# Hydrogeological effects on terrestrial gravity measurements

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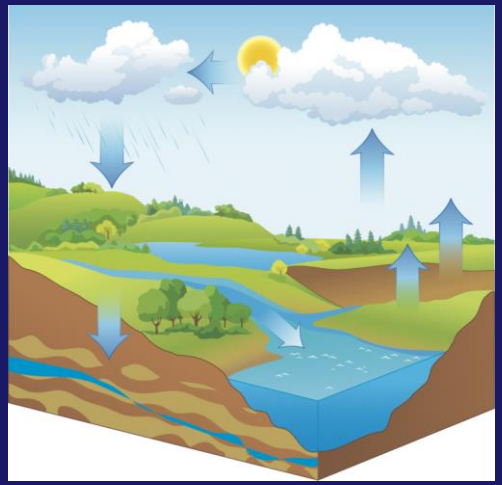
# General context



- Knowledge of water mass balance paramount for sustainable development
- Water cycle intensively monitored & analysed

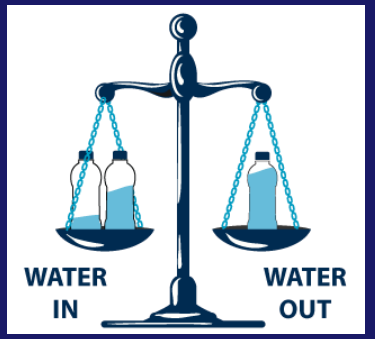
- For 10 years gravimeters are included in the observing system

➔ Expensive, difficult to use & process, mixes different signals, short-range…

# Why terrestrial gravimetry?

**Gravity measurements → unique technique sensible to the whole mass**

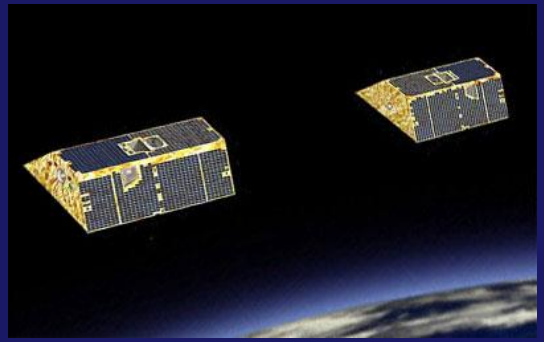
**Precise, traceable, stable: allows separating sources**




# Why not only GRACE?

**GRACE is great, but:**

- **Footprint ≥ 400 km,**
- **Sampling rate 10 days**



# Terrestrial gravimetry for small-scale monitoring

**Major small-scale processes still poorly known: recharge, evapotranspiration, rainfall (raingauge = point: $10^{-7}$ km² vs. 0.5 km² (gravimeter))**

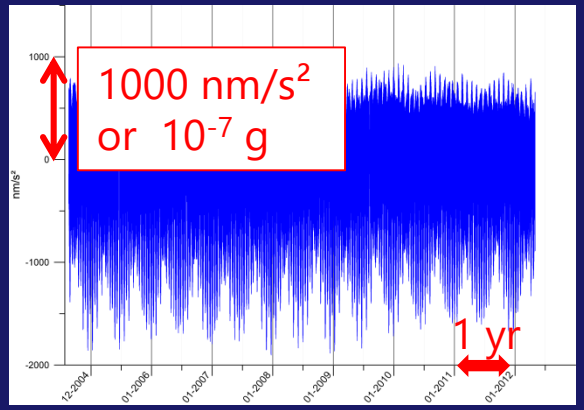
**→ Gravimeter great at the 50 ha scale:**

- ✓ **Small watersheds**
- ✓ **Different contexts: peatland, karst, forest, field, strong topography, saturated vs. vadose,...**

