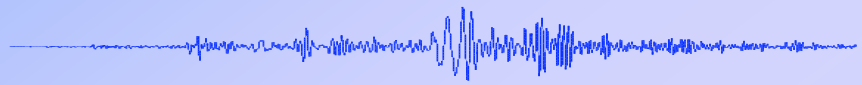
Quality Control at ORFEUS Data Center

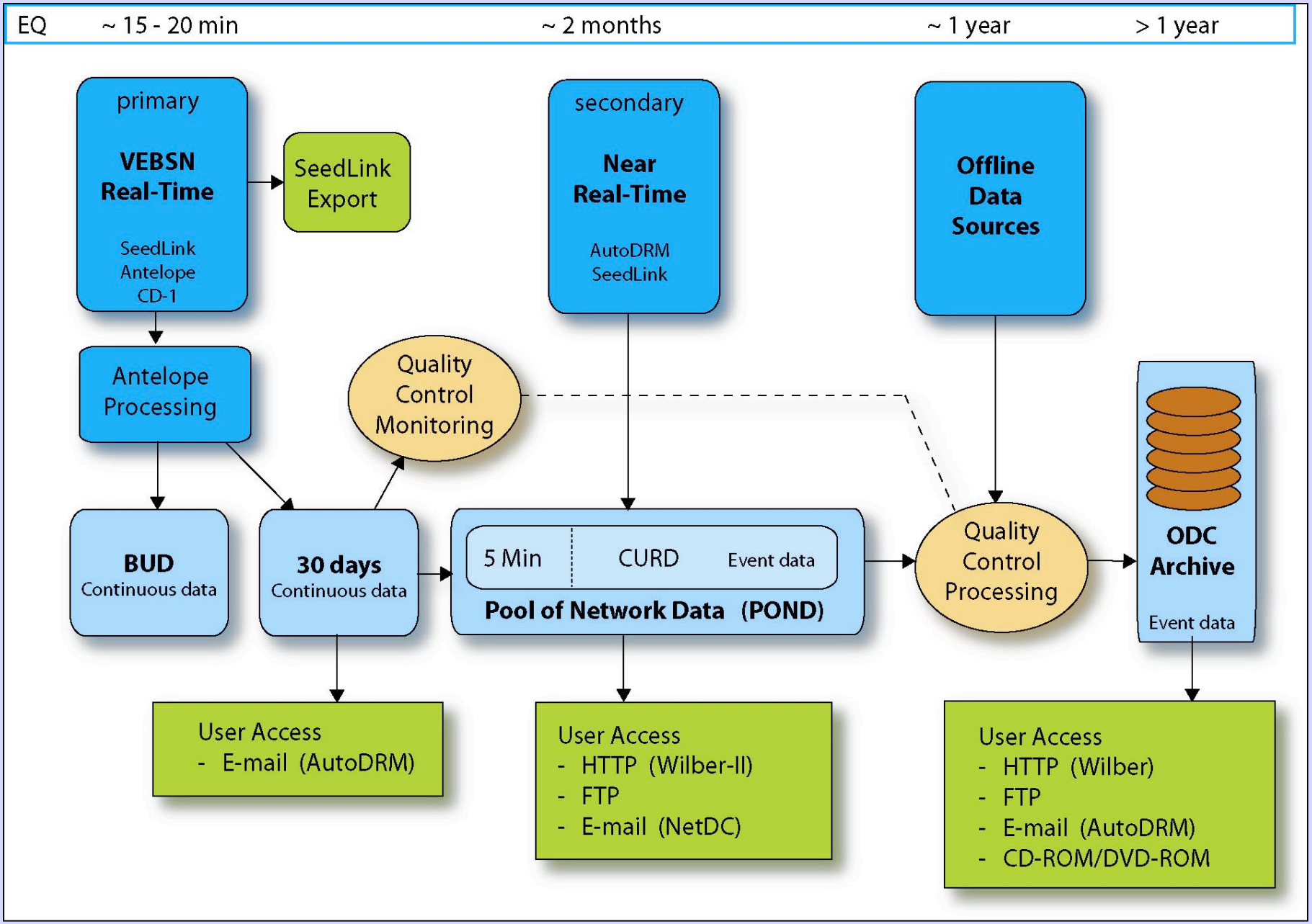


Reinoud Sleeman
ORFEUS Data Center
sleeman @ knmi.nl

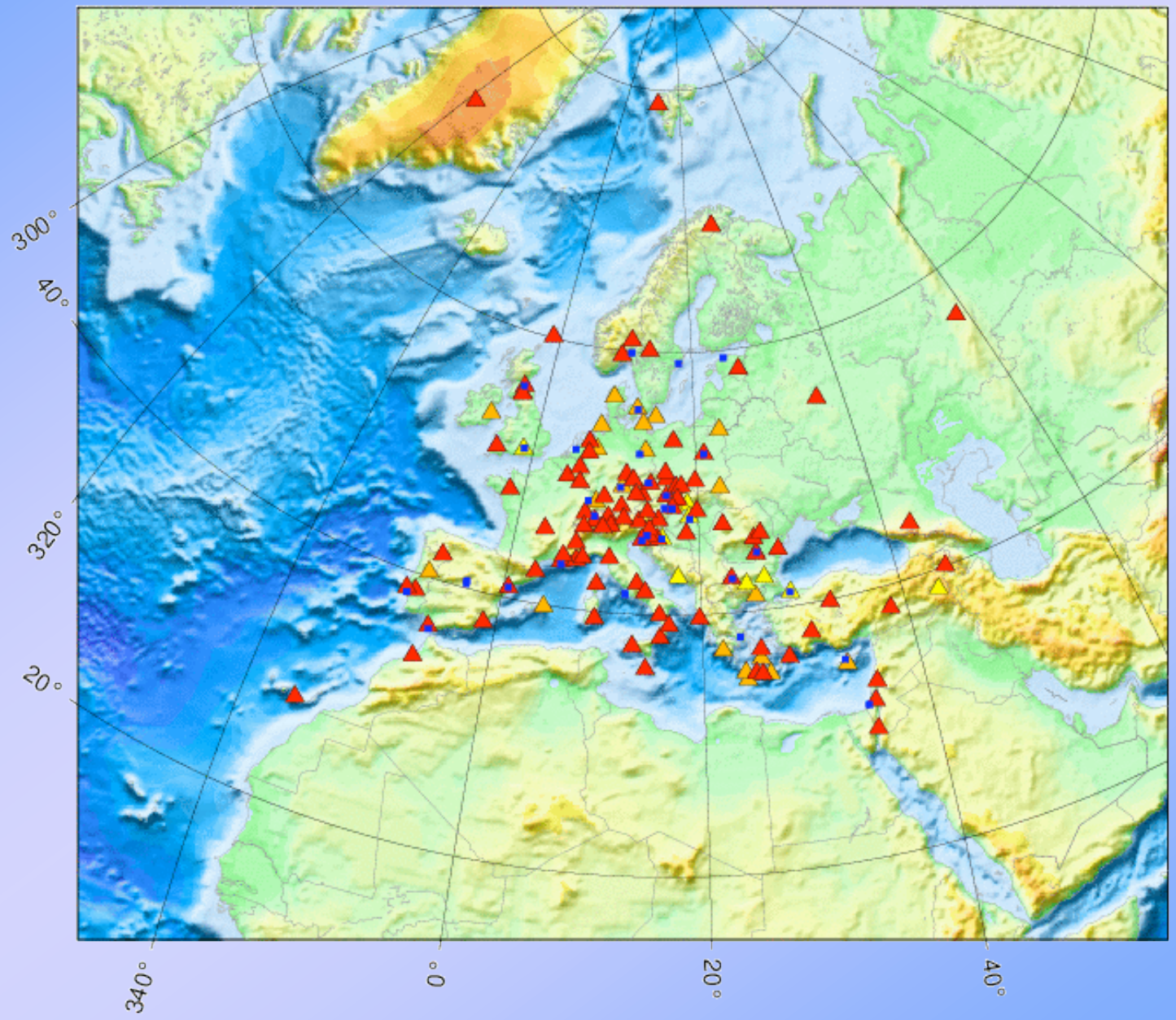
IRIS / ORFEUS Workshop
Understanding and Managing
Information from Seismological Networks

28 Feb – 4 Mar 2005, Palmanova, Italy

Orfeus Data Center: data pipeline



VEBSN – Virtual European Broadband Seismograph Network



Quality Control at ODC: new (RT) stations

- **validation and verification of station information**
  - ⇨ station code (NEIC registered: neic.usgs.gov)
  - ⇨ network code (FDSN registered: www.fdsn.org)
  - ⇨ system information (sensor, digitizer, sampling rate, etc.)
  - ⇨ system response (validation of completeness & consistency)

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- **monitoring of communication and waveform quality (for RT stations)**
  - ⇨ quarantine system (reliability, stability, gaps, time-order, overlaps, …)
  - ⇨ waveform data

Quality Control at ODC: tools

- **Antelope ®**

  communication, gaps, clipping, …..

- **software (**evalresp, PDCC, seedtools, verseed, …)

  SEED problems

seedtools:

- **edit SEED volume**
- **verify SEED volumes**
- **merge multiple SEED volumes**
- **extract SEED subvolumes**
- **repair SEED volumes**
- **build full SEED (dataless + mini-SEED)**
- **~ 100 different options**

Quality Control at ODC: tools

- **Antelope ®**

  communication, gaps, clipping, …..
- **software (**evalresp, PDCC, seedtools, verseed, …)

  SEED problems
- **new development: Quality Control Monitor (QCM)**

  to monitor the quality of the data and the seismic station and

  to verify the seismic information (meta-data, waveform)

Quality Control Monitor (QCM)

Applied on VEBSN

- **overall quality of data versus time (PSD vs. time)**
  - ⇨ monitor changes in behavior of seismic system
  - ⇨ malfunctioning of seismic instrumentation
  - ⇨ changes in response information
  - ⇨ changes in local site conditions
  - ⇨ long term behavior

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  - ⇨ changes in local site conditions
  - ⇨ long term behavior
- **statistical representation**
  - ⇨ statistical distribution of the background noise (PSD vs. freq.)

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  - ⇨ changes or changes in response information
  - ⇨ changes in local site conditions
  - ⇨ long term behavior
- **statistical representation**
  - ⇨ statistical distribution of the background noise (PSD vs. freq.)
- **data availability: StreamView**
  - ⇨ gaps, overlaps, etc.

Overall quality of data versus time (PSD vs. time)

Procedure:

- data extraction (30 min. segments)
  - less than 28 minutes is represented as a gap

Overall quality of data versus time (PSD vs. time)

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  - less than 28 minutes is considered as a gap
- PSD estimation (periodogram averaging, Welch (1967))
  - only positive frequencies (Peterson's noise model)
  - 0.007 Hz - Nyquist frequency
  - PSD smoothing (constant relative bandwidth of 1/10 decade)

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  - only positive frequencies (Peterson's noise model))
  - 0.007 Hz - Nyquist frequency
  - PSD smoothing (constant relative bandwidth of 1/10 decade)
- instrument response deconvolution
  - no digital filters
  - *poles and zeros, normalization factors, total gain*
  - *poles and zeros, recalculated normalization factors, total gain*
  - *total gain only*

PSD estimation (Welsh, 1967):

- **50 % overlapping time sections (~ 800 sec)**
- **tapering (normalized Hanning window)**
- **Fourier transform**
- **Periodogram:** $PSD(f) = \frac{1}{nf}\left|X(f)\right|^2$
- **averaging over the number of time sections**

Synthetic test:

- white noise
- RMS = gain STS-1 sensor x gain digitizer
- Δt = 0.025 sec
- deconvolve for STS-1 response and total gain

  $I(w) = O(w)/H(w)$

Synthetic test:

- white noise
- RMS = gain STS-1 sensor x gain digitizer
- Δt = 0.025 sec
- deconvolve for STS-1 response and total gain

  $I(w) = O(w)/H(w)$

Expected result:

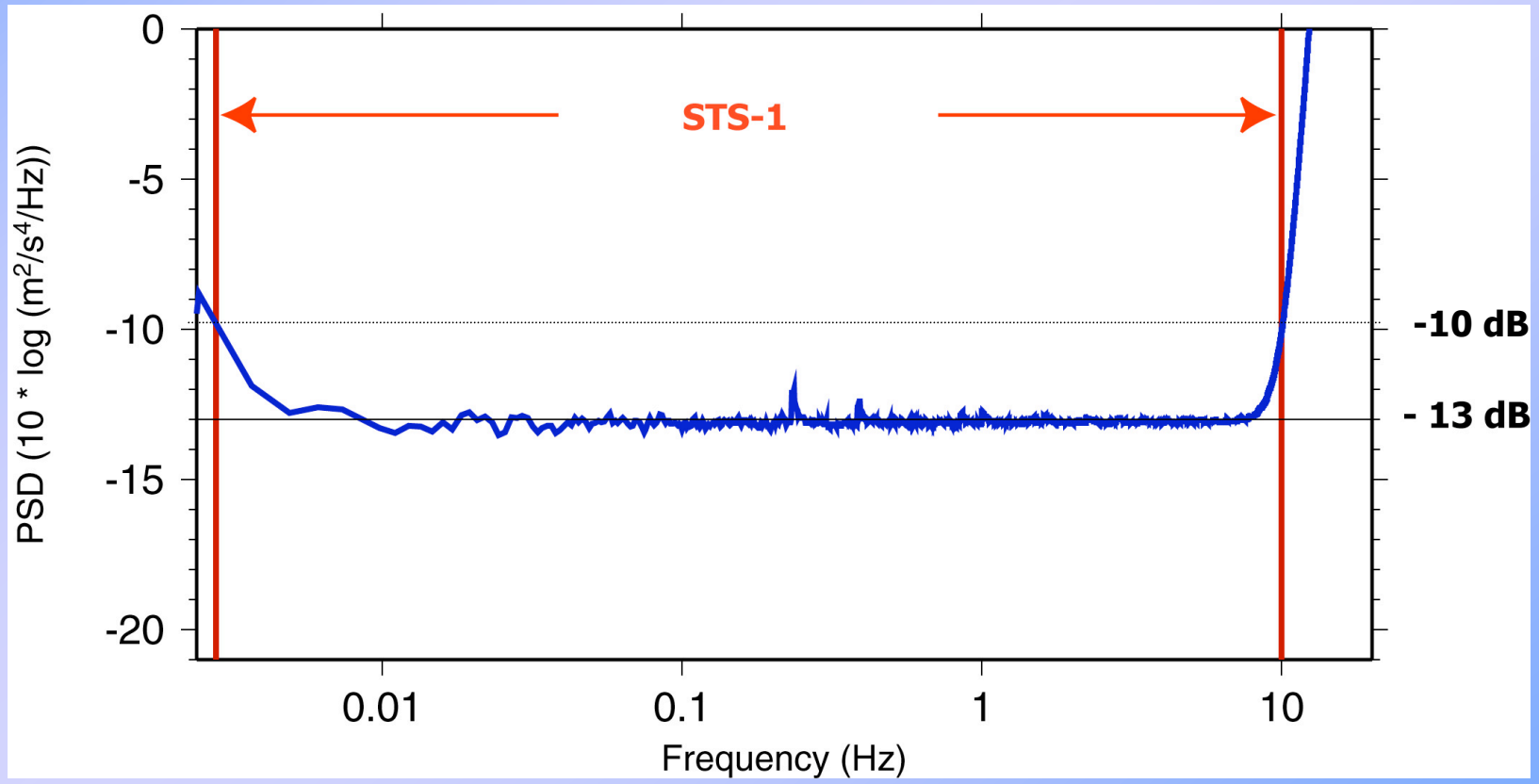
- RMS = 1 [360 sec. – 10 Hz]
- PSD = $10 \cdot \log (2 \times \sigma^2 \times \Delta t)$ (one-sided PSD)

  = -13 dB
- -10 dB @ 360 sec and @ 10 Hz

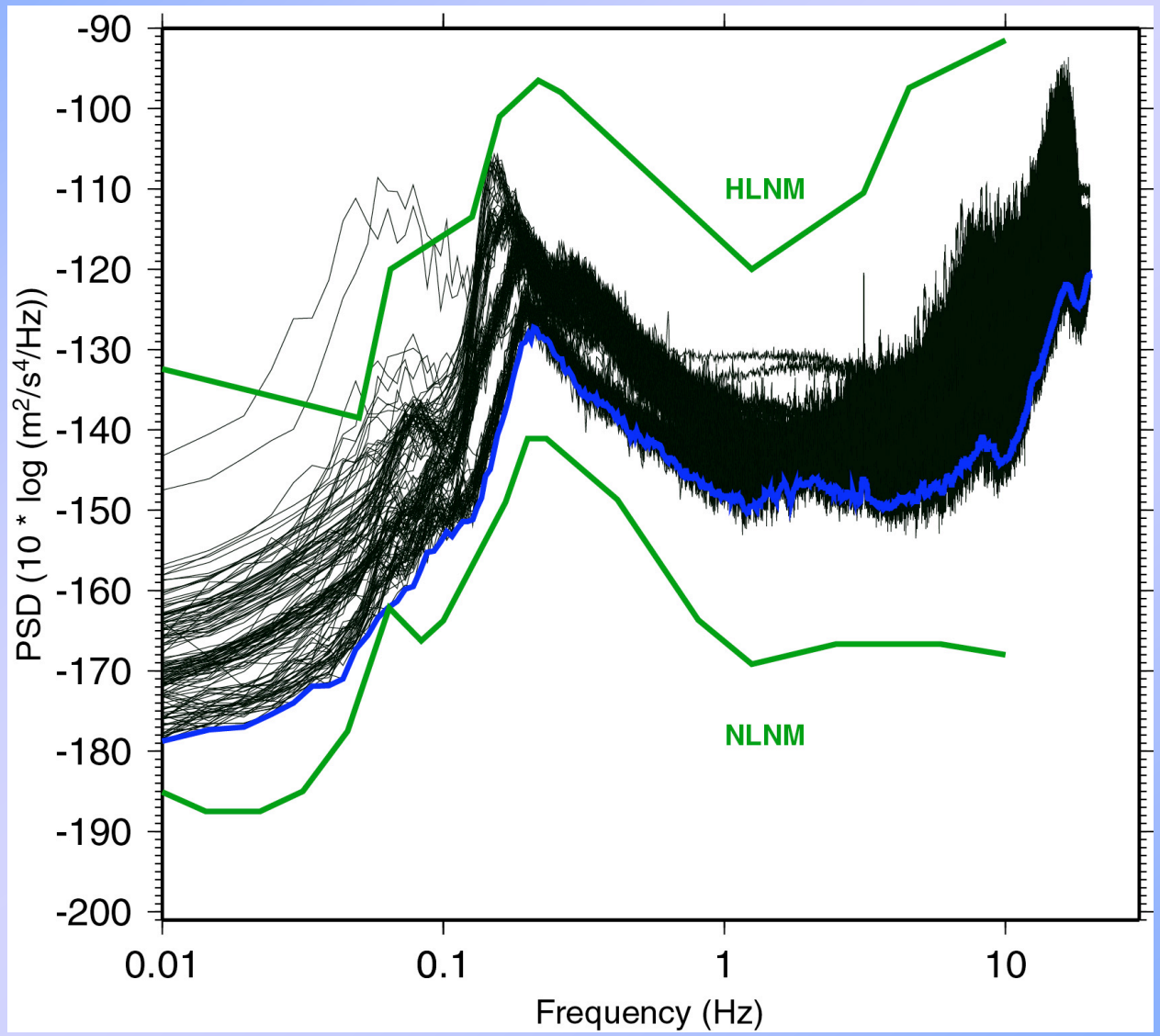
Synthetic test: result

$PSD = 10 \cdot \log (2 \times \sigma^2 \times \Delta t)$ (one-sided PSD)

