



# What have we learned from data from purpose-built, direct-bury sensors at Poker Flat, Alaska?

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PASSCAL installed sensors at Poker Flats Research Range, Alaska in November 2012 as the second phase of direct-burial emplacment testing (the first phase of which occurred from Fall 2011 through Spring 2013 near San Antonio, NM). The purpose of this phase of testing was to compare of purpose-built direct bury sensor installations to a standard TA second generation vault, a prototype TA shallow-borehole, and, after July 2013, PASSCAL temporary vault installations.

The Poker Flats experiment also provided an opportunity to:

- test enclosure and power system designs
- test telemetry systems
- gain exposure to, and use of, first-production-run Nanometrics Centaur dataloggers and related real-time data flow and station management software

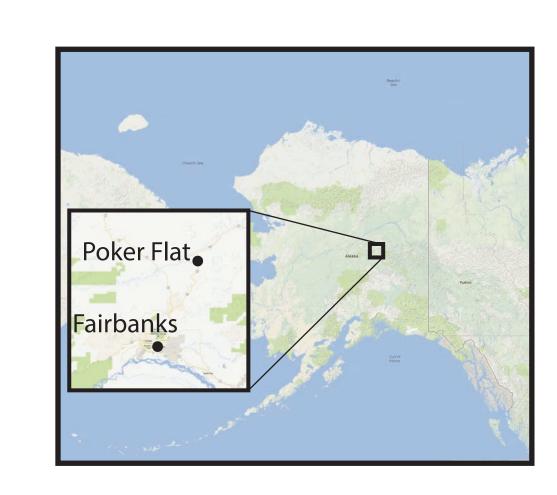


Figure 1. Location of the PASSCAL direct burial emplacement studies at Poker Flats Research Range, a facility operated by the University of Alaska, Fairbanks.

### Installation of a Purpose-built Direct Bury Sensor

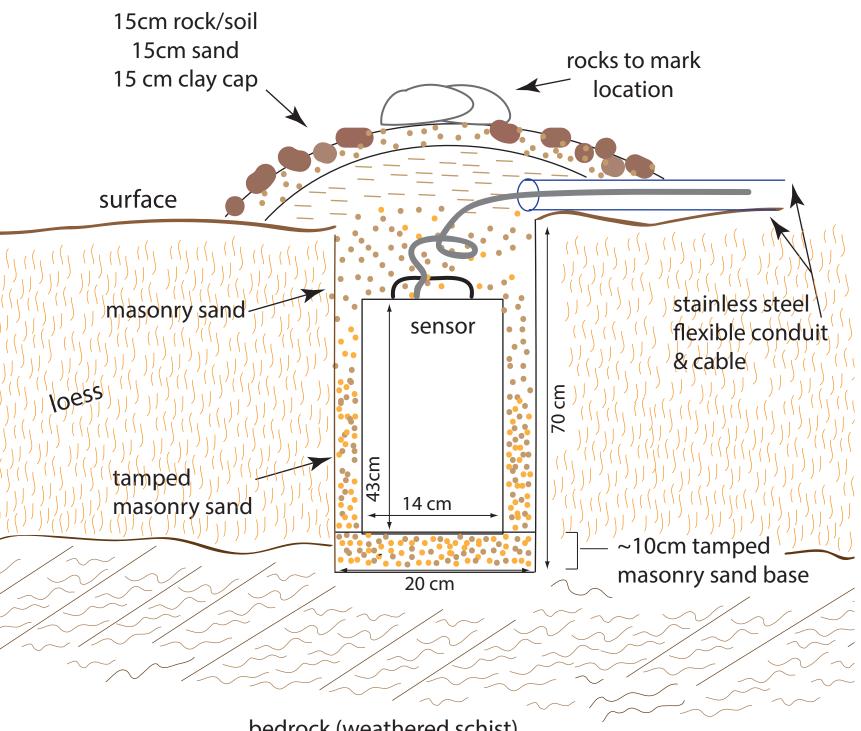


Figure 2. A direct burial installation diagram of a Nanometrics Trillium 120PH. Before burying the sensor the cable is loosely looped near the top to ensure sufficient strain relief exists between the sensor and the channel dug for the cable. After the sensor is oriented and leveled, sand is poured around the sensor and tamped in multiple iterations to ensure maximum compaction and coupling to the host material.

