Station report OS

(Onsala Space Observatory, Sweden)

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1. Onsala Space Observatory – a short guide
2. Local vertical motion and gravity rates
3. The gravimetry laboratory
4. AG campaigns and multi-campaign adjustment
5. SG calibration

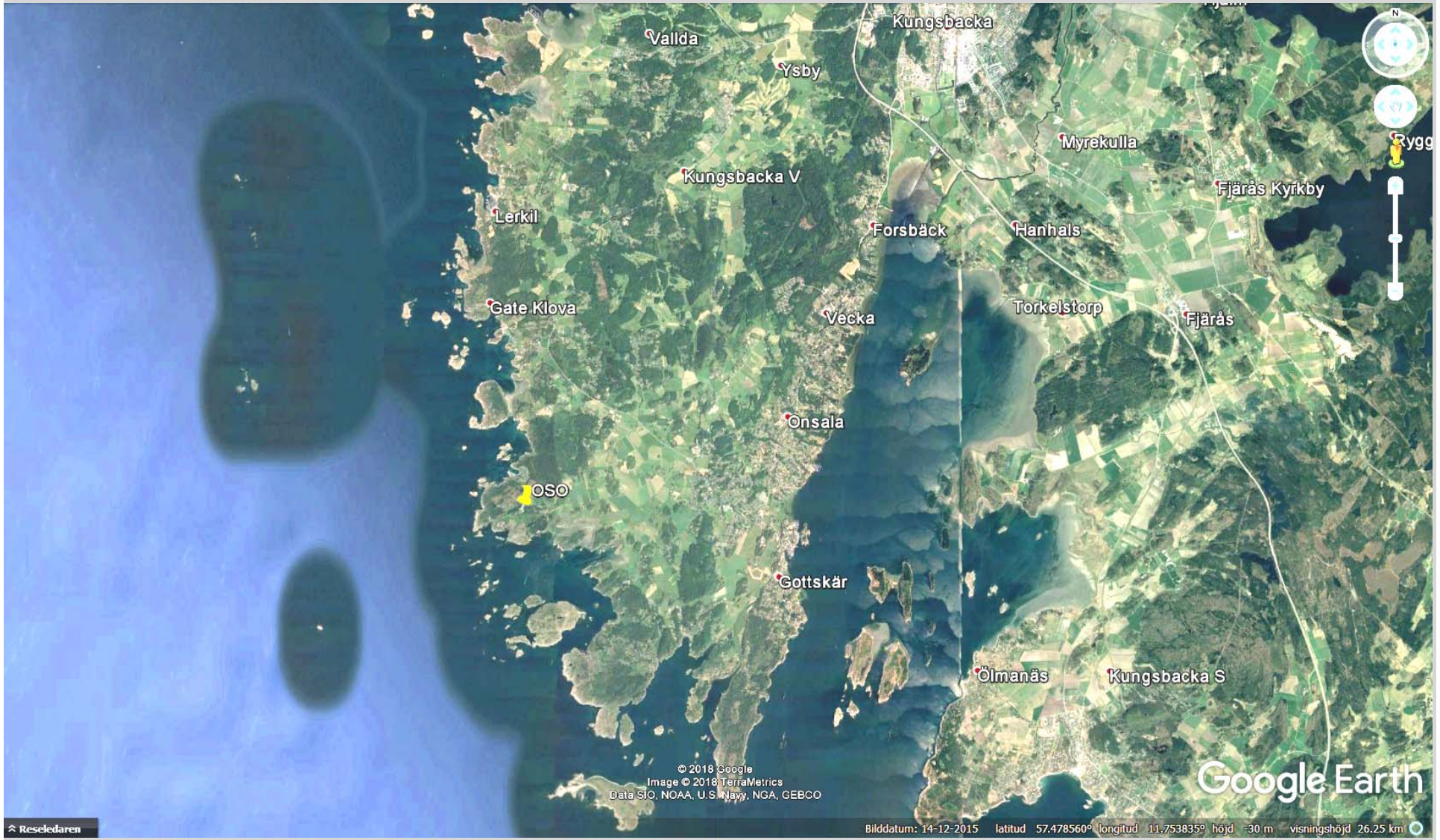
Chalmers and Onsala

- Chalmers is a university of technology in Göteborg (Gothenburg), Sweden
- Department of Space, Earth and Environment Science (SEE), extended May 1, 2017. Concerning earth science,
  - Radar remote sensing (forestry and agriculture, sea ice and oil spill, ocean waves,…)
  - Optical remote sensing (volcanic gasses, air pollution)
  - Global Environmental Measurements and Modelling (tropo- strato- meso-sphere; ozone, CFC's, radiation, mass transport,…; satellite atmosph. sounding and spectroscopy ….)

