Surface deformations of the Earth related to its time dependent gravity field and dynamics: new results and future plans

Papp, G., Benedek, J., Mentes, Gy., Ruotsalainen, H., Meurers, B., Leonhardt, R., Kis, M., Koppán, A., Hutchinson, P. and Szántó, M.

Our investigations are supported by NKFIH-OTKA K128527 project

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General research aims:

Monitoring of surface deformation for

1) the investigation of ***local*** tectonic processes,

2) the investigation of ***global*** phenomena related to the time variations of the Earth's gravity field.

Infrastructure:

Observatories in the Pannonian basin and in Australia operating

1) a superconducting gravity meter (GWR SG025),

2) extensometers/strainmeters,

3) tilt sensors.

All instruments have ***nano-range*** or better resolution (nm/s^2, nm,nrad).

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resulting
- pre- (?) and post-seismic deformations
- orogenic deformations
- sediment compaction
- basin sinking
- etc…

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including
- solid earth (body) tides
- ocean loading effects
- mass redistribution

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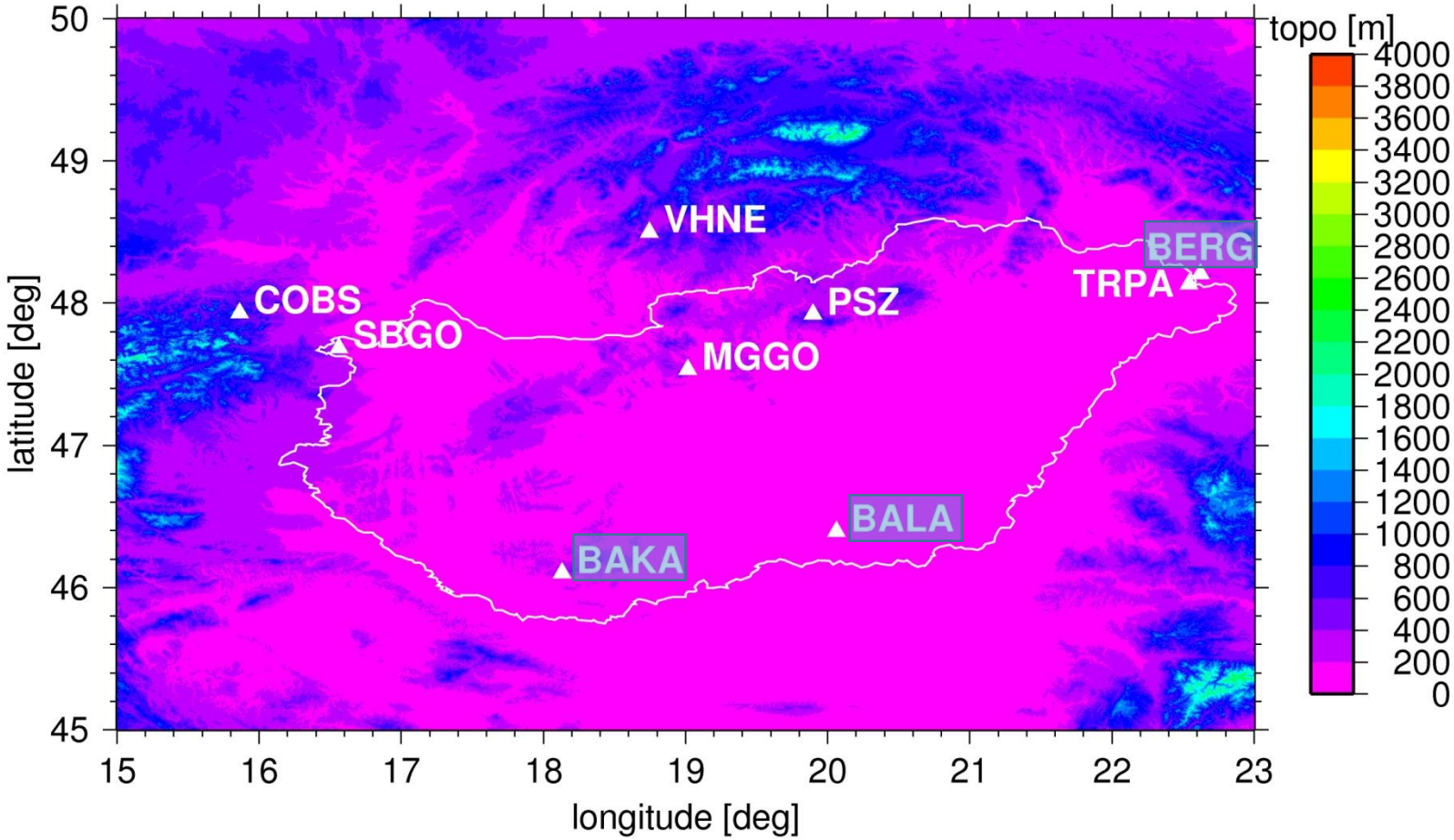
Permanent and temporal geodynamical stations



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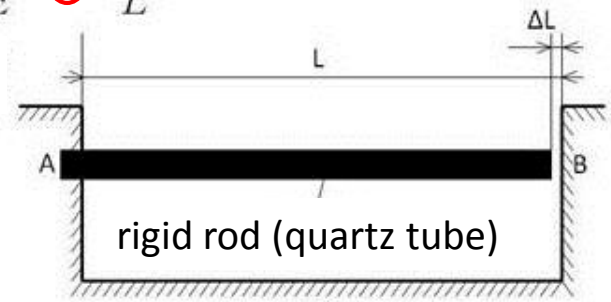
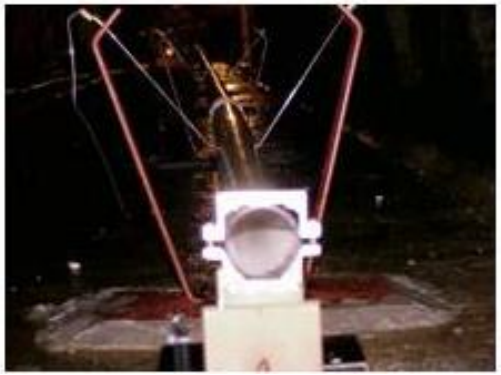
strain

$$\frac{\sigma}{E} = \varepsilon = \frac{\Delta L}{L} \longrightarrow \Delta L = \varepsilon L$$



basement rock



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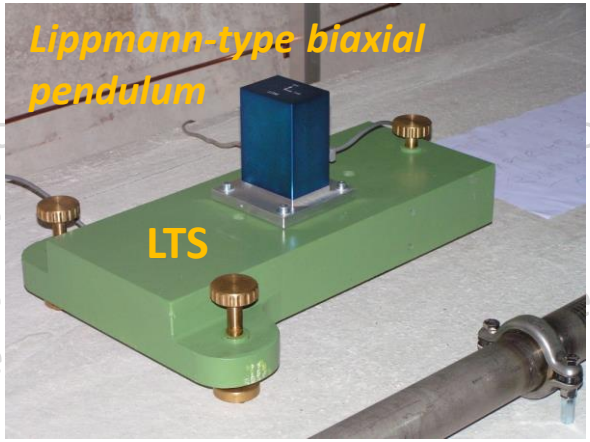

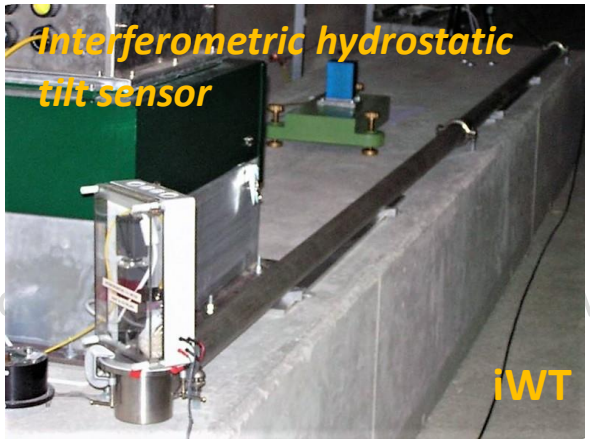

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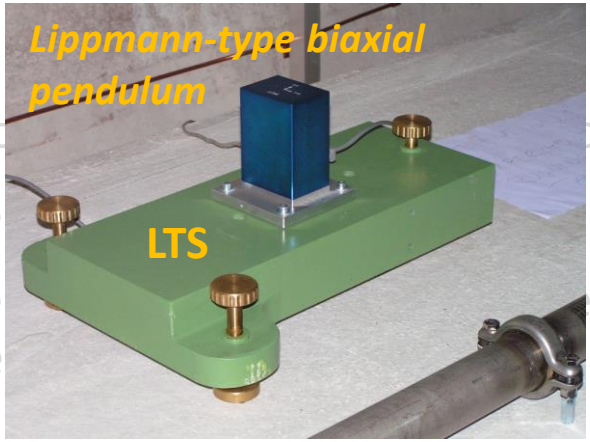

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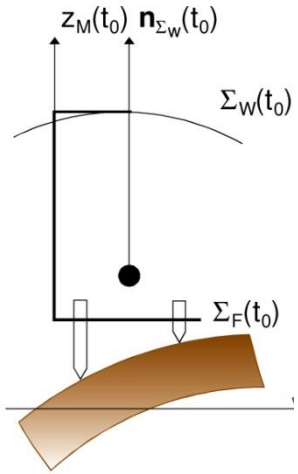

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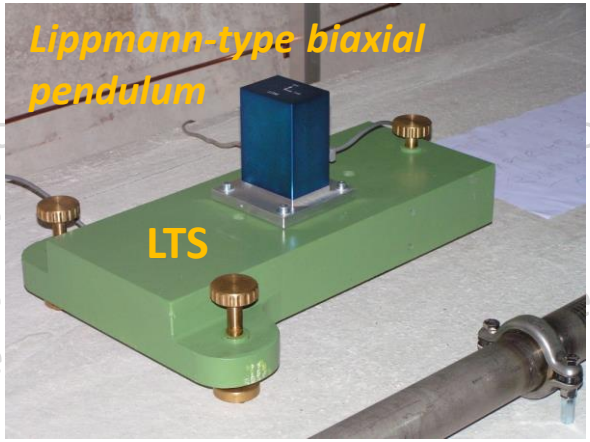