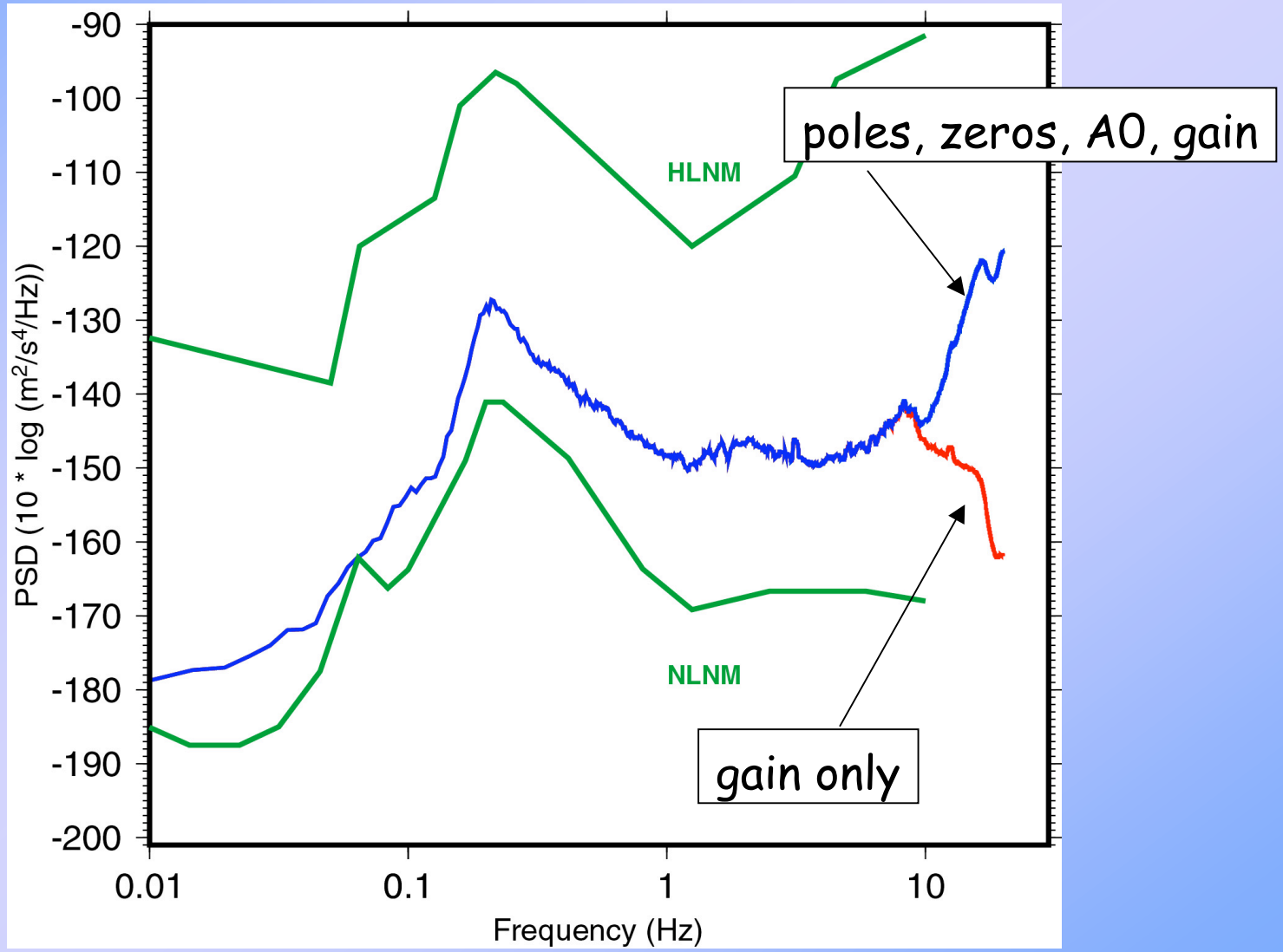
$= -13$ dB



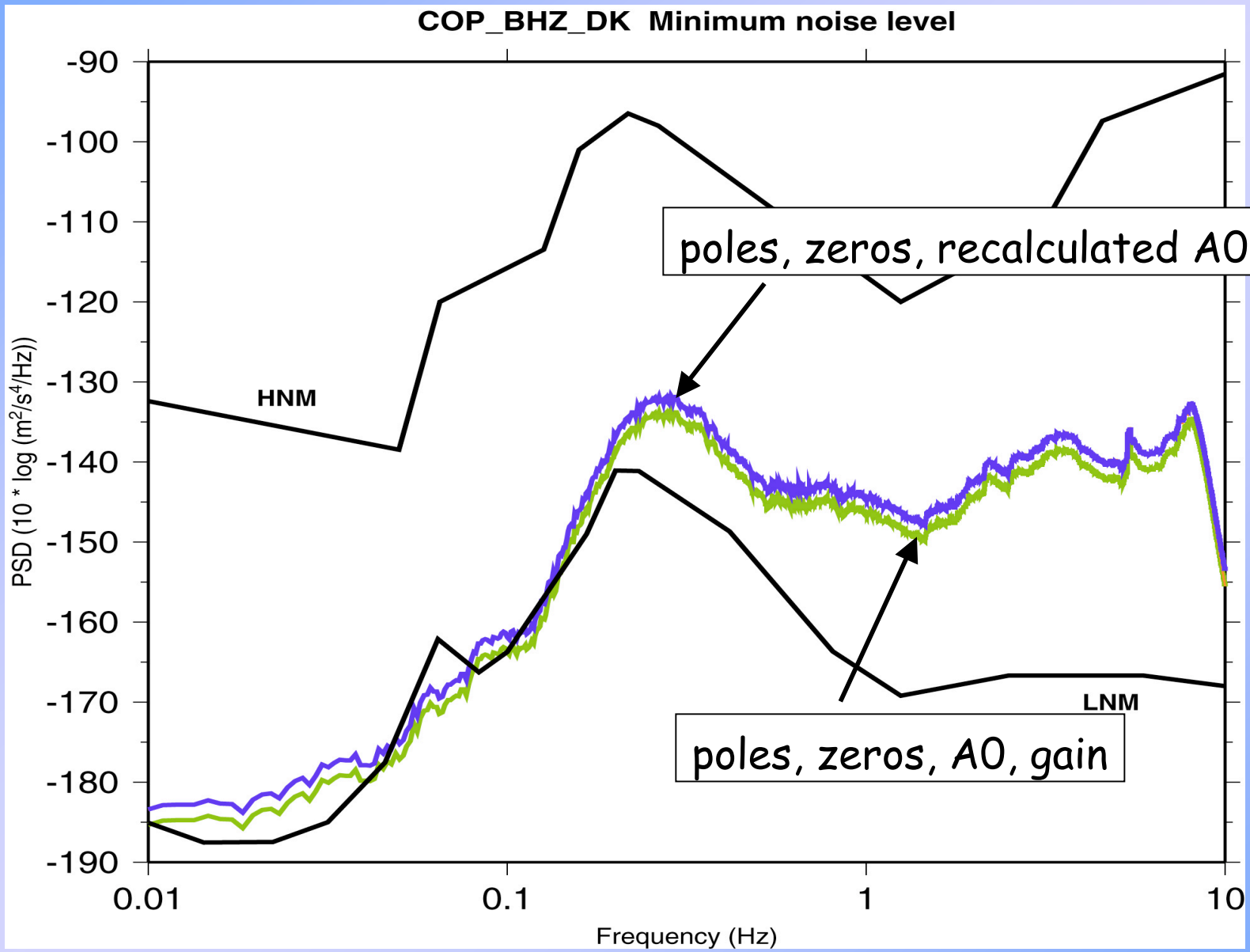
Minimum of smoothed PSD's

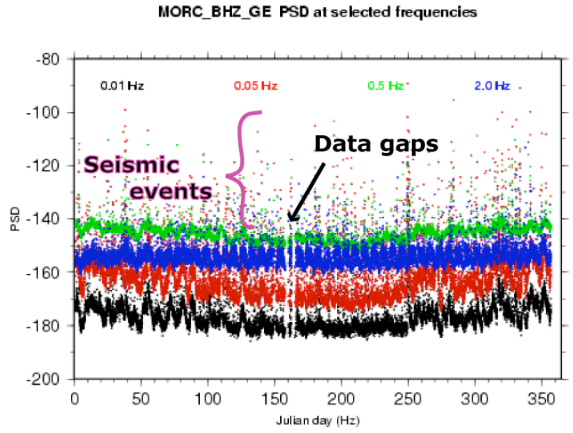


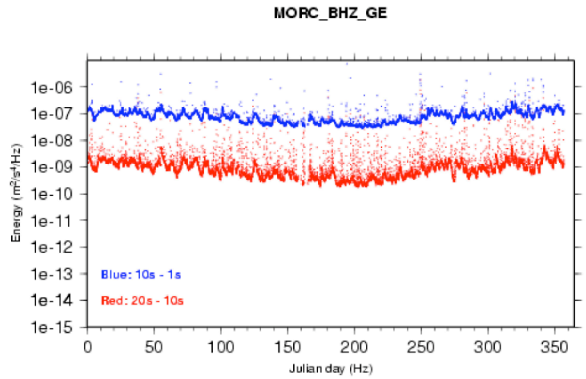
Instrument response deconvolution

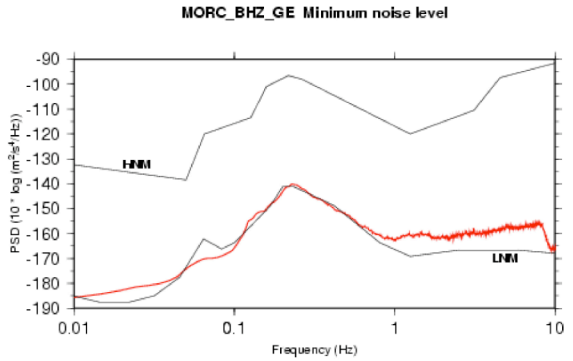


Instrument response deconvolution









PSD vs. time – presentation
(in cooperation with Josep Vila)

PSD at selected frequencies vs. time

(0.01, 0.05, 0.5, 2.0 Hz)

Noise energy in two frequency bands vs. time

(0.05 – 0.1 Hz and 0.1 – 1.0 Hz)

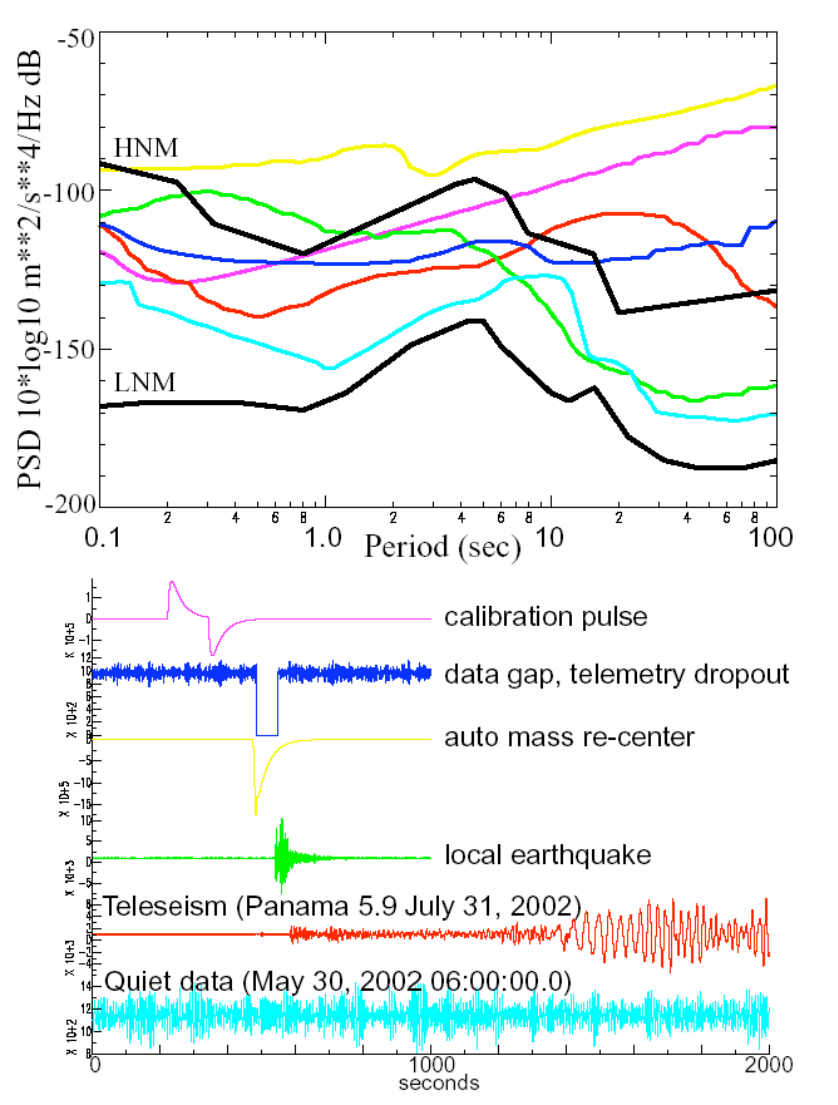
Minimum noise level vs. frequency

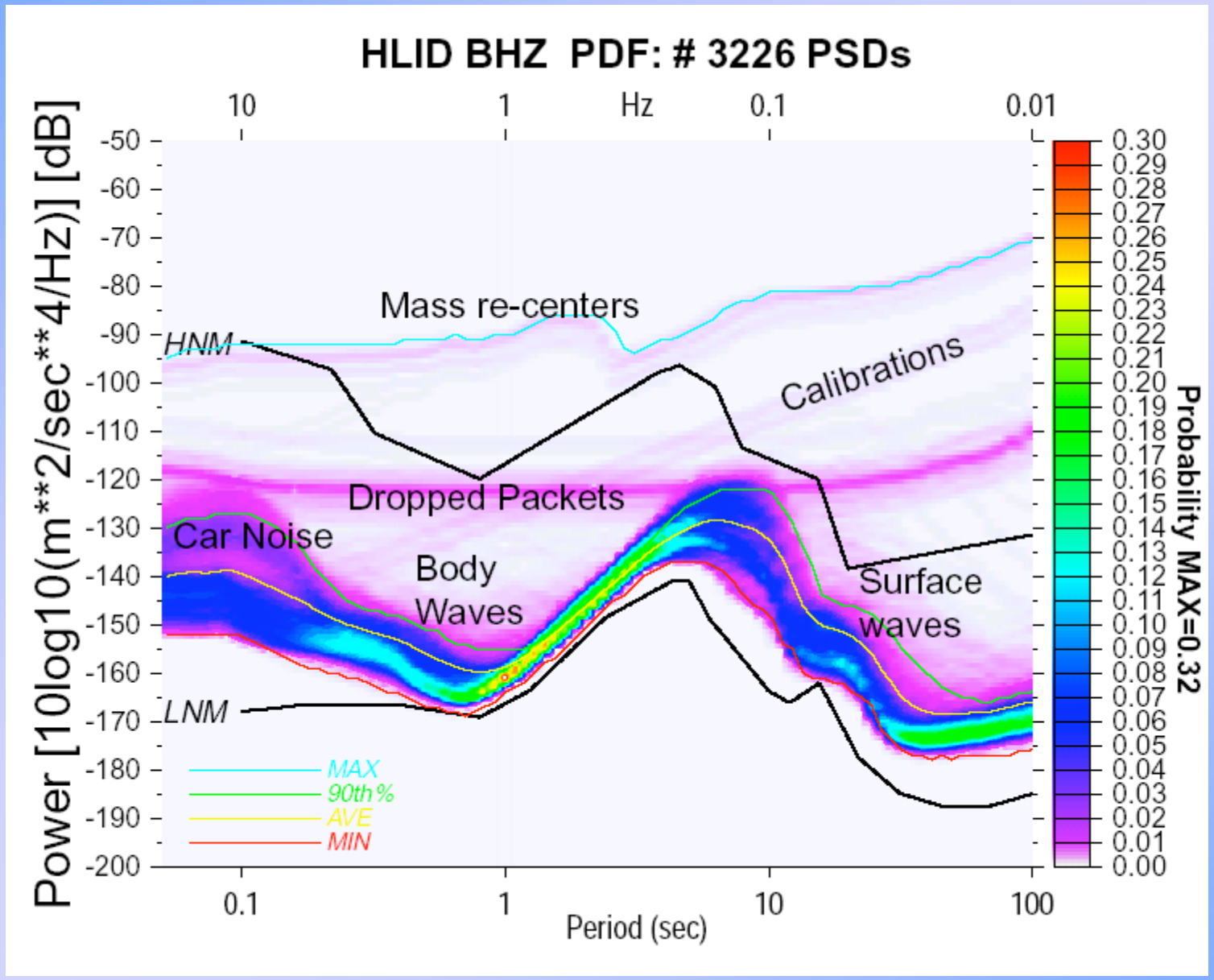
(@ 0.2 Hz above –150 dB)

- poles and zeros, normalization factors, total gain
- poles and zeros, recalculated normalization factors, total gain
- total gain only

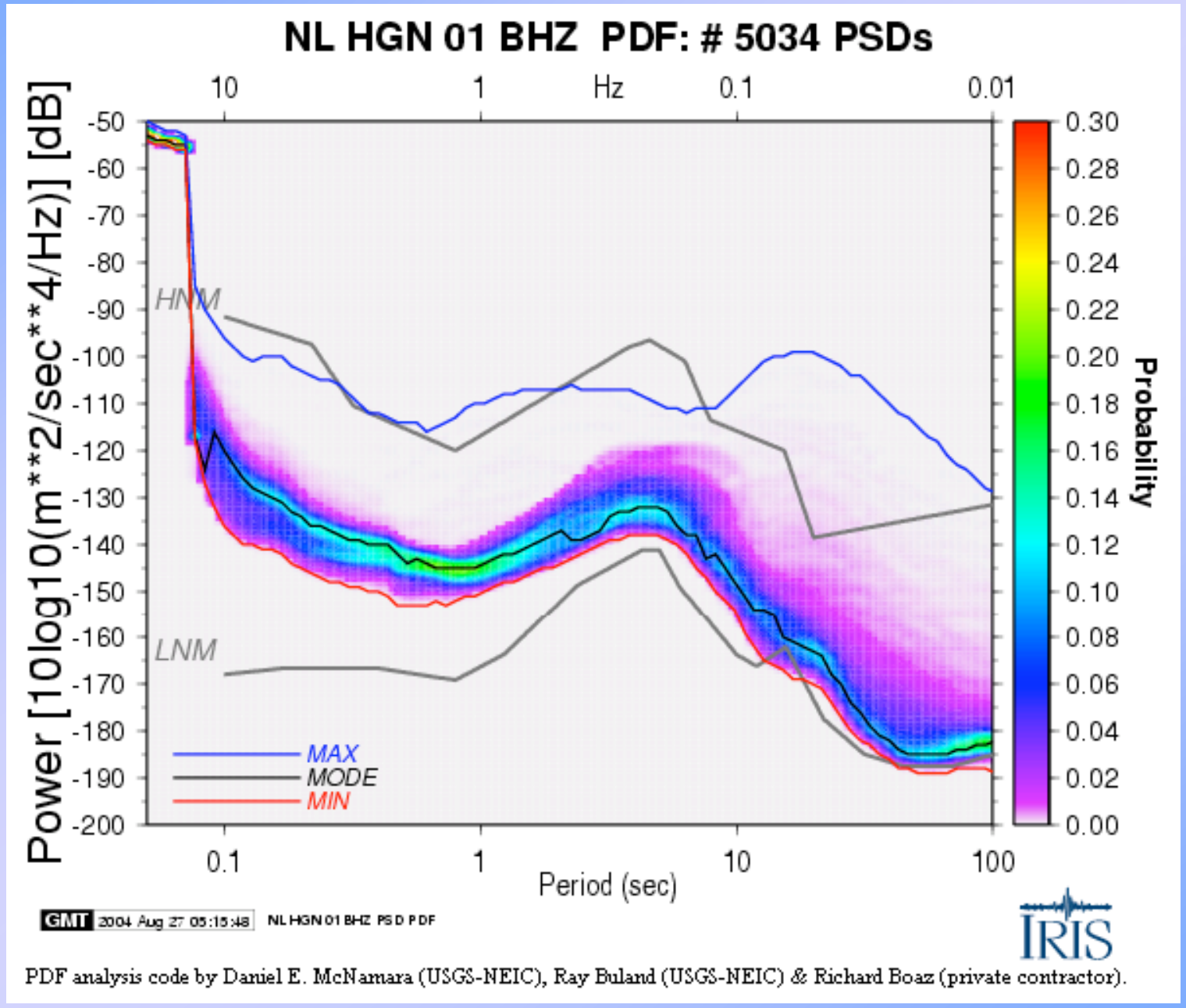
Statisctical distribution of background noise

