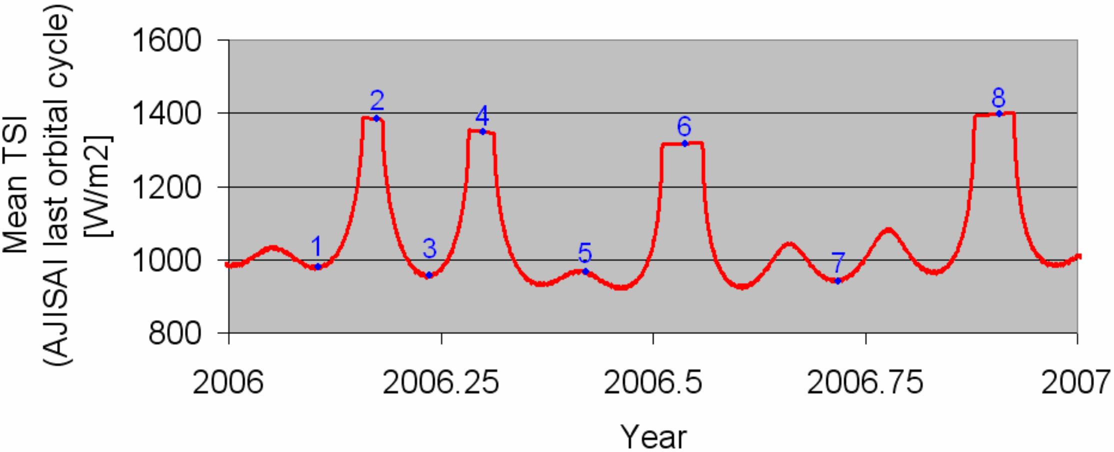


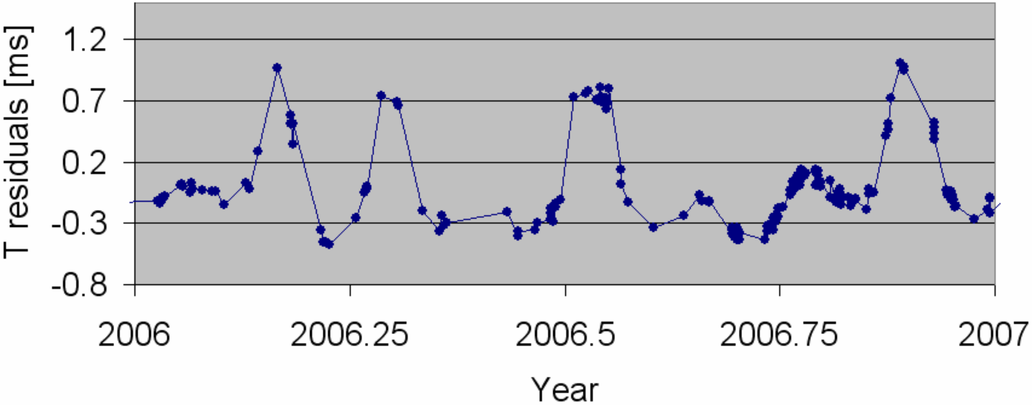
Sun activity

Graz kHz SLR – spin of Ajisai

Model of the spin period residuals

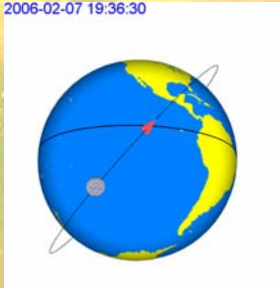
Mean TSI acting on Ajisai during last orbital cycle





view from the Sun direction

1



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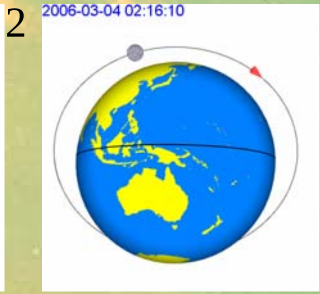

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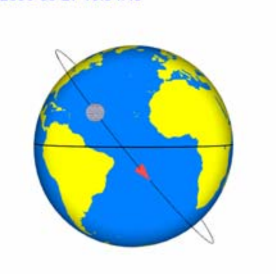