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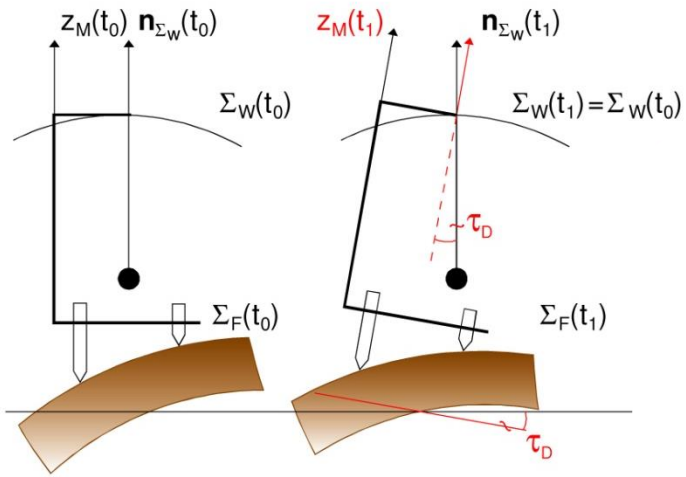

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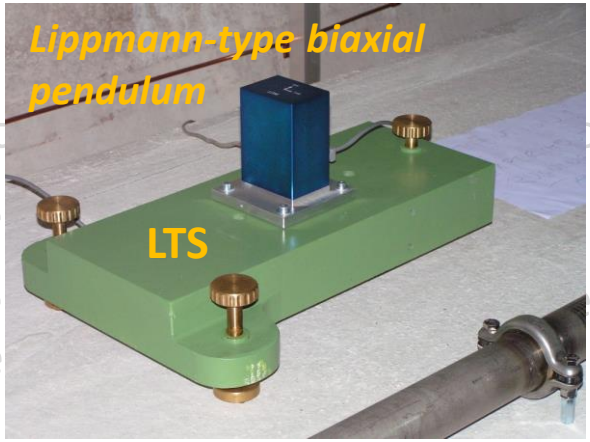

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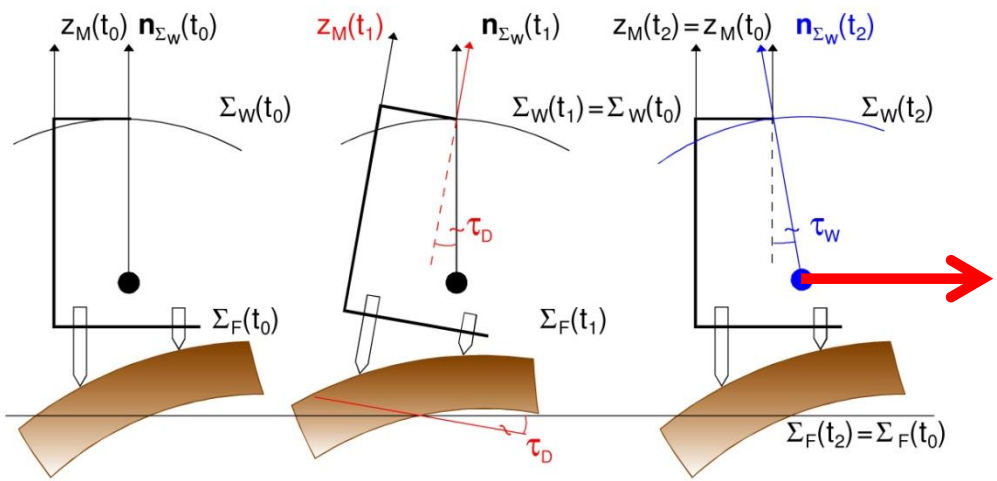

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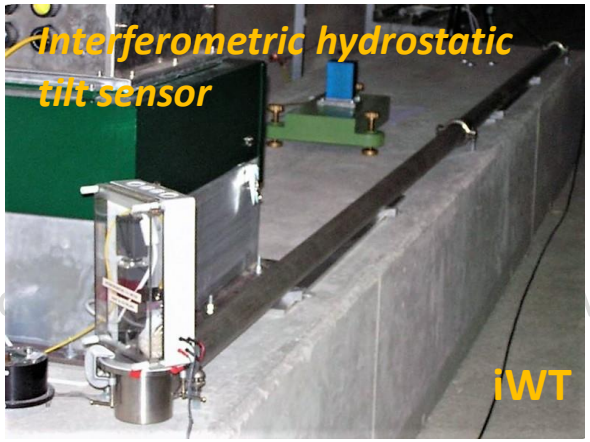

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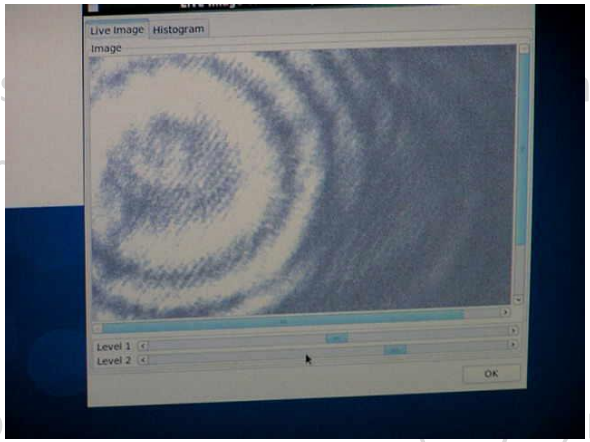

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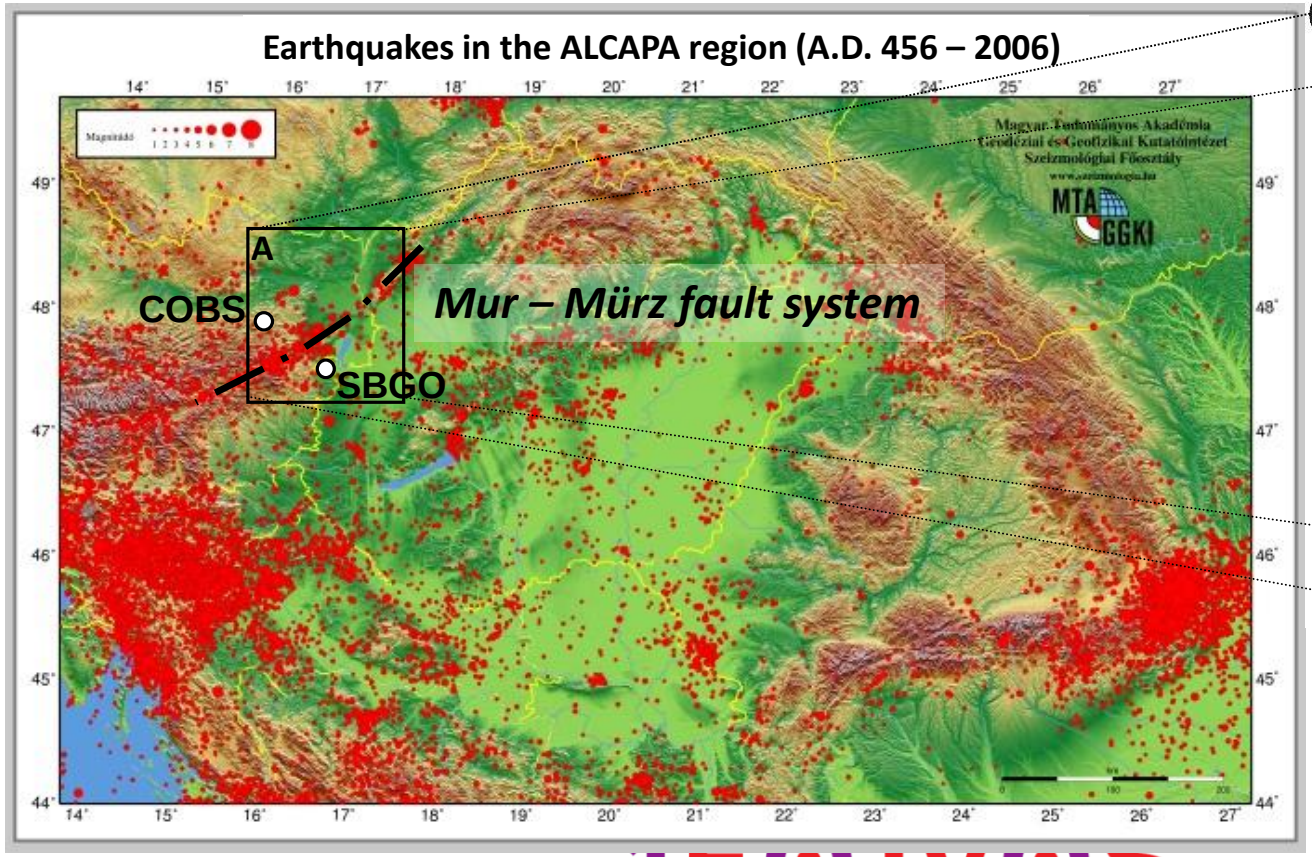

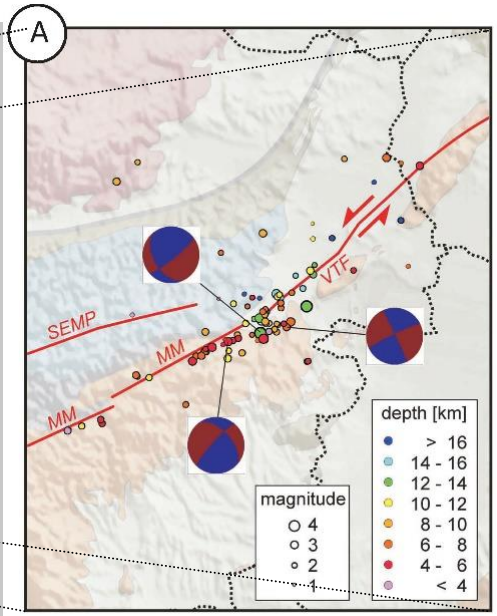

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Gábor Virág: Processing of the old and new measurements of EOMA I. order network

