Hydrological changes in high alpine environments detected with relative gravimetry

Riccardo Scandroglio[1], Markus Heinze[2], Till Rehm[3], Roland Pail[2], Michael Krautblatter[1]

1) Landslide Research Group, TU Munich, Germany
2) Institute of Astronomical and Physical Geodesy, TU Munich, Germany
3) Environmental Research Station Schneefernerhaus, Germany

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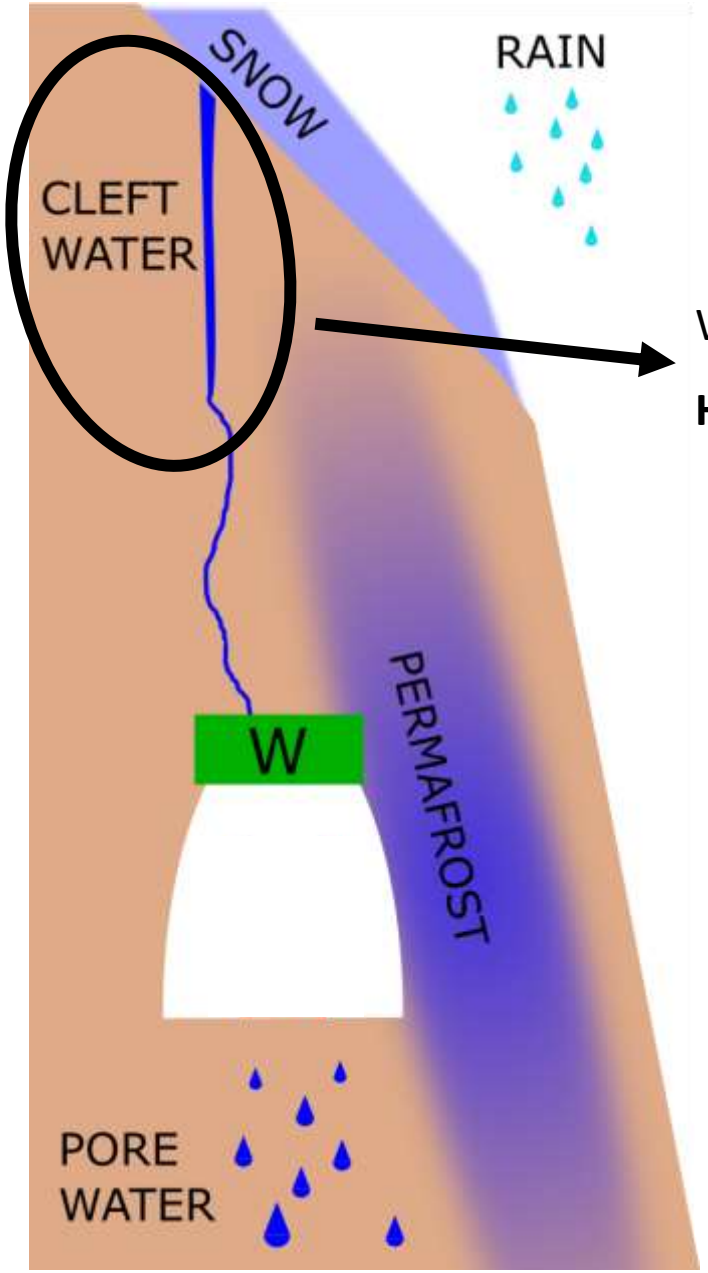


Water was detected after many rockfall events…

…but its destabilizing power was never clearly defined.

Which pressures can be generated?

How much water can accumulate?

Water measures

Snow modelling

Water balance in bedrock

Periods of accumulation
= HYDROSTATIC PRESSURES?

Can gravimetry detect it?

ZUGSPITZE Germany, 2962 m asl

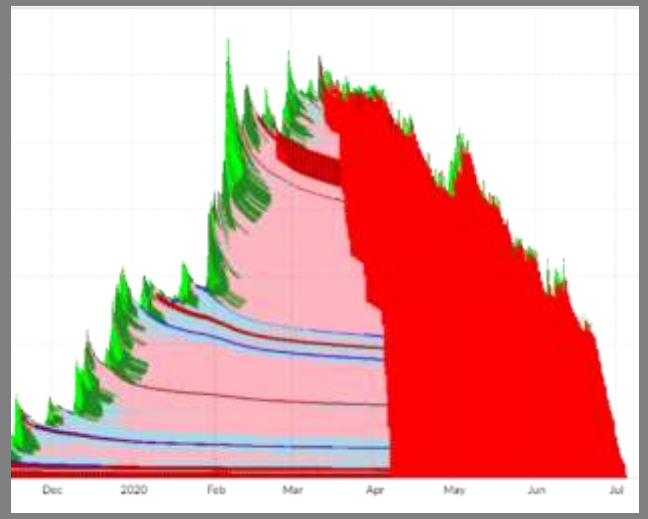
Wetterstein Limestone / 800m long tunnel in compact bedrock / Clefts, fine grained filling

