Updating the Finnish First Order Gravity Network Using the Outdoor Absolute Gravimeter A10

Jaakko Mäkinen (1), Marcin Sekowski (2), Jan Krynski (2),
Jyrki Näränen (1), Arttu Raja-Halli (1),
Hannu Ruotsalainen (1), Heikki Virtanen (1)

(1) Finnish Geodetic Institute, Masala, Finland
(2) Institute of Geodesy and Cartography, Warsaw, Poland

NKG General Assembly 2010, Sundvolden, September 27-30, 2010

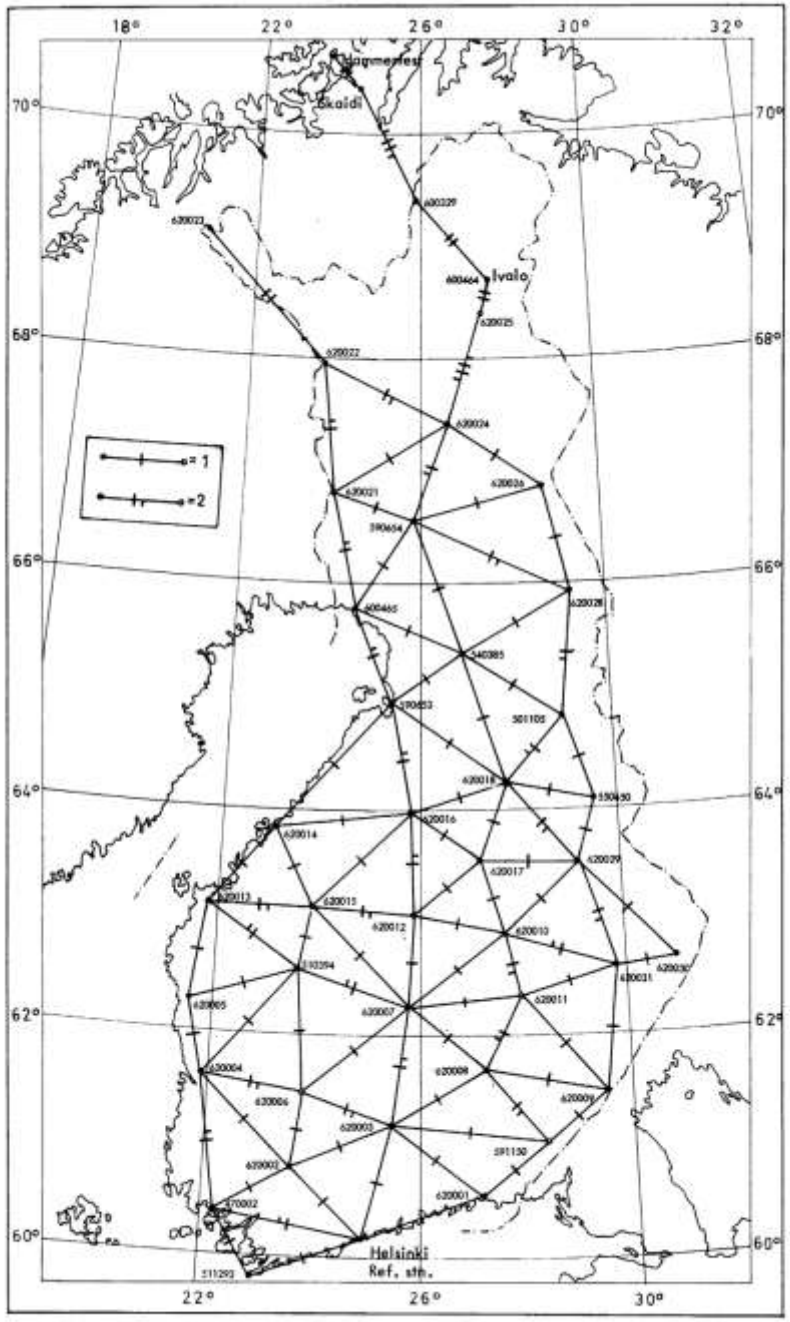


Fig. 1. The first order gravity net of Finland. 1 = double measurement, 2 = triple measurement

First Order Gravity Net (FOGN) measured in 1962-1963

Kiviniemi
Publ. Finn. Geod. Inst. 59

Accuracy 30 µgal

Purpose of the FOGN

- reference sites for gravity mapping by the FGI and others
- outdoors, accessible at any time without prior arrangements
- easy to find even in winter with plenty of snow
- reasonably-permanent stations in monumental buildings, mostly on church stairs; stations are not marked
- local gravity changes come mostly from reconstruction of steps, e.g. to allow wheelchair access
- otherwise the local stability of the gravity values (about 0.01 mgal) is sufficient for the purposes of the FOGN
- note: no geodynamical ambitions
- they belong to the zero order net of absolute stations and to the Fennoscandian Land Uplift Gravity Lines

FOGN present status

- measured 1962-63 by Aimo Kiviniemi, Worden Master 227
- present zero and scale derived from a readjustment into IGSN71 by T. Honkasalo in 1971
- epoch 1963.0, mean tide system (from IGSN71)
- original estimate for accuracy of gravity differences 0.03...0.06 mgal (one-sigma)
- control measurement in 1988 by Kiviniemi
- performed in large loops, 2 x LCR-G (G-55, G-600)
- rms for discrepancies (1988-1963) of gravity differences without correction for land uplift was 0.035 mgal (JM)
- values of preserved stations were not revised in 1988