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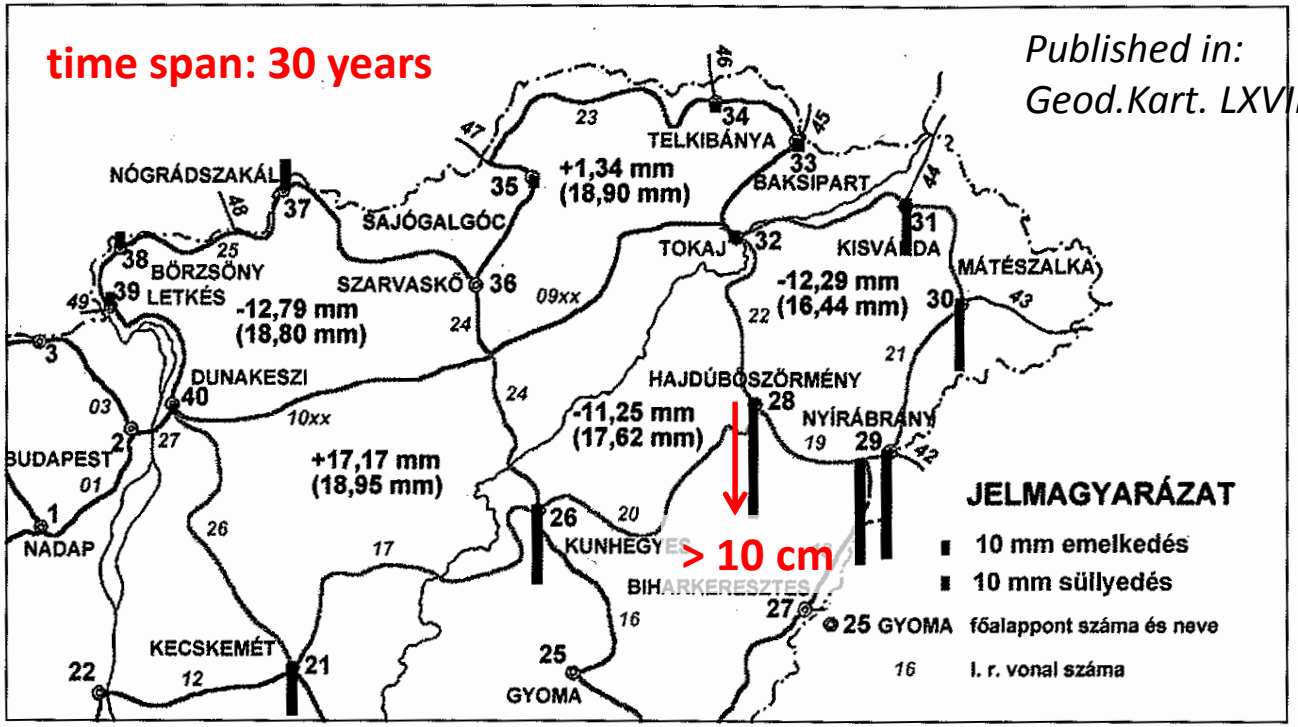
Geod.Kart. LXVIII/11-12, 2016



5. ábra. Főalappontok és csomópontok magasságainak változása

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Observation of tidal effects at COBS: gravity and deformation

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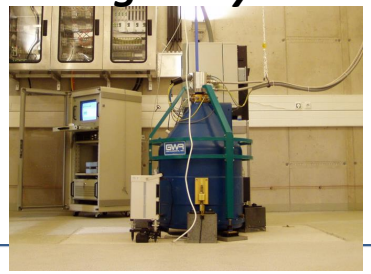
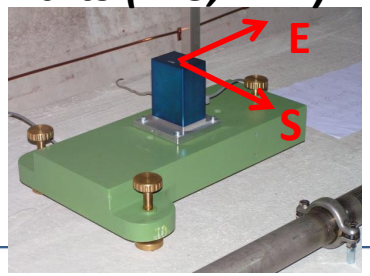
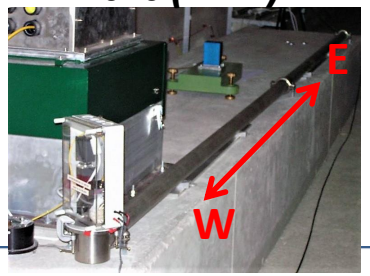
GWR SG05 — gravity

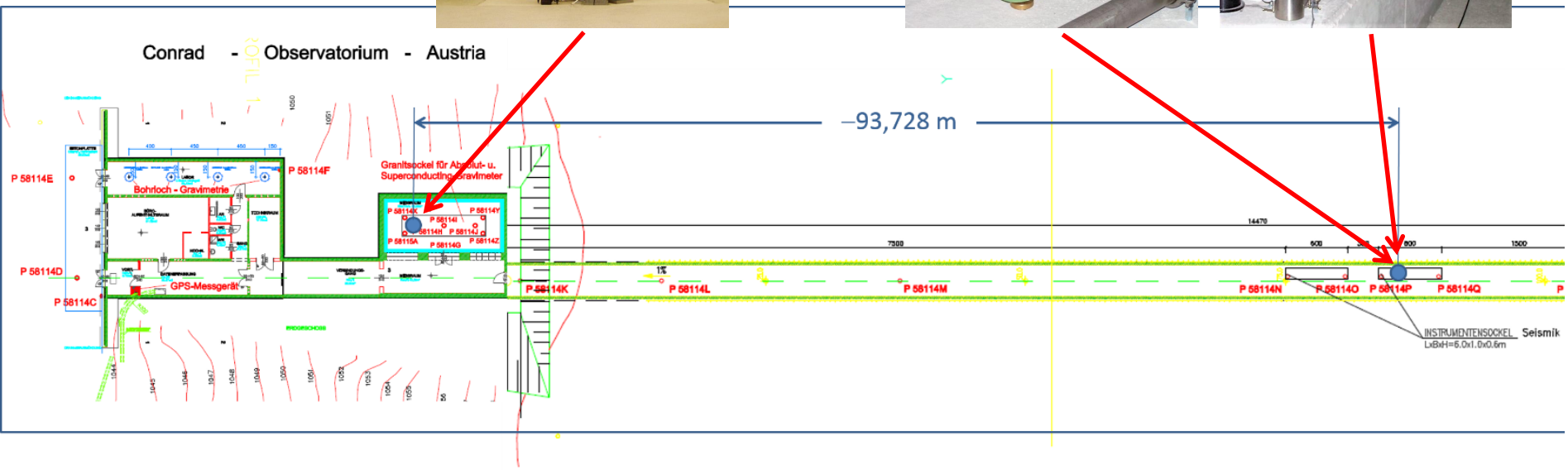


LTS — tilts (N-S, E-W)



iWT — tilt (E-W)





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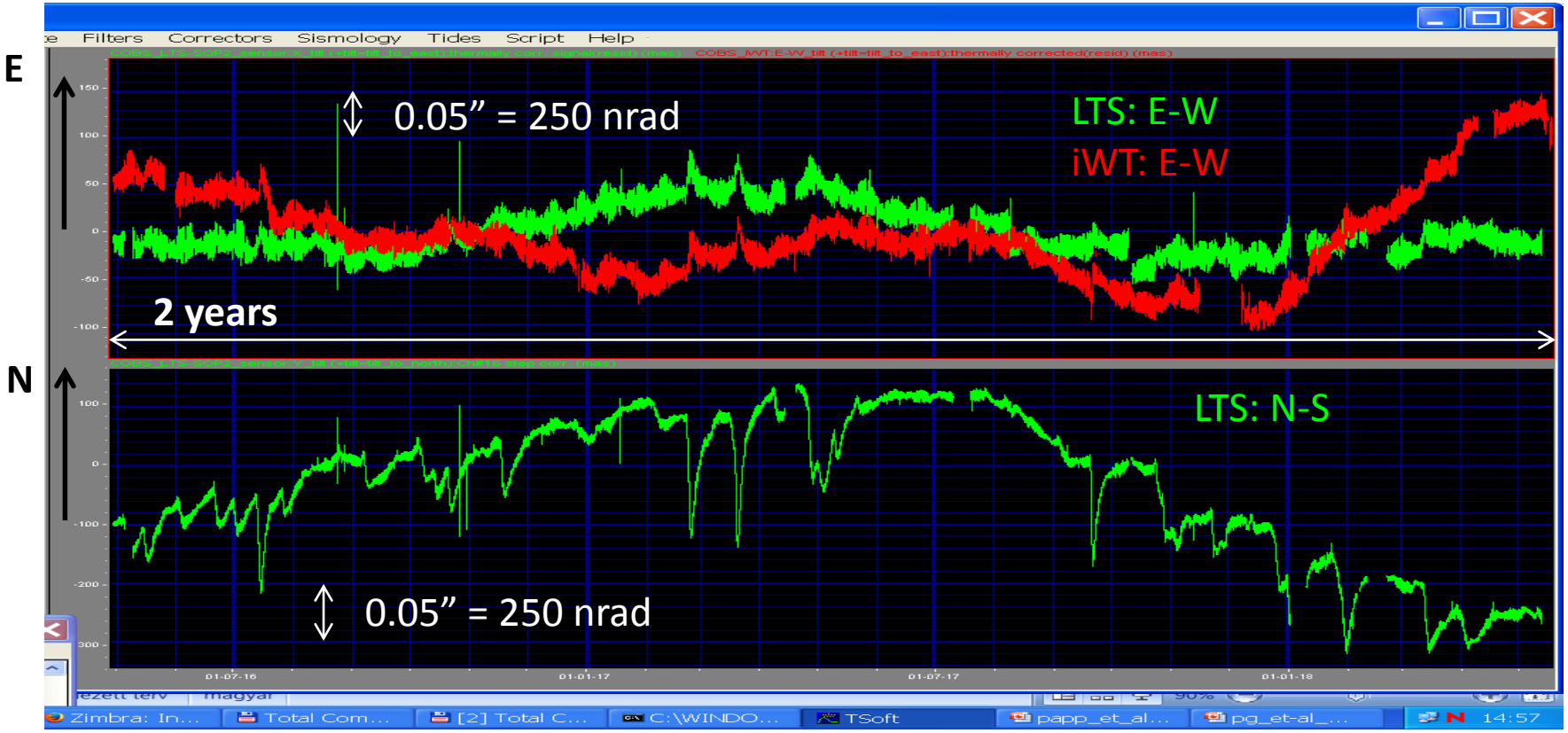
Observation of tidal effects at COBS: gravity and deformation

