A new generation of VBB sensors (STS1 – STS2) – STS6A – T360

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GEOSCOPE (IPGP)

Very Broad Band Sensors

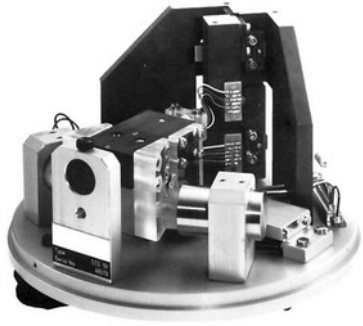
- 360s cut frequency, up to 1000s and even more
  - But also high frequencies up to 50Hz
- STS-1:
  - E. Wielandt, G. Streckeisen: *The leaf-spring seismometer: Design and performance.* Bulletin of the Seismological Society of America, 1982
  - Installed in the first GEOSCOPE station (20 stations in 2022)
  - Discontinued in the 90's
- STS-2/STS-2.5: 120s + shielding
- New generation: STS-6A and T360

STS-1: Construction

- 3 separated components
  - Possible mis-orthogonality
- Vertical different from horizontal
- Difficult Installation:
  - On sand at the beginning
  - Vacuum
  - Fragile
  - Manually centered and nivelled

Brochure 80's

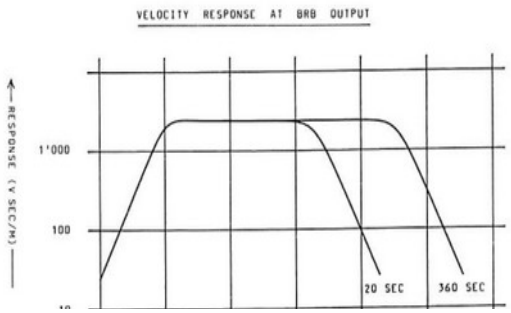
STS-1 Vertical

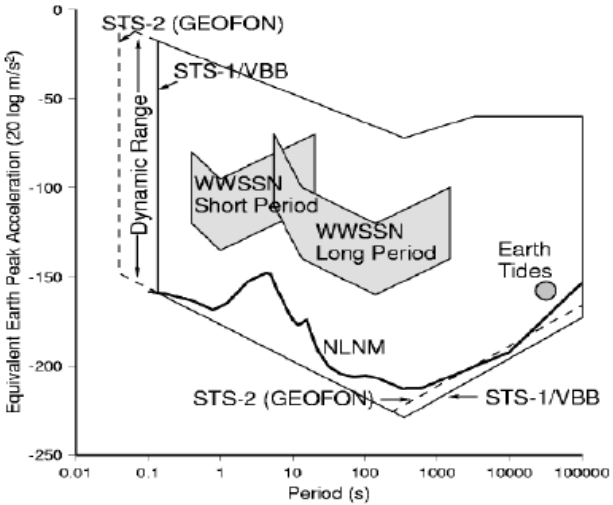


STS-1 Horizontal

STS-1: specifications

Velocity response at BRB output





- Flat in velocity from 10Hz to 360s
- Extension from 20s to 360s with electronic board swap
- Unmatched performances until recently
  - Self-noise under NLNM
- LP output (« mass position »)

STS-1: Installation

- Protections against pressure and temperature variations
  - Vacuum + foam cube
- Protection against magnetic field variations
  - mu-metal shield for vertical component
- Vacuum sensors for pressure monitoring :
  - High influence of vacuum on Z mass position centering (Archimedes' principle, buoyancy in the air)
- Holcomb 1992: « Warp-free base plates »