Re-measurement of the FOGN

- Future uses of the FOGN shall be the same as the old uses: reference for gravity survey
- in other words, no geodynamical task added
- old stations retained and remeasured 2009-2010 with A10
- co-operation with IGiK Warsaw
- A10-0020 of IGiK operated by Marcin Sekowski
- 19 FOGN sites occupied in 2009 and 32 sites in 2010
- Support measurements started in 2010, will be completed in 2011

A10-020 work

- Single setup is 8x120=960 drops, 1 second drop interval, duration 24 min
- Station occupation consists of two independent setups in different orientations (180 deg rotation)
- The A10 dropper mechanism (unlike the FG5) does not have a preferred orientation
- but independent setups
    - help to eliminate gross errors
    - provide error statistics
    - improve accuracy especially on instable sites
- Absolute (FG5) sites occupied by A10 during campaign1-2 times per week

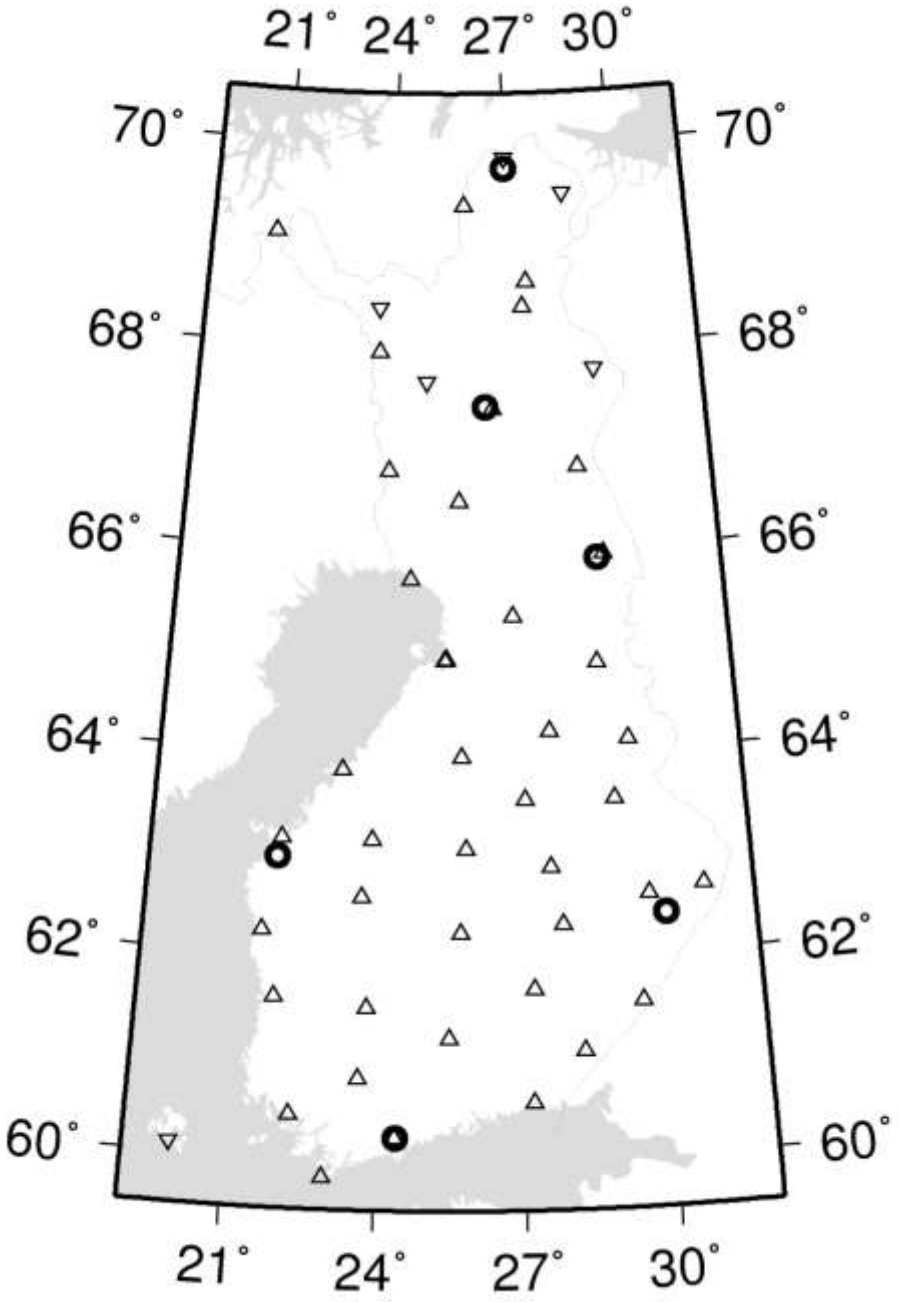
Turku station, FOGN creation in 1962

FOGN control measurement in 1988
2 x LCR-G

Turku, remeasurement 2010

A10-020 of the IGiK

Turku, remeasurement 2010