120 years of climate measurements

→ **PRECIPITATION**

15 years of ERT and T monitoring

→ **PERMAFROST**



SNOW MODELLING

with Bavarian Avalanche Service and WSL-SLF

Modelling of the snow

→ **WATER FROM SNOWMELT**

flowing in the bedrock‘s cracks

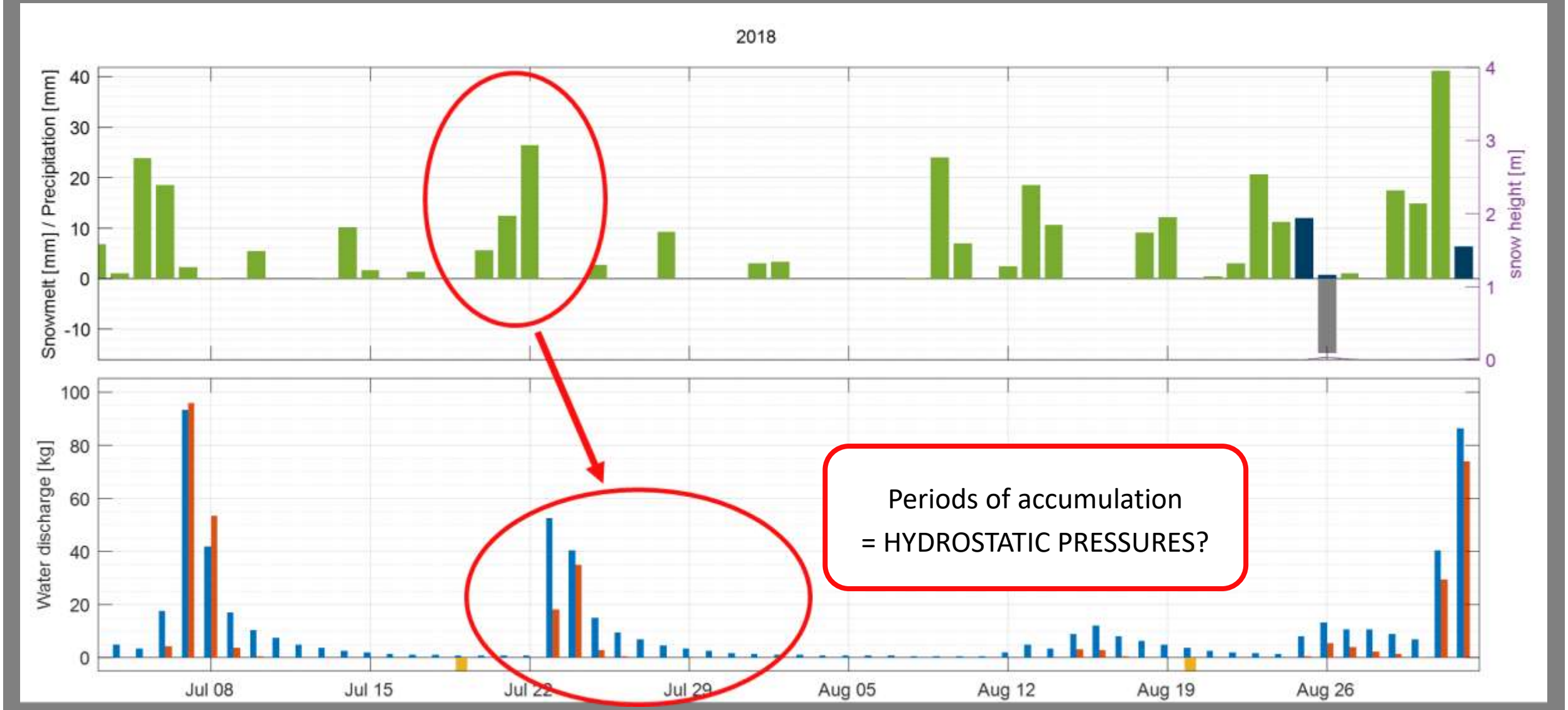
WATER LOGGERS

- 2 loggers
- 0,1 L resolution and hourly records
- Under 40 to 60 meters of bedrock
- Aruino loggers