Procedure (D. McNamara, R. Buland, R. Boaz (IRIS)):




HLID BHZ PDF: # 3226 PSDs
10
1
Hz
0.1
0.01
Power [10log10(m**2/sec**4/Hz)] [dB]
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
Mass re-centers
HNM
Calibrations
Dropped Packets
Car Noise
Body
Waves
Surface
waves
LNM
MAX
90th %
AVE
MIN
0.1
1
10
100
Period (sec)
Probability MAX=0.32
0.30
0.29
0.28
0.27
0.26
0.25
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00

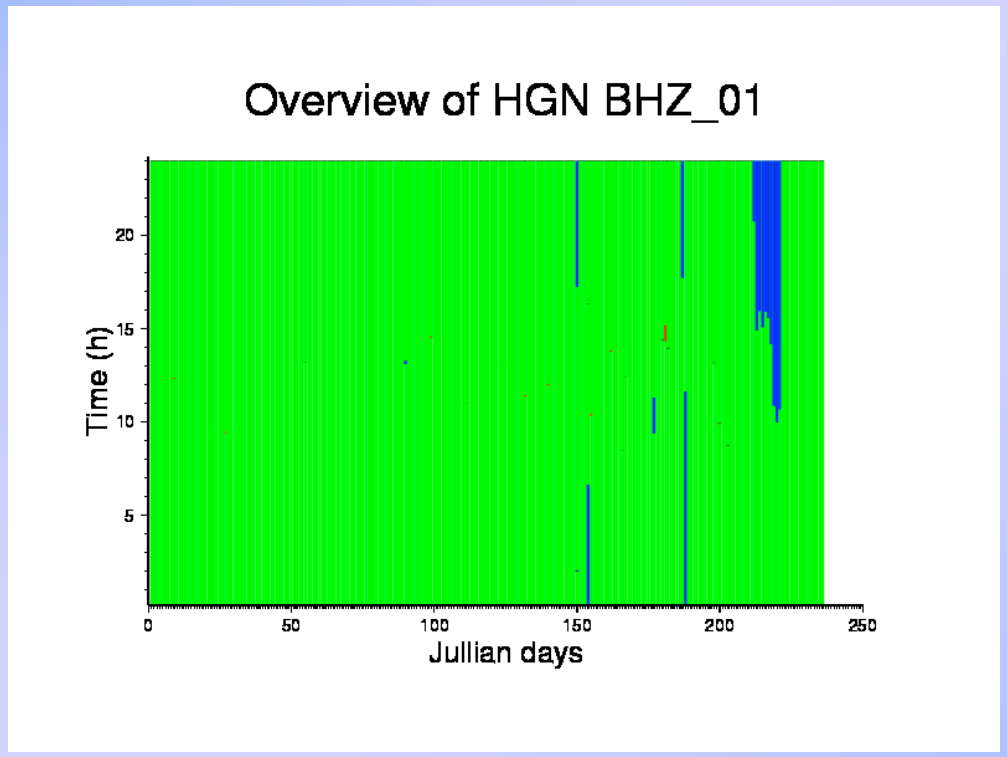
Taken from IRIS DMC



availability of data: StreamView

(in development: Lucas Calje)

⇨ gaps, overlaps, patterns



Data ok

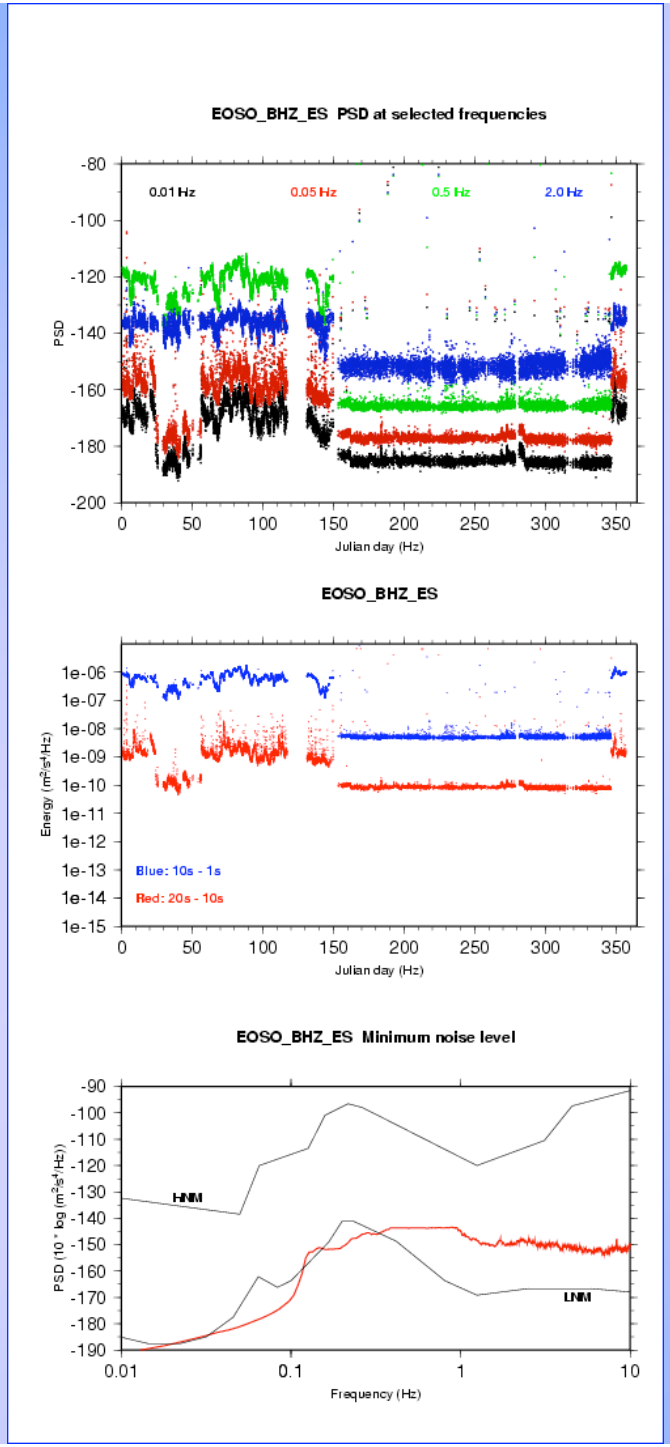
Data overlap

Data gap

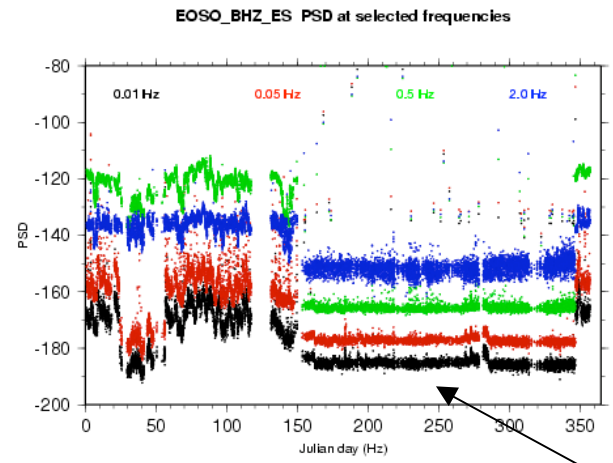
Possible future extensions

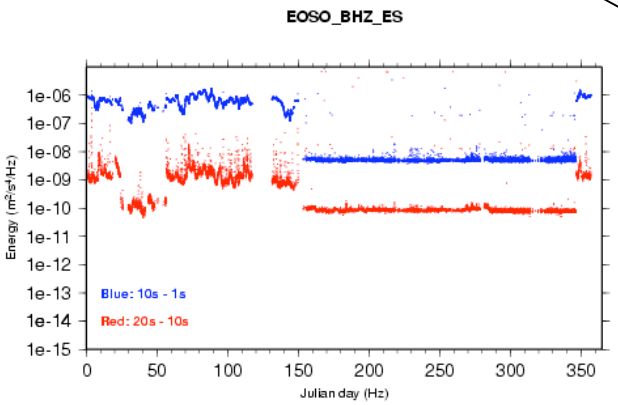
- near real-time processing
- small time-scale waveform data quality monitoring
  (e.g. spikes, clipping, discontinuities)
- detailed quality control monitor (e.g. clock flags, data quality flags)
- improved phase picking, identification
- data compression
- timing
- sensitivity (magnitude)
- …
- automated feedback procedures to network operators

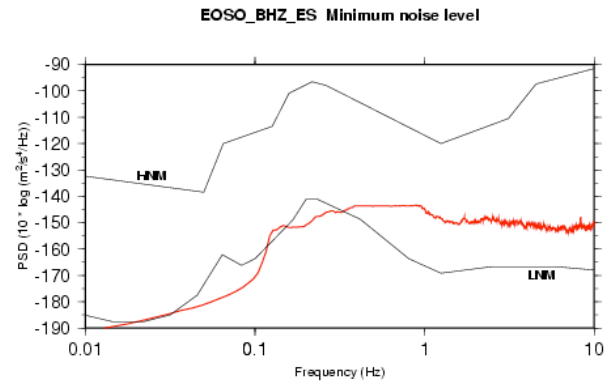
Example 1


EOSO_BHZ_ES PSD at selected frequencies
0.01 Hz
0.05 Hz
0.5 Hz
2.0 Hz
PSD
Julian day (Hz)
EOSO_BHZ_ES
Energy (m²s⁴/Hz)
Blue: 10s - 1s
Red: 20s - 10s
Julian day (Hz)
EOSO_BHZ_ES Minimum noise level
PSD (10 * log (m²s⁴/Hz))
HNM
LNM
Frequency (Hz)

