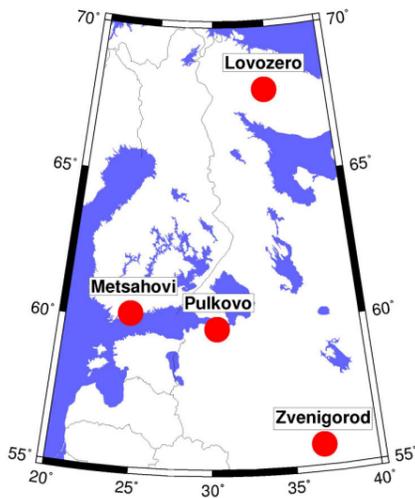


# Comparisons of six absolute gravimeters at four sites 2004–2007

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SITES AND GRAVIMETERS				
Site	Metsähovi	Zvenigorod	Pulkovo	Lovozero
Year/month	2004/7(10)	2005/10	2007/6	2007/6
<b>Gravimeter</b>				
FG5-101	2x3 points			
FG5-110		2 points	2x1 points	2x1 points
FG5-220	2 points			
FG5-221	2x3 points	2x2 points	2x1 points	2x1 points
FG5-301	2x3 points			
GBL P001	2x3 points			

"LxM points" = L independent occupations at each of M points, rotating gravimeter 180 degrees in between to eliminate Coriolis effects in the mean

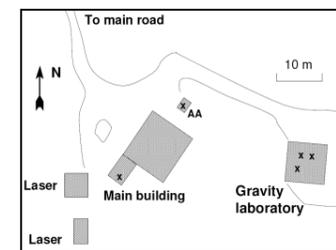
FG5-101, FG5-301 BKG  
 FG5-110, GBL-P001 TsNIIGAiK  
 FG5-220 IfE  
 FG5-221 FGI

## METSÄHOVI GEODETIC OBSERVATORY

- Proposed regional comparison site for absolute gravimeters (AG)
- Four piers on bedrock
- National reference station for gravity
- AG time series 1980–
- Superconducting gravimeter SG GWR T020
- Continuous GNSS: GPS and GLONASS (IGS)
- Satellite Laser Ranging SLR
- Very Long Baseline Interferometry VLBI
- Environmental sensors:
  - Groundwater
  - Soil moisture
  - Meteorology: precipitation, temperature, air humidity, wind, solar radiation
- Model for hydrological cycle under construction



Metsähovi gravity laboratory



Metsähovi interior, some participants with GBL-P001 and FG5-101



Metsähovi ground plan

GBL P001 (right) is a robustified field version of GABL by Arnavov group (Novosibirsk), built in 1995

- drop 0.46 m, starting at 1 m
- 2-mode HeNe laser in interferometer, compared with (not slaved to) an iodine-stabilized laser
- does not have co-accelerating chamber; correction for air resistance needed
- passive isolation device
- oil diffusion vacuum pump

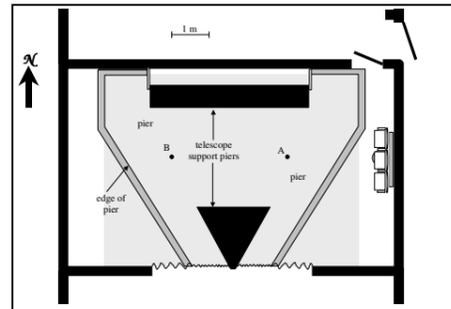


## General setup

- Metsähovi dedicated lab, others are field sites
- Uncertainties (1-σ) for all FG5s is around 2.5 μgal modified from FG5-221 submission to ICAG-2005, GBL-P001 has around 8 μgal based on info from the manufacturer
- Gradient uncertainty essential only in GBL-P001 vs. the FG5s, practically insignificant between the FG5s
- Relative ties measured but not used here



Zvenigorod site: Observatory of the Institute of Astronomy of the Russian Academy of Sciences.



Zvenigorod ground plan; the building is in background in the photo left.



Gravity observatory of TsNIIGAiK at the premises of the Pulkovo Astronomical Observatory.



Pulkovo interior with FG5-221.



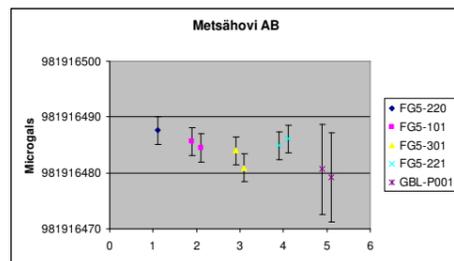
Entrance to Lovozero site in a vacated factory in Revda. TsNIIGAiK fundamental GNSS station.



