

# Tectonic, Climatic and Anthropogenic effect in Western Europe by Repeated Absolute Gravity Measurements

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Special thanks to:  
Michael Mölmann-Coers (Jülich)

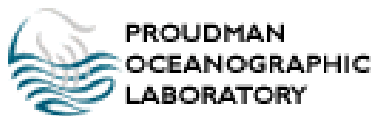
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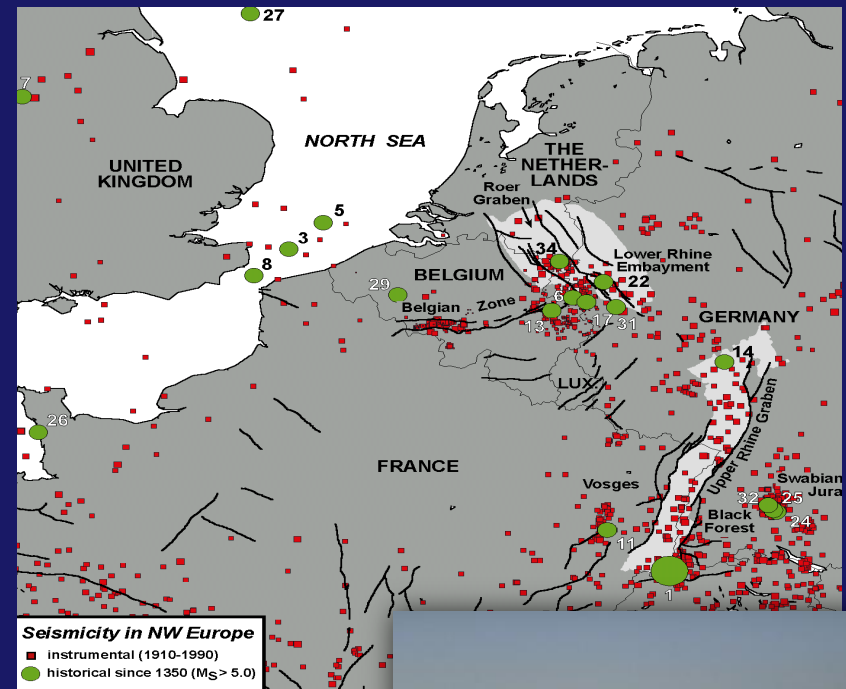
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# How is the ground moving in Northwestern Europe ?

Available information :

1. Known seismic activity:
  - (a) present-day seismicity;
  - (b) large historical earthquakes;
2. Geology + paleoseismology ;
3. Continuous GPS measurements ;
4. 10 years of dedicated geodetic experiments:
  - (a) CGPS across the Feldbiss fault zone (Roer graben);
  - (b) Absolute gravity.



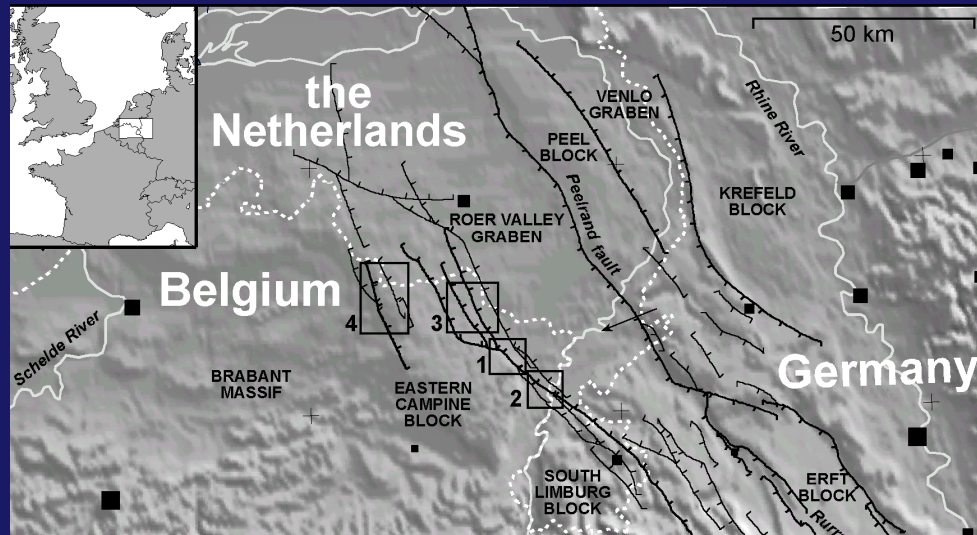
# Strain rate and seismic activity (Lower Rhine Embayment)

Paleoseismology, geology and historical seismicity agree:

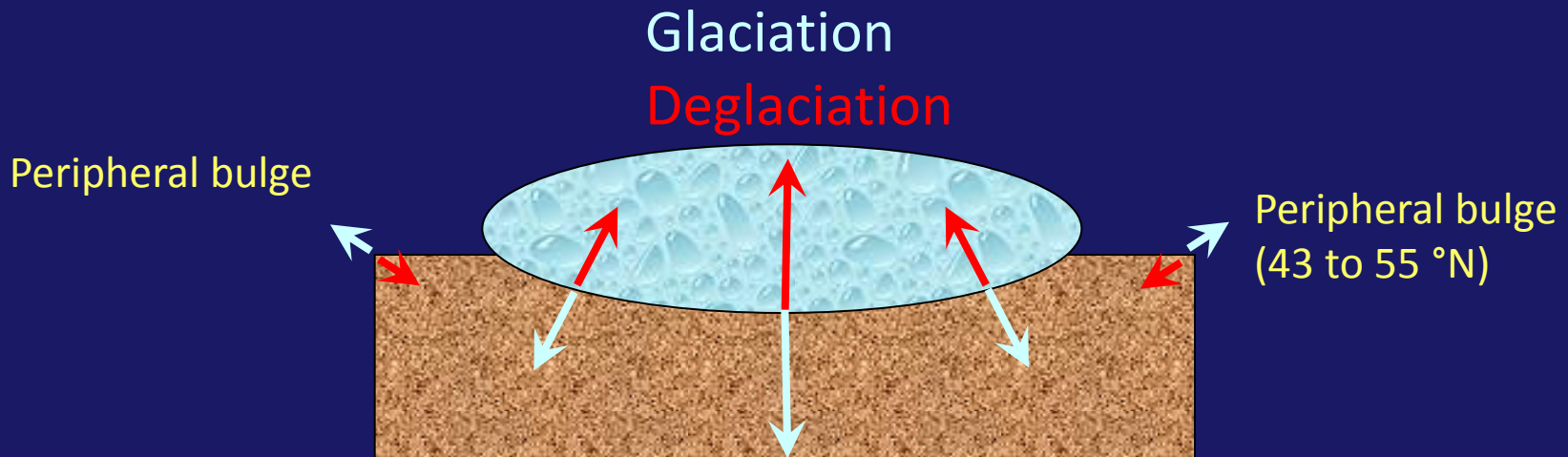
Total moment release  $\sim 1-2 \cdot 10^{16}$  N.m/yr

350 km of active faults with an average slip rate around 0.1 mm/yr during the Late Pleistocene.

