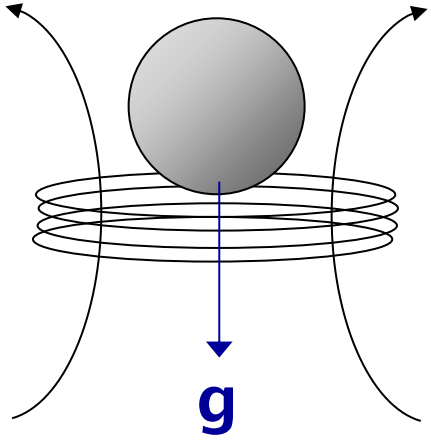
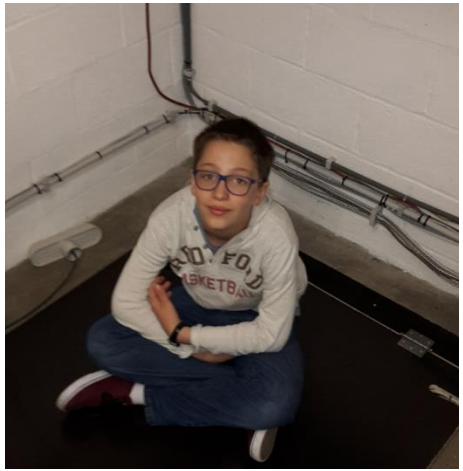
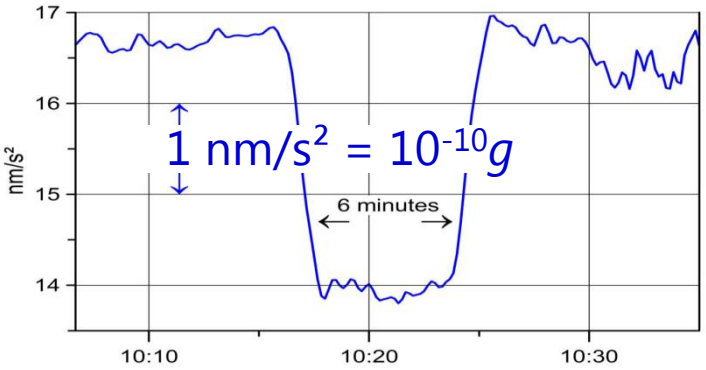
How radar can be supported by gravimeters for estimating hail intensity

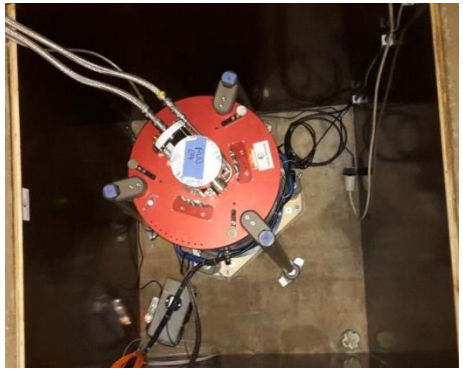
M. Van Camp, L. Delobbe,
S. Wilfert,
A. Watlet, O. Francis, and D. Delforge

Superconducting gravimeter?

