Superconducting Gravimeters for Determining Long Period Gravity Changes

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GGOS and GRAV-D

GGOS applications require the static geoid to be accurate at a level of 1 mm and to be stable at a level of 0.1 mm/yr, consistent with the accuracy and stability of the terrestrial reference frame.

For the time variable geoid, the monitoring of the water cycle at sub-regional to global scales appears to be the most demanding applications requiring the geoid variations to be monitored to 1 mm, stable to 0.1 mm/yr, with a spatial resolution of 50 km and a time resolution of 10 days."

Table of Gravity / Height Ratios [after de Linage et al. (2007)]

application	(μGal / mm)
long wavelength free-air gradient (FAG)	– 0.308
elastic incompressible layer (ρ = 2500 kgm^{-3}) with attraction + FAG	– 0.203
elastic compressible layer (ρ = 2500 kgm^{-3}) with attraction + FAG	– 0.235
mean value outside load area, no local attraction; also tidal loading	– 0.26
hydrology loading in basins, depends on area	- 0.74 to - 1.73
atmospheric loading, IB hypothesis, varies with latitude and coastline	+0.30 to +0.47
soil moisture	- 0.28

So the static geoid, and the geoid variations, need to be

accurate to 0.3 μGal and stable at a level of 0.03 μGal/yr

with a spatial resolution of 50 km and a time resolution of 10 days

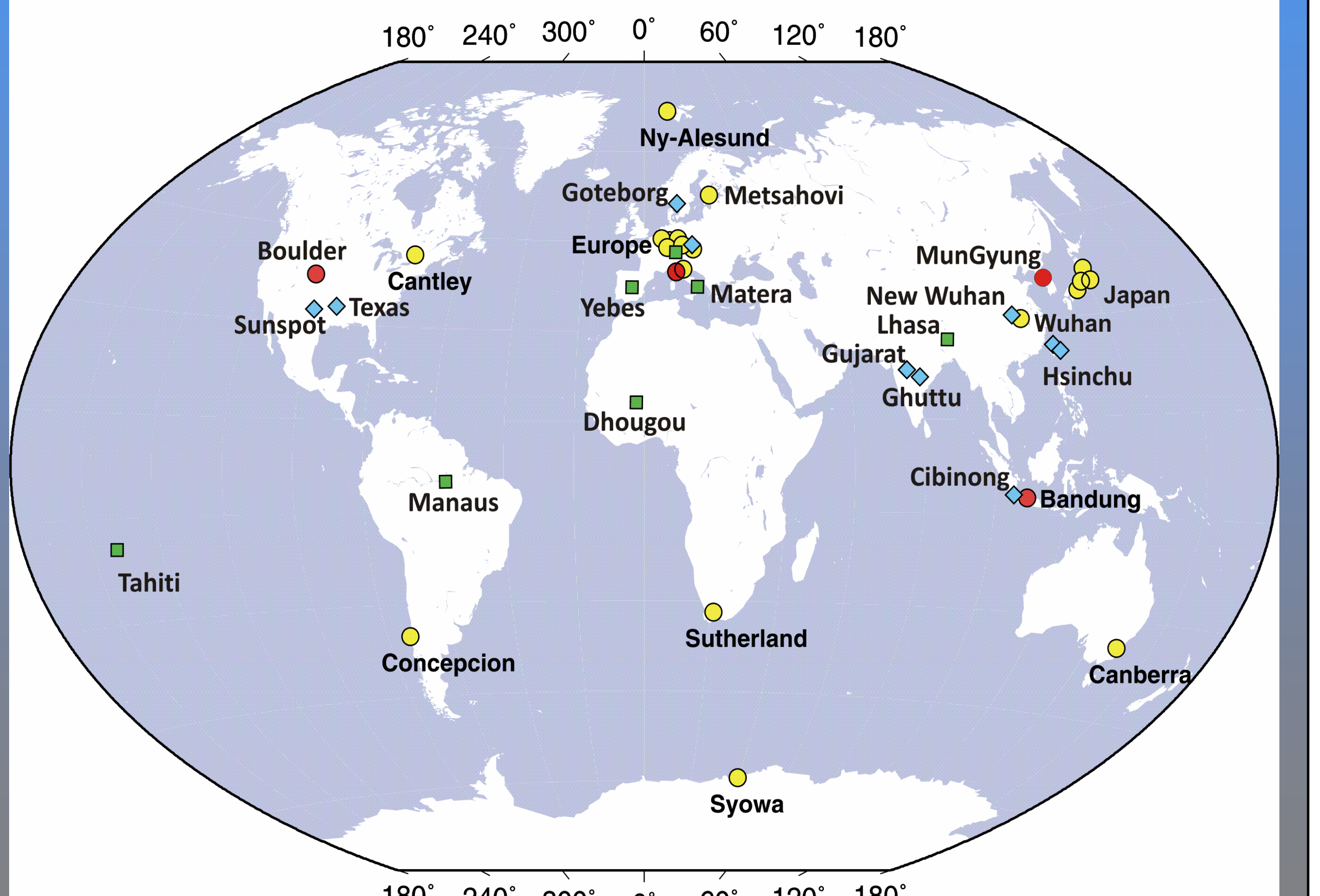
[AG fails all 3, SG fails spatial, and GRACE fails short wavelength/ accuracy]