→ Measuring such a deformation rate:  
**hopeless with geodesy?**



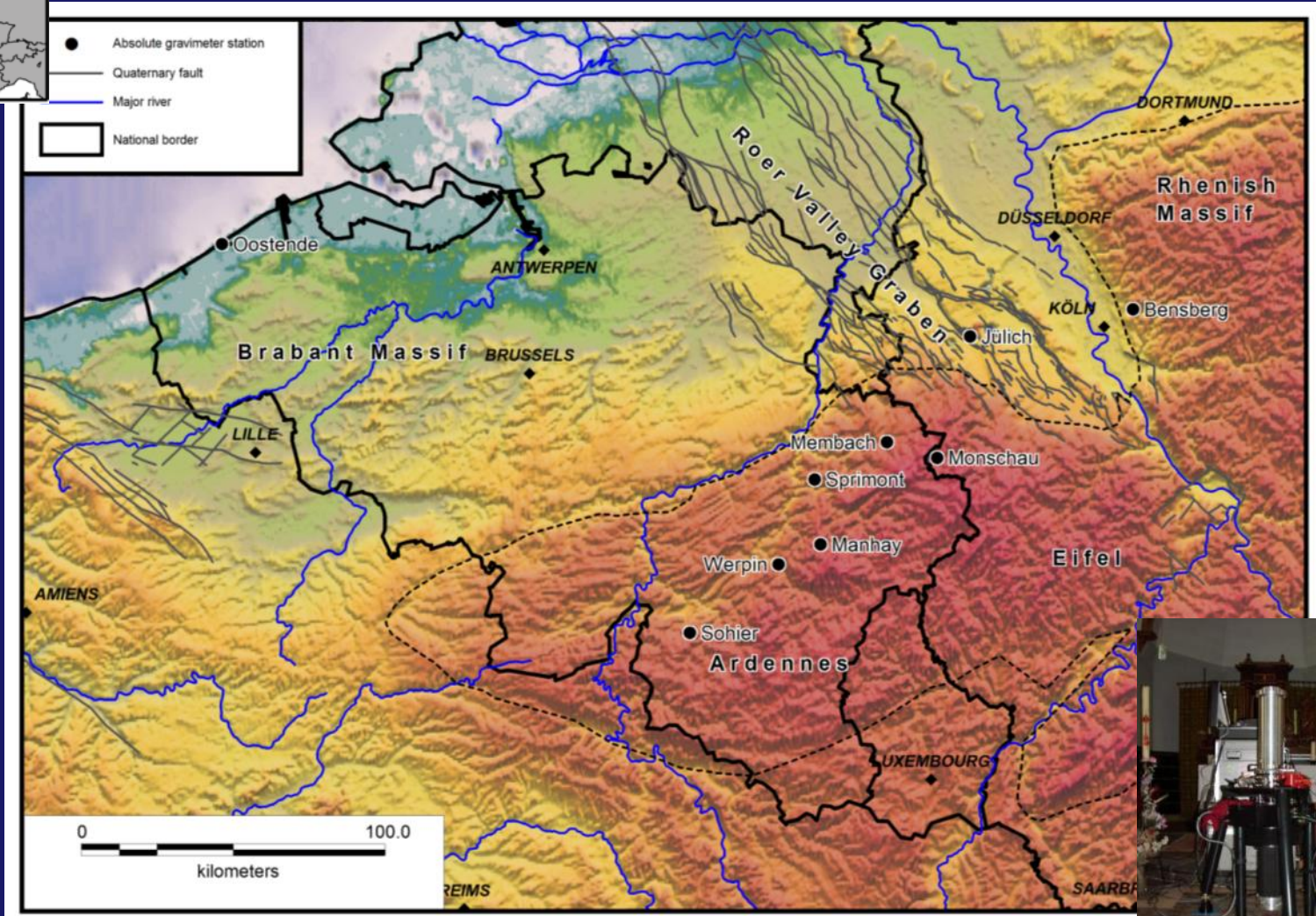
# Strain rate and GIA around 50°N (peripheral zone)



GIA effects on the peripheral bulge predicted by models based on GPS measurements in Fennoscandia : -0.9 mm/year in Belgium (Milne et al., 2001)