- Onsala Space Observatory (OSO): Part of Sweden's National Research Infrastructure
  - Radio Astronomy and Astrophysics
  - Ground-based Aeronomy and Radiometry
  - Space Geodesy (VLBI, GNSS)
    - Gravimetry

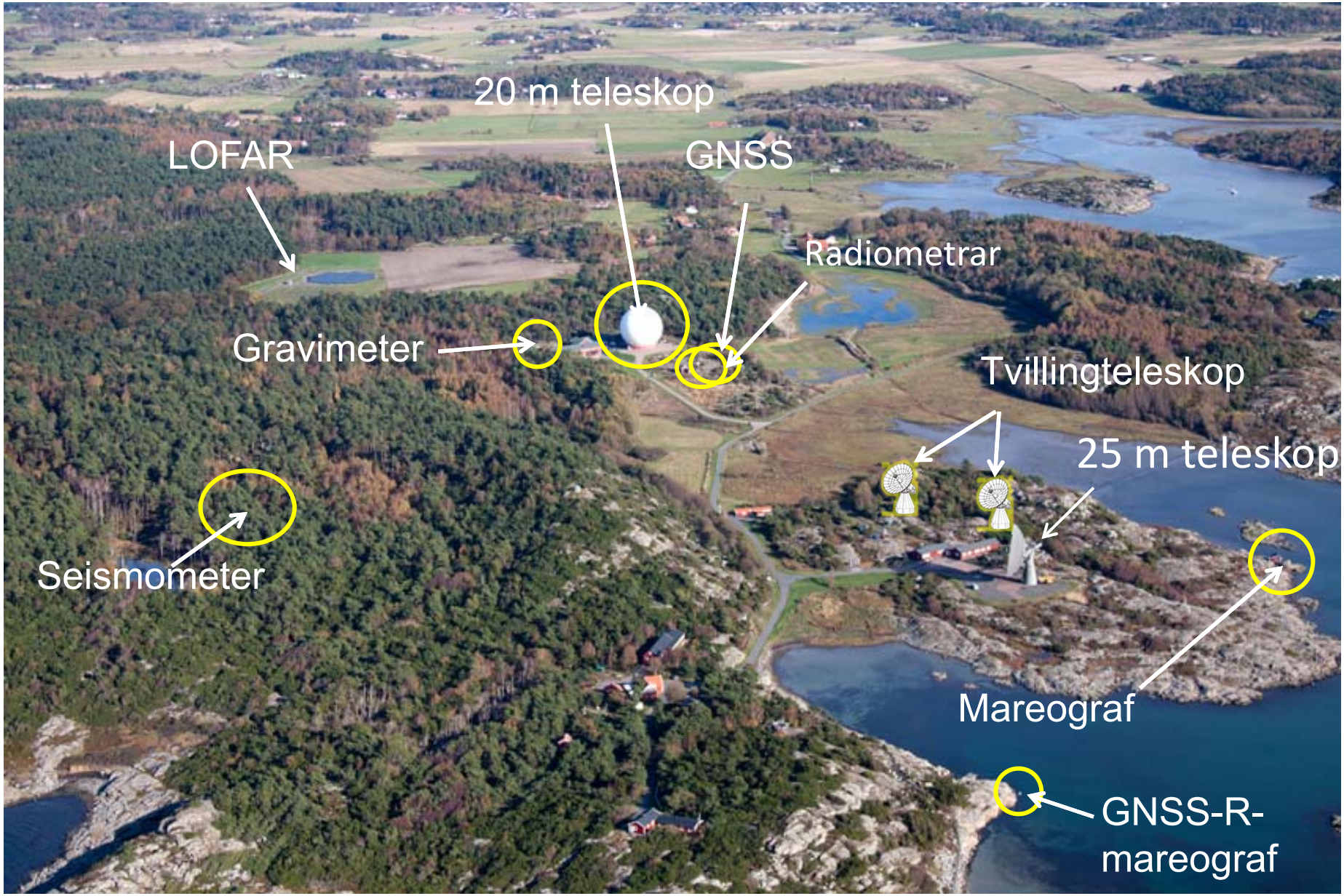
Where we are


Kristiansand
Trollhättan
Jönköping
Göteborg
Borås
OSO
Hjørring
Fredrikshamn
Klitmøller
Ålborg
Växjö
Kalmar
Halmstad
Holstebro
Viborg
Randers
Århus
Karlskrona
Helsingborg
Kristianstad
Lund
Köpenhamn
Esbjerg
Odense
© 2018 Google
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 GeoBasis-DE/BKG
Google Earth
Reseledaren
Bilddatum: 14-12-2015 latitud 56.830624° longitud 11.895554° höjd -11 m visningshöjd 537.25 km


Kungsbacka
Valda
Ysby
Myrekulla
Kungsbacka V
Fjärås Kyrkby
Lerkil
Forsbäck
Hanhals
Gate Klova
Vecka
Torkelstorp
Fjärås
Onsala
OSO
Gottskär
Ölmanäs
Kungsbacka S
© 2018 Google
Image © 2018 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth
Reseledaren
Bilddatum: 14-12-2015 latitud 57.478560° longitud 11.753835° höjd -30 m visningshöjd 26.25 km

Facilities at Onsala Space Observatory

- OSO has:
  - 20 m radio telescope (VLBI before VGOS)
  - 25 m radio telescope (S to C band, eventually MEO and LEO satellite tracking)
  - OTT Twin telescopes (VGOS) since May 2017
  - GNSS tracking for IGS, SWEPOS network,… and a well-determined position and velocity in the ITRF.
  - GNSS tide gauge (and other, modern mareographs)
  - Water vapour radiometers (also: CO, O_3)
  - and …


20 m teleskop
LOFAR
GNSS
Radiometrar
Gravimeter
Tvillingteleskop
25 m teleskop
Seismometer
Mareograf
GNSS-R-
mareograf

