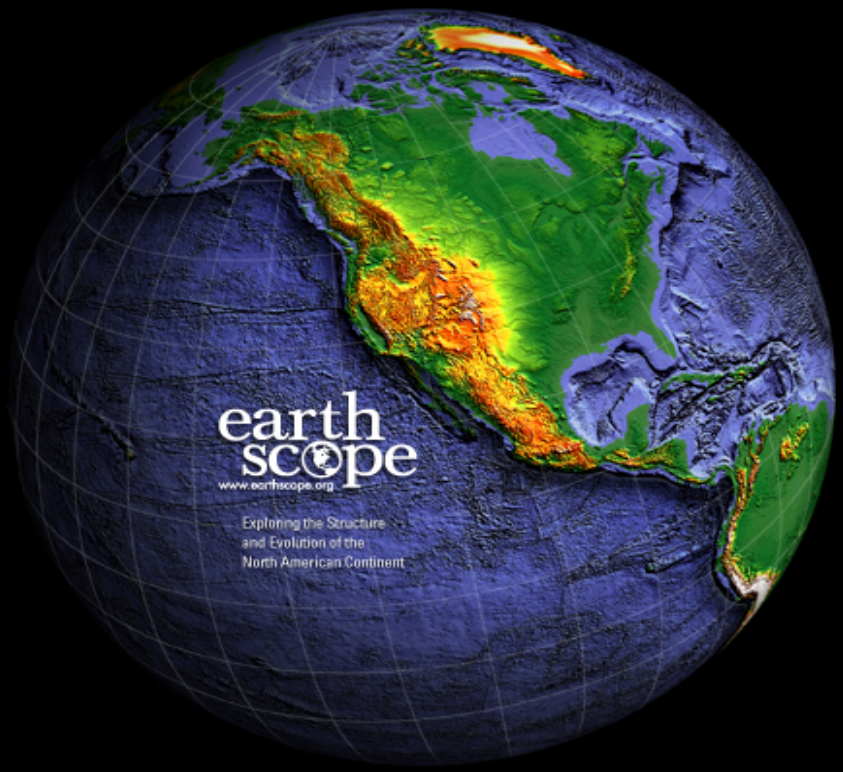
# Transportable Array

## Plans For Alaska and Yukon




Robert Busby, TA Manager
Katrin Hafner, Chief of Operations
Bob Woodward, Director USArray

*EarthScope National Meeting*
*Raleigh NC*
*May 13-15, 2013*

# Outline

Introduction to EarthScope's Transportable Array (TA)

Describe the deployment plans for Alaska and Yukon

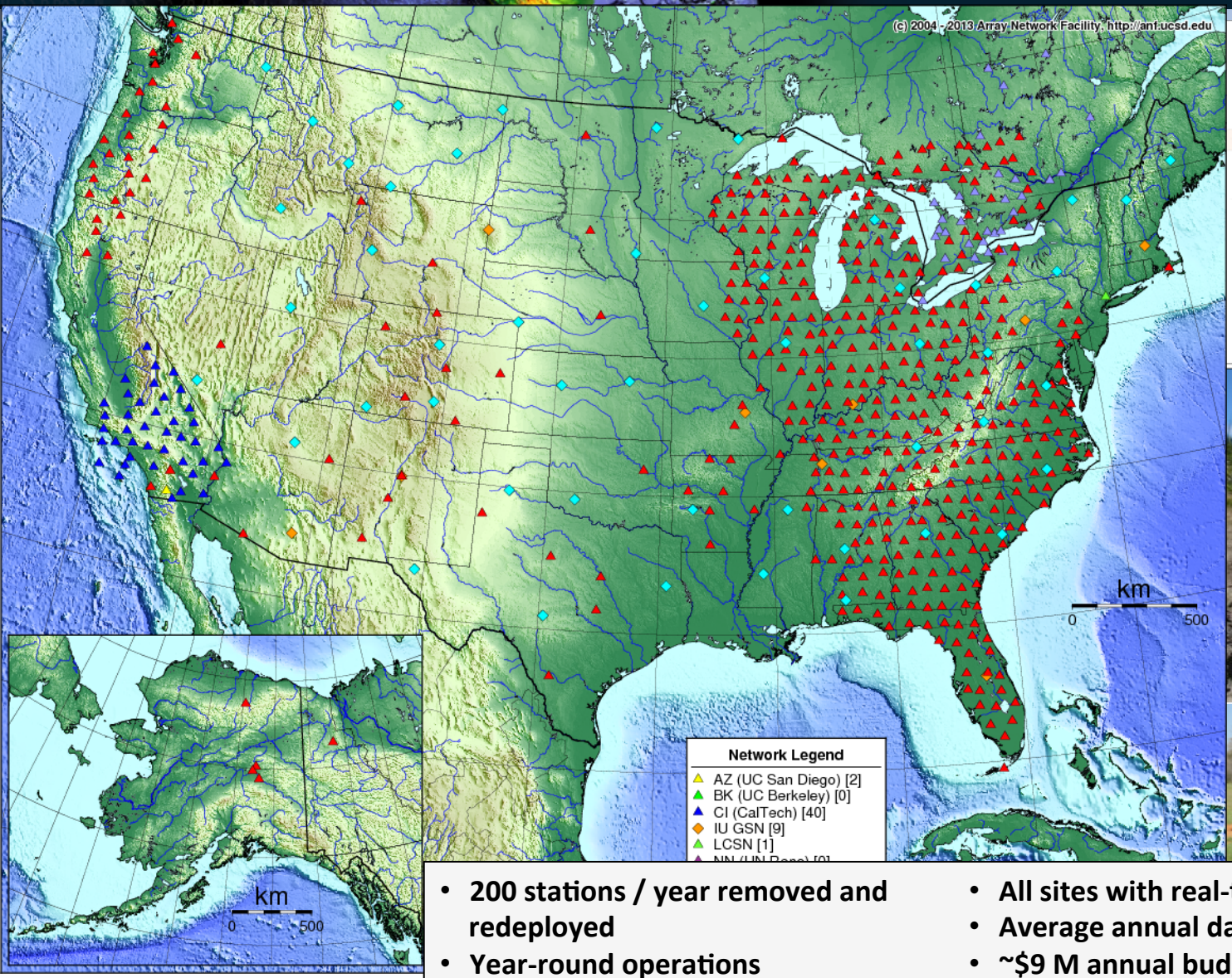
- Geography
- Schedule
- Approach to Logistics

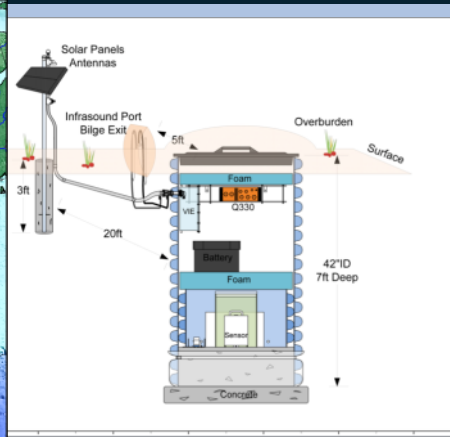
*Interleave aspects of the Station Design related to Sensor Emplacement and Performance-specifically Long Period Horizontals.*

*Parallels in OBS and Portable deployments*

*Affects Permitting and Logistics, and therefore the budget.*

# Introduction to the TA



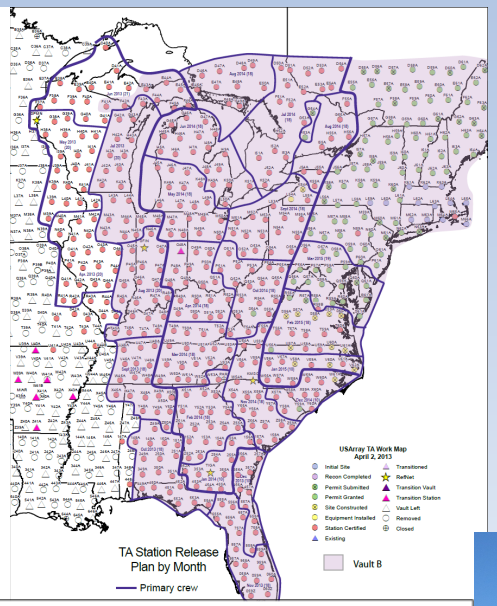



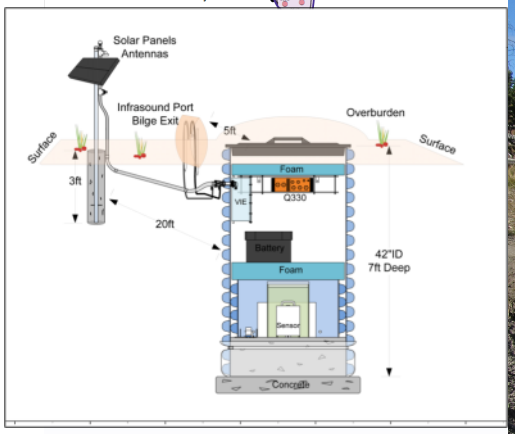

- 200 stations / year removed and redeployed
- Year-round operations
- 1,500 stations in past 7 years

- All sites with real-time telemetry
- Average annual data return >98%
- ~$9 M annual budget