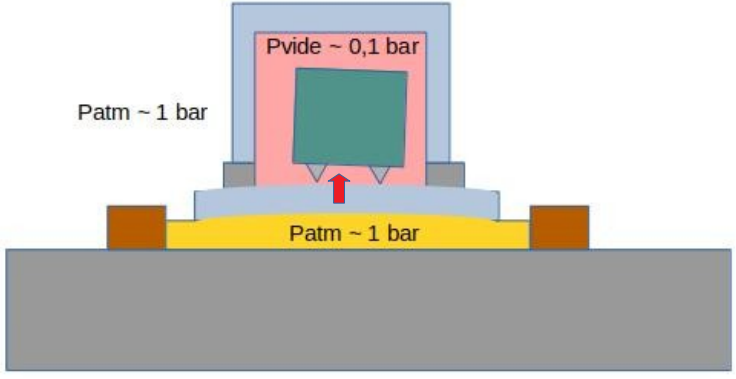
Installation on sand

Warp-free base plates

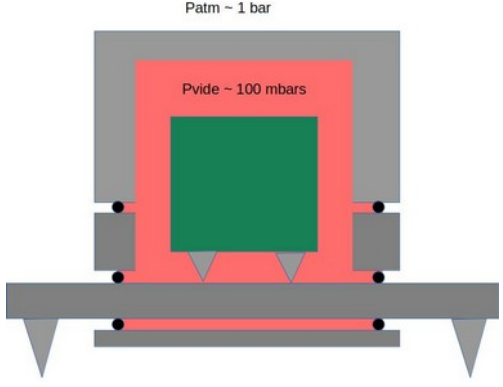
STS-1: Warp-free base plate

- Isobaric stress on base plate

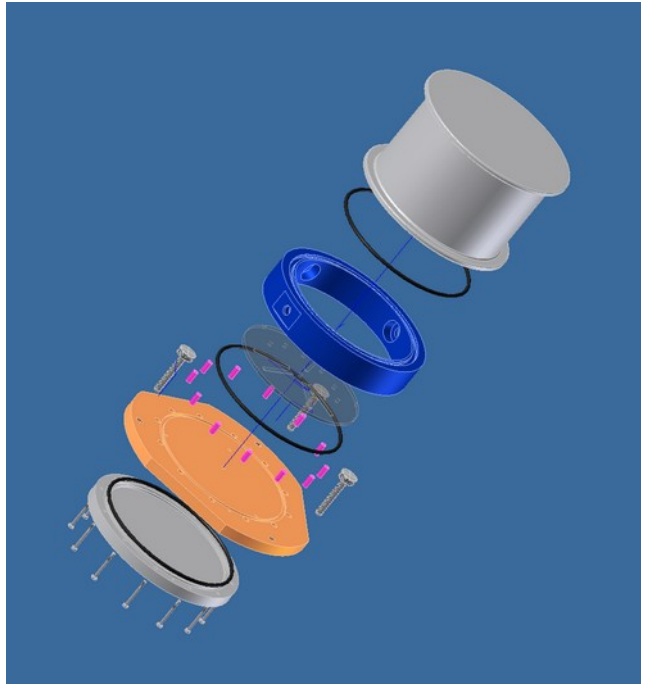
  => No bend



Installation on sand

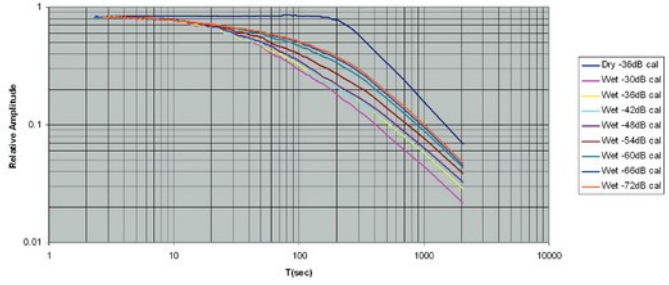


Warp-free base plate

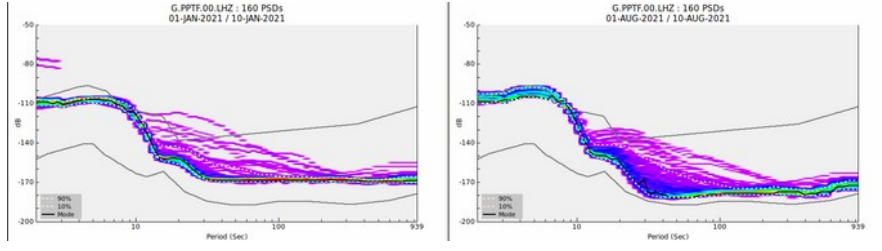


STS-1: Electronics

- Hutt & Ringler have shown non linearity in the electronics due to humidity conditions
  - Hutt, C. & Ringler, Adam. (2011). Some Possible Causes of and Corrections for STS-1 Response Changes in the Global Seismographic Network. Seismological Research Letters.
- The design of a modern electronics was started in 2007 with Berkeley and Metrozet
- Same performances and new features:
  - Only one box instead of 3
  - Remote electrical calibration
  - Remote and automatic mass centering
- But many manufacturing problems
- Discontinued in 2018
  - GEOSCOPE: 5 boxes given by GSN (thanks again!)
  - Can be maintained a few more years ...

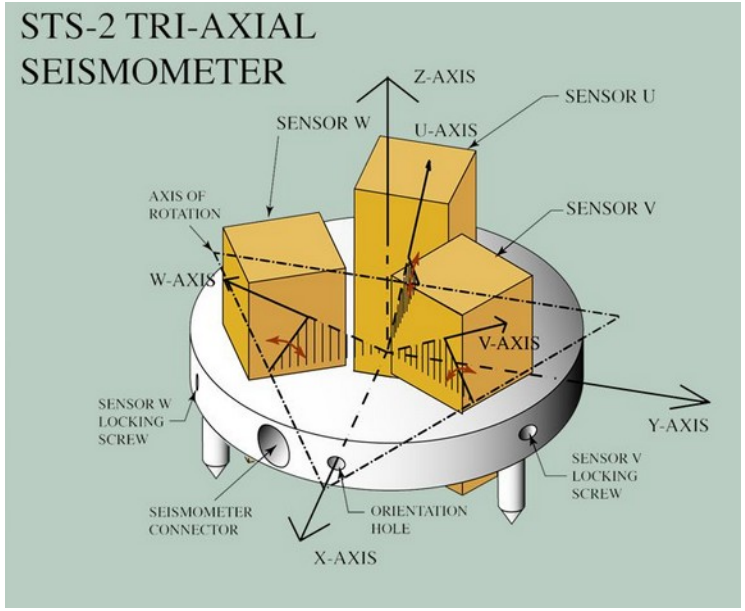


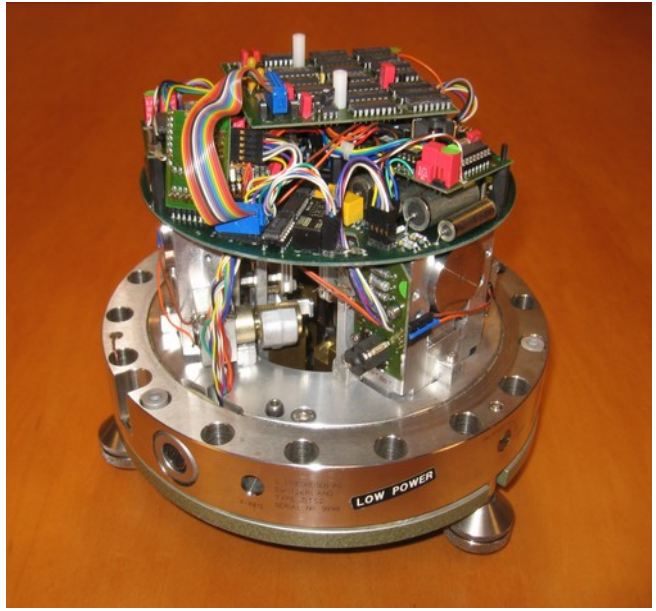
Metrozet E300 electronics box



Bad sensor cable (left), cable changed (right)

STS-2: Galperin Configuration

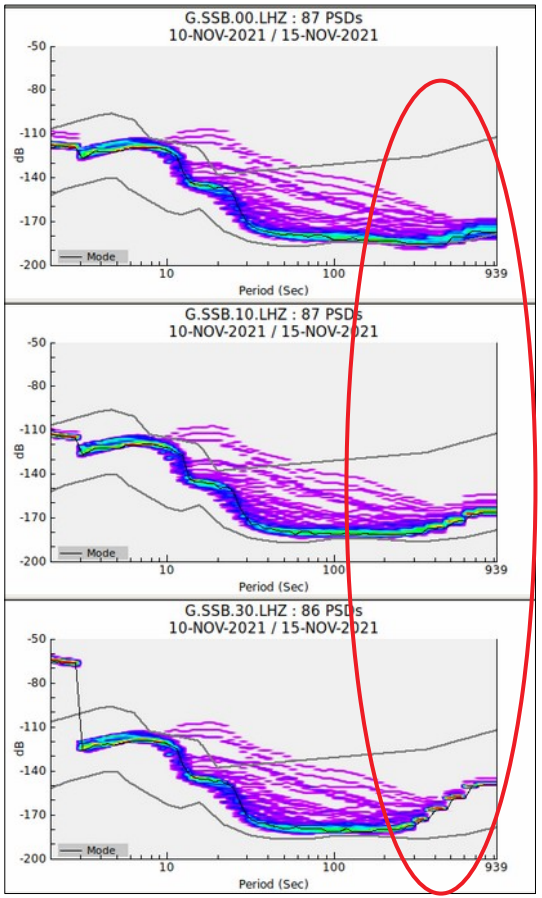




STS-2: Shielding

- Stuttgart shielding / CasSis

Different shielding methods currently being evaluated in EOST (Hélène Jund)