Tilts related to Earth tides and many other phenomena: nonlinear components (n>2)

29-04-2016 – 13-05.2018



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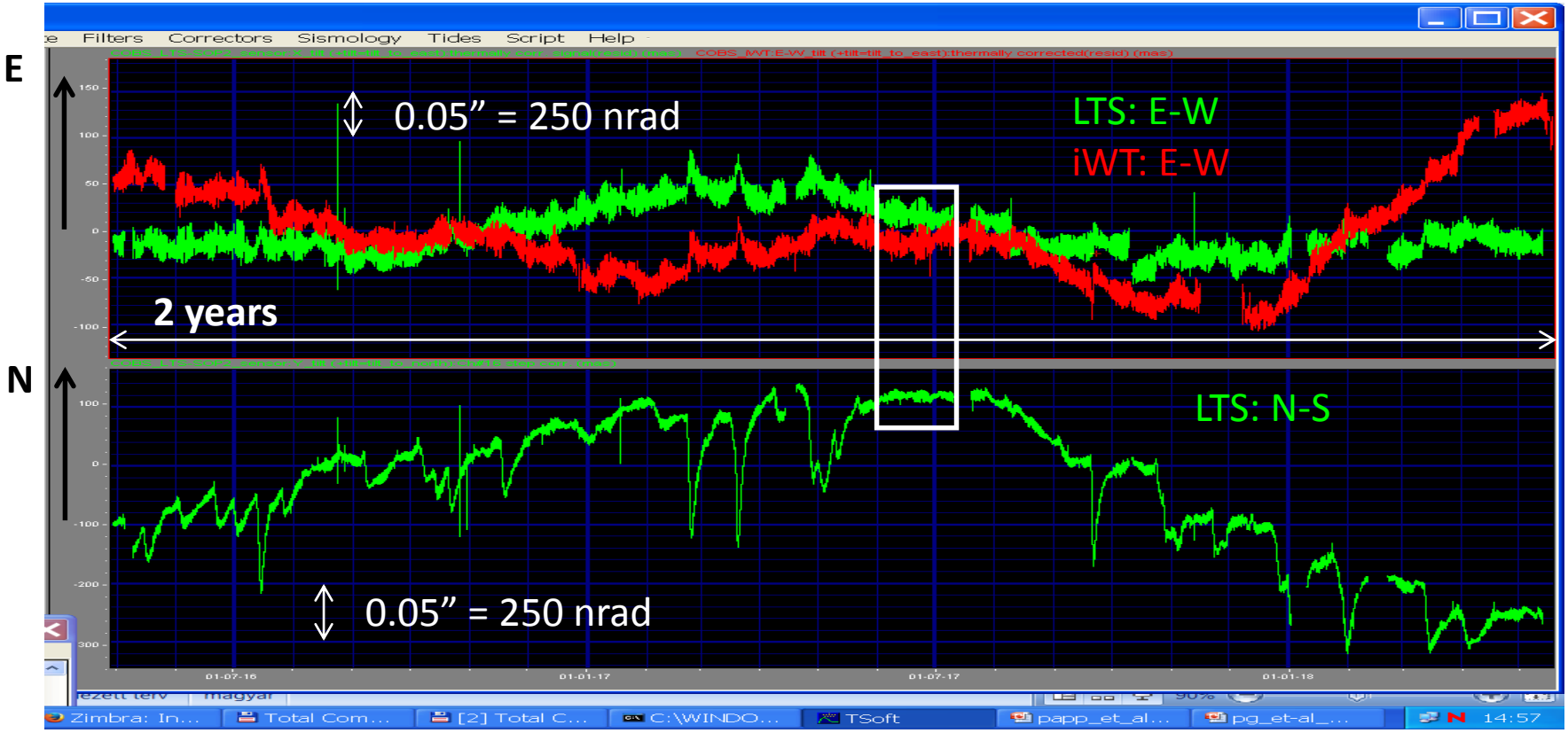

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Harmonic analysis of **tilt** *time series recorded at COBS: standard procedure using ETERNA package*

		N-S			E-W					
		LTS-Y			LTS-X			iwt-X		LTS/iwt
Darwin	γ (WD)	amp [mas]	γ σ(γ)	ϕ σ(ϕ)	amp [mas]	γ σ(γ)	ϕ σ(ϕ)	γ σ(γ)	ϕ σ(ϕ)	
Q1	0.6940	0.1235	2.9289 1.3921	-17.218 12.022	0.9257	0.6976 0.0490	1.776 4.042	0.6937 0.0851	-13.136 7.011	1.0056
O1	0.6944	0.6449	**1.2940** 0.1533	12.022 9.648	4.8347	**0.7105** 0.0104	-7.020 0.838	**0.6783** 0.0170	-12.356 1.434	1.0475
K1	0.7362	0.9070	**1.2184** 0.1536	10.551 7.200	6.7995	**0.7808** 0.0073	-8.045 0.462	**0.7346** 0.0108	-11.556 0.839	1.0629
N2	0.6911	1.5053	**0.6744** 0.0306	-4.524 2.590	2.0279	**0.7516** 0.0889	-2.863 0.676	**0.7200** 0.0115	-4.697 0.918	1.0439
M2	**0.6911**	7.8622	**0.6574** 0.0060	-2.313 0.522	10.5916	**0.7404** 0.0019	-3.853 0.147	**0.6827** 0.0023	-5.559 0.192	1.0845
S2	0.6911	3.6579	**0.6599** 0.0128	-1.436 1.128	4.9278	**0.6865** 0.0044	-1.609 0.363	**0.6306** 0.0519	-5.493 0.460	1.0886

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$$\gamma_n = \frac{b_{\beta,n}}{b^{th}_{\beta,n}} = 1 + k_n - h_n$$

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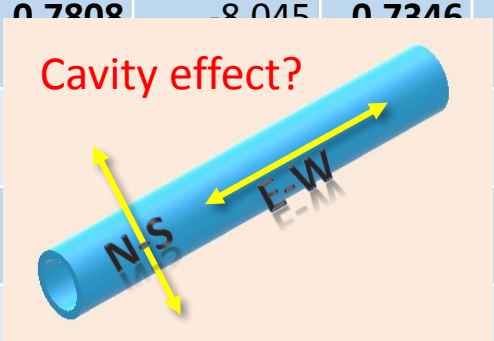

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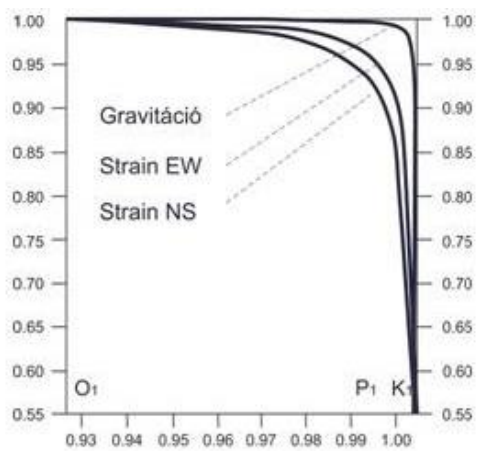
Harmonic analysis of strain time series recorded at SBGO: investigation of FREE CORE NUTATION (FCN)

$f_{FCR}=1+1/T_{FCN}$, where $T_{FCN} \approx 430$ days $\Rightarrow$ FCN modulates tidal components having near-to-diurnal frequency

(K1, P1, Ψ1, Φ1,…)

scale problem $\Rightarrow$ K1/O1, P1/O1, etc…

modulation effect



frequency (cpd)

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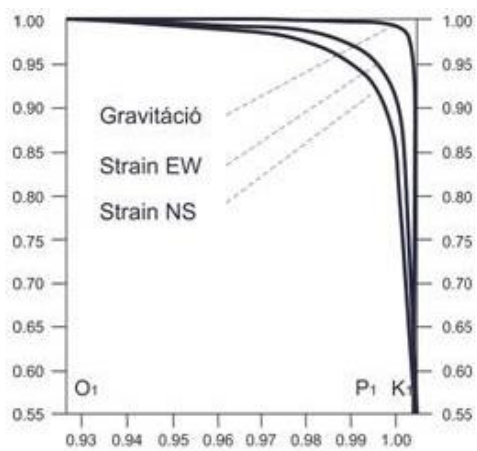

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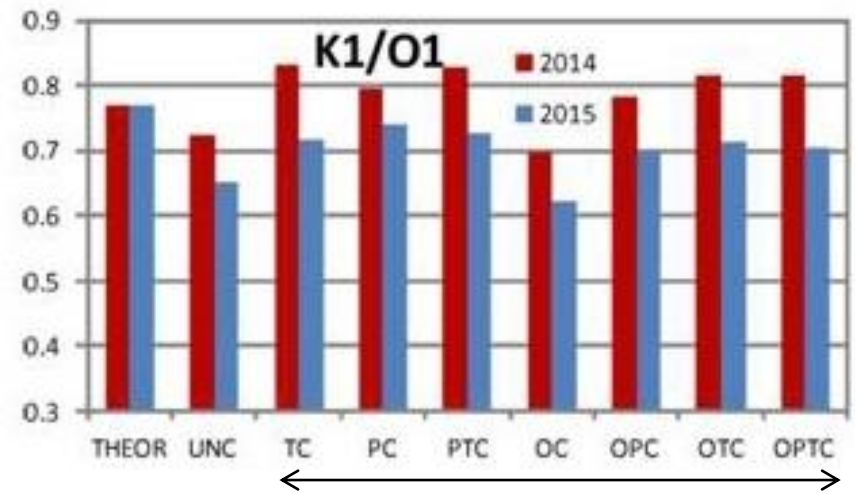