# Station Design- tank vaults

http://www.passcal.nmt.edu/taweb

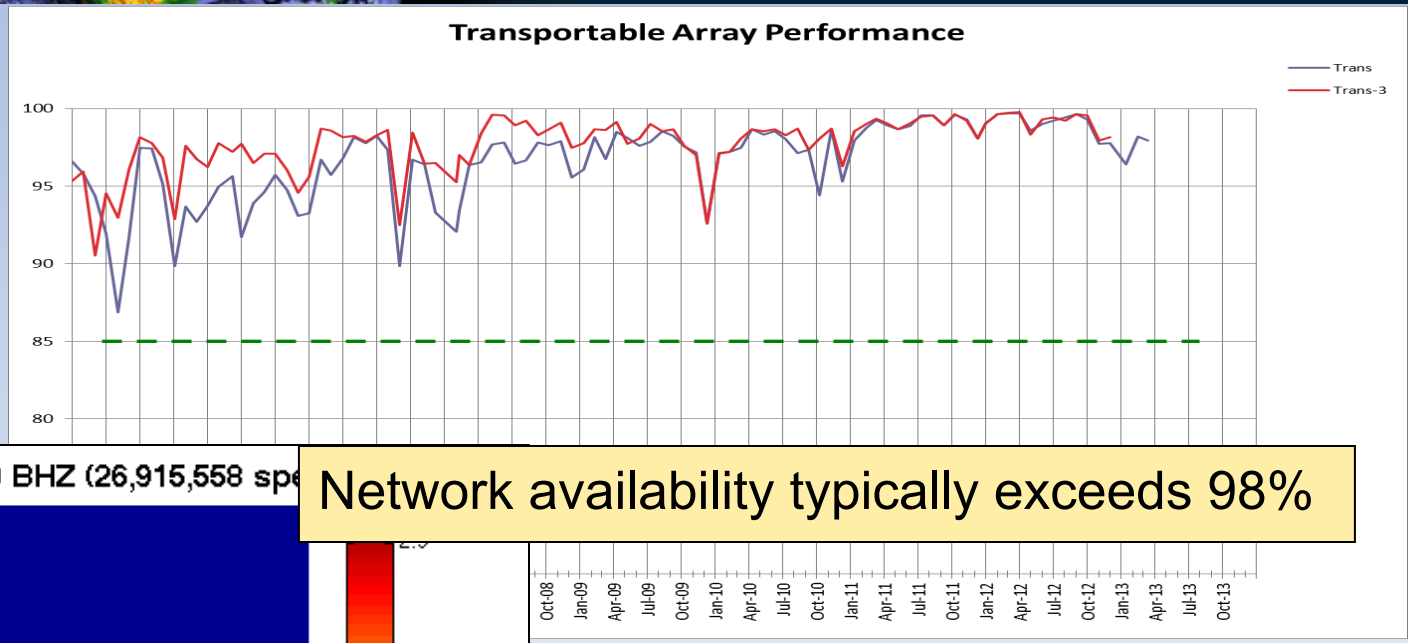


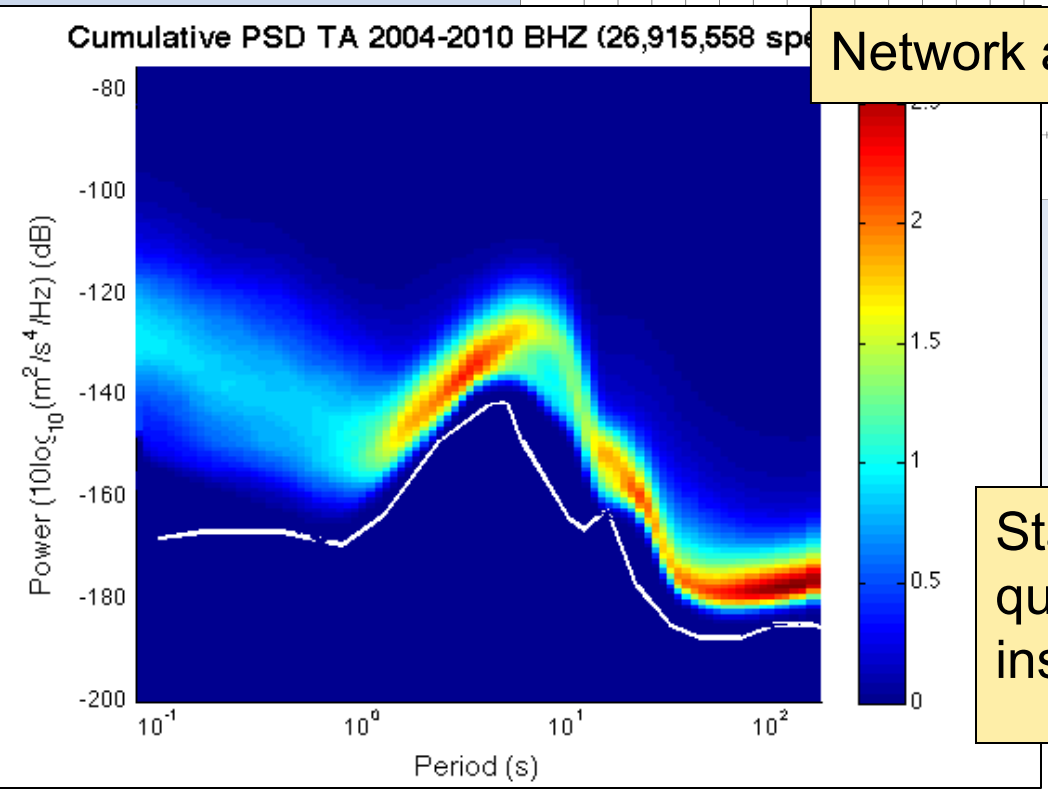




Freeman Engineered Products
custom rotomolded HDPE tank

**$1200**
**105 kg**

# TA Performance



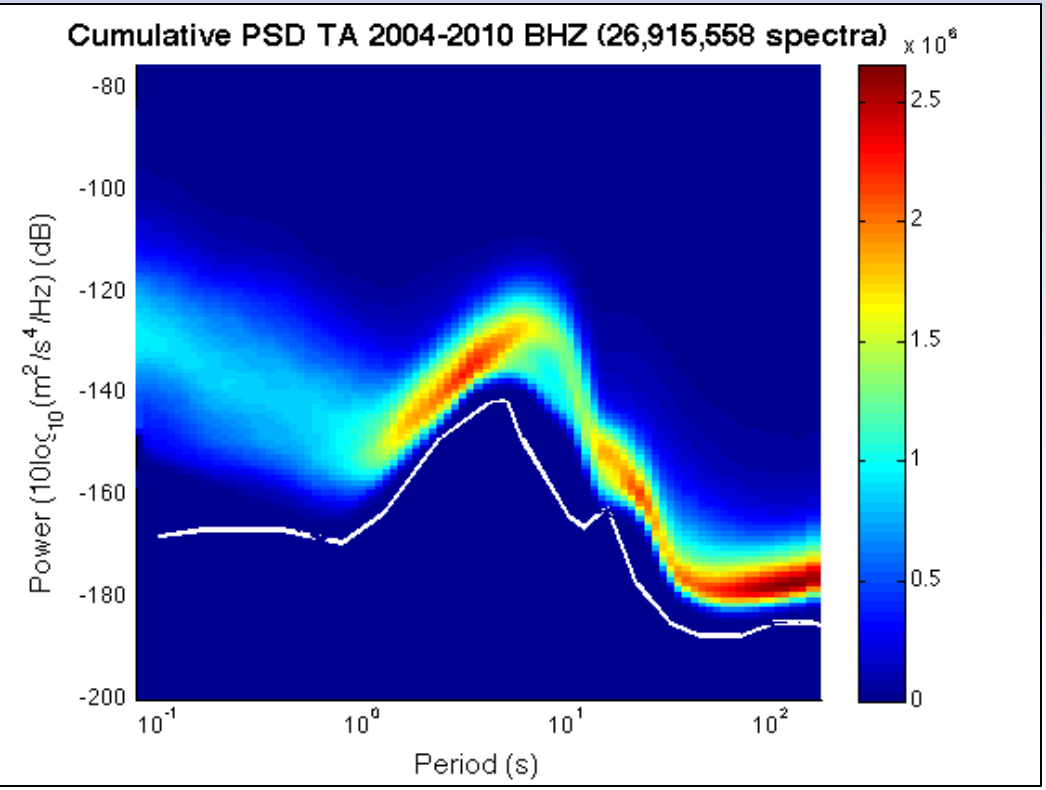

Network availability typically exceeds 98%

Station noise highly uniform and quite low for temporary installations

# Power Spectral Density

Power spectral density of hour long time series, every half hour, 48 per day.

Stacked onto same plot, topography of stack indicated by color range.




**IRIS DMC calculates PDFs for all seismic data received.**

**Makes plots available in the QUACK service.**
**http://www.iris.edu/servlet/quackquery**

**Or there is a matlab plot rendering, with bin files available using web services**
**http://www.iris.edu/dms/products/pdfpsd/**

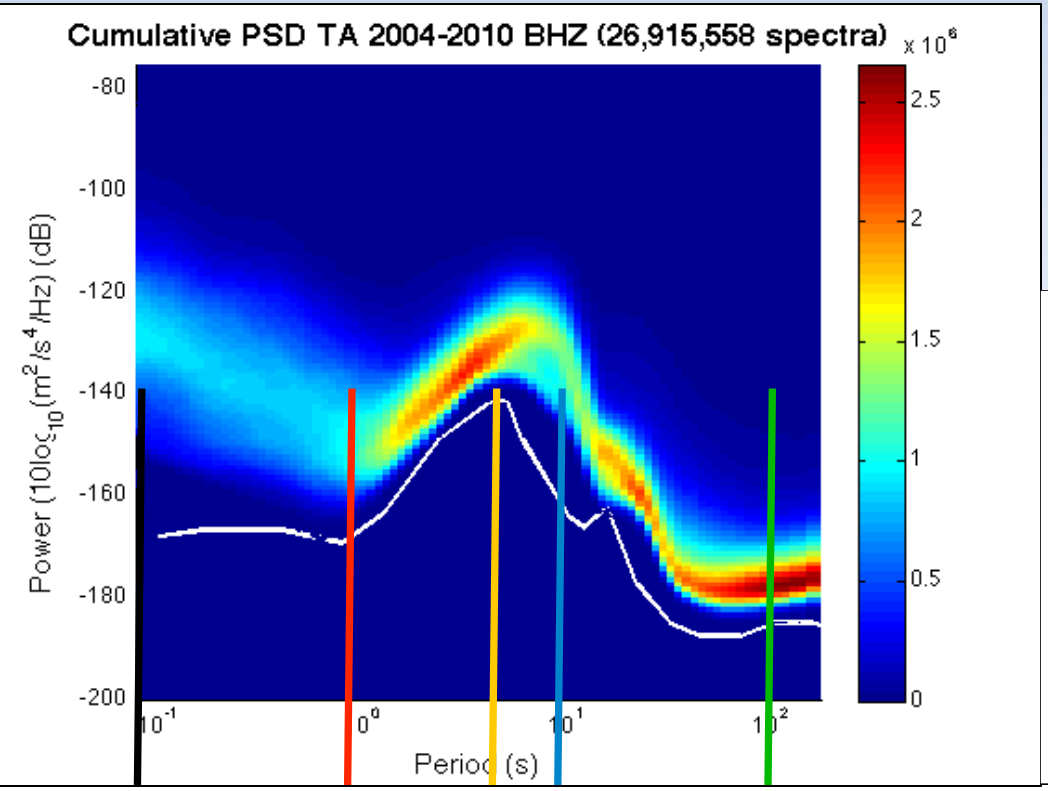
**McNamara and Boaz USGS Open File report 2005-1438**

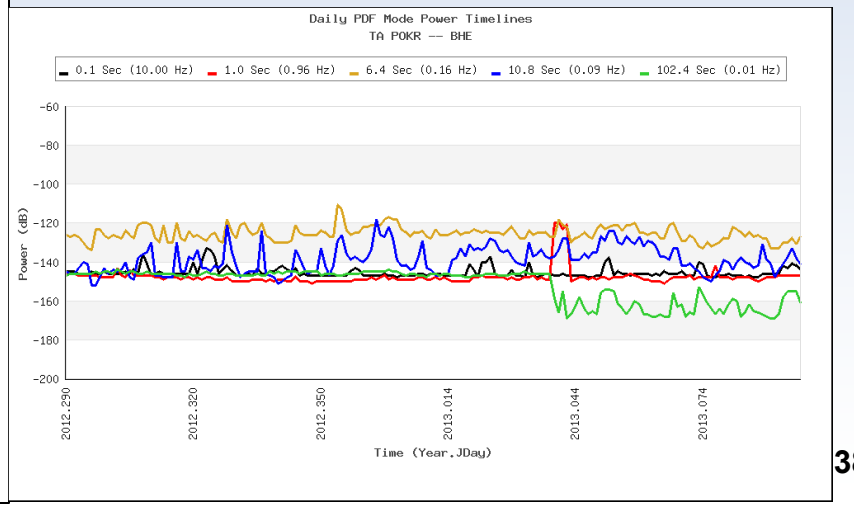
# Power Spectral Density

A mode is the amplitude most often observed for that frequency.

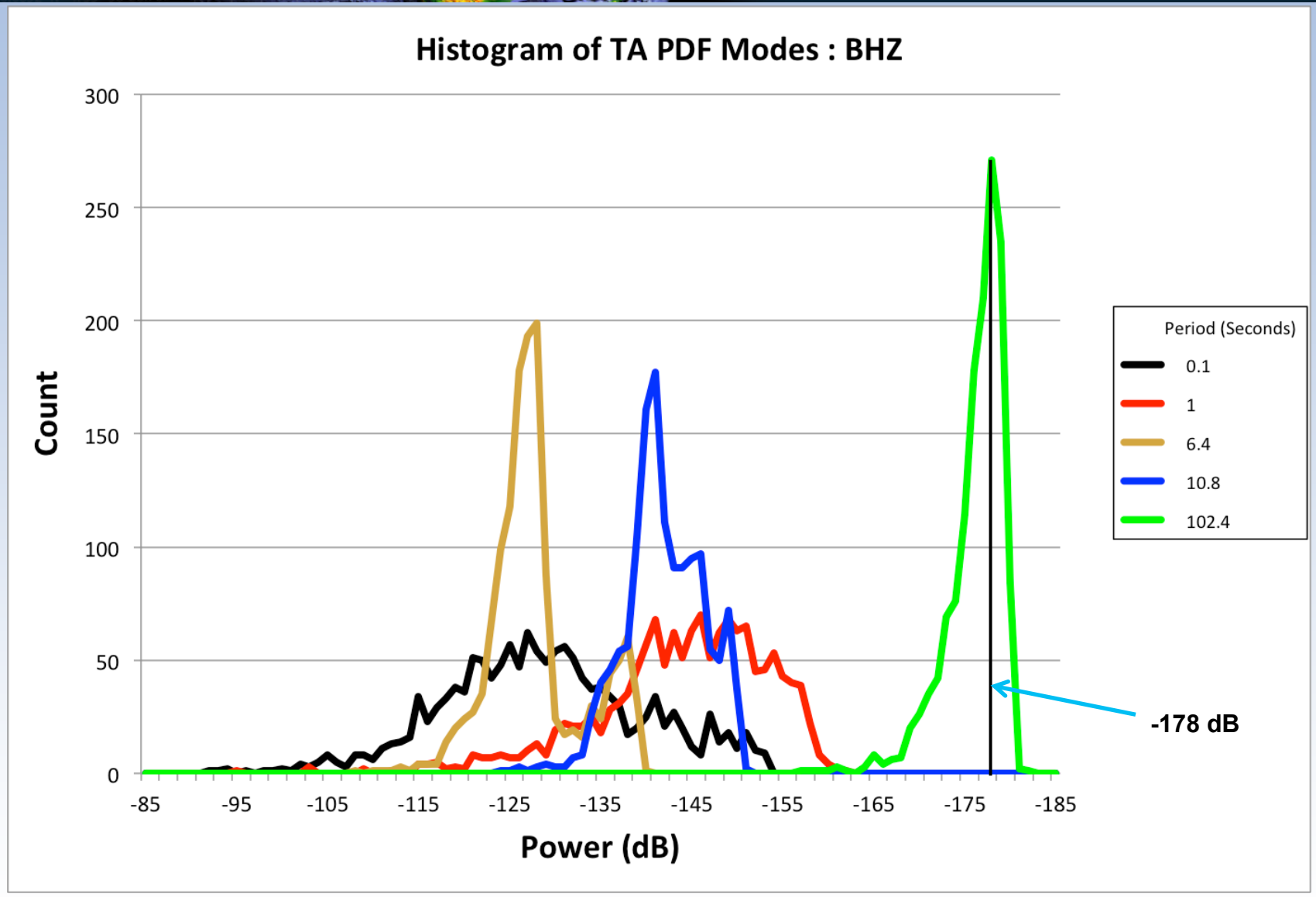
We identify some representative frequencies

and show the time history of the mode or for a large number of stations, plot the histogram of number of stations.

