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Using Distributed Acoustic Sensing to observe seismicity from underground chemical explosions

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[2]https://doi.org/10.2172/2345984

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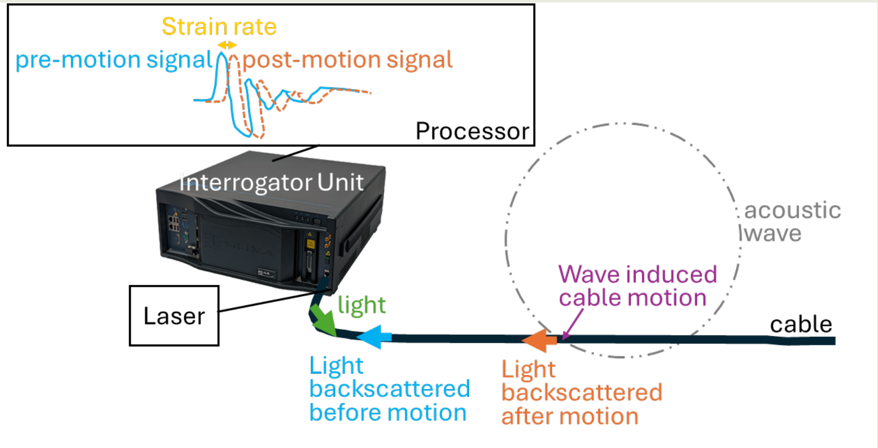
DAS enhances pattern analysis for complex wavefields near explosions.

- Near underground explosions, seismicity is complex and ground motion patterns can be intricate
- Pattern characterization can be limited by traditional sensing methods - sparse sampling of multiple paths
- Pattern characterization can be enhanced using Distributed Acoustic Sensing (DAS) – an optical technique for measuring deformation of a fiber optic cable
- When a cable is coupled to the ground, it deforms with ground movement, enabling dense motion measurements



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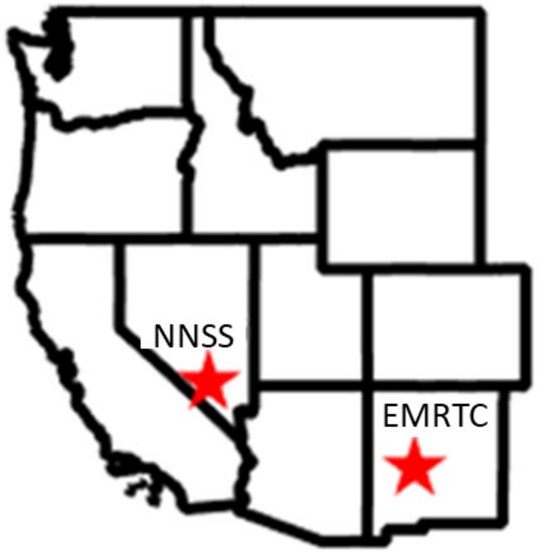
DAS patterns have been analyzed for explosions across a range of yields.

Map of Western U.S.A.



Summary of Chemical Explosion Experiments

Experiment	Location	Yield (kT TNT equivalent)	Scaled Range ($m\ kT^{-1/3}$)	Scaled Depth[a] ($m/kT^{-1/3}$)
PE1-A[b]	NNSS	1.63×10^{-2}	568-3513	992
DAG-1[c]	NNSS	9.08×10^{-4}	826-4061	3976
DAG-3[c]	NNSS	9.08×10^{-4}	826-3206	1549
BCD-1[d,e]	EMRTC	5.0×10^{-6}	2047-4113	3567
BCD-2[d,e]	EMRTC	5.0×10^{-6}	2047-3812	3216
BCD-3[d,e]	EMRTC	5.0×10^{-6}	2047-3474	2456

NNSS = Nevada National Security Site; EMRTC = Energetic Materials Research and Testing Center; kT = kiloton; TNT = trinitrotoluene; m = meters;.