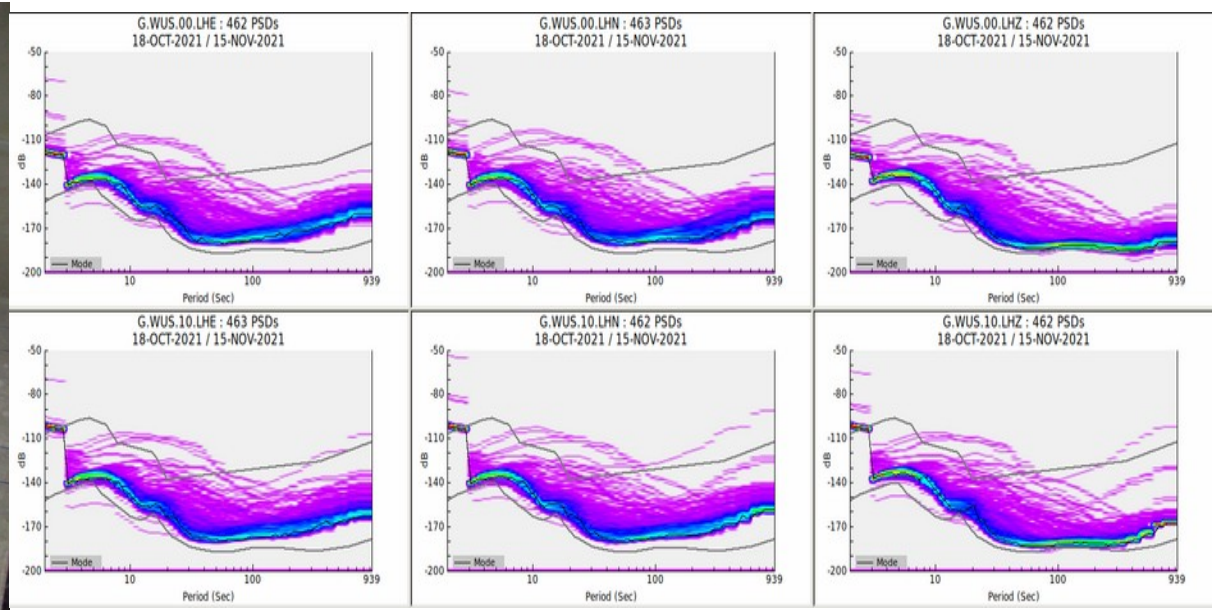


STS-1 Z

STS-2 Z, Full insulation (Stuttgart shielding)

STS-2 Z, thermal protection only

STS-2: WUS, high quality site, simple protection



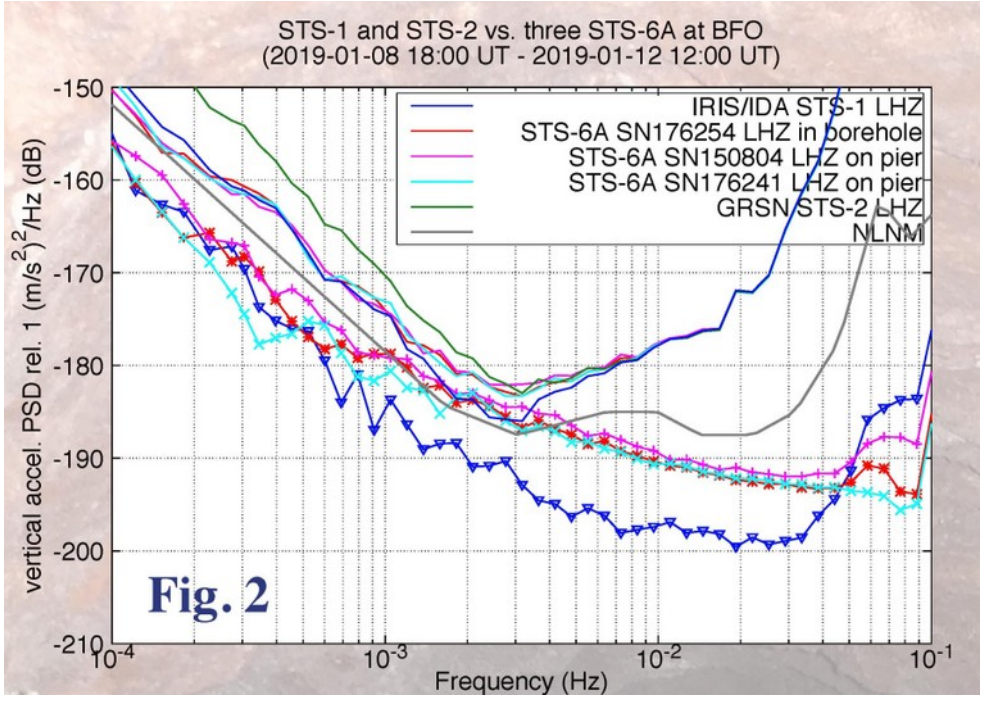
STS-1

STS-2

Streckeisen STS-6A

- Released in 2018
- Posthole / borehole, hole lock system
- 50Hz → 360s
- Equivalent or even « better than the STS-1 »
- Posthole/borehole but also core drilling on existing pier (GSN)
- GEOSCOPE has only 1 unit
- Became discontinued (?) in 2021 …

Tests at BFO



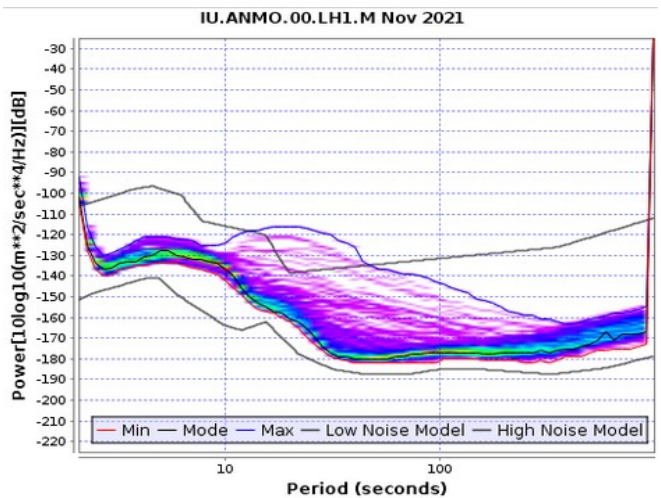
Extracted from online poster:

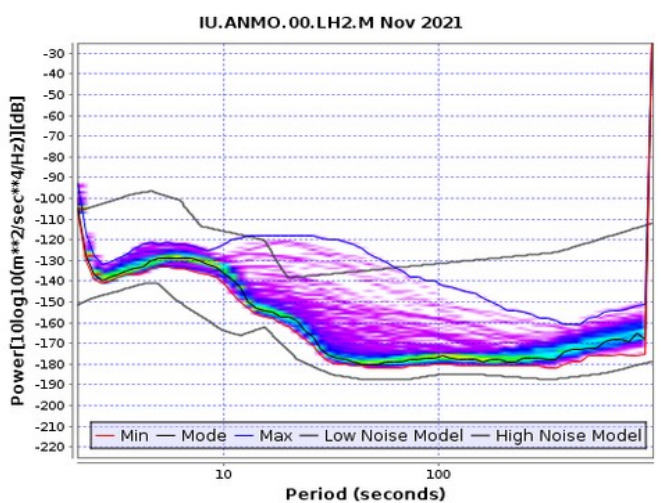
Quest for Optimal Seismometer Installation : Experiments with three STS-6A Seismometers at BFO.

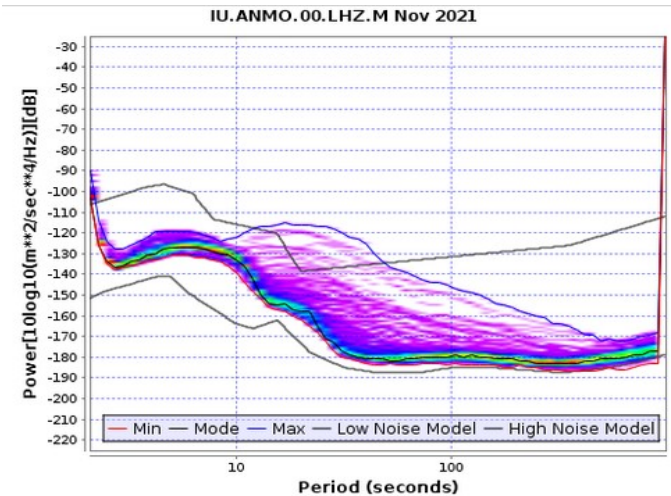
R.Widmer-Schnidring, P. Duffner, T. Forbriger, A. Ringler and R. Freudenmann

STS-6A: IU.ANMO

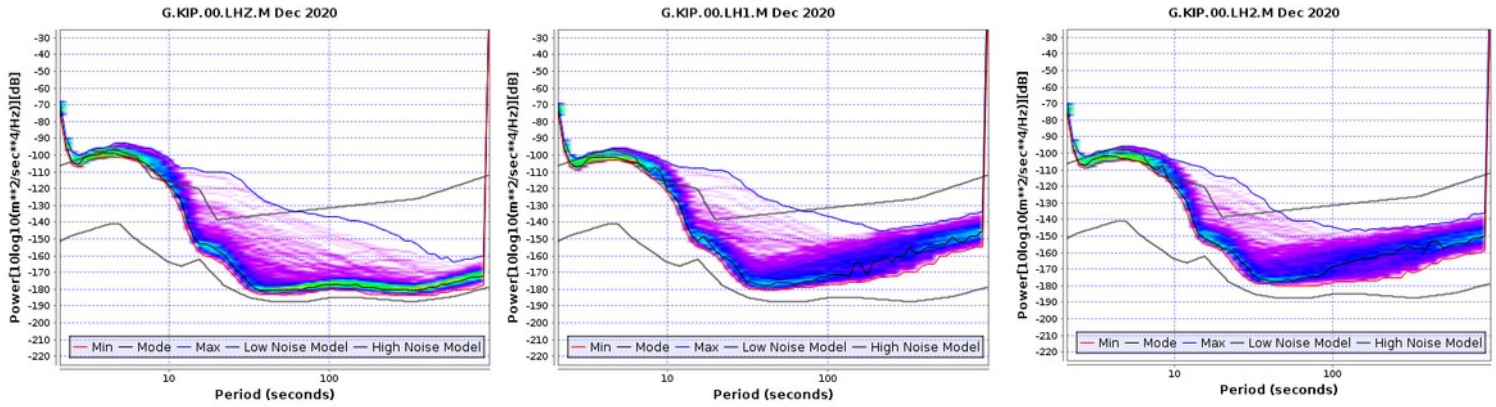
- Depth: 188m
- Remarkable horizontal performances