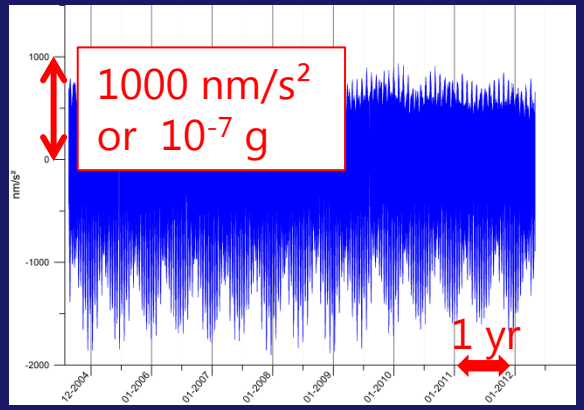




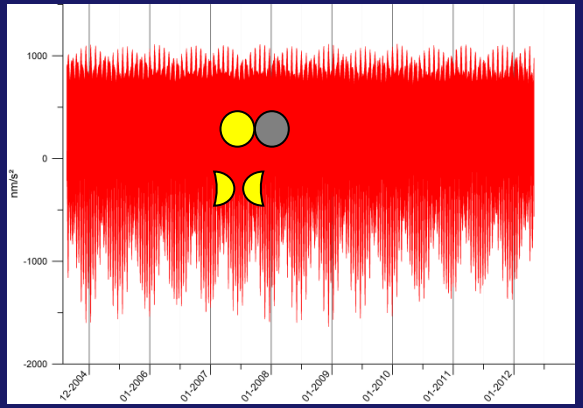




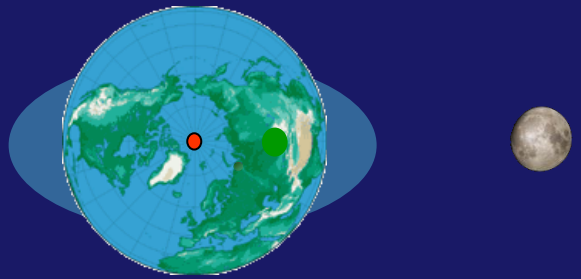
Gravity time series 2004-2012

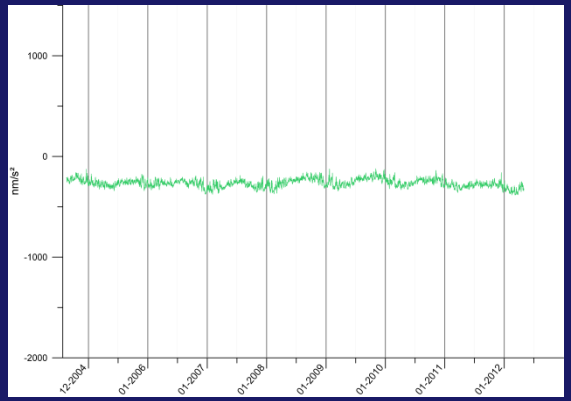


Observed signal



Modeled tide

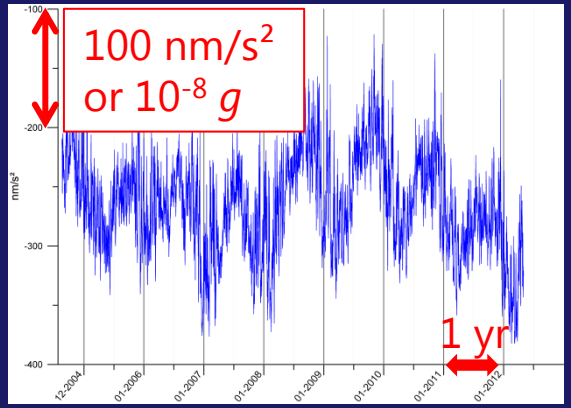


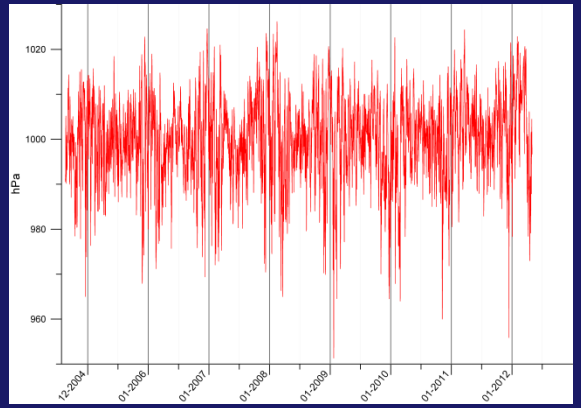


After correcting for Earth tide

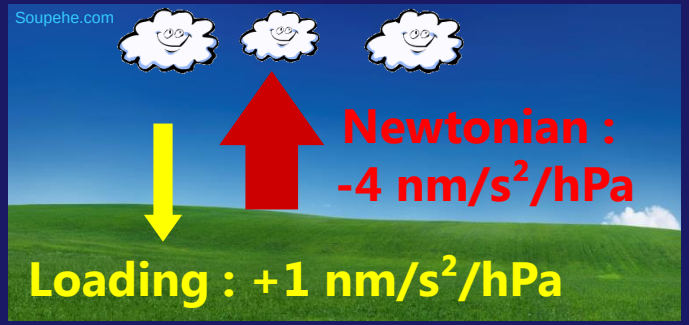
X10 ➔