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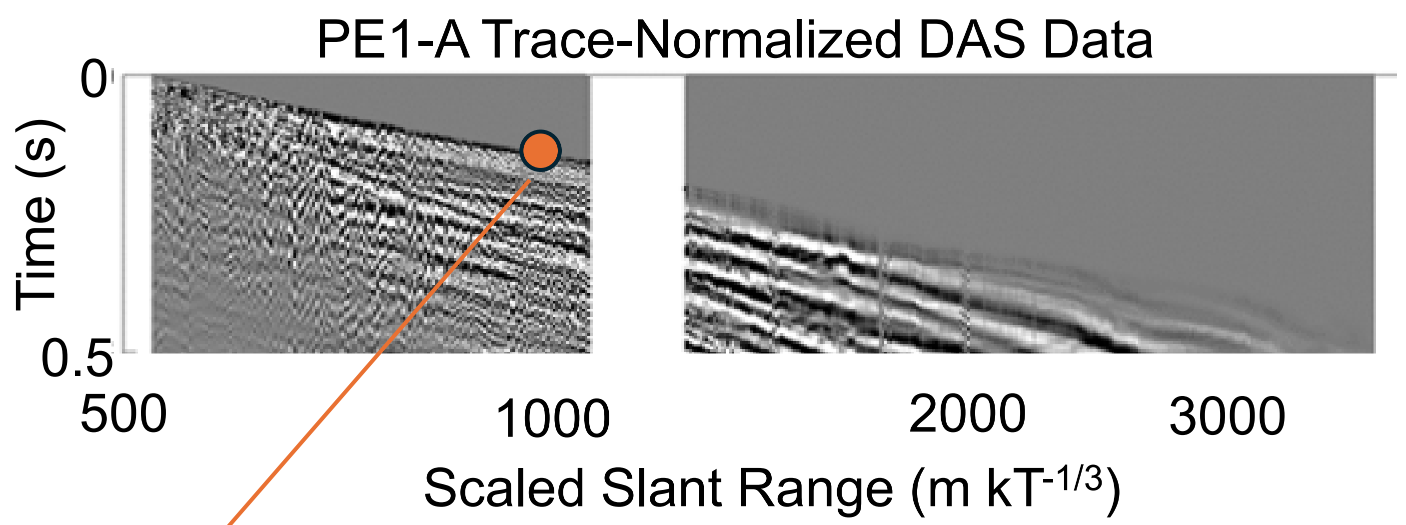
Peak accelerations were computed as function of slant range for DAS.



Maximum Strain Rate * Phase or Group Velocity[1] * Correction[2,3] * $(2*W^{-1/3})$ = Scaled Peak Acceleration