Twin telescope inauguration
May 18, 2017

50’th anniversary First Transatlantic
VLBI Baseline - April 5, 1968/2018

King Carl XVI Gustaf at
25m radio telescope
inauguration 1967

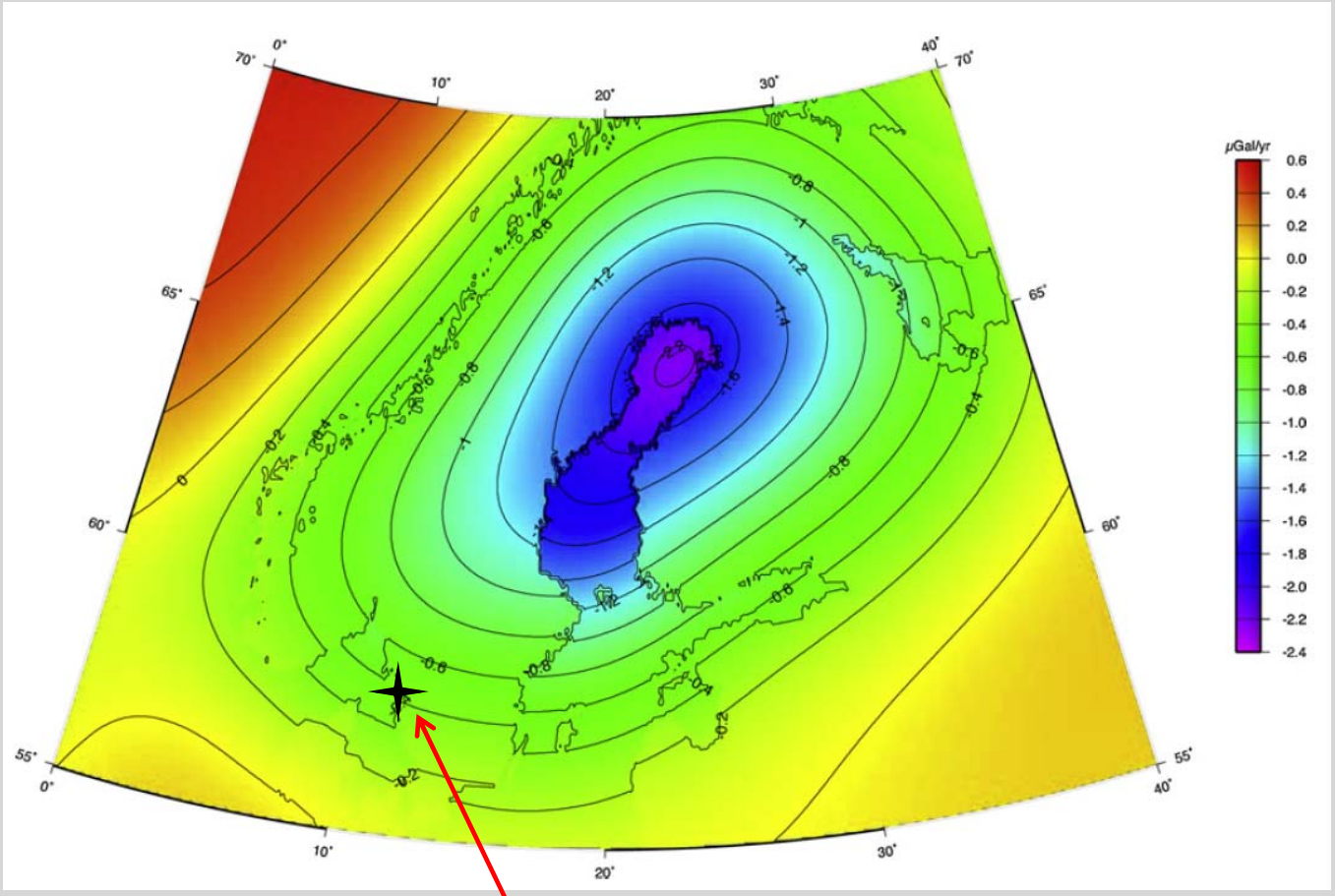
Vertical rates at Onsala

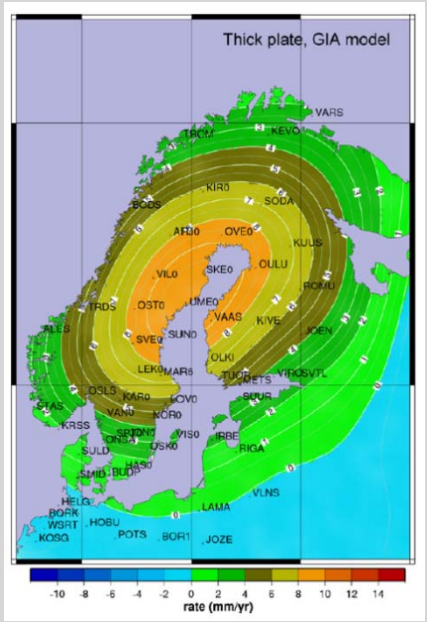
GNSS JPL		2.653 ± 0.12[1](0.053[2]) mm/yr
GNSS M. Rajner, Gipsy		2.656 ± 0.12[1](0.052[2]) mm/yr
GNSS ITRF2014		2.83 ± 0.05 mm/yr
VLBI ITRF2014		2.82 ± 0.06 mm/yr
GIA model	120-0.5--5 (M+al 2004)	2.38 mm/yr
	120-0.8-10	2.26 mm/yr
	120-1.0-20	1.70 mm/yr
Rel. sea level (Ringhals) 1968-2016		0.3 ± 0.6 mm/yr
Rel. sea level (Göteborg) 1968-2018		1.6 ± 0.4 mm/yr
	… air pressure added	1.4 ± 0.3 mm/yr
		0.7[3] ± 0.3 mm/yr
Gravity	120-0.5-10 (O+M+S+Å 2015)	-3.56 ± 0.12 nm/s²/yr
	(H.Steffen)	-4.7 nm/s²/yr
	AG multi-campaign adjustment	-4.34 ± 0.13 nm/s²/yr [a]
		-4.30 ± 0.13 nm/s²/yr [b]
		-4.59 ± 0.13 nm/s²/yr [c]

