Seismic Equipment, Seismic Data and Metadata

Justin Sweet, IRIS
Adapted from presentation by:
George Slad, IRIS/PASSCAL Instrument Center

Sensors

Sensors by frequency range of interest

- Seismic waves contain a wide range of frequencies that no one sensor records well
- Analogous to light and sound

Seismic	Light	Sound
Short-period	Blue	Treble
Long-period	Red	Bass

- The frequency range is large because the process of earth deformation occurs at many different rates and scales.

Eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/seismometers.html

Frequency Ranges

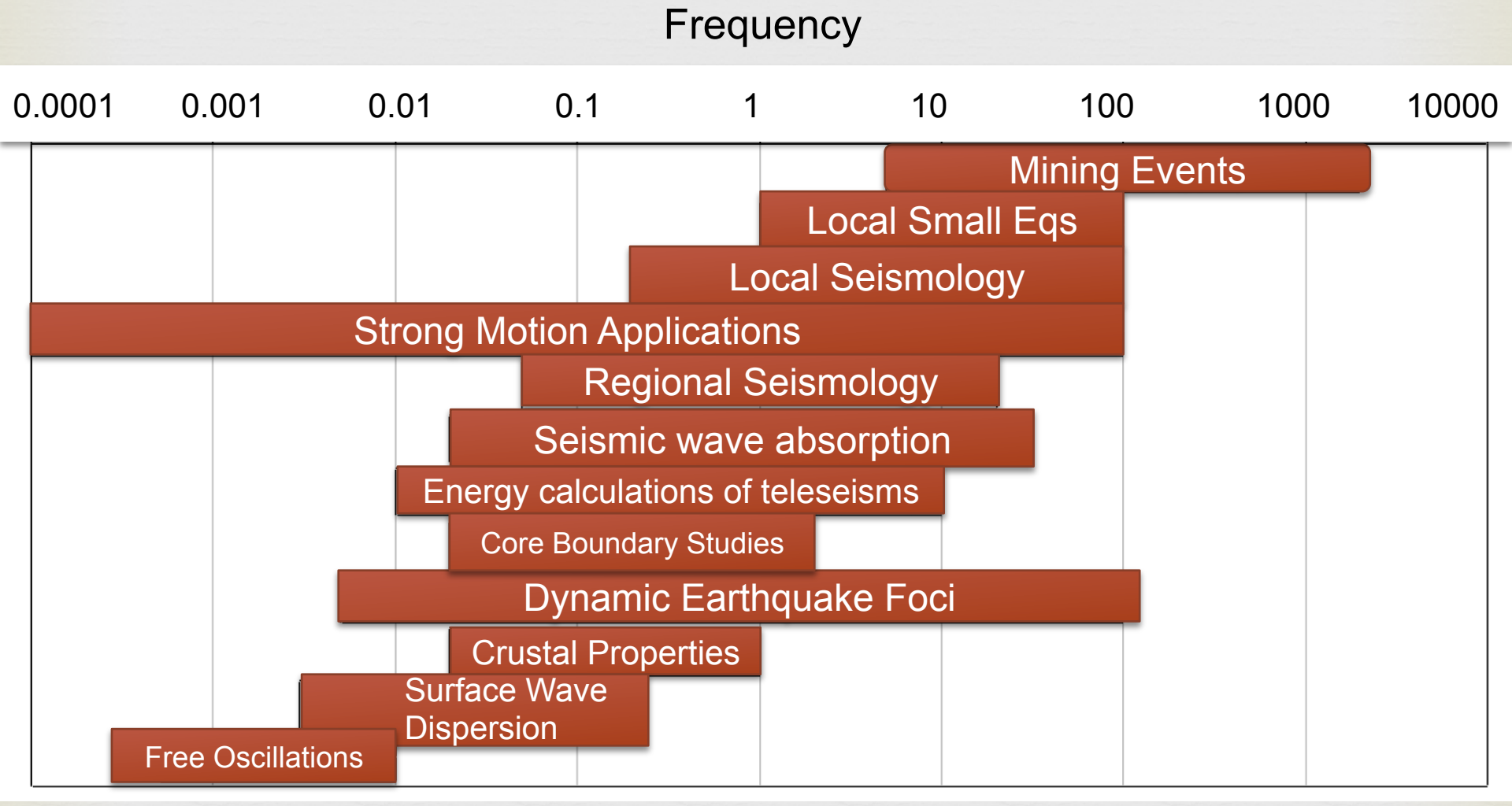
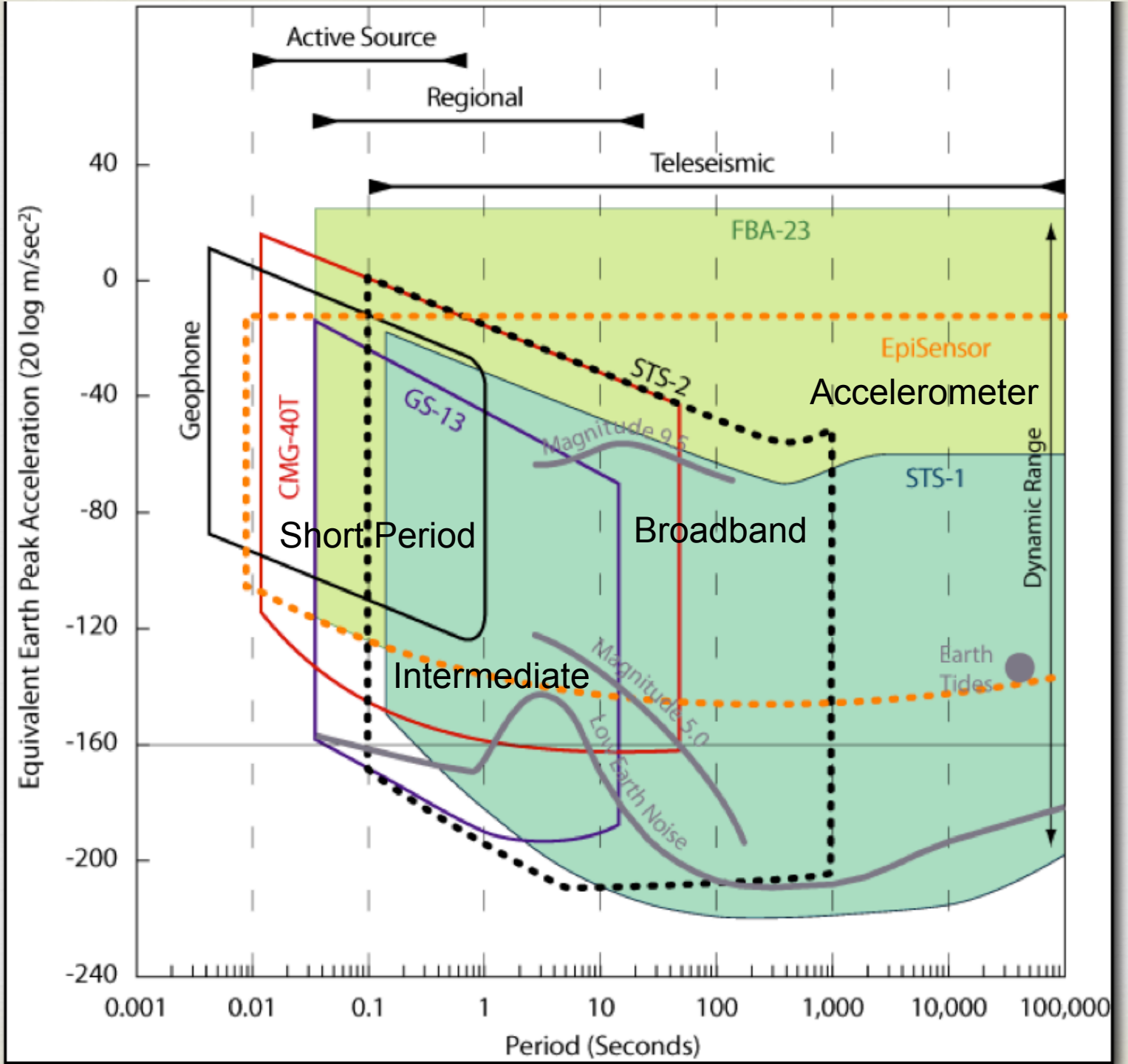