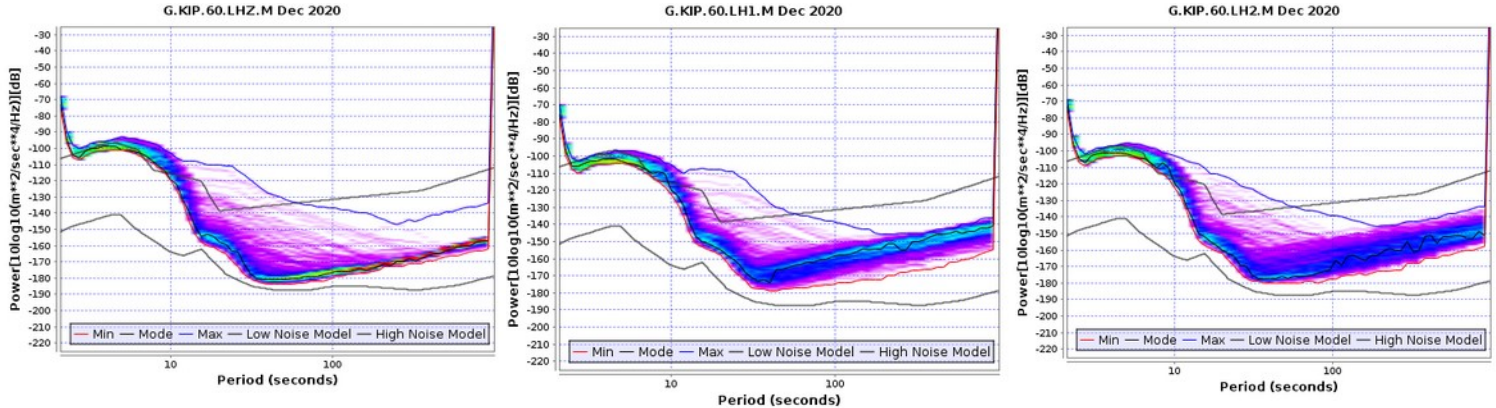




STS-6A: IU/G.KIP



STS-6A

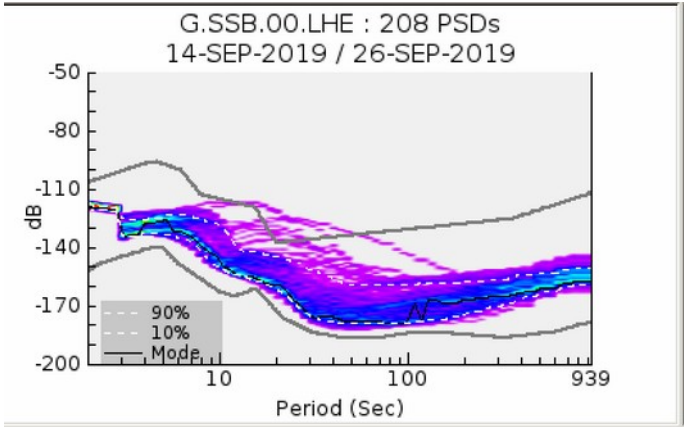


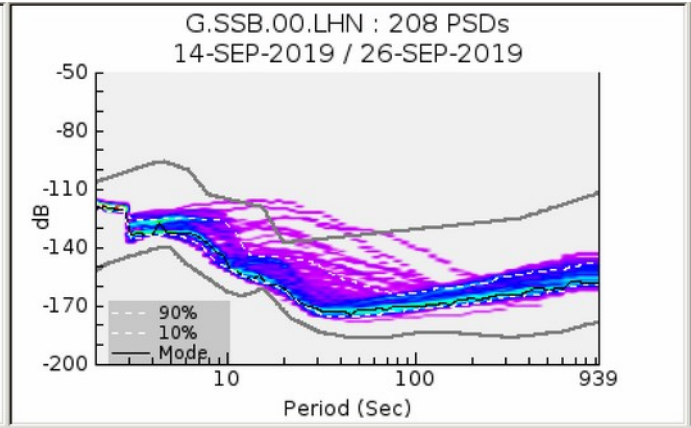
STS-1
(problem on the Z)

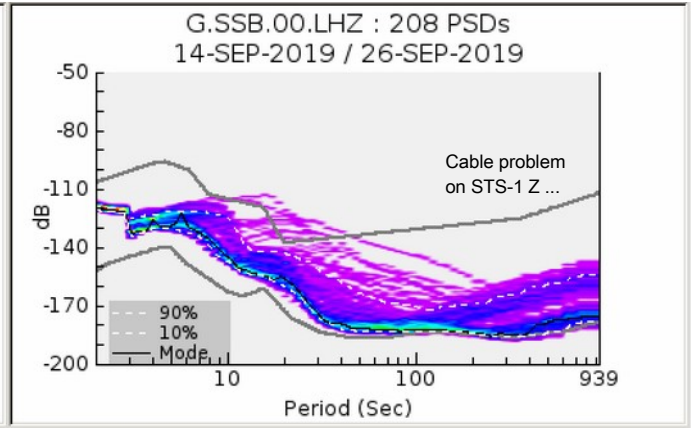
SSB test site

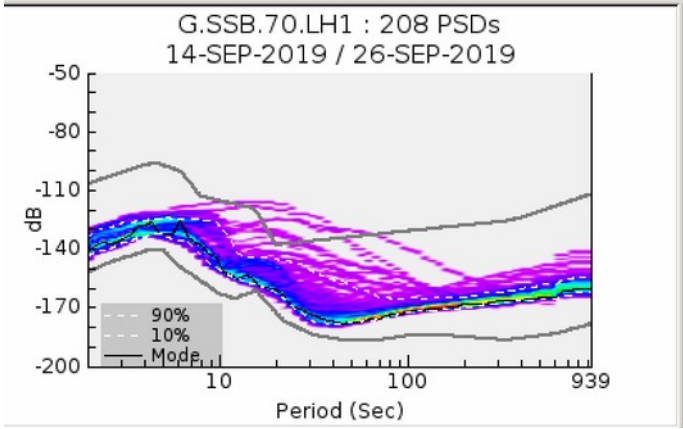
- STS-1 + STS-2 as references
- STS-1 + E300 under test
- 300m old train tunnel in solid rock
- Several piers for vault sensors
- One posthole ~10m depth