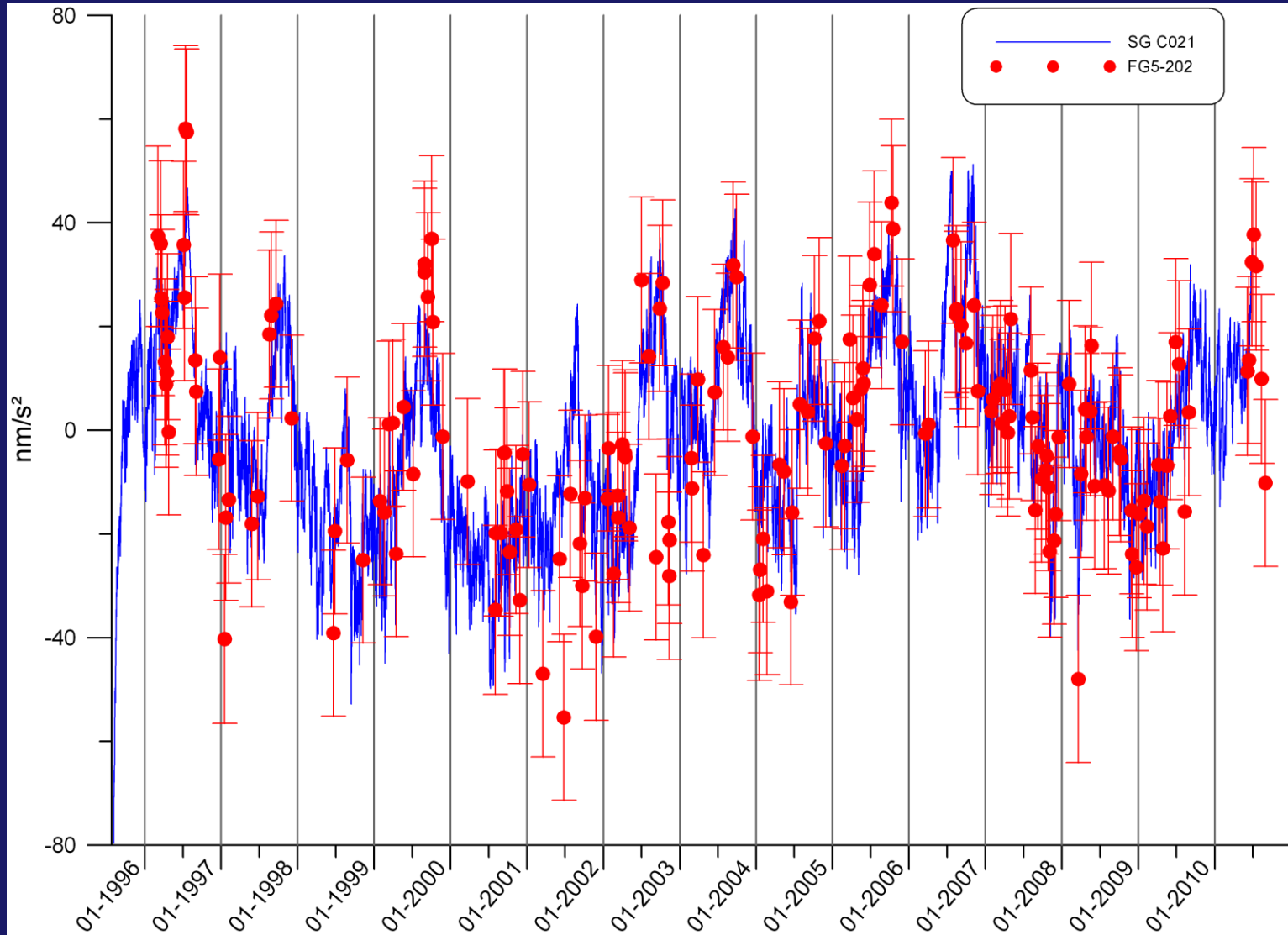
- Presently not well estimated by geodetic measurements  
(strangely enough: some signal on the vertical CGPS, but ~0 on horizontal)
- **But not hopeless!**
- Absolute gravity measurements can help