A10-020 of the IGiK

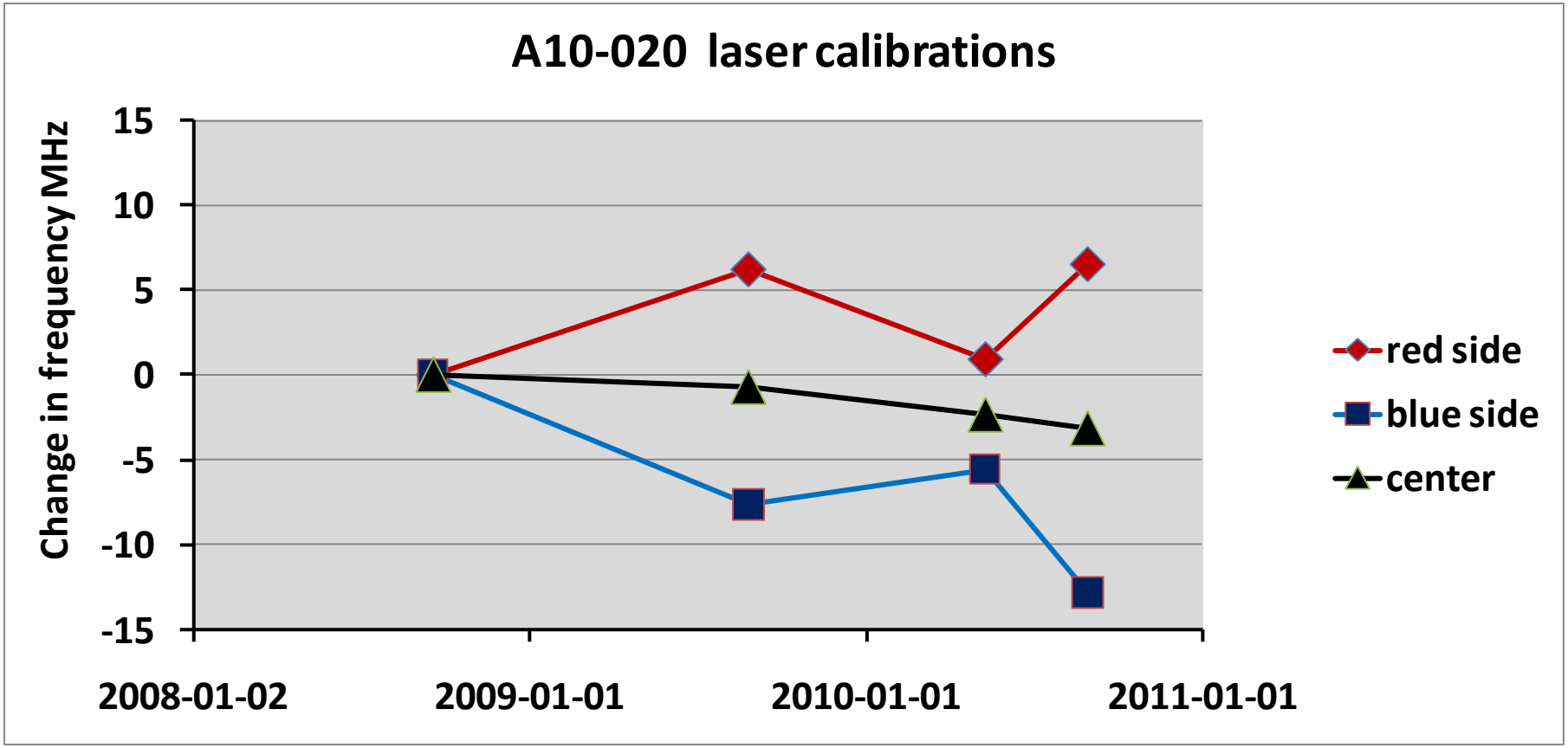


Final network
51 sites measured with A10

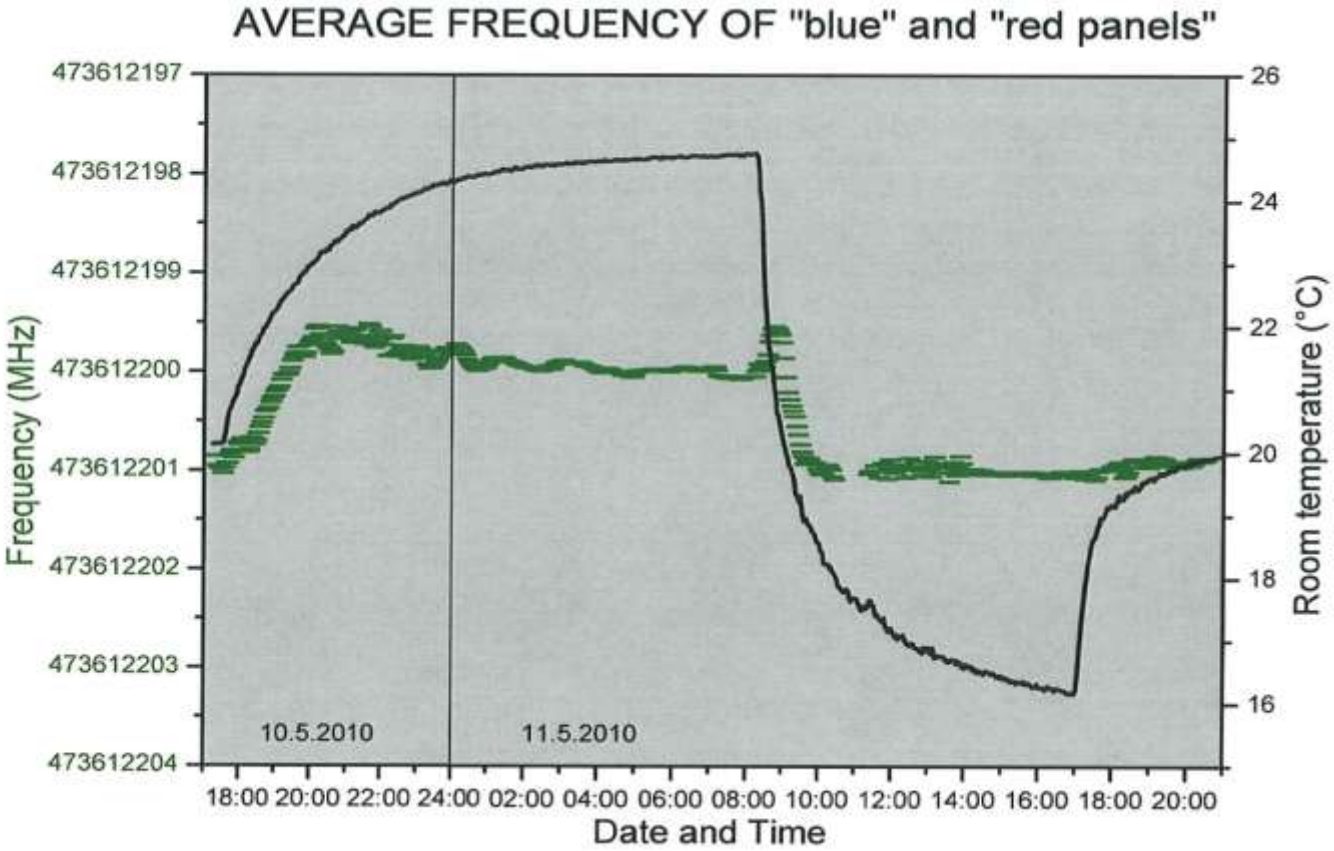
Circles:
Control sites with FG5 results

A10 operation

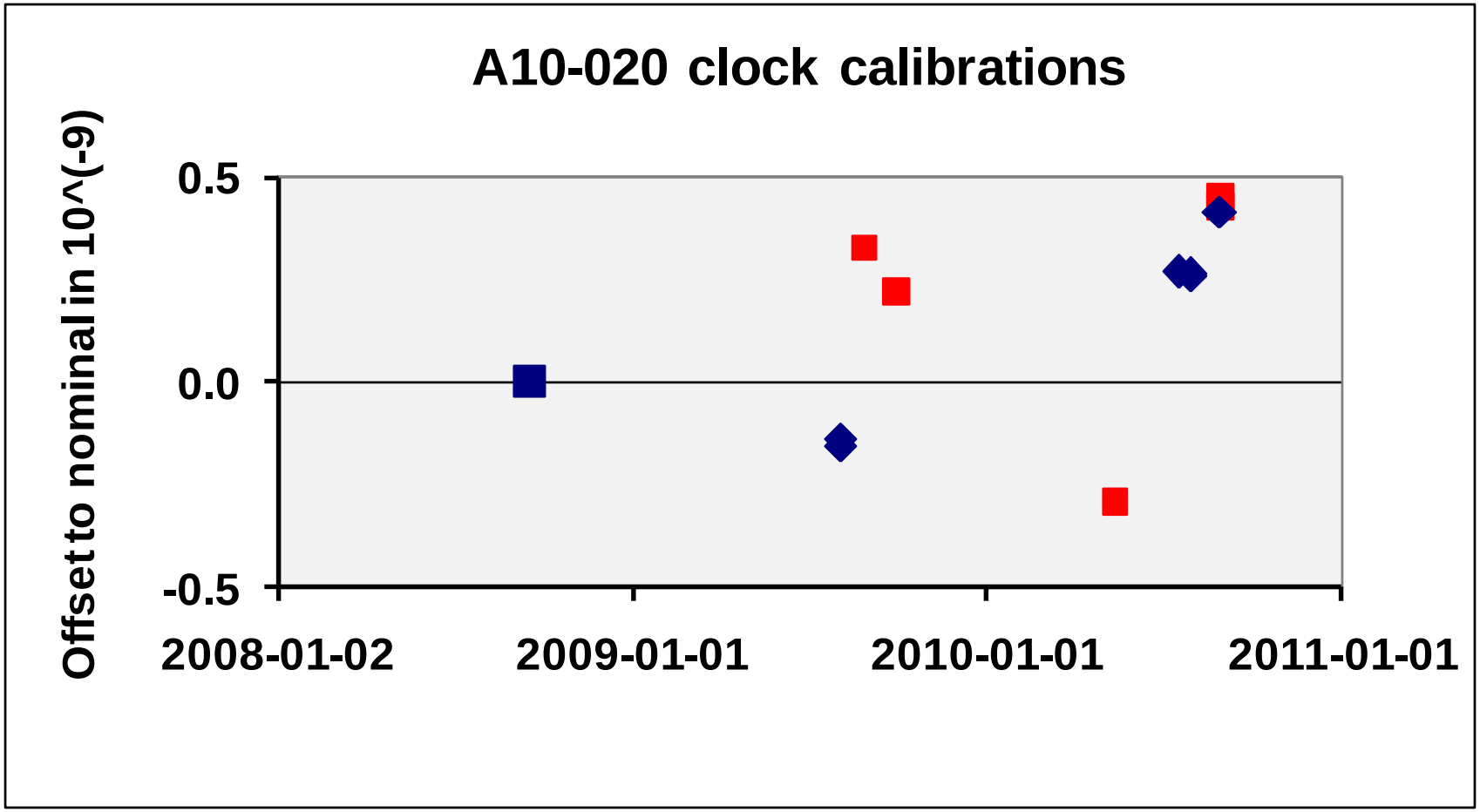
- 2 setups N/S at each station
- ave(N-S) = -0.6 µgal, RMS(N-S) = 6.5 µgal
- FG5-sites visited 1-2 times/week,
- ave(A10-FG5)=1.1 µgal
- RMS(A10-FG5)= 4.4 µgal
- laser and rubidium calibration for each campaign at MIKES metrology
- temperature tests in laboratory: laser frequency and gravimeter g