Correction types:

Harmonic analysis of strain time series recorded at SBGO: investigation of FREE CORE NUTATION (FCN)

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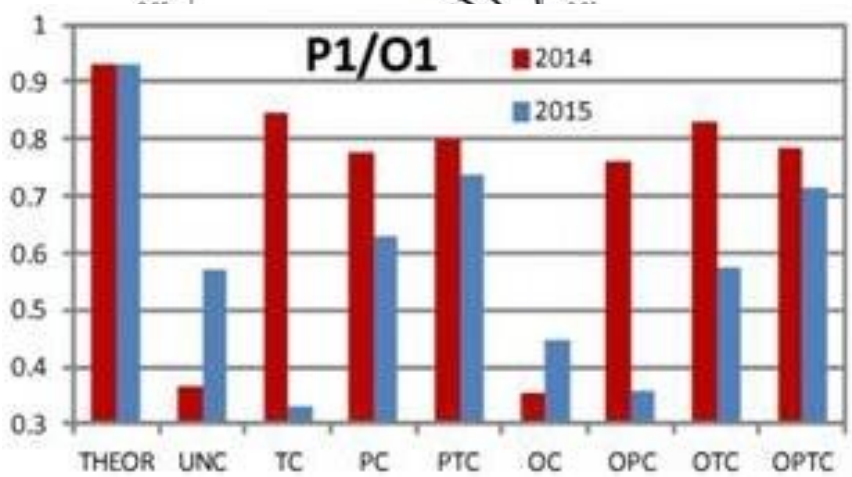
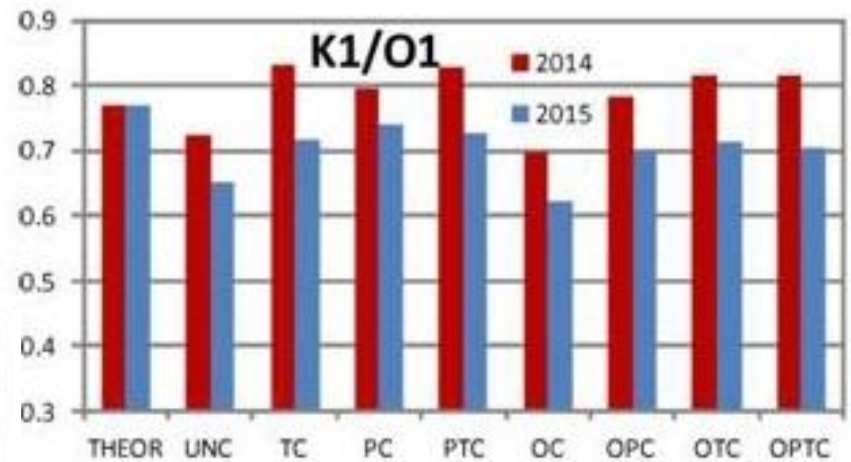
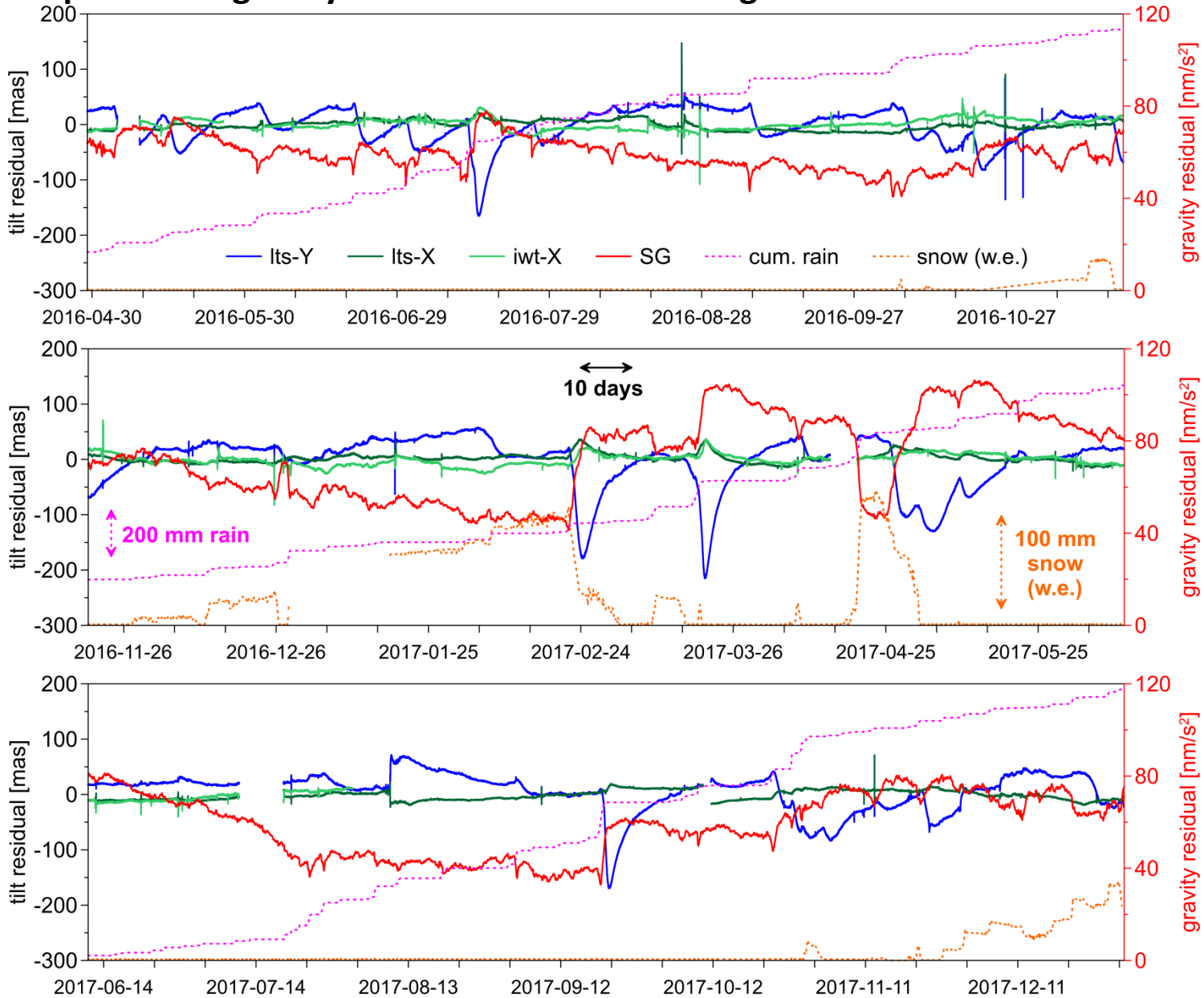