Punctual measure of

→ **WATER FLOW IN CLEFTS**

WATER DYNAMIC



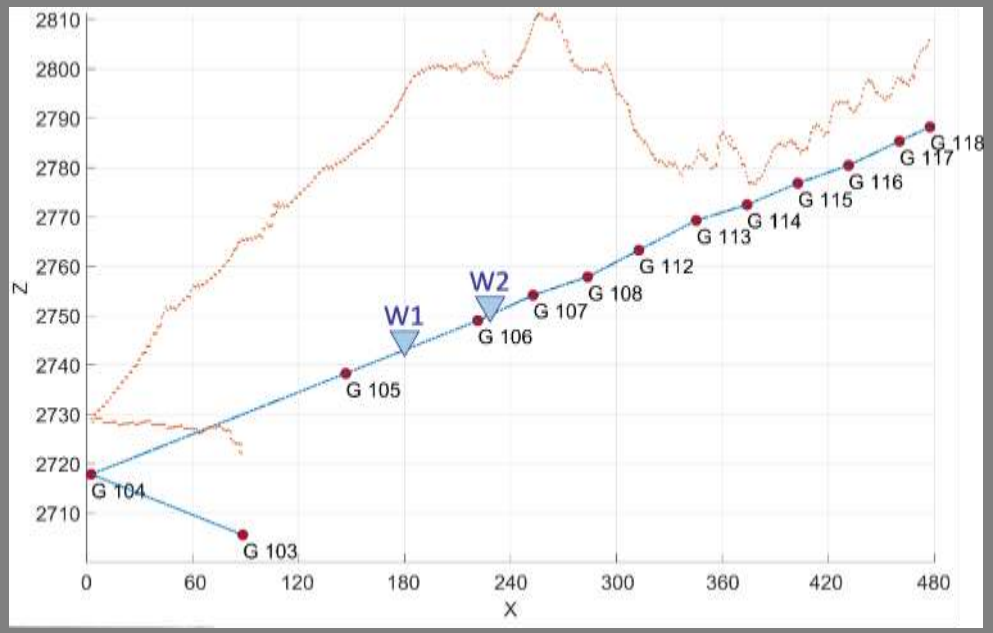
RELATIVE GRAVIMETRY

with Scintrex CG-5, without absolute calibration,

therefore relative to (i) a reference point and (ii) the first measure.