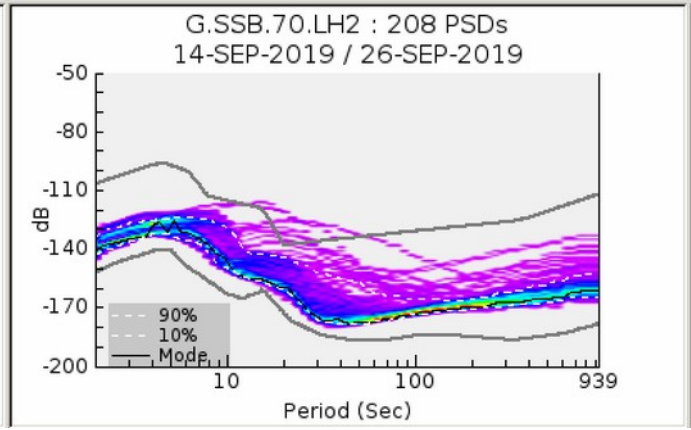
STS-6A : Tests at SSB

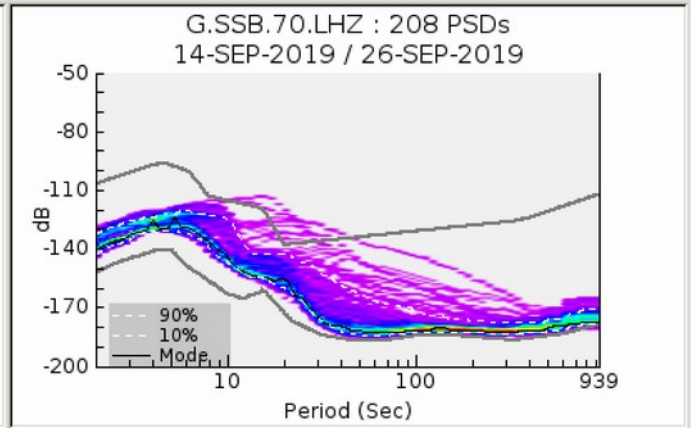






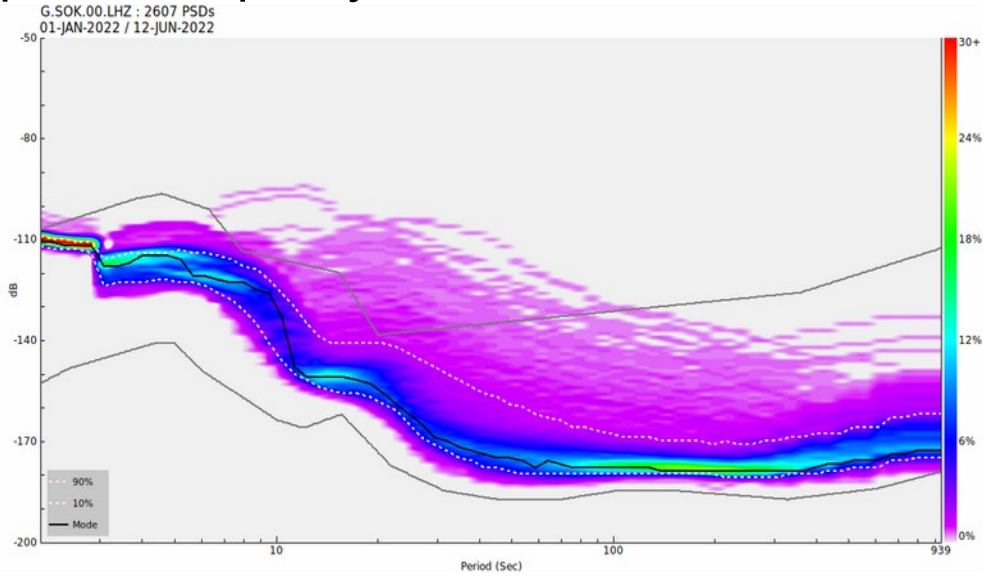






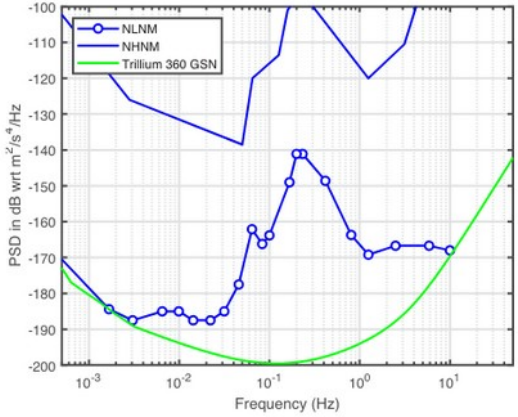
STS-6A: Vertical at SOK

- 4.5m depth only
- Vertical very good
- Horizontal disappointing due to poor site quality
  - 20m depth drilling in november



Nanometrics T360-GSN

- Vault – Posthole – Borehole models
- 50Hz → 360s
- 2 versions : normal and « GSN »
- « vault » version accepted by GSN to replace STS-1
- Easy setup and installation
- Additionnal features with Centaur (remote bubble …)
- Self-noise under NLNM