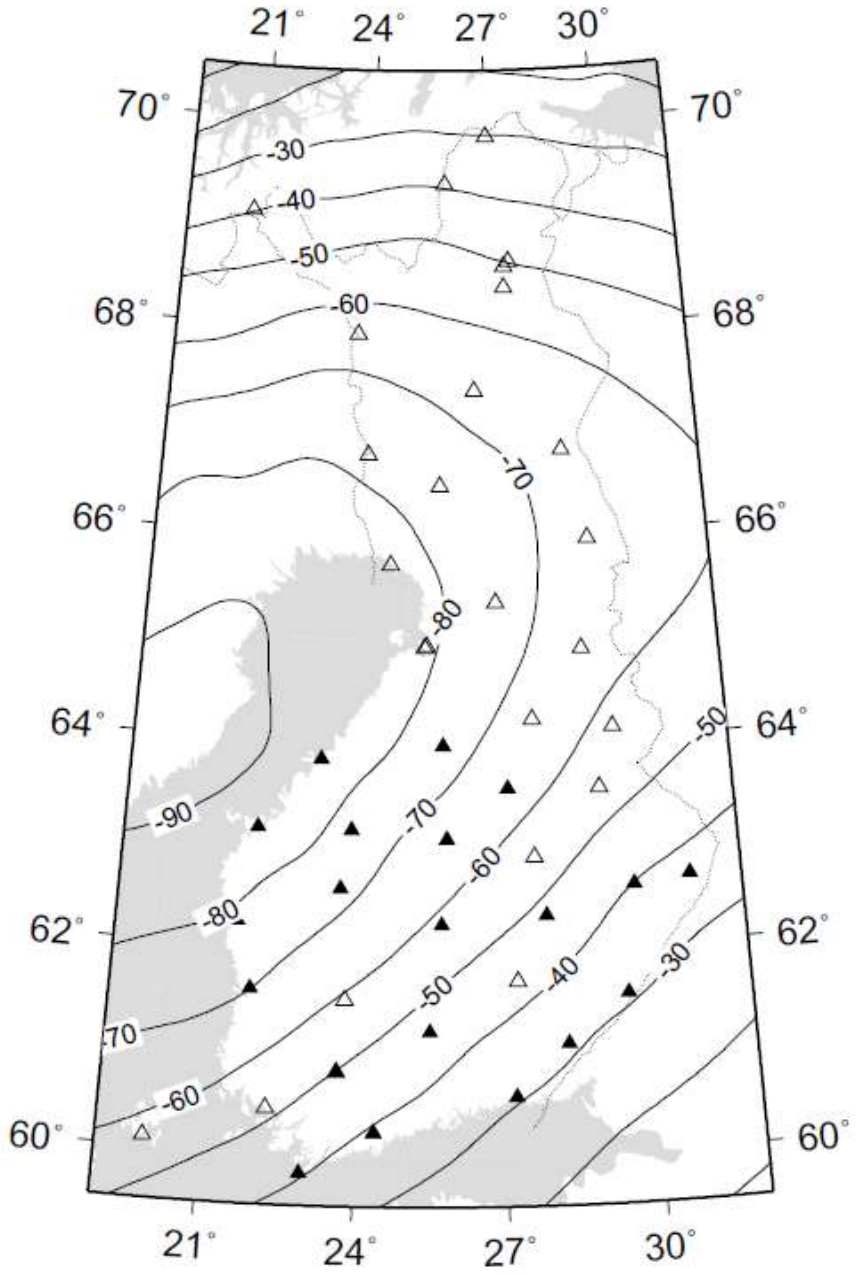
Change of laser frequency since factory calibration
1 MHz ≈ 2 μgal



In situ response of laser center frequency (dashed line) to ambient temperature in laboratory (solid line)