[1]Wang et al, 2018; [2]Cagniard, 1962; [3]Baird, 2020

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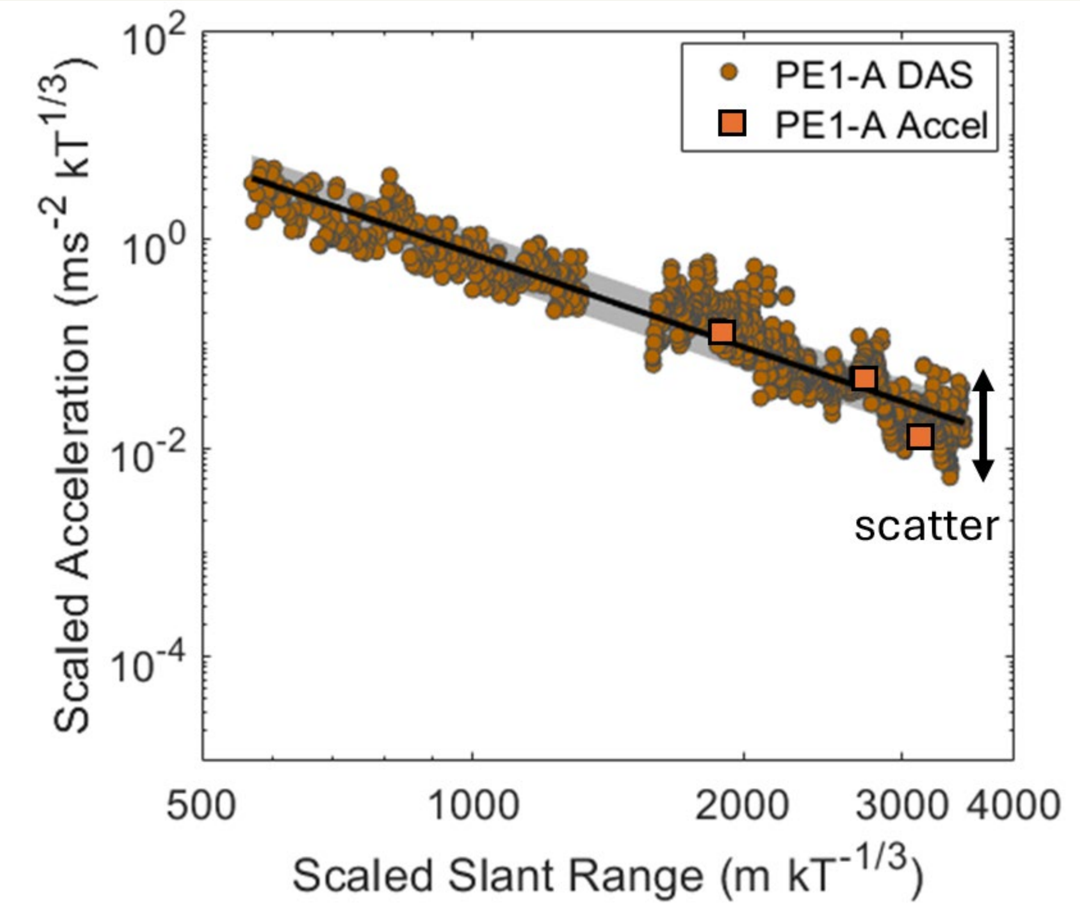
PE1-A peak accelerations have a single trend with scatter for both DAS and discrete sensors.

- Single trend in scaled acceleration with distance, but values vary by an order of magnitude
- PE1-A DAS-derived scaled accelerations compare well with co-located accelerometer data
- DAS provide context for discrete data, decrease in amplitude of furthest station is within expected scatter, not change in behavior