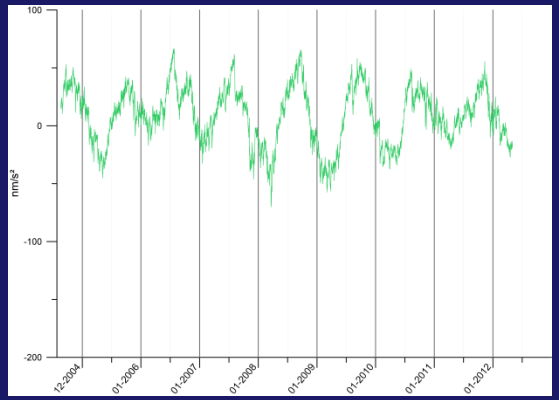
Gravity time series 2004-2012





Atmospheric pressure

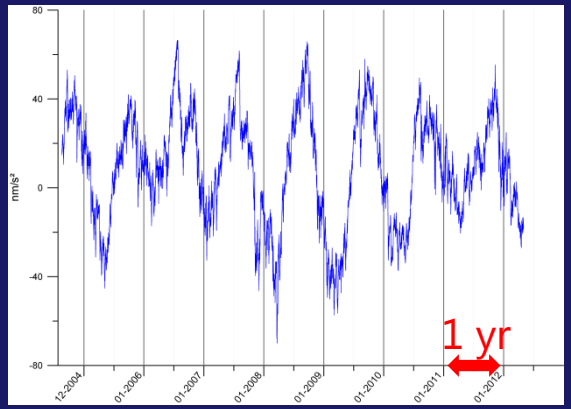




After correcting for tide and pressure

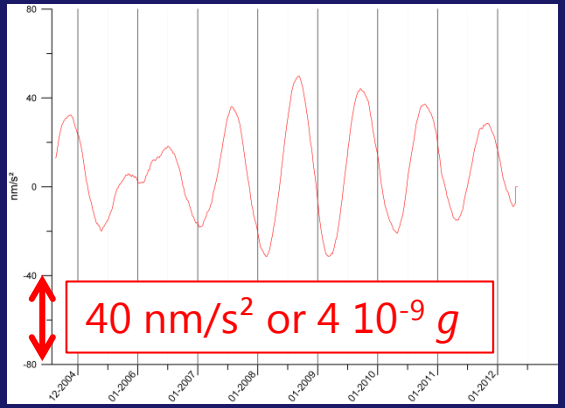
X2.5 ➔

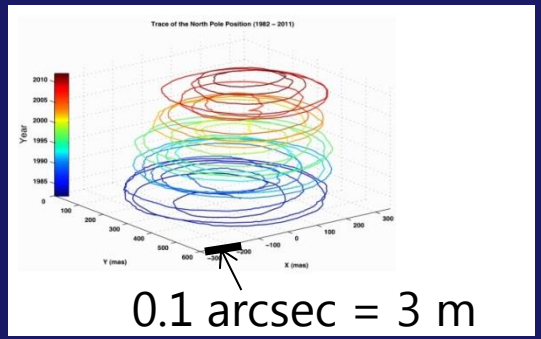
Gravity time series 2004-2012



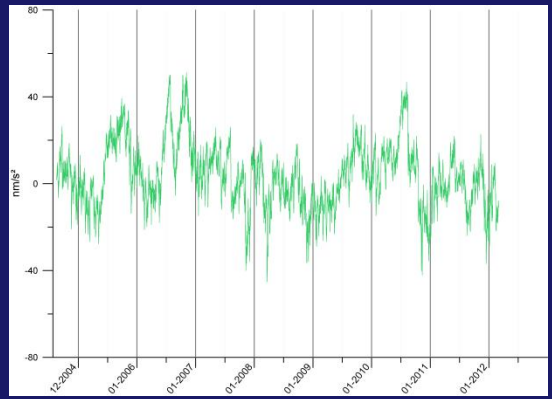
Observed signal (after correcting for tide & pressure)