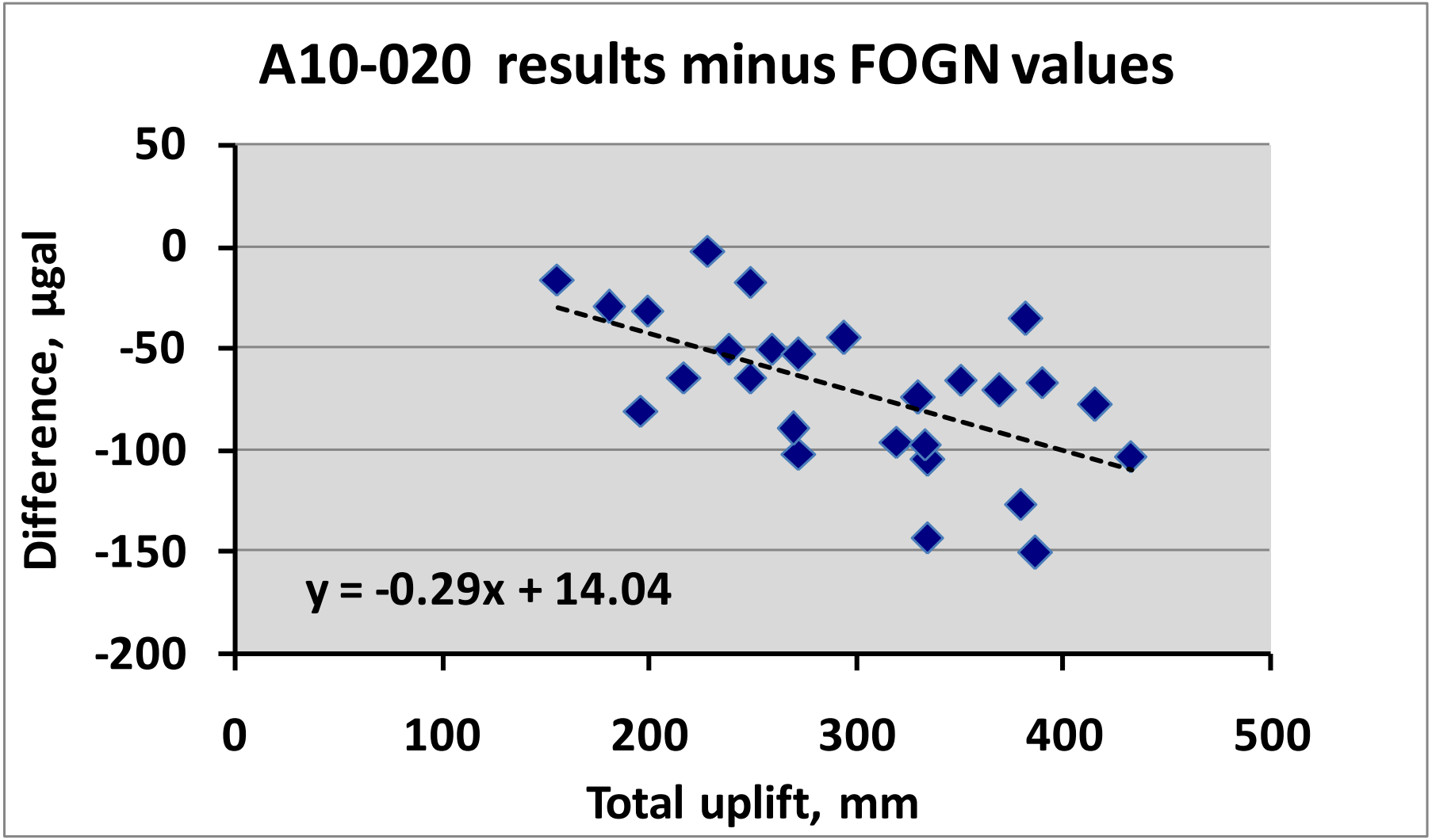


Change of clock frequency since factory calibration
Full scale = 1 µgal



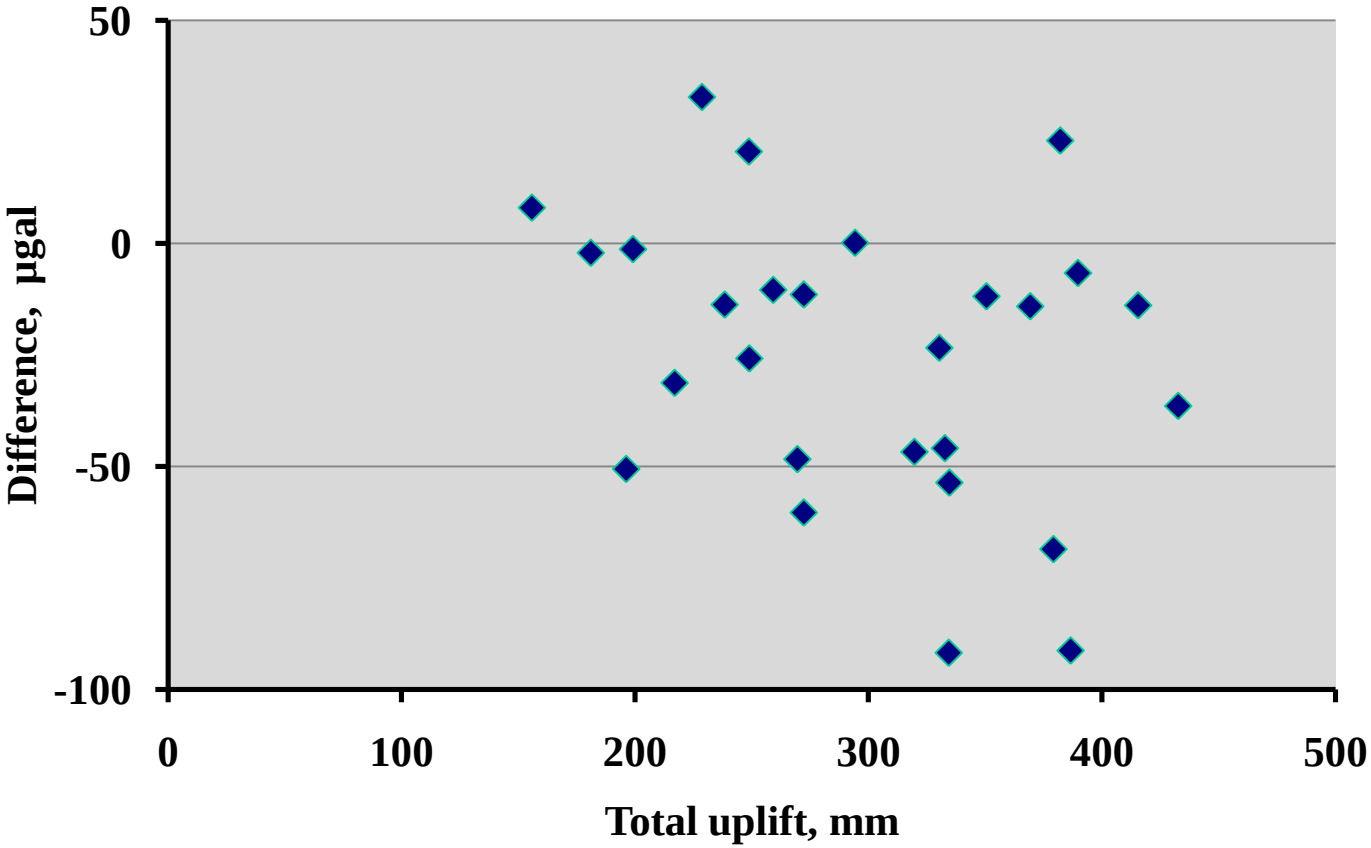
Postglacial rebound

Expected gravity change 1963 – 2010



A10-020 minus FOGN (corrected to zero-tide)
vs. total uplift 1963.0 → 2010.0 in mm
estimated from NKG2005LU_ABS
Slope -0.29 µgal/mm is too steep
But preliminary g-calculations only!