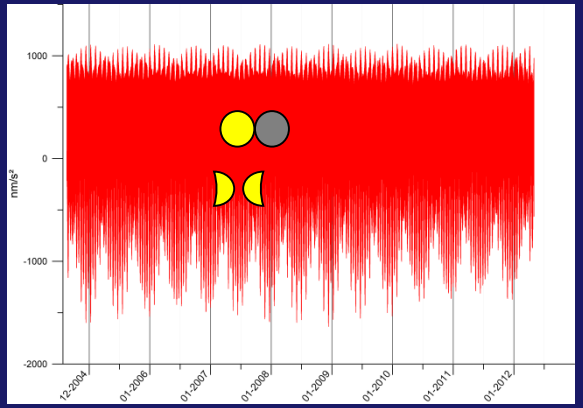
# How recovering the complex hydrological processes from the available information?

**This is what we are trying to do for more than 20 years at Membach and Rochefort, Belgium.**

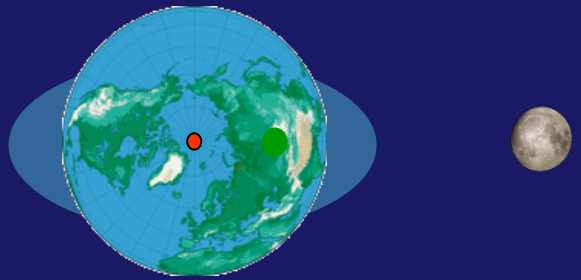
# Gravity time series 2004-2012

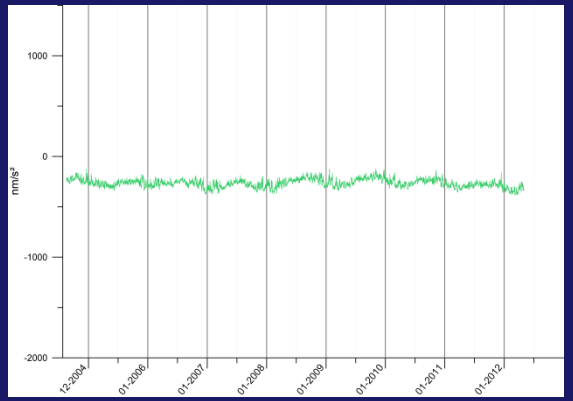