Polar motion



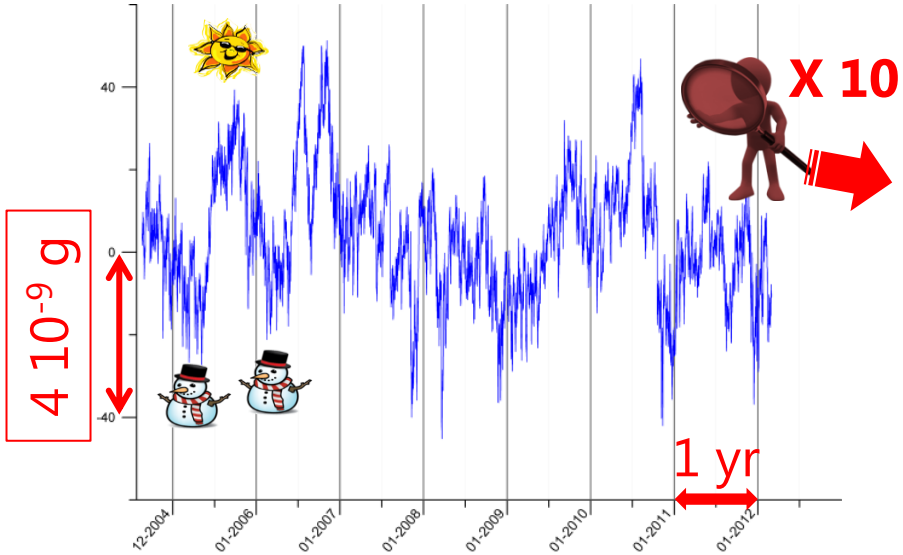


From Chen et al., GRL 2013



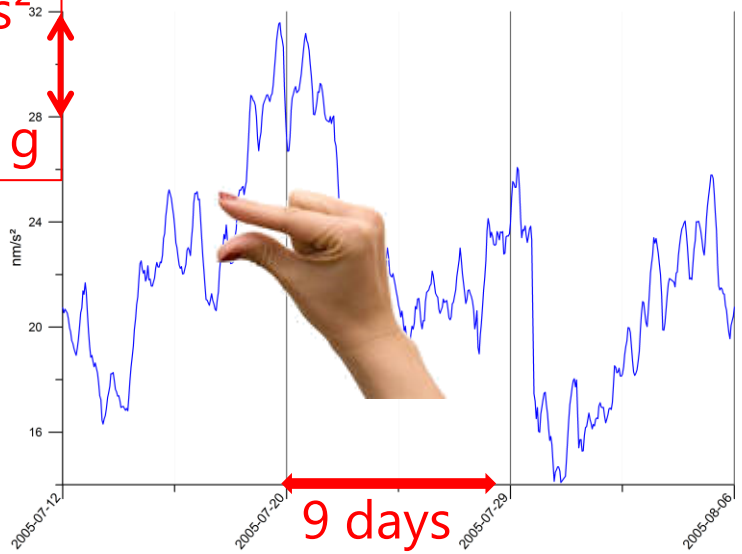
After correcting for tide, pressure, pole

Hydrological effects on *g*



X 10

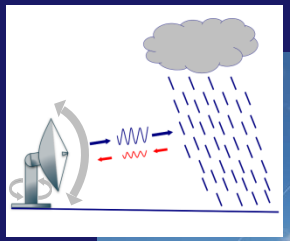
4 nm/s²
⇔
4 10-10 g



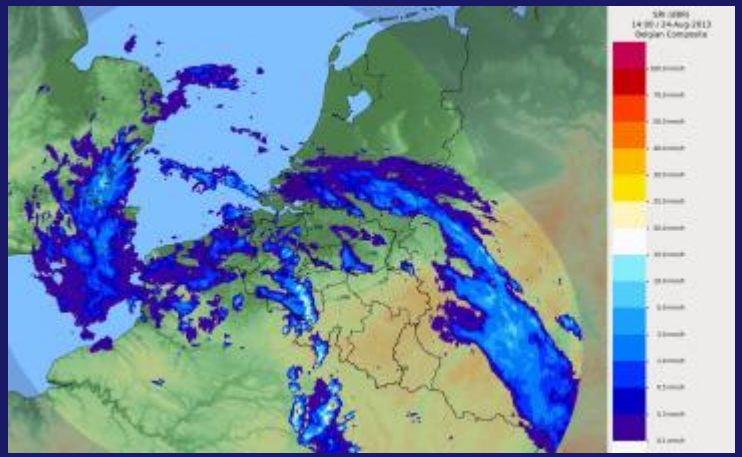
Seasonal variations !
(g lower during winter because more water is above the gravimeter)

We work at a few 10^{-10} *g* level

Measuring hail?



Radar: 250 m in range, 1 deg. in azimuth (1.7 km at 100 km)
Which accuracy? Difficult to characterize
Raingauge? Too local: << m^2 scale!

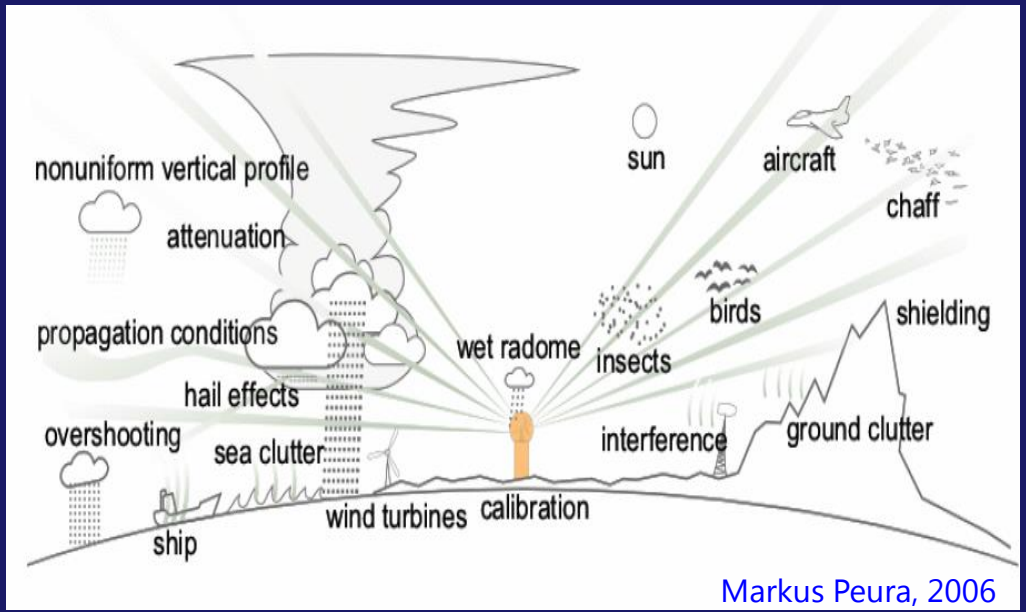


Gravimeter able to weigh water at the 50 ha scale !
→ Direct, traceable

Measuring rain and hail?

