Comparative Noise Performance of Portable Broadband Sensor Emplacements by PASSCAL and Flexible Array

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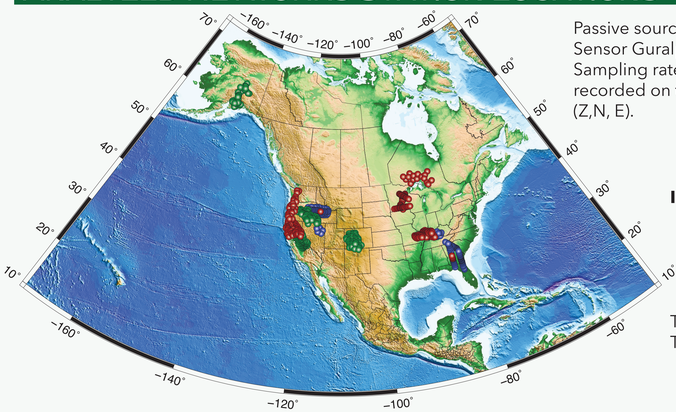
ABSTRACT

IRIS PASSCAL has supported portable broadband seismic experiments for close to 30 years. During that time we have seen a variety of sensor vaults deployed. The vaults deployed fall into two broad categories, a PASSCAL style vault and a Flexible Array style vault. The PASSCAL vault was constructed of materials available in-county and it was the Principle Investigator (PI) who established the actual field deployed design. These vaults generally are a large barrel placed in a 1-1.5 m deep hole. A small pier, decoupled from the barrel, is fashioned in the bottom of the vault (either cement, paving stone or tile) for the sensor placement. The sensor is insulated and protected. Finally the vault is sealed and buried under ~30 cm of soil. The Flexible Array (FA) vault was provided to PIs by the EarthScope program, offering a uniform portable vault for these deployments. The vault consists of a 40 cm diameter by 1 m tall piece of plastic sewage pipe buried with 10-20 cm of pipe above grade. A rubber membrane covers the bottom and cement was poured into the bottom, coupling the pier to the pipe. The vault is sealed and buried under ~30 cm of soil.

Cost, logistics, and the availability of materials in-country are usually the deciding factors for PIs when choosing a vault design and frequently trades are made given available resources. Recently a third type of portable broadband installation, direct burial, is being tested. In this case a sensor designed for shallow, direct burial is installed in a ~20 cm diameter by 1 m deep borehole. Direct burial installation costs are limited to the time and effort required to dig the borehole and emplace the sensor. Our initial analyses suggest that direct burial sensors have lower noise levels on both horizontal and vertical channels across a range of periods spanning <1 s to 100 s. Moving towards an instrument pool composed entirely of direct burial sensors (some with integrated digitizers) could yield higher-quality data at lower cost.

Until recently vault performance for portable installations supported by the PASSCAL program was anecdotal. A formal comparison of these various installation techniques is the subject of this poster. We've selected a suite of experiments that are representative of the three installations and compare their noise performance by using PSD probability density functions (McNamara and Buland, 2004).

ANALYZED NETWORKS STATION LOCATIONS

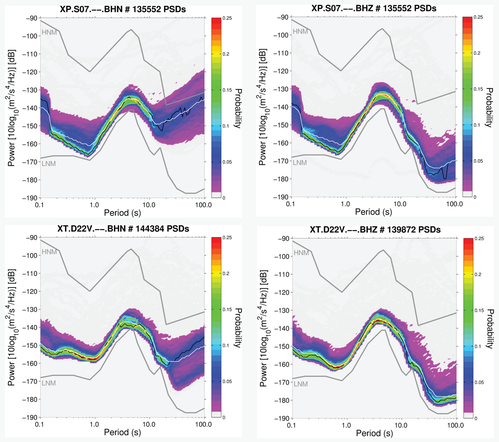


Passive source
Sensor Guralp - CMG-3T
Sampling rates - 40 and 50sps
recorded on three components
(Z,N, E).