✓21 measuring points, of which 13 in the tunnel

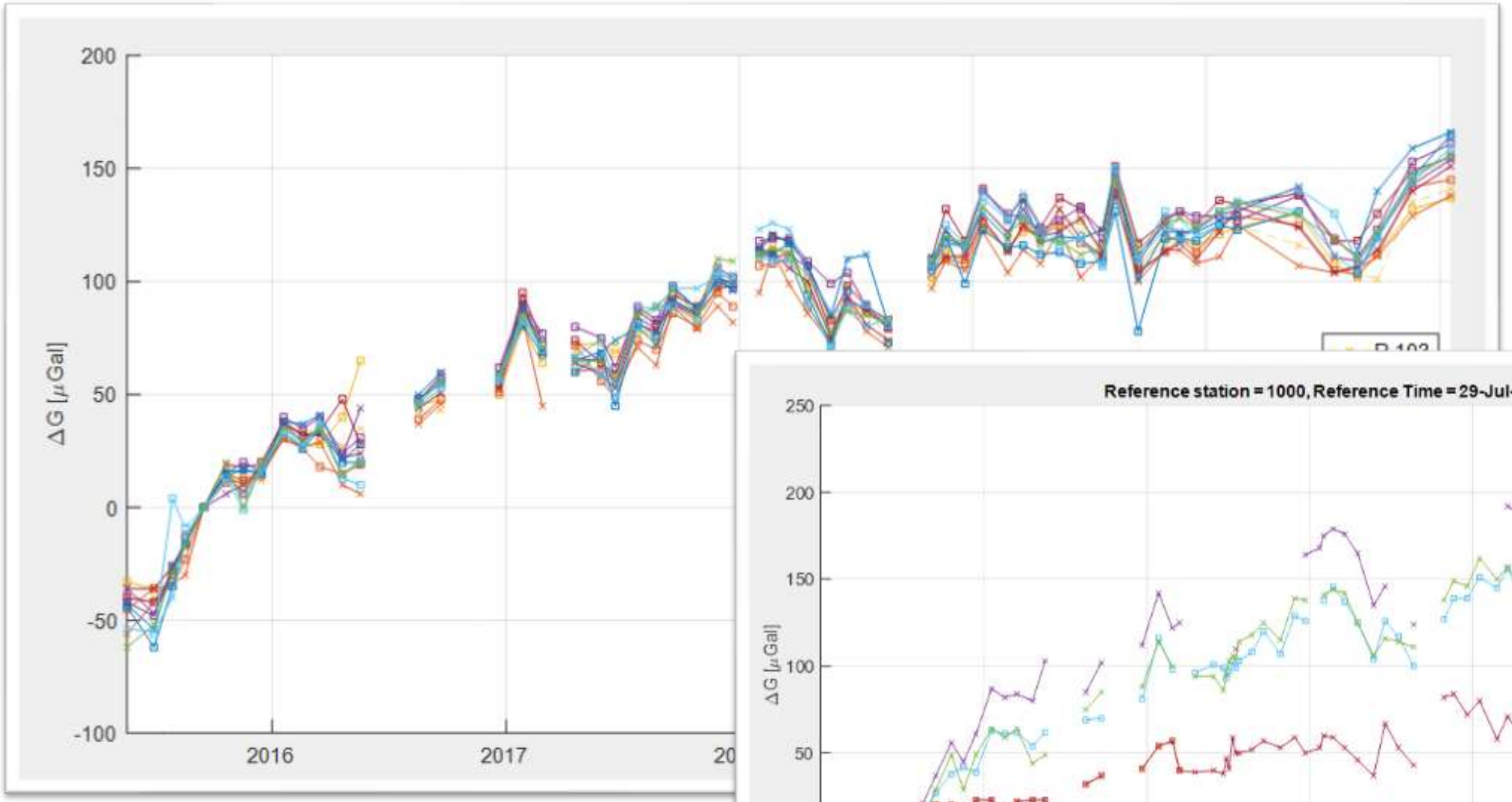
✓64 monthly repetitions since 2015

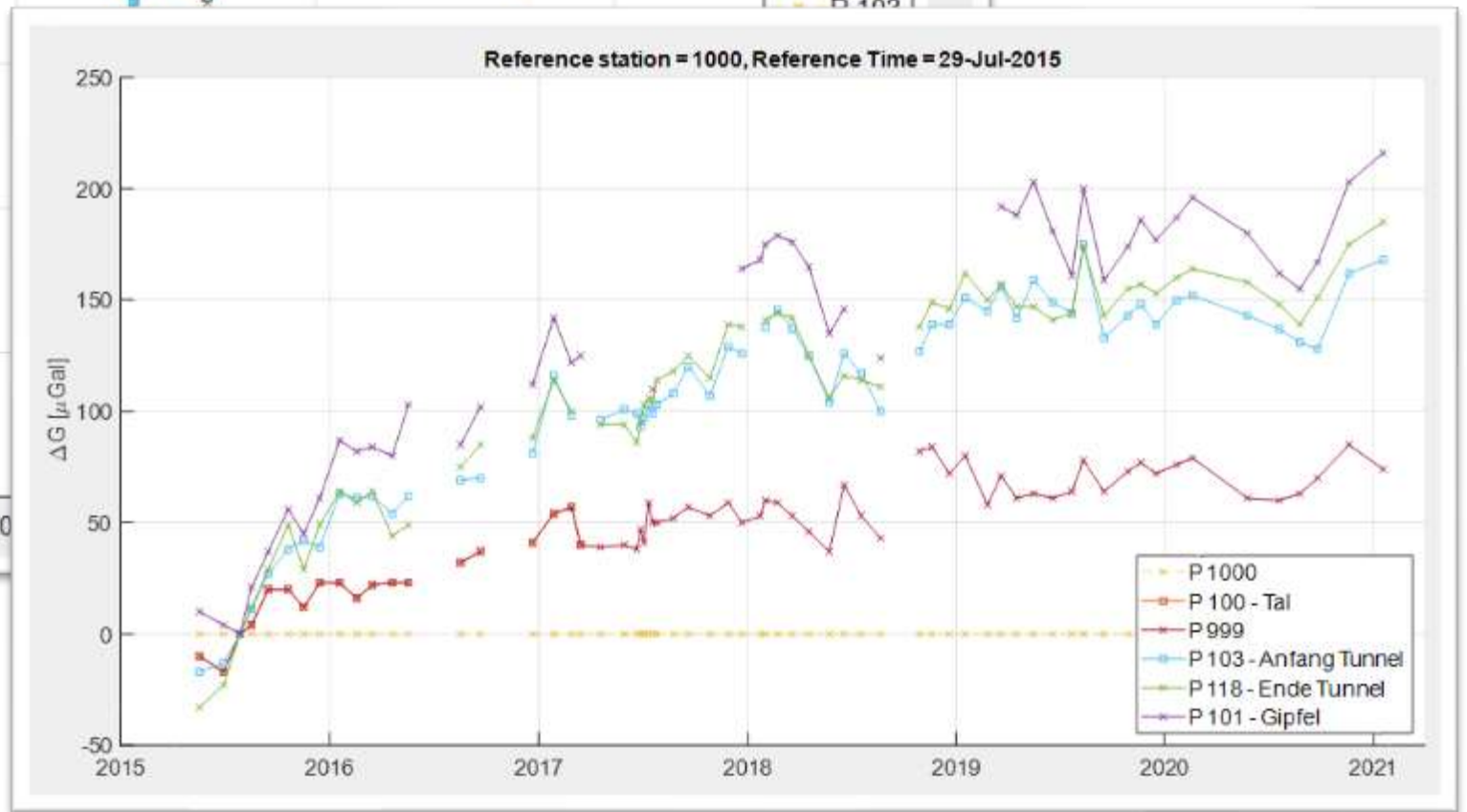


MASS CHANGES

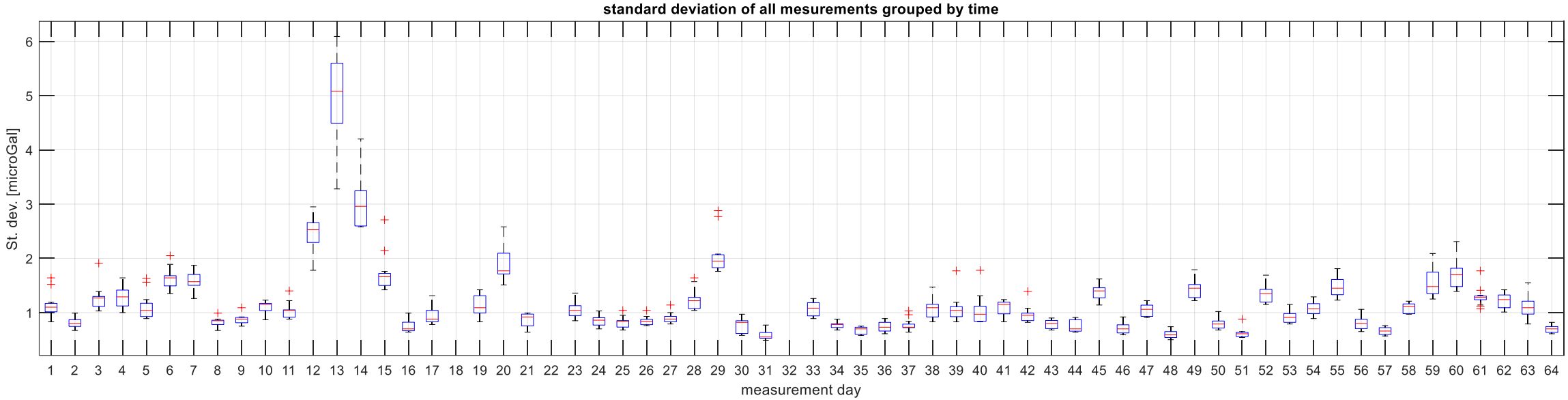
Supposing that external grav. mass movements have no influence because of their distance, all changes can be reconducted to