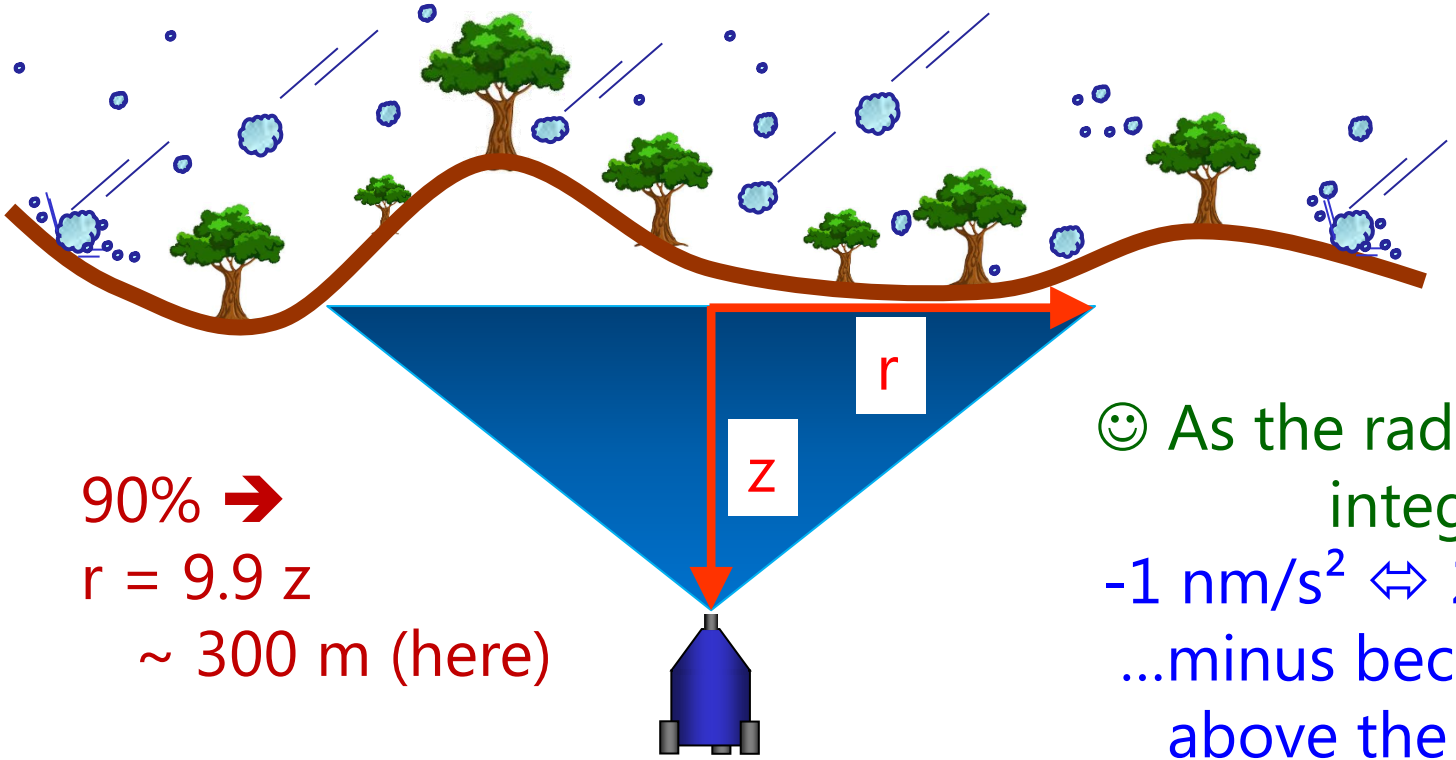
Radar ⇔ converting reflectivity into actual rain/hail falls…
…but which accuracy?
Raingauge? ➔ convective storms exhibit strong spatial variations over short distances

1) Ground clutter (beam hits objects)
2) Overshooting (beam above rain)
3) Radar calibration
4) Radome & atmospheric attenuation
➔underestimation
5) vertical profile of reflectivity (melting zone= overestimation)
6) Conversion reflectivity-rain rate



Markus Peura, 2006

Underground gravimeter as raingauge: Sensitivity cone



90% ➔
r = 9.9 z
~ 300 m (here)

☺ As the radar, gravimeter integrates
-1 nm/s² ⇔ 2.5 mm water
…minus because water is above the gravimeter

