Water, gravity and trees: Relationship of tree-ring widths and total water storage dynamics

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Water resources

Water stored in the subsurface is an important fresh water source:

• drinking water
• food production
• natural vegetation

Observations of past are necessary to improve:

• the understanding of the environmental system
• the prediction of future developments
• more efficient use of the resource water
Estimation of (subsurface) water storage

GW Level

Sampling

Lysimeter

Point scale

→ representative; upscaling?

ERT

SPA

GPR

COMOS

Gravimeter

InSAR

Hyperspectral

Aircraft

Satellite

Global scale

→ High-precision gravimeter

Sampling

Lysimeter

TDR

GNSS

GRACE
High-precision gravimeter

- Integral signal of the hydrological system: snow, soil moisture, groundwater, …

- The exploration of subsurface water storage change.

- Intermediate scale

→ Relatively short time series available
Tree rings: archive of the environment

Temperature
PDSI, humidity
Precipitation
SPI

Discharge

$\Delta S_{\text{Total}}$

$\Delta S_{\text{Vegetation}}$

$\Delta S_{\text{Snow}}$

$\Delta S_{\text{Vadose Zone}}$

$\Delta S_{\text{Groundwater}}$
Study site: Geodetic Observatory Wettzell

Location:
- Bavarian forest

Climate:
- MAP: 850 mm
- MAT: 7 °C

Landuse:
- Grassland

Soil:
- Cambisols

Geology:
- Gneiss

The Geodetic Observatory Wettzell is operated by the Federal Agency for Cartography and Geodesy (BKG)
Tree ring processing

**Tree-ring chronology**

- Cross-dating/quality check:
  - Series Intercorrelation: 0.57
  - Mean average sensitivity: 0.25

**Tree ring width**

- Detrending, standardizing, and removal of endogenous disturbances


Wide Narrow

WinDENDRO
Superconducting gravimeter (SG)

SG measure the variation of the Earth’s gravity field [Gal]: $1 \mu\text{Gal} = 10^{-8} \text{m/s}^2$

SG data processing:
- solid Earth tides
- ocean tide loading
- polar motion
- atmospheric effects
→ modelled and removed
→ remaining signal: ‘SG residuals’
→ SG residuals mainly caused by water storage changes

Data acquisition and control electronics

Compressor

Liquid He filled Dewar with Niobium sphere
Interpretation of gravity measurements

→ Coupled hydrogeophysical inversion

- Water storage change

Hydrological model
- GLUE approach
- 50000 parameter sets
- “behavioral” models: best 0.1%

Geodetic model

Measured SG-residuals

Hydrological gravimeter response

Creutzfeldt et al., 2010 (HESS)
Total water storage change

**Graph Description:**

The graph illustrates the trend of SG residuals [µGal] and water storage [mm] from 2000 to 2009. The SG residuals show periodic fluctuations, with confidence intervals indicated by error bars. The water storage data is represented by different lines, indicating modelled and measured water storage changes. The graph also includes AG residuals for comparison.

**Source:**

Creutzfeldt et al., 2012 (JGR)
Relationship: 2000 - 20009

Relationships between precipitation, evapotranspiration, humidity, snow height, groundwater level, streamflow, water storage, SPI 12 month, and PDSI from 2000 to 2009, with correlation coefficients and p-values.
Corr. coefficient and confidence intervals
Relationship: 1947 - 2009

- Temperature
- Precipitation
- Humidity
- Streamflow
- pot. Evapotranspiration
- SPI-12 month
- PDSI
- Water storage change
Water storage reconstruction

Water storage change [mm]

Water storage change [mm]

Tree ring width [mm]

Sample number [-]
Conclusion

- Tree-ring growth is primarily controlled total water storage in the subsurface
- High-precision temporal gravity measurements help to reveal the strong relationship
- Tree rings allow the reconstruction of subsurface water storage variations
- Longer time series (measurements) are needed

→ multi-disciplinary study, combining the different scientific disciplines hydrology, dendrochronology and geodesy
I am happy to take your question

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.