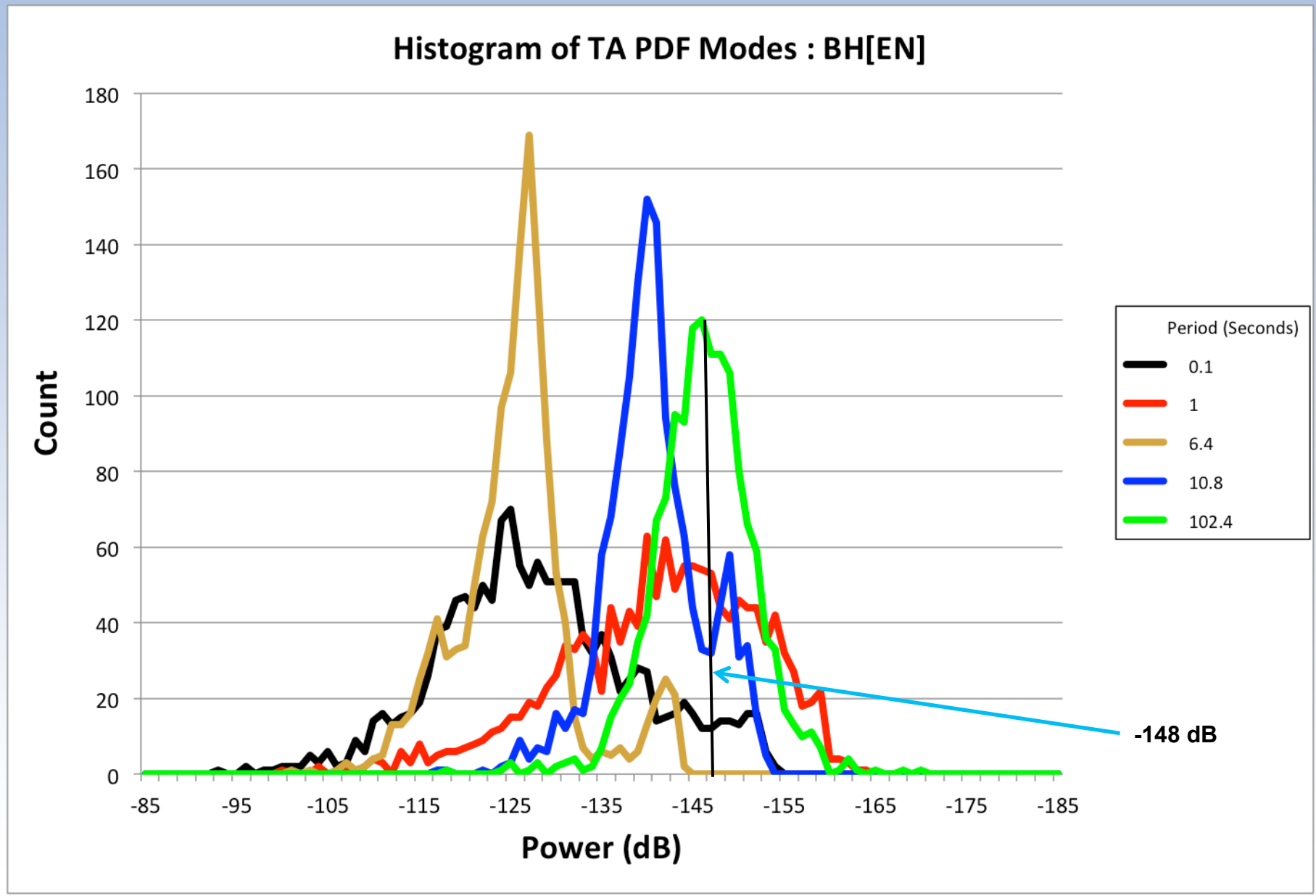


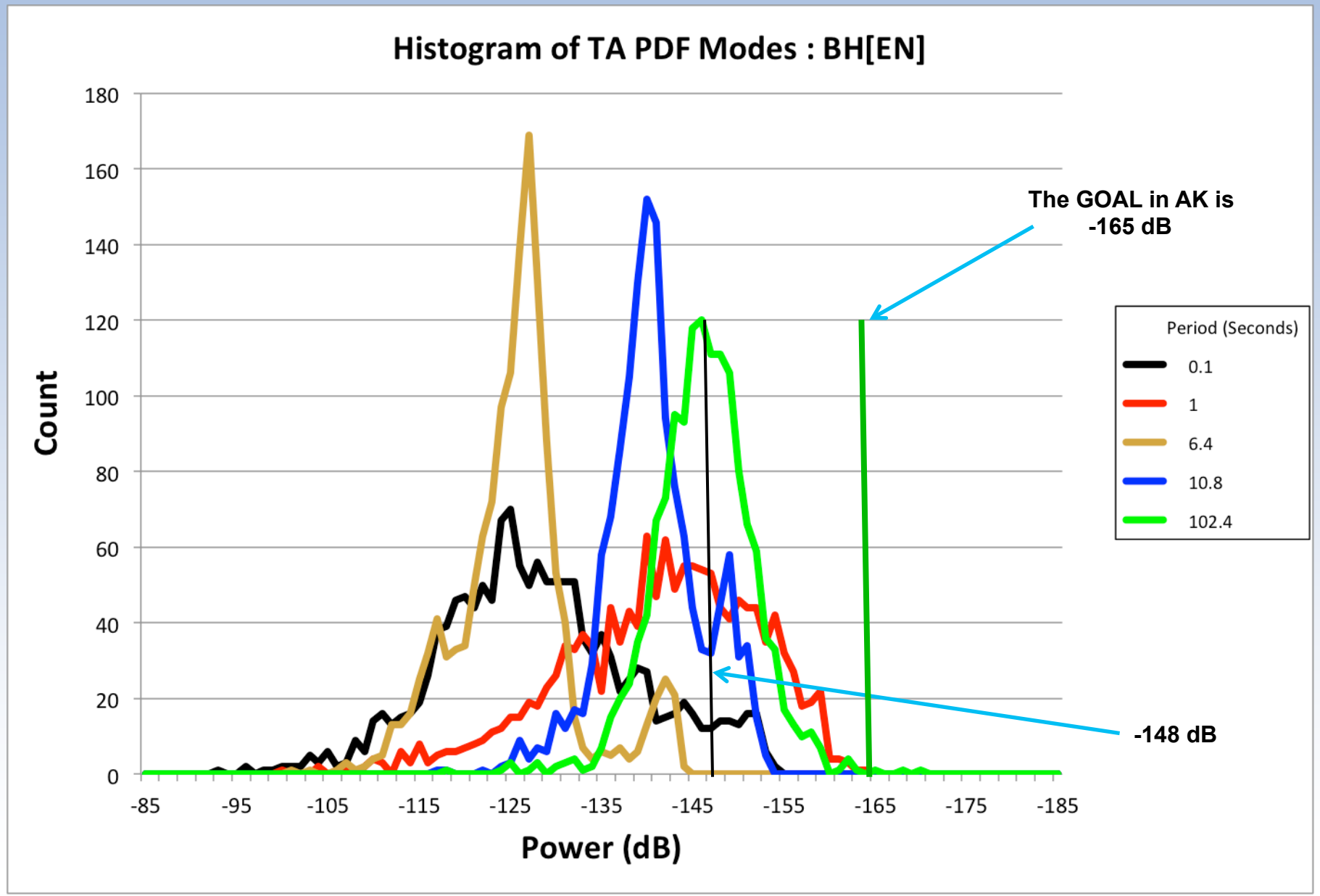
# Histograms


Histogram of TA PDF Modes : BHZ
Count
300
250
200
150
100
50
0
-85
-95
-105
-115
-125
-135
-145
-155
-165
-175
-185
Power (dB)
Period (Seconds)
0.1
1
6.4
10.8
102.4
-178 dB

# Histograms

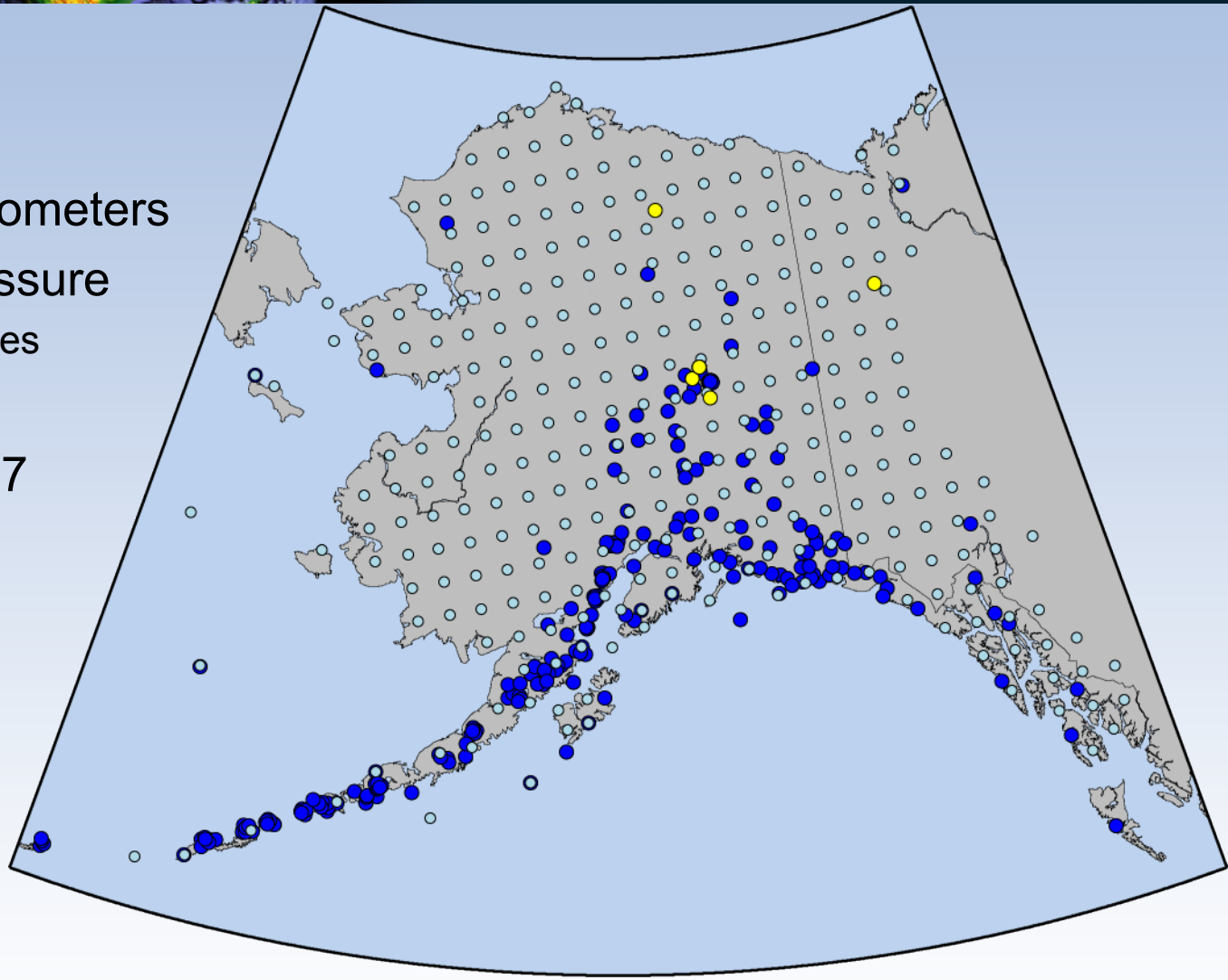

Histogram of TA PDF Modes : BH[EN]
Count
180
160
140
120
100
80
60
40
20
0
-85
-95
-105
-115
-125
-135
-145
-155
-165
-175
-185
Power (dB)
Period (Seconds)
0.1
1
6.4
10.8
102.4
-148 dB

# Histograms


Histogram of TA PDF Modes : BH[EN]
Count
180
160
140
120
100
80
60
40
20
0
-85
-95
-105
-115
-125
-135
-145
-155
-165
-175
-185
Power (dB)
The GOAL in AK is -165 dB
-148 dB
Period (Seconds)
0.1
1
6.4
10.8
102.4

# TA in Alaska / Yukon

- ~300 sites
- 85 km spacing
- Broadband Seismometers
  - Infrasound, pressure
  - Some met packages
- Communications
- fully deployed 2017



**www.usarray.org/alaska**

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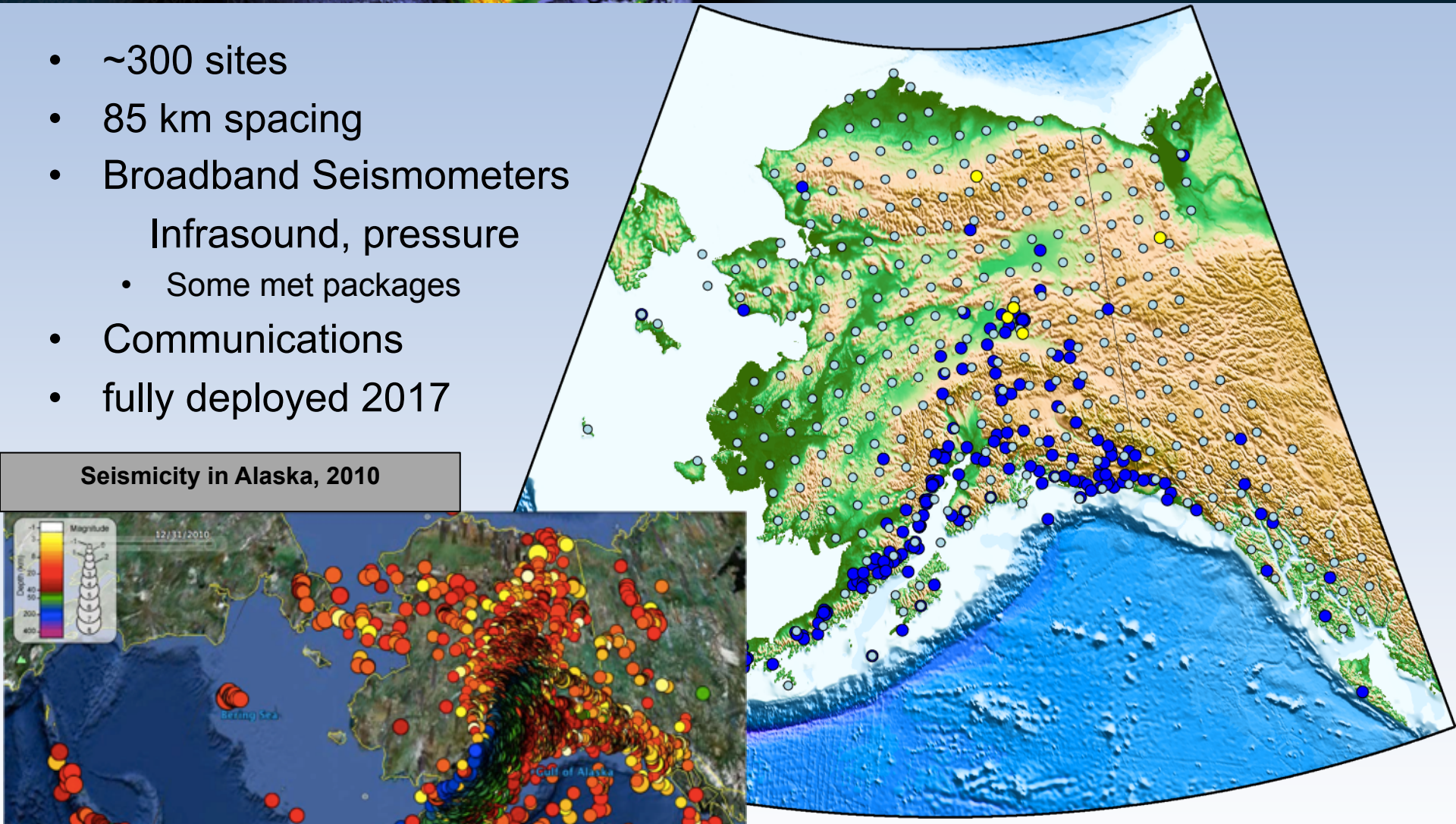


**Seismicity in Alaska, 2010**




**www.usarray.org/alaska**

# Station Design Aspects

- Sensor emplacement to achieve highest quality data
- Power strategies to balance weight, reliability, complexity
  - Solar panels, advanced chemistry batteries, fuel cells
- Communications scaled by ( data volume and latency ) vs. cost