[1] flicker noise, Monte-Carlo test
[2] extended Gauss-Markov (PEF)
[3] ext'd Gauss-M., Monte-Carlo test

[a] Nodal tide reduced
[b] Nodal tide eff. slope reduced
[c] like above, a skewness corr. skipped

With the Sea-level equation and ICE-5G





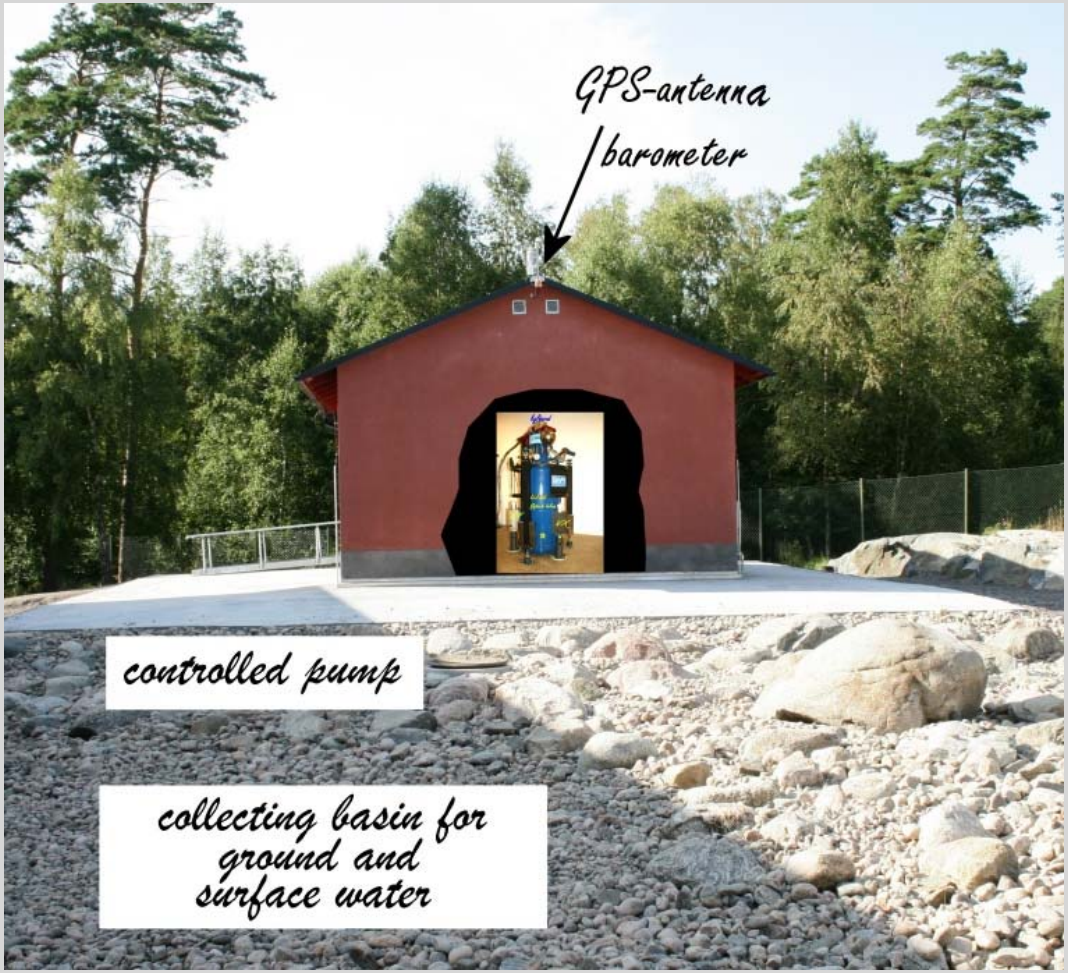
Vertical displacement from Bifrost GNSS

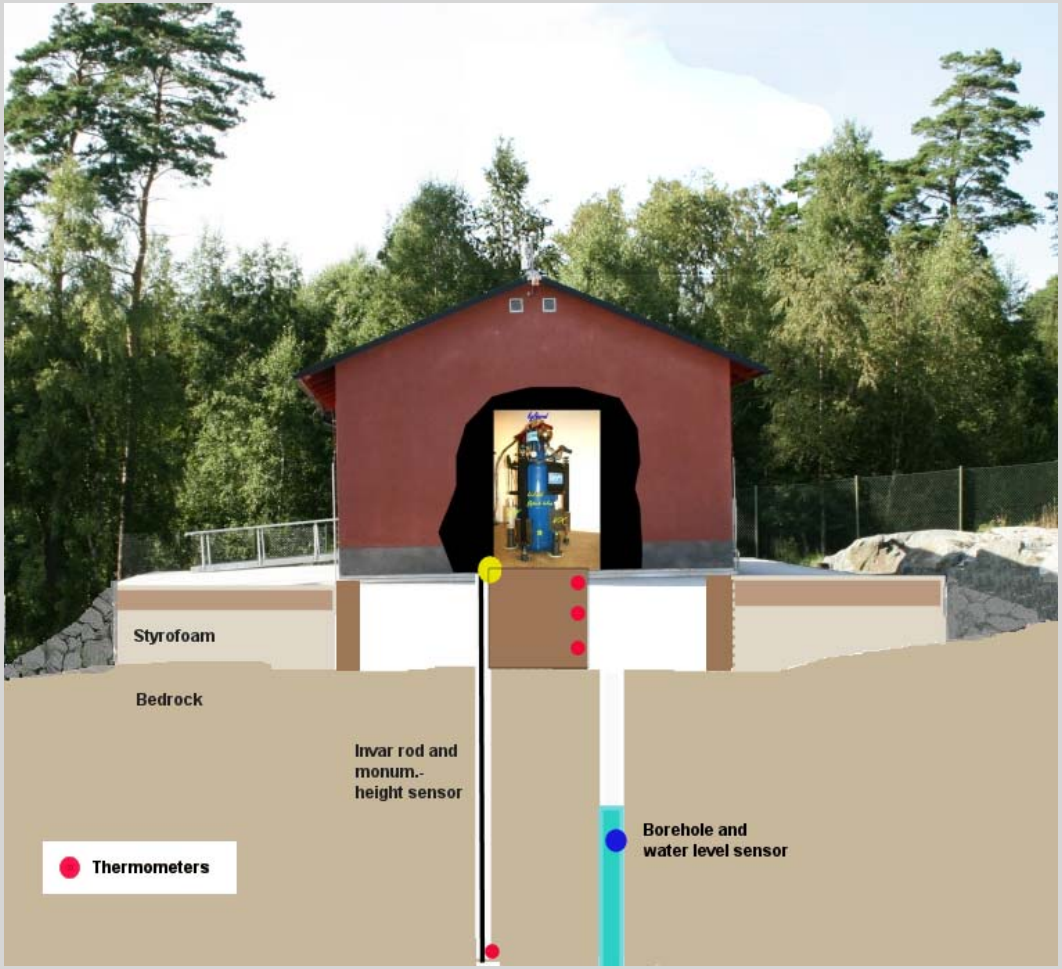
Predicted gravity change – at Onsala, -3.6 to -4.7 nm/s^2/yr

Olsson et al. (2012), doi: 10.1016/j.jog.2012.06.011

Steffen et al. (2016), *Geophys. Res. Abs.* 18, EGU2016-12816, EGU General Assembly

