Complementary gravimetric monitoring of water storage changes - lysimeters and superconducting gravimeters

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Introduction

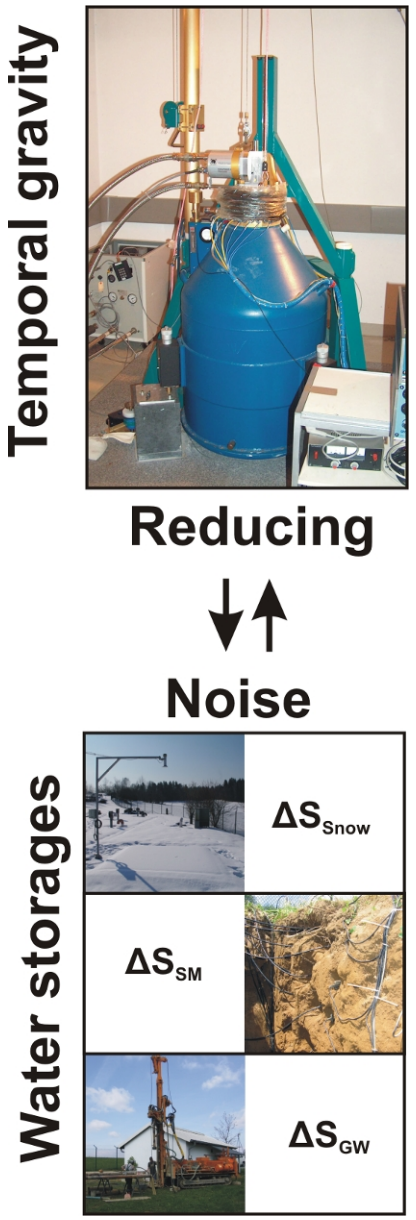
GFZ Helmholtz-Zentrum Potsdam

Problem:

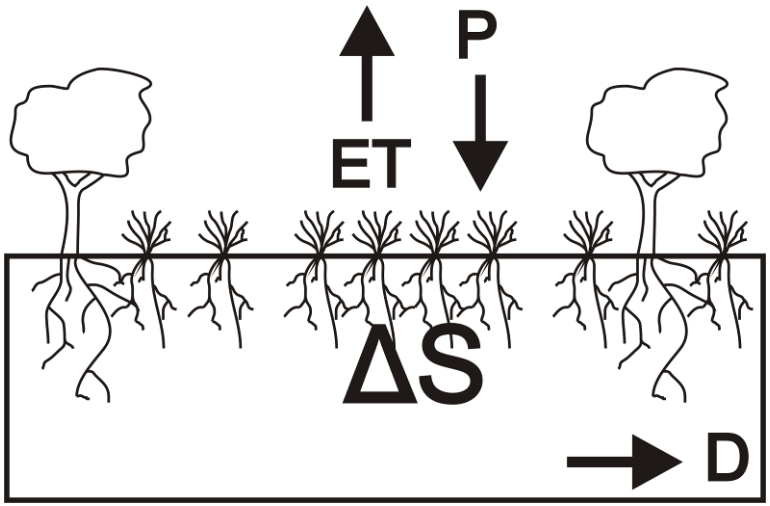
- Gravimeter observations are influenced by local water storage changes (WSC)
- The intrinsic hydrological effect can mask the geodetic / geophysical phenomena of interest.
- Independent estimation of hydrological gravity effect is associated with high level of uncertainty.

Question:

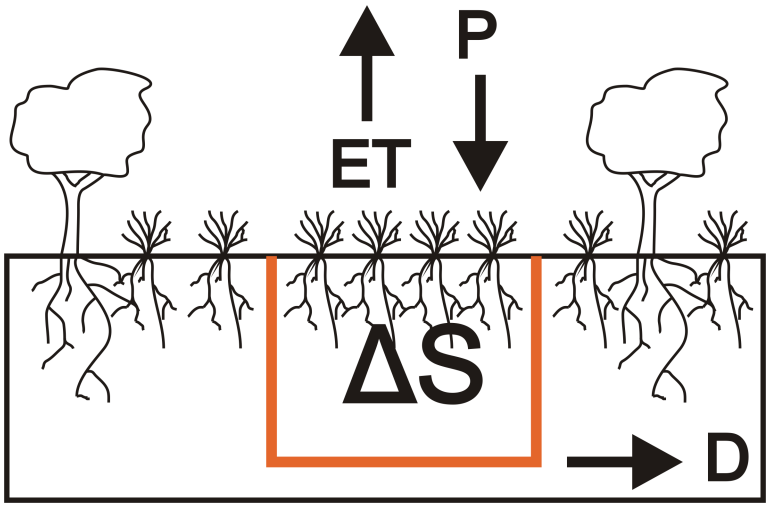
- How can we improve the estimation of WSC to reduce temporal gravity signal from the hydrological influence?



Lysimeter

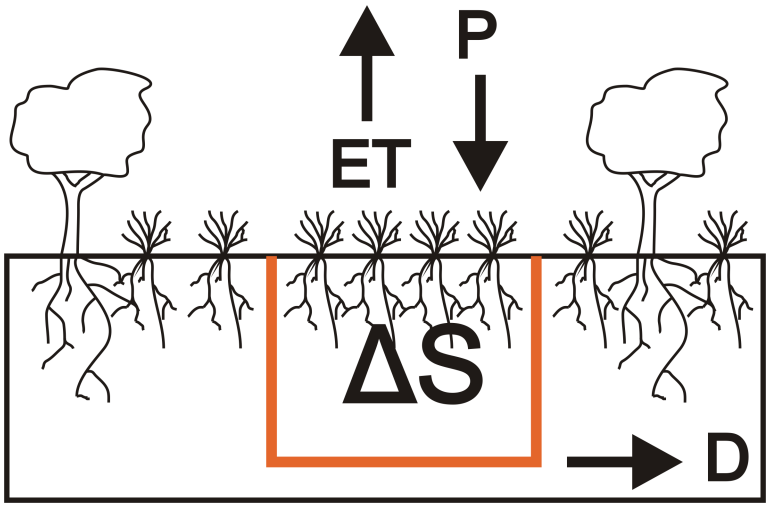


Lysimeter



$$\Delta S = P - ETa - D$$

Lysimeter



$$\Delta S = P - ETa - D$$

weighable: direct estimation of ΔS, ETa, and P small volume (crop, grass)	non weighable: indirect estimation of ΔS, ETa, and P large volume (trees)
monolithic: natural infiltration condition	refilled: natural infiltration condition?
suction controlled: natural drainage conditions high-tech	free drainage: less drainage low-tech