GRAV-D is a proposal by the National Geodetic Survey to re-define the vertical datum of the US by 2017.

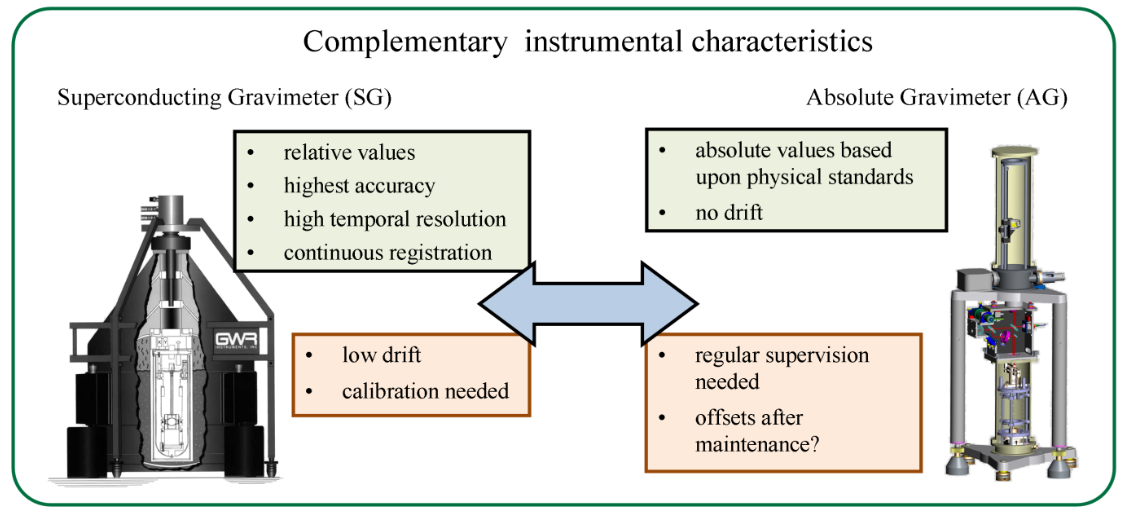
Campaign # 2. A low-resolution "movie" of gravity changes: This is primarily a terrestrial campaign and will mostly encompass episodic re-visits of absolute gravity sites, attempting to monitor geographically dependent changes to gravity over time