**Post Hole Broadband Seismometers**

**Toolik Lake Field Station, North Slope Alaska**

# Sensor emplacement

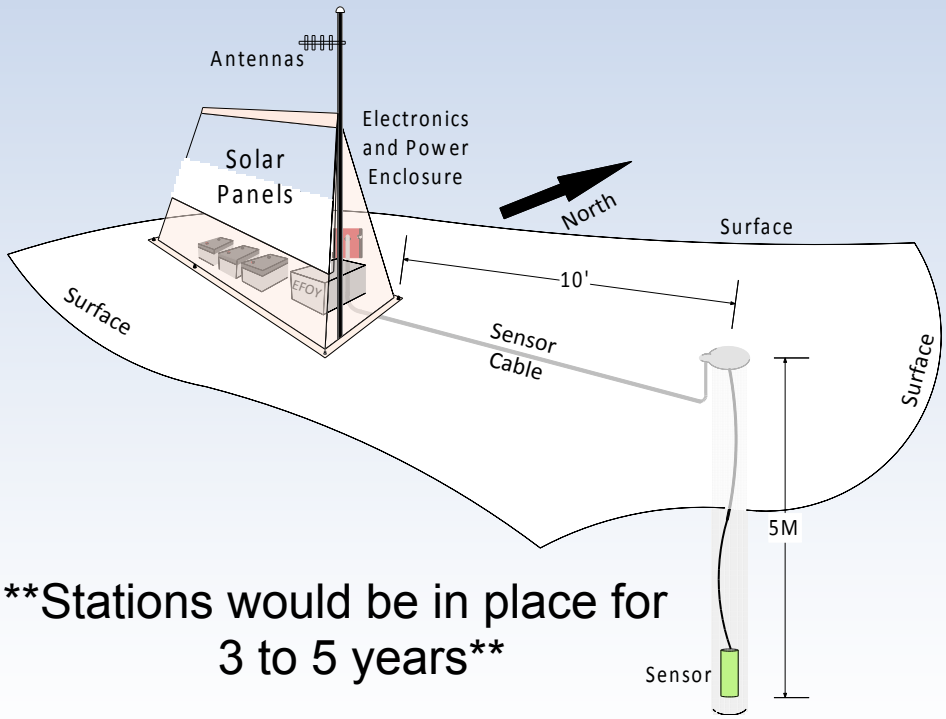
**High quality long period Seismic data requires stable emplacement of the $20k 3 axis sensor**

**In rock outcrops, a diamond coring machine can create 6” diameter holes to depths of 1.8m in an hour. In permafrost soil & silt, coring is also possible. Portable auger and coring drills are under test. Design goal is <500kg.**

Motivation: Alaska, all equipment designed for transport in fixed wing aircraft or helicopter.

# Basic Description of Buried Sensor Design for AK

- Sensor: 3 component Broadband seismometer & auxiliary sensors
- Datalogger & local data storage
- Power & data telemetry

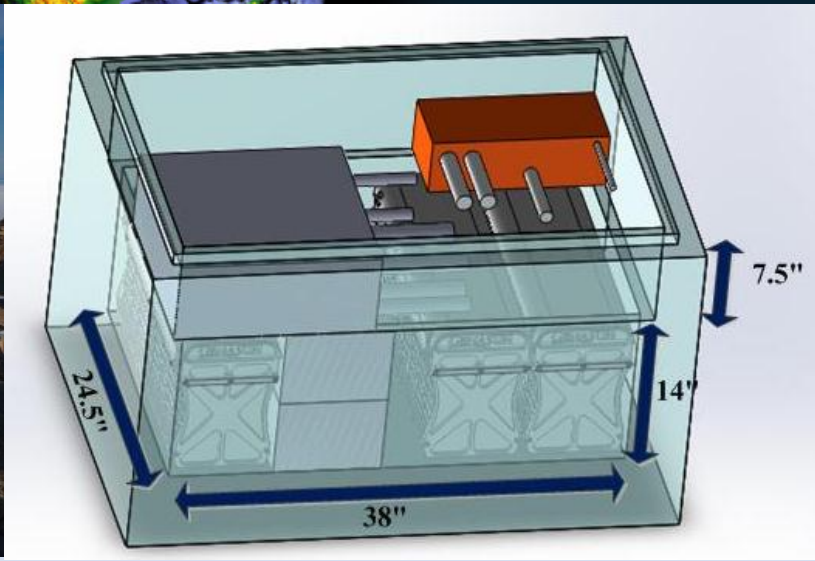



**Stations would be in place for 3 to 5 years**

Depth 5M in Soil, 1-3M in rock

TOLK Seismic Station

# Comparing Enclosures



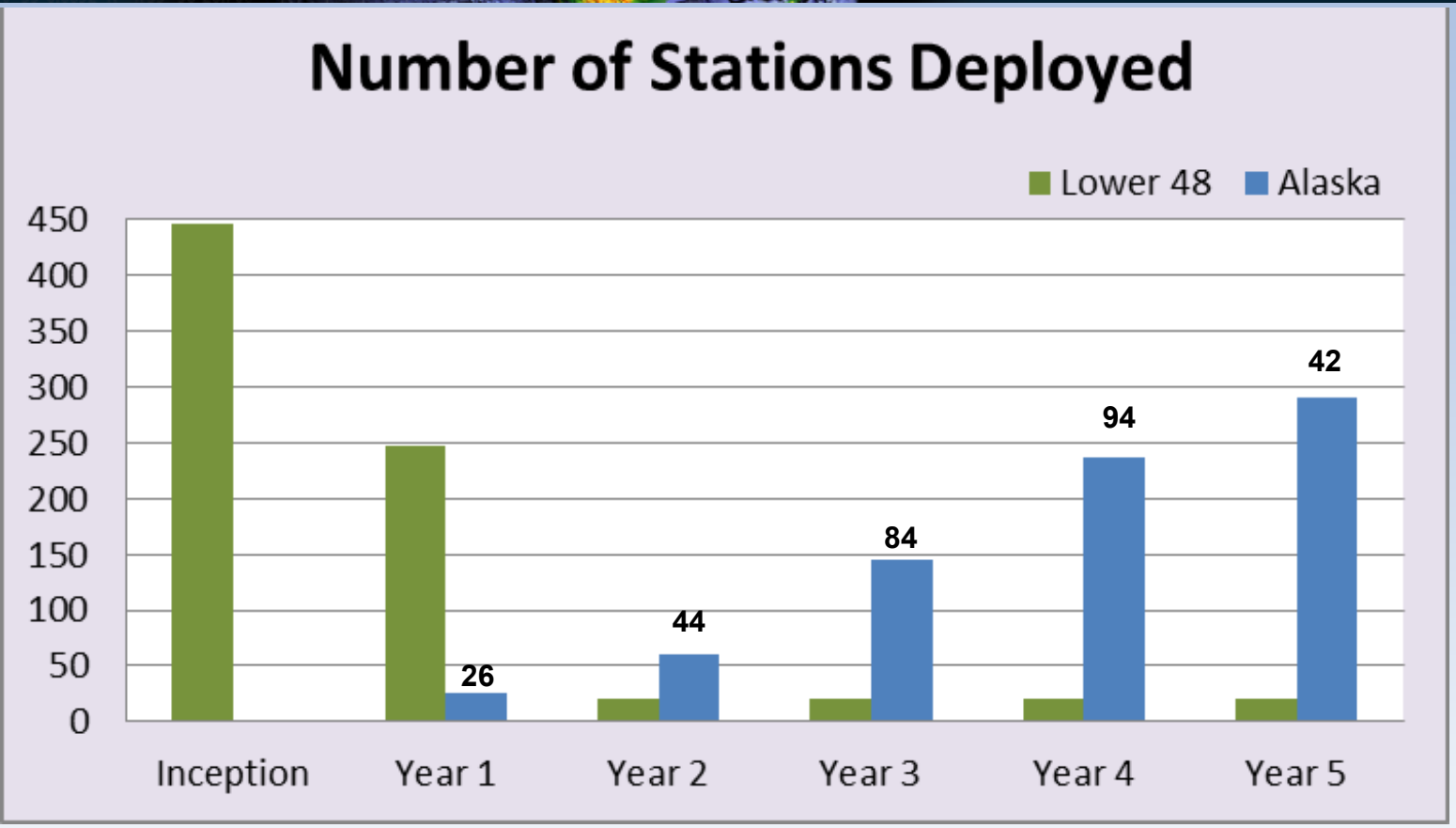

**Comparing how many Lead Acid vs. LiFePO4 batteries you can wedge into two different types of enclosures, factor in the weight of the overall package and a transit cost of $25/kg round trip.**

| | #Pb batts | #LiFePO4 | Cap cost | Weight | Transit Cost | Total Cost | KWH | cost/KWH |
|---|---|---|---|---|---|---|---|---|
| BOX1 | 3 | 2 | $ 10,650 | 328 | $ 8,200 | **$ 18,850** | **12.2** | $ 1,545 |
| BOX2 | 4 | 3 | $ 15,100 | 411 | $ 10,275 | **$ 25,375** | **17.8** | $ 1,426 |
| BOX2 | 16 | 0 | $ 5,500 | 642 | $ 16,050 | **$ 21,550** | **19.2** | $ 1,122 |
| HUT | 24 | 0 | $ 9,500 | 1025 | $ 25,625 | **$ 35,125** | **28.8** | $ 1,220 |
| HUT | 16 | 0 | $ 7,500 | 769 | $ 19,225 | **$ 26,725** | **19.2** | $ 1,392 |

# Concept of Operations

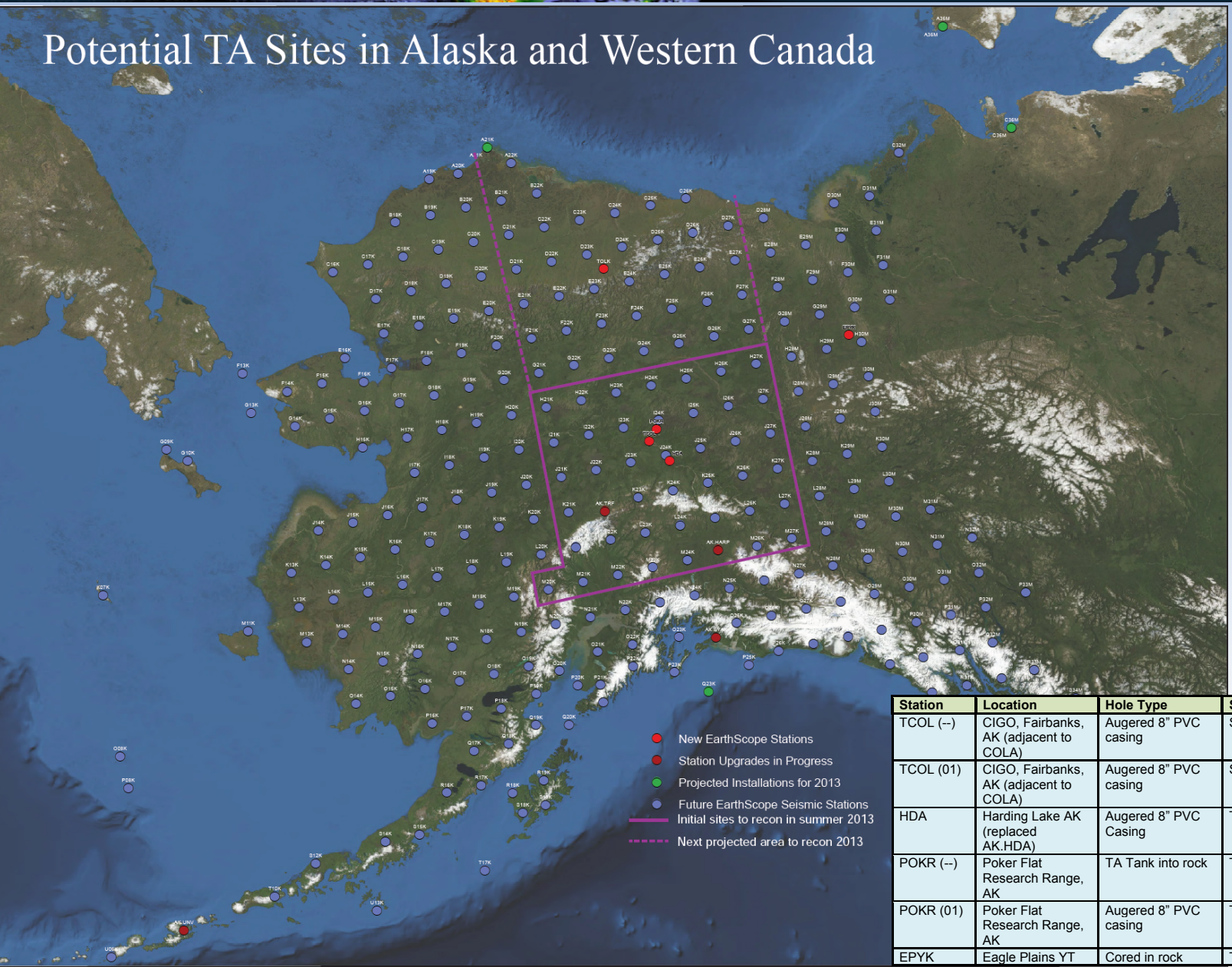
- Operations Base in Anchorage
- Spoke from village hubs
- Helicopter lift of drill rig

# Project Schedule



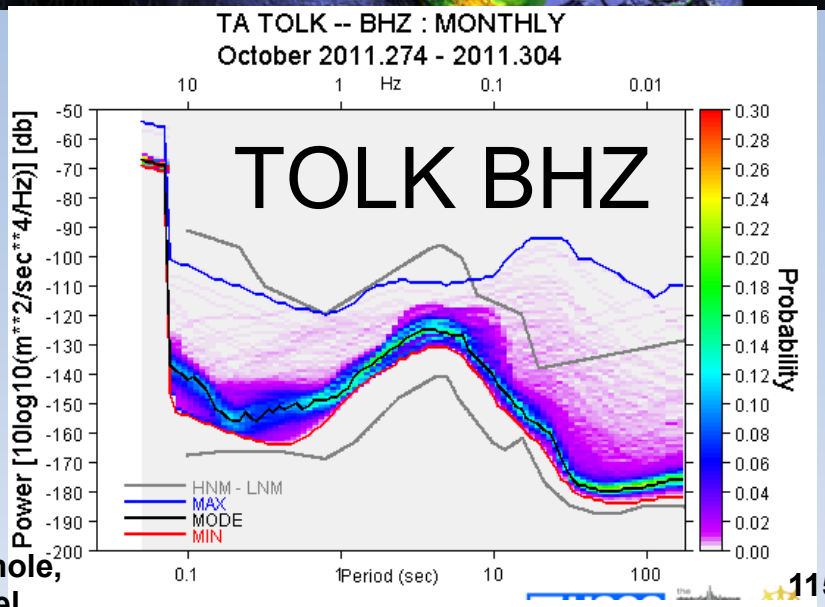

- Schedule balances roll-up in east with roll-out in Alaska
- Alaska field schedule is seasonally driven
  - Late spring – early fall
- Schedule provides longer operational window in AK
- Additional time for Alaska organizations to assemble plans to make selected stations permanent or collaborative science.