4

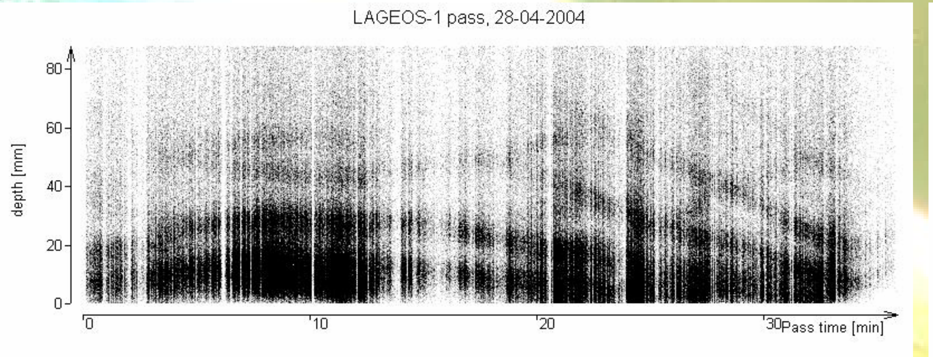
5

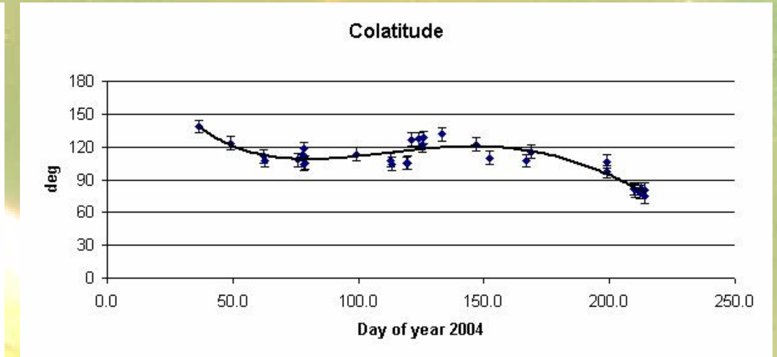
6

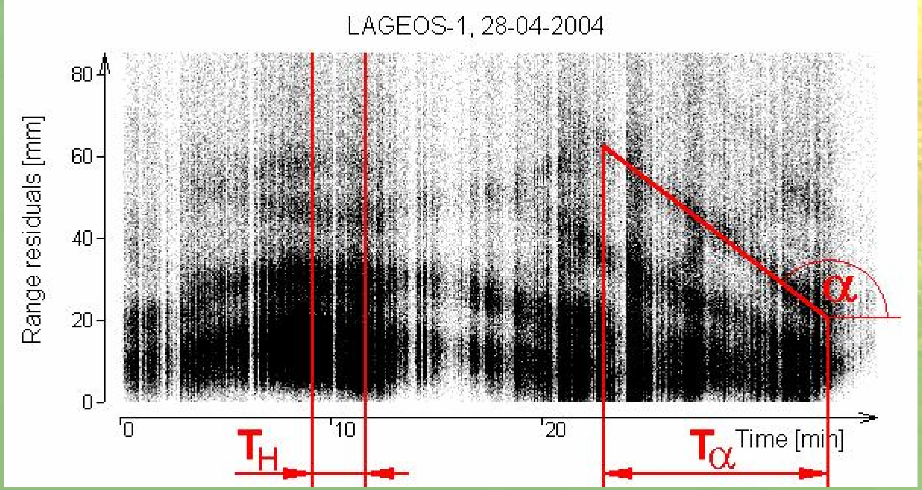
7

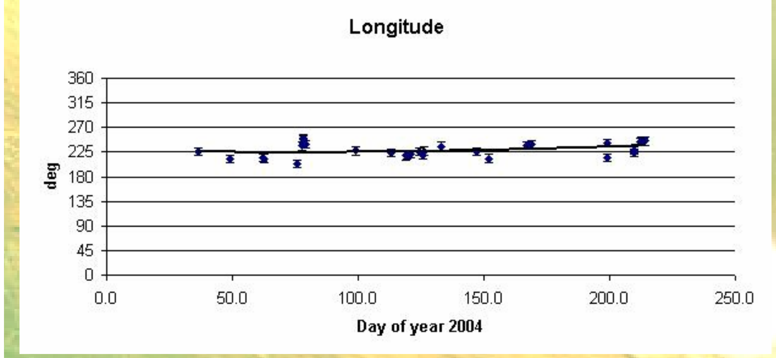
8

Graz kHz SLR – LAGEOS-1