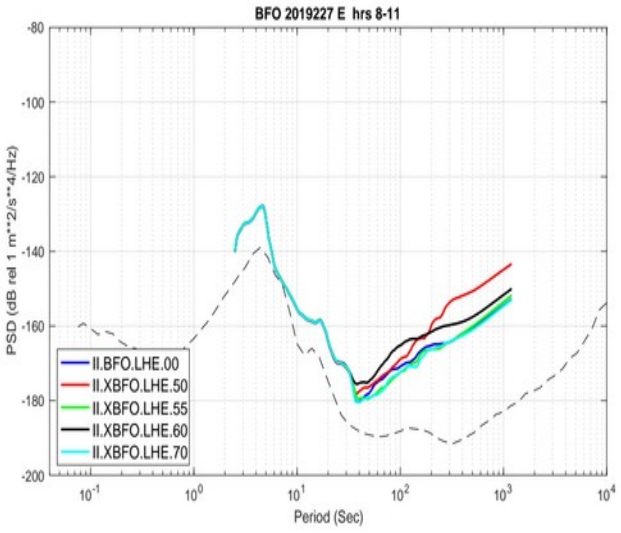
Trillium360
GSN Vault

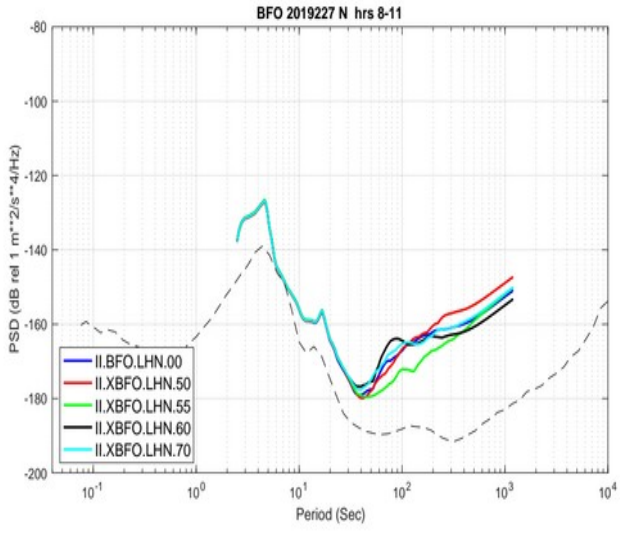
Trillium360
GSN Posthole

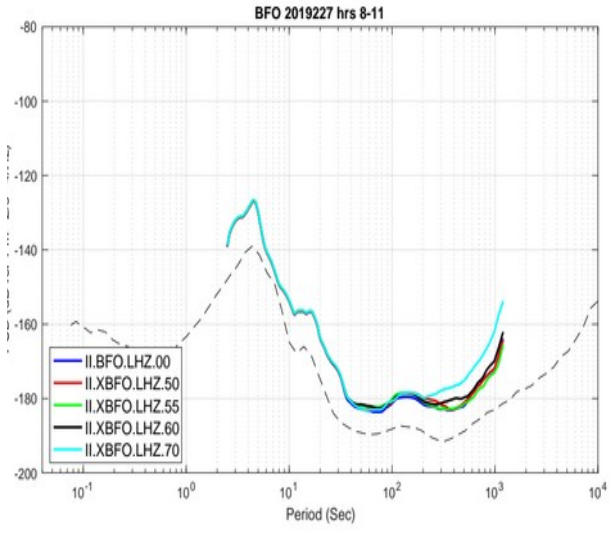
Trillium360
GSN Borehole

T360: GSN results

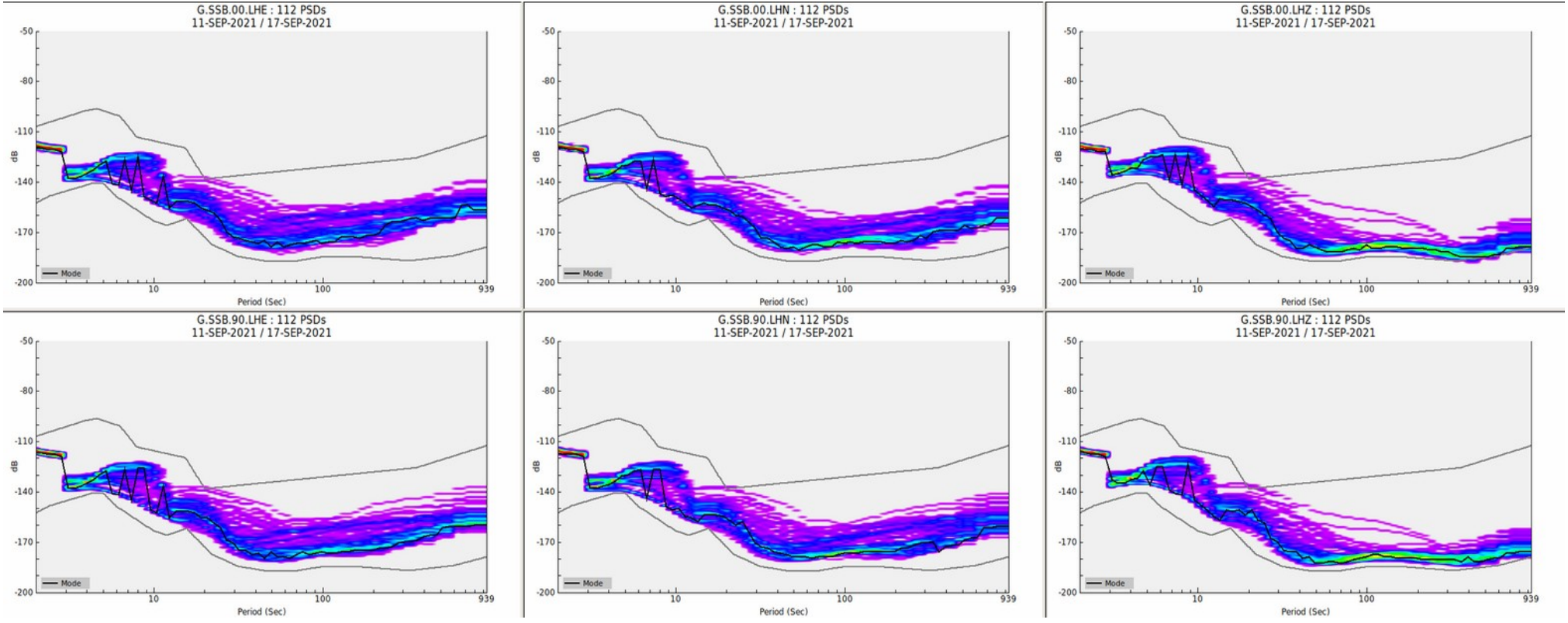
- 3x T360 and 1x STS-6A installed at BFO and compared to STS-1 in 2019
- Very similar performances