A10-020 results minus FOGN values

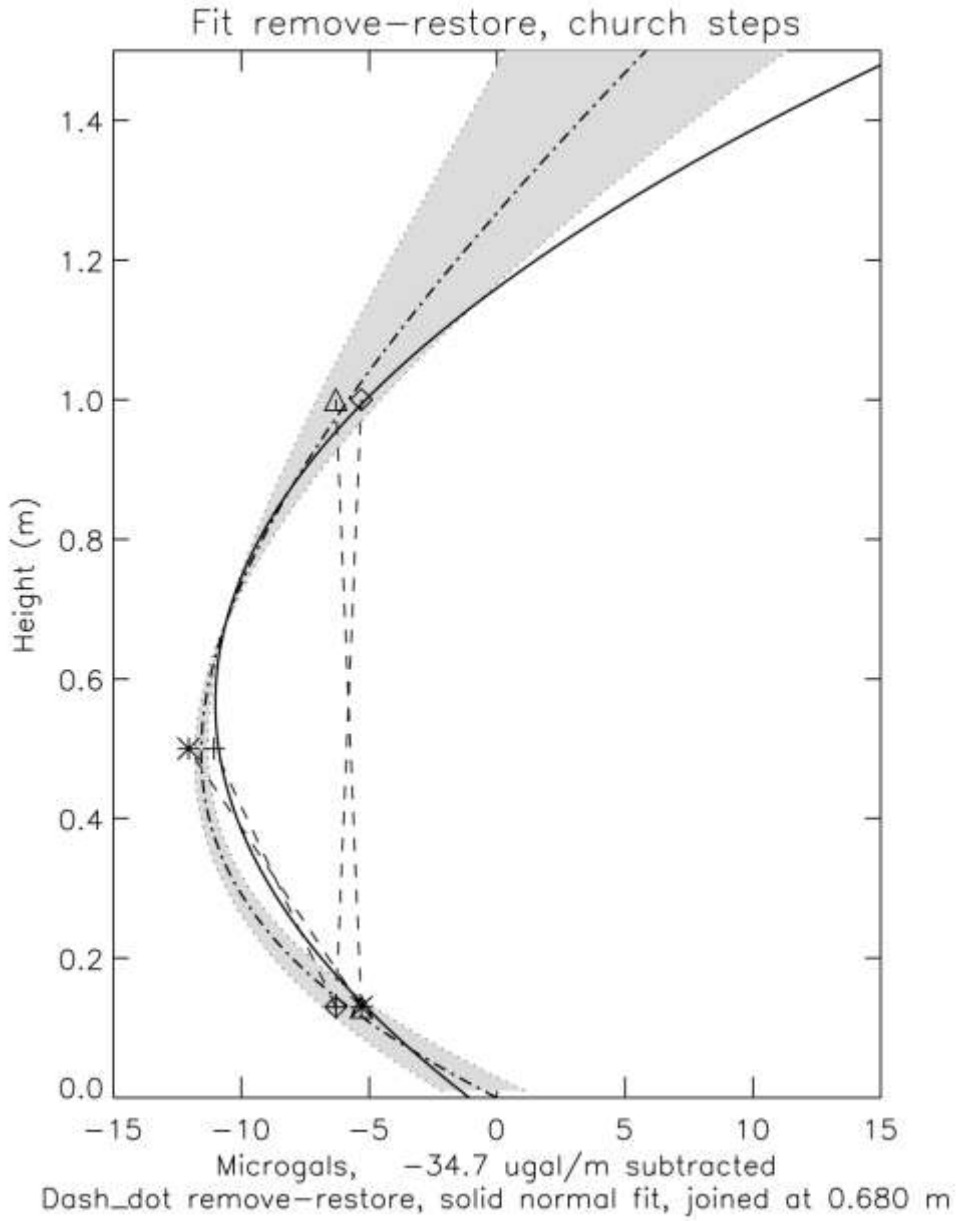


A10-020 minus FOGN
in zero-tide and corrected for gravity change 1963.0 → 2010.0
using NKG2005LU_ABS and -0.154 µgal/mm

N=27, mean=-25 µgal, st. dev.= 32 µgal

Supporting measurements

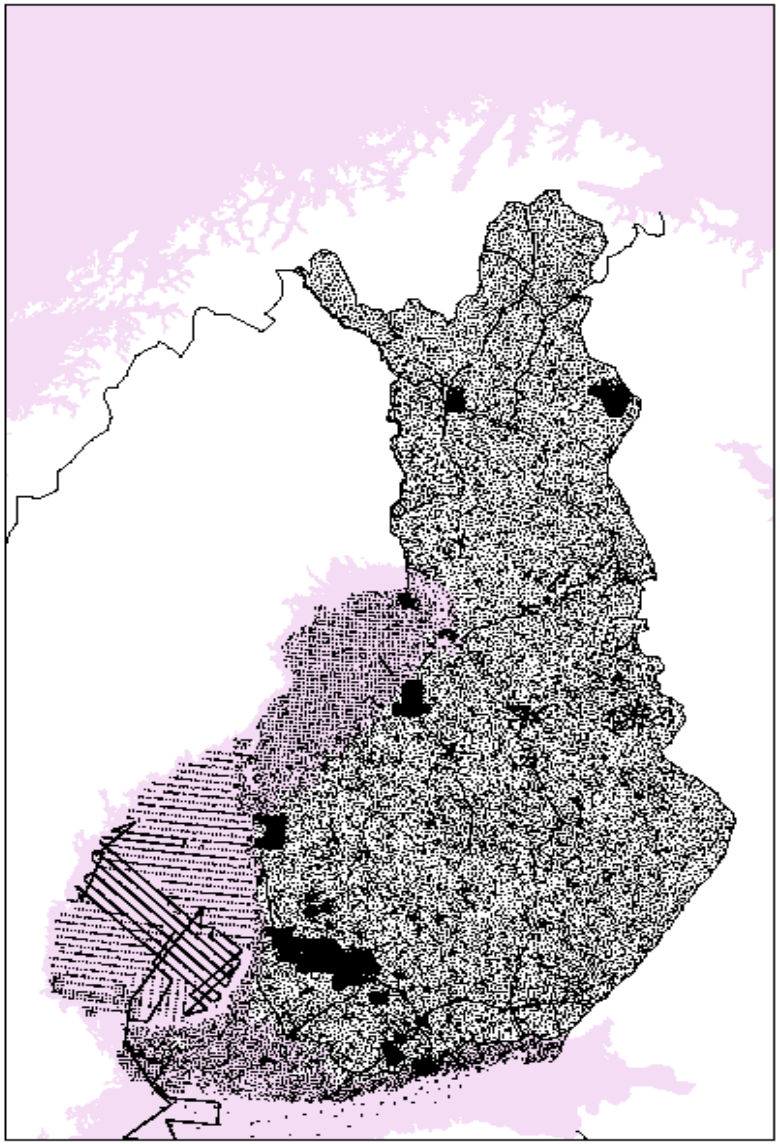
- separate 2-person expedition, will be completed in 2011
- 3-level gradients for A10 computation, for users, and for connecting
  - Worden 1962-63 at about 0.5 m height (tripod)
  - LCR-G 1988 at about 0.12 m height (plate)
  - A10-020 at 0.681 m
- relative ties when FOGN and A10 stations are not identical
- levelling to BM with better than 1 cm accuracy
- 3-D coordinates from RTK-GPS in combination with tachymeter
- plan was to make terrestrial laser scan of sites but scanner was busy elsewhere most of 2010
- photos, sketches, dimensions, control distances



Gravity above typical church stairs changes very non-linearly

Using the results

- New values for FOGN g=g(z)
- Epoch: taking 2000.0 consistent with N2000
- Recalculate all surveys connected to FOGN since 1962
- For FOGN stations lost before present, find proxy stations and connect with relative measurements
- additional spot checks
- performed 2011 by the support team to minimize driving around Finland
- Pre-1962 surveys used “Fundamental gravity network” with distortions of up to 1 mgal in some parts
- Fundamental gravity network shares some stations with FOGN and the rest were connected in the 1960s
- however, correction was not performed nodal point to nodal point but by areal interpolation
- will be redone now



National gravity net FGI

35000 stations