LAGEOS-1 pass, 28-04-2004

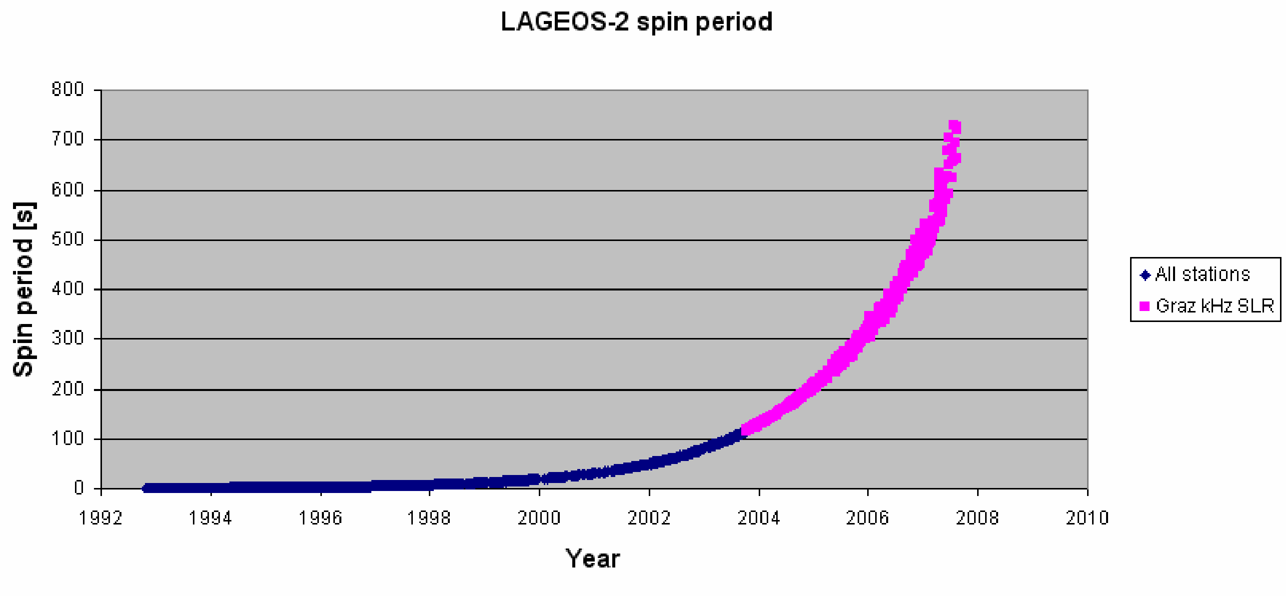

Colatitude

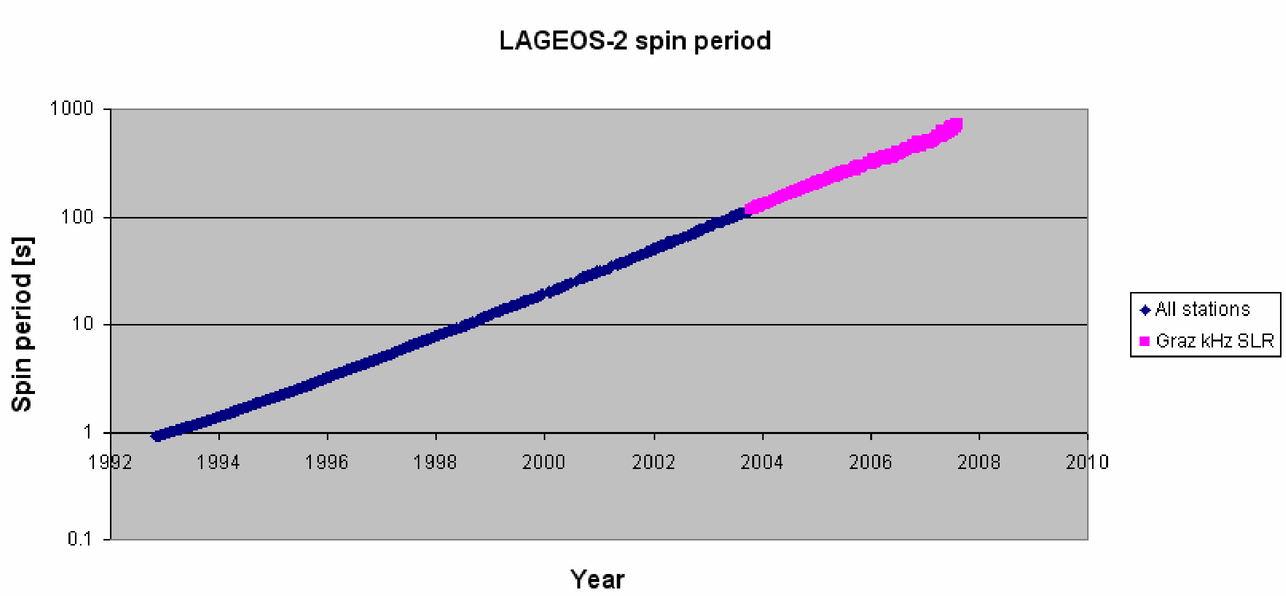

LAGEOS-1, 28-04-2004


Longitude

T=5775 s

Graz kHz SLR – LAGEOS-2