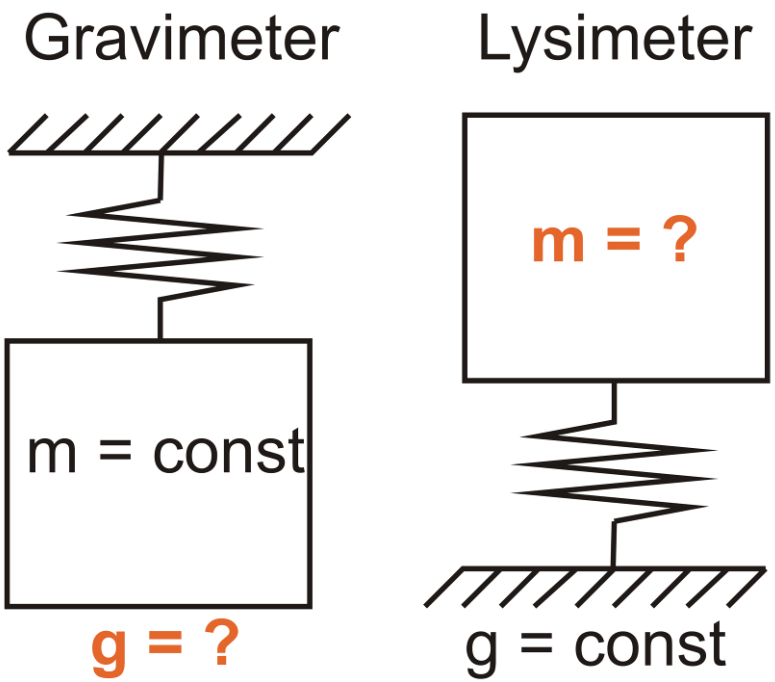
Objective

To use a lysimeter as an independent monitoring device to estimate the hydrological gravity response from local WSC without performing any calibration against the gravimeter residuals.

Lysimeter vs. Gravimeter

Are lysimeter and gravimeter complementary?

$$F = m \times g$$



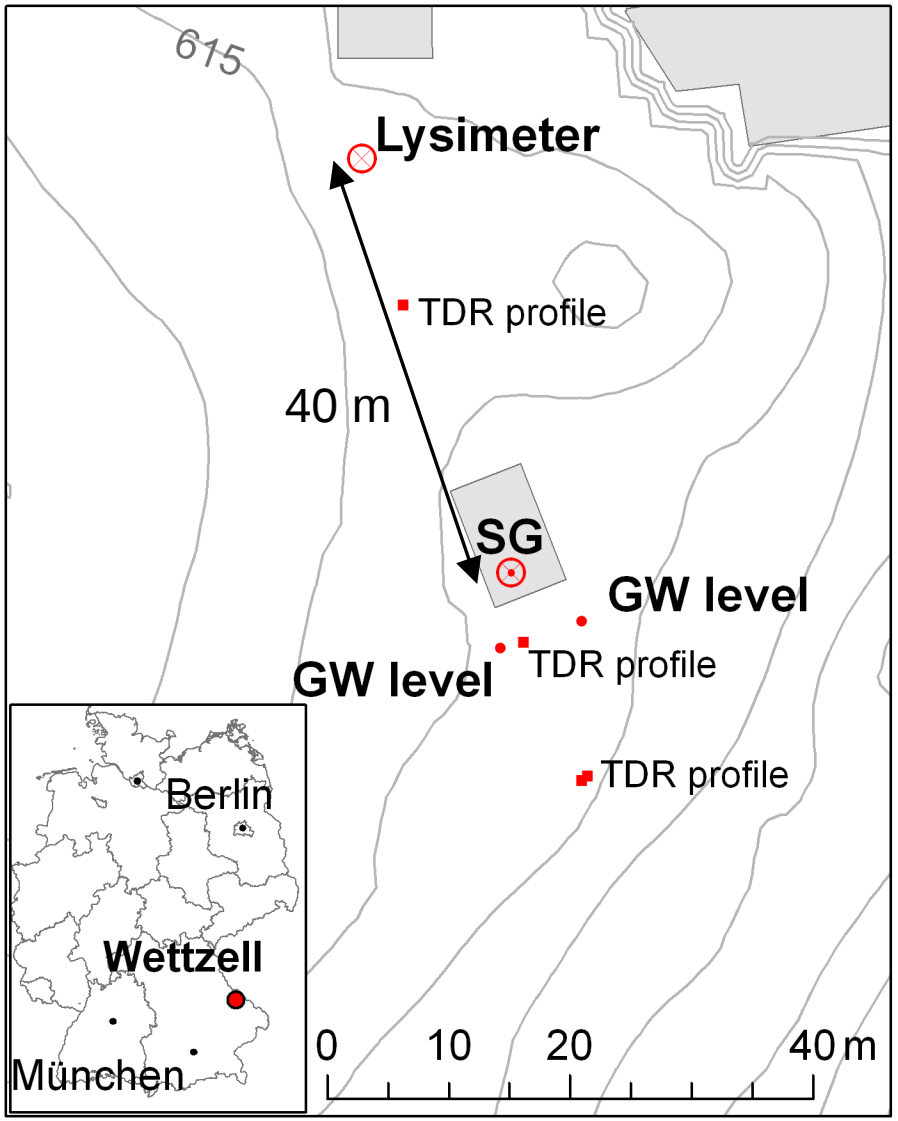
Geodetic Observatory Wettzell

Important water storages at the Geodetic Observatory Wettzell:

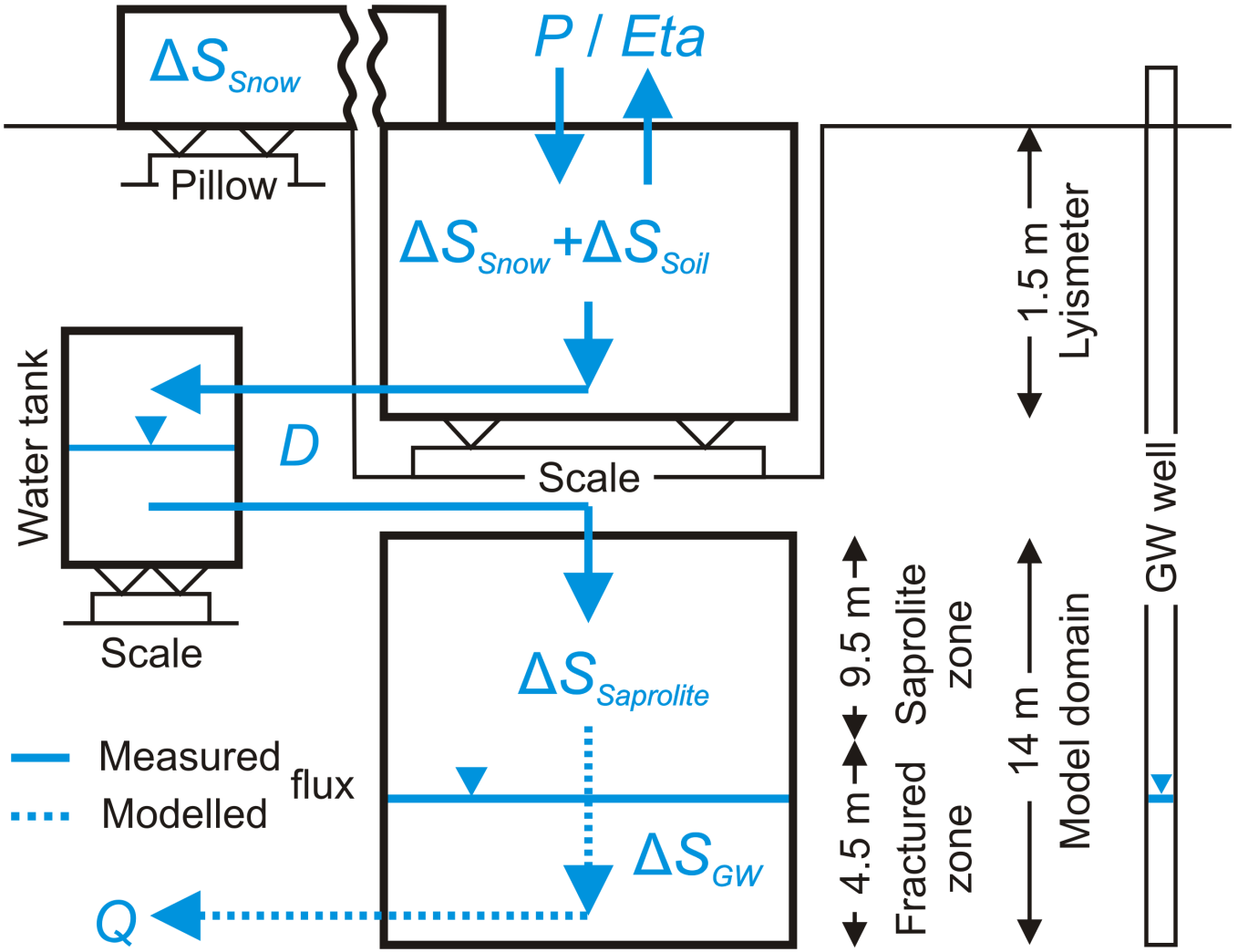
- snow pack
- top soil
- unsaturated saprolite
- fractured aquifer

Creutzfeldt et al., 2010 (WRR)

Observatory is operated by the **Federal Agency for Carto-graphy and Geodesy (BKG)**