Installs :
- PASSCAL Vault,
- Flexible Array Install,
- Direct Burial & Posthole

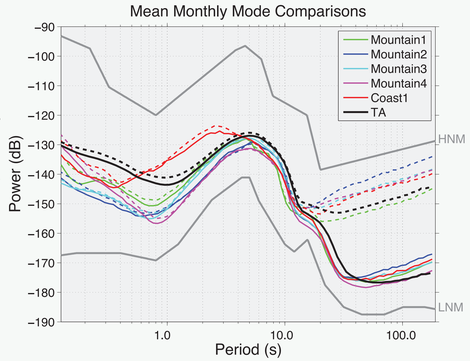
Total 15 Networks
Total 860 stations

METHODS



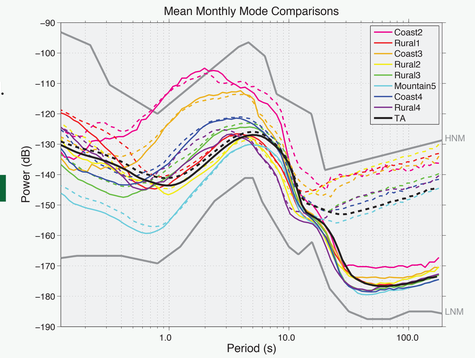
- The IRIS DMC now routinely produces power spectral densities (PSDs) though its MUSTANG data quality metrics service
- We gather these PSDs and calculate probability density functions (PDFs) for one month of data at each station channel (examples, left)
- From these PDFs we calculate the mode for that particular month (black line), though it should be noted that there is often considerable variation in the power at a given period
- The median mode among all stations within a network is selected as the network mode for each month
- We take the mean of these network monthly modes (MMM) to produce the results shown for the PASSCAL, Flex Array, and direct-burial networks (above right)
- This method of network analysis was chosen in order to directly compare network performance with the Transportable Array (TA), which routinely calculates the mean of the monthly mode (MMM) for quality control purposes

MEAN MONTHLY MODE COMPARISONS



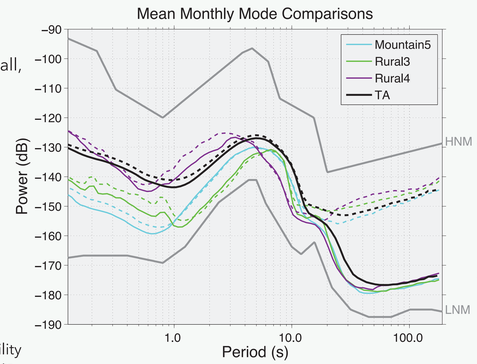
PASSCAL networks

- Below ~2s, most PASSCAL installation type networks show lower noise levels than the TA MMM
- Above ~11s, PASSCAL networks tend to be noisier than the TA MMM for horizontal channels
- Vertical channels at PASSCAL networks remain quieter than the TA MMM below about 40s
- The high noise levels seen on both the vertical and horizontal channels of network Coast1 below ~4s may be caused by proximity to the coast
- Lower long-period horizontal noise seen for network Mountain1 demonstrates the ability of PASSCAL-type vault installations to achieve noise levels considerably lower than other PASSCAL networks and comparable to TA vault deployments



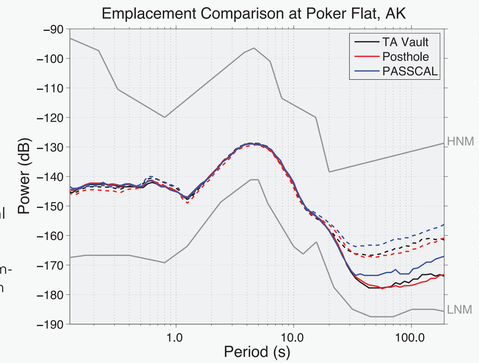
Flexible Array networks

- At periods shorter than 6-8s, FA networks show a very wide range of noise levels, with some networks spiking above the HNM (e.g. Coast2) and others falling as much as 20dB below the TA MMM (e.g. Mountain5)
- At longer periods (>10s) the FA vertical channels cluster near the TA MMM, while horizontal channels are noisier than the TA, some by as much as 15dB
- Network Mountain5 is notable for being quieter than the TA MMM at all periods and for both horizontal and vertical channels. Part of the reason for this may be the very quiet location in which this network was installed
- Networks Coast2, 3 and 4 show very high noise levels below 10s, likely a result of their proximity to the Pacific coast



Direct burial networks

- There were only 3 networks that used a direct burial installation type for their broadband sensors
- Significant differences can be seen in noise levels at periods less than about 5s, with one network near or just above the TA MMM, and the others falling below the TA by as much as 20dB
- Note that network Mountain5 was located in a particularly quiet location, which may explain why its noise levels are so low
- Above about 10s the three direct burial networks are much more similar and closely follow the TA MMM; horizontal noise levels are just above or nearly equal to the TA, while vertical noise levels come in just below the TA