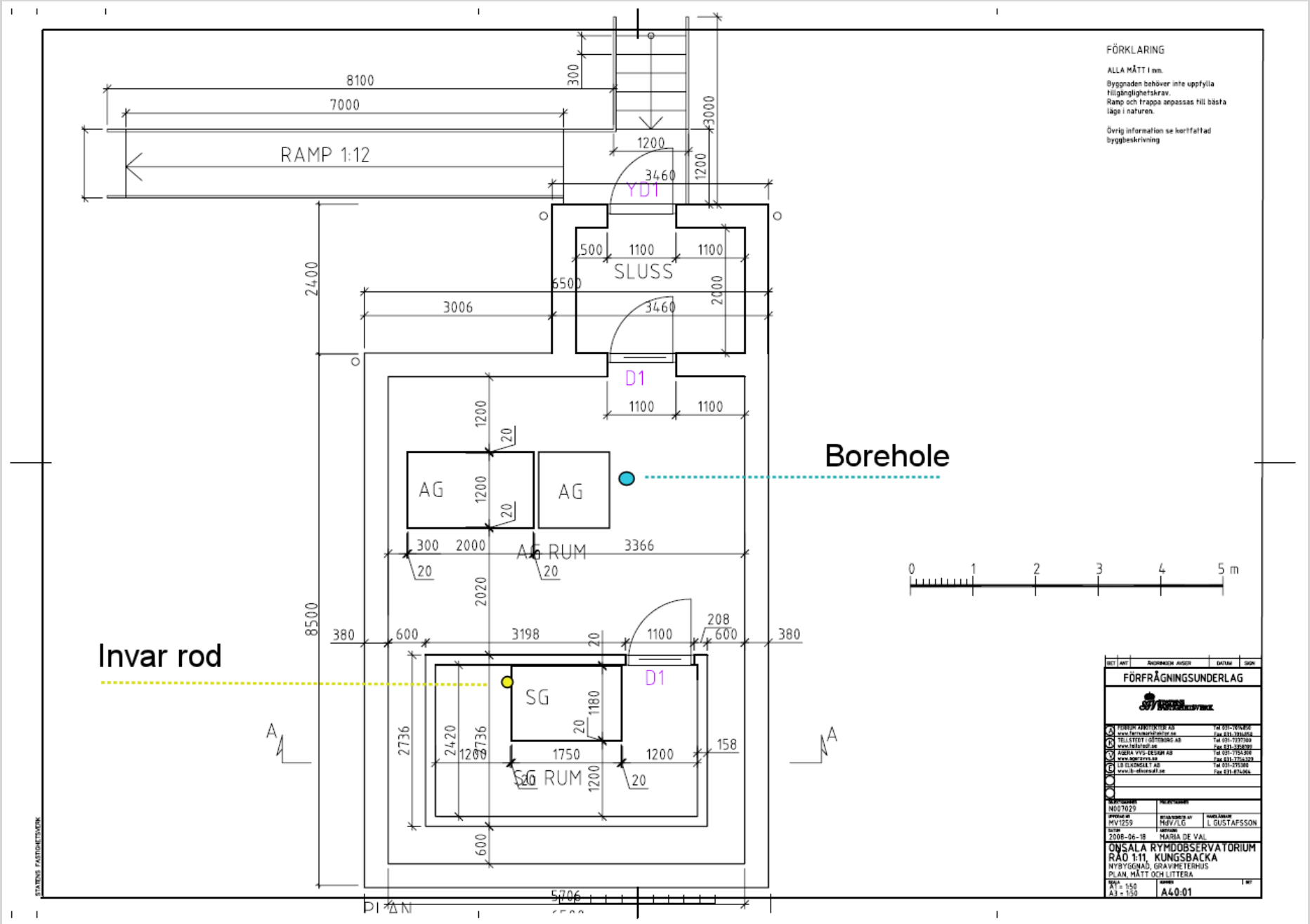
Established: June 15, 2009




Styrofoam
Bedrock
Invar rod and
monum.-
height sensor
Borehole and
water level sensor
Thermometers

Feb.(?) 2008

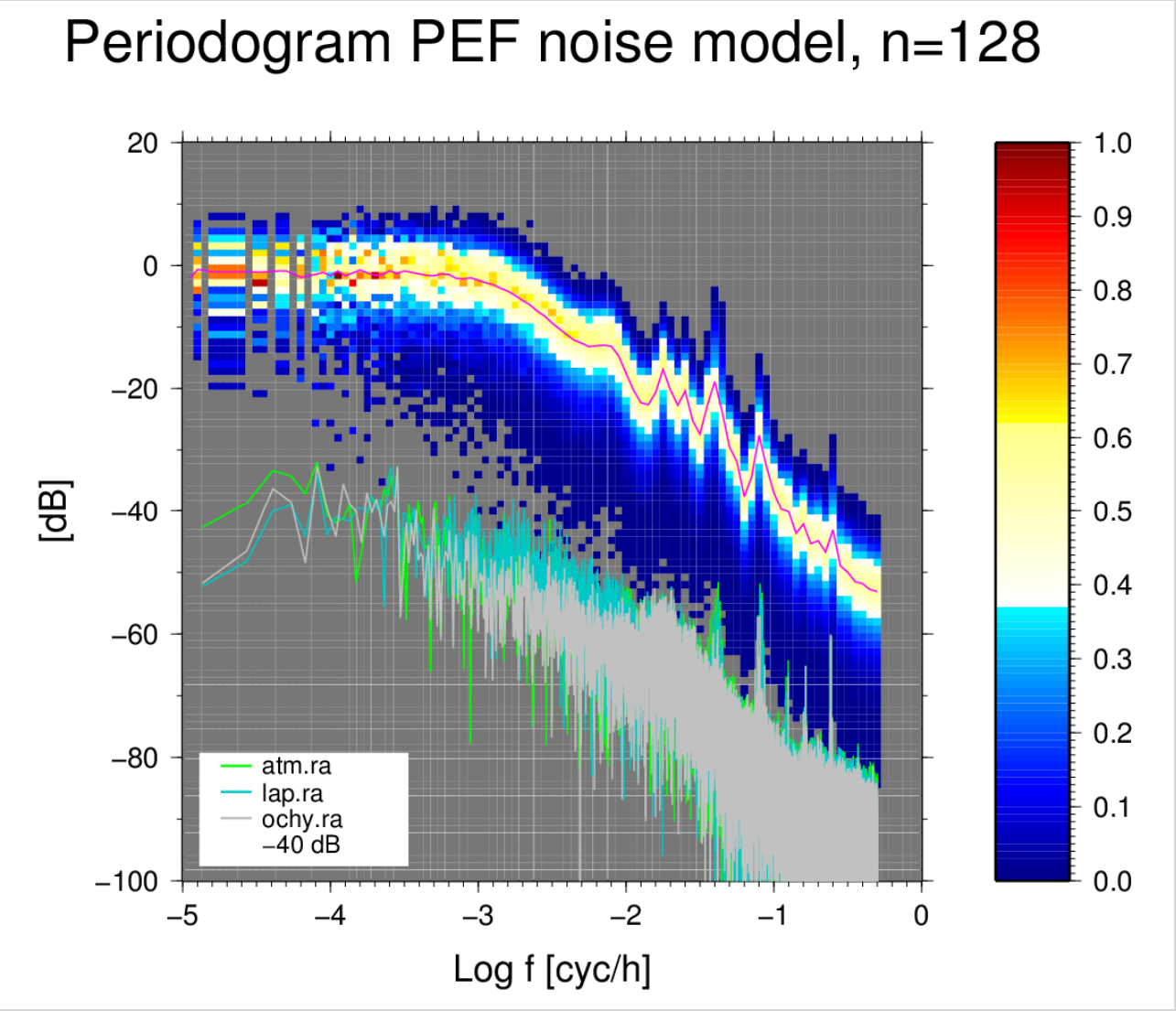

Feb. 4, 2010


FÖRKLARING
ALLA MÅTT I mm.
Byggnaden behöver inte uppfylla tillgänglighetskrav.
Ramp och trappa anpassas till bästa läge i naturen.
Övrig information se kortfattad byggbeskrivning
RAMP 1:12
8100
7000
300
3000
1200
1200
3460
YD1
SLUSS
500
1100
1100
6500
2000
3006
3460
2400
D1
1100
1100
1200
20
AG
1200
20
AG
Borehole
300
2000
AG RUM
3366
20
20
2020
8500
380
600
3198
20
1100
208
600
380
Invar rod
SG
1180
20
D1
A
A
2736
2420
2736
1200
1750
1200
158
SG RUM
1200
20
20
600
5706
PLAN
0
1
2
3
4
5 m
FÖRFRÅGNINGSUNDERLAG
ONSALA RYMDOBSERVATORIUM
RÅÖ 1:11, KUNGSBACKA
NYBYGGNAD, GRAVIMETERHUS
PLAN, MÄTT OCH LITTERA
A40:01
STATENS FASTIGHETSVERK