Comparison of gravity and tilt residuals: investigation of local effects at COBS



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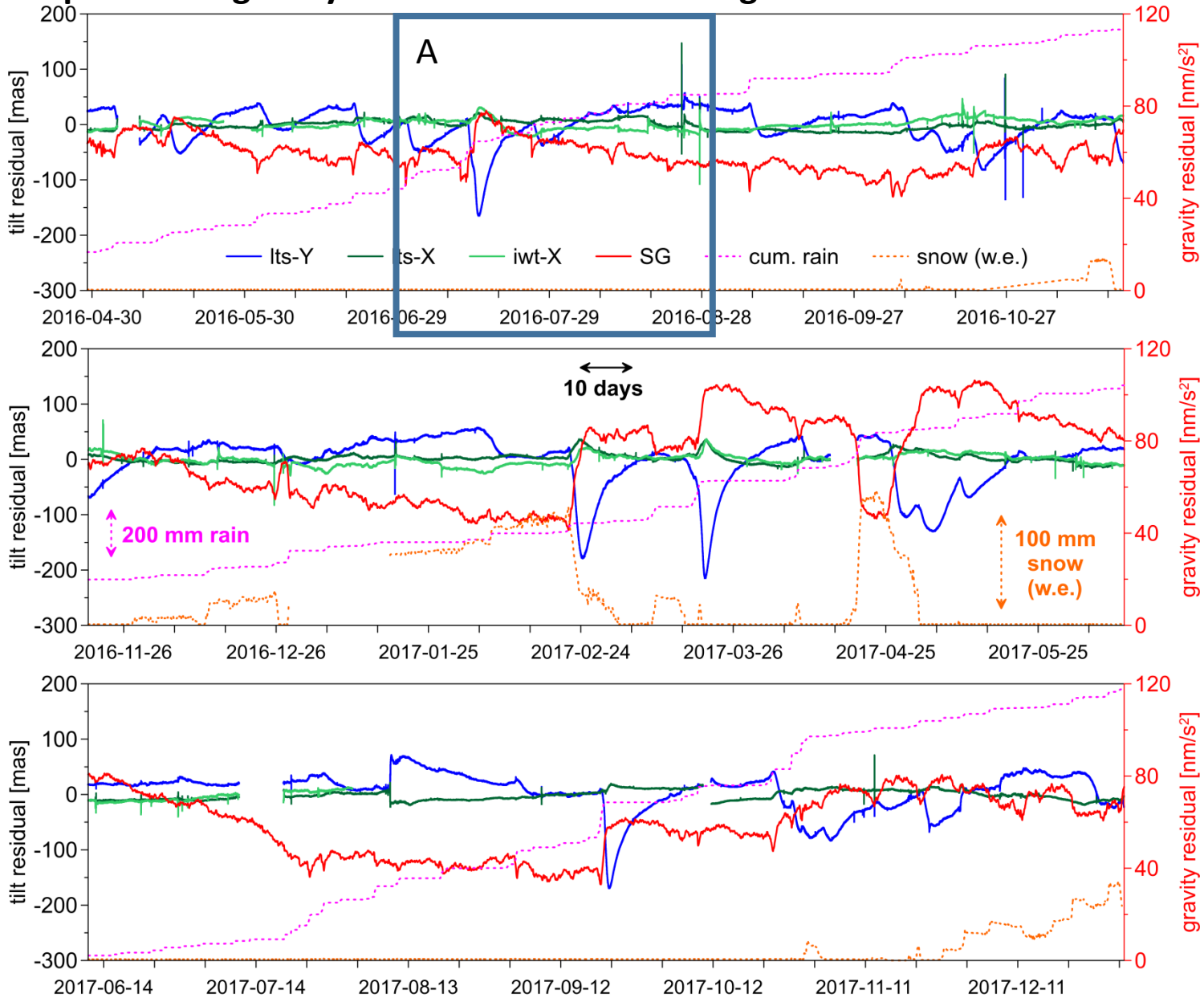
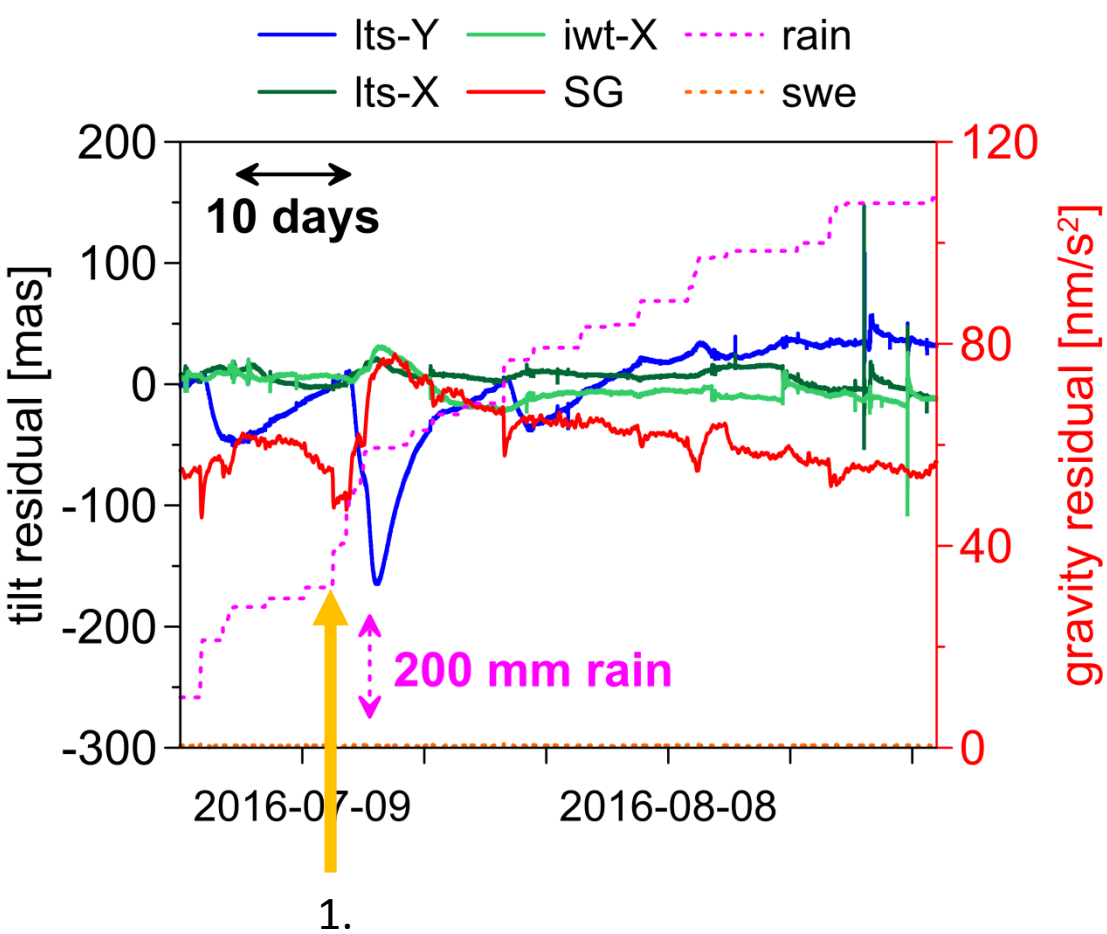
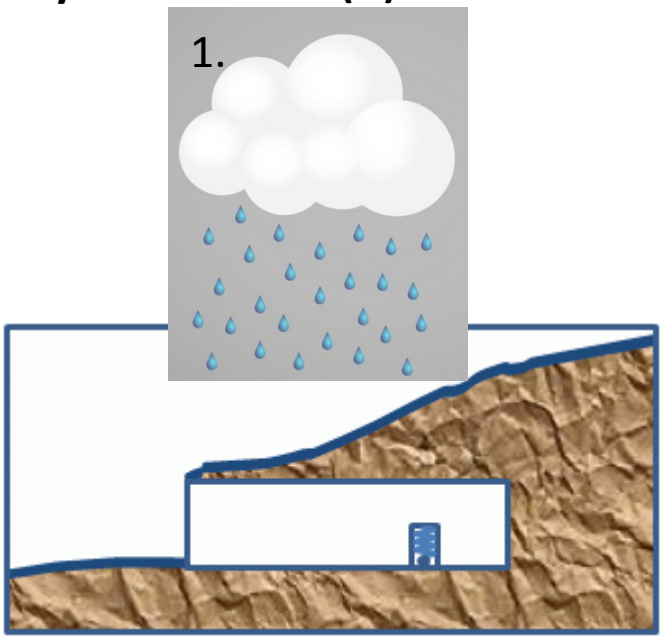


The effect of precipitation on the residual gravity and tilt data (A)





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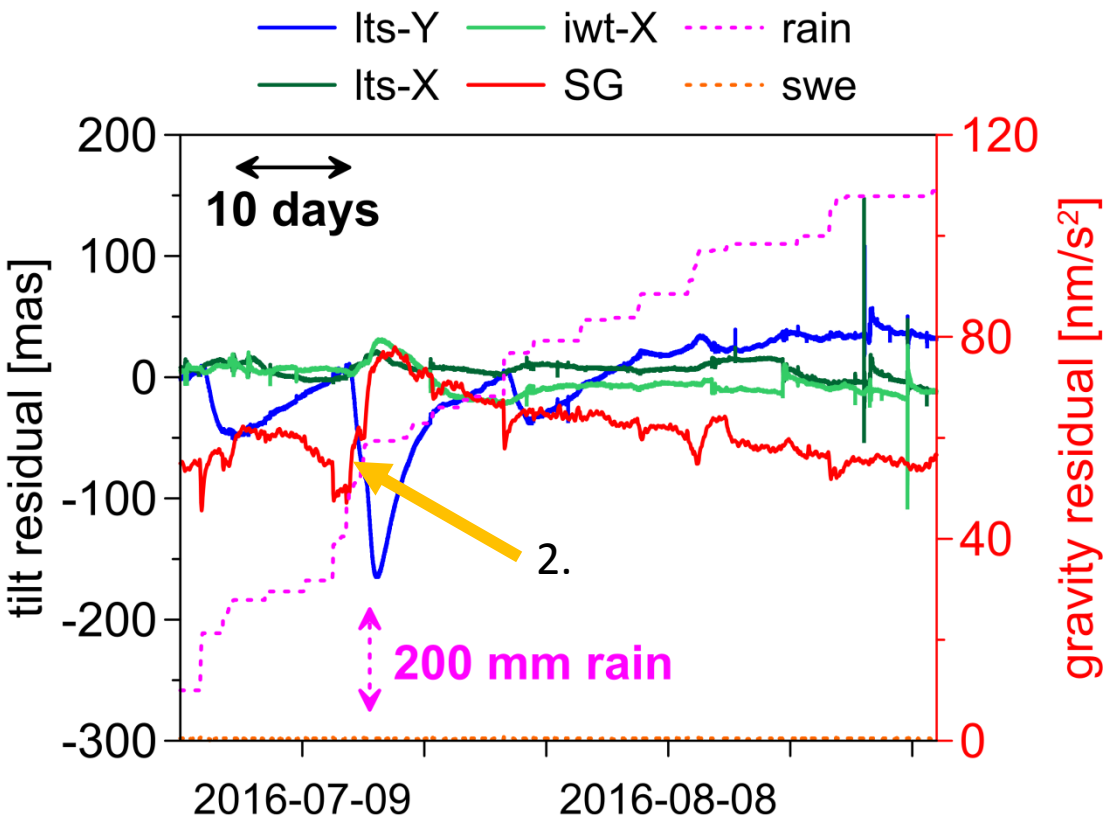

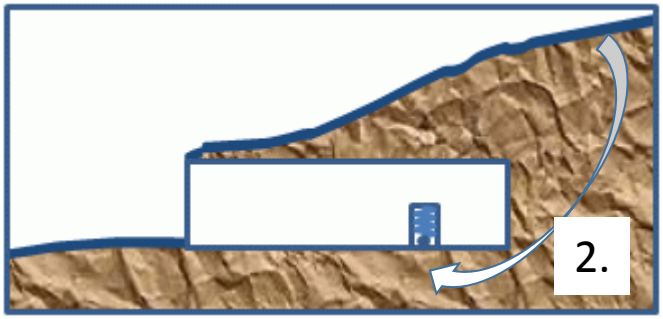

N-S tilt decrease delayed by 2 – 5 hr w.r.t. gravity increase
→
residual anomalies:
caused by different sources, but triggered by the same hydrological process

Tilt time series recorded at TPSO, Victor Harbor, Australia

04-09-2018 – 19-02-2019

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Tilt time series recorded at TPSO, Victor Harbor, Australia