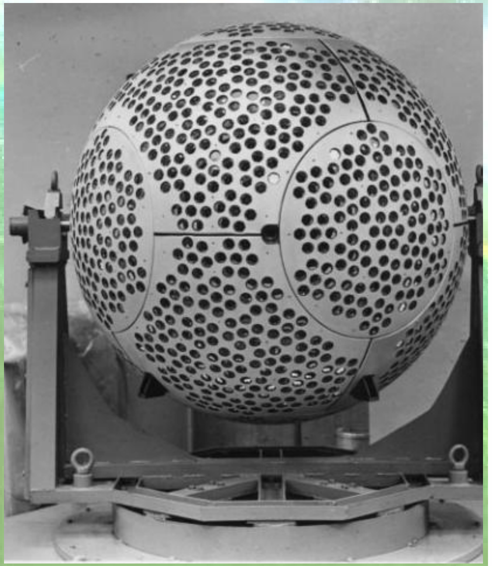


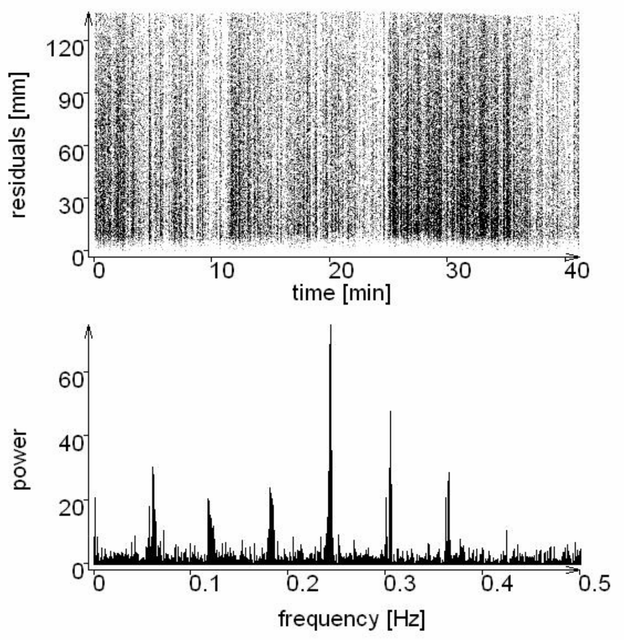
Full 15 years spin period history,

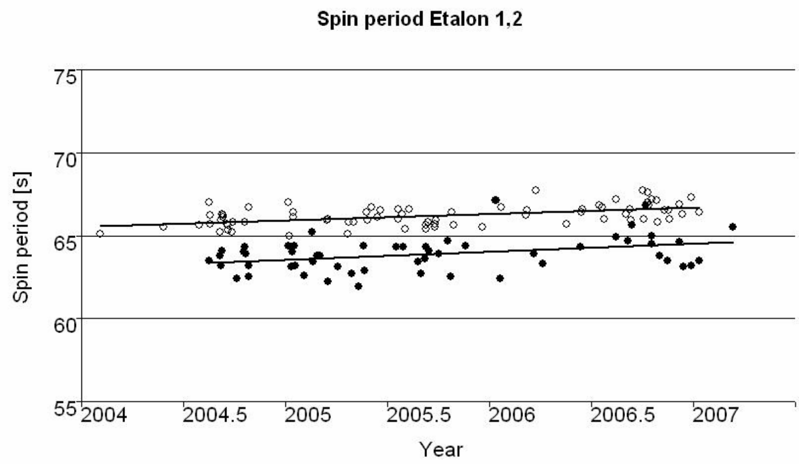
Only Graz kHz system can measure L2 spin of more than 100s