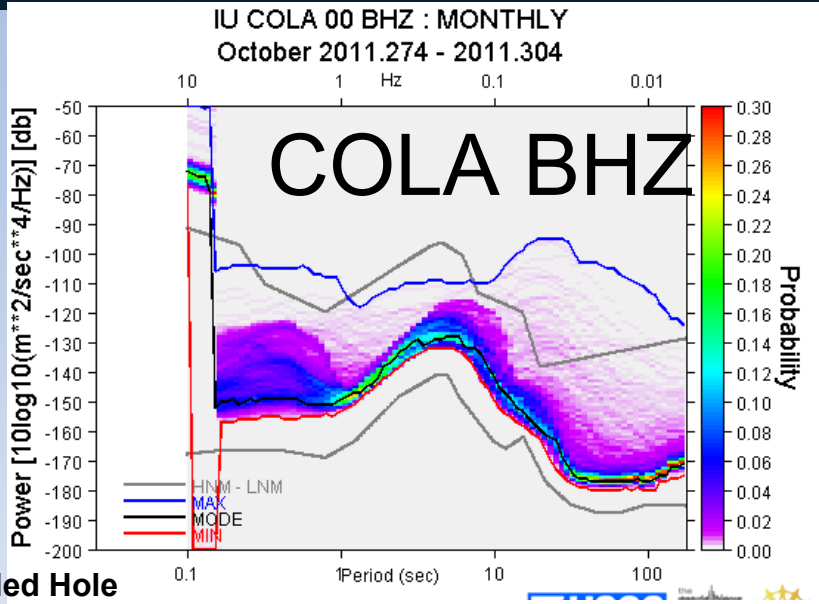
# Alaska Test Stations




| Station | Location | Hole Type | Sensor | Depth (m) | Started |
|---|---|---|---|---|---|
| TCOL (--) | CIGO, Fairbanks, AK (adjacent to COLA) | Augered 8" PVC casing | STS-4B | 10 | 10/9/2012 |
| TCOL (01) | CIGO, Fairbanks, AK (adjacent to COLA) | Augered 8" PVC casing | STS-4B | 5 | 10/9/2012 |
| HDA | Harding Lake AK (replaced AK.HDA) | Augered 8" PVC Casing | T120PH | 5 | 10/4/2012 |
| POKR (--) | Poker Flat Research Range, AK | TA Tank into rock | T240 | 2 | 10/12/2012 |
| POKR (01) | Poker Flat Research Range, AK | Augered 8" PVC casing | T120PH | 5 | 10/12/2012 |
| EPYK | Eagle Plains YT | Cored in rock | T120PH | 1.4 | 10/15/2012 |

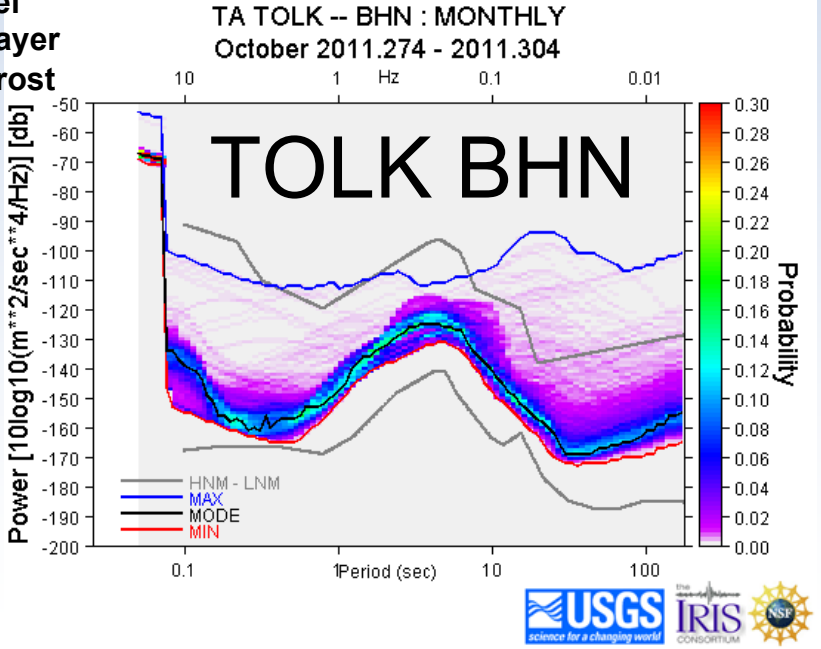
# TOLK & COLA

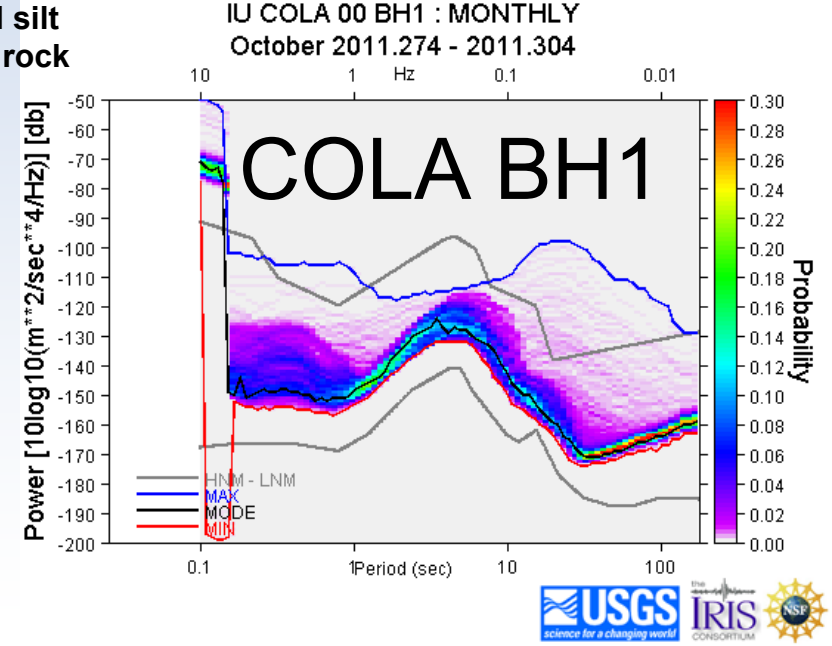


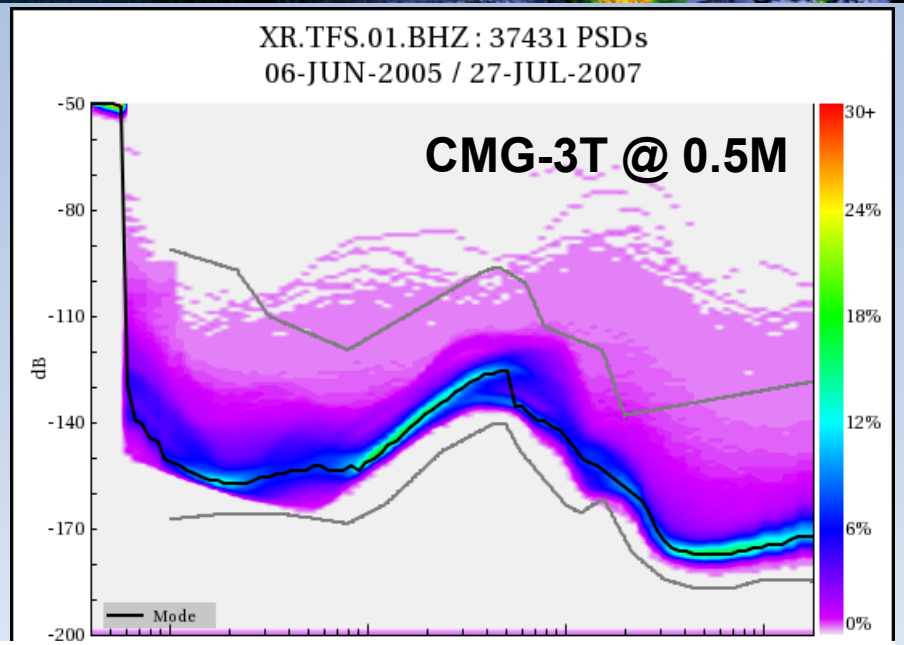

**5M drilled hole,**
**1M gravel**
**1M active layer**
**3M permafrost**

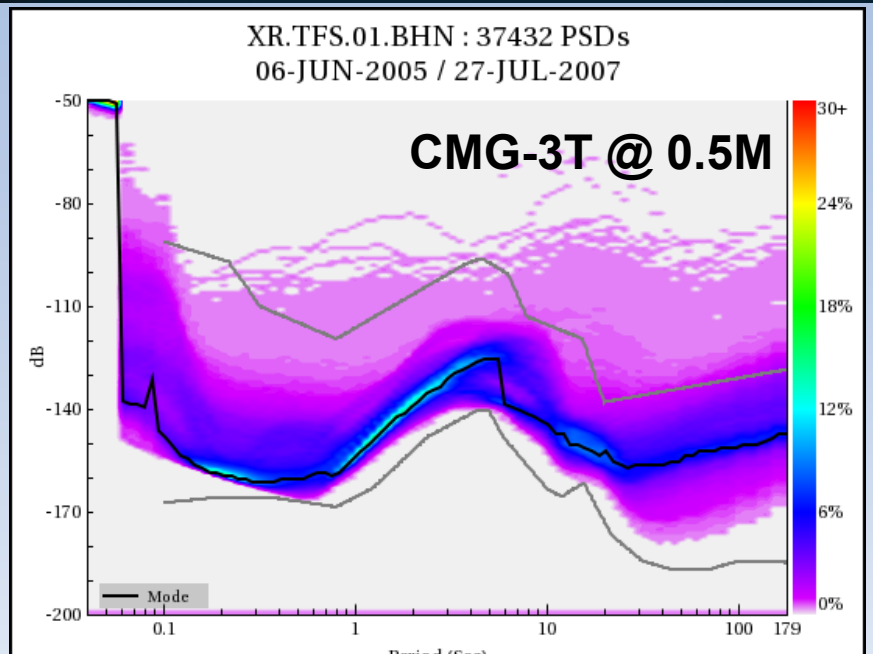
**115M drilled Hole**
**80M silt**
**35M rock**