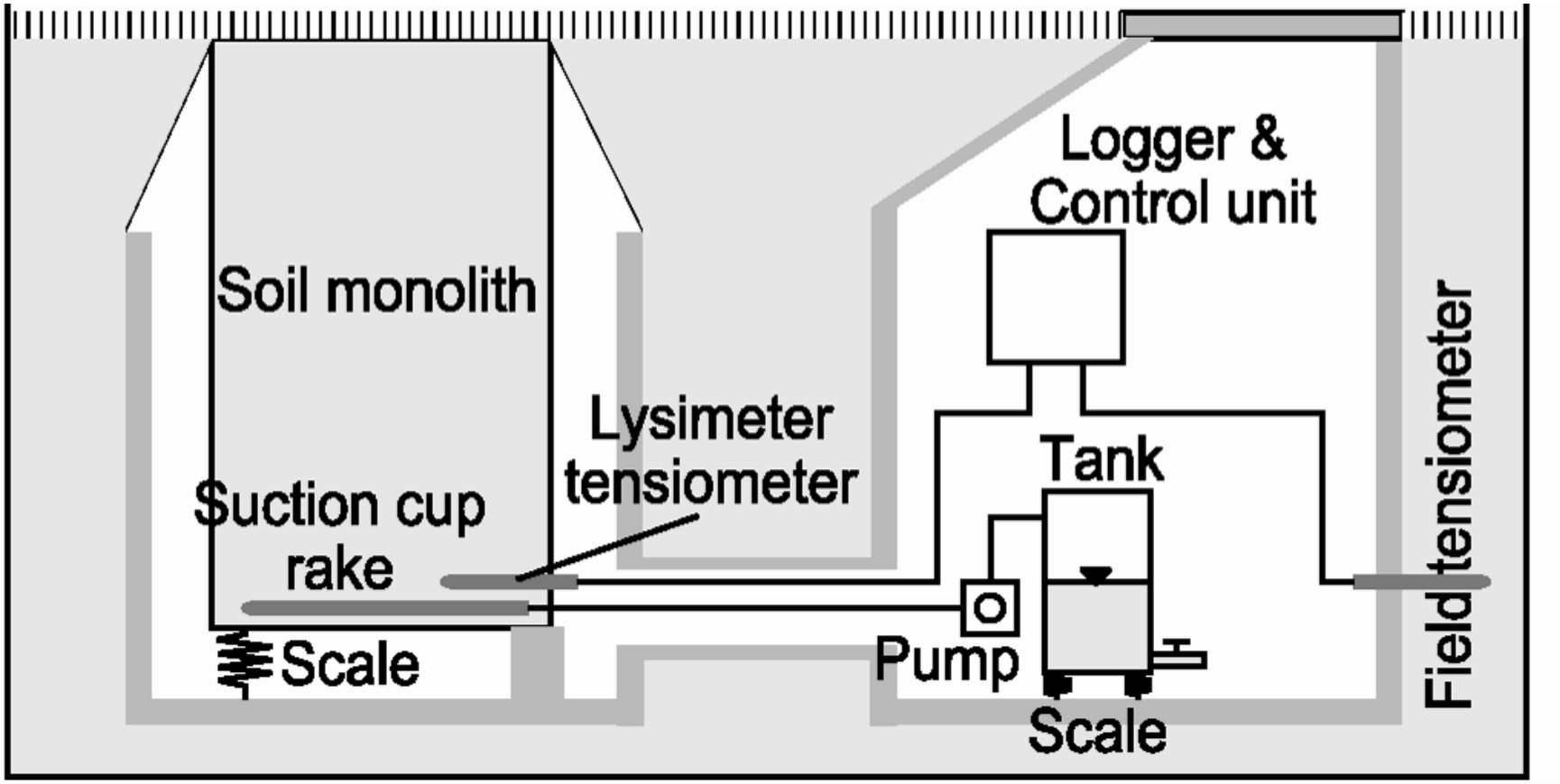


Method: Estimation of water storages



Creutzfeldt et al., 2010 (GJI)