Observed signal




**Modeled tide**

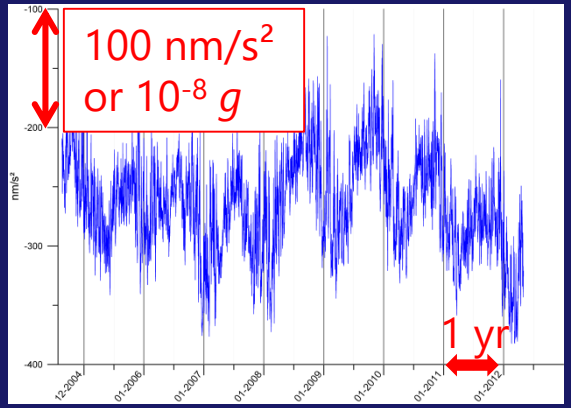


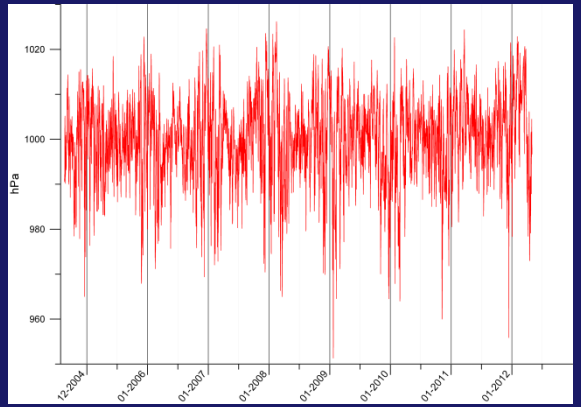



After correcting for Earth tide

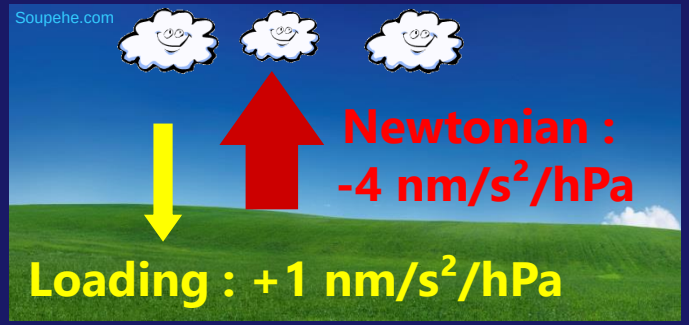
**X10 ➔**

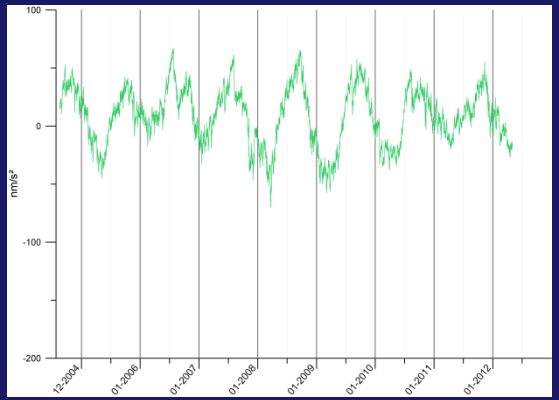
# Gravity time series 2004-2012




**Atmospheric pressure**

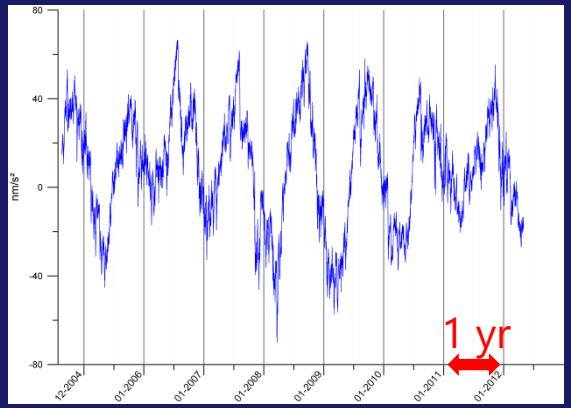