# Repeated Absolute Gravity measurements: profile

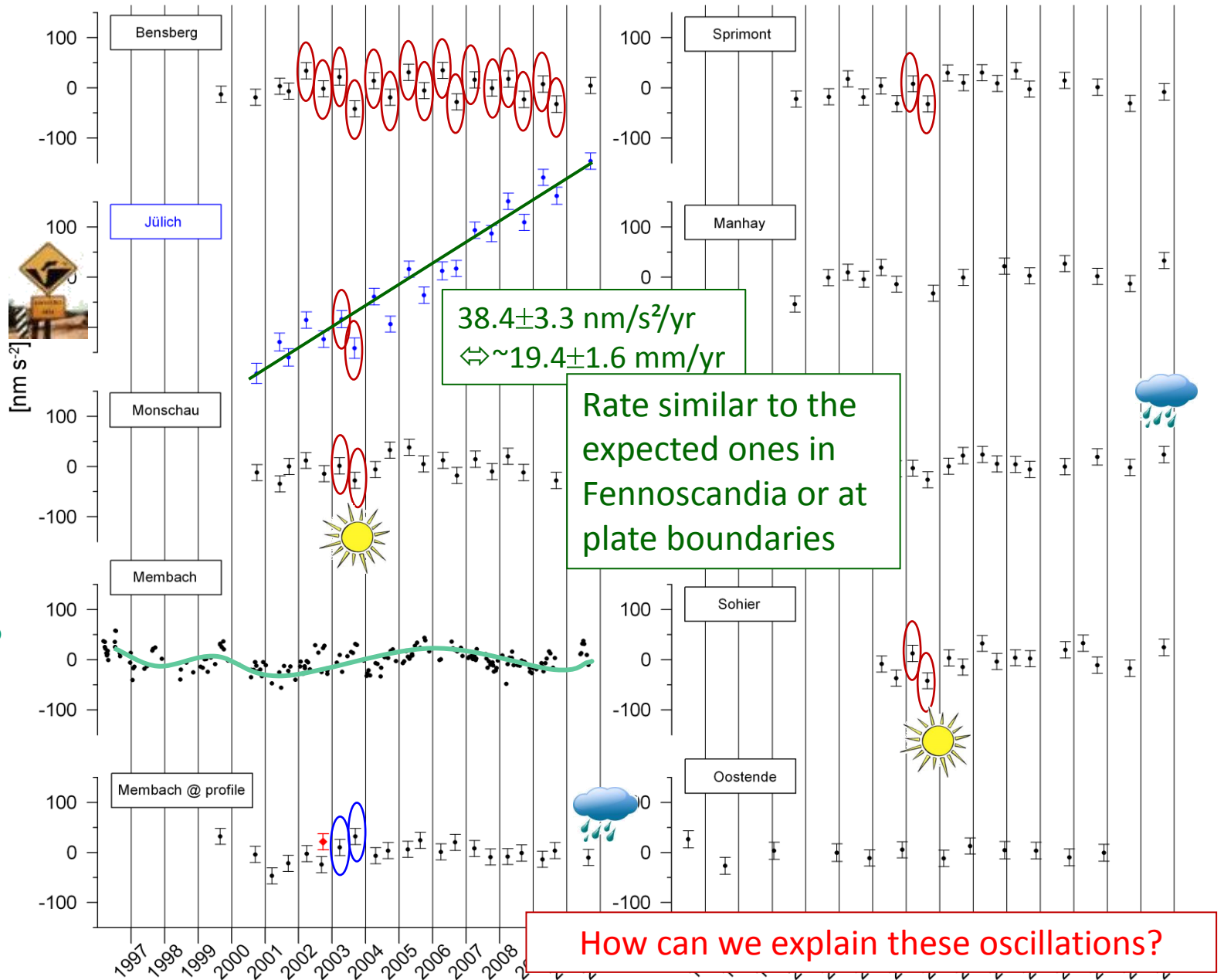


# Membach: reference station:

- 1 Superconducting gravimeter
- about 1 AG measurement/month

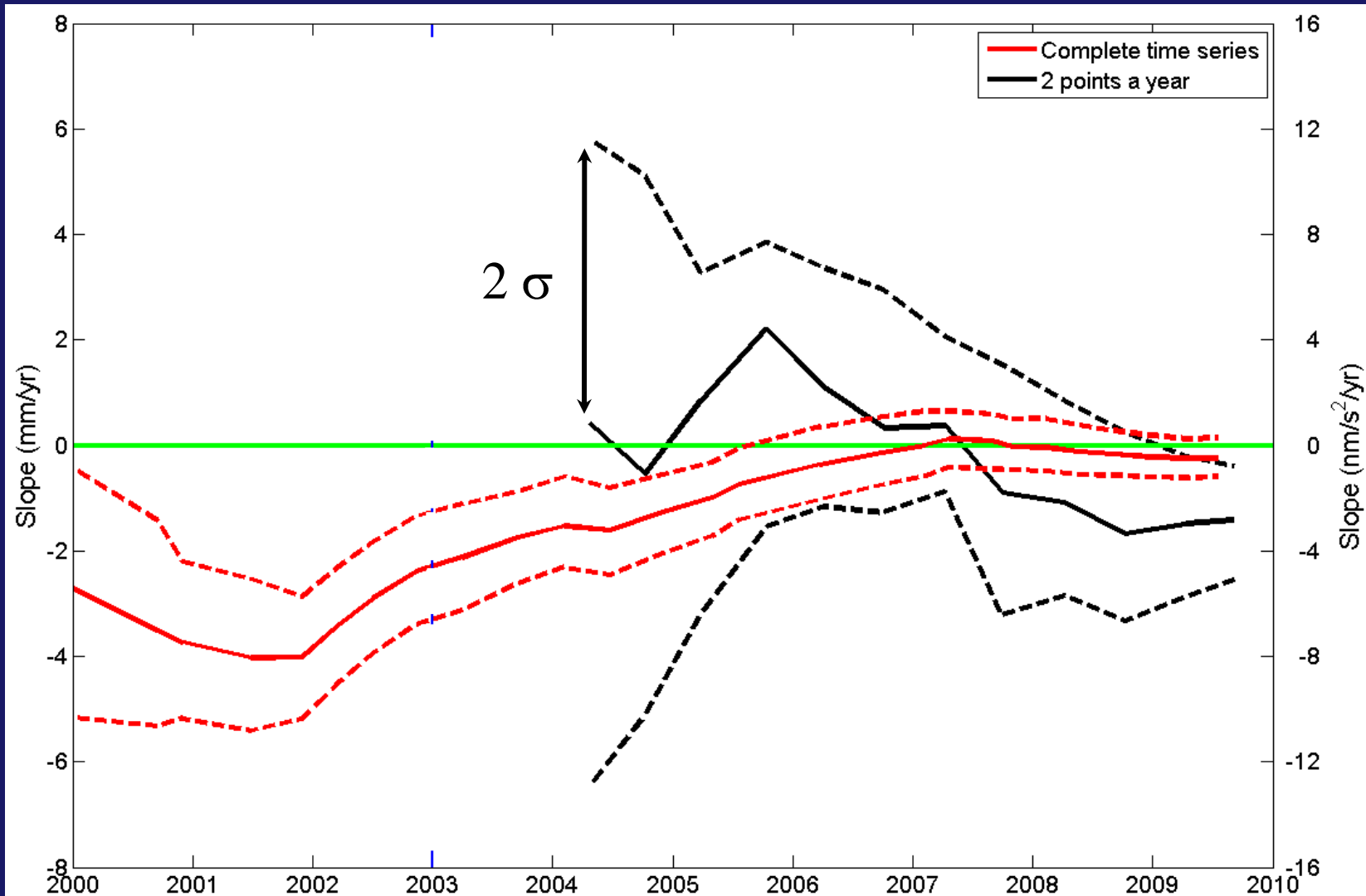