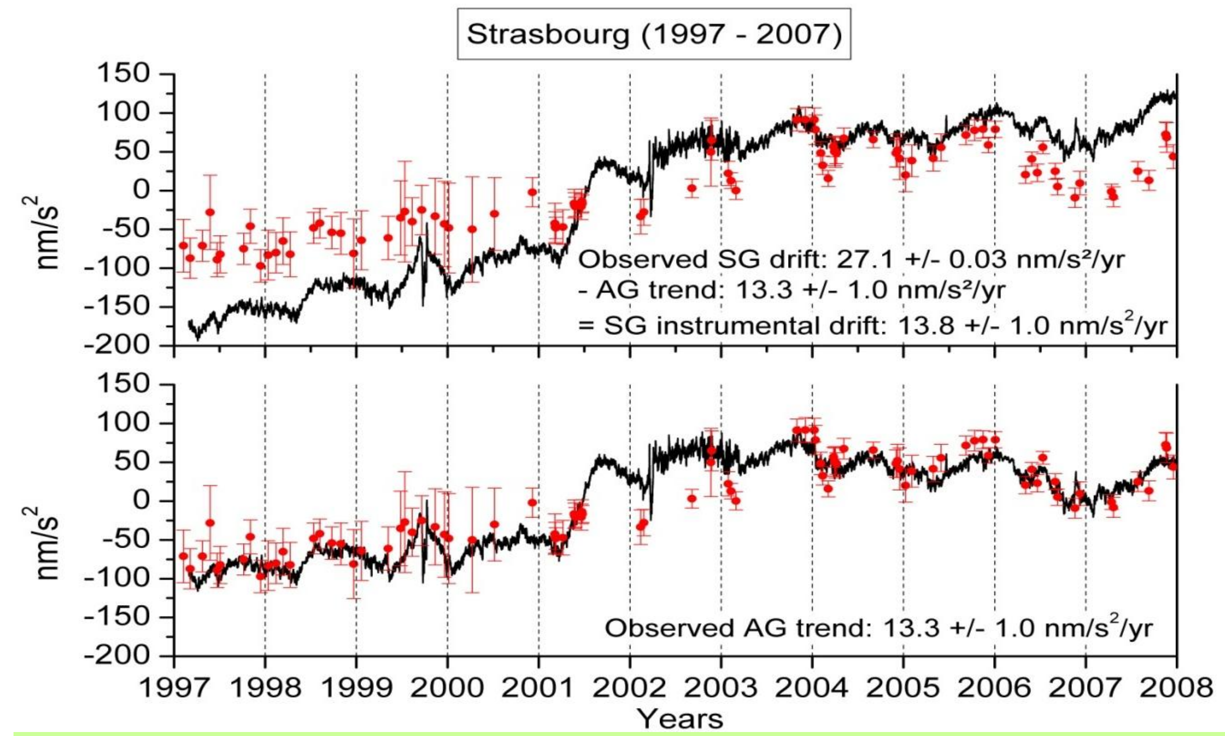
Superconducting Gravimeters

GGP Stations - Past, Current, Recent and Planned

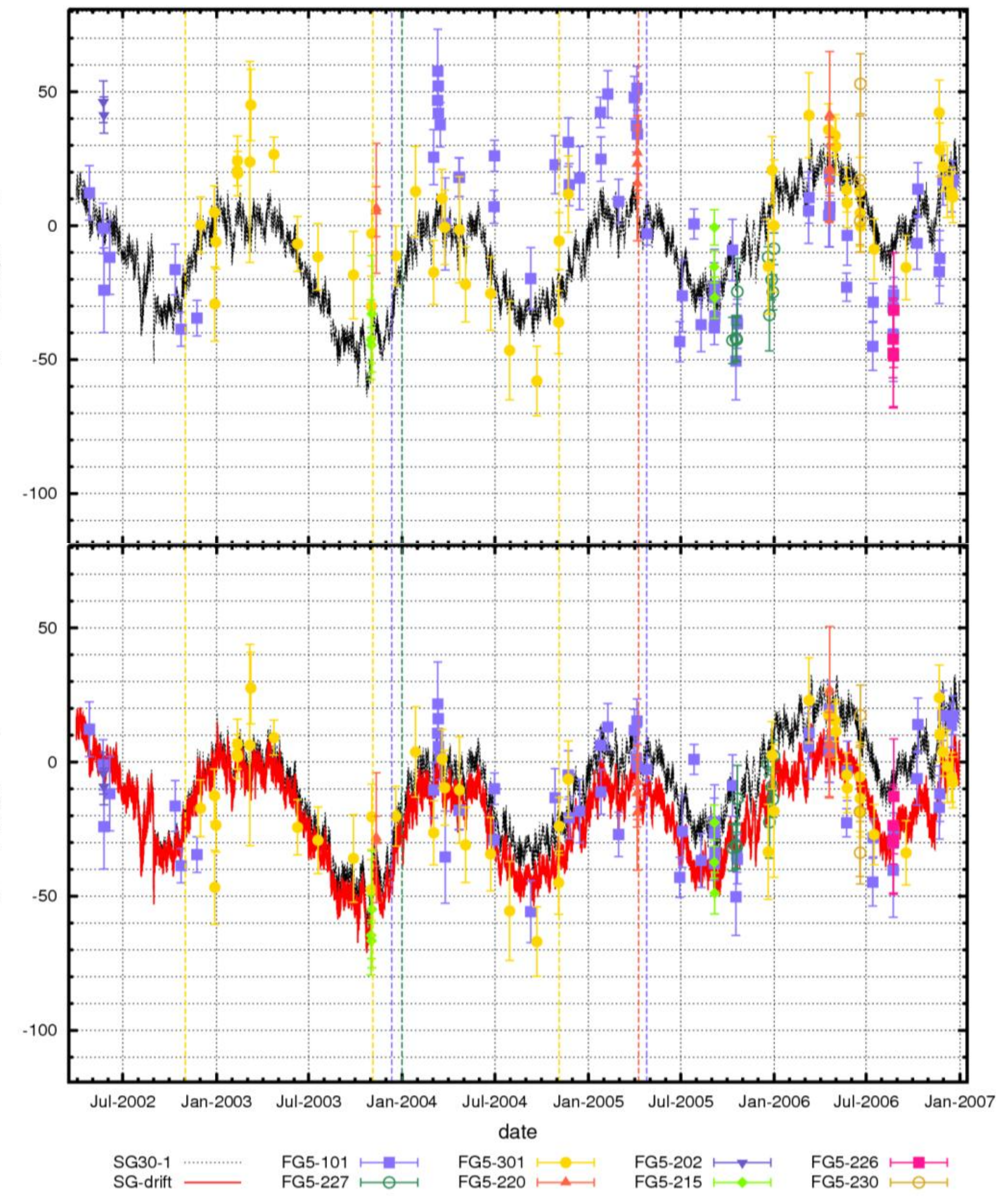


SG-AG COMPARISONS

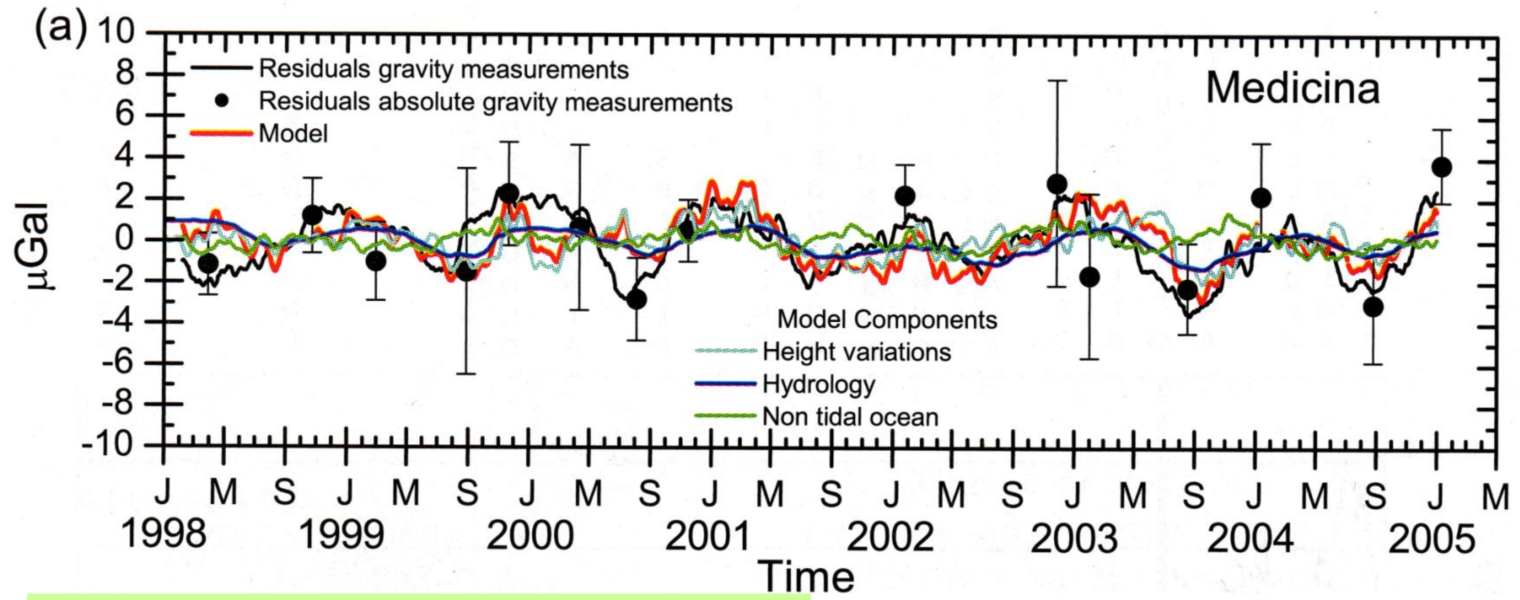




Superposition of AG FG5#206 measurements and SG GWR-C026 time-varying gravity at Strasbourg from March 1997 to December 2007. The upper plot represents the