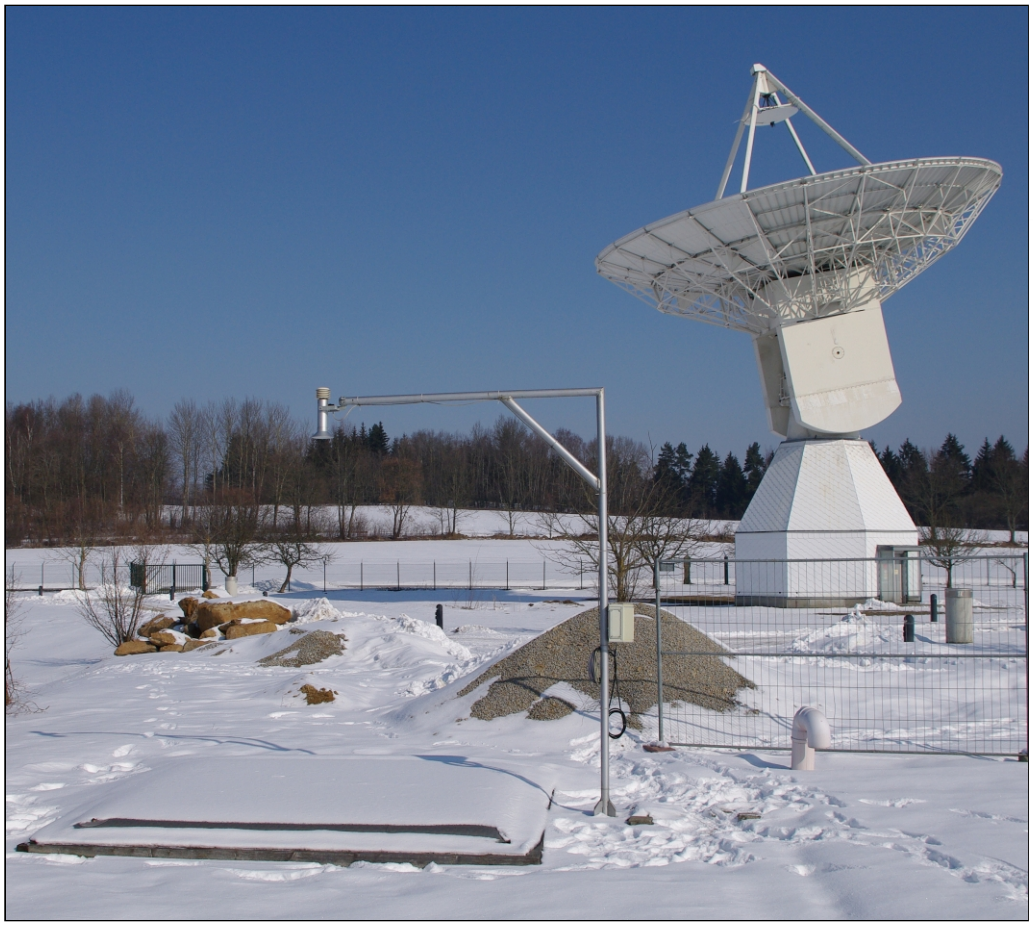
Lysimeter

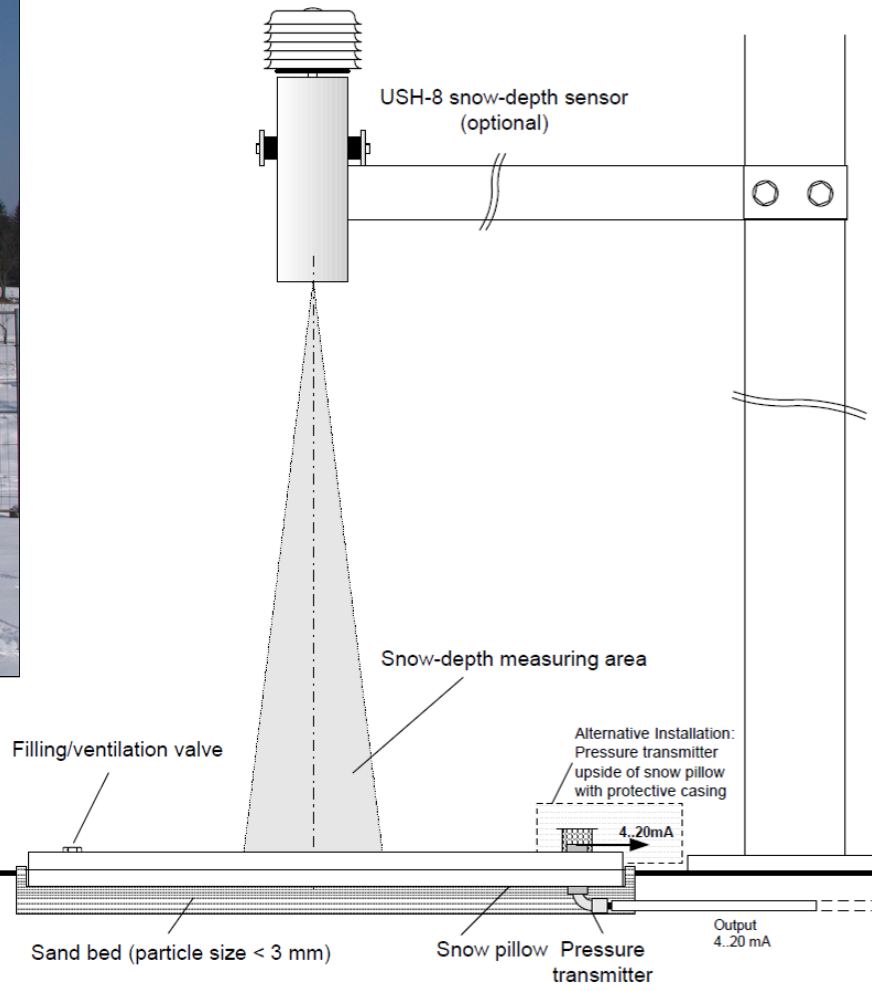

Logger &
Control unit
Soil monolith
Lysimeter
tensiometer
Tank
Suction cup
rake
Field tensiometer
Scale
Pump
Scale

Installation

Installation

Snow storage





Snow monitoring system:

- Snow height: ultrasonic sensor
- Snow water equivalent: snow pillow

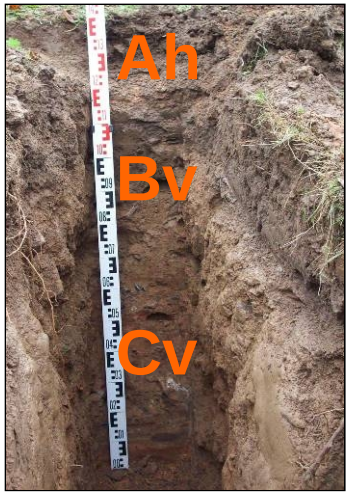
Groundwater storage

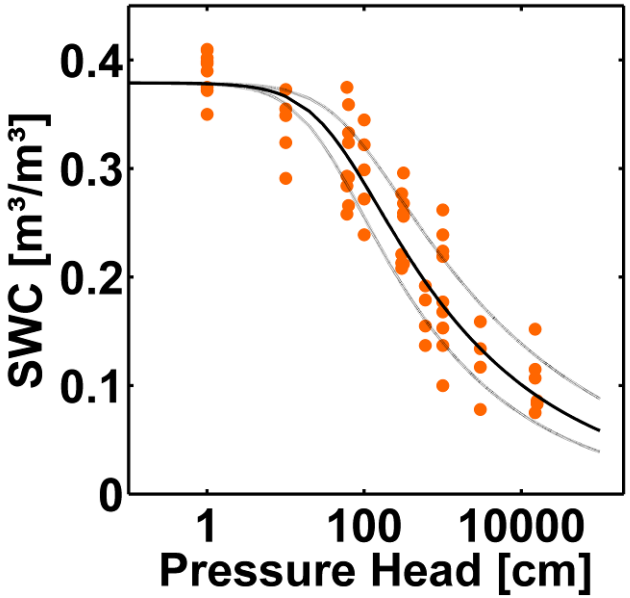
- Drilling and sampling
  - Undisturbed samples
  - Core samples
- Pump test
  - Specific yield: 1 – 2%

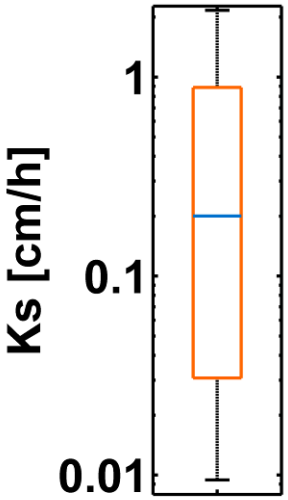
  → Several assumptions
- GW level monitoring
  - Pressure transducer

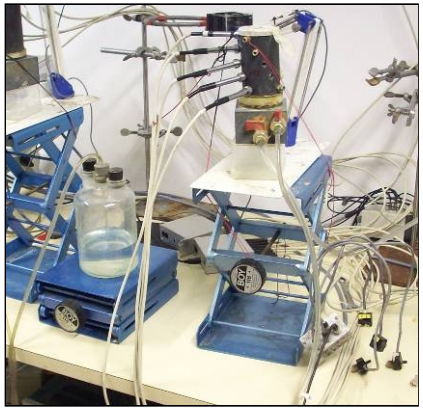
Soil properties

- Soil classification/sampling
- Lab analysis:
  - hydraulic conductivity
  - pF curves
- Parameter estimation
  - Mualem-van Genuchten