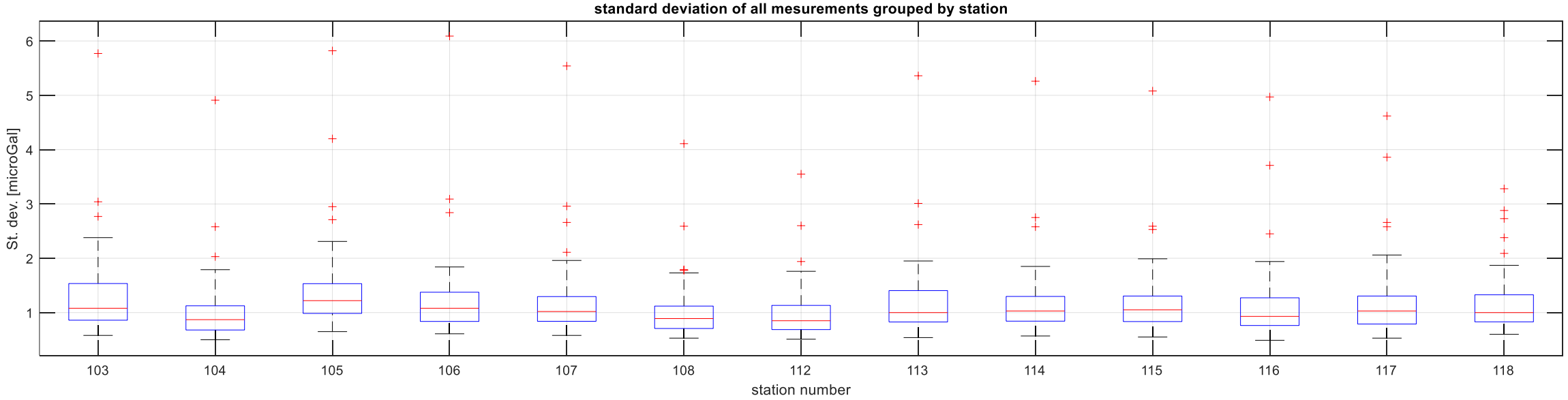
→ HYDROLOGICAL SIGNALS


200
150
100
50
0
-50
-100
ΔG [μGal]
2016
2017


Reference station = 1000, Reference Time = 29-Jul-2015
250
200
150
100
50
0
-50
ΔG [μGal]
2015
2016
2017
2018
2019
2020
2021
P 1000
P 100 - Tal
P 999
P 103 - Anfang Tunnel
P 118 - Ende Tunnel
P 101 - Gipfel

MEASUREMENT ERRORS





What to do?