Figure adapted from www.GeoSig.com



Very Broadband (VBB) and Broadband Sensors (BB)

- Utilized in global seismology studies

- VBB (e.g. STS-1, KS-54000)
  - low noise
  - flat velocity response ~300 seconds to ~5 - 10 Hz
  - large dynamic range

- BB (e.g. STS-2, CMG3-T, T240 & T120)
  - flat velocity response from < 100-120 s -- ~ 50 Hz

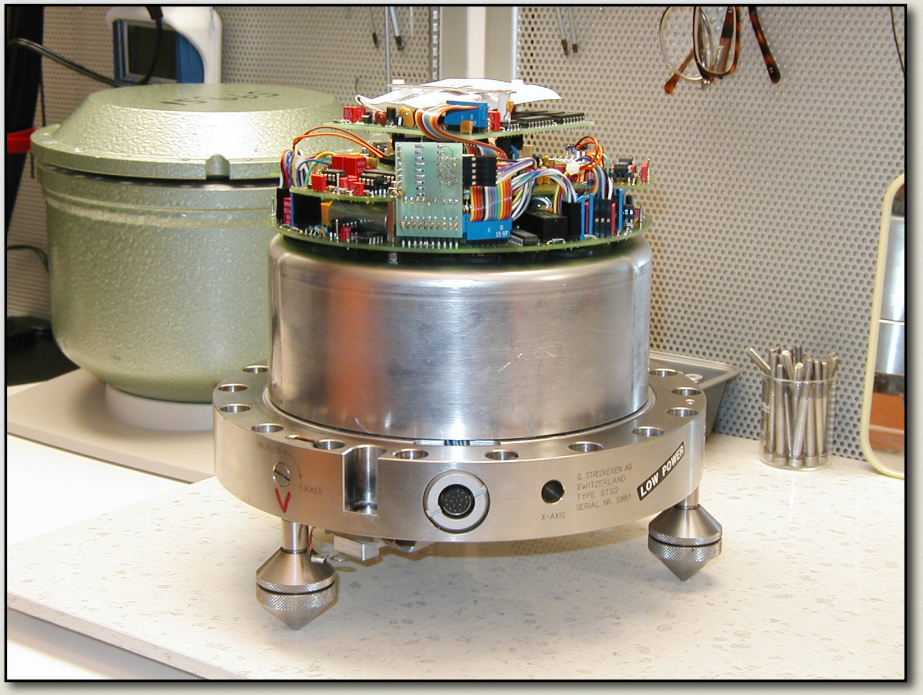
http://ida.ucsd.edu/Sensors/sts1.html

http://www.iris.edu/hq/files/programs/gsn/instrumentation/54000.jpg

http://www.earth.sinica.edu.tw/~smdmc/seismology/einstrument.htm

Guralp CMG-3T

STS-2



Intermediate Sensors

- 3 component seismometers with corner periods of 30-40 seconds
- Common intermediate period sensors are CMG40T and Trillium 40

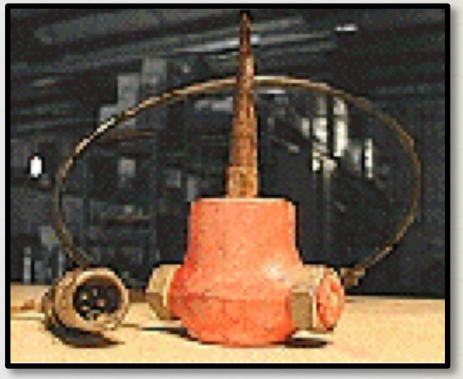
http://www.earth.sinica.edu.tw/~smdmc/seismology/einstrument.htm
http://www.passcal.nmt.edu

Short Period

- 3 component seismometers that cover high frequency bands (1-100+ Hz)
- Used in both passive and active experiments

High Frequency

- Cover high frequency bands of 4.5 to 100 Hz
- Most often used in active source experiments
- Common examples are L28s,vertical geophones for Texans, Y28/GS11,



Accelerometers

- Known as strong-motion sensors
- Designed to measure large amplitude, high frequency seismic waves
- Strong ground motion often to blame for structural damage
- Examples include Episensor ES-T

Data/Datalogger

- Requirements
  - Stable oscillator (regular precise interval sampling)
  - Robust timing (GPS)
  - High Resolution, Linear A/D
  - reliable OS and data storage
  - means to interface with telemetry systems
  - simple, easy-to-understand user interface
  - useful state-of-health and logs for trouble-shooting

Dataloggers

- 1 channel Dataloggers
  RT-125A (Texan)

- 3-6 channel Dataloggers
  Q330
  RT-130

http://www.passcal.nmt.edu/content/instrumentation/dataloggers

Real-Time Telemetry

http://earthquake.usgs.gov/monitoring/operations/station.php?network=IU&station=PTCN

What powers these stations?

http://www.passcal.nmt.edu/~bob/passcal/slise/images/1130.jpg

http://www.emergency-response-planning.com/Portals/87350/images/power%20lines%201-resized-600.jpg

Where we ~~may be~~ **are** going:

Purpose-Built Direct Burial Broadband Sensors

Direct Burial Evolution

- Chile RAMP 2010
- Sweetwater Array 2014

- Simple/Quick Installs (~30 – 60 minutes)
- Comparable quality data
- Purpose-built sensors
  - Water-proof
  - Increased tilt tolerance

Generalized Data And Meta-Data

Who collects the meta-data?

- Permanent Networks
  - Network operators on the ground
  - GSN/TA field engineers document everything
- Temporary deployments:
  - PIs
  - grad students
  - volunteers

http://www.iris.edu/hq/gallery/photo/1952

Meta-data… from the beginning

Pre-experiment

IDEA – Science objective

- Recording parameters and Sensors

LOGISTICS – Planning, resources, availability

- How will meta-data be collected

FIELD WORK – Installation & service

- Organize and collect field notes (i.e., meta-data)
- Field notes are generated with:
  - What stations were where and when
  - Orientation and equipment specifics
- Raw data are retrieved on compact flash disk, USB drive, B14 baler
- Keep multiple backups!

Experiment

All of the field notes provide the meta-data and the raw data collected is your waveform data

Meta-data – really important!

- Without accurate meta-data, data are almost useless
- Common errors:
  - -Wrong equipment types
  - -Wrong location (lat, long, elev)
  - -Wrong start and/or end dates
  - -Wrong sensor orientation
  - -No serial numbers or they are incorrect
- All of this info comes from field notes, please take them carefully!