# Repeated AG measurements (1/yr or 2/yr)

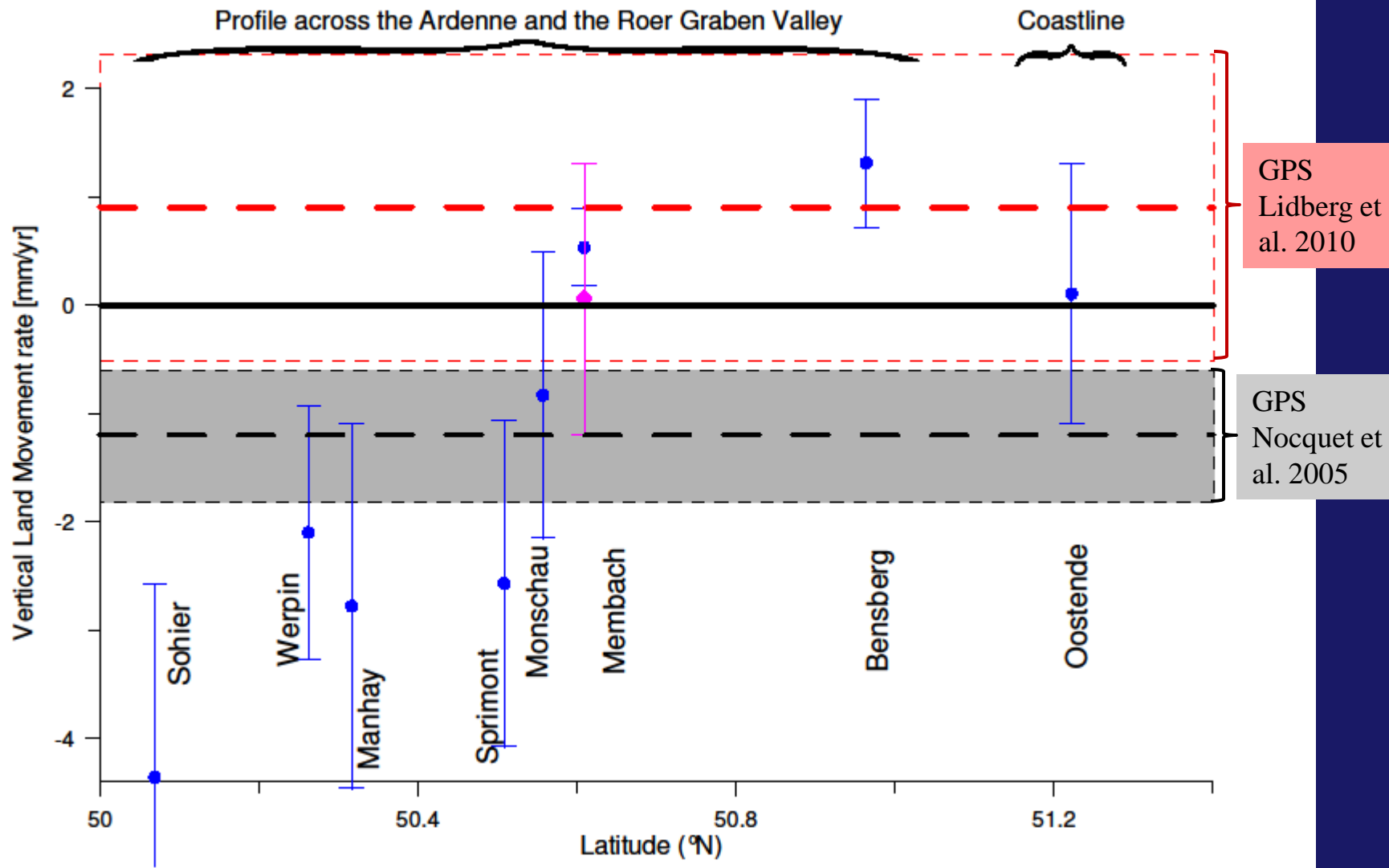


# What about the stability of repeated AG measurements?

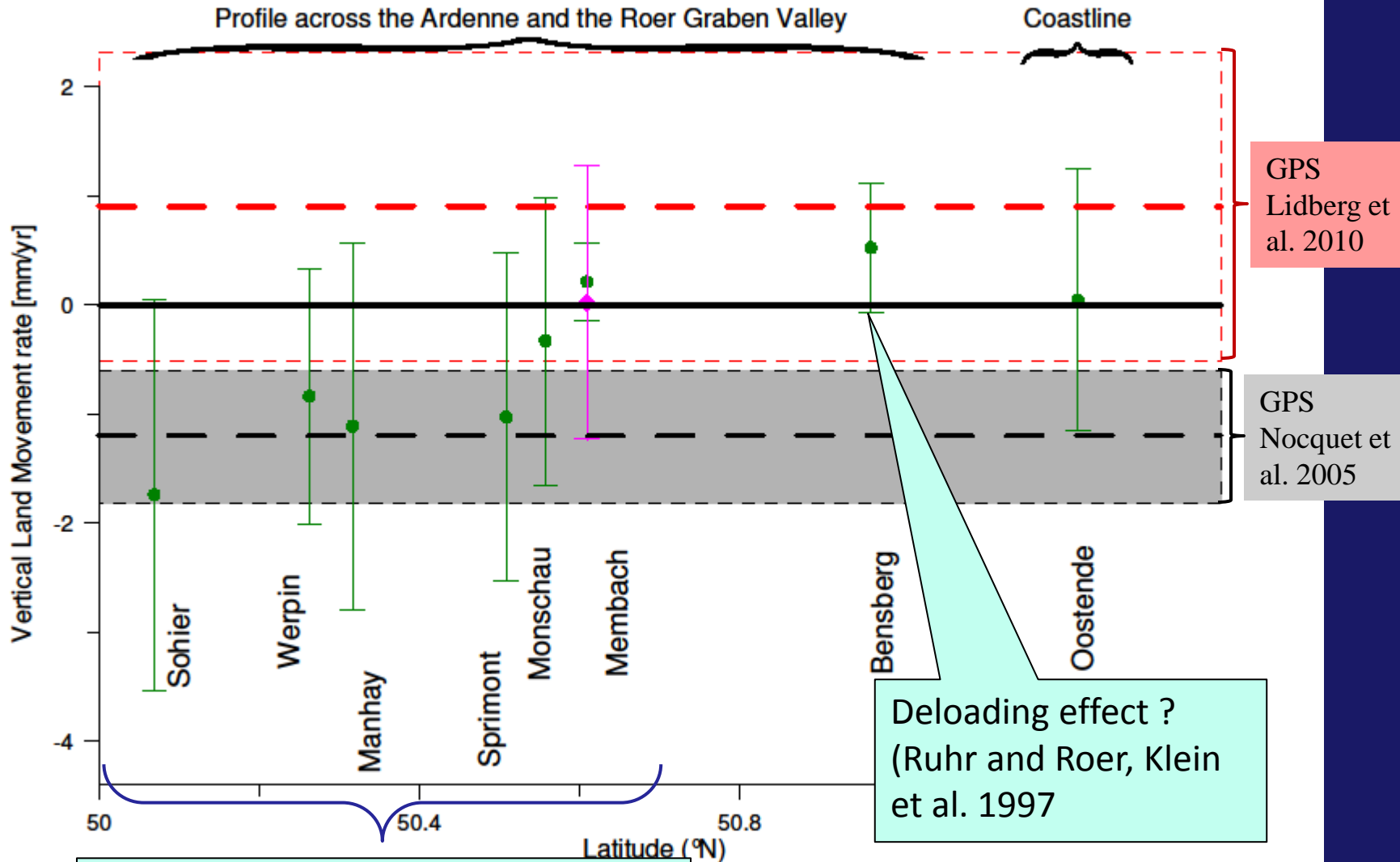
→ Gravity rate of change as a function of the length of the time series (Membach)