Hydrological modeling

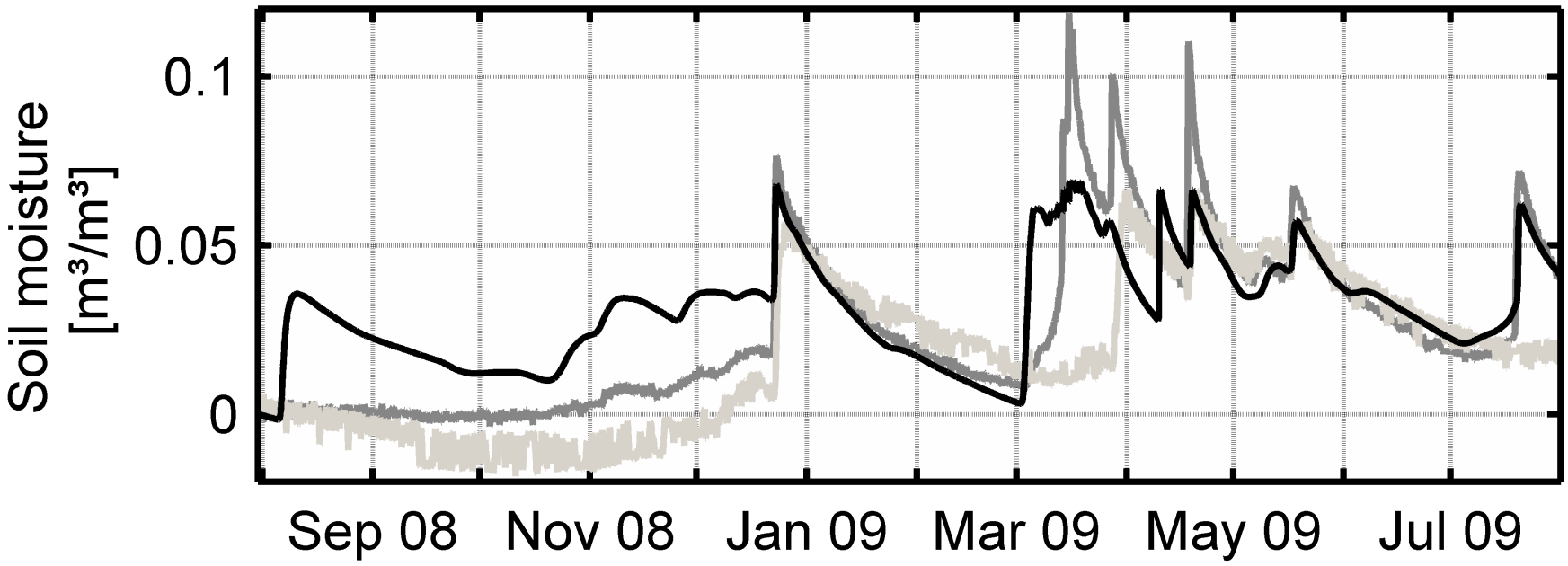
- HYDRUS 1D:
  - physically-based model
  - 1D model
- upper boundary: drainage
- lower boundary: GW level
- model parameters:
  - laboratory analysis
  - pump test

		Unit	Saprolite	Fractured bedrock
Depth	*From*	m	1.5	11
	To		11	19
θ_r		m^3/m^3	0	0
θ_s		m^3/m^3	0.38	0.02
α		cm^{-1}	2.64	2.64
n		-	1.23	1.23
l		-	0.5	0.5
K_s		m/h	0.002	0.0108