SG time-varying gravity without correction of the SG instrumental drift and the lower plot represents the superposition after removing the instrumental part from the SG trend. The linear instrumental drift between 1997 and 2007 has been estimated to 13.8 +/- 1.0 nm/s2/yr [after Rosat et al., 2009)].

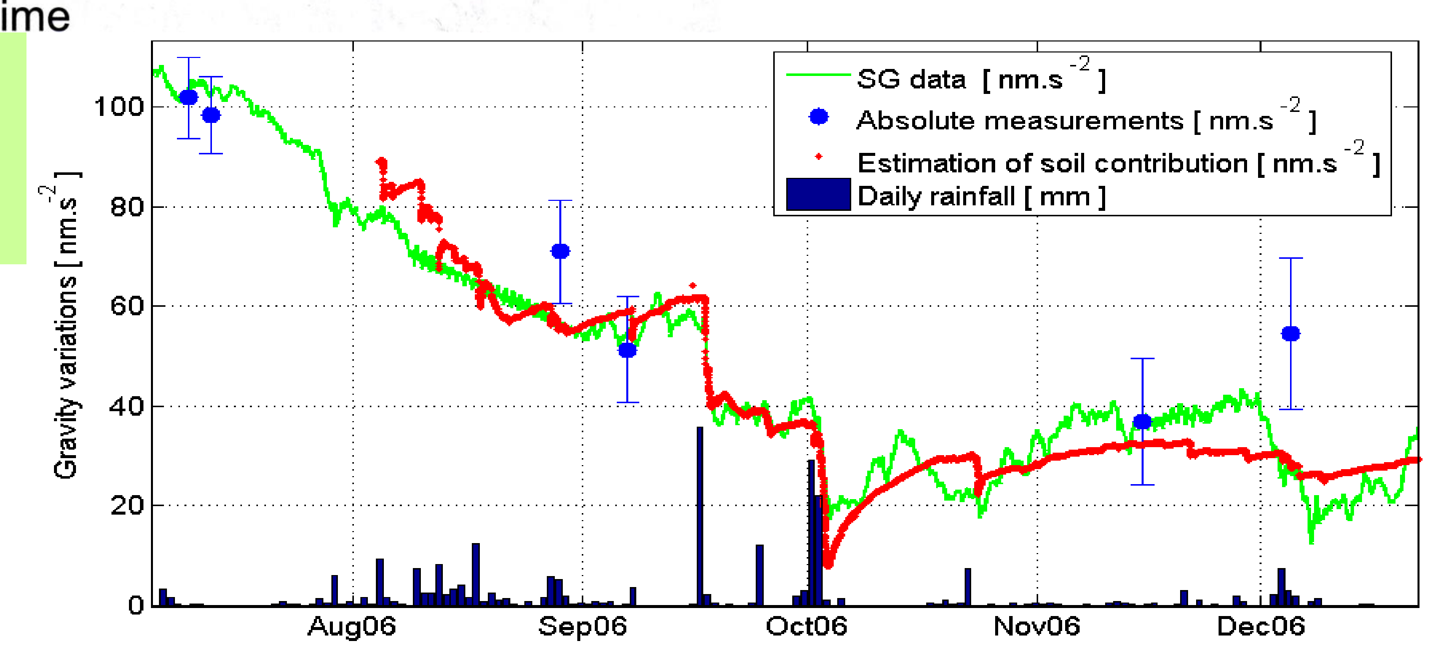


Combination of AG and SG observations at the station Bad Homburg (Germany); upper graph: SG-30 residual gravity function (black) and AG measurement results of 8 AG, symbols in selected colours; lower graph: SG and AG observations prior (black/upper curve) and after combination (red/lower curve); AG measurement results show smaller residuals after offset determination for the individual AG [after Wilmes et al. (2009)].