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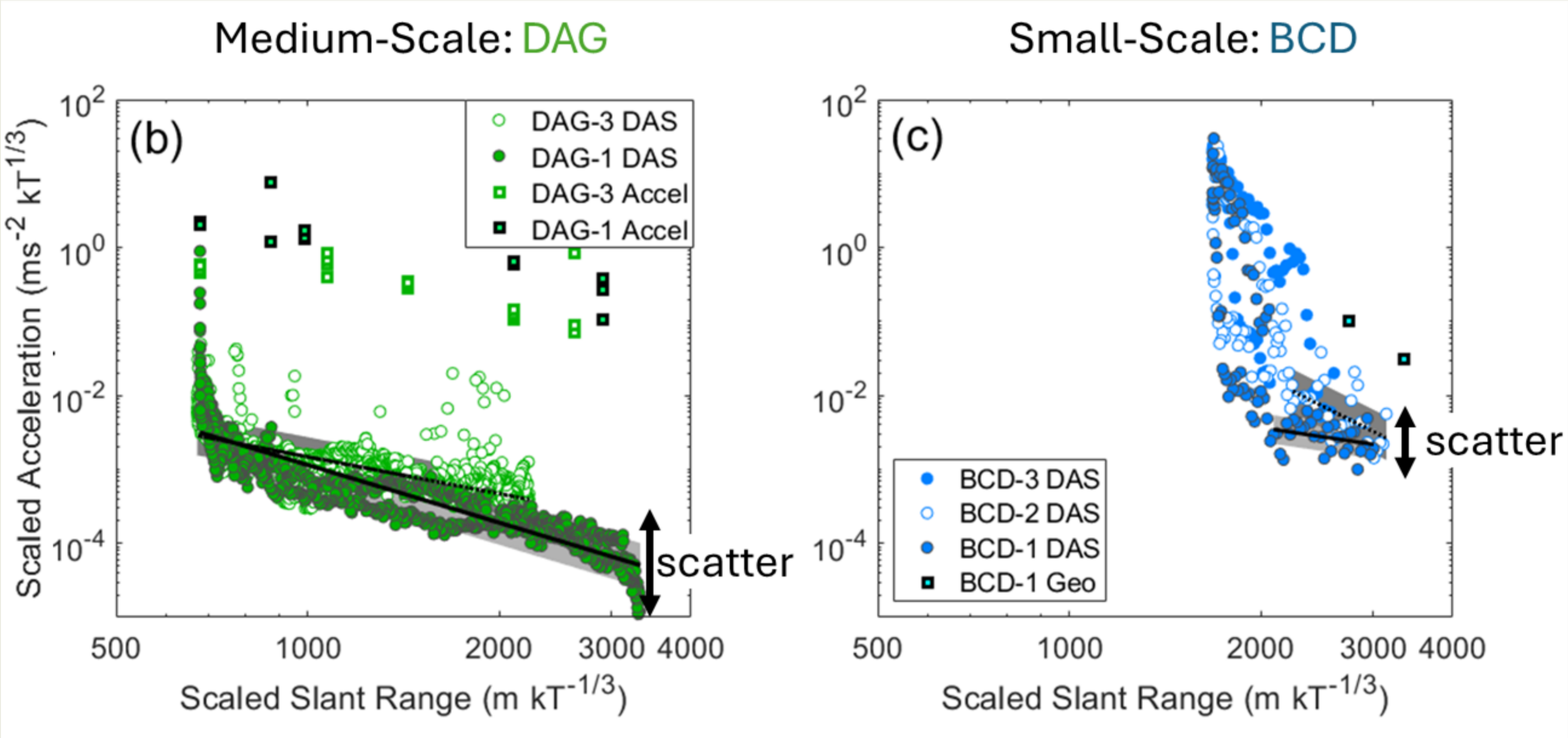
Single trend and scatter appear independent of yield; some discrete sensors inconsistent.



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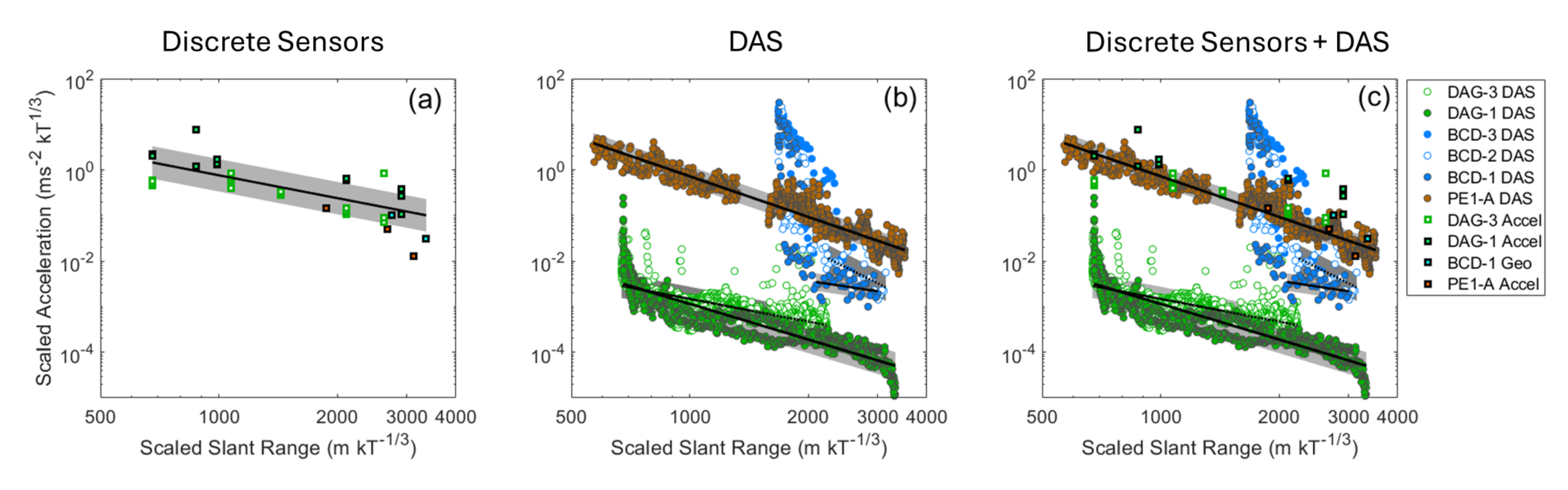
General trends distinguish each series despite scatter.