Example 1

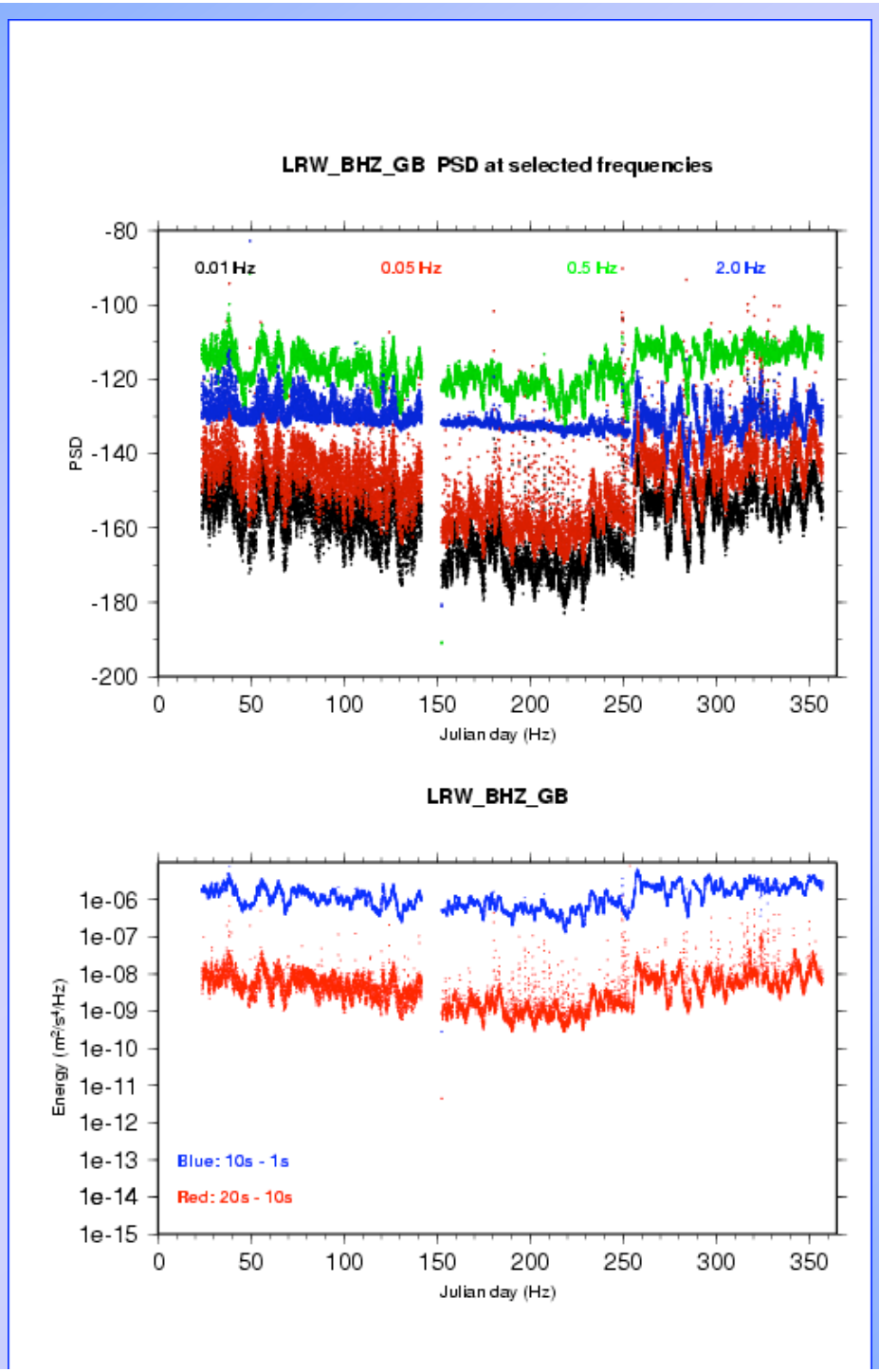




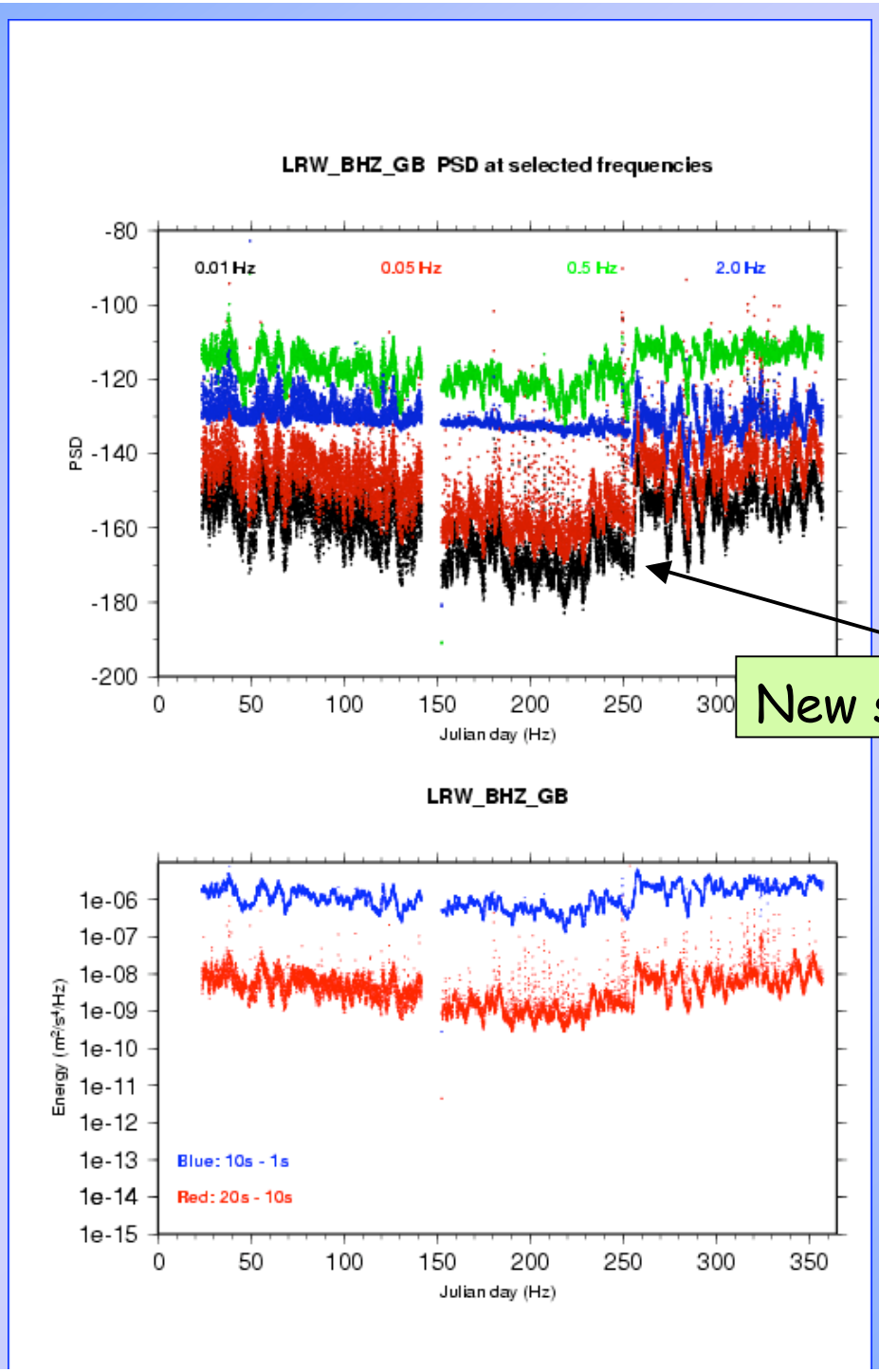


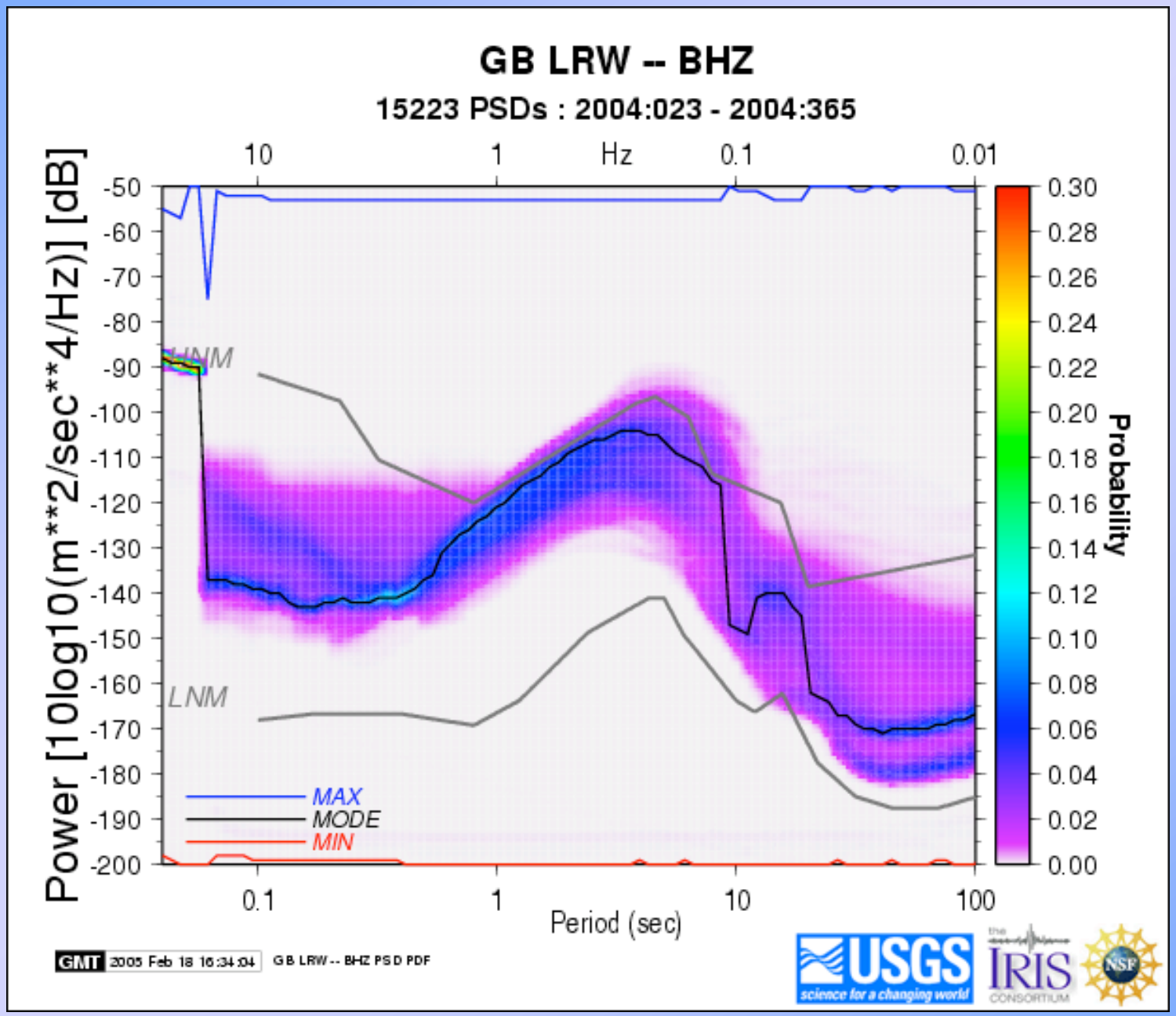
disconnected sensor ?
seems not likely

Example 2

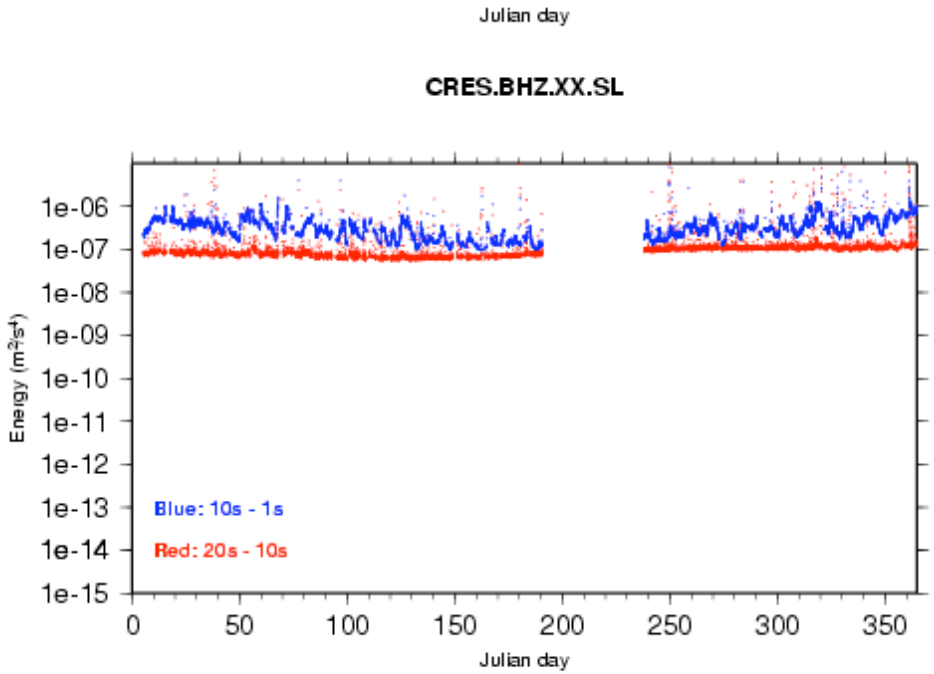

LRW_BHZ_GB PSD at selected frequencies
0.01 Hz
0.05 Hz
0.5 Hz
2.0 Hz
PSD
-80
-100
-120
-140
-160
-180
-200
0
50
100
150
200
250
300
350
Julian day (Hz)
LRW_BHZ_GB
Energy (m²/s⁴/Hz)
1e-06
1e-07
1e-08
1e-09
1e-10
1e-11
1e-12
1e-13
1e-14
1e-15
Blue: 10s - 1s
Red: 20s - 10s
0
50
100
150
200
250
300
350
Julian day (Hz)