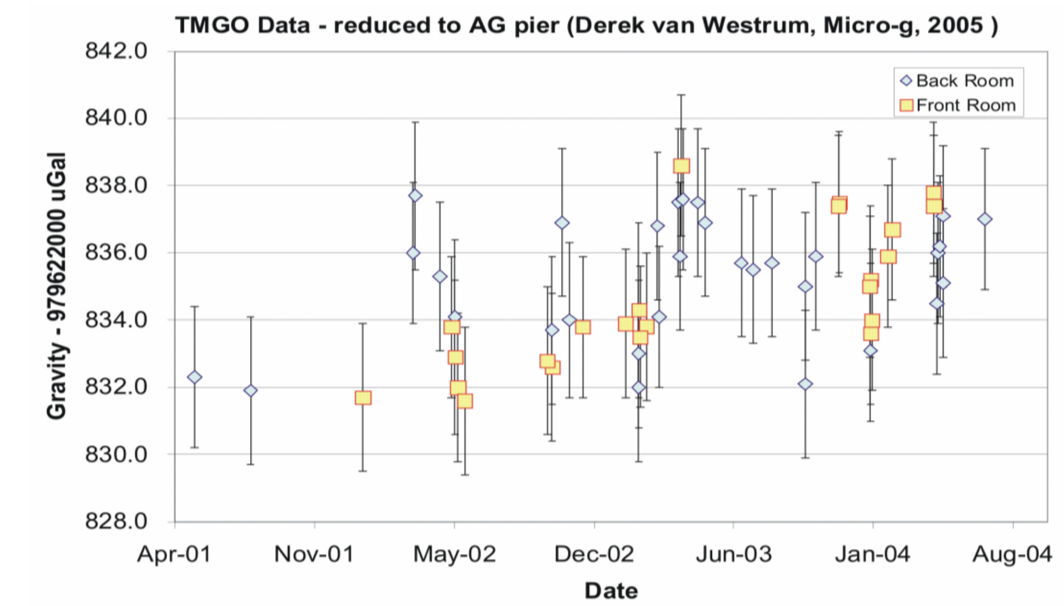


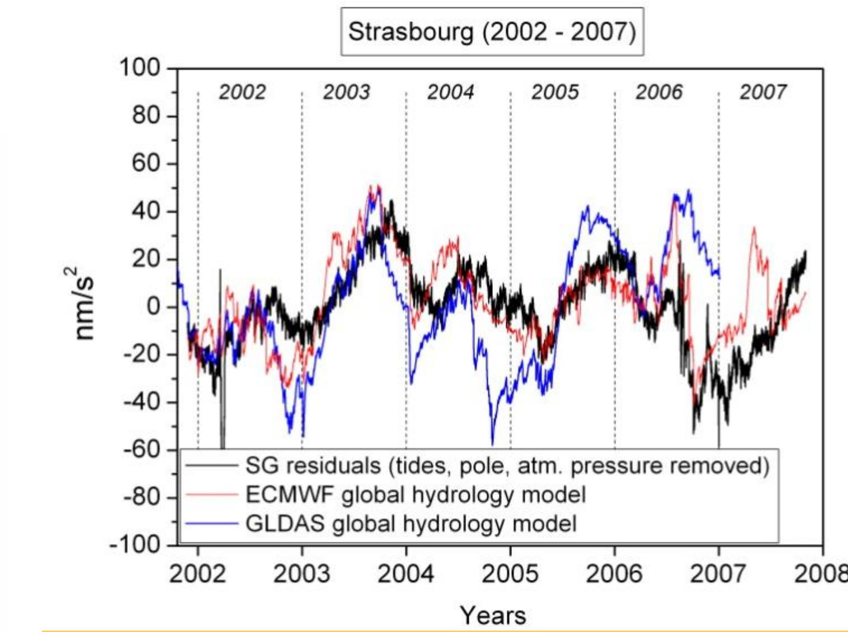
← Comprehensive model of SG, AG, CGPS. and hydrology data from the Medicina fiducial station (which includes VLBI). Note the good agreement between AG and SG, but occasional disparities with the model [after Zerbini et al. (2007)].