→ well-constrained physically-based model

Validation: Model

Modeled and measured soil moisture change in the depth of 2.0 m



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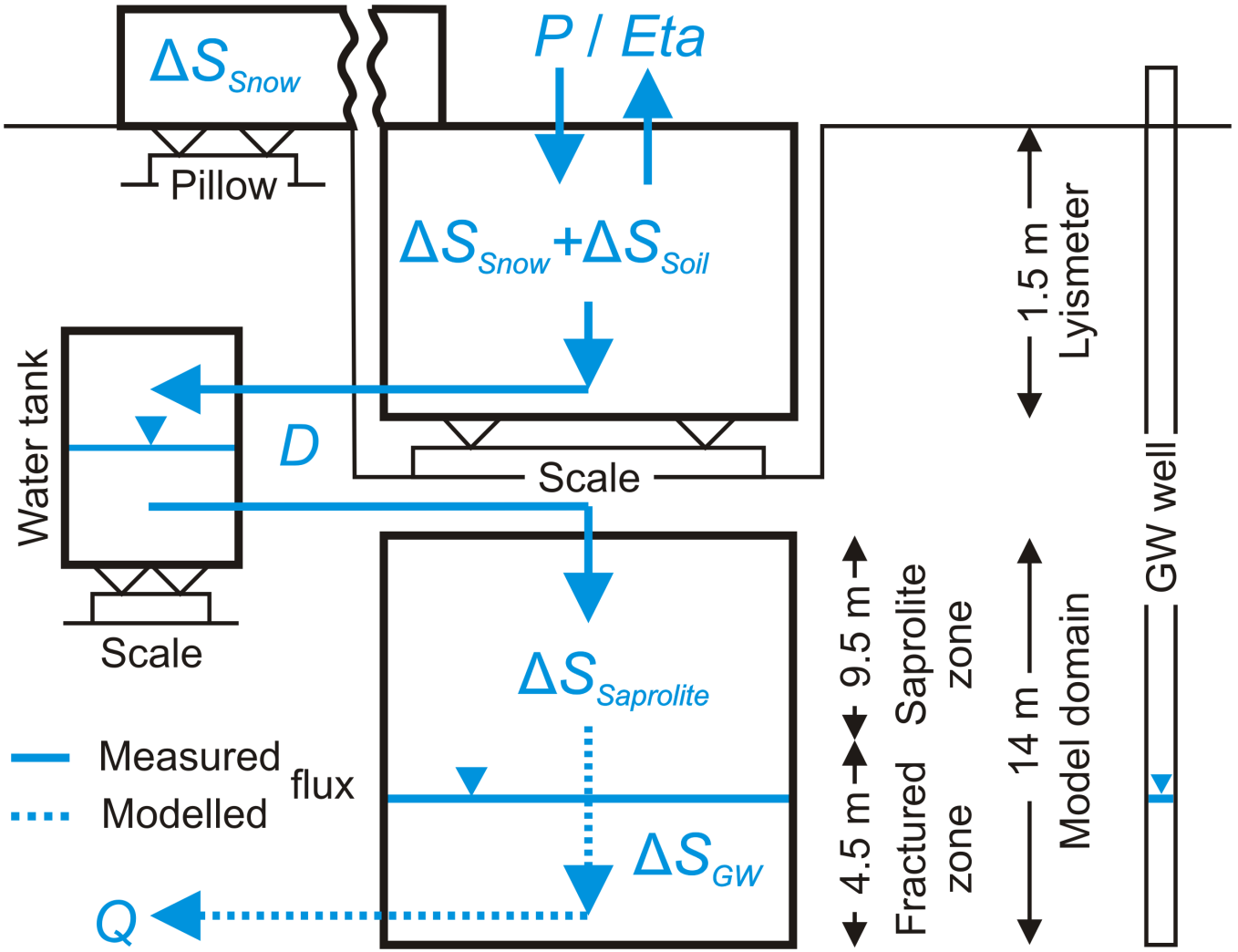
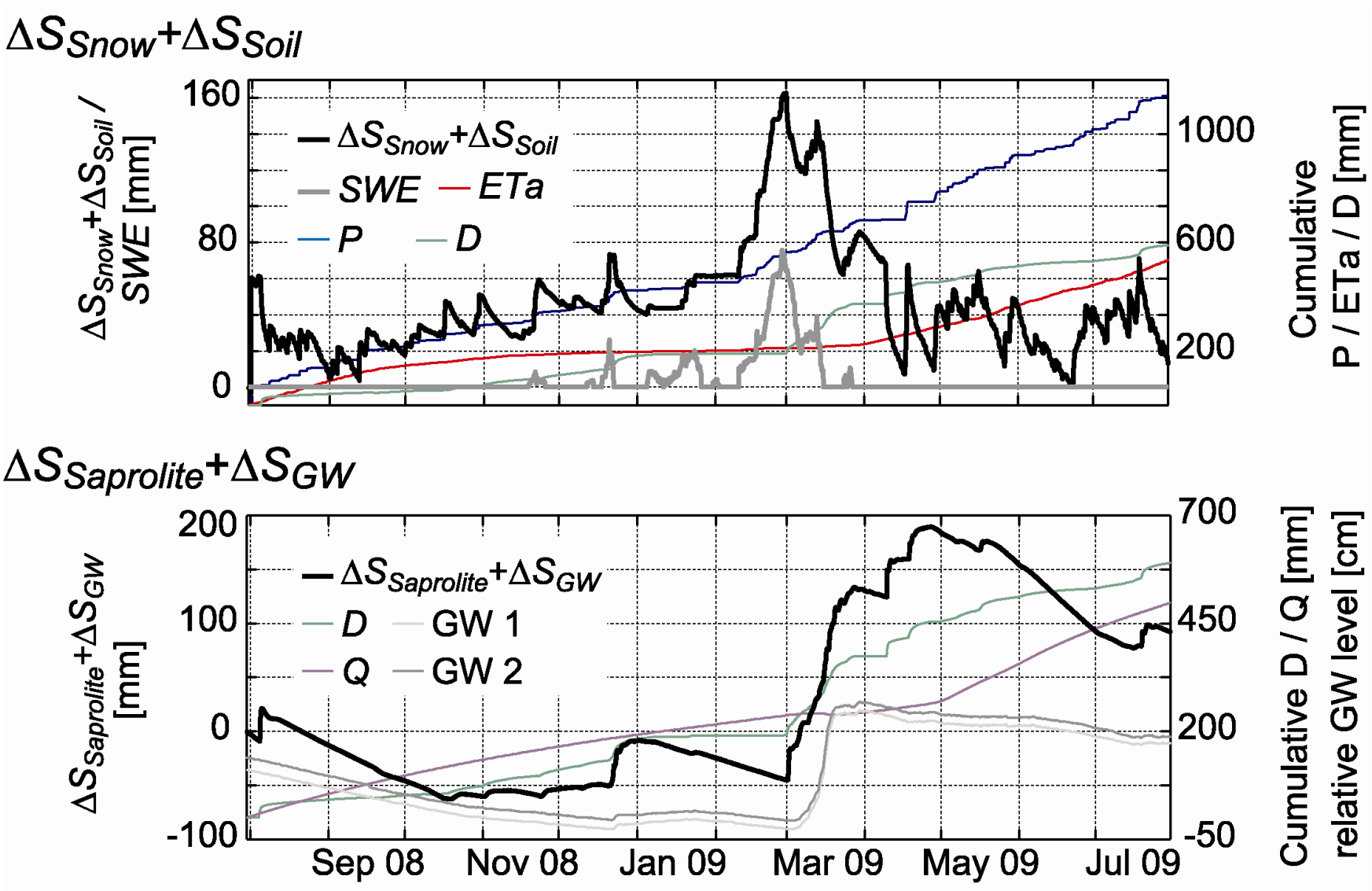


Creutzfeldt et al., 2010 (GJI)