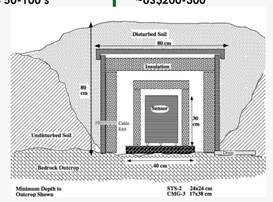


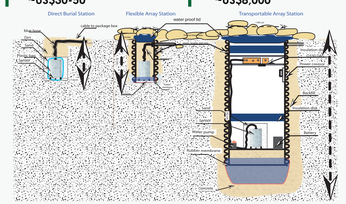
The future: posthole sensors

- IRIS/PASSCAL is in the process of testing a new generation of purpose-built, directly-buried posthole sensors
- These sensors are designed to be water-resistant, cold-tolerant, and can be buried directly within postholes--greatly reducing the time and cost required for installation in the field
- Initial testing of posthole sensors at Poker Flat, Alaska (left) shows that these sensors (buried to a depth of 0.75m) can provide data with noise levels equal to co-located TA vault style installations and at only a fraction of the cost

COMPARISON OF VAULT TYPES

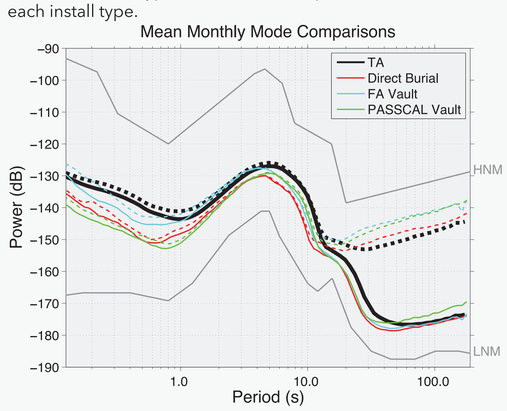
PASSCAL Vault	FA Vault	Direct Burial	TA Vault
Equipment Sensor: Guralp CMG-3T Datalogger: Quanterra Q330 or RefTek RT-130 Burial Details: The target depth ~ 80-180 cm (31-70 in) Sensor pad of about 40cm Insulation recommended Bury sensor with soil 1-1.5 m (3'-3.5") for broadband. **Materials Cost:** **~US$ 50-100's**	Equipment Sensor: Guralp CMT-3T Datalogger: Quanterra Q330 Burial Details: About 13cm sand on top of sensor 8cm space vault lip to sand 10cm vault lip to grade Tarp over vault ~4 layers < 2.5cm dirt on top of vault **Materials Cost:** **~US$200-300**	Equipment Sensor: Guralp CMT-3T Datalogger: Quanterra Q330 Burial Details: About 8cm sand below sensor Sensor in a 25cm plastic bag and heavy cordura bag Vault filled with sand to top of sensor. About 0.5m of dirt on top of sensor Four medium size rocks on top **Materials Cost:** **~US$30-50**	Equipment Sensor: Guralp CMG-3T, Streckeisen STS-2, Nanometrics Trillium-120PHQ Datalogger: Quanterra Q330 Burial Details: 1.1m diameter HDPE plastic corrugated sewer pipe buried vertically 1.8m into the ground and a pad of 1.5 cu yd of concrete. ~2cm EPDM geomembrane ~15 yd of concrete (to a depth of 20cm poured into tank) **Materials Cost:** **~US$8,000**





REMARKS & CONCLUSIONS

The various installs included in this analysis provide an insight into the overall performance that can be expected for PASSCAL, Flexible Array (FA) and Directly Buried (DB) installs. We average the mean monthly mode (MMM) of the networks from each install type to determine a representative MMM for each install type.



Current results lead to the following observations:

Short Period (<1 sec)
- In the vertical component, representative MMM for PASSCAL vault, directly buried sensor and Flexarray vault outperform TA. PASSCAL and DB displaying very close values.
- In the horizontal components PASSCAL and DB installs outperformed TA .
- FA vault appears to be the noisiest of the non-TA installs, but this result may be biased by 2 FA networks that were particularly noisy at short periods.

Long Period (>10 sec)
- Horizontal component: Direct Burial installs provides the closest performance to TA's with noise levels around 3dB above TA.
- In the vertical component PASSCAL is the noisest of all installs with about 8 db above the TA values, while FA and DB installs are very close to or just below TA values.

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