Comparison of SG and AG measurements with rainfall and soil moisture for the Strasbourg site J9. Because the gravimeter is under the soil moisture horizon, gravity decreases with rainfall [after Longuevergne (2008)]. →

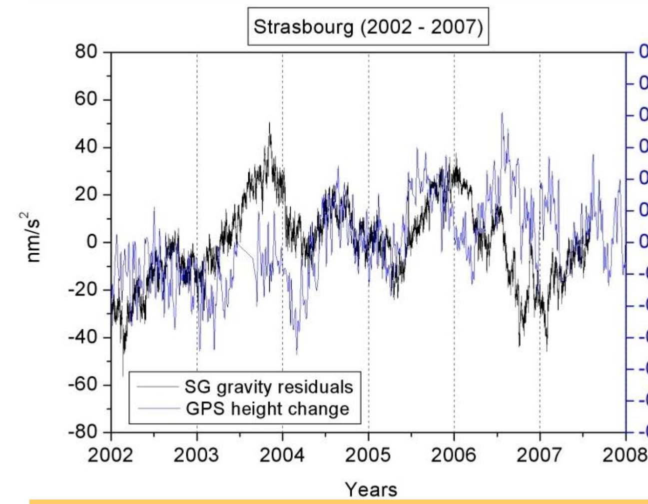


AG, SG, GPS, and HYDROLOGY

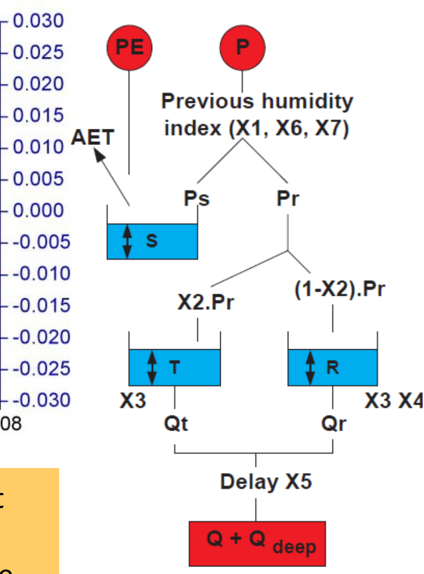


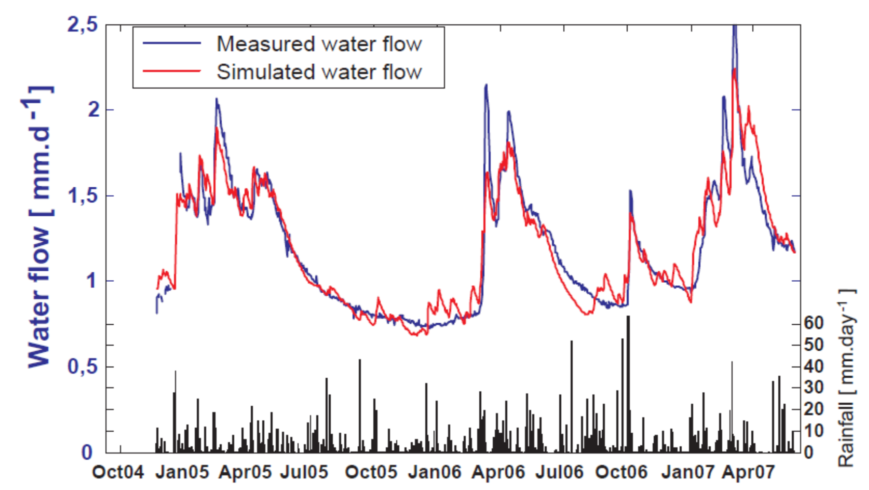


SG gravity residuals and global hydrology effects at Strasbourg. In blue is the continental water content effect using GLDAS global model and in red using the ECMWF model of soil moisture and snow [after Rosat et al., 2009)].



SG gravity residuals (in black) and GPS height changes (in blue) observed at Strasbourg, J9 site from 2002 to late 2007. Note the positive correlation between both signals due to the fact that the local hydrological masses dominate and are located above the SG [after Rosat et al. (2009)].