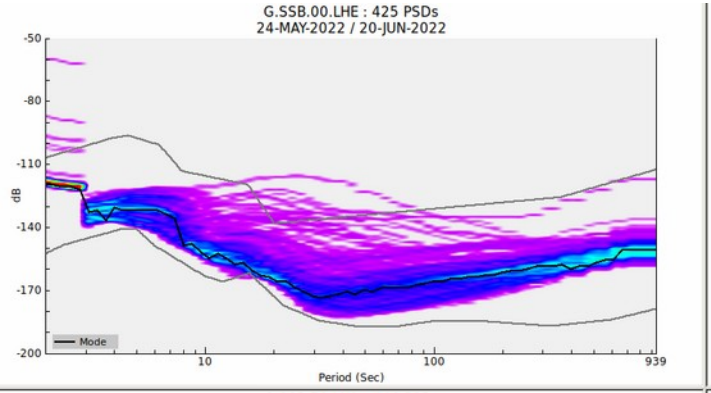


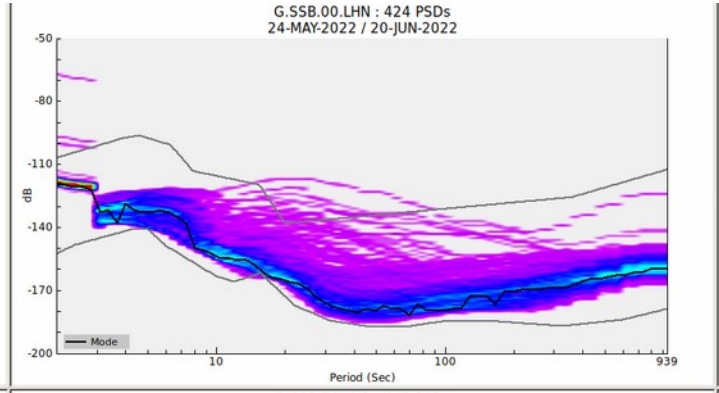


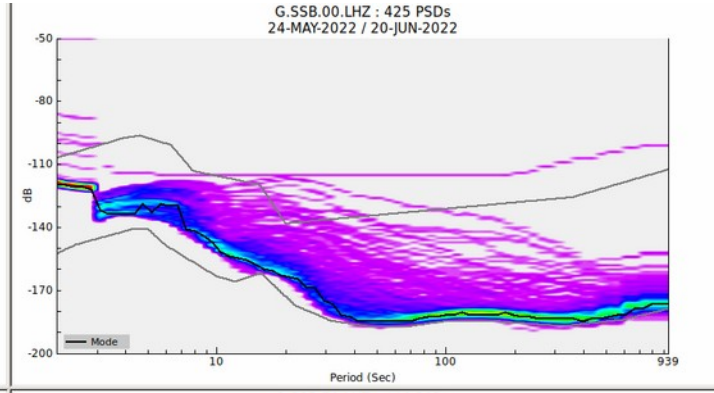
T360-GSN-vault : tests at SSB

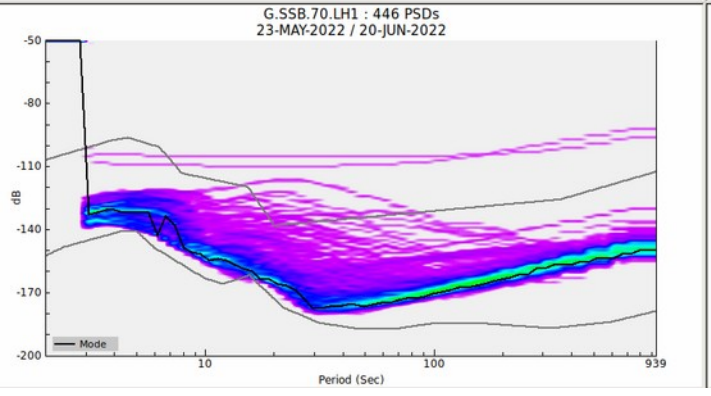


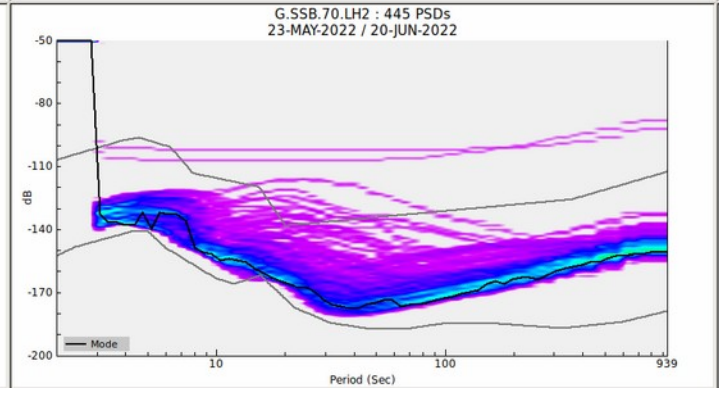
STS-1 / T360PH: tests at SSB

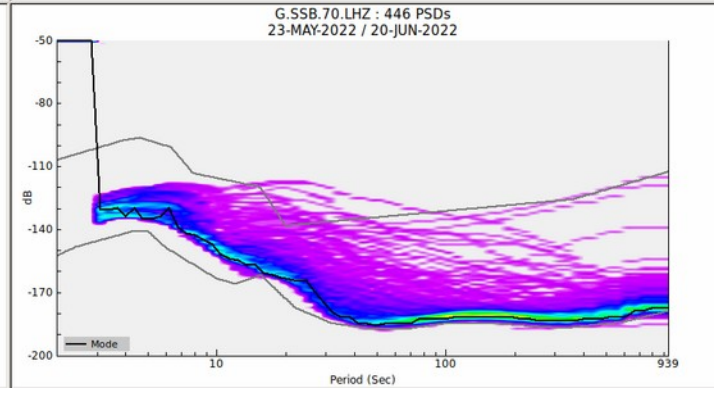






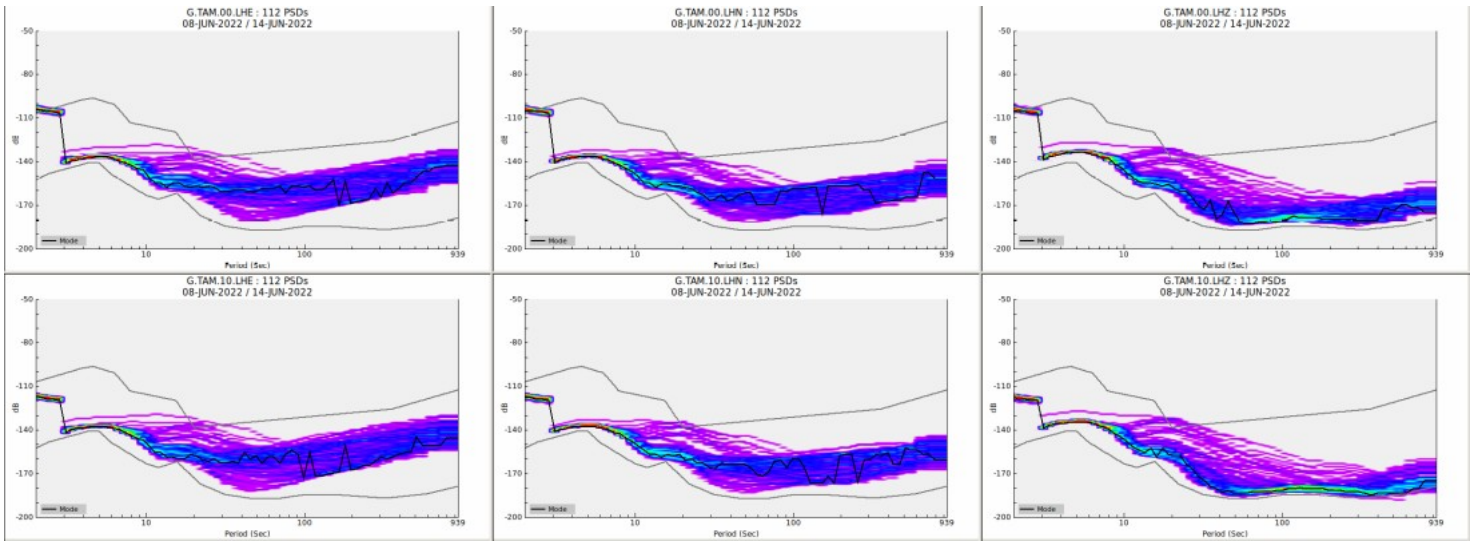






First T360 installed at TAM

- Very promising but not yet as good as the STS-1
  - DCDC regulator sent but not installed
- STS-1 still running old Streckeisen electronics with some malfunctionning periods of time
  - T360 locid 00 – STS-1 locid 10



T360-GSN-vault : power supply sensitivity

- The tests at SSB have shown a high sensitivity to power supply quality
- The charger had a problem
  - peaks on T360 signals but not on STS-2's
  - problem solved with a DC/DC
- An inline DCDC regulator cable is available from Nanometrics

Conclusion

- After a period of doubt, the future is quite clear (at least for GEOSCOPE ...)
- Posthole installations lead to better performances (thermal protection, horizontal noise) but T360-vault can be clearly as good as STS-1 under good conditions
- Is Nanometrics now the only choice ? (STS-7 not tested yet)
- GEOSCOPE :
  - 17 stations STS-1 to double with a new generation sensor (10 years ?)
  - 6 bougth to date (4 Vault + 2 Posthole)
  - First installation of a T360-vault in TAM : remotely possible