After correcting for tide and pressure

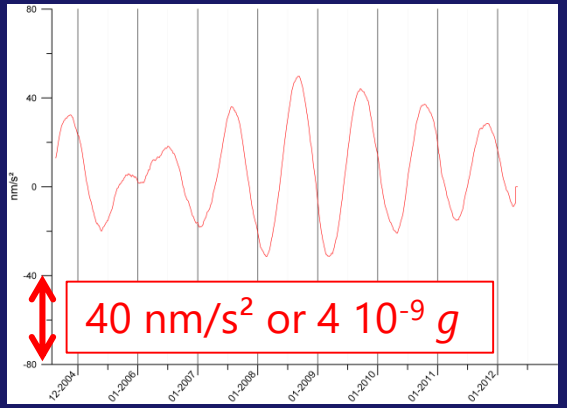
X2.5 ➔

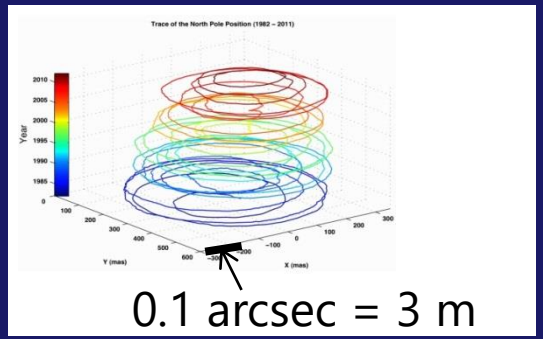
# Gravity time series 2004-2012



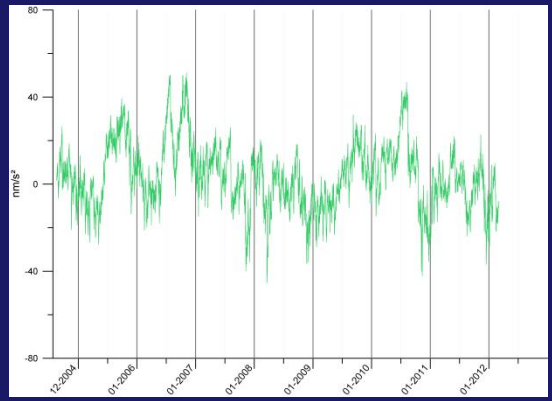

Observed signal
-tide
-pressure

## Polar motion



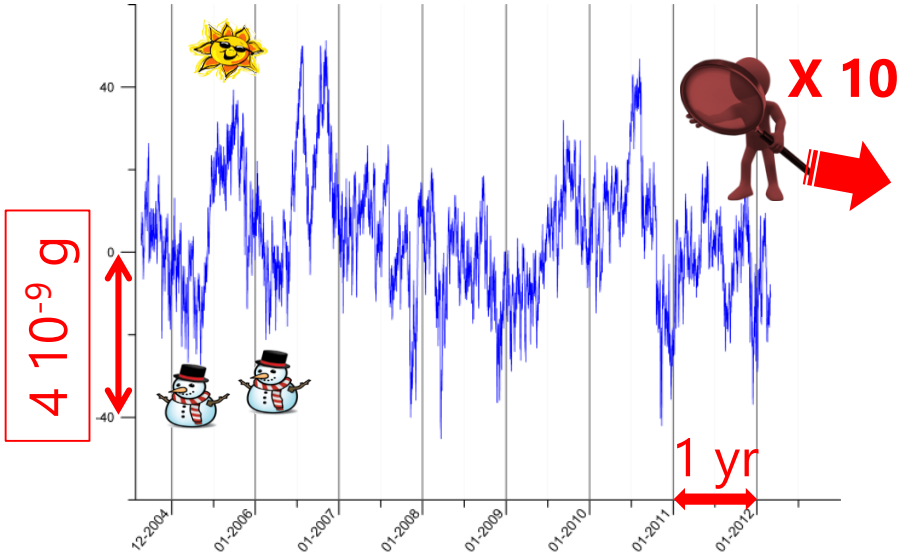




From Chen et al., GRL 2013