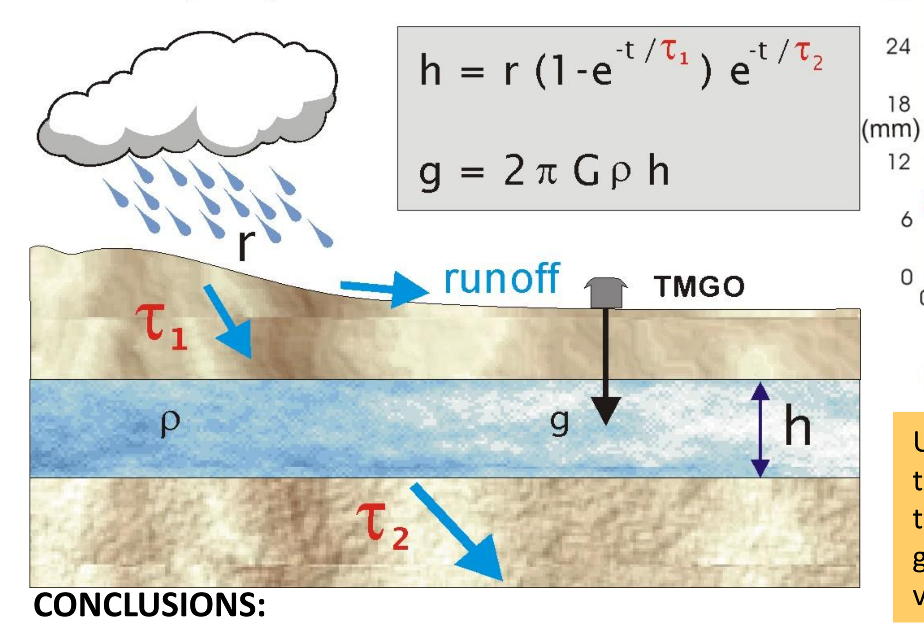


Modified IHAC lumped model based on 7 parameters (X1-X7). In red, forcing data, *PE*, *P*, *Q* and *Qdeep* are potential evapotranspiration, precipitation, runoff out of the mine and deep runoff respectively. In blue, S, T, R correspond to modeled water-height in the 3 reservoirs, respectively soil, quick and slow storage. R store level variations are used to estimate water height variations [after Longuevergne, 2008)].

Spring Rains in Boulder, 1995

$$h = r\,(1 - e^{-t/\tau_1})\, e^{-t/\tau_2}$$

$$g = 2\pi G \rho h$$



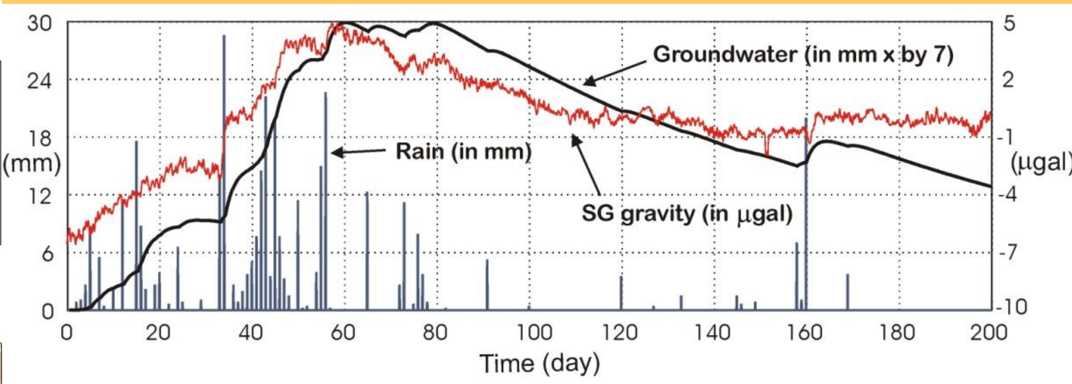


Figure 2. Gravity Variations Due to Rainfall, Boulder TMGO

Using the first 200 days of data (where the correlation is strongest), we find that τ_1 = 4 hrs, the recharge time constant, and τ_2 = 91 days, the discharge time constant. The groundwater/gravity admittance from the first 200 days gives 0.0414 μgal / mm; for the whole record it is 0.00925 μgal mm−1. The value calculated for the Bouguer slab is 0.0419 μgal / mm.

CONCLUSIONS:

AG measurements alone are insufficient without a hydrological model to estimate storage and flow. The best hydrological validation is with an SG. The combination of both instruments is required to achieve GGOS and GRAV-D goals.

Acknowledgments

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