# Gravity vs. GPS: $\dot{g}/z = -1 \text{ nm/s}^2/\text{mm}$

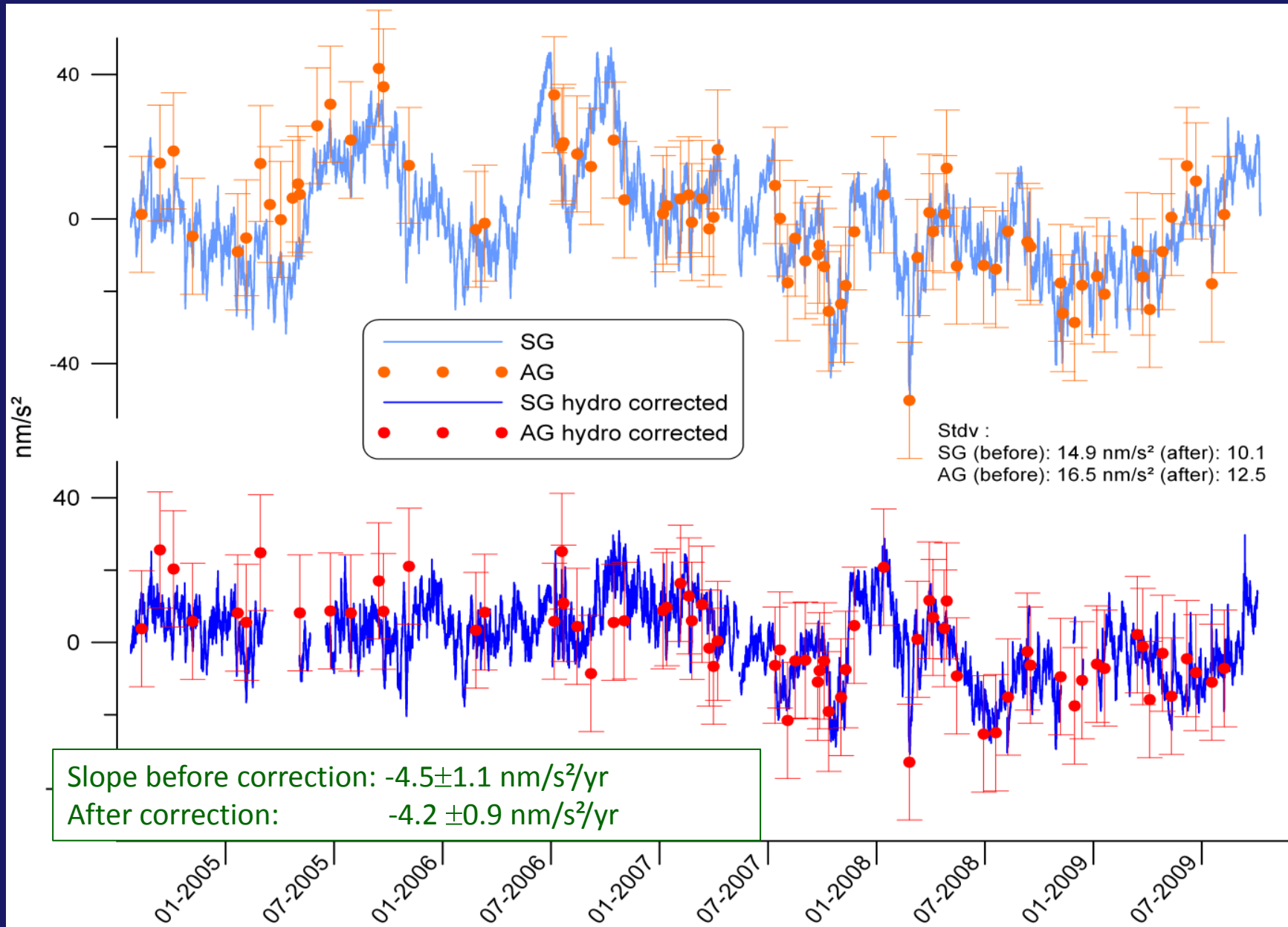


# Gravity vs. GPS: $\dot{g}/z = -2.5 \text{ nm/s}^2 / \text{mm}$

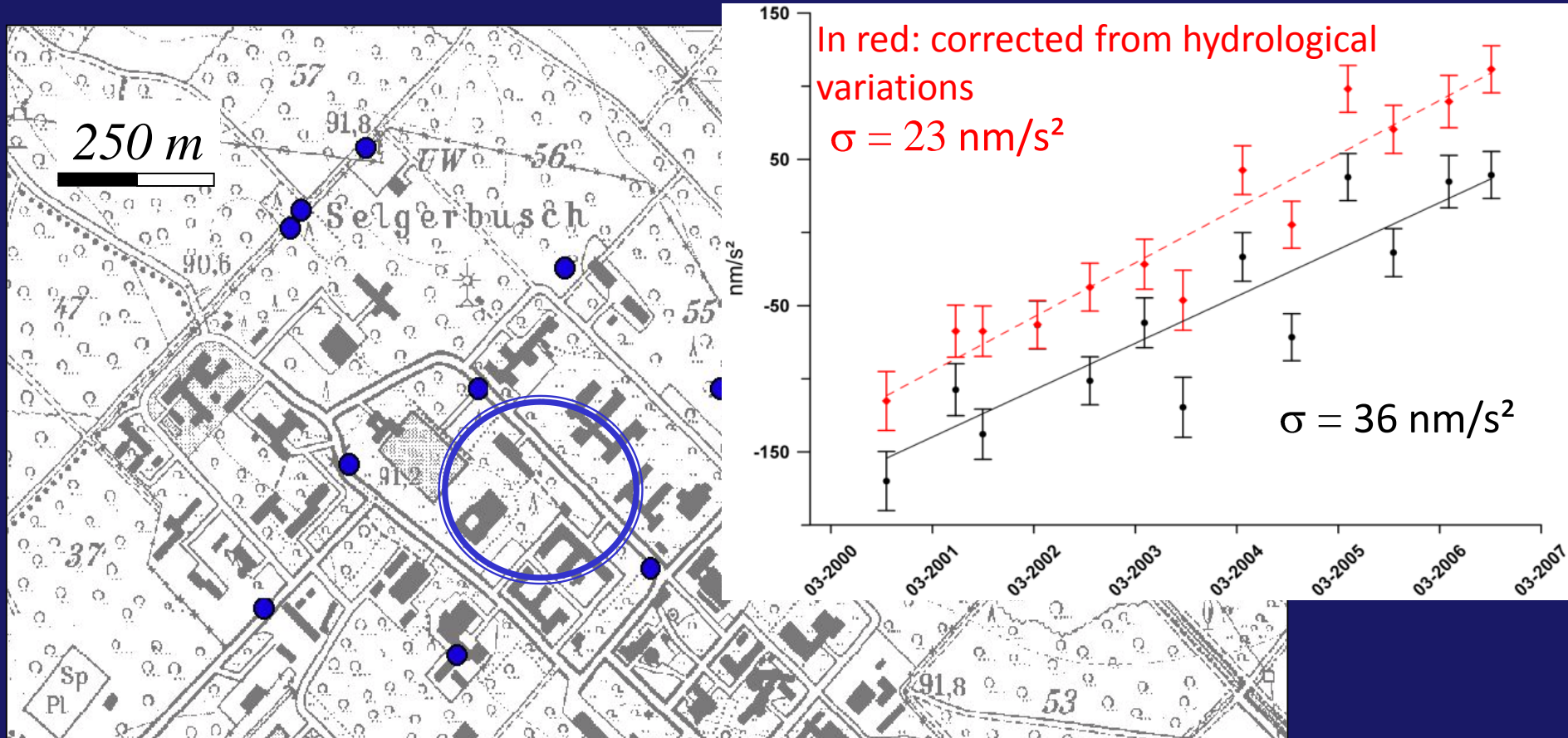


Shoulder uplift in response to rifting in the Roer Graben?