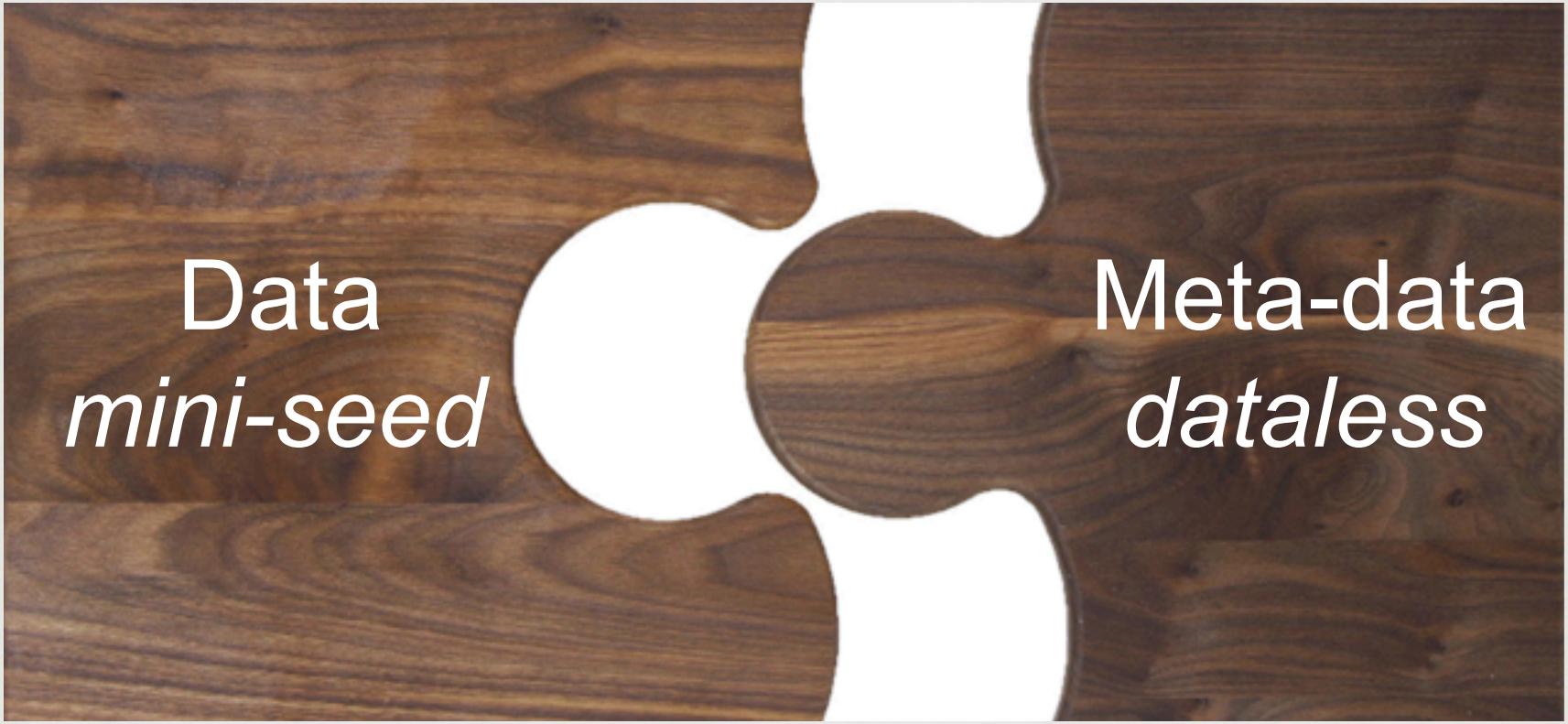
Data Formats

SEED/MiniSEED/Dataless and SAC

SEED

- The Standard for the Exchange of Earthquake Data (SEED) is an international standard format for the exchange of digital seismological data
- Designed for use by earthquake research community, primarily so there was a uniform standard for exchange between institutions of unprocessed Earth motion data
- Adopted by the Federation of Digital Seismographic Networks (FDSN) in 1987

SEED volume



Miniseed: data only

Fixed section of data header

- STATION NAME <sta>, example: STA1, EP01
- NETWORK CODE <net>, example: XN, PI
- CHANNEL NAME-refer to Appendix A in SEED manual
- LOCATION CODE
  - Usage varies by network
  - Usually left blank in PASSCAL experiments
- Start/end time
- Total number of samples
- Sample rate
- Data header quality indicator: example: D, R, Q, M

Time – series

Miniseed: data only

Fixed section of data header

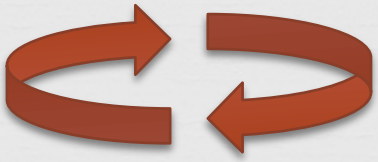
- **S**TATION NAME, example: STA1, EP01
- **N**ETWORK CODE, example: XN, PI
- **C**HANNEL NAME, refer to Appendix A in SEED manual
- **L**OCATION CODE
  - Usage varies by network
  - Usually left blank in PASSCAL experiments
- Start/end time
- Total number of samples
- Sample rate
- Data header quality indicator: example: D, R, Q, M

Time – series

Full SEED volume

Dataless

Mini-seed



- Station name
- Network code
- Channel name
- Location code
- Start/end time
- Sample rate
- Number of samples

Dataless SEED

Contains the meta-data for your experiment. Including: instrument types & response; station coordinates; compression type, *etc*.

A dataless contains NO waveform data.

Meta-data: Required Information

Network

- FDSN network code assigned

Station

- Number of stations, location, SEED station name

Instrumentation

- Type of sensor and datalogger, serial numbers, sensor orientation, gain

Time

- Start time, end time, exact times when configurations change

Data streams recorded

- Number of data streams
- Sample rates recorded

SEED

Reference Manual

Standard for the **E**xchange of **E**arthquake **D**ata

SEED Format Version 2.4
August, 2012

http://www.fdsn.org/seed_manual/SEEDManual_V2.4.pdf

MiniSEED Example

XR_ST11__HHZ, 000002, D
start time: 2013,146,00:00:40.525000
number of samples: 3097
sample rate factor: 100 (100 samples per second)
sample rate multiplier: 1
number of blockettes: 1
time correction: 0
data offset: 64
first blockette offset: 48
BLOCKETTE 1000: (Data Only SEED)
next blockette: 0
encoding: STEIM 2 Compression (val:11)
byte order: Big endian (val:1)
record length: 4096 (val:12)

171 179 208 272 306 326

Dataless Example

```
#          +-------------------------------------------------------------------------+
#          | Station header   |          Station  ST11          |       SEED
tape |
#          +-------------------------------------------------------------------------+
#
B050F03       Station code:                  ST11
B050F04       Latitude:                   33.733700
B050F05       Longitude:                   -82.152700
B050F06       Elevation:                  135.000000
B050F09       Name:                      Modoc, SC
B050F10       Owner Code Lookup:  2            modoc
B050F11       32-bit word order:             3210
B050F12       16-bit word order:             10
B050F13       Starting date:              2013,102,00:00:00.0000
B050F14       Ending date:                2013,171,23:59:59.9999
B050F15       Update flag:               N
B050F16       Network Code:                XR
```

```
#            +-----------------|   Station  ST11   |    Channel HHZ    |-----------------+
#            +                 +-----------------------------------+                     +
#
B052F04    Channel:                          HHZ
B052F03    Location:
B052F05    Subchannel:                        0
B052F06    Instrument lookup:       6            Guralp CMG3T/Reftek 130 Datalogger
B052F07    Comment:                          T34432 9255
B052F08    Signal units lookup:     4            M/S - velocity in meters per second
B052F09    Calibration units lookup:     5        V - emf in volts
B052F10    Latitude:                         33.733700
B052F11    Longitude:                         -82.152700
B052F12    Elevation:                        135.000000
B052F13    Local depth:                       0.000000
B052F14    Azimuth:                          0.000000
B052F15    Dip:                             -90.000000
B052F16    Format lookup:     3                 Format Information Follows
B030F03         Format Name: Steim2 Integer Compression Format
B030F05         Data family:   50
B030F06         Number of Keys:   14
.
.
.
B052F17    Log2 of Data record length:           12
B052F18    Sample rate:                      100
B052F19    Clock tolerance:                   0.0001
B052F21    Channel flags:                    G
B052F22    Start date:                      2013,117,00:00:00.0000
B052F23    End date:                         2013,171,13:01:00.0000
B052F24    Update flag:                       N
```

```
#            +            +-----------------------------------------+            +
#            +            |   Response (Poles & Zeros),  ST11 ch HHZ  |            +
#            +            +-----------------------------------------+            +
#
B053F03     Transfer function type:                A [Laplace Transform (Rad/sec)]
B053F04     Stage sequence number:                   1
B053F05     Response in units lookup:              M/S - velocity in meters per second
B053F06     Response out units lookup:              V - emf in volts
B053F07     A0 normalization factor:               5.71402E+08
B053F08     Normalization frequency:                 0.3
B053F09     Number of zeroes:                       2
B053F14     Number of poles:                       5
#             Complex zeroes:
#               i  real         imag         real_error    imag_error
B053F10-13     0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
B053F10-13     1  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
#             Complex poles:
#               i  real         imag         real_error    imag_error
B053F15-18     0 -3.701000E-02  3.701000E-02  0.000000E+00  0.000000E+00
B053F15-18     1 -3.701000E-02 -3.701000E-02  0.000000E+00  0.000000E+00
B053F15-18     2 -1.131000E+03  0.000000E+00  0.000000E+00  0.000000E+00
B053F15-18     3 -1.005000E+03  0.000000E+00  0.000000E+00  0.000000E+00
B053F15-18     4 -5.027000E+02  0.000000E+00  0.000000E+00  0.000000E+00
```

```
#          +              +-------------------------------------+             +
#          +              |      Channel Gain,  ST11 ch HHZ     |             +
#          +              +-------------------------------------+             +
#
B058F03    Stage sequence number:              1
B058F04    Gain:                          1.504190E+03
B058F05    Frequency of gain:                 3.000000E-01 HZ
B058F06    Number of calibrations:             0
#
#          +            +----------------------------------------+             +
#          +            |   Response (Coefficients),  ST11 ch HHZ   |          +
#          +            +----------------------------------------+             +
#
B054F03    Transfer function type:            D
B054F04    Stage sequence number:              2
B054F05    Response in units lookup:          V - emf in volts
B054F06    Response out units lookup:          COUNTS - digital counts
B054F07    Number of numerators:              0
B054F10    Number of denominators:             0
#
#          +                +---------------------------+                +
#          +                |   Decimation,  ST11 ch HHZ   |              +
#          +                +---------------------------+                +
B057F03    Stage sequence number:              2
B057F04    Input sample rate:                 1.024000E+05
B057F05    Decimation factor:                 1
B057F06    Decimation offset:                 0
B057F07    Estimated delay (seconds):          0.000000E+00
B057F08    Correction applied (seconds):       0.000000E+00
```