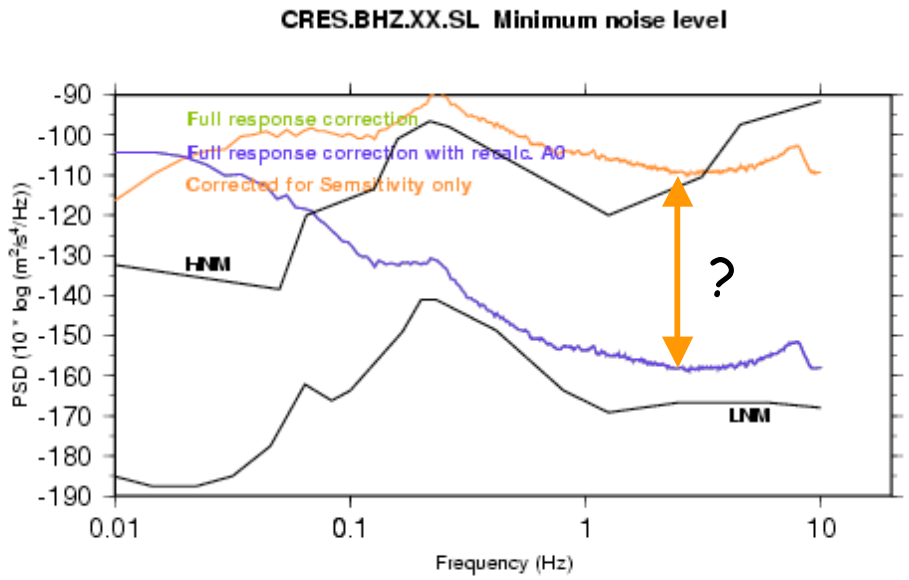
Example 2


LRW_BHZ_GB PSD at selected frequencies
0.01 Hz
0.05 Hz
0.5 Hz
2.0 Hz
PSD
-80
-100
-120
-140
-160
-180
-200
0
50
100
150
200
250
300
Julian day (Hz)
New sensor + digitizer
LRW_BHZ_GB
Energy (m²/s⁴/Hz)
1e-06
1e-07
1e-08
1e-09
1e-10
1e-11
1e-12
1e-13
1e-14
1e-15
Blue: 10s - 1s
Red: 20s - 10s
0
50
100
150
200
250
300
350
Julian day (Hz)

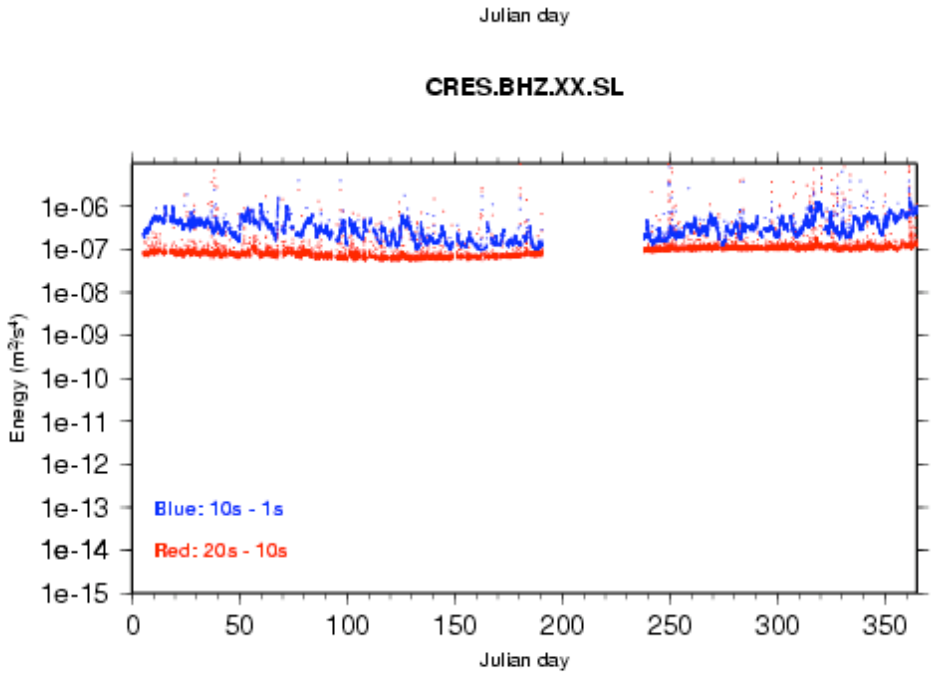

GB LRW -- BHZ
15223 PSDs : 2004:023 - 2004:365
10
1
Hz
0.1
0.01
Power [10log10(m**2/sec**4/Hz)] [dB]
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
HNM
LNM
MAX
MODE
MIN
0.1
1
10
100
Period (sec)
Probability
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
GMT 2005 Feb 18 16:34:04
GB LRW -- BHZ PSD PDF
USGS
science for a changing world
IRIS
CONSORTIUM
NSF

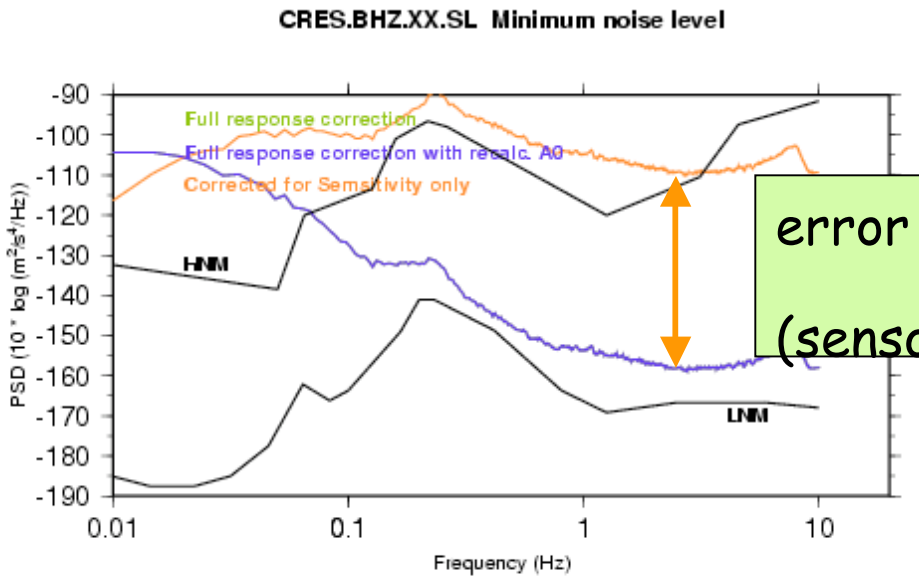
Example 3


Julian day
CRES.BHZ.XX.SL
Energy (m²s⁴)
1e-06
1e-07
1e-08
1e-09
1e-10
1e-11
1e-12
1e-13
1e-14
1e-15
Blue: 10s - 1s
Red: 20s - 10s
0
50
100
150
200
250
300
350
Julian day


CRES.BHZ.XX.SL Minimum noise level
PSD (10 * log (m²s⁴/Hz))
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
Full response correction
Full response correction with recalc. A0
Corrected for Sensitivity only
HNM
LNM
?
0.01
0.1
1
10
Frequency (Hz)

Example 3

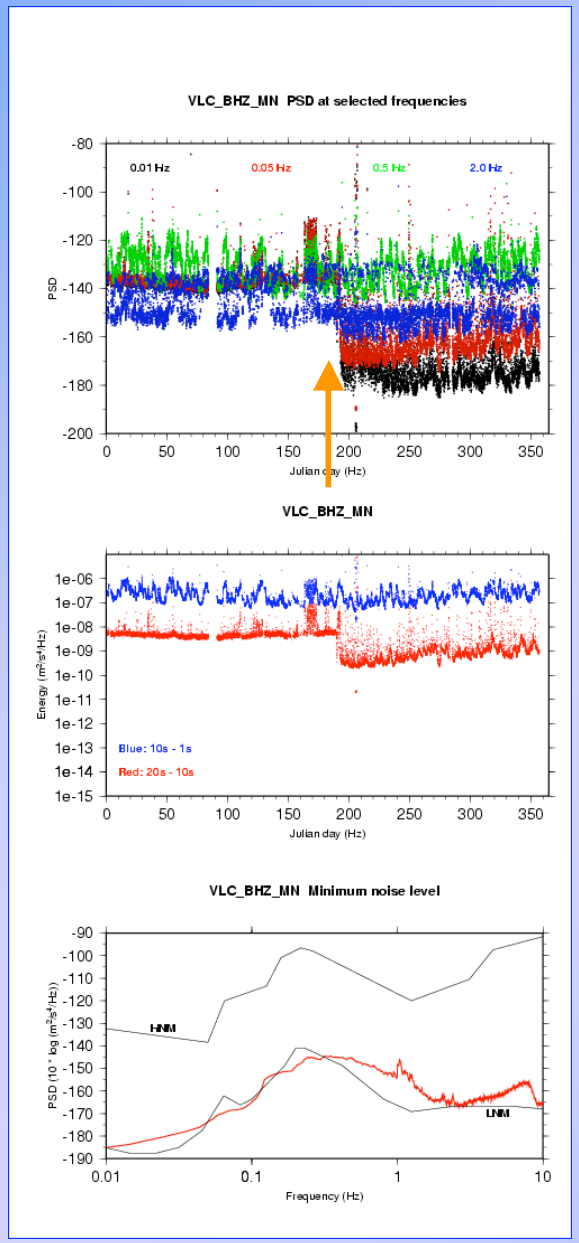




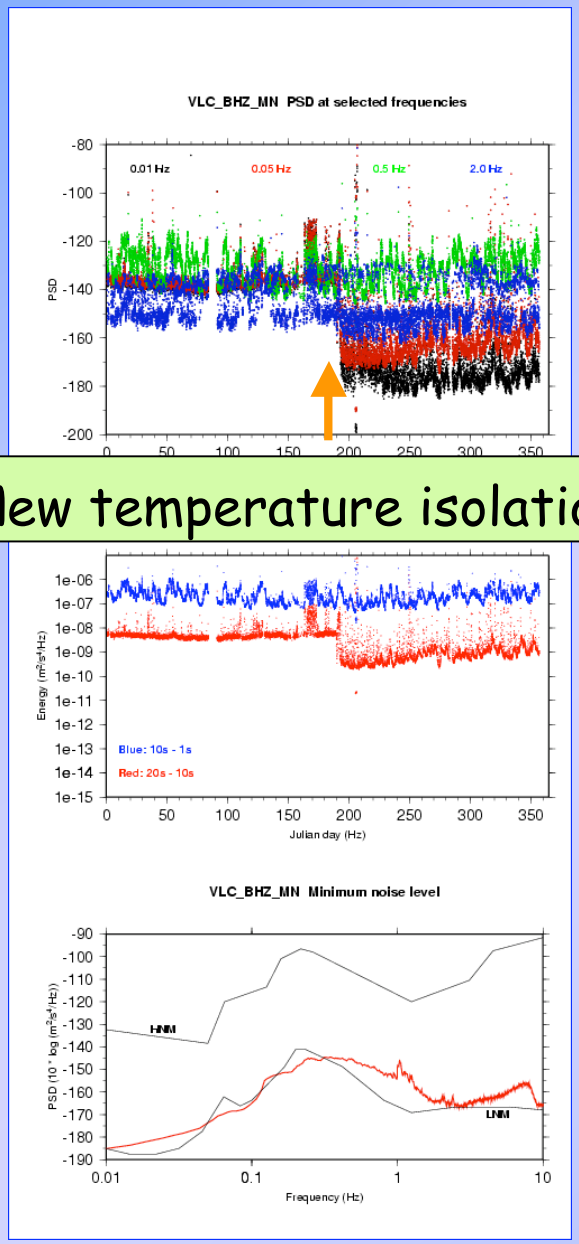
error in meta-data

(sensor gain)

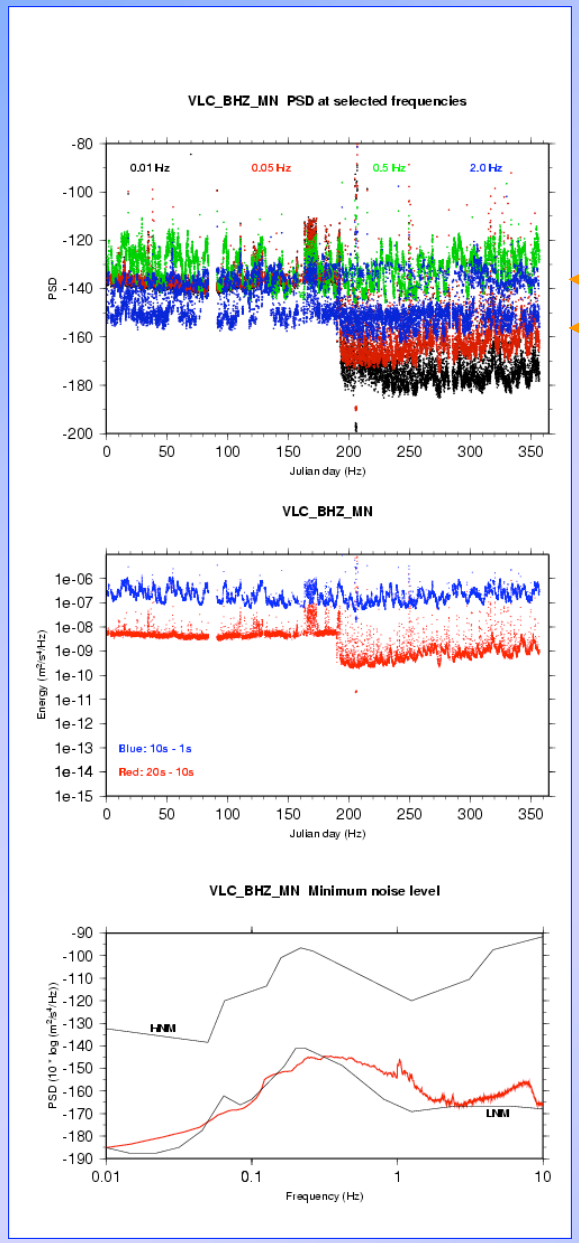
Example 4


VLC_BHZ_MN PSD at selected frequencies
0.01 Hz
0.05 Hz
0.5 Hz
2.0 Hz
PSD
Julian day (Hz)
VLC_BHZ_MN
Energy (m²s⁴/Hz)
Blue: 10s - 1s
Red: 20s - 10s
Julian day (Hz)
VLC_BHZ_MN Minimum noise level
PSD (10 * log (m²s⁴/Hz))
HNM
LNM
Frequency (Hz)