# Membach: absolute and superconducting gravimeters: applying a local hydrological model (> 08-2004)



# Jülich : groundwater data



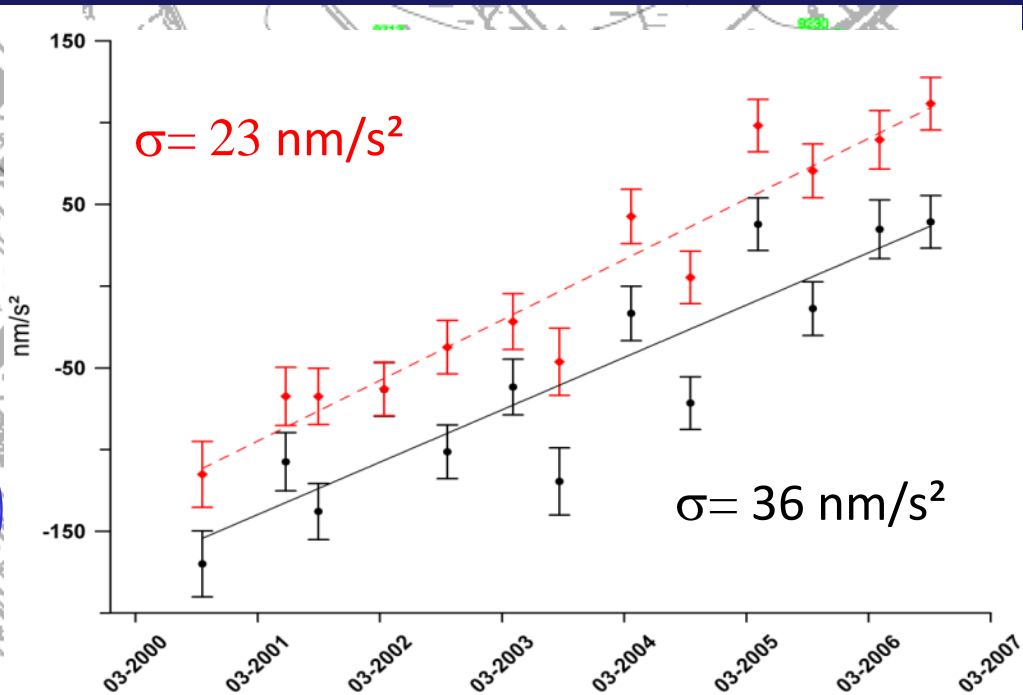
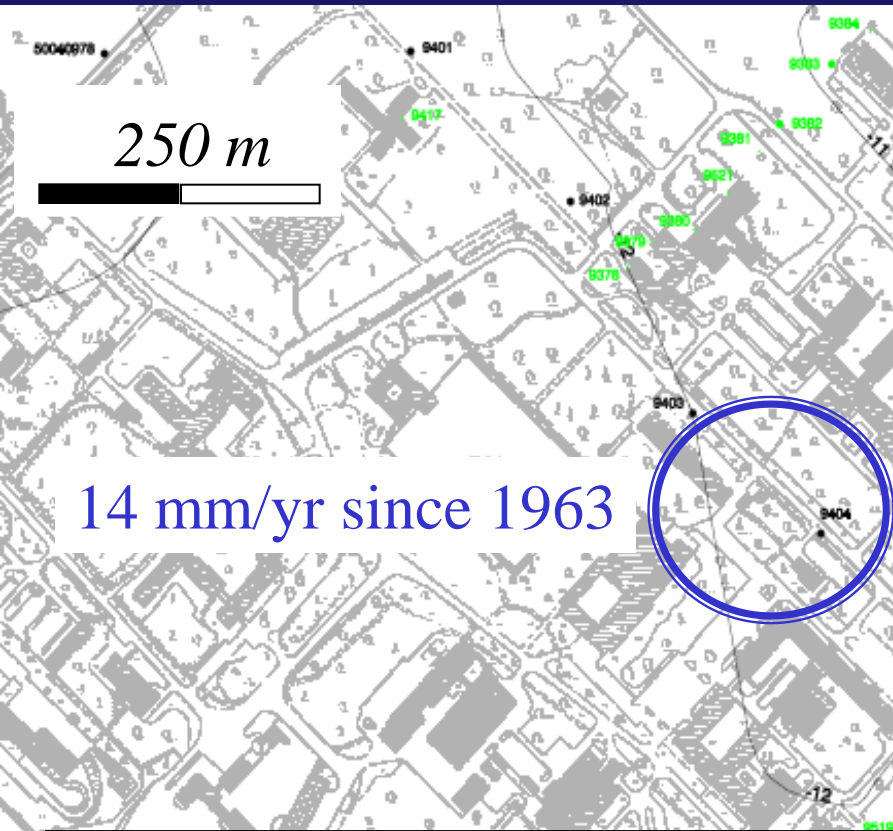
Based on well data

→ Porosity = 22% : minimizes the seasonal gravity variations:  
in agreement with hydrogeological information

!!!! Soil moisture (unsaturated zone) not taken into account

Well data from  
Erhard Huth (Landesumweltamt  
NRW)

# Jülich: AG, hydrology and levelling



Jülich (2000-2006)	Rate of change ( $\pm 2\sigma$ )
Uncorrected	$32 \pm 10 \text{ nm/s}^2 \Leftrightarrow 16 \pm 5 \text{ mm/yr}$
Corrected	$37 \pm 7 \text{ nm/s}^2 \Leftrightarrow 18 \pm 3 \text{ mm/yr}$

Differences not really significant

# Hydrology: and elsewhere? PSDs And for longer periods?

## What you can do:

1) Like Jülich, Membach:

Try to correct for local and large-scale effects (but I'm not so optimistic, not applicable everywhere)

2) Be patient : wait till hydrological signal averages zero.  
But how long ???

→ Investigating long superconducting gravimeter time series and predictions from LaD hydrological model (Milly & Schmakin)

# Hydrology at longer periods <sup>PSDs</sup>

In the time domain: ☹️

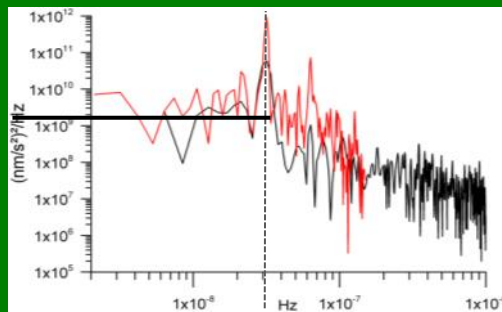
But similar in frequency domain : 😊

Power spectrum densities of SGs and LaD:

black: SG (in the best case, since 1995)

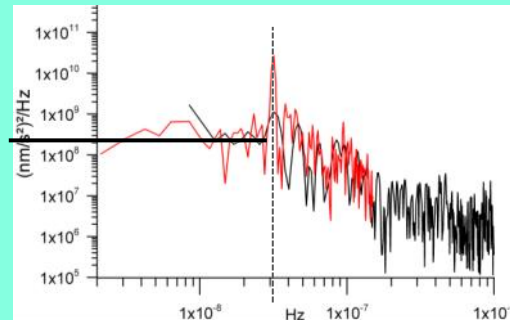
red : LaD (since 1980)