I. Correct the drift by interpolation

II. Use the data without correction

III. Correct the drift with the superconducting gravimeter

I. Correct the drift by interpolation

a. Mean of all values

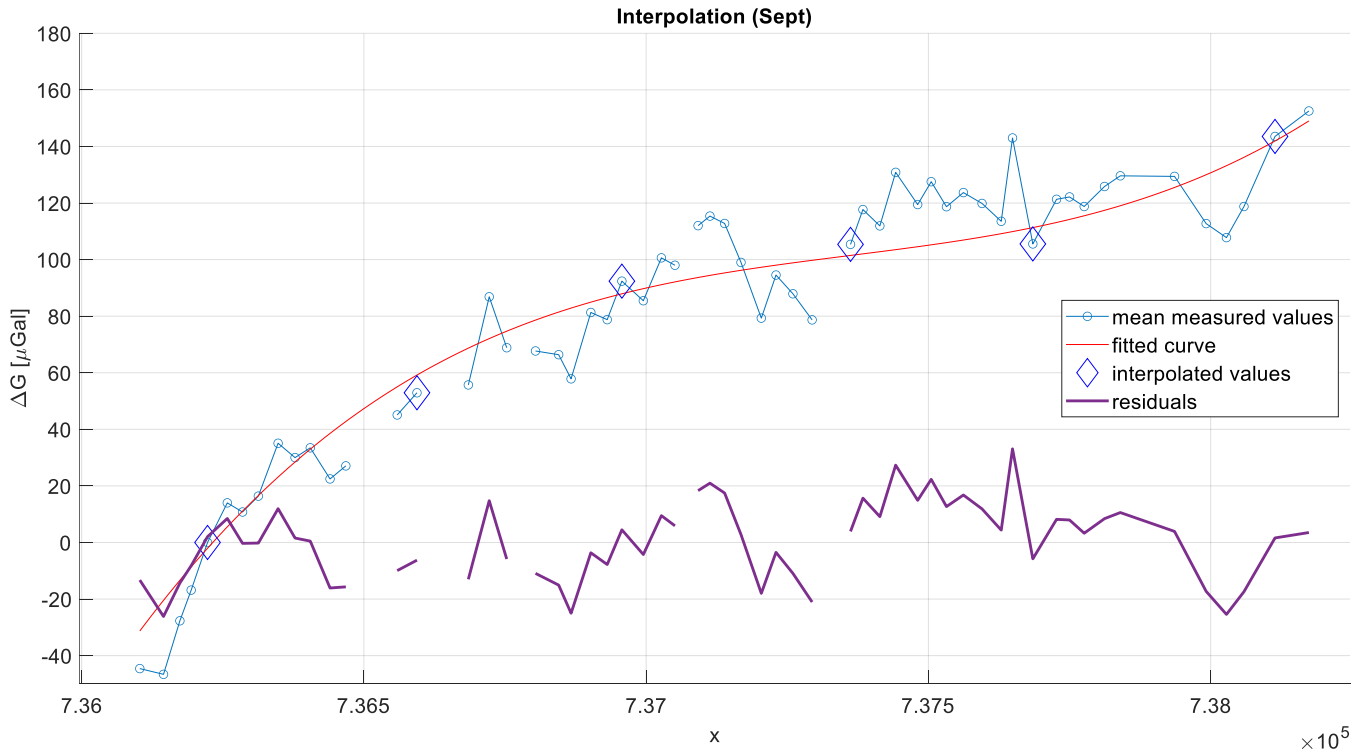
b. Interpolate septembers

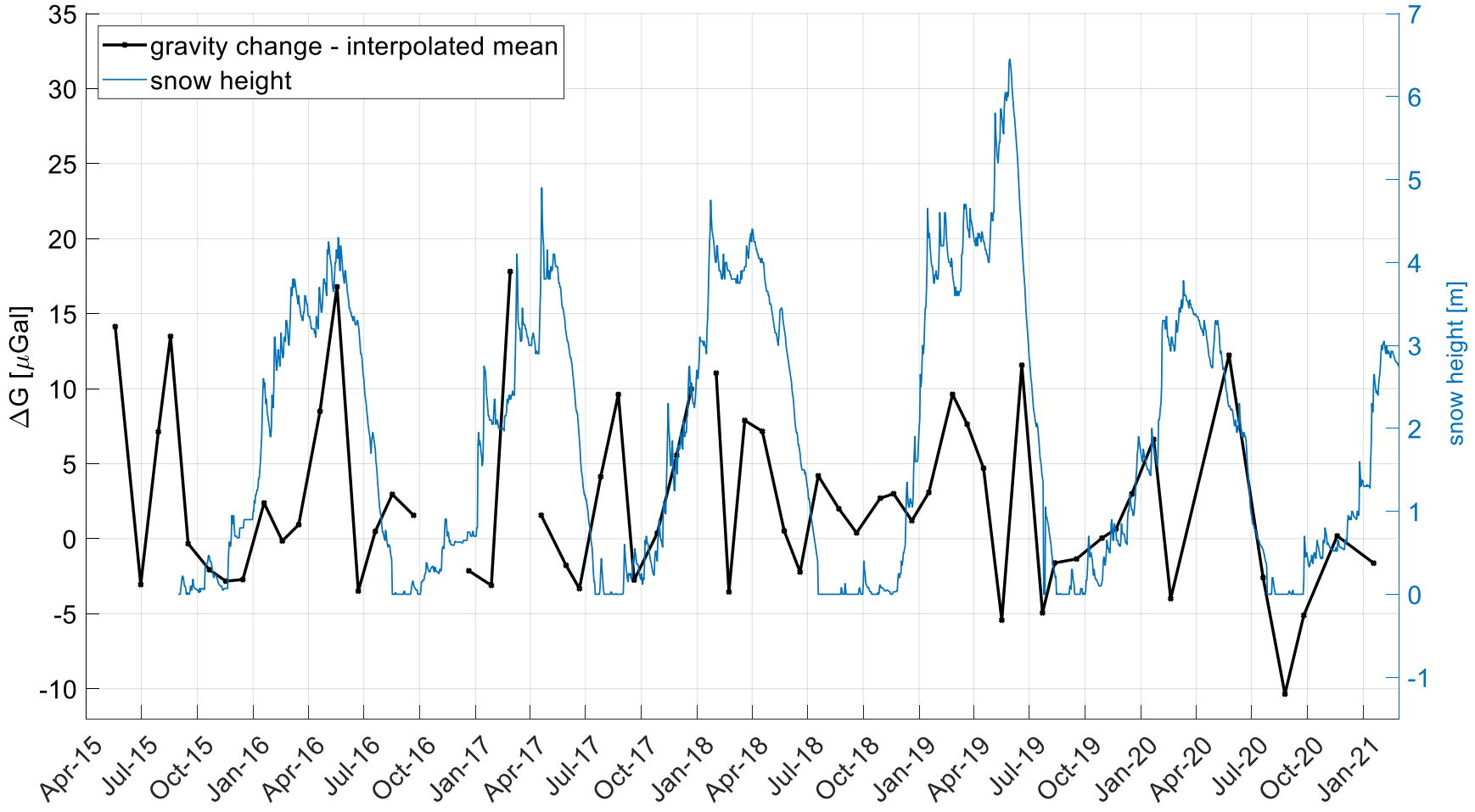
c. Calculate residuals from interpolation

Voigt C, et al (2021) :