Resources & self-service

- Archive of GWR files G1 A1 A2 L1 L2
- Archive of SNSN Seismometer, eventless
- SG miniseed server. Connect with seedlink / seisgram2k from anywhere: -seedlink " 129.16.208.216:18000#SG_OSO:HG?"

- SG live home page: http://holt.oso.chalmers.se/hgs/SCG/monitor-plot.html
- SG weekly analysis results:
- http://holt.oso.chalmers.se/hgs/4me/toe/toe.html



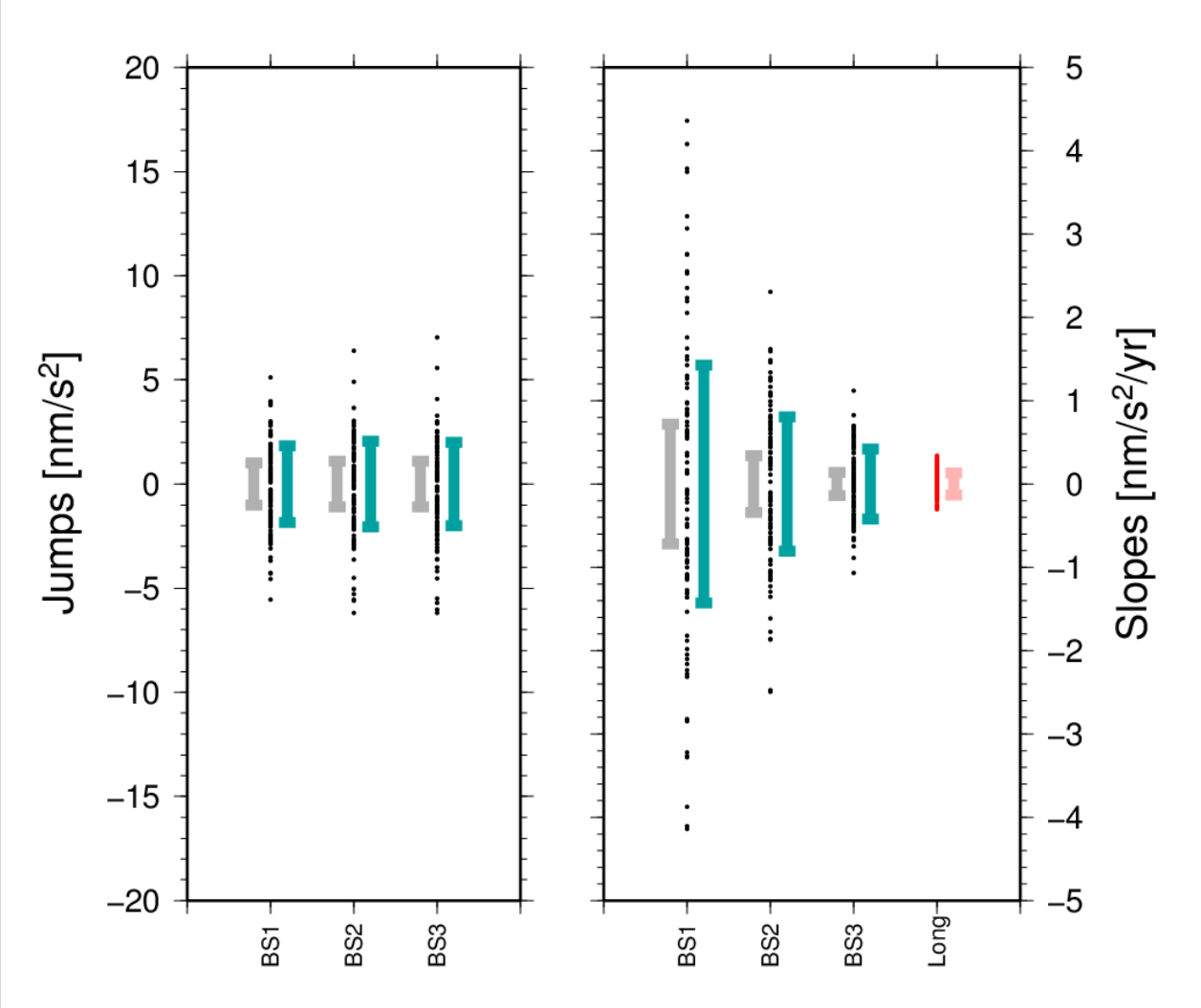
Arguing pro PEF noise, contra flicker noise

PEF = Prediction error filter (J.P. Burg's Max. Entropy method), a.k.a. Extended Gauss-Markov

100 noise innovations with "atm.ra" as the premise.