Water storage changes

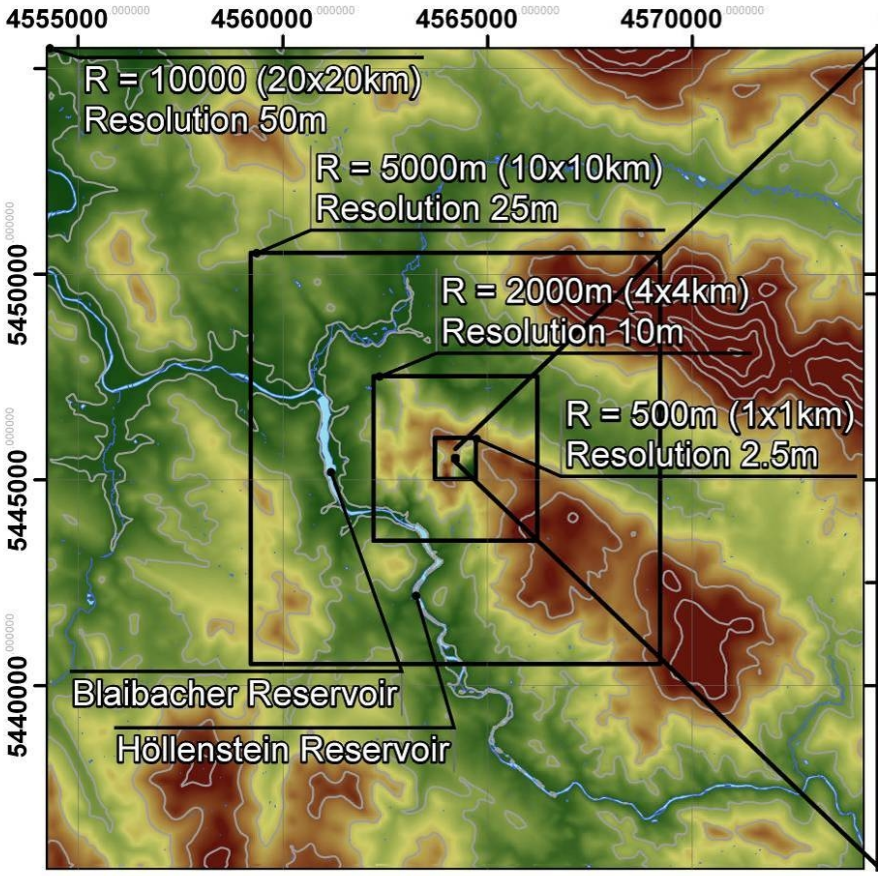


Creutzfeldt et al., 2010 (GJI, in revision)

Gravity response

Geodetic model:

- Nested discretization domain
- Homogeneous elementary bodies
- Extended point mass approach (MacMillan equation)

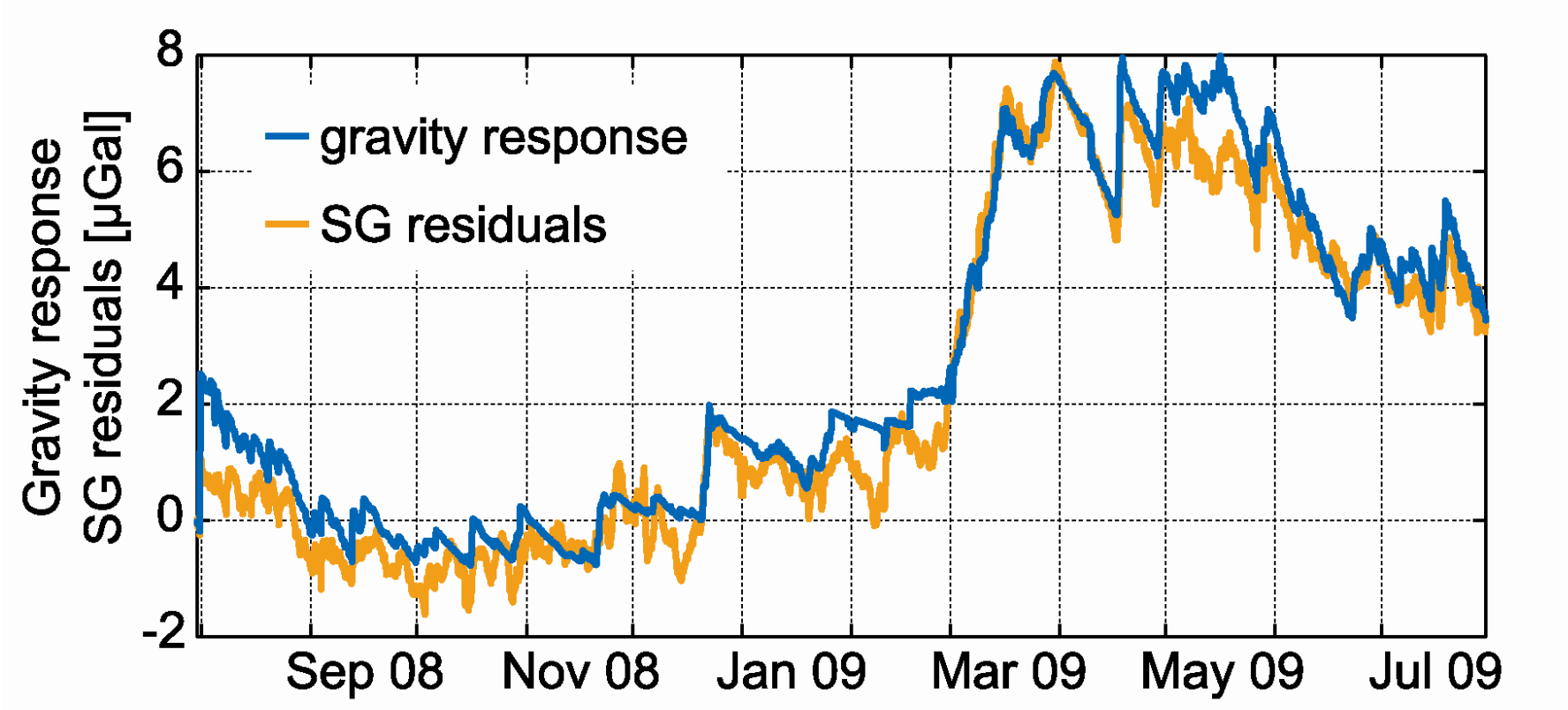


SG residuals

- GWR SG CD029
- Pre-processing:
  - spikes, disturbances and offsets
  - scale factor and instrumental drift (FG5 measurements)
- Modeling and removal of
  - solid Earth tides
  - ocean tide loading
  - polar motion
  - mass changes in the atmosphere

→SG residuals

SG residuals / Gravity response



Creutzfeldt et al., 2010 (GJI)

Conclusion

- First comparison of gravimeter and lysimeter measurements
- Lysimeter measurements improve the independent estimation of local water storage changes
- Gravity residuals are caused to a larger extent by local WSC in comparison to previous studies
- For geophysical studies beyond local hydrology, the installation of a lysimeter is recommended



Thank you very much for your attention!





References:

Creutzfeldt, B., A. Güntner, T. Klügel, and H. Wziontek (2008), Simulating the influence of water storage changes on the superconducting gravimeter of the Geodetic Observatory Wettzell, Germany, Geophysics, 73(6), WA95.

Creutzfeldt, B., A. Güntner, H. Thoss, B. Merz, and H. Wziontek (2010), Measuring the effect of local water storage changes on in-situ gravity observations: Case study of the Geodetic Observatory Wettzell, Germany, Water Resources Research, 46, W08531.

Creutzfeldt, B., A. Güntner, H. Wziontek, and B. Merz (2010), Reducing local hydrology from high precision gravity measurements: a lysimeter-based approach, GJI, 183(1), 178-187.