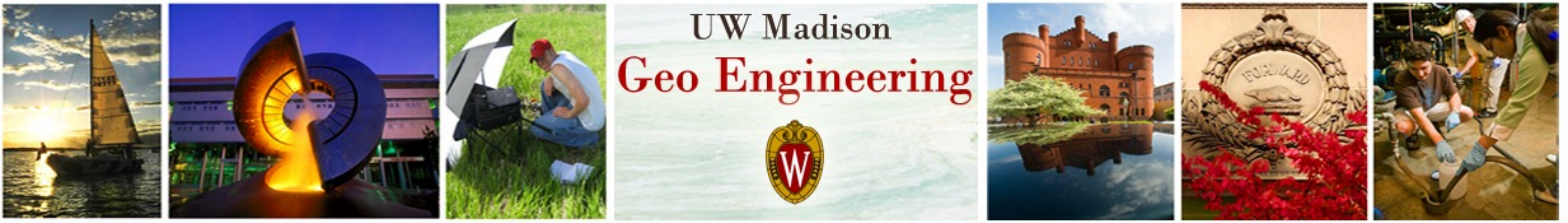


College of Engineering

geophysical • geotechnical • geological • geoenvironmental

Examples of Dedicated and Dark Fiber DAS Applications in Civil Engineering Infrastructure

Dante Fratta and the UW-Madison DAS group

Geological Engineering

University of Wisconsin-Madison

Examples of DAS uses in Civil Engineering Infrastructure

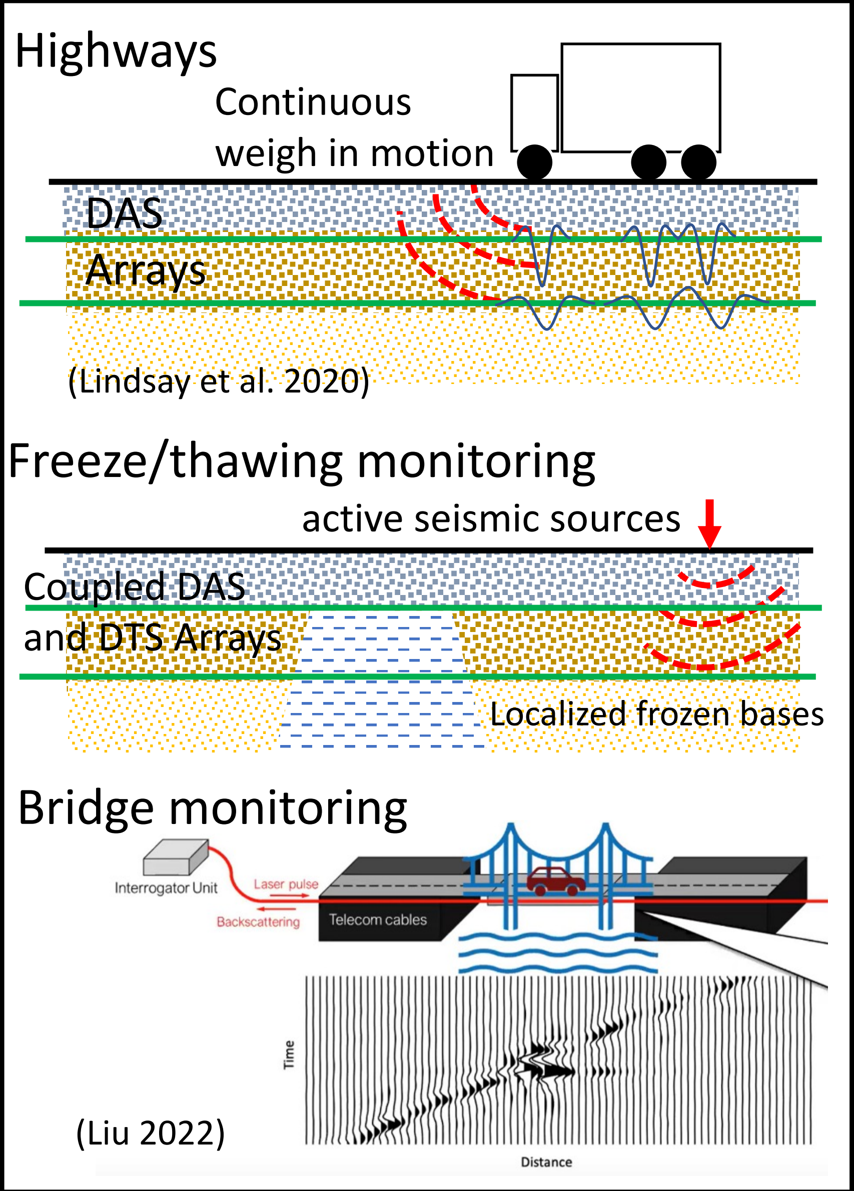
- The distributed nature of DAS arrays

  ⇒ creates conditions for assessing the infrastructure at multiple scales

- Long-term measurements using *dedicated* fibers

  ⇒ allows for the operation and performance monitoring of long pieces of infrastructure (e.g., roads, railways, pipelines, levees)

  ⇒ facilitates the long-term deterioration monitoring of the infrastructure and its environment (opportunities for OFDR)



Examples of DAS uses in Civil Engineering Infrastructure

- Availability of *