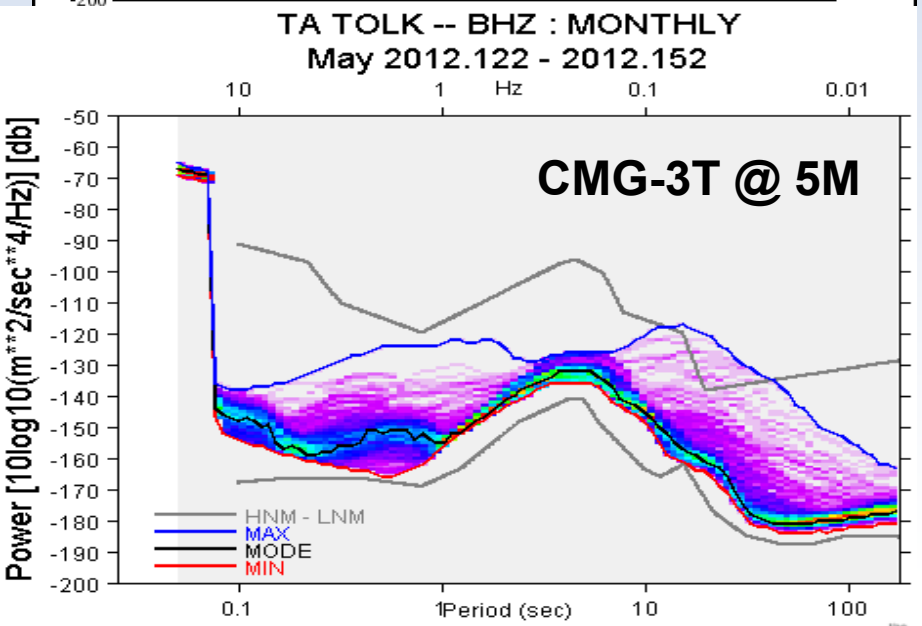


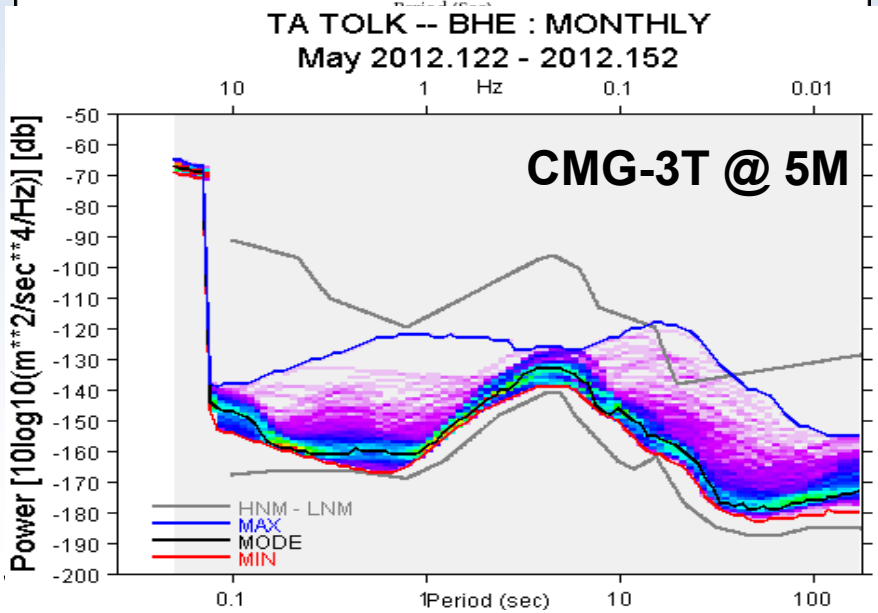



# Toolik TA & Portable



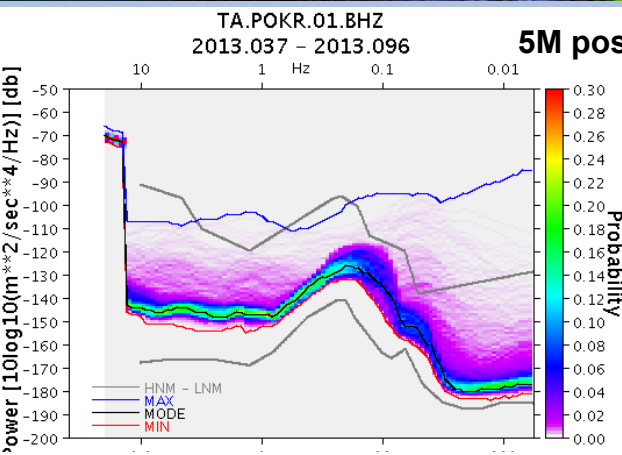



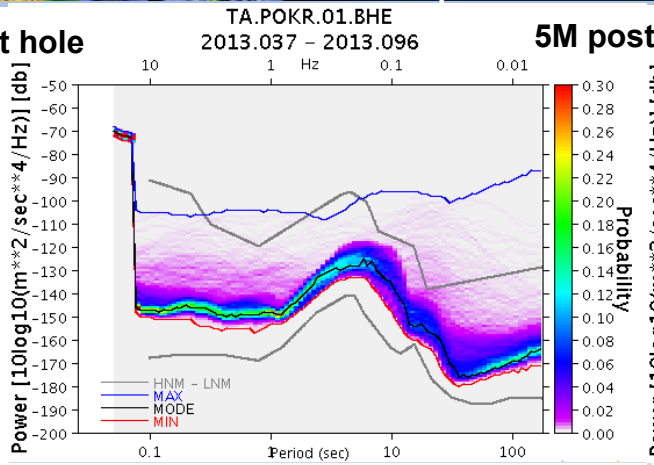



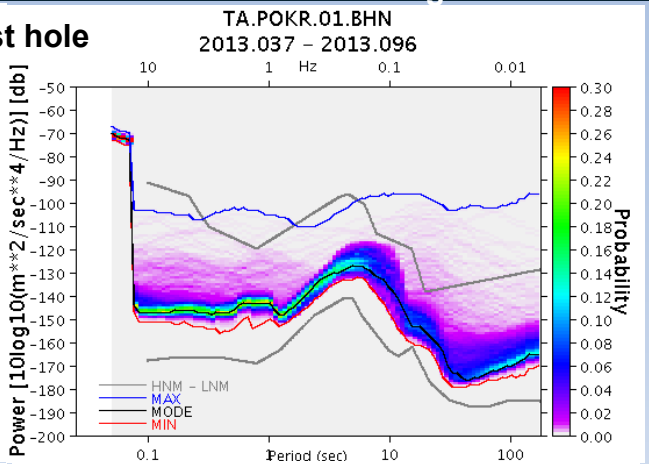



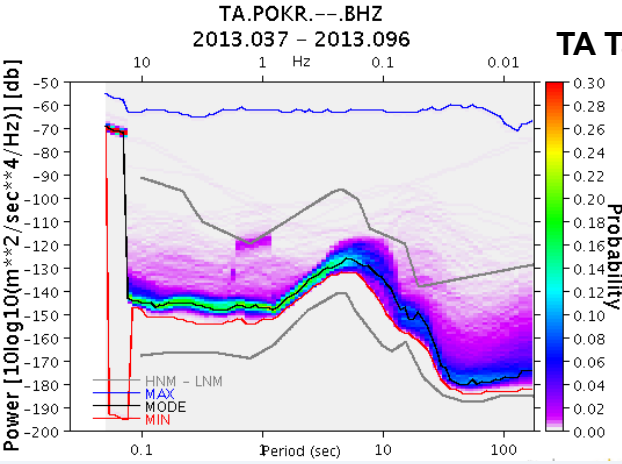
# TA.POKR experiment

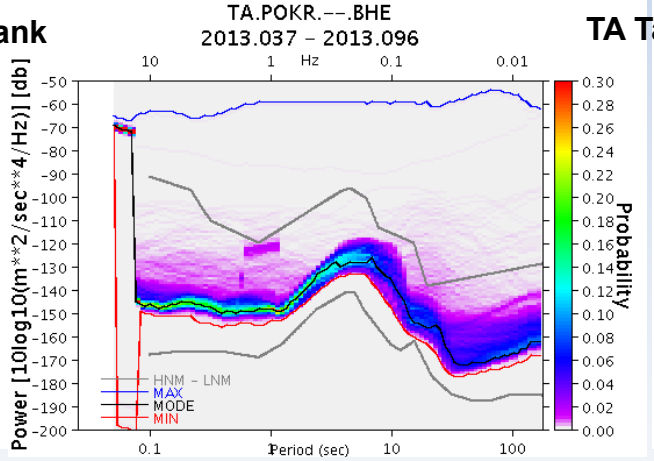
**Special thanks to Poker Flat Research Range Staff!**

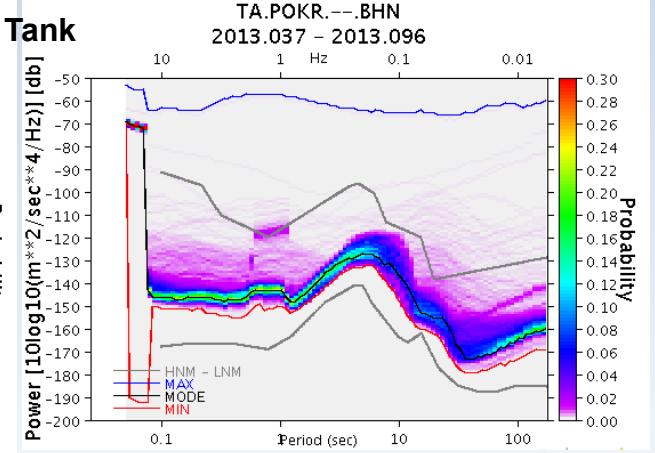
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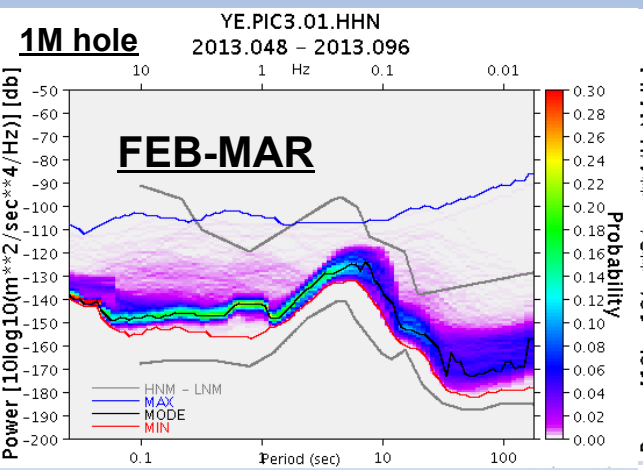
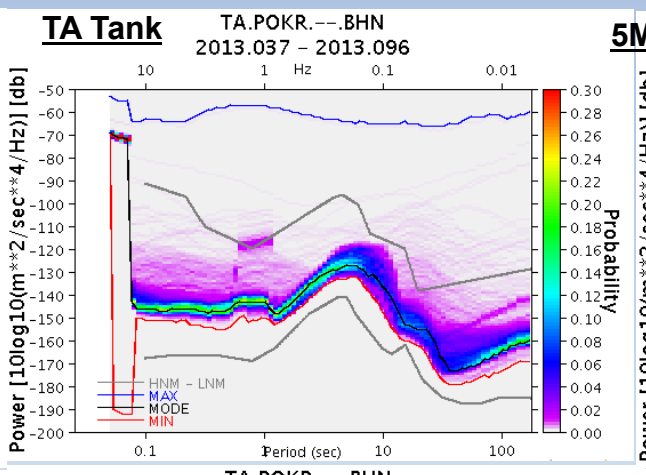
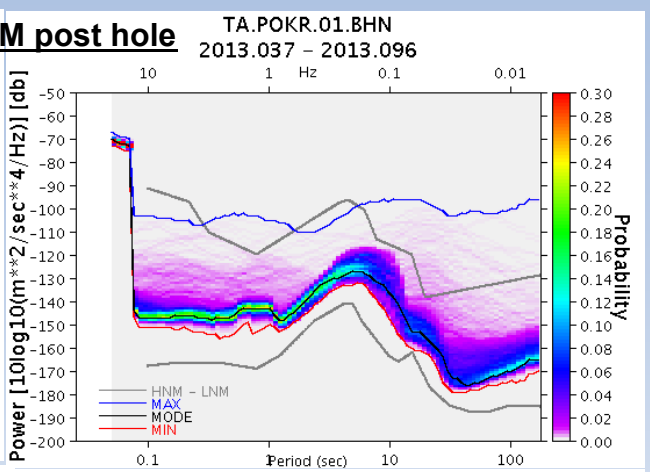
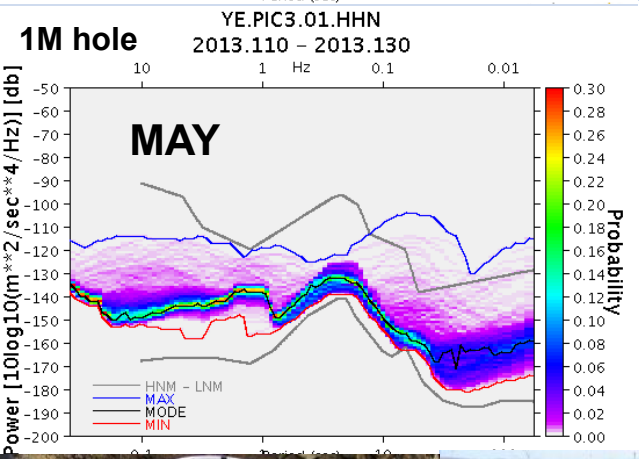
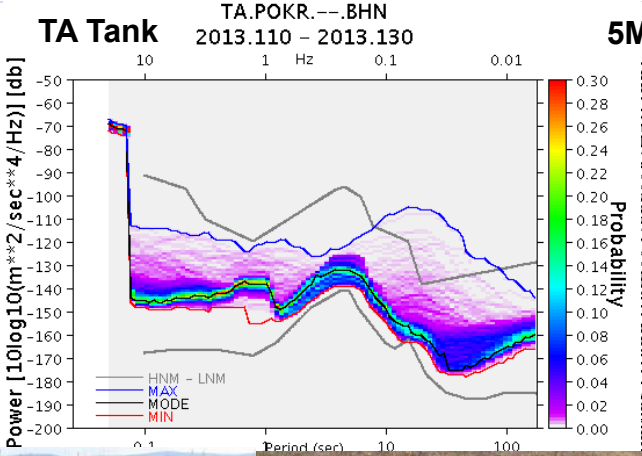
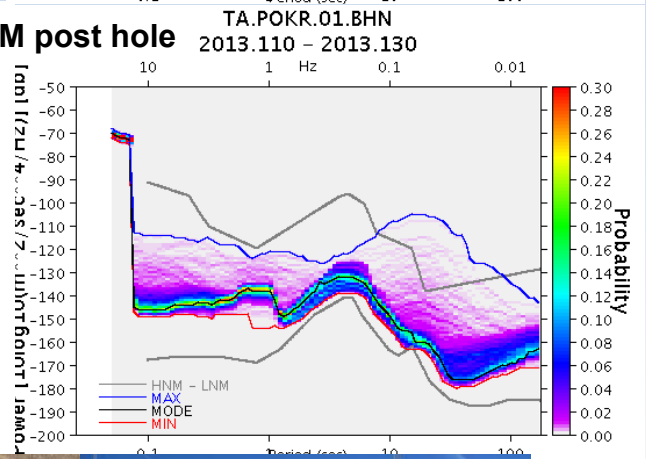