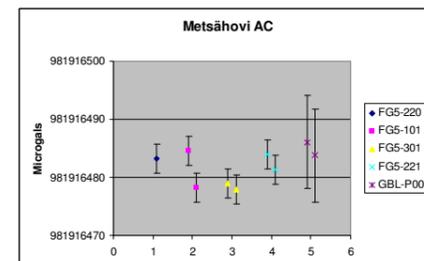
Lovozero interior with FG5-110.

## Metsähovi experimental setup

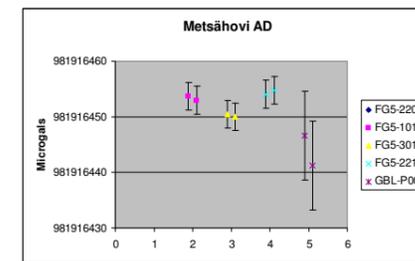
- All frequency standards compared with hydrogen maser
- All barometers compared with standard barometer
- For the FG5-101, 220, 301, GBL-P001 a full factorial experiment with (4 gravimeters) × (3 sites) × (2 azimuths) sequenced to make site and azimuth factors orthogonal to linear rate in time
- Significant differences between N/S azimuths in some FG5, averaged out and not treated here
- SG had large drift due to helium fill-up, not usable
- Site (AB, AC, AD) reference values as weighted means, using weight=(uncertainty)<sup>-2</sup>
- Differences of site reference values used to transfer results to any site



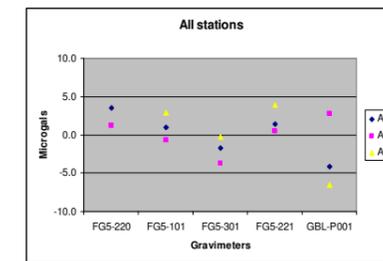
Comparison at Metsähovi AB, 1-σ uncertainties



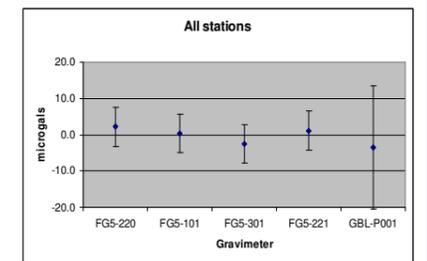
Comparison at Metsähovi AC, 1-σ uncertainties



Comparison at Metsähovi AD, 1-σ uncertainties



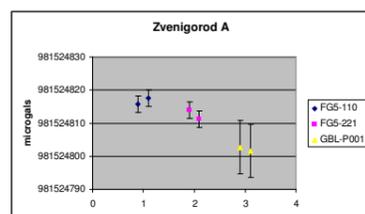
Metsähovi all, differences to reference value



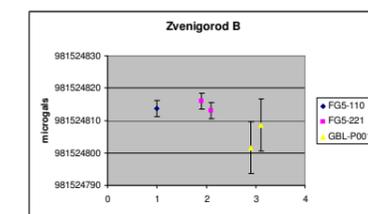
Metsähovi all, differences of instrument means to reference value with expanded uncertainty (95%)

## Zvenigorod experimental setup

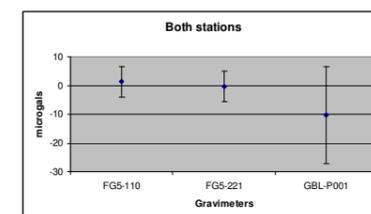
- Mutual comparisons of frequency standards and barometers
- Incomplete factorial: (3 gravimeters) × (2 sites) × (2 azimuths), one azimuth with FG5-101 missing
- Site (A, B) reference values as weighted means, using weight=(uncertainty)<sup>-2</sup>
- Differences of site reference values used to transfer results to either site



Comparison at Zvenigorod A, 1-σ uncertainties



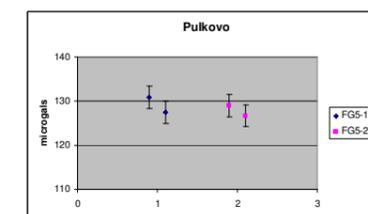
Comparison at Zvenigorod B, 1-σ uncertainties



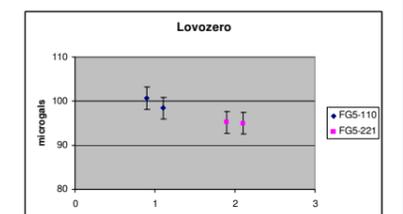
Zvenigorod both, differences of means to reference value with expanded uncertainty (95%)

## Pulkovo and Lovozero

- Mutual comparisons of frequency standards and barometers
- (2 gravimeters) × (1 sites) × (2 azimuths)
- Difference of N/S azimuths significant
- No reference values plotted here, only differences of gravimeter results



Comparison at Pulkovo, 1-σ uncertainties



Comparison at Lovozero, 1-σ uncertainties