The seasonal minima (…) *are* ***16 September 2020 and 21 September 2019***

… agreeing with absolute gravity observations between 2004 and 2019 by Timmen et al. (2021).





✓ Strong correlation with snow height!

Positive values are interpreted as an increase of mass above the point (= snowpack).

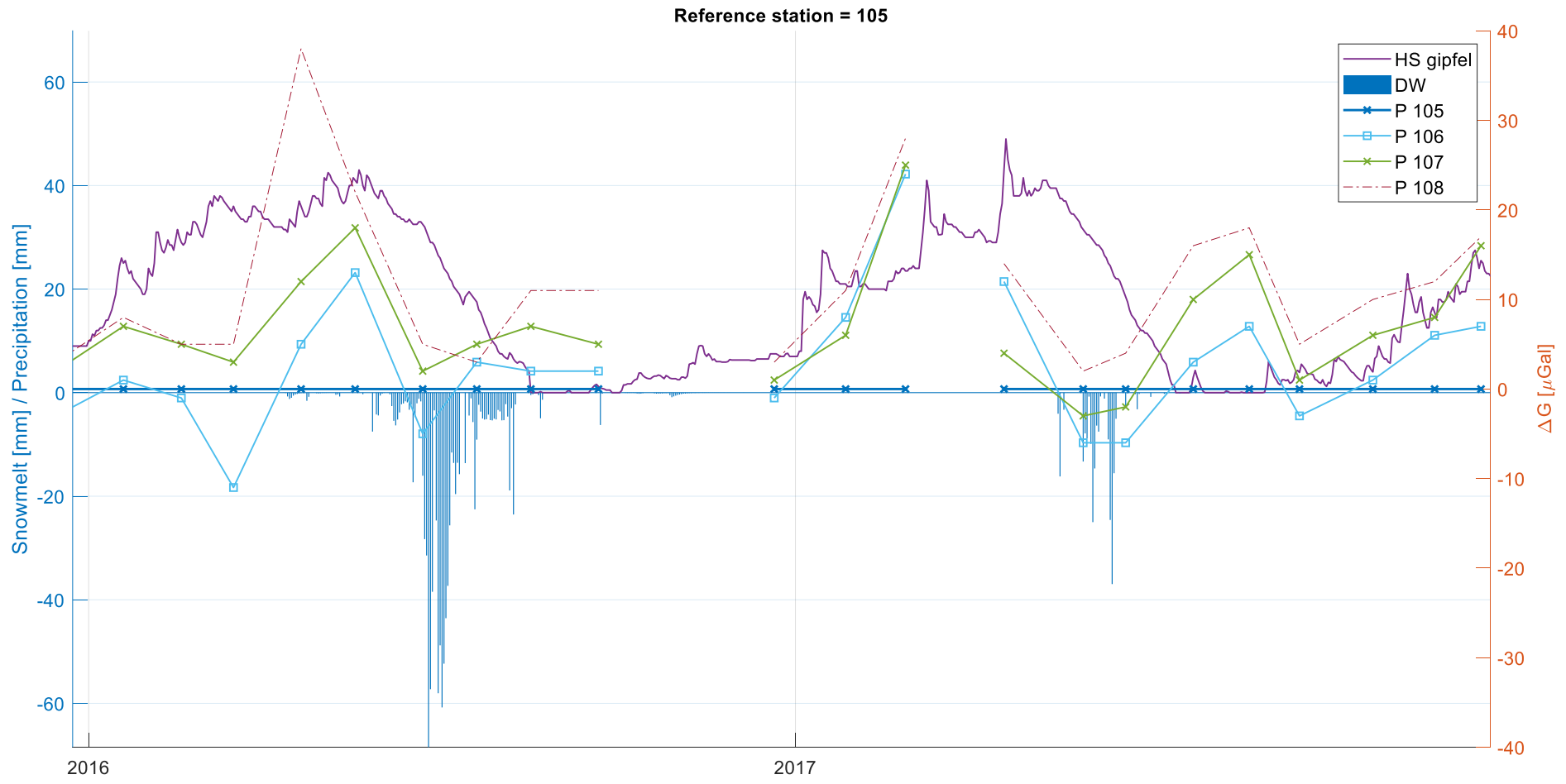
Negative values are interpreted as an increase of mass under the point (= meltwater).