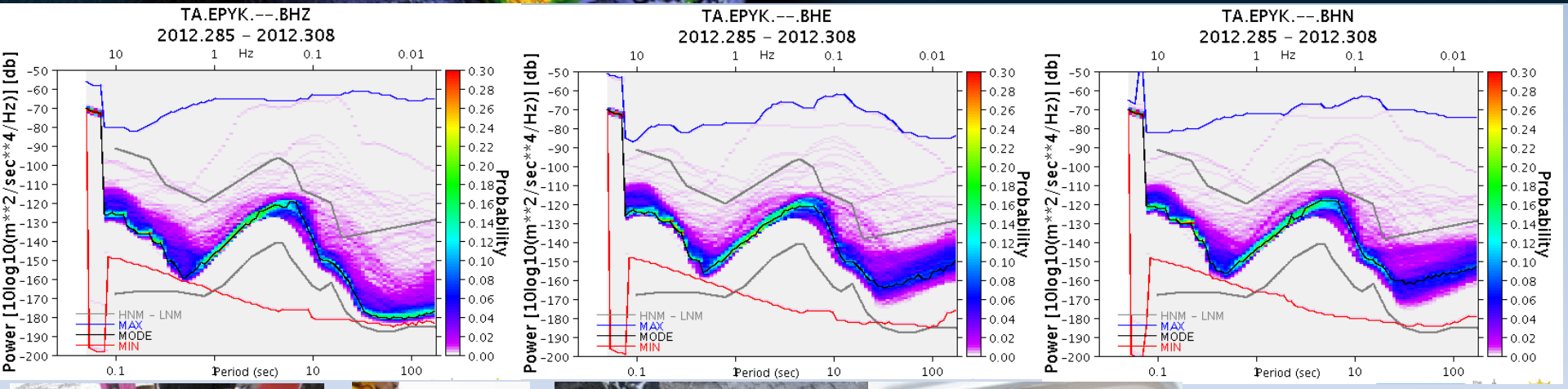



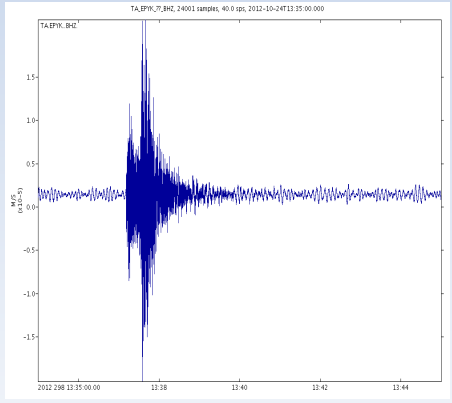




# Eagle Plains Yukon



**Oct 24, 2012 M4.5 Vertical**

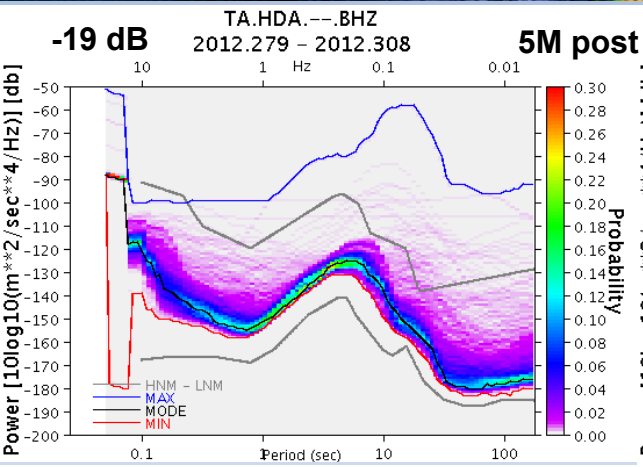
**Stop Action Video of install**

http://www.youtube.com/watch?v=JTTv6wqCqco

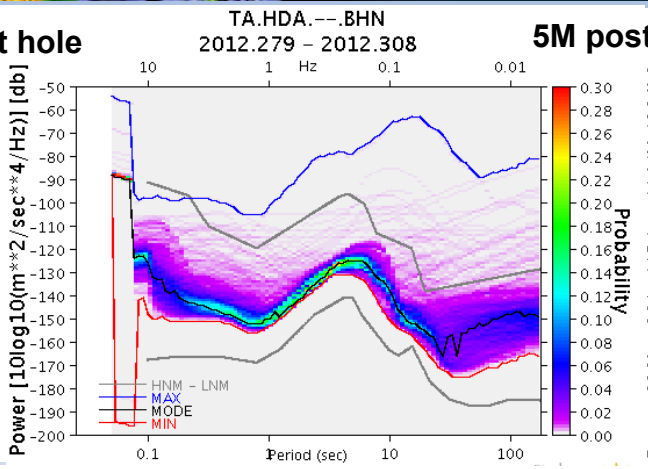
**Oct 13, 2012 complete**

# TA.HDA Harding Lake

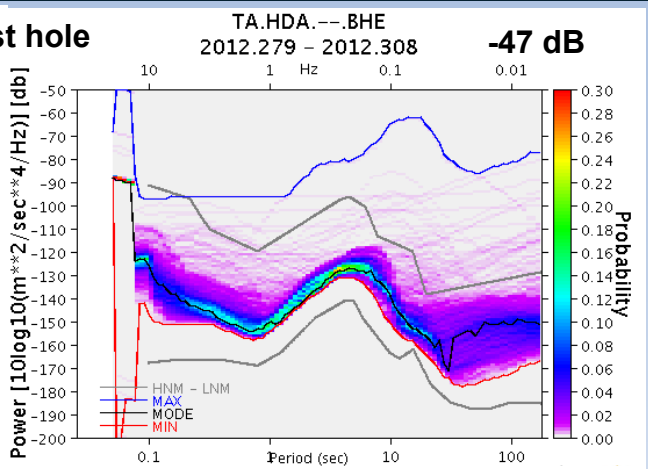
-19 dB




5M post hole

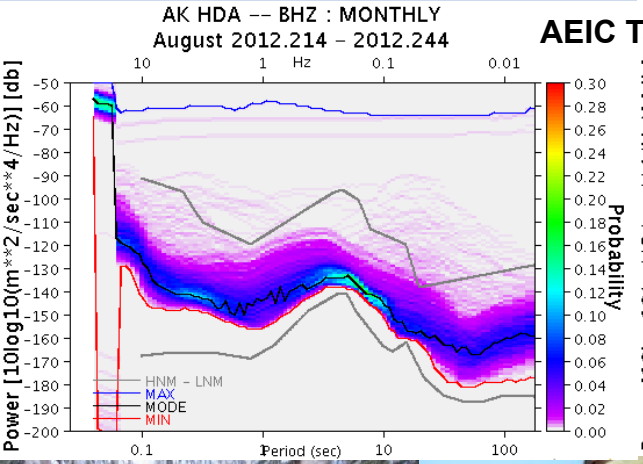



5M post hole

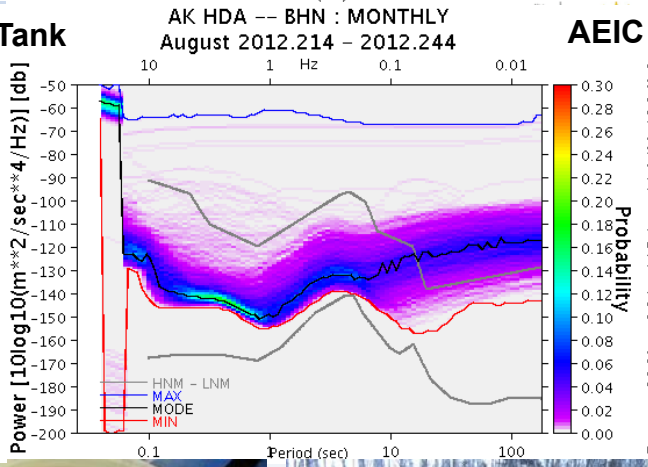



-47 dB

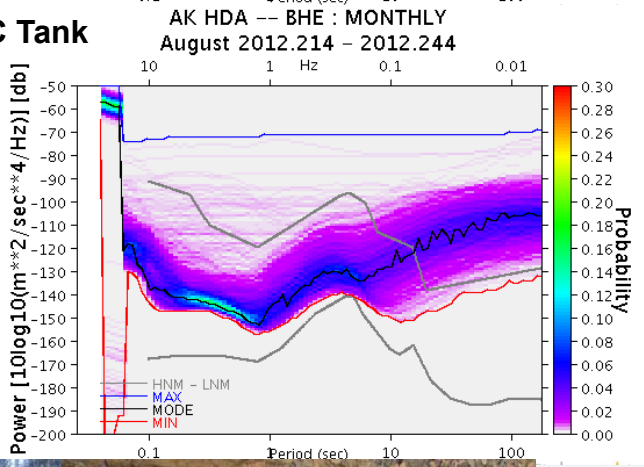
AEIC Tank



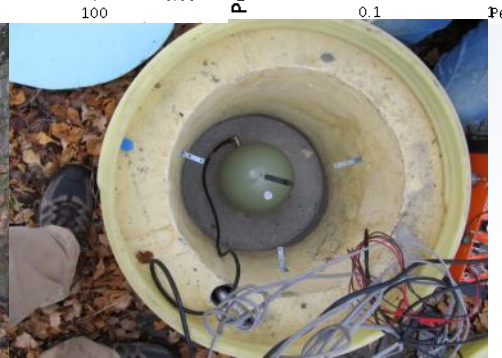

AEIC Tank



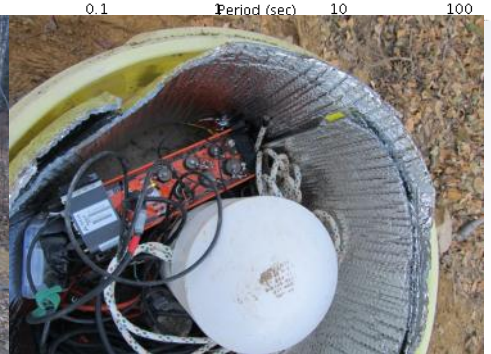

AEIC Tank




AEIC Tank



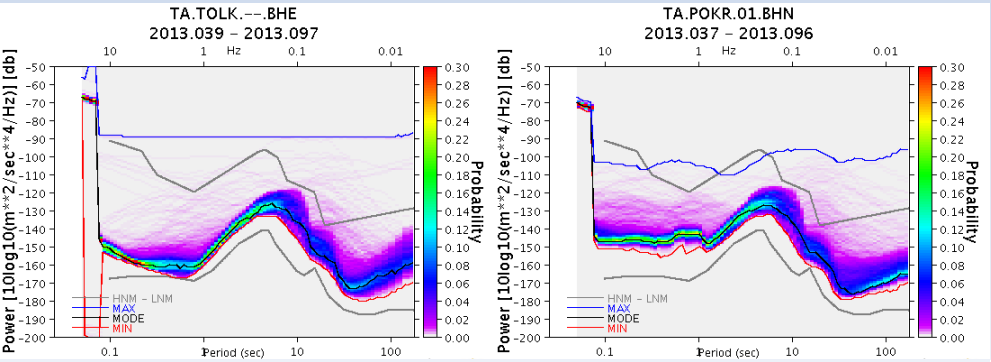
5M post hole

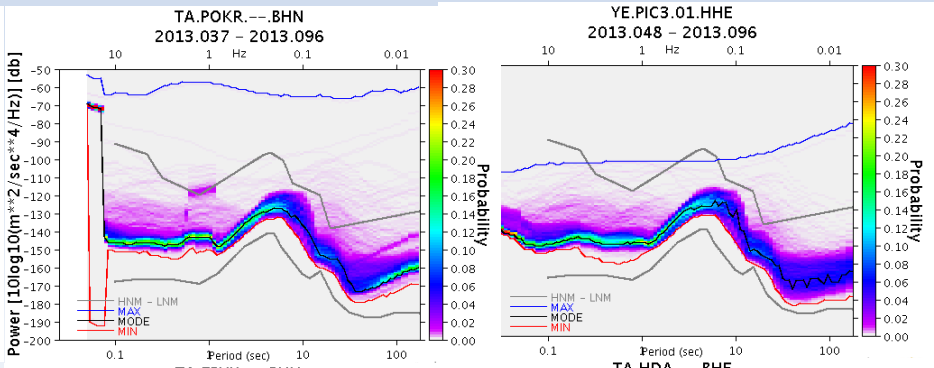


# Performance summary

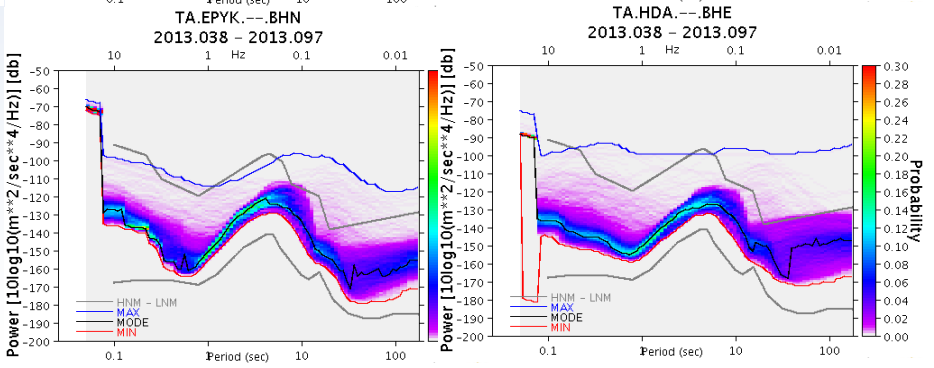
Horizontal Long Period (100 sec)

- TOLK 4m and 5M boreholes -165dB
- POKR 5M borehole -168dB
- POKR TA Tank -164dB
- Poker Flat 1M hand dug -166dB




- EPYK 1.5M core hole -159dB
- HDA 5M borehole -150dB



# Conclusion

Sensor Emplacement in narrow post holes, or boreholes offer performance advantages to shallow pits or tanks.

The method of emplacement is more suitable to the conditions in Alaska-remote, permafrost, freeze/thaw at surface,

Sensors suitable for such deployments have recently become more available.

# For More Information

## On the Web

- EarthScope
  *www.earthscope.org*
- USArray
  *www.usarray.org*
  *ALASKA PROGRESS*
  *www.usarray.org/alaska*
- PBO
  *pboweb.unavco.org*
- National Science Foundation
  *www.nsf.gov*

**EarthScope** is funded by the National Science Foundation.

**EarthScope** is being constructed, operated, and maintained as a collaborative effort with UNAVCO, IRIS, and Stanford University, with contributions from the US Geological Survey, NASA and several other national and international organizations.