Example 4

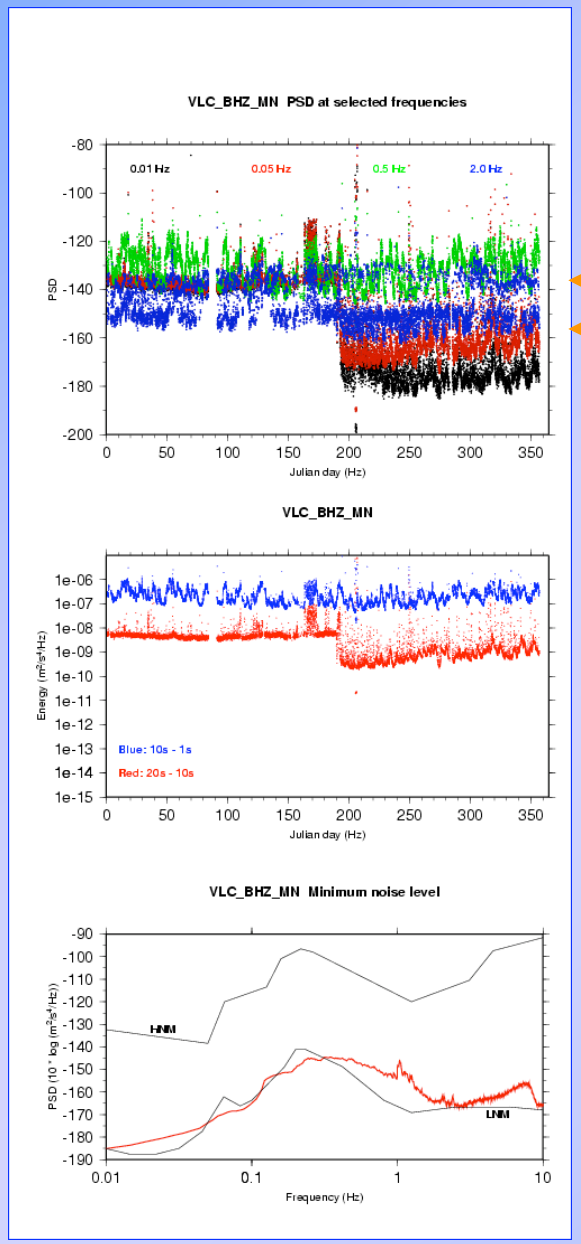

VLC_BHZ_MN PSD at selected frequencies
0.01 Hz
0.05 Hz
0.5 Hz
2.0 Hz
PSD
-80
-100
-120
-140
-160
-180
-200
0
50
100
150
200
250
300
350
New temperature isolation sensor
Energy (m²s⁴/Hz)
1e-06
1e-07
1e-08
1e-09
1e-10
1e-11
1e-12
1e-13
1e-14
1e-15
Blue: 10s - 1s
Red: 20s - 10s
Julian day (Hz)
VLC_BHZ_MN Minimum noise level
PSD (10 * log (m²s⁴/Hz))
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
HNM
LNM
0.01
0.1
1
10
Frequency (Hz)

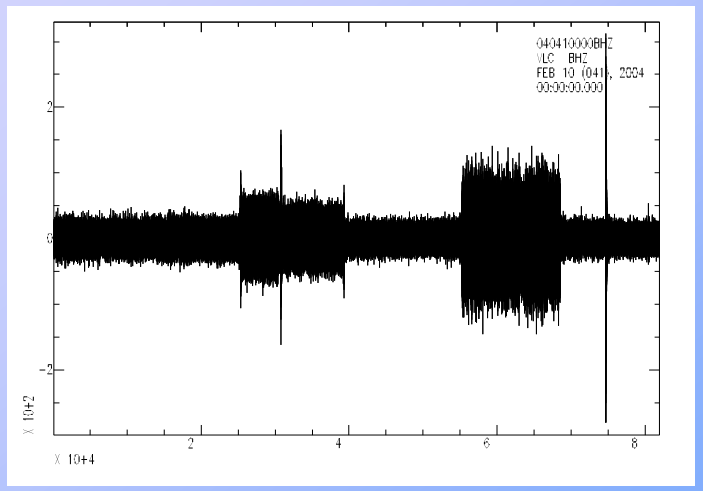
Example 4

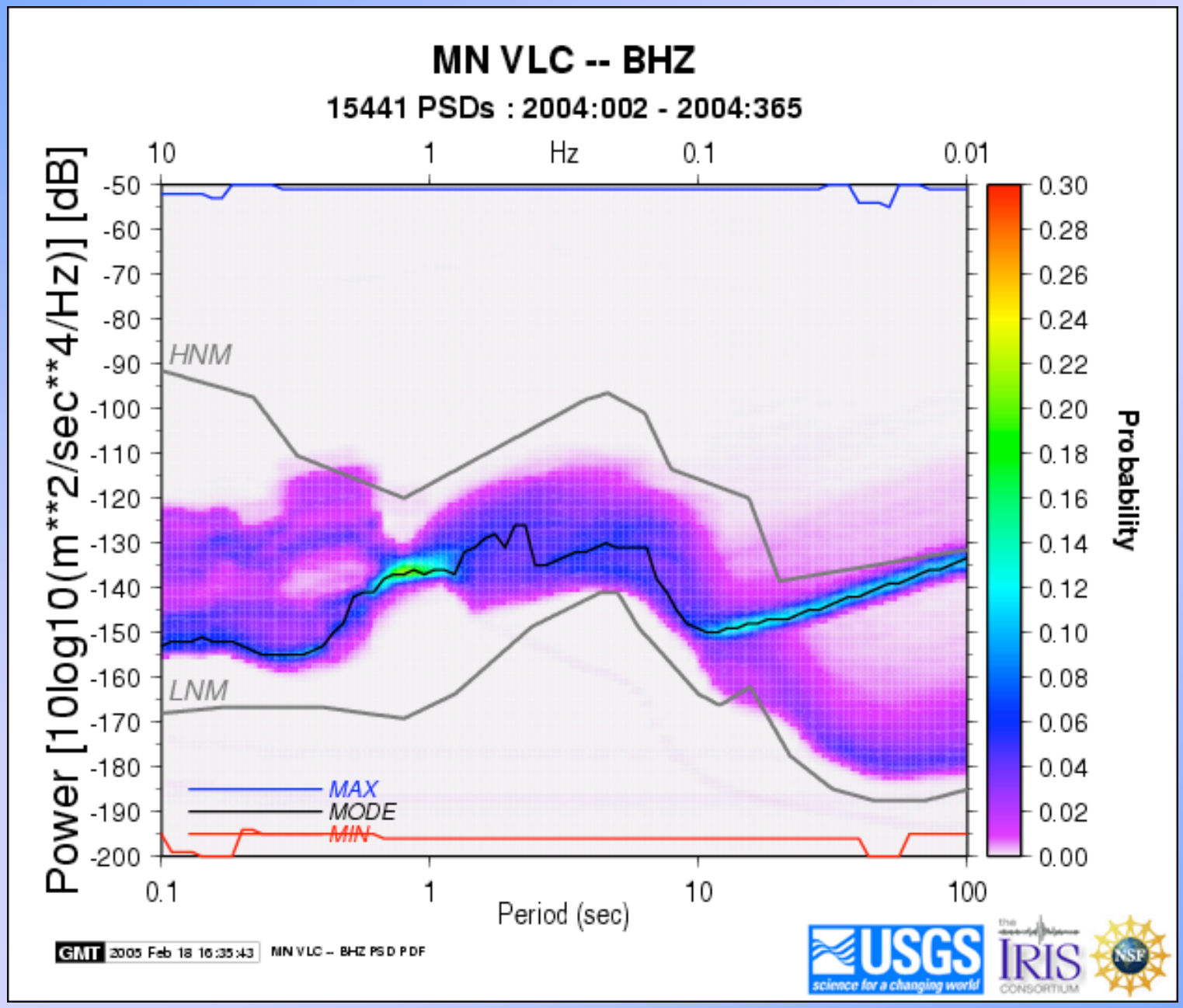

VLC_BHZ_MN PSD at selected frequencies
0.01 Hz
0.05 Hz
0.5 Hz
2.0 Hz
PSD
Julian day (Hz)
VLC_BHZ_MN
Energy (m²s⁴/Hz)
Blue: 10s - 1s
Red: 20s - 10s
Julian day (Hz)
VLC_BHZ_MN Minimum noise level
PSD (10 * log (m²s⁴/Hz))
HNM
LNM
Frequency (Hz)

?

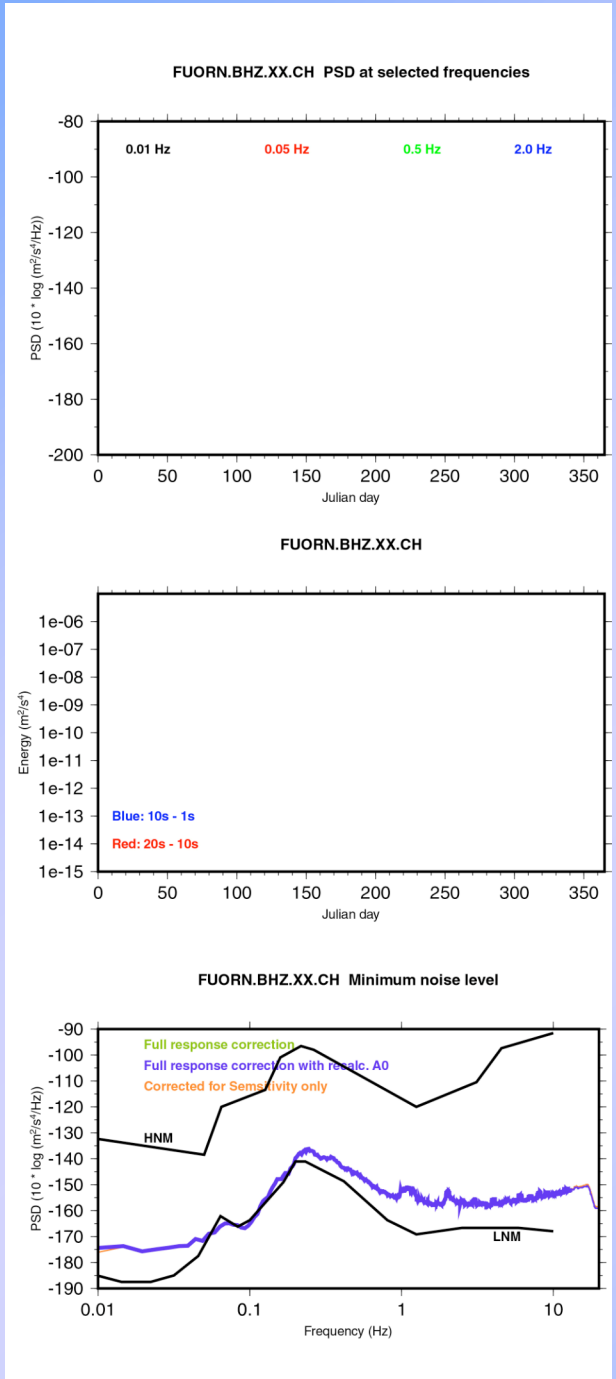
Example 4


VLC_BHZ_MN PSD at selected frequencies
0.01 Hz
0.05 Hz
0.5 Hz
2.0 Hz
PSD
Julian day (Hz)
VLC_BHZ_MN
Energy (m²s⁴/Hz)
Blue: 10s - 1s
Red: 20s - 10s
Julian day (Hz)
VLC_BHZ_MN Minimum noise level
PSD (10 * log (m²s⁴/Hz))
HNM
LNM
Frequency (Hz)


04041000BHZ
VLC BHZ
FEB 10 (041), 2004
00:00:00.000
X 10+2
X 10+4


MN VLC -- BHZ
15441 PSDs : 2004:002 - 2004:365
10
1
Hz
0.1
0.01
Power [10log10(m**2/sec**4/Hz)] [dB]
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
HNM
LNM
MAX
MODE
MIN
0.1
1
10
100
Period (sec)
Probability
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
GMT 2005 Feb 18 16:35:43
MN VLC -- BHZ PSD PDF
USGS
science for a changing world
IRIS
CONSORTIUM
NSF