# Installation of a Standard Broadband Sensor in a PASSCAL Temporary Vault

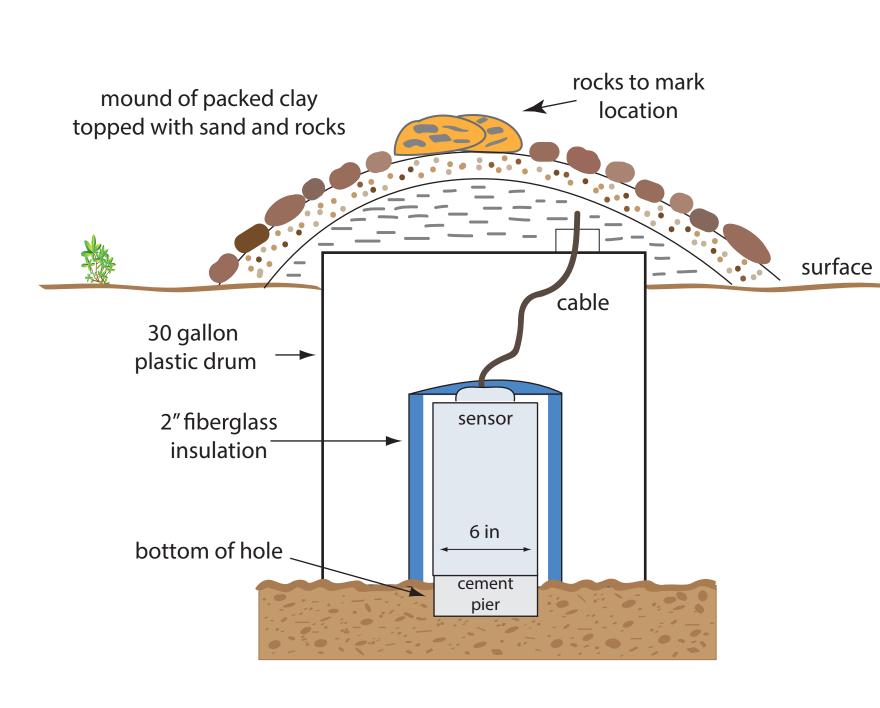


Figure 3. PASSCAL vault diagram. The bottom of a 30 gallon plastic barrel is removed and quick-setting concrete serves as the sensor's pier. To reduce thermal effects from daily temperature swings, the ground above the sensors is covered with a mound of soil and rocks.

#### **Installation Details**

Installation Type	SEED reference	Sensor	Depth - sensor base (cm)	Datalogger	Power System	Telemetry
PIC DB TC direct-burial compact	YE.PIC2	TR-Compact Post Hole (pre- production, direct-bury unit)	76	Nanometrics Trident Centaur – after 2013/09/17	AC charger and battery	ethernet
PIC DB PH direct-burial post hole	YE.PIC3.01	TR-120PHQ (pre-production, enhanced performance unit)	/h	Nanometrics Taurus/ Centaur – after 2013/09/17	AC charger and battery	ethernet
PIC vault 1, PASSCAL temporary vault	YE.PIC4	TR-120	53	Quanterra Q-330	AC charger and battery	ethernet
PIC vault 2, PASSCAL temporary vault	YE.PIC4.00	TR-120	53			
TA vault - 2 <sup>nd</sup> gen. TA vault	TA.POKR	TR-240	~2 m	Quanterra Q-330	AC power supply	ethernet
TA 5m borehole, cased borehole	TA.POKR.01	TR-120PH/ STS-4B – after 2013/06/14	~5 m			
direct-burial post hole	YE.PIC1.01	TR-120PH	76	Quanterra Q-330	Primary/Secondary hybrid - air cells/PV with AGM batteries PV w/AGM batteries - after 7/25/2013	Xeos Iridium modem RUDICS data telem
shallow direct-burial	YE.PIC1.02	L-28	25			