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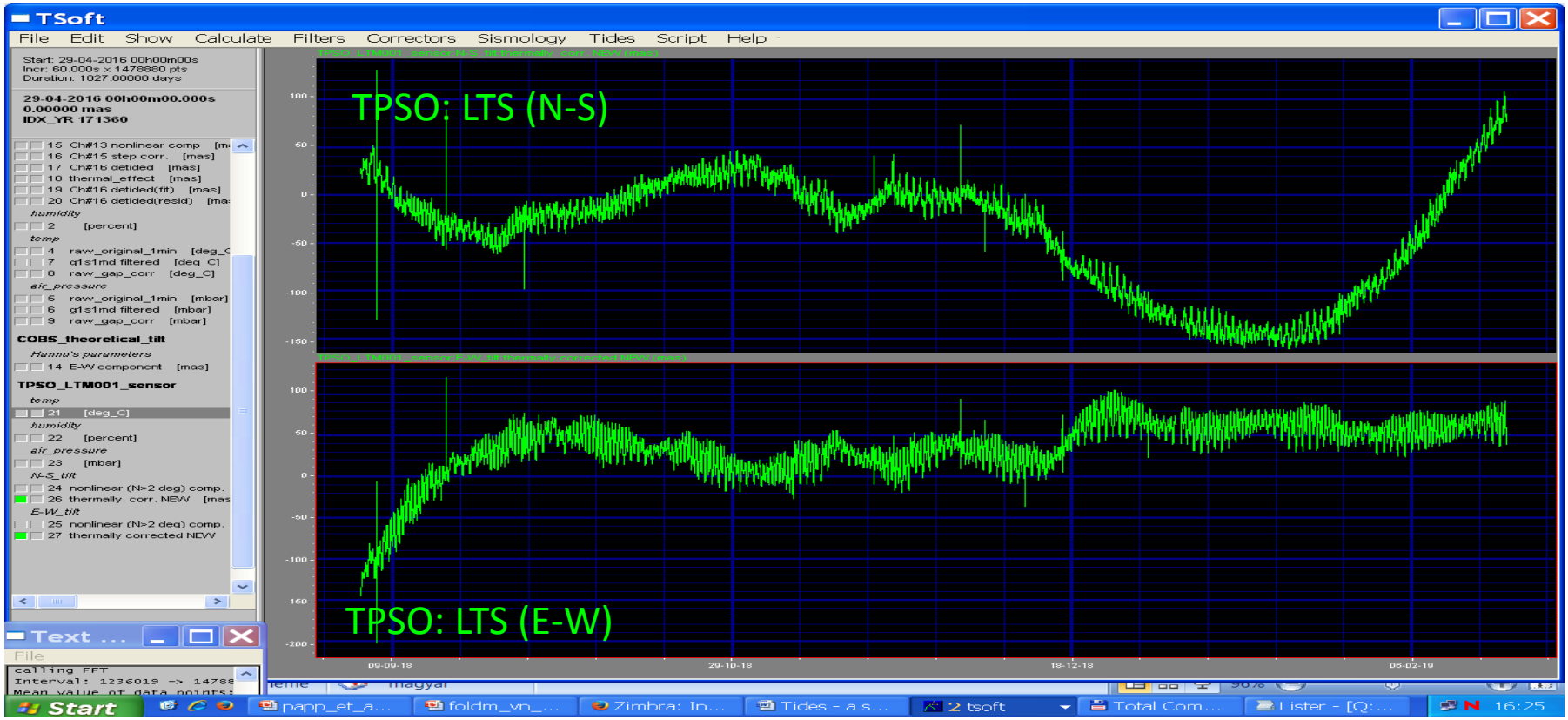
Investigation of ocean loading effects ⇒ validation of models (TOPEX, FES2014,…)



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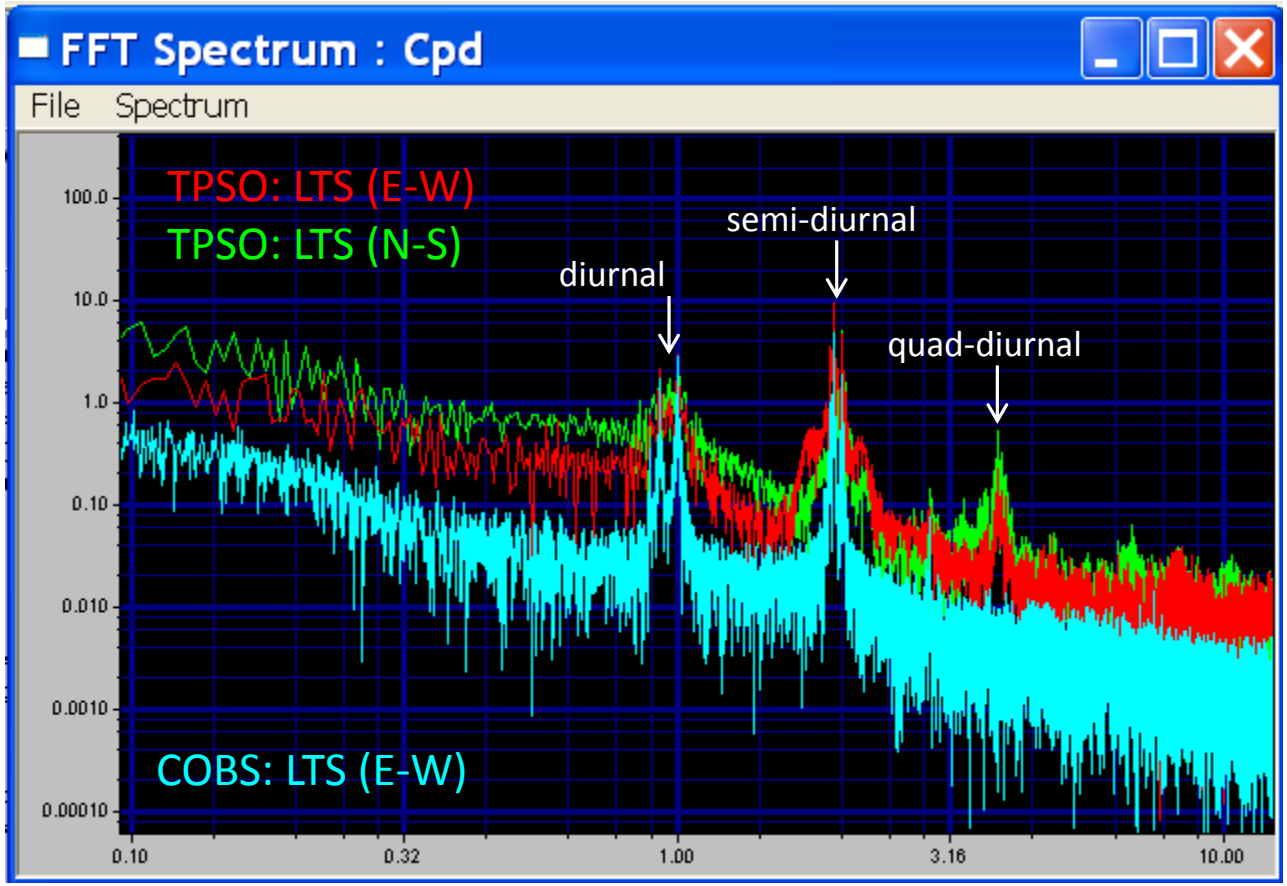
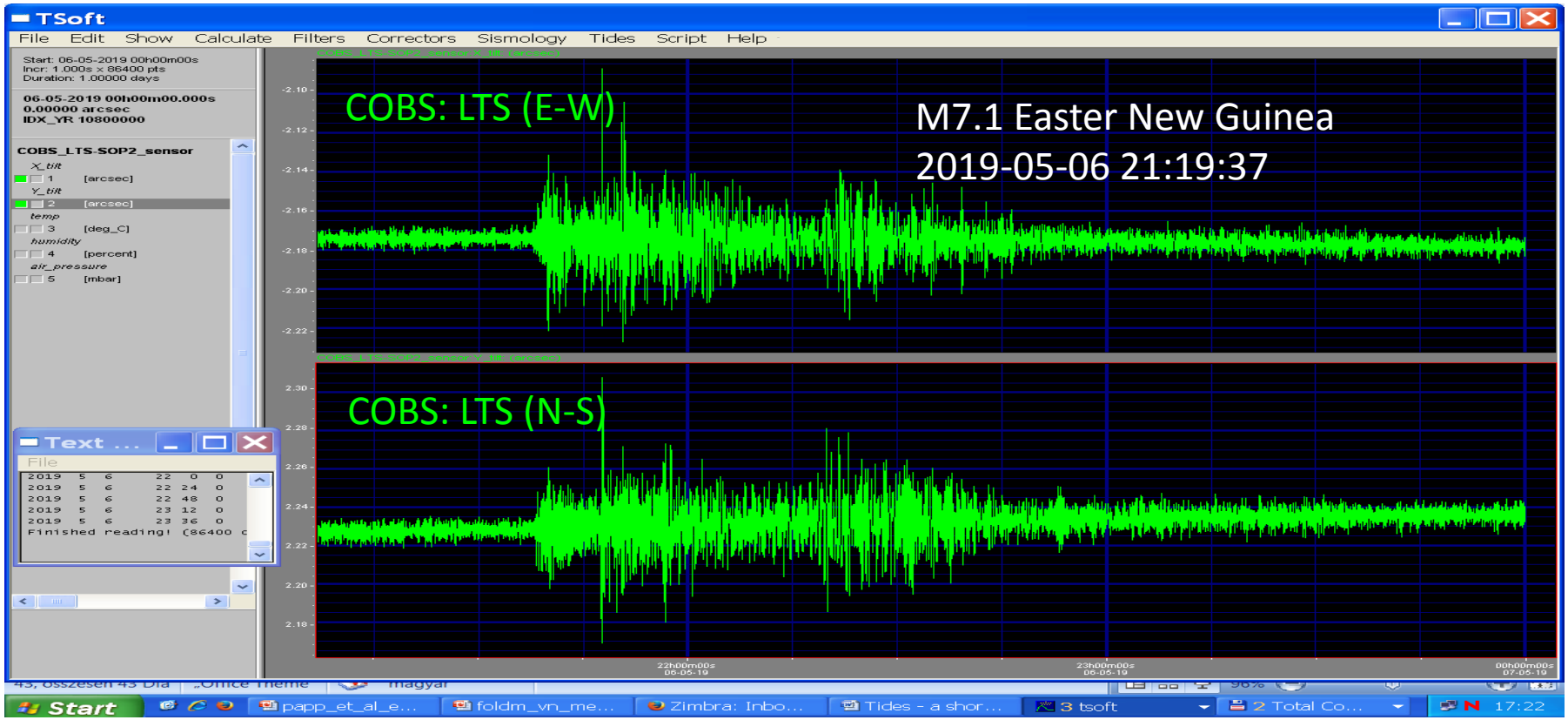
Comparison of FFT spectra of tilt time series recorded at COBS and TPSO