1 cpy



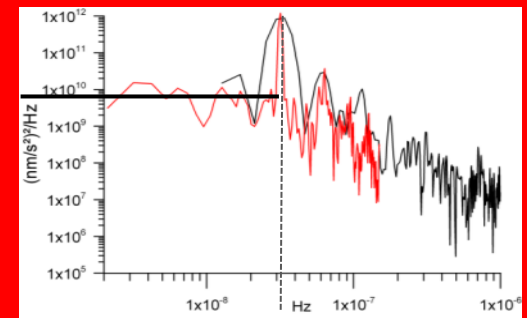
Medicina (Italy)

1 cpy



Sutherland (South Africa)

1 cpy



Tigo (Chile)

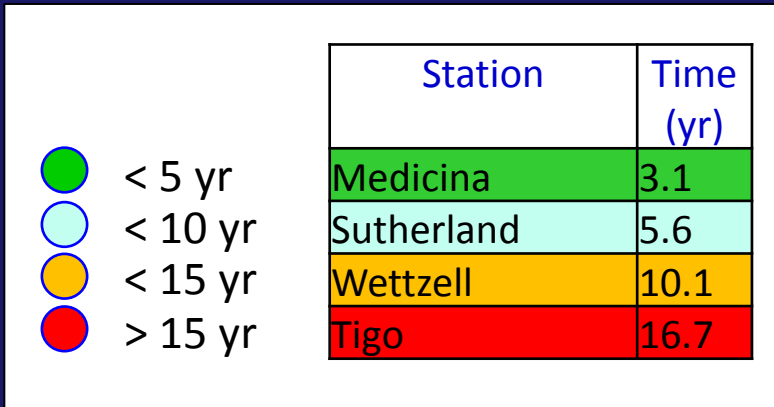
😊 Toward a flattening at periods  $> 1$  year,  
for both SG and LaD

➔ Hydrology follows a "Generalized Gauss-Markov"  
behavior, which is included in the gravity signal

# Given the Generalized Gauss-Markov noise:

Time necessary (years) to be able to measure a slope with an uncertainty of  $1 \text{ nm/s}^2 / \text{yr}$  ( $\Leftrightarrow \sim 0.5 \text{ mm/yr}$ ) ( $1\sigma$ ), based on SG & LaD time series:

3 to 17 years



Not contradicted by the profile: after 10 years :  $1\sigma \approx 1.5 \text{ nm/s}^2 / \text{yr}$

# Repeated absolute gravity measurements: Conclusions

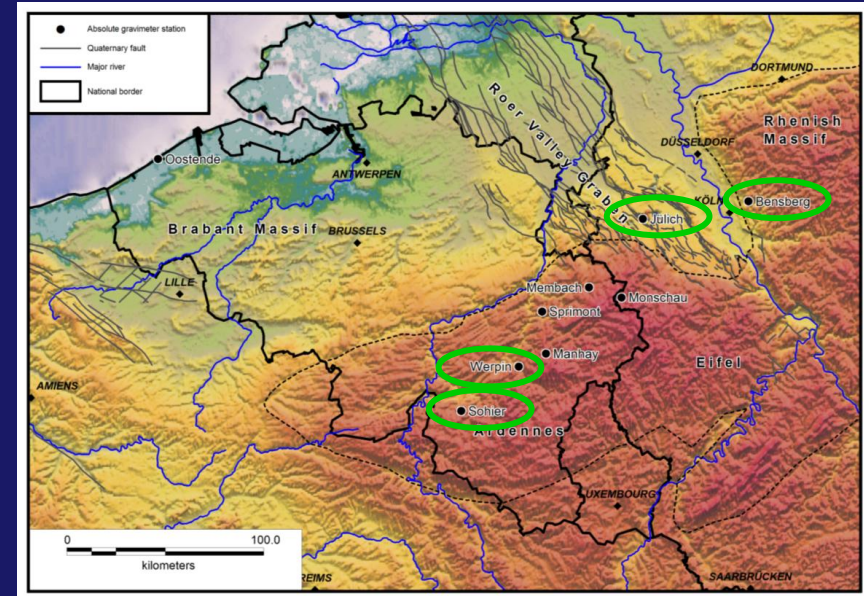
At 4 of the 9 sites: significant gravity rate of change ( $2\sigma$ ) :

-1.3±1.2 (Bensberg)

38.4±6.6 (Jülich)

2.1±2.4 (Werpin)

4.4±3.2 (Sohier)



Annual term ranges  $9\pm 2$  (Membach) to  $43\pm 18$  (Sohier)

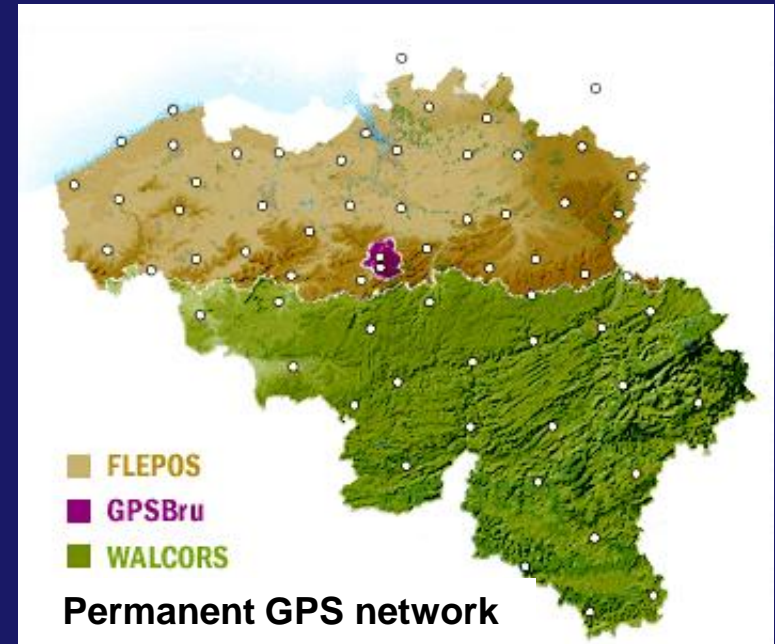
→ Deformations related to GIA or Roer Valley Graben close or below the accuracy of geodetic techniques, suffer from anthropogenic effects

→ Unless significant climate change, hydrology should not mask the GIA effect on the peripheral bulge.

→ Long AG time series may also be useful to investigate slow environmental changes !

# Perspectives

→ Process the European GPS time series,  
+ InSAR in the Roer Graben



- Use the Absolute Gravity data as a constrain for the vertical component (see Teferle et al., *GJI*, 2009)
- Necessity to improve GIA model to investigate other tectonic processes
- Necessity to work on the  $(dg/dt)/(dz/dt)$  ratio