SAC file

```
 FILE:
2013.146.00.00.00.0050.XR.ST11..HHZ.D.SA
C - 1
 ------------------------------------------
       NPTS = 8640000
          B = 0.000000e+00
          E = 8.639998e+04
     IFTYPE = TIME SERIES FILE
      LEVEN = TRUE
      DELTA = 1.000000e-02
       IDEP = UNKNOWN
     DEPMIN = -2.575600e+04
     DEPMAX = 2.416400e+04
     DEPMEN = 2.389532e+02
     KZDATE = MAY 26 (146), 2013
     KZTIME = 00:00:00.005
      KSTNM = ST11
      CMPAZ = 0.000000e+00
     CMPINC = 0.000000e+00
       STLA = 3.373370e+01
       STLO = -8.215270e+01
       STEL = 1.350000e+02
       STDP = 0.000000e+00
      KHOLE =
     LOVROK = TRUE
      NVHDR = 6
      NORID = 0
      NEVID = 0
     LPSPOL = FALSE
     LCALDA = TRUE
     KCMPNM = HHZ
     KNETWK = XR
```

Viewing Data

Viewing Data

- PASSCAL Quick Look (PQL) reads mini-seed
- Provides a means to quickly assess data quality for:
  - Time series, SOH information
  - Spectra
  - Header information
  - Filtering
  - View in absolute, relative time (helicorder plots)

PQL

Station Metrics

What's out there…

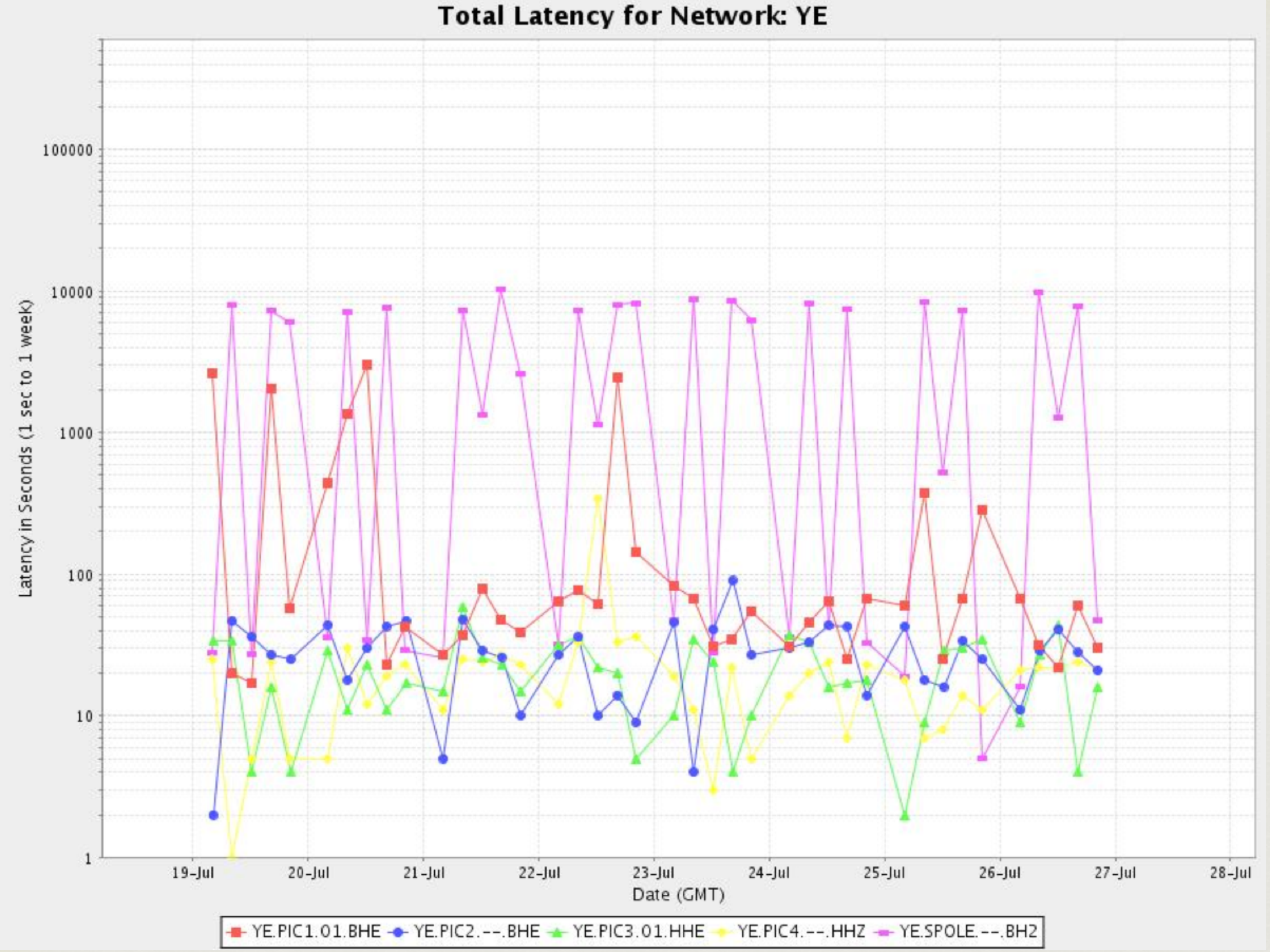
- Mass positions
- Timing
- Latency/Gaps (telemetry)
- RMS
- Power Spectral Density Plots (PSDs)
- Probability Density Functions of PSDs

What's coming…

- DMC's Mustang…

Looking at the PIC Direct Burial Testing Network (YE) via QUACK

- Network Operations Overview
  - Latency
  - Gaps
- Sensor comparisons
  - Channel RMS values
  - PDF PSD