Future perspectives of deformation measurements

- **Seismological applications?**



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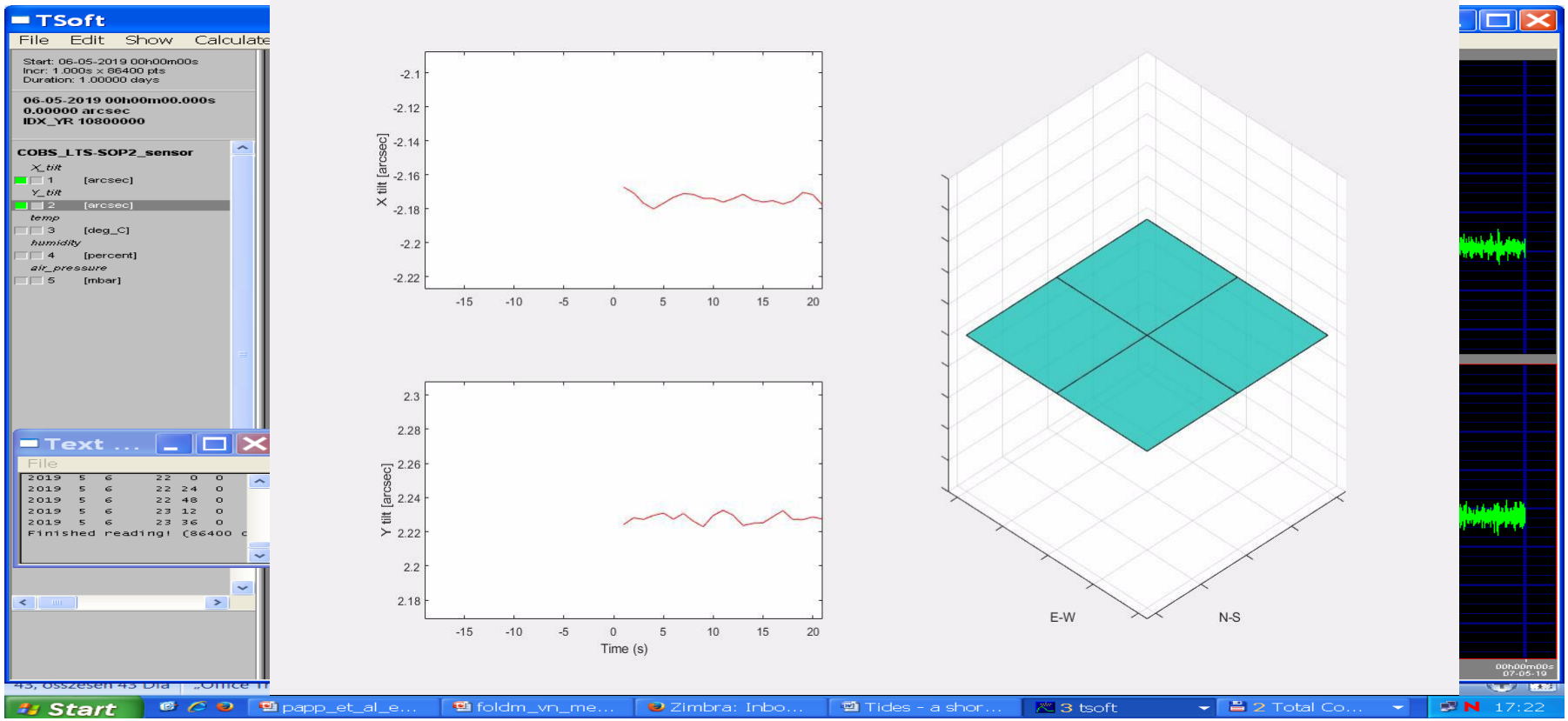


Future perspectives of deformation measurements

- **Seismological applications?**
- **Monitoring of the change of the shape of the Earth?**

The happy Earth

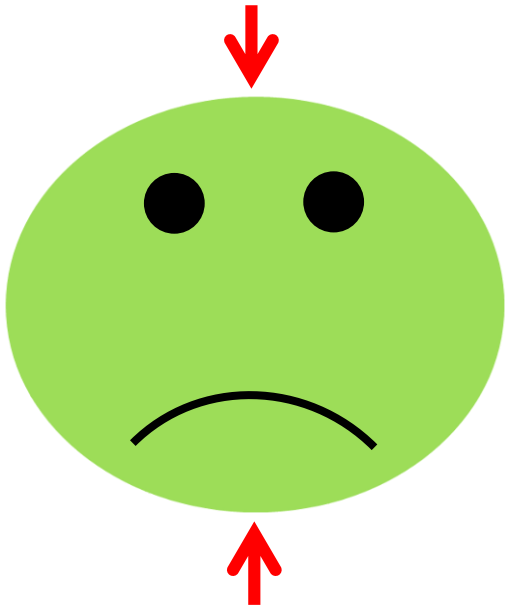
Future perspectives of deformation measurements

- **Seismological applications?**
- **Monitoring of the change of the shape of the Earth?**

Still happy…

Future perspectives of deformation measurements

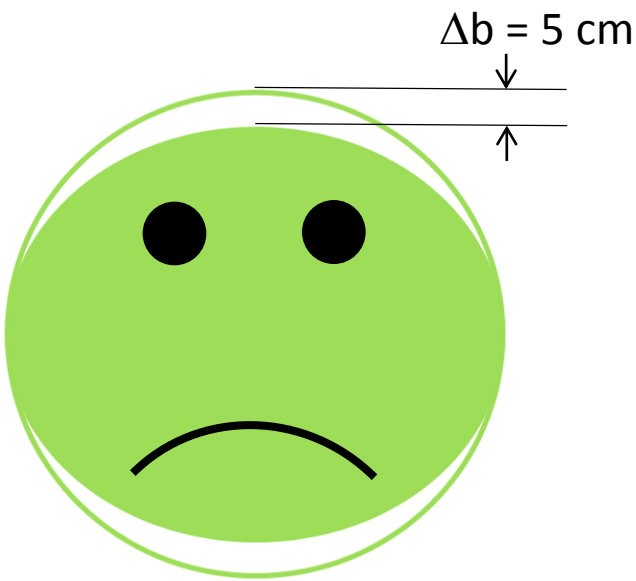
- **Seismological applications?**
- **Monitoring of the change of the shape of the Earth?**

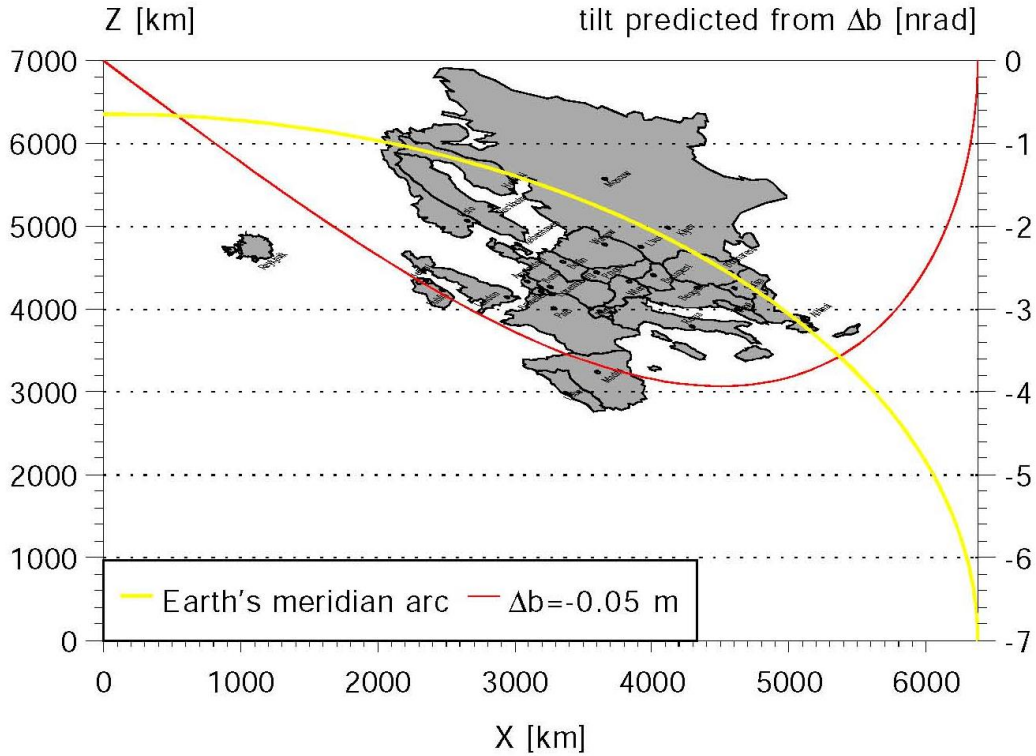


Not so happy and deformed Earth

Future perspectives of deformation measurements

- **Seismological applications?**
- **Monitoring of the change of the shape of the Earth?**





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