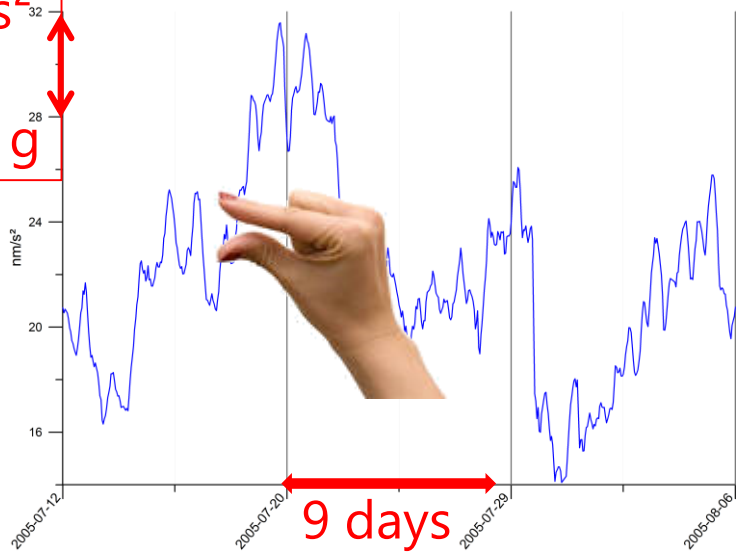

After correcting for
tide, pressure, pole

# Hydrological effects on *g*




X 10

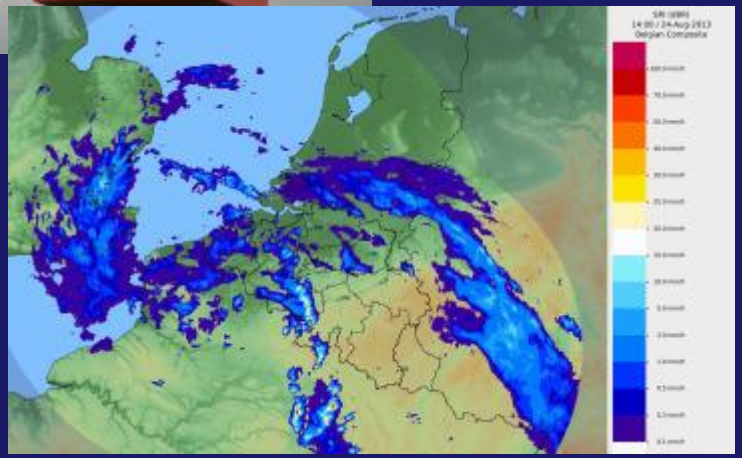
4 nm/s²
⇔
4 10⁻¹⁰ g




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

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

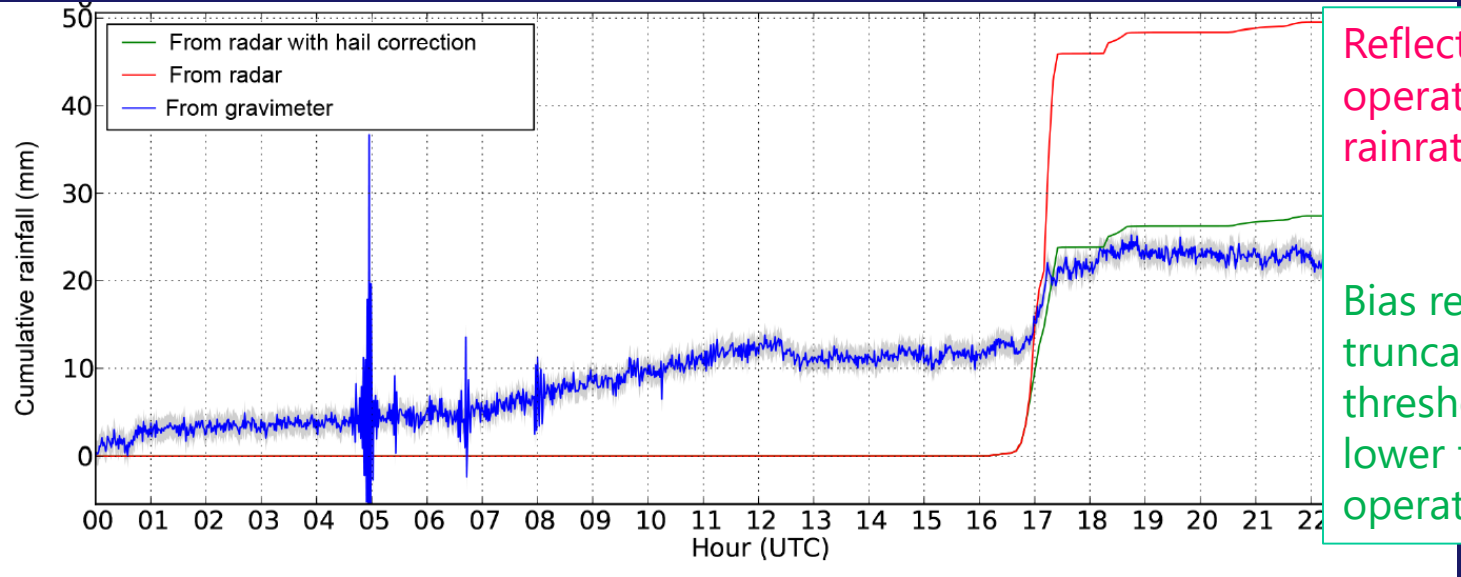
# Measuring hail?