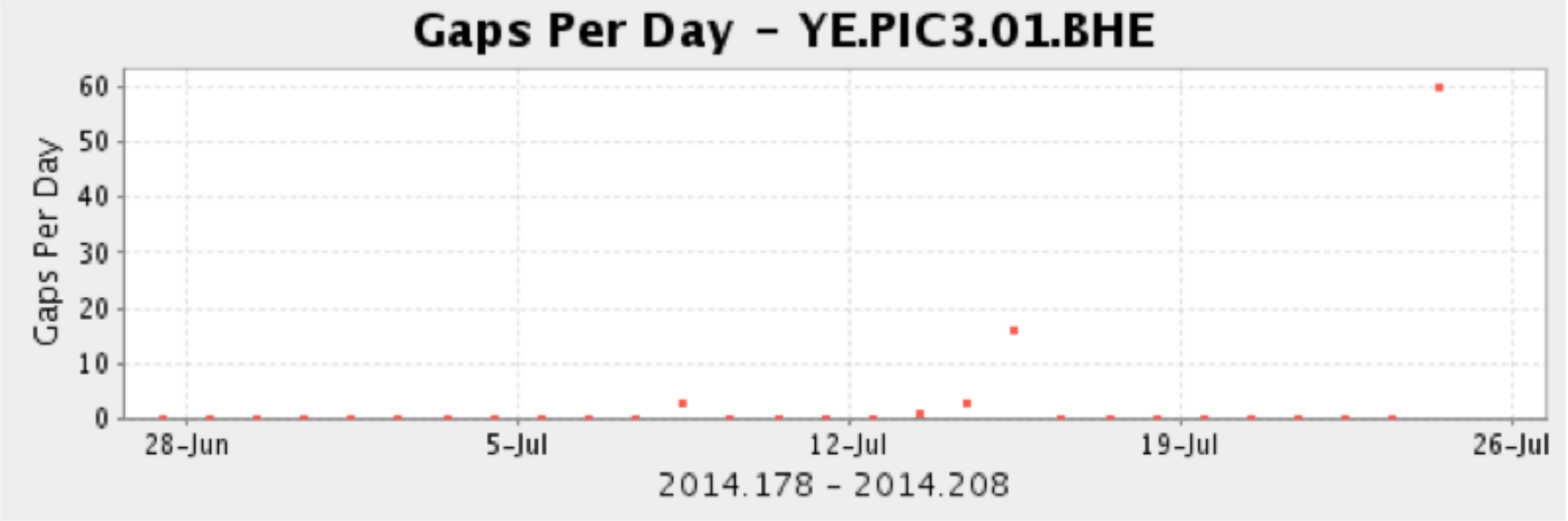


http://www.iris.washington.edu/servlet/latency/selector.do

Number of Gaps Per Day

www.iris.edu/servlet/quackquery/qcPlotPage.do?startTime=2014.178&schemas=BUD&station=PIC3&location=01&selectName=Num

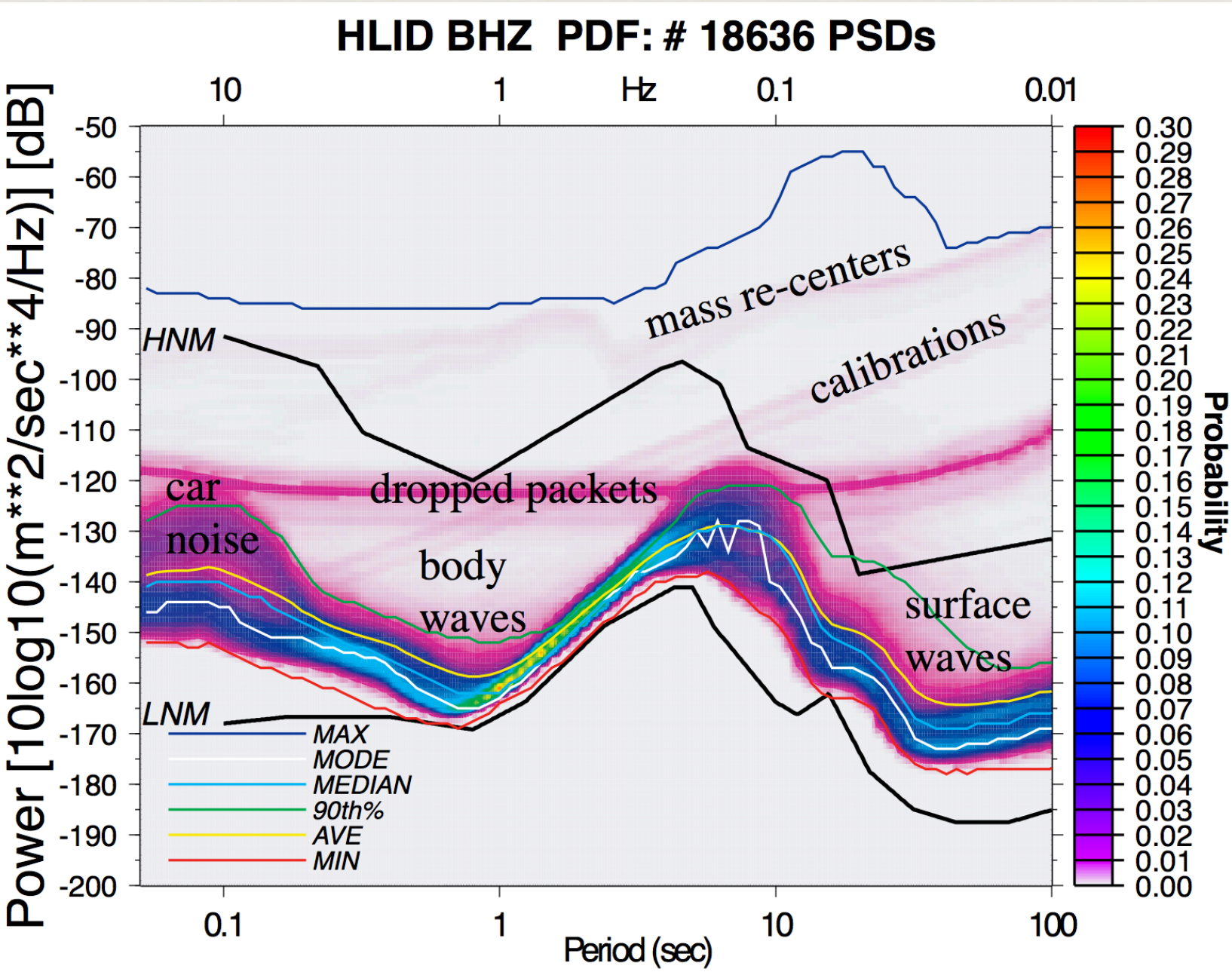
Send To Printer



http://www.iris.washington.edu/servlet/qrm/multiDay.do

Power Spectral Density (PSDs)

- Power Spectral Density (PSD) show the energy content of a waveform as a function of frequency
- Why do we use them? What can you do with a PSD?
- What can we do with a large number of PSDs – a.k.a. Probability Density Functions?



McNamara and Buland, 2003

View Power Density Functi...

www.iris.edu/servlet/quackquery/pdfPlots.do?network=TA&length=31&yyyyDDD=

PASSCAL | QC | WBS | User Utilities | Secure Pages | Support | IRIS | DMC | DMC - data requ... | Aviation Weather | rc.swcp | Google Calendar | Exp DB