Selection of events

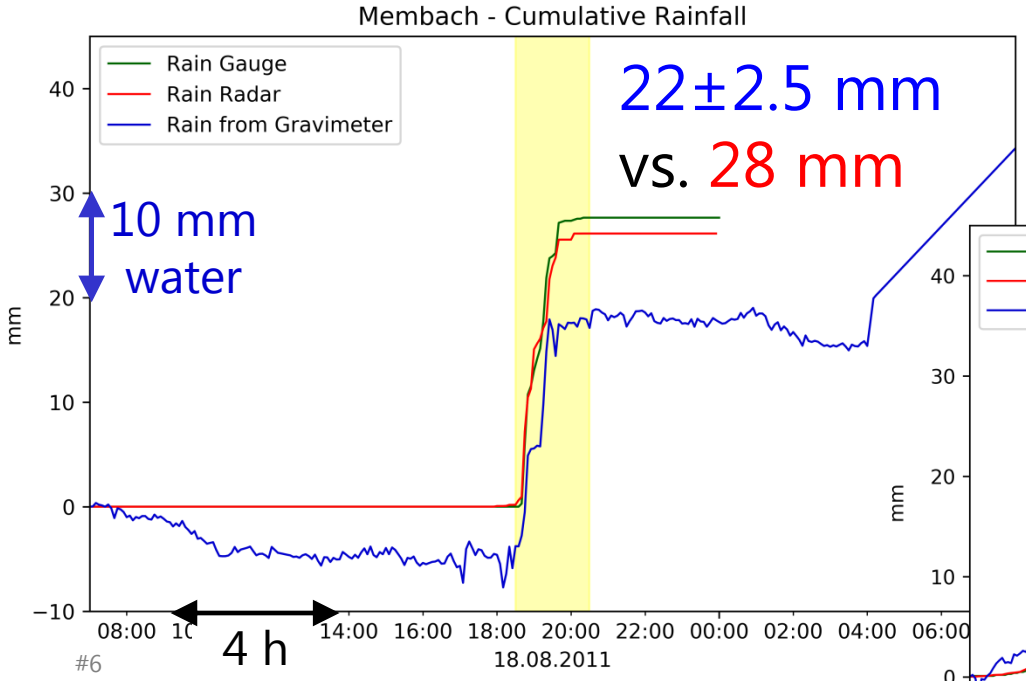
Short events (~1h)
Probability hail >50%
(Waldvogel algorithm)

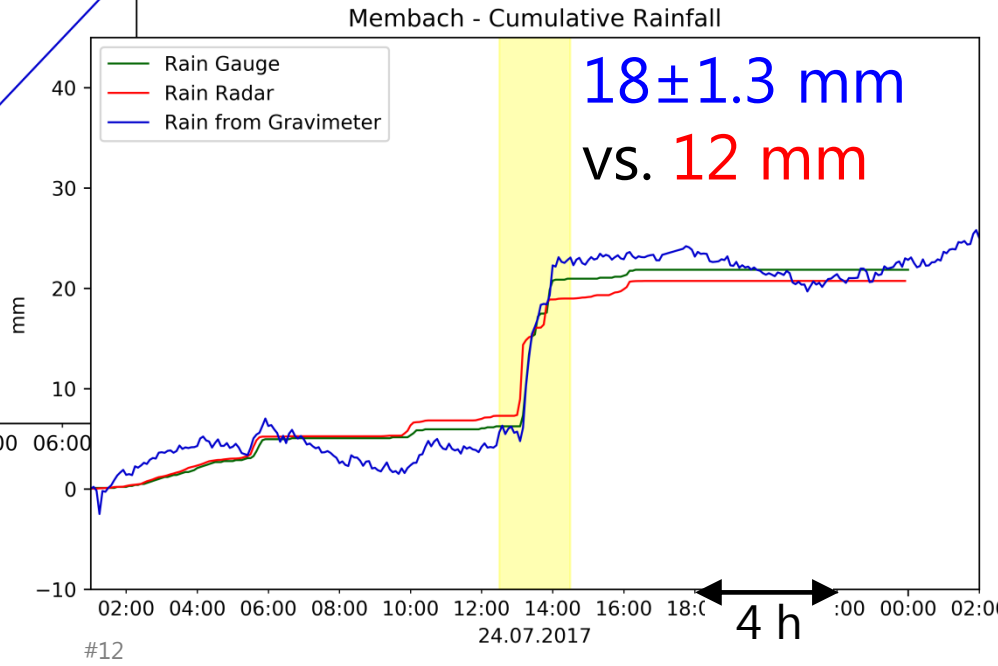
Why hail?