# Installation History

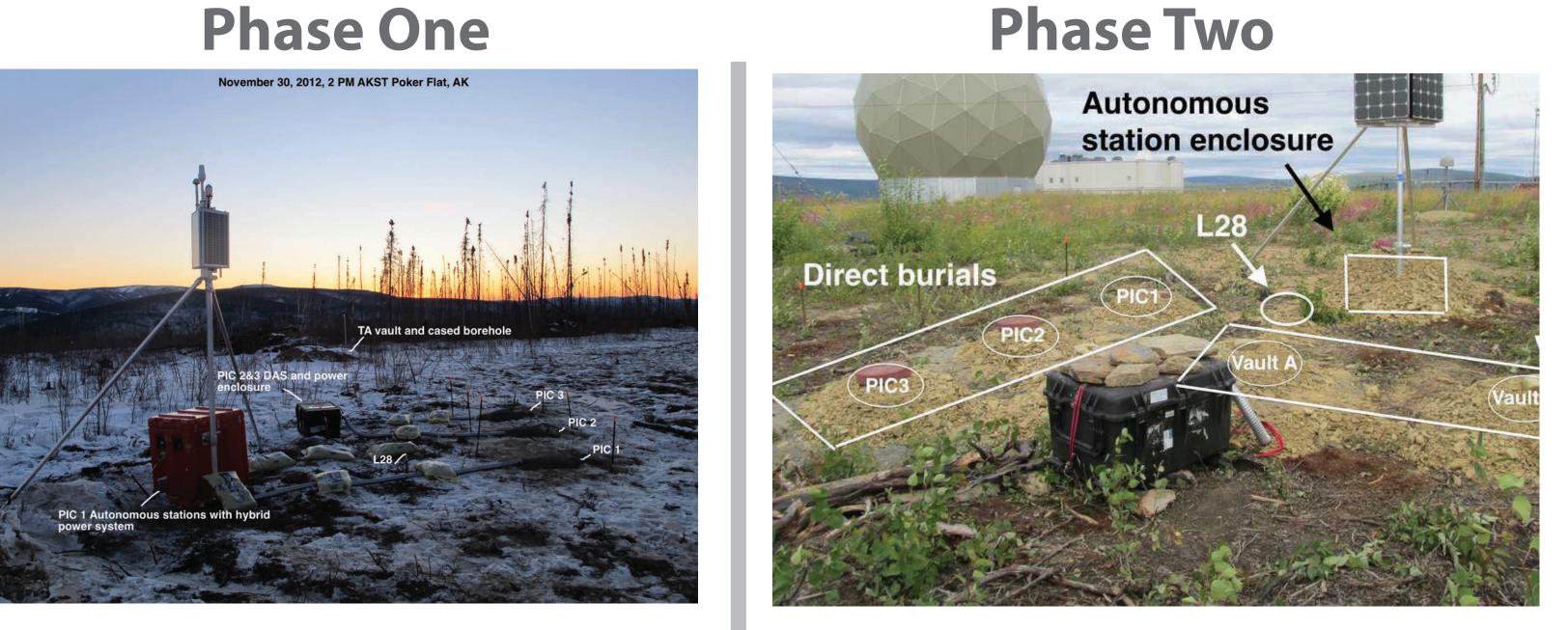


Figure 4. PASSCAL stations at Poker Flat, November 2012. Note PIC1, autonomous station, completely exposed. Phase 1 power system testing: 1200 Amp-Hrs of air cell batteries (primary power), and lampshadestyle 60W, 3 solar panel array, and 208 Amp-Hrs of AGM batteries (secondary power).