Home

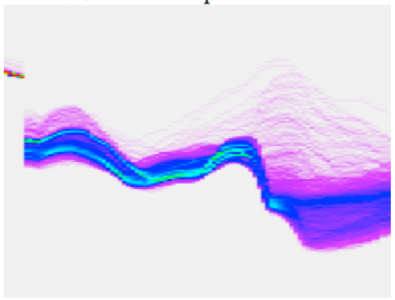
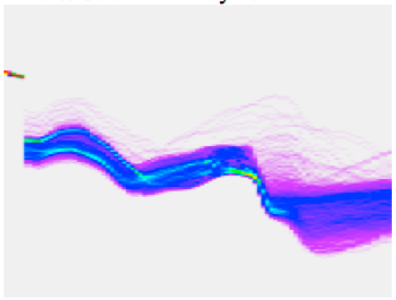
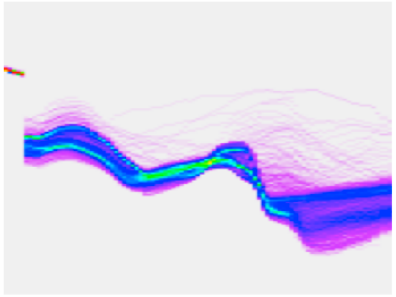
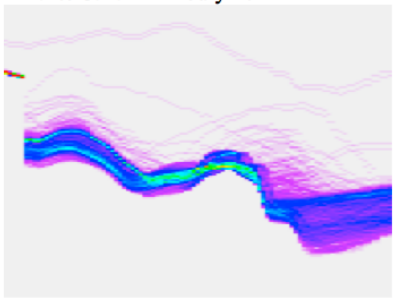
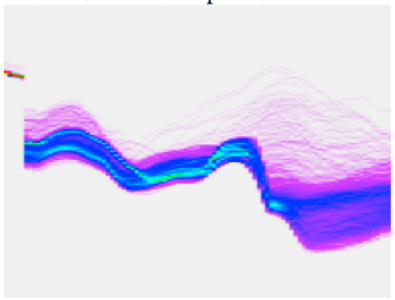
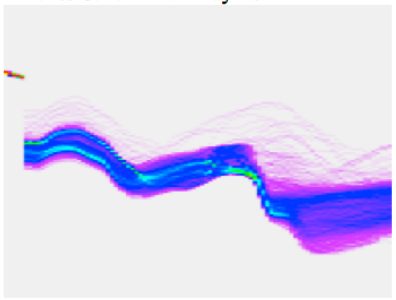
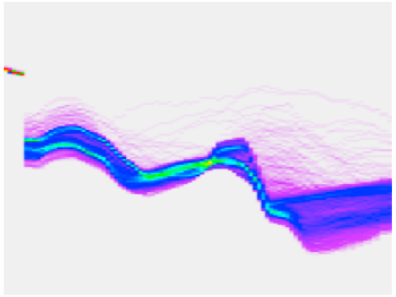
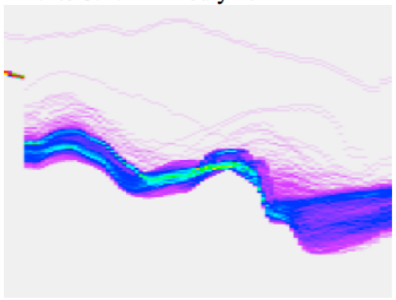
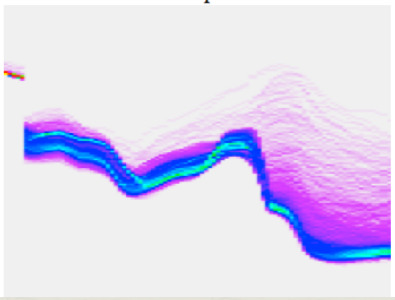
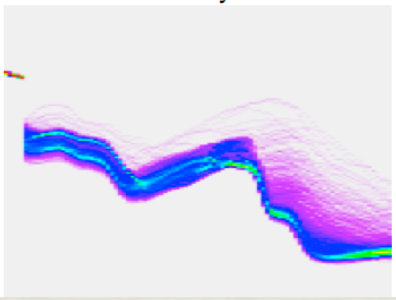
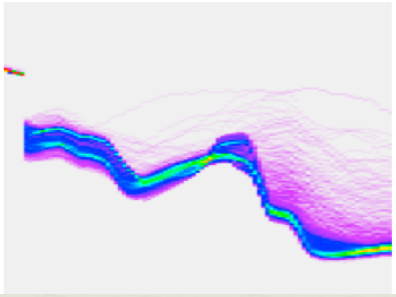
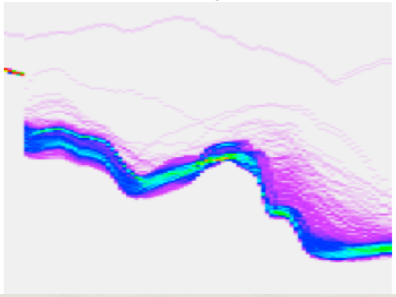
Chart Data | Plot Data | Explore Data | View Reports | View PDFs

current time:
2014.203 22:25:03 GMT

Filter

Network: TA Browse by: month

<< Prev Next >>

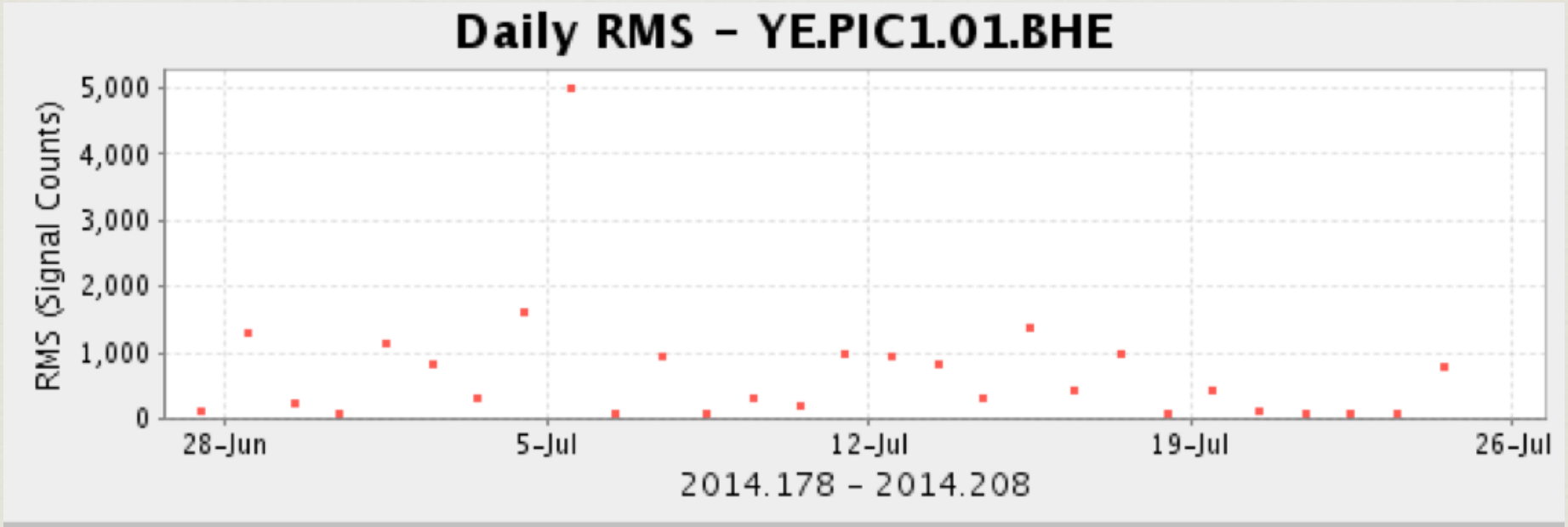
April 2014	May 2014	June 2014	July 2014
TA.109C.--.BHE - April 2014	TA.109C.--.BHE - May 2014	TA.109C.--.BHE - June 2014	TA.109C.--.BHE - July 2014
			
TA.109C.--.BHN - April 2014	TA.109C.--.BHN - May 2014	TA.109C.--.BHN - June 2014	TA.109C.--.BHN - July 2014
			
TA.109C.--.BHZ - April 2014	TA.109C.--.BHZ - May 2014	TA.109C.--.BHZ - June 2014	TA.109C.--.BHZ - July 2014
			