II. Use data without correction

Using a station

in the tunnel

as reference station



III. Correct the drift with GFZ´s Superconducting Gravimeter

(Voigt C, et al. 2021)

+ High temporal resolution

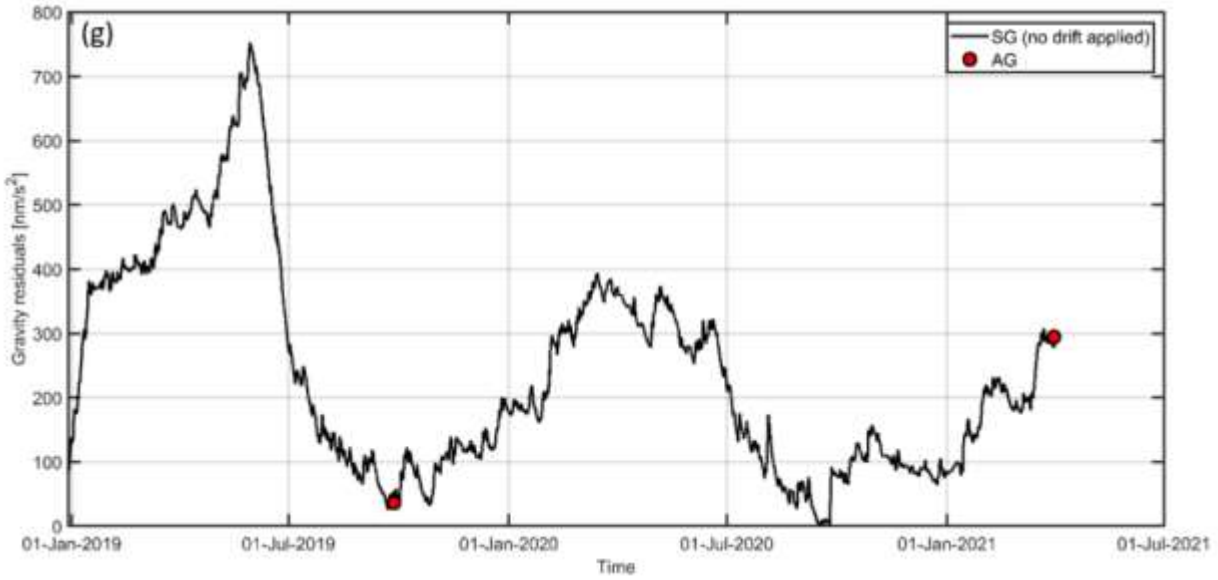
+ Calibrated with absolute measurement

+ 11 comparison measurements in 2 years

+ 2 long time measurements (6 hours / 1 day)

- Only one measuring point

- Measurements available only for 2019-2021



Voigt C, et al. 2021

Results will come soon…

Other ideas are welcome…

Thank you
for your attention!

Riccardo Scandroglio
Landslide Research Group
TU Munich

r.scandroglio@tum.de

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