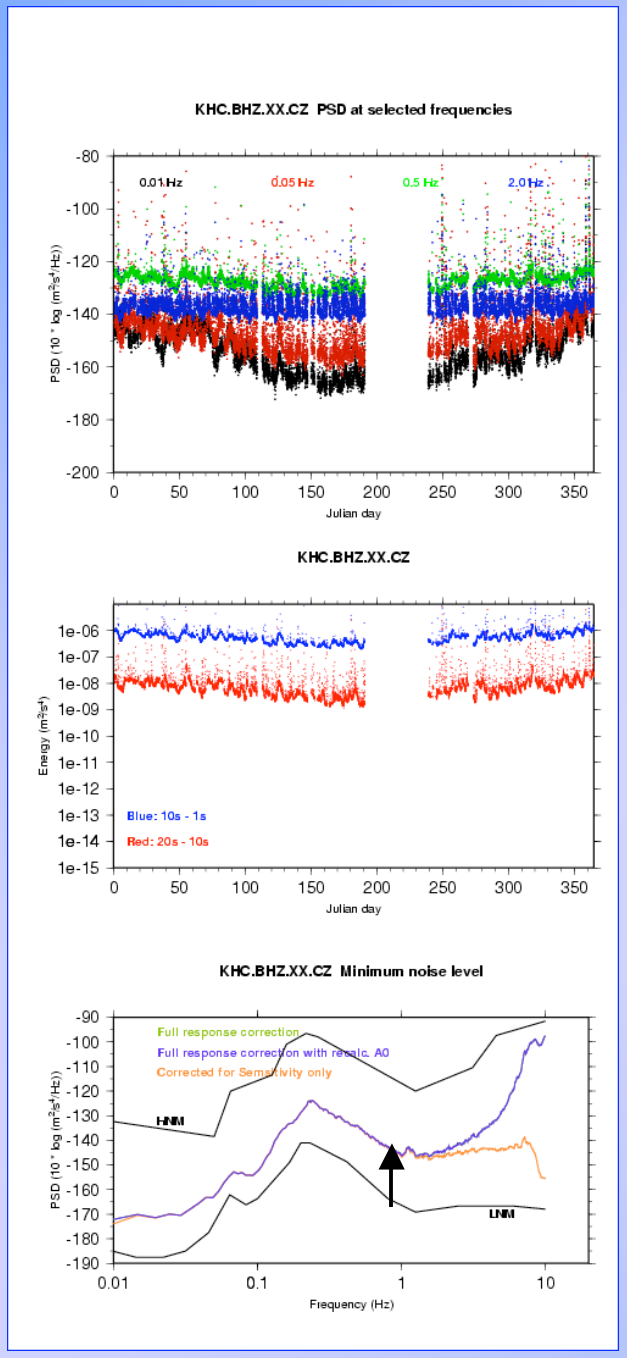
Example 5



error in meta-data:

(normalization factor)

Example 6



suspicious gain in meta-data

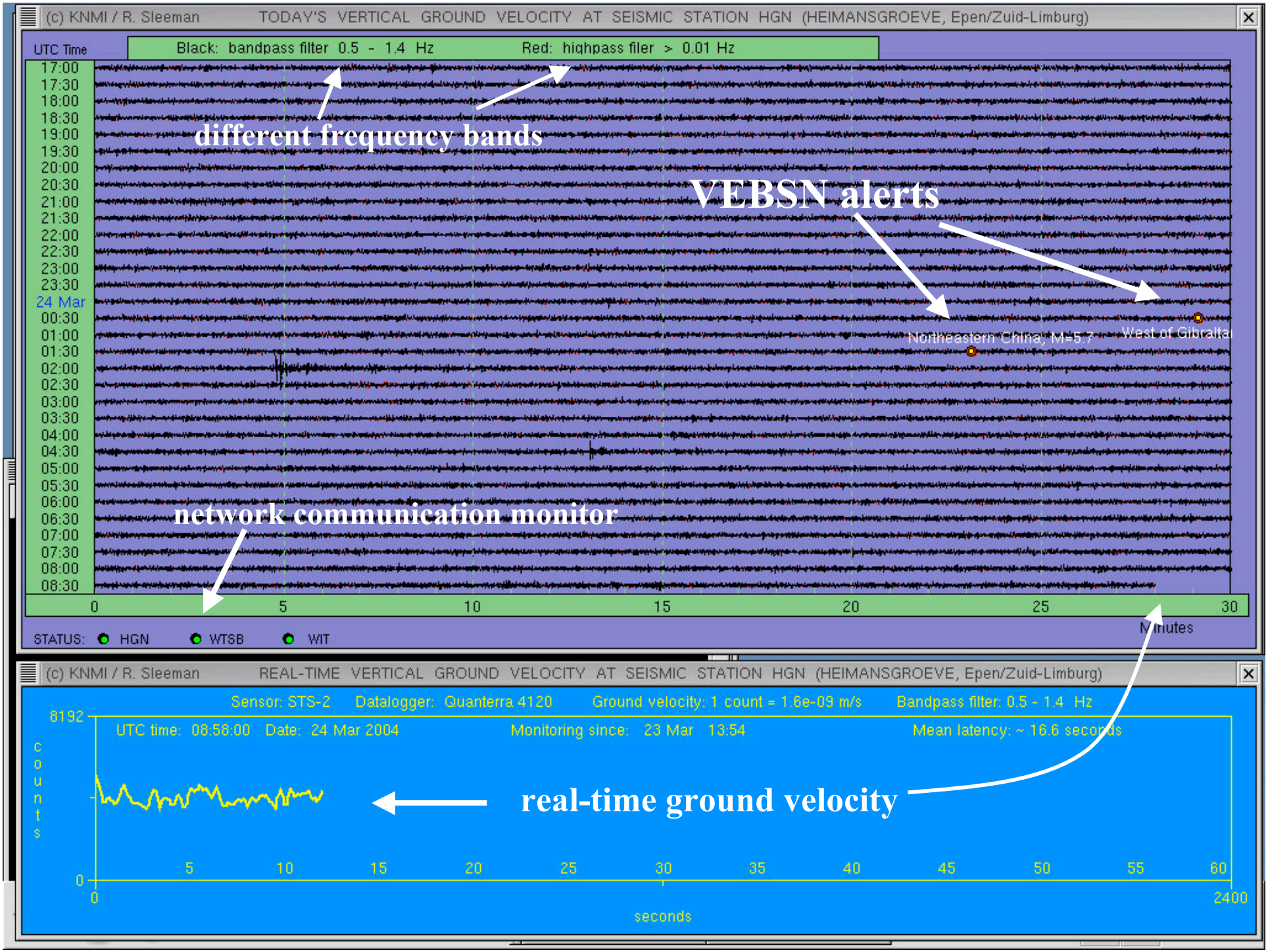
QCM will become available: orfeus.knmi.nl

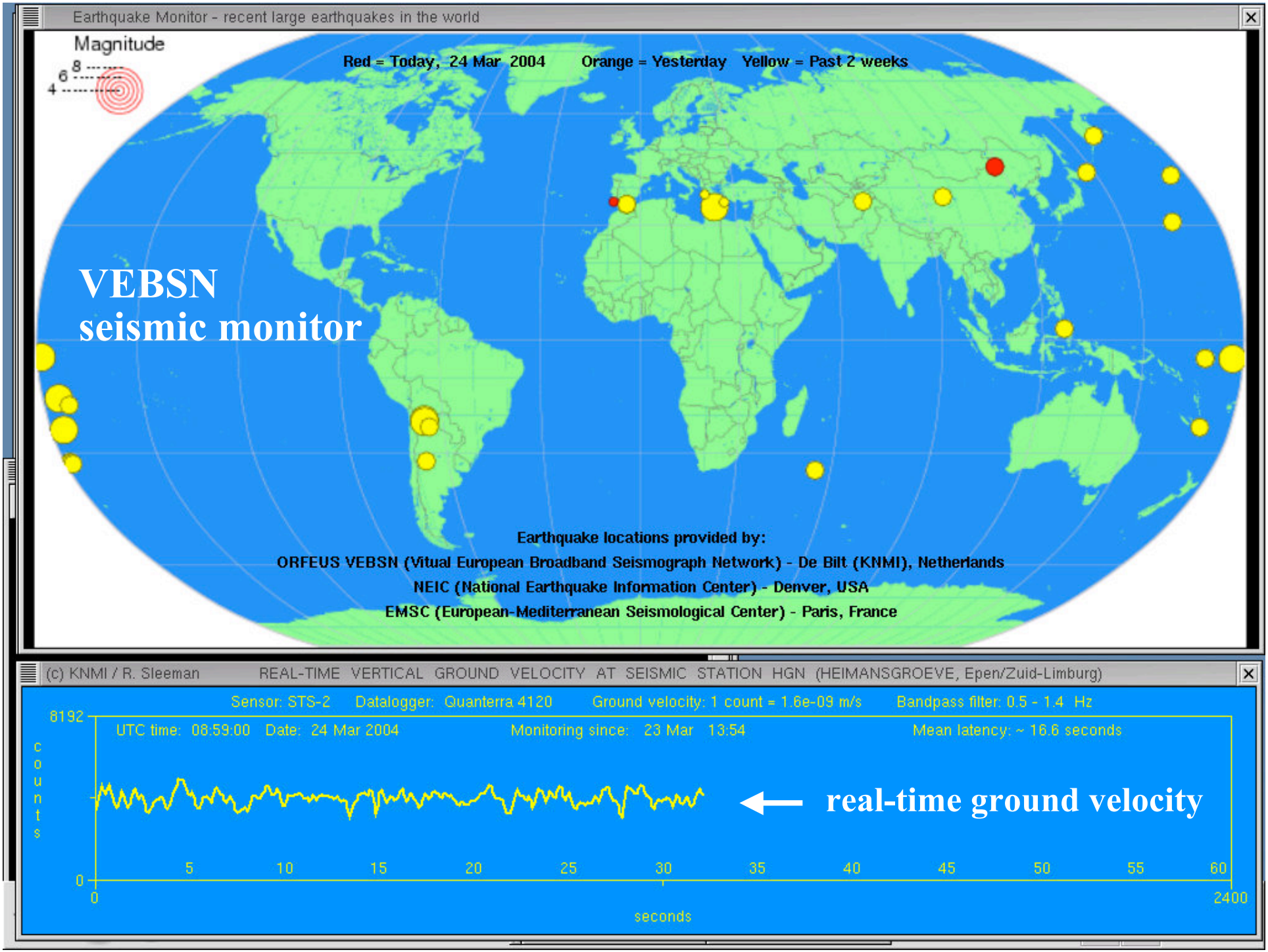
NET-RECORDER,
an all-in-one, real-time seismic monitor for:

- waveform data from any SeedLink server
- status of your network
- VEBSN alerts
- VEBSN seismicity map

In use in several seismological observatories and exhibitions to serve public earthquake monitoring needs

Software requires libslink and lynx (or any other text-based browser) and runs on Linux


(c) KNMI / R. Sleeman TODAY'S VERTICAL GROUND VELOCITY AT SEISMIC STATION HGN (HEIMANSGROEVE, Epen/Zuid-Limburg)
UTC Time
Black: bandpass filter 0.5 - 1.4 Hz
Red: highpass filer > 0.01 Hz
different frequency bands
VEBSN alerts
Northeastern China, M=5.7
West of Gibraltar
network communication monitor
24 Mar
Minutes
STATUS: HGN WTSB WIT
(c) KNMI / R. Sleeman REAL-TIME VERTICAL GROUND VELOCITY AT SEISMIC STATION HGN (HEIMANSGROEVE, Epen/Zuid-Limburg)
Sensor: STS-2 Datalogger: Quanterra 4120 Ground velocity: 1 count = 1.6e-09 m/s Bandpass filter: 0.5 - 1.4 Hz
UTC time: 08:58:00 Date: 24 Mar 2004 Monitoring since: 23 Mar 13:54 Mean latency: ~ 16.6 seconds
8192
counts
0
real-time ground velocity
seconds
2400


Earthquake Monitor - recent large earthquakes in the world
Magnitude
8
6
4
Red = Today, 24 Mar 2004
Orange = Yesterday
Yellow = Past 2 weeks
VEBSN
seismic monitor
Earthquake locations provided by:
ORFEUS VEBSN (Vitual European Broadband Seismograph Network) - De Bilt (KNMI), Netherlands
NEIC (National Earthquake Information Center) - Denver, USA
EMSC (European-Mediterranean Seismological Center) - Paris, France
(c) KNMI / R. Sleeman
REAL-TIME VERTICAL GROUND VELOCITY AT SEISMIC STATION HGN (HEIMANSGROEVE, Epen/Zuid-Limburg)
Sensor: STS-2
Datalogger: Quanterra 4120
Ground velocity: 1 count = 1.6e-09 m/s
Bandpass filter: 0.5 - 1.4 Hz
8192
UTC time: 08:59:00
Date: 24 Mar 2004
Monitoring since: 23 Mar 13:54
Mean latency: ~ 16.6 seconds
counts
real-time ground velocity
0
5
10
15
20
25
30
35
40
45
50
55
60
0
2400
seconds