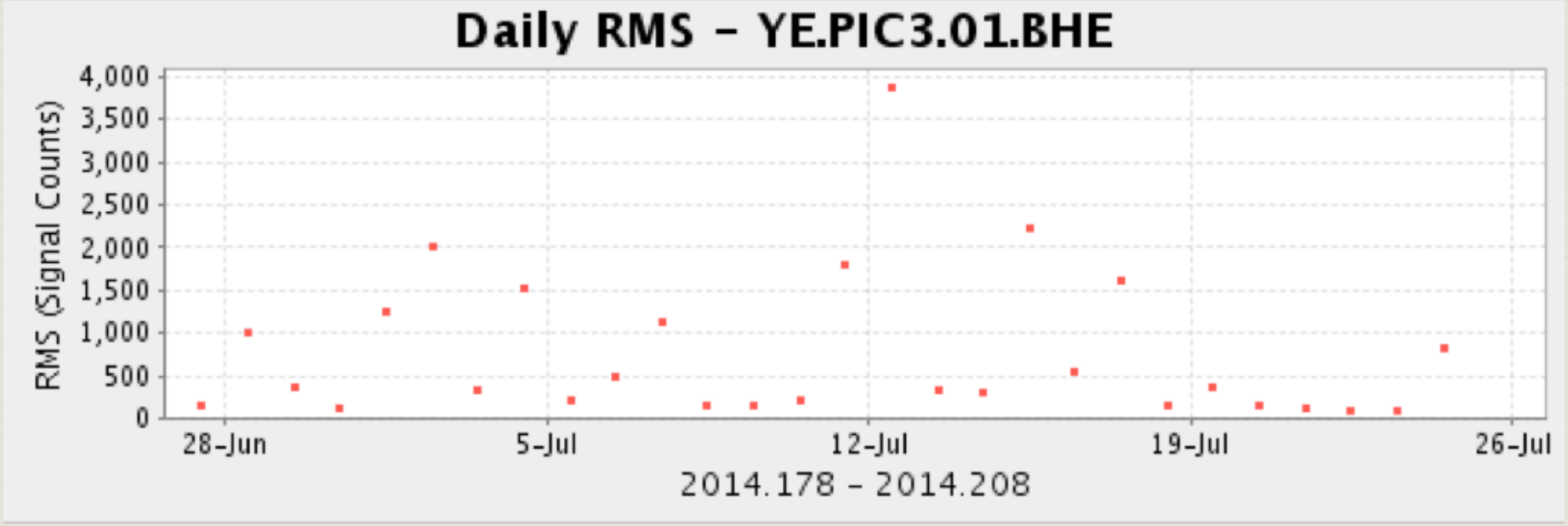
End

Sensitivity Problem

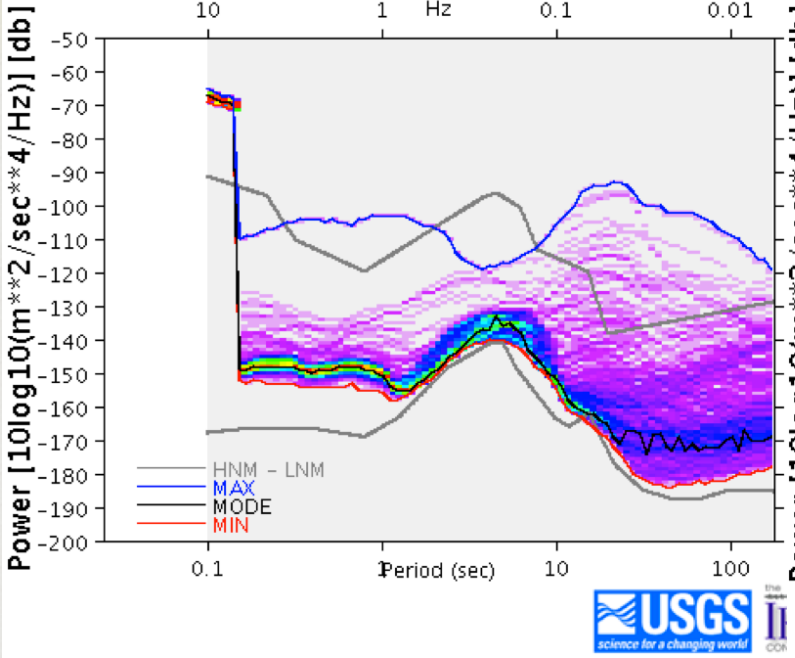
- Poker Flat, Alaska PASSCAL test stations
  - Prototypes
  - Direct burial emplacements

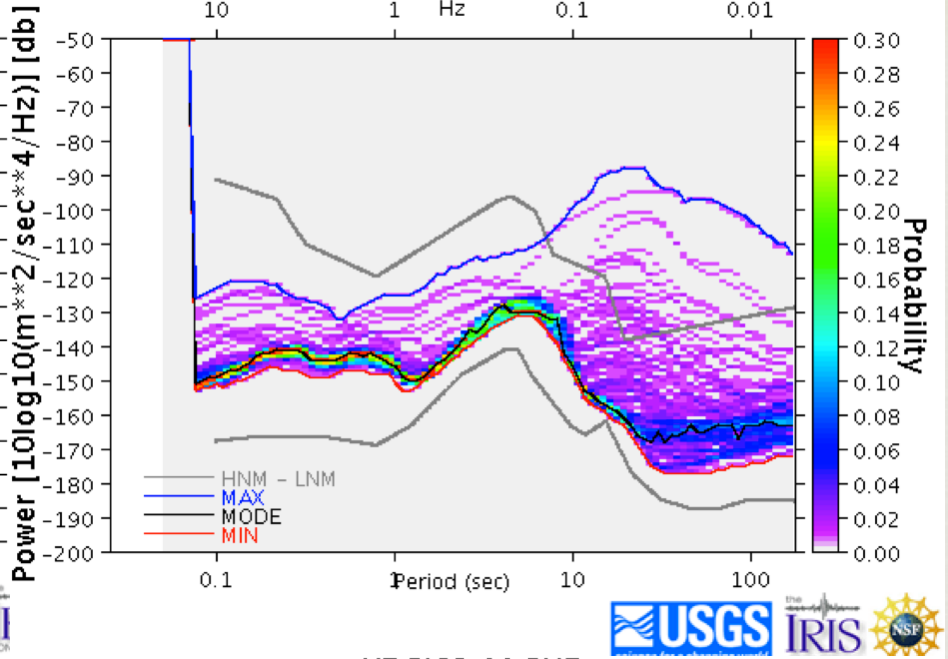
- Comparing:
  - TA POKR - Trillium 120 Post Hole
  - YE PIC2 – Trillium Compact Post Hole



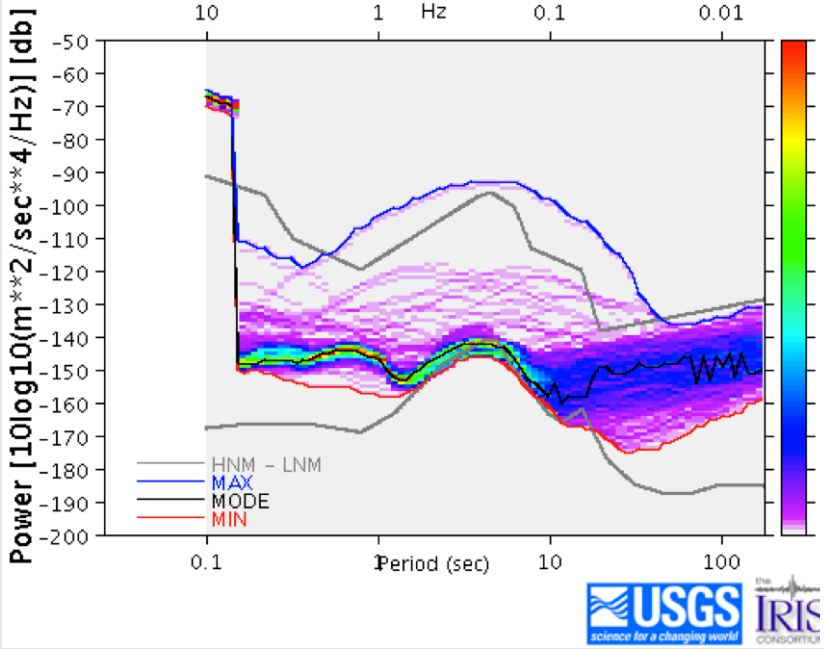


http://www.iris.edu/servlet/quackquery/multiplot_network.do?selectedPlot=Daily+Signal+RMS&network=YE