Radars known to overestimate it
→ reflectivity depends on (diameter)^6

The underground gravity stations
The radar

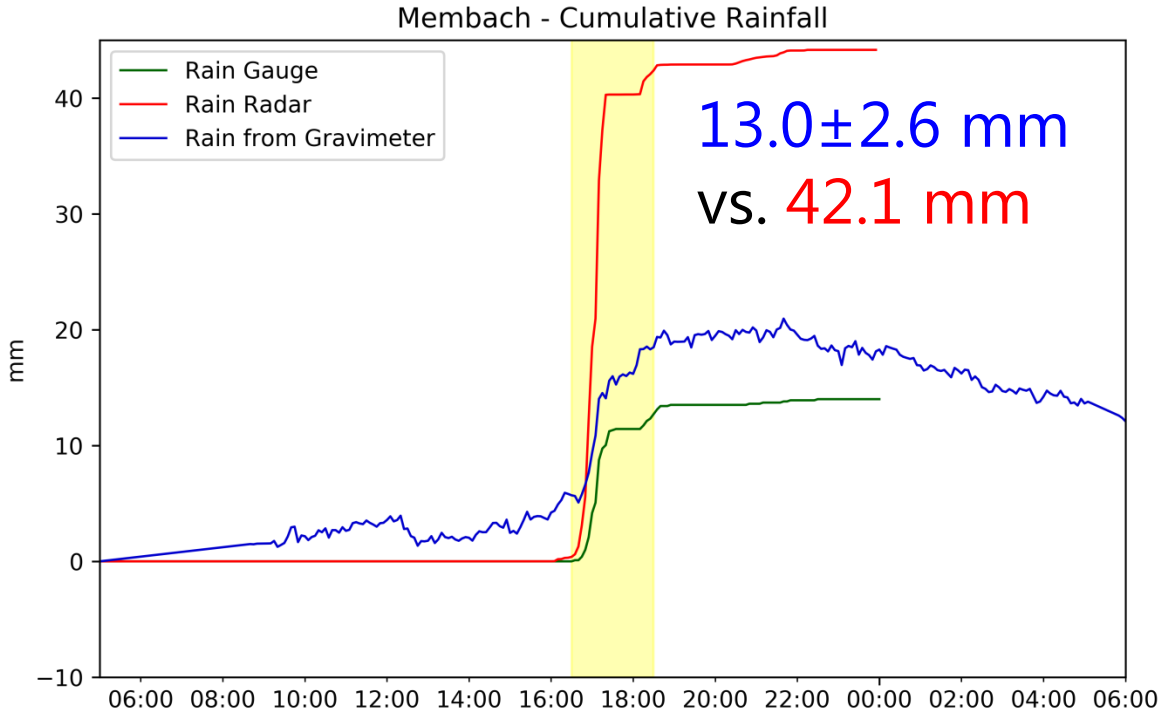
Membach: cumulative rainfall





☺ **Timing & amplitude**

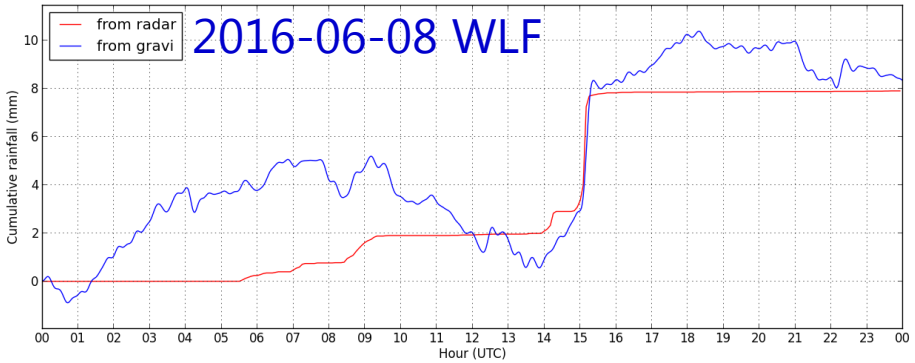
Membach: cumulative rainfall



😐 **Amplitude**

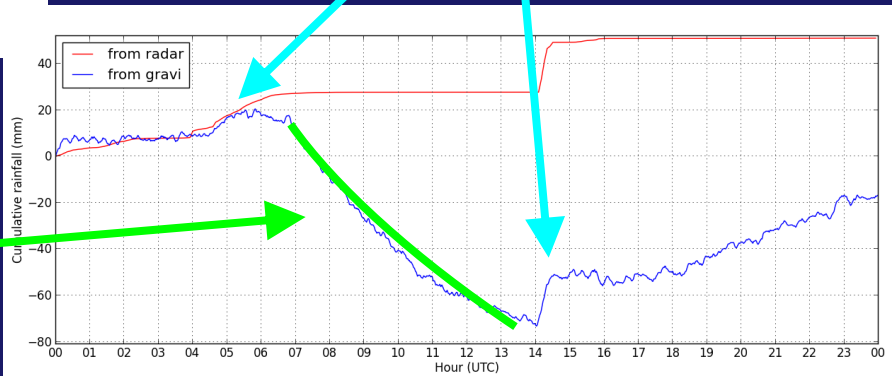
☺ **timing**

Walferdange, Rochefort: cumulative rainfall



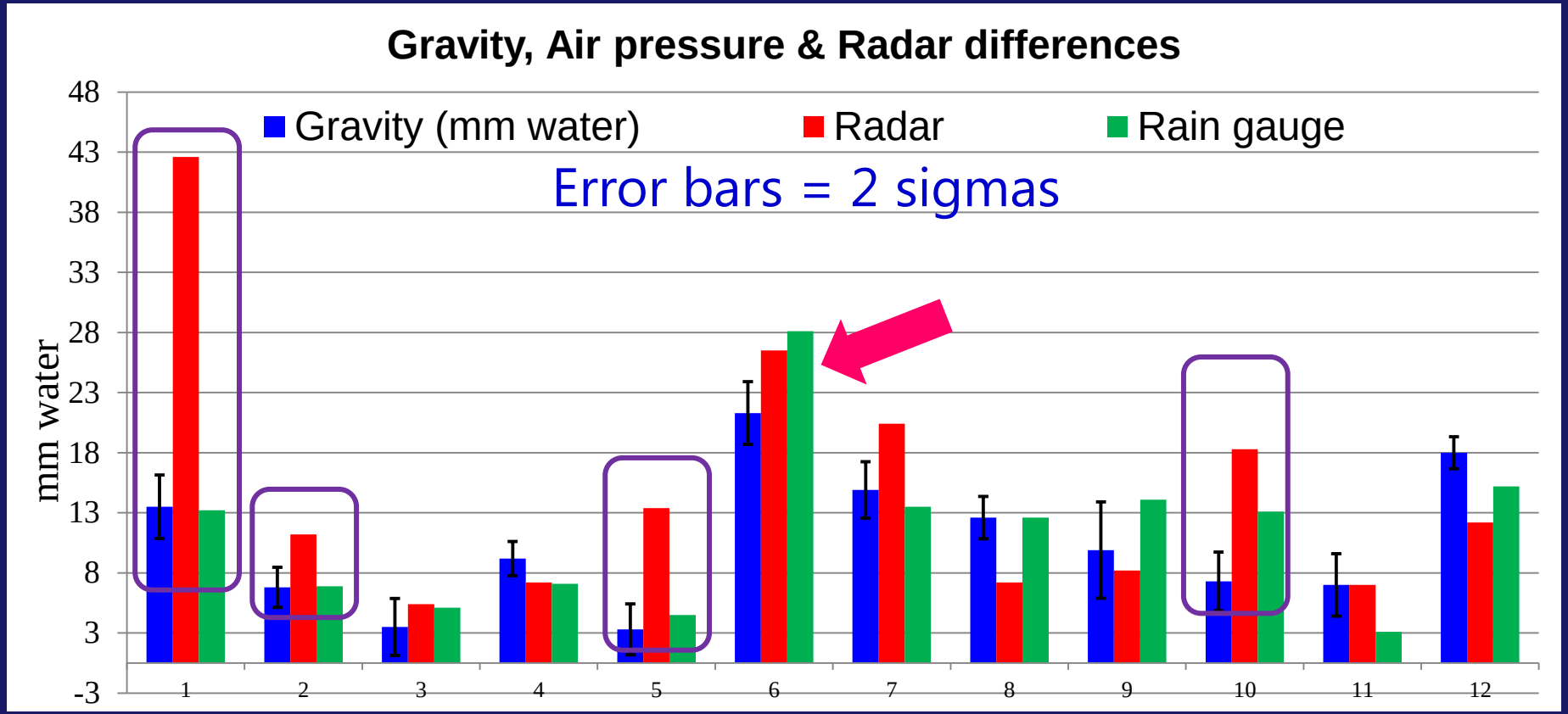
Gravity effect of precipitation above gravimeter

Gravity effect of flash flood of the cave underneath gravimeter



2016-07-23 RCH

12 events @Membach



Noise sources

– Atmospheric effect: pressure recovers at a same level after the hail fall:

Max. 1.6 hPa difference before/after event ➔ if 10% of error on the correction: 0.5 nm/s^2 ⇔1.2 mm rain

– Evapotranspiration: negligible within a few hours

– ☹ Raingauge not WMO compliant

– Runoff ?

→ Events are short: ~1 hour

→ Different in WLF, RCH and MEM;

→ Ground not saturated: all events between May & September, no significant rain 4 days before

Conclusions

- 21 events 2006-2017

- Strong event (>10 mm / 1 h) are rare: 1-2/year
- Signature of intense precipitation clearly visible in gravity data, timing agree within minutes
- Gravimeter detects most of the intense events,
- Radar tends to overestimate w.r.t. gravimeter: most probably due to hail (6/12 cases in Membach; 1/4 in Walferdange, 0/2 in Rochefort)
- Ongoing: looking for all strong rainfall events (>100)