# Initial Site Planning

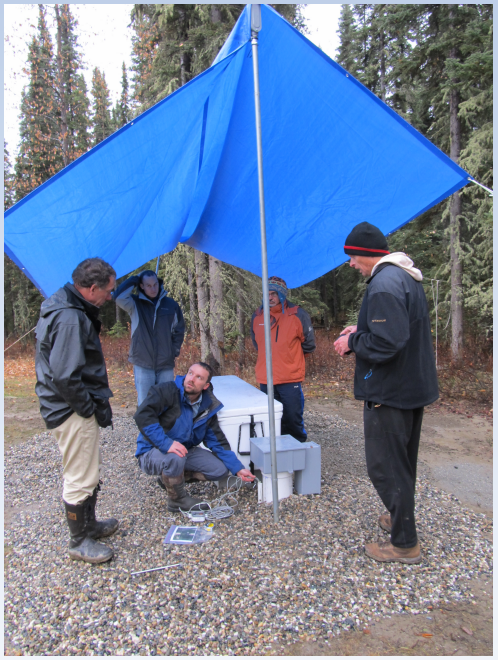
# Potential Collaborations

**Seismology Groups:**

NRCan, Yukon Geological Survey
NOAA / Alaska Tsunami Warning Center,
UAF Alaska Earthquake Information Center and GPS,
USGS Alaska Volcano Observatory

PI led;

Audet – Yukon and NWT
Dallimore – Beaufort Sea
…



**Other Disciplines:**

Soil Temperature

Romanovsky UAF
Dallimore PGC

Meteorlogical

NOAA Weather Service
BLM – Fairbanks, National Petroleum Reserve

Paleoclimate, organic core samples

LDEO - Pateet

# Scope Management

**Scope Management options will depend on where we are in the timeline of the project and the scale necessary and in cooperation with governance Advisory Committee**

**<u>Alternatives include</u>;**

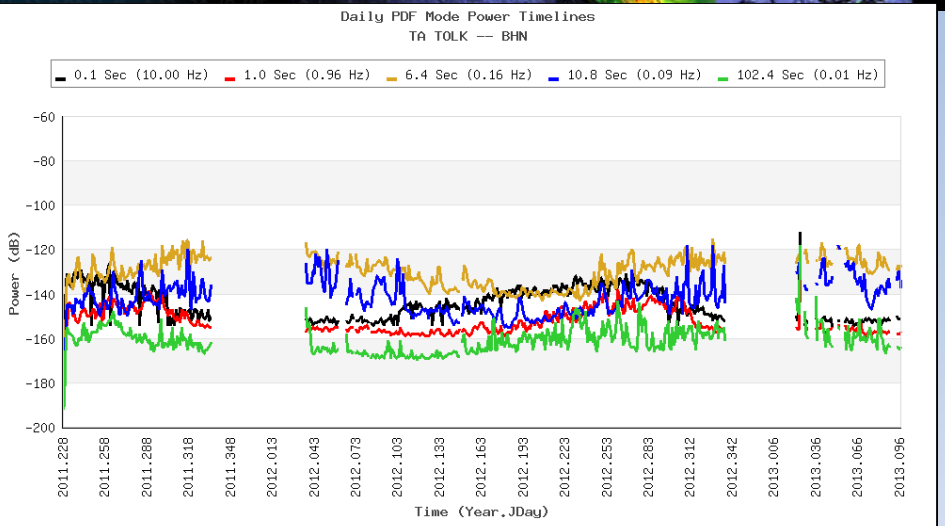
**Eliminating some or all stations planned for the Aleutians,**
**Eliminating or just enhancing Islands stations**
**Reducing the geographic footprint in Canada,**

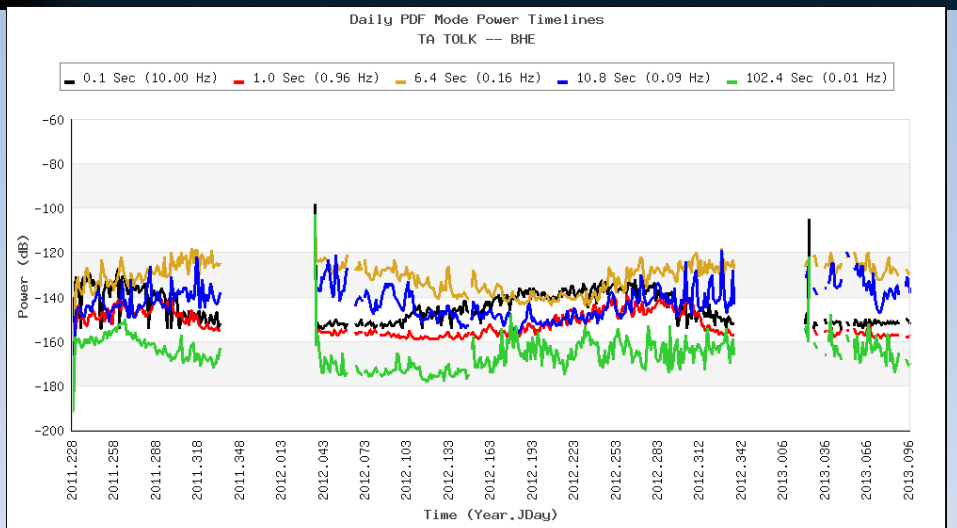
**Reducing the telemetry;**
**in terms of real-time data volume, to 1 sps, to just SOH in the dark,**
**using lower cost methods**

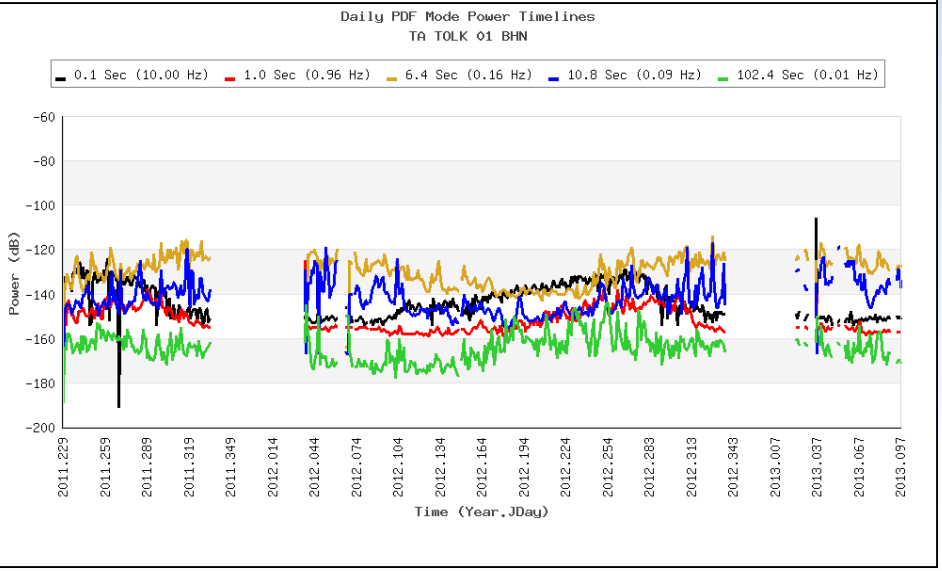
**Reducing the effort expended for station construction to more affordable techniques which are lower performing in terms of seismic noise year-round.**

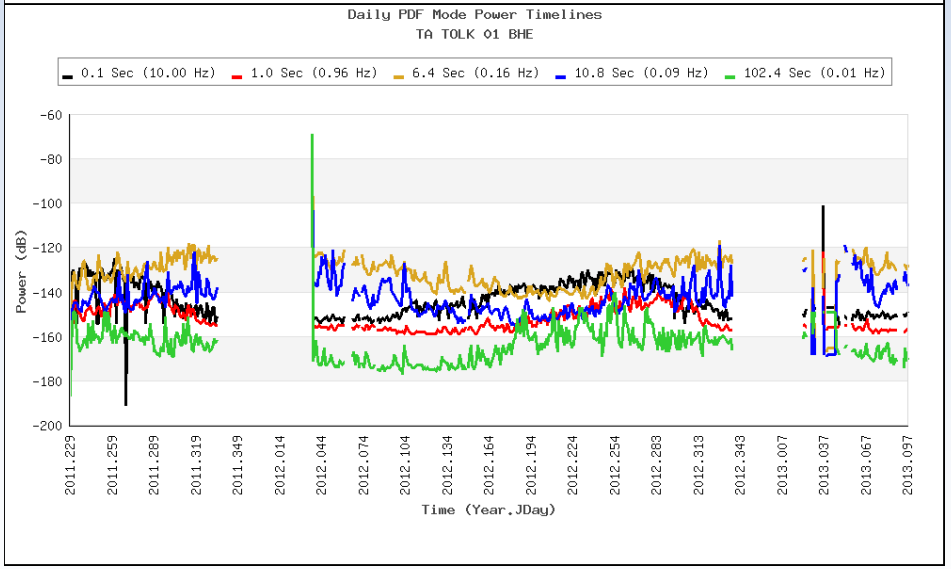
**In general, reduced resources steer objectives toward a smaller core of moderately performing stations with continuous data collected on local archive and transmitting a smaller portion of data when possible.**

# TOLK annual cycle




**North 5M top**
**4M bottom**

**12” PVC casing, cement bottom**
**CMG-3T with 24” sand**

**East 5M top**
**4M bottom**

# Communications

Objective:

Deliver 40 Mbytes/day, with latencies under 4-6 hours. Need not be a continuous connection, but that is preferred when power and cost allow it. Must be under 2 Watts average daily power.

12 Gb/day compared with about 23 Gb/day today.

Complexities:

Can send data as file transfers or streaming packets or a combination to obtain highest compression.

Options:

Freewave and Cell where available

InMarSat M2M BGAN Hughes 9502 terminal $0.5/Mbyte

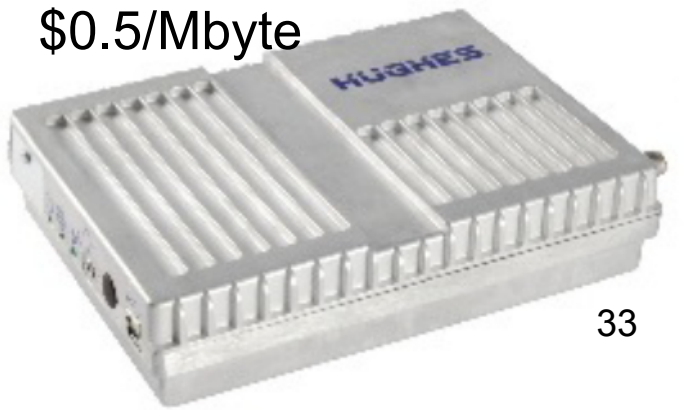
GlobalStar data network

Iridium Open Port

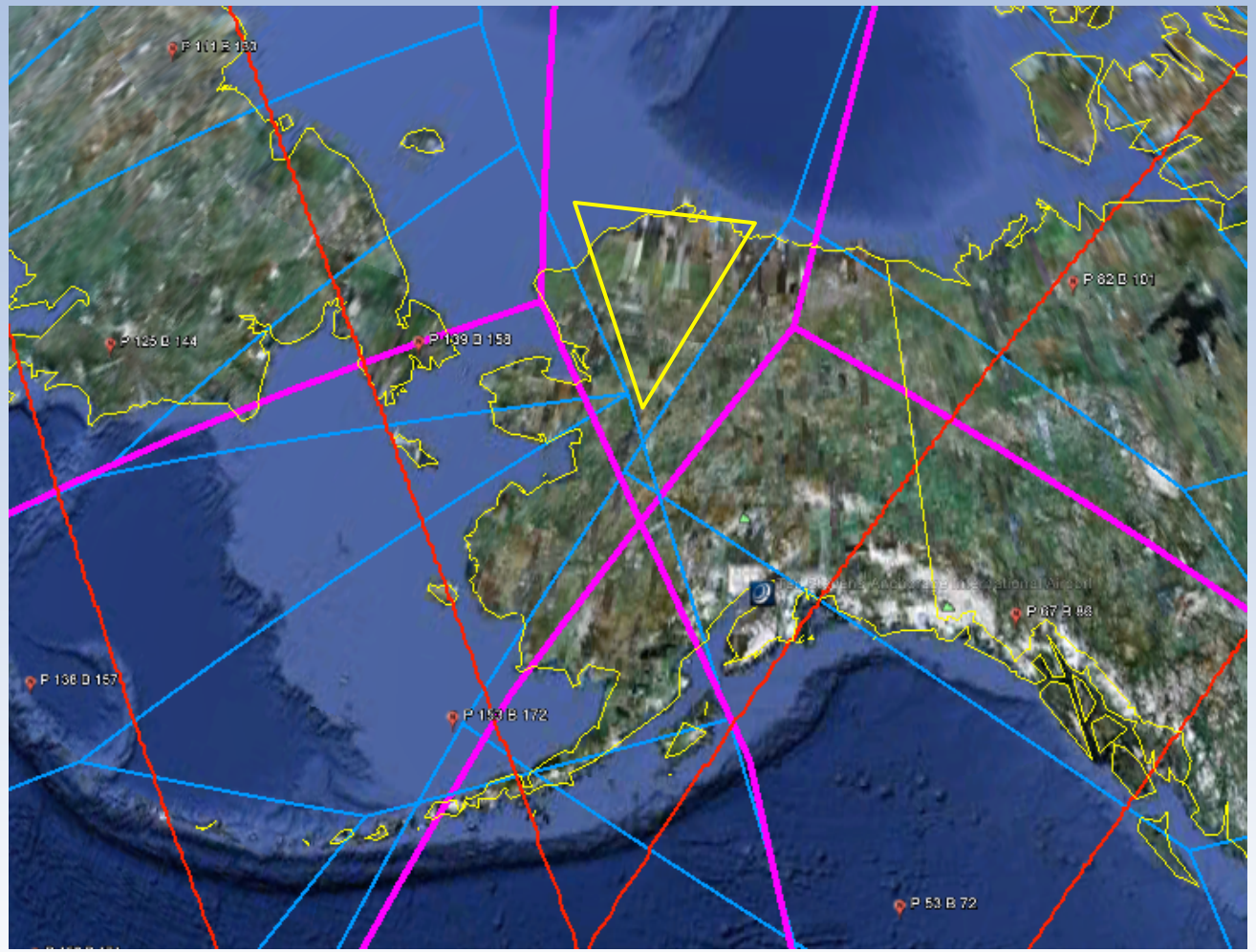
**11-15W full transmit at 400kbps**
**1W standby, SMS wakeup**
**0.1W sleep**
**$1000**

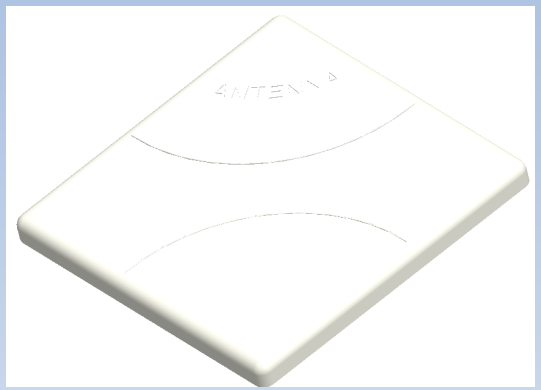
~ $850k annually

**Hughes 9502 Inmarsat BGAN M2M Terminal**



# BGAN I4 EIRP Elevation



**12 x 12 x 2 inch flat plate**
**20 degree requirement**

**Reported to work in Barrow.**

**RED Lines = 10 Degree elevation = minimum recommended for BGAN**
**PINK Lines = Regional Beams of APAC and AMER satellites = Should Work**
**BLUE Lines = Narrow Beams = Hard to reach**

**This map depicts Inmarsat's expectations of coverage, but does not represent a guarantee of service. The availability of service at the edge of coverage areas fluctuates depending on various conditions.**