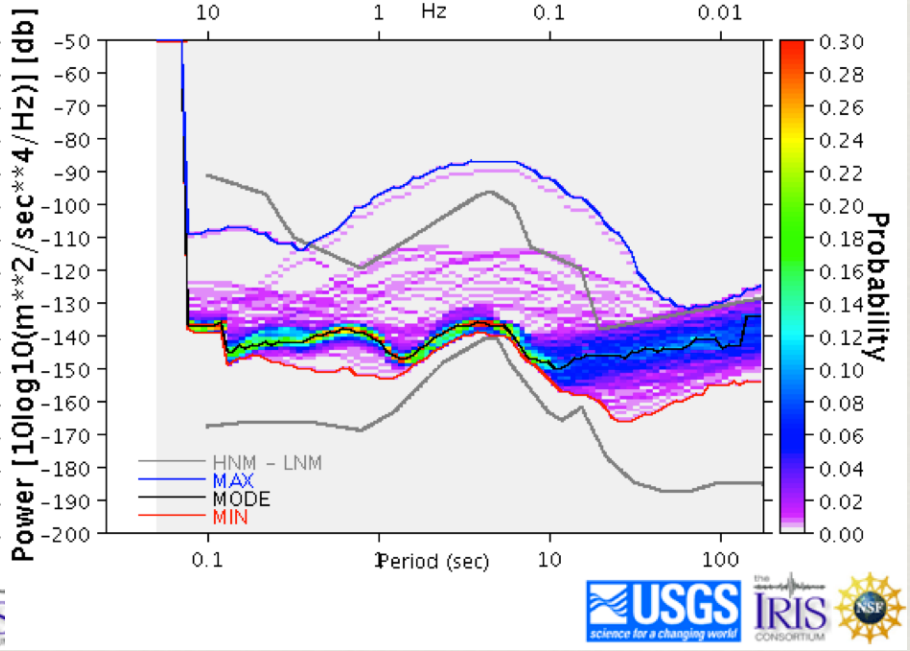


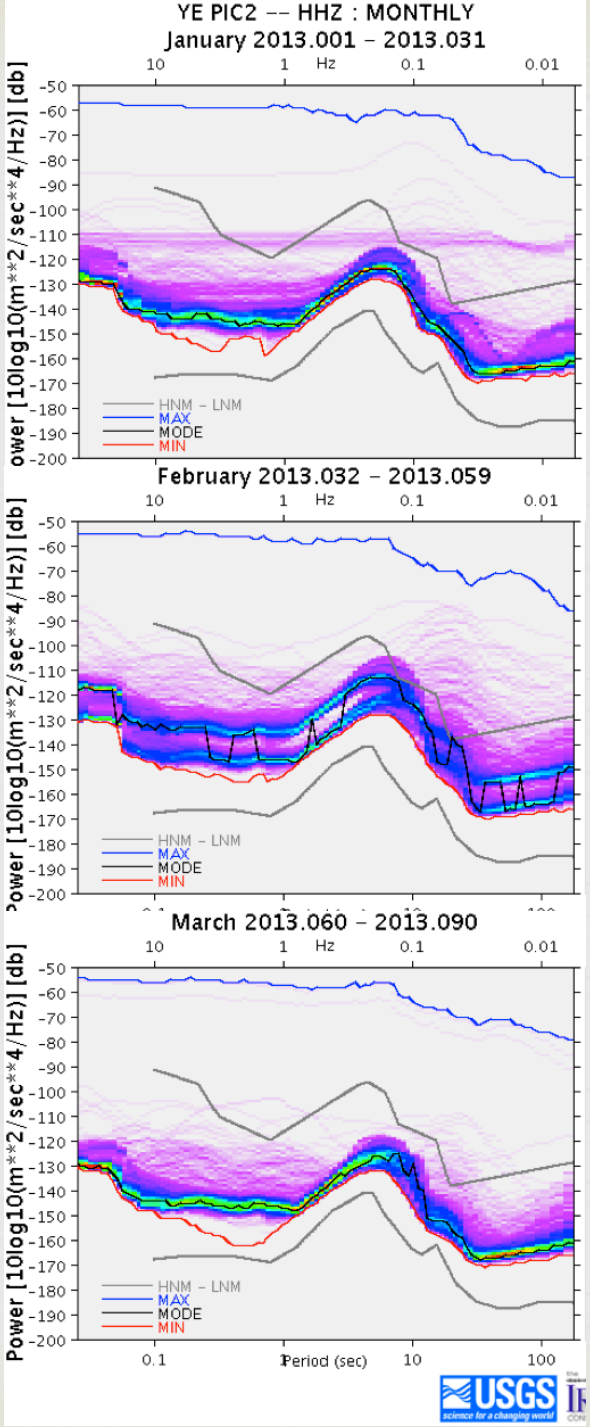


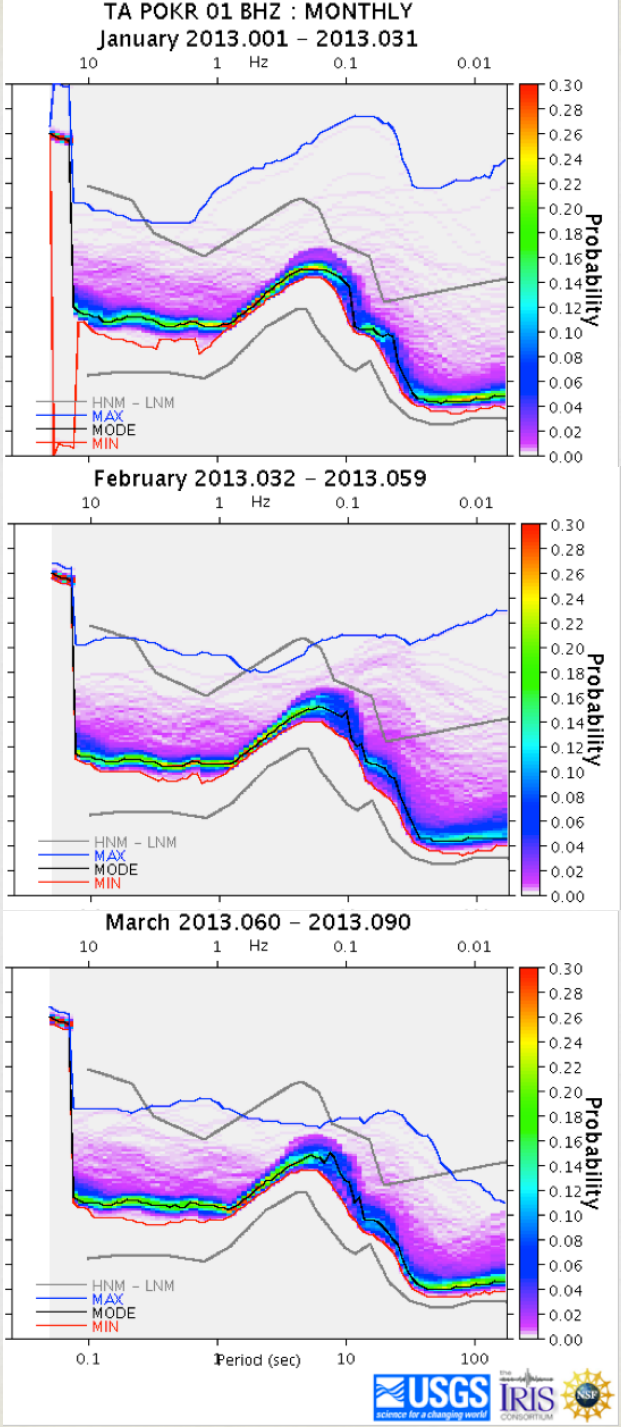
YE.PIC1.01.BHE
2014.198 – 2014.204



YE.PIC3.01.BHE
2014.198 – 2014.202




YE PIC2 -- HHZ : MONTHLY
January 2013.001 - 2013.031
February 2013.032 - 2013.059
March 2013.060 - 2013.090
Power [10log10(m**2/sec**4/Hz)] [db]
Hz
Period (sec)
HNM - LNM
MAX
MODE
MIN
USGS


TA POKR 01 BHZ : MONTHLY
January 2013.001 - 2013.031
February 2013.032 - 2013.059
March 2013.060 - 2013.090
Probability
Hz
Period (sec)
HNM - LNM
MAX
MODE
MIN
USGS
IRIS


2014 PASSCAL Experiment: Illuminating the architecture of the greater MoUnt St. Helens… (iMUSH)