Radar: @40 ha scale…but which accuracy?
Raingauge? Too local: << $m^2$ scale!


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

# Radar- and gravimeter-derived cumulative rainfall for June 14, 2006




Reflectivity to rainrate using operational reflectivity-rainrate converstion

Bias removed with truncation of reflectivity threshold at 48 dBZ lower than 55 dBZ used operationally

*Delobbe et al., HESS 2018*

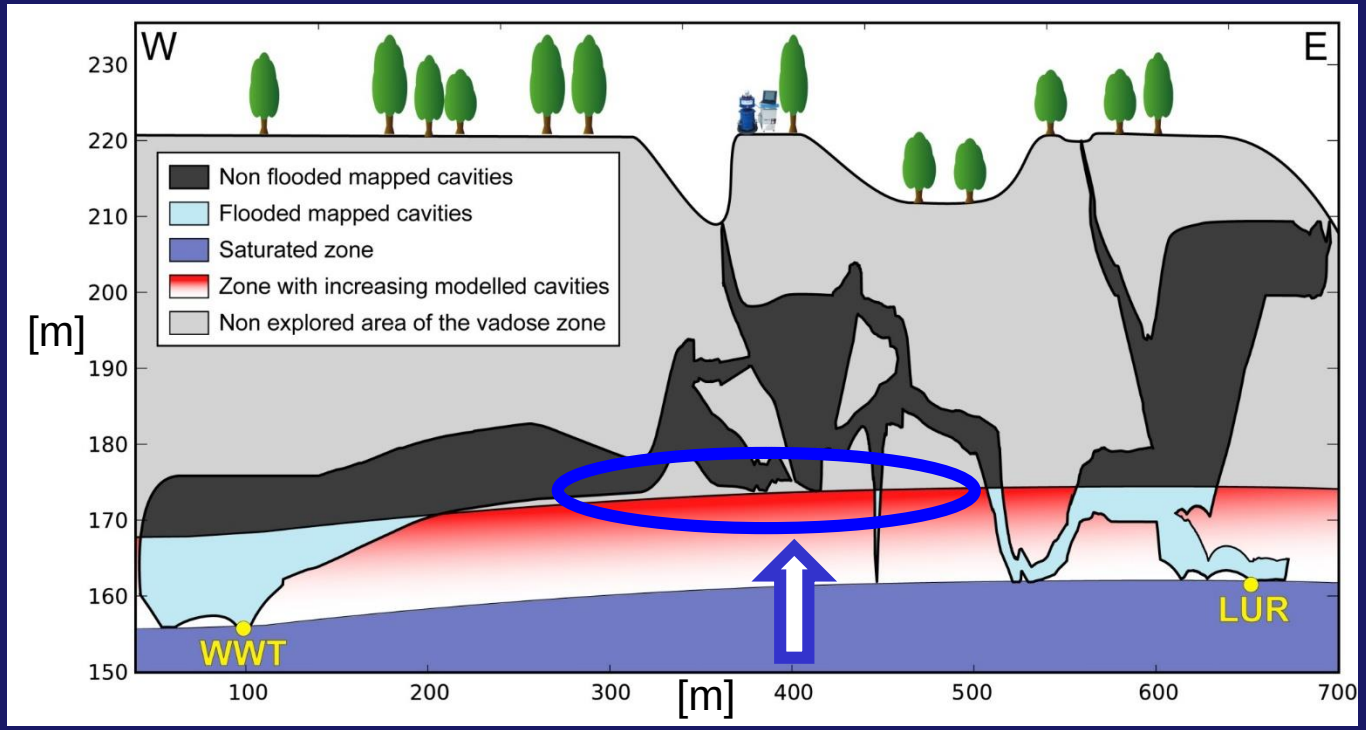
# Underground flash floods in karst

http://www.derochefort.be/dusch_de_rochefort.html

A. Watlet

# Flash floods in karst

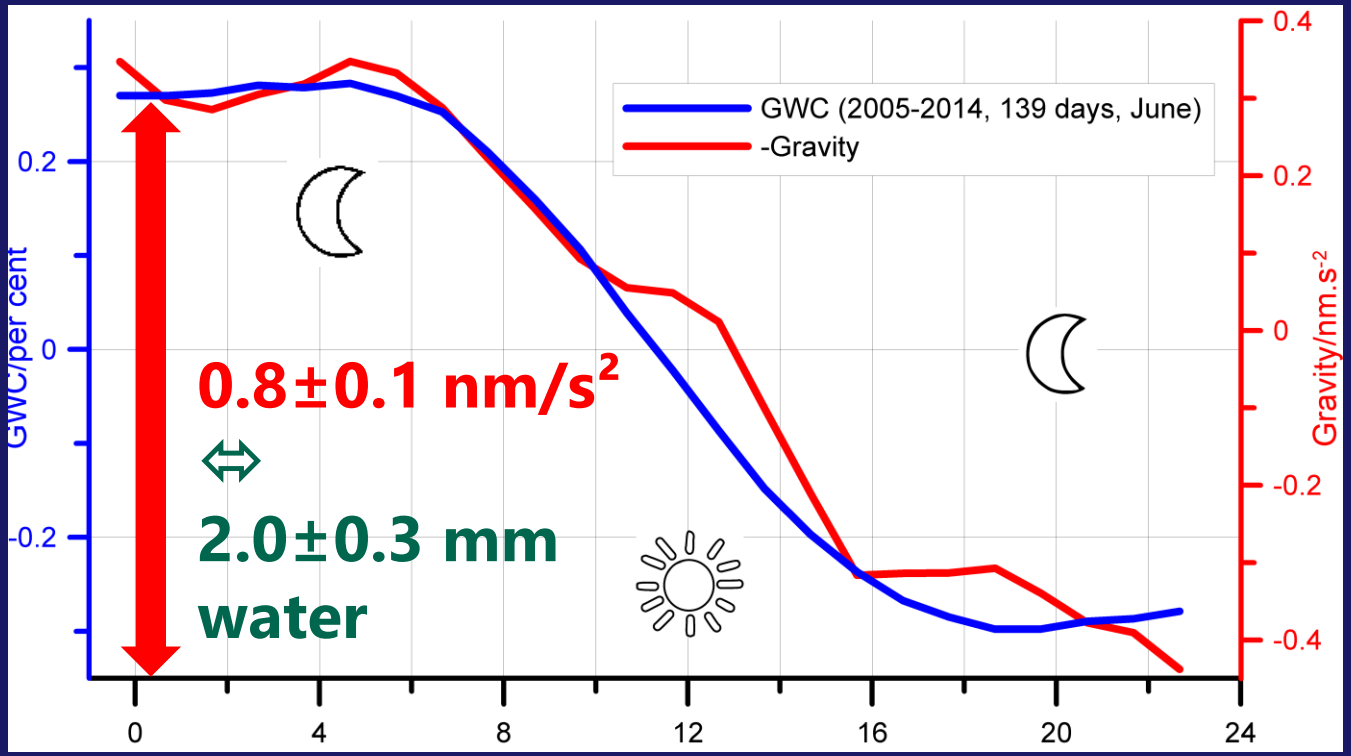
Gravimeter allowed to localize vertically unknown cavities in the karst




We need voids here!!

*Watlet et al., WRR, 2019 (submitted)*

# Ground water content and -gravity
# Stacked gravity data, June




⇔1.9±0.2 mm from eddy covariance tower (similar forest, 34 km from Membach)

*Van Camp et al., GRL 2016*

# Seismic noise and hydrogeology

# Gravimeters: the Swiss knive of hydrologists?

- Multi-disciplinary
- Multi-instrumentation
- 20 years of hard work:
  - -Deep knowledge of the instrument
  - -Deep knowledge of the gravity data processing
  - -Need for long time series

➔allowed extracting and interpreting elusive signals