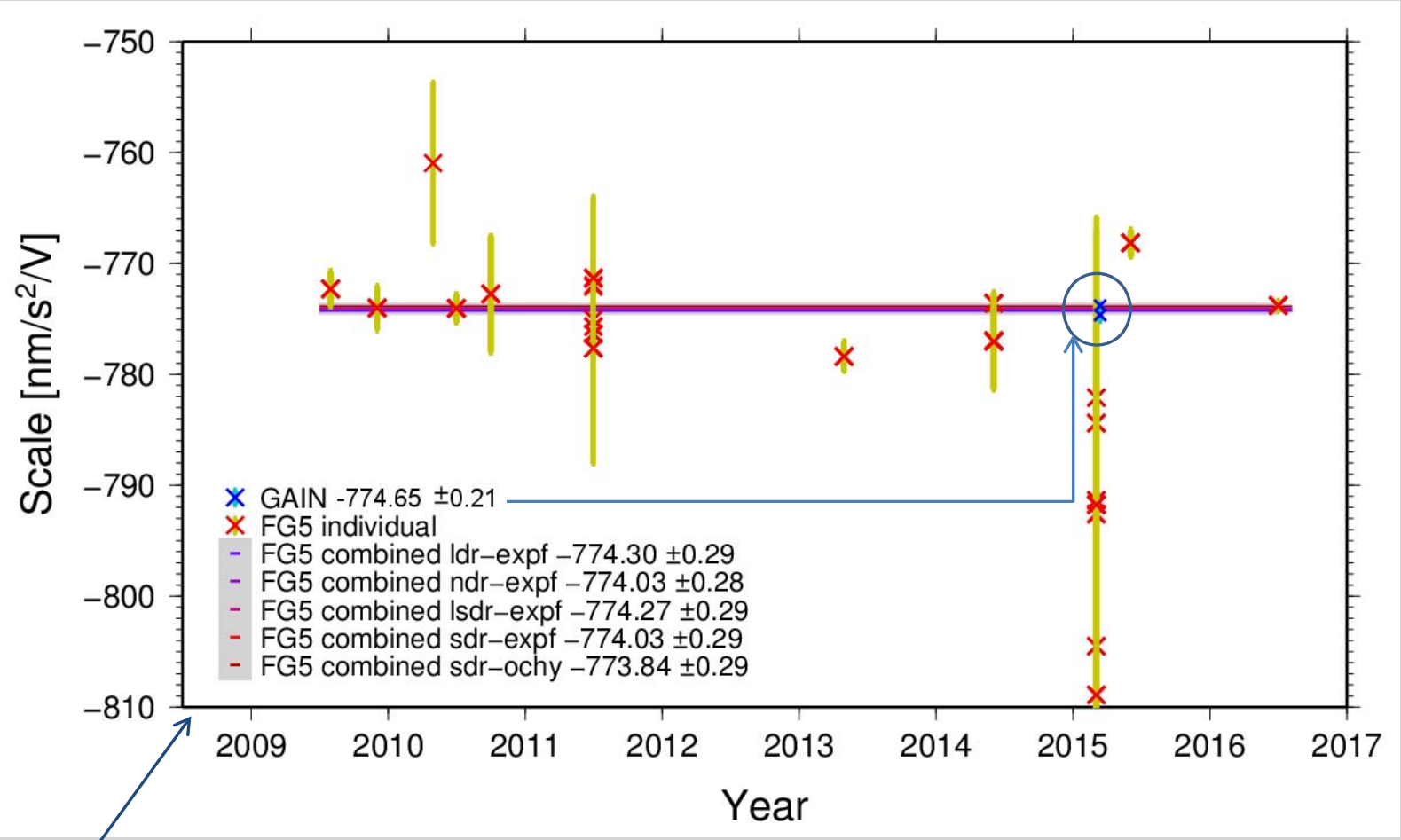
Residuals from regression:
atm: Atmacs
ochy: ECCO1 and ERAin
lap: local barometer

Monte-Carlo test of (tide and) drift analysis



Notice:
Long-term slope repeatablity STDEV from MC is ± 0.2 nm/s²/yr

SG calibration



a range of variants to account for SG-drift and
excepting some AG campaigns from common instrument bias
Note: max – min < 2 std devs

SG calibration

- Low-pass filtered SG to reject micro-seisms. In one noisy campaign (Feb. 2015) a broadband seismometer (Guralp CGT-3, 120 s) was used to reduce the AG drop noise and – en passant – adjust the FG5 time stamps.

↓ Scale factors one campaign at a time: sagging AG-levels co-vary with tide

↑ Multi-campaign adjustment: Estimate a drift rate for every setup; examples:

symb	End-start [nm/s²]	Std-dev [nm/s²]			
SLa1	-13.86 ±	7.36	SLd1	-17.32 ±	7.53
SLa3	-15.71 ±	13.94	SLd2	14.09 ±	6.87
SLa4	-16.65 ±	6.22	SLu0	17.81 ±	9.20
SLa6	-67.06 ±	4.27	SLu1	-19.61 ±	8.25
SLb0	19.00 ±	9.71	SLu2	-8.47 ±	7.14
SLb6	-38.87 ±	9.23	SLv0	42.59 ±	6.82
SLb7	-14.26 ±	10.74	SLv1	-44.34 ±	6.68
SLc0	60.60 ±	16.69	SLv2	46.61 ±	7.89
SLc4	-11.47 ±	9.36	SLv3	-27.64 ±	7.74
SLc5	33.10 ±	12.21	SLw5	14.69 ±	6.20
SLd0	-13.61 ±	3.69	SLt0	-46.38 ±	7.28

Multi-campaign analysis: Secular rate of gravity change