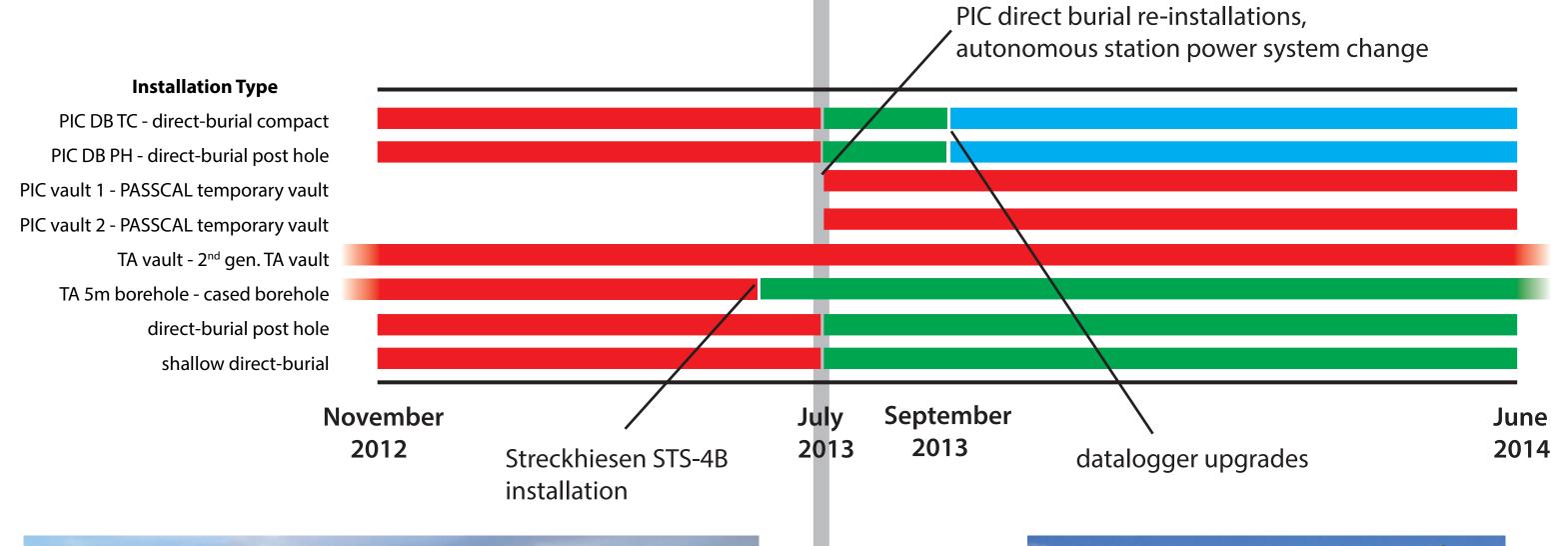




Figure 6. Tim Parker augering the first of 3 holes for directly buried sensors. Sensors are emplaced in loess resting on weathered schist bedrock. Holes are 20 cm in diameter, separated by 1.3 m.



Figure 8. Orienting the T120PHQ. A North line is machined into the top plate of the sensor and illuminated with a laser to translate the compass north line to sensor.



Figure 5. PASSCAL installations July 2013, with

new temporary vault installations (right),

(624 Amp-Hrs).

PIC vault installations,

autonomous station now buried. Phase II

power testing: Lampshade-style 90 W, 2 solar

panel array, and large bank of AGM batteries

Figure 7. Autonomous station enclosure. Burying the enclosure significantly reduced temperature swings and extreme cold temperatures the box was exposed to during earlier testing.

PIC Vault2 -Trillium 120 PA

borehole

**PSD PDFs of the Vertical Component** 

**PSD PDFs of the Horizontal Components** 

comparble to the TA borehole (within 1-2 dB at > 20 s)

Self-noise of Trillium Compact is clearly visible beyond 20 s

Summer, ~10-15 dB over that of the TA installs beyond 20 s

Figure 10. Three month medians of monthly medians of PSD PDFs. The Summer 2013 PIC vault

Winter 2012-13 evident on the horizontal components; the issue was corrected by Spring 2013.

PIC vaults are noisier above 30 s, by as much as 8-10 dB over PIC DB posthole and TA

• Installations are nearly indistinguishable for periods lower than 20 s during Winter and

Noise levels of all sensors horizontal components increased significantly during

Summer-Fall PIC DB compact appears to perform better than PIC DB posthole (above)

10 s, by as much as 4 dB). Possible orientation differences could account for this

Noise levels are reduced by Fall and Winter 2013-2014, but are still relatively high

data is not shown as it is only contains the month of August. The TA vault had issues during

Noise levels are nearly indistinguishable below 20 s and the PIC DB posthole is



Figure 9. In July 2013, Tim Parker and Kasey Aderhold (pictured), a PASSCAL student intern, installed two Trillium 120PA sensors in PASSCAL temporary vaults.

Analysis Methods:

We probabilistically analyzed data collected at the Poker Flat test site from December 2012 - March 2014 using the following methods:
- channel-specific power spectral density probability distribution functions (PSD PDFs from 1-hour segments)
- channel to channel magnitude squared coherency probability distribution functions (MSC PDFs, 1 hour segments)

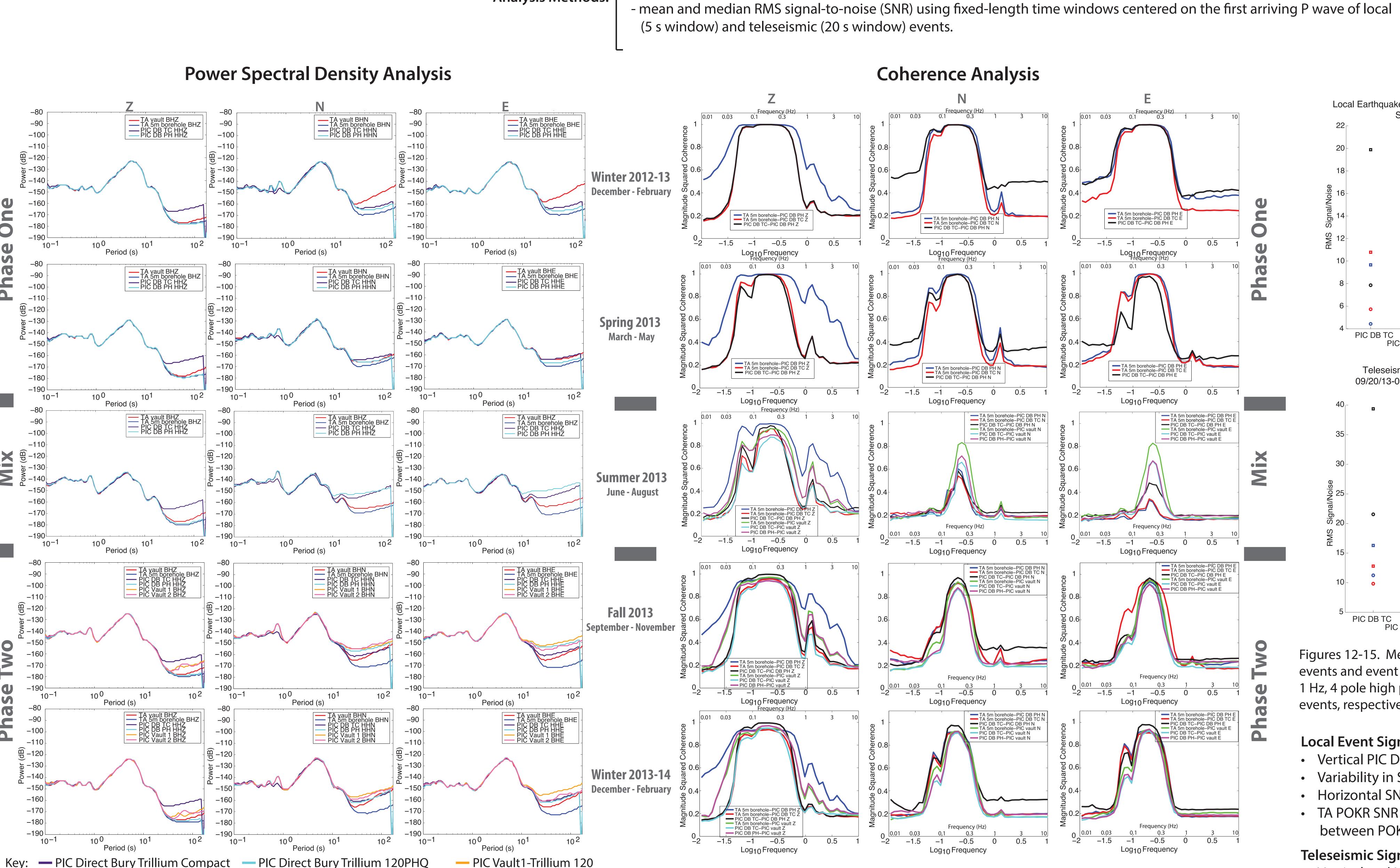
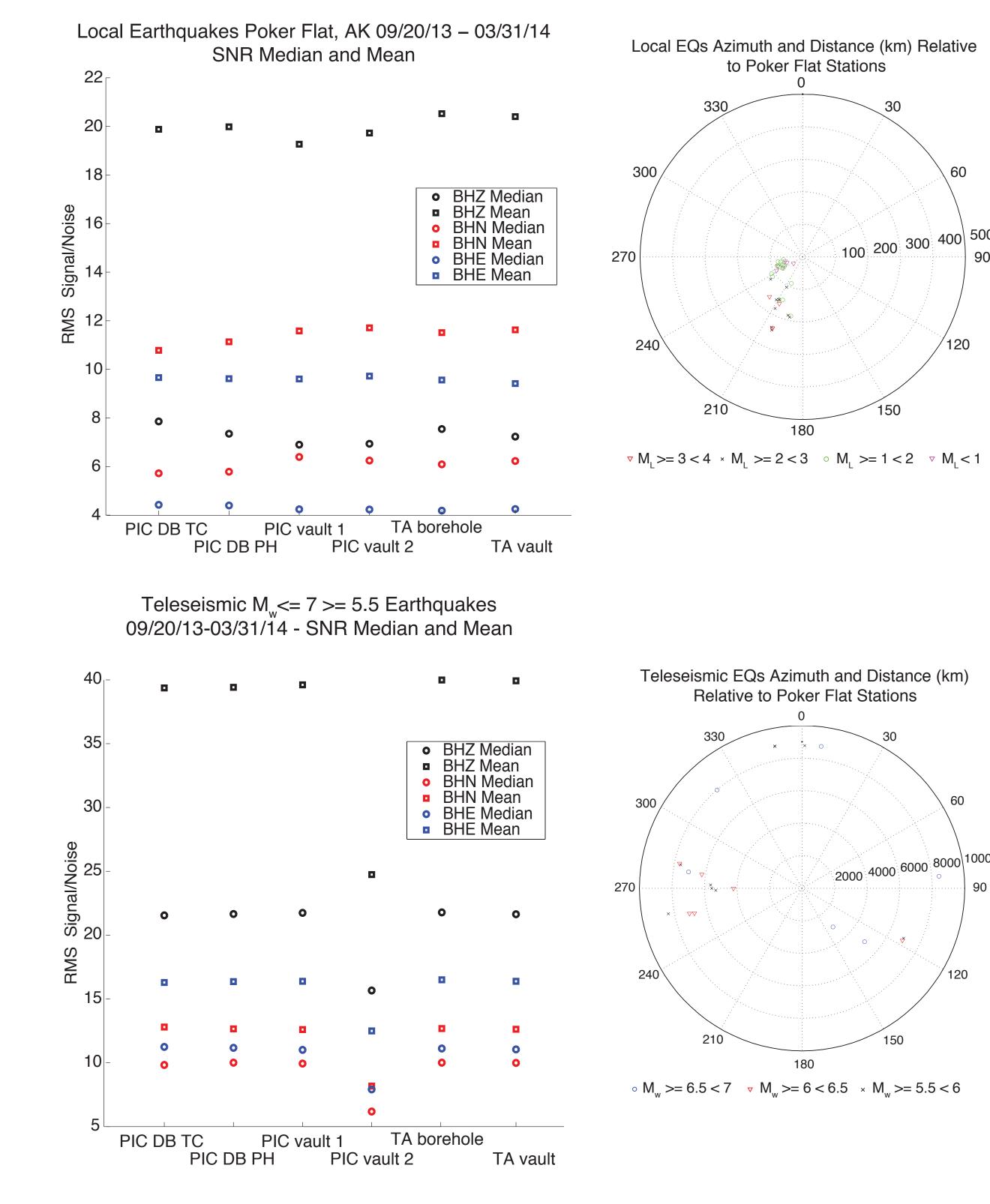


Figure 11. Three month medians of monthly medians of the MSC (magnitude-squared coherence).

#### Coherence

- Vertical inter-station comparisons are coherent over 0.05-0.5 Hz
- Horizontal inter-station comparisons are coherent over a narrower range of frequencies
- Stations most coherent in Winter, least coherent in summer
   Summer shows largest variations in inter-station coherence
- Variability in coherence observed between horizontal comparisons, likely attributable to site effects and/or orientation differences

# Signal-to-Noise Analysis



Figures 12-15. Mean and Median SNR as calculated from local and teleseismic events and event azimuth, distance and magnitude coverage. Data filtered with a 1 Hz, 4 pole high pass and 0.5-3 Hz, 4 pole band-pass, for local and teleseismic events, respectively.

#### Local Event Signal-to-Noise (SNR)

- Vertical PIC DB installs appear to have slightly higher SNR than PIC vaults
- Variability in SNR is observed between like installations
- Horizontal SNR tends to be higher for PIC vaults than PIC DB installs
- TA POKR SNR are comparable to PIC installations. Variance in SNR observed between POKR sensors

### Teleseismic Signal-to-Noise (SNR)

- Vertical and Horizontal SNR are comparable between PIC installations, with the exception of PIC vault 2
- Small variations in SNR observed between PIC DB horizontal components
- No significant relationship observed between event distance and SNR
- At the frequencies used in the above analysis, the SNR for TA installs are comparable to the PIC sites with the exception of PIC vault 2

## Results

- Direct burial installations are comparable to PASSCAL temporary and TA vault installations at this site at periods less than 10s.
- The Trillium Compact DB install has comparable SNR to the Trillium 120 PHQ (PIC DB PH) and the Trillium 120 (PIC vault) installations.
- There are differences between co-located like installations that could be attributed to the near surface soil integrity.

We thank Nanometrics, for the use of their equipment and their technical support, the University of Alaska, Fairbanks, for the use of the Poker Flats Research Range facilities, Carl Tape for the microseismicity event catalog, and Kasey Aderhold for her help with installs and figure display ideas for SNR analysis

knowledgements