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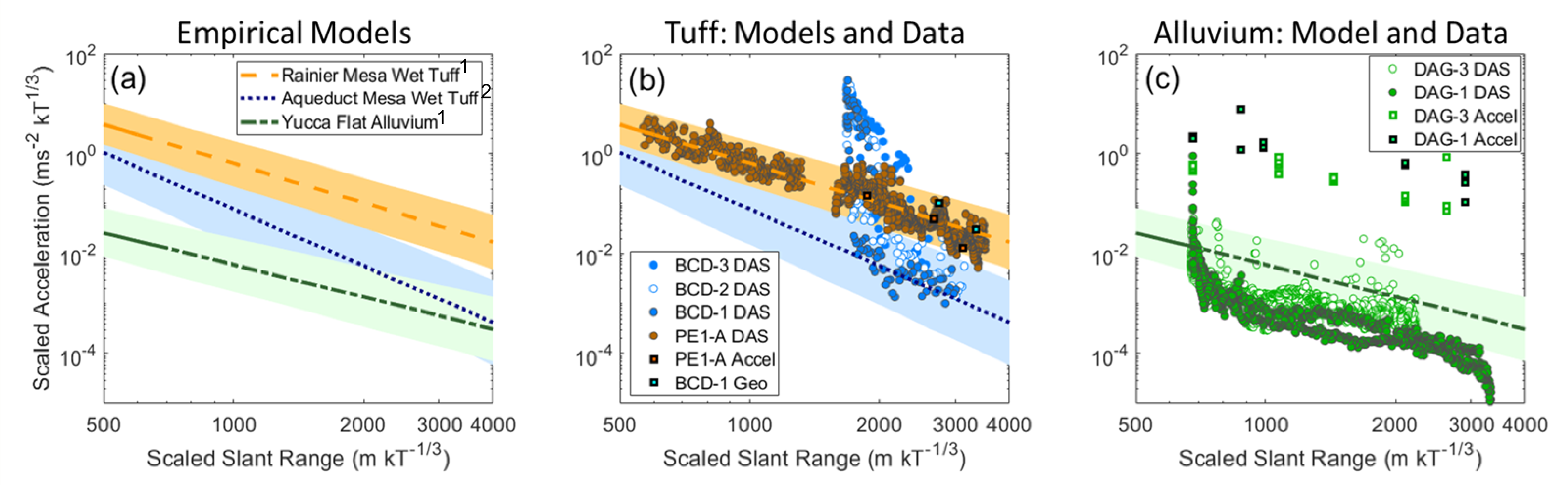
Trends in this range follow extrapolated empirical models of emplacement geology.



[1]Perret and Bass, 1975; [2]Ford, 2020

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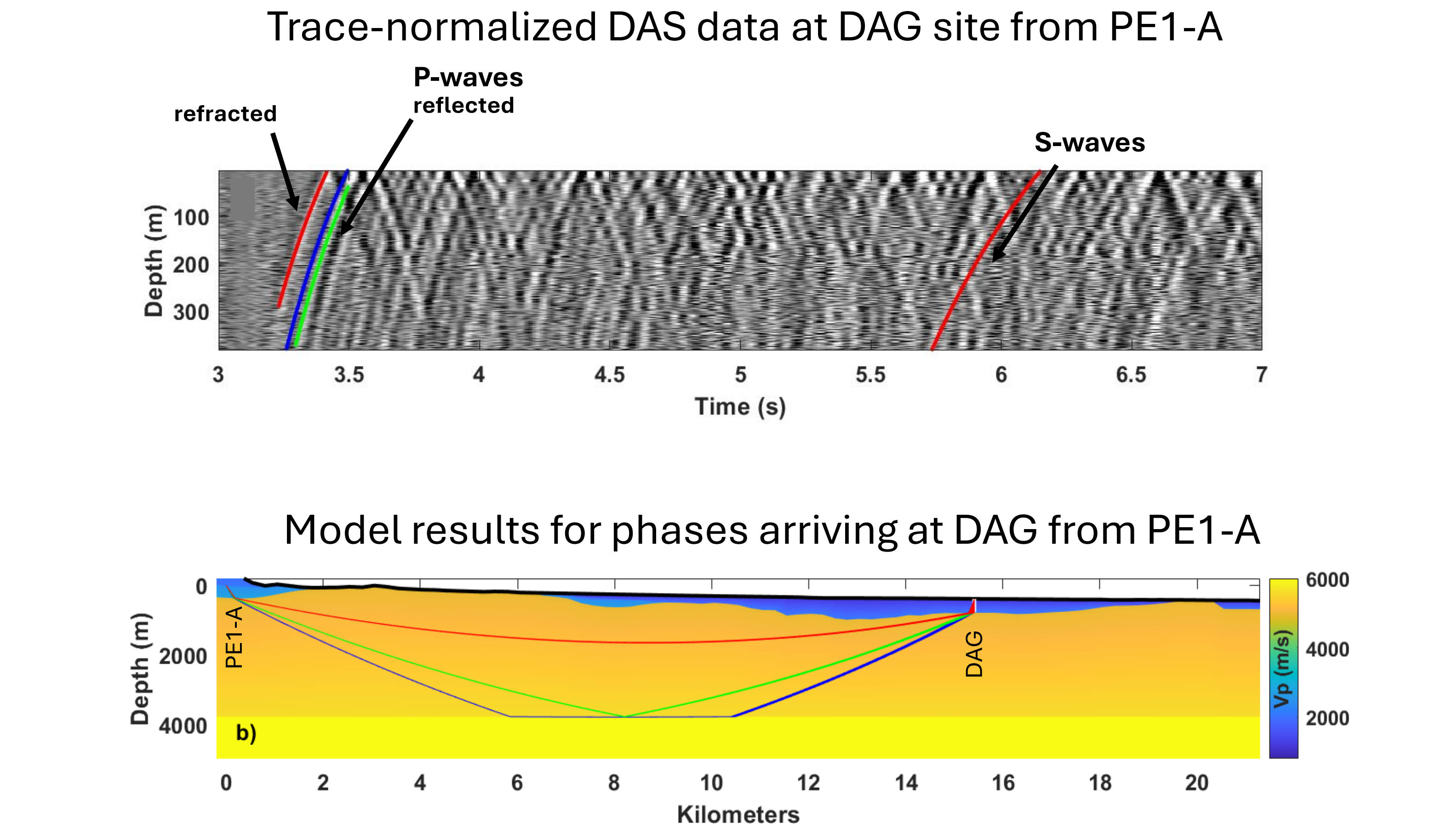
By ~12,000 m $kT^{-1/3}$, trends seem to be set by local geologic paths.



DAS data was also measured 15-km from PE1-A at the DAG site.

DAS arrivals were modeled in SW4 with an updated site model, requiring a velocity gradient down to a 4-km boundary.

DAS arrivals are interpreted as refracted and reflected waves.

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DAS enhances pattern analysis for complex wavefields near explosions.

DAS data from underground chemical explosions revealed dominant controls on ground motion patterns across varying yields.

Between 350–4000 m $kT^{-1/3}$, emplacement geology dictated ground motion trends for each series, independent of yield, with scatter described by linearly extrapolated strong motion models.

By 12,000 m $kT^{-1/3}$, path geology in the upper 4 km became dominant, highlighting critical geologic influences.

Further study is needed to compare DAS results to single-point sensors.

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