Study of various perturbations and RE

Graz kHz SLR – ETALON-1, 2







~70k
measurements/h

Spin period of the ETALONs is
increasing by ~0.5 s/year

Spin parameters - application

Improving the accuracy of the perturbations' models

The magnetic torque

$$\Gamma_{magnetic} = V\alpha'\varpi \times B(\varpi \cdot B) - V\alpha''(B \times \varpi) \times B$$

Bertotti and Iess, 1991

The gravitational torque

$$\Gamma_{gravitational} = -\frac{3m^2}{4L^2}(C-A)(3\cos^2\vartheta - 1)(n \cdot L)(n \times L)$$

Farinella et al., 1996

Solar radiation pressure causes a torque:

$$\Gamma_{offset} = \frac{I_0 h C_R A_{cross}}{c}(s \times r_{sun})$$

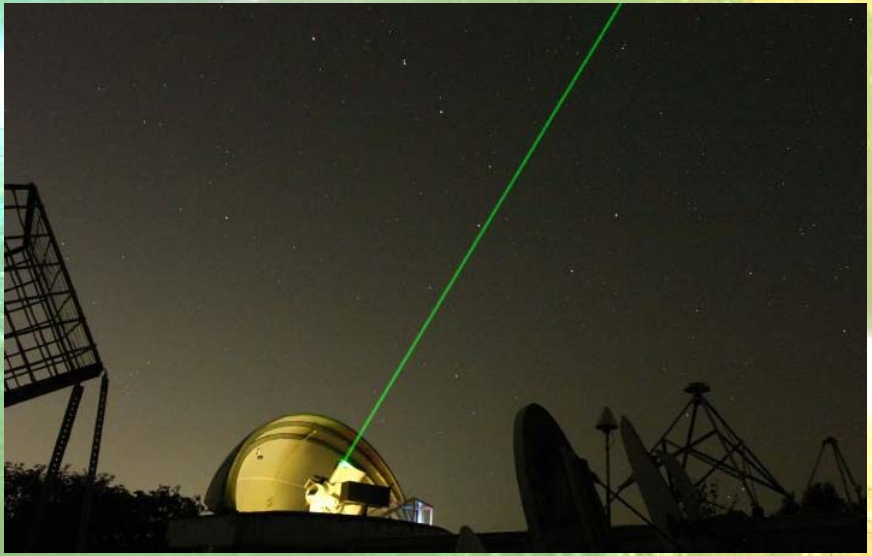
Vokrouhlicky, 1996

Bertotti, B., and Iess, L. The rotation of LAGEOS, J. Geophys. Res., 96 (B1), 2431-2440, 1991

Farinella, P., Vokrouhlicky, D., Barlier F. The rotation of LAGEOS and ist long-term semimajor axis decay, J. Geophys. Res., 101 (B8), 17,861-17,892, 1996

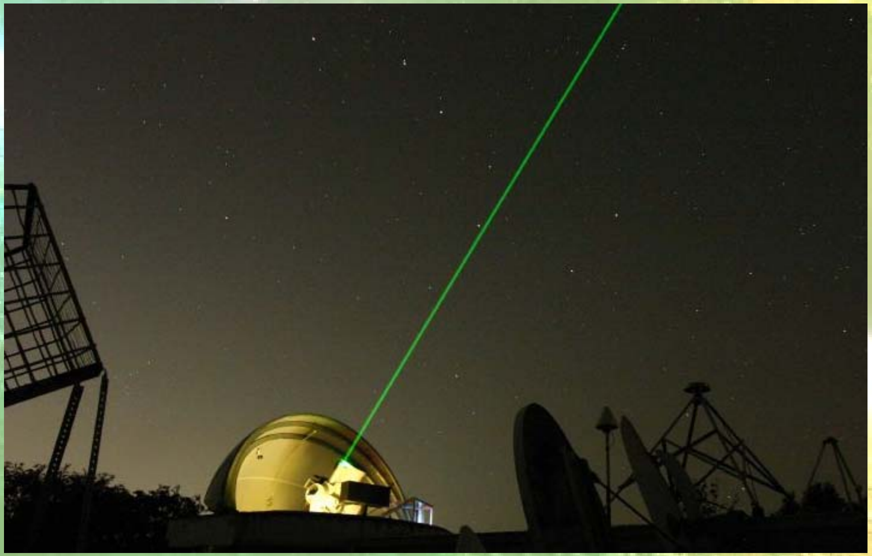
Vokrouhlicky, D. Non-gravitational effects on LAGEOS' rotation. Geophys. Res. Lett., 23, 3079-3082, 1996

Graz kHz SLR – atm. seeing

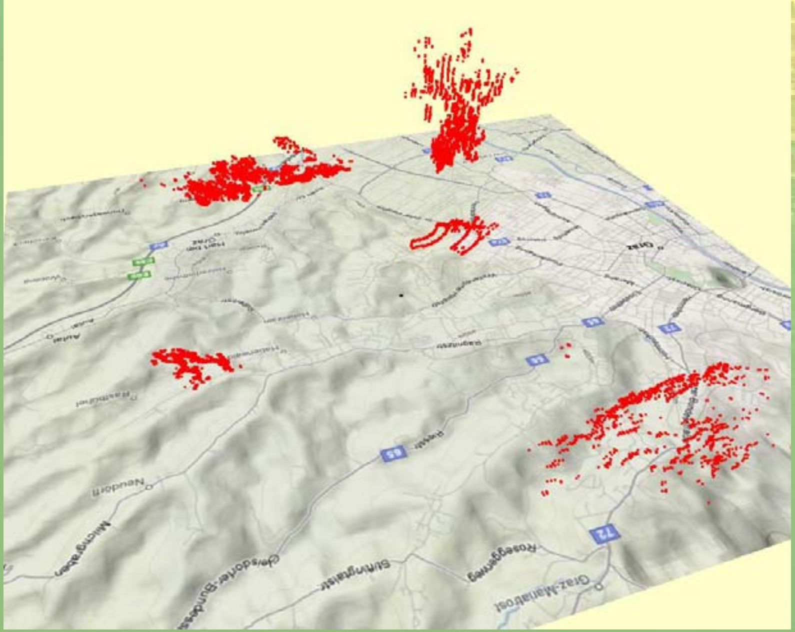


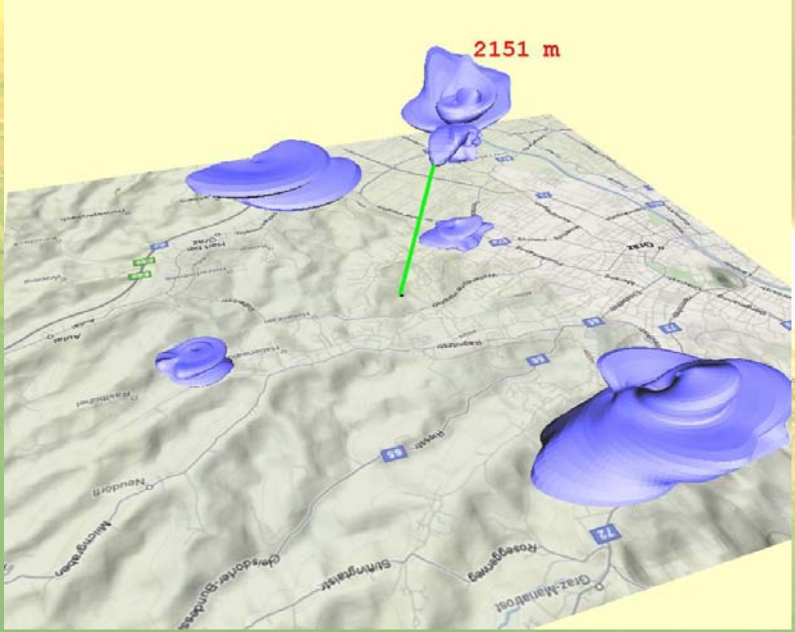
- Real Time Image Processing: Determine Peak of Laser Beam
- Calibrated with standard astronomical methods

Graz kHz SLR – Lidar



- Clouds detection
- Range measurement to the clouds





Graz – the first kHz SLR system

- more accurate range measurements = improvement of POD (navigation systems HEO, LEO)

- much more scientific data: spin determination of various sat.

kHz SLR allows to investigate values of the SP and their changes, it gives an unique possibility to study the tiny petrurbating forces (RE)

- more information about the atmospheric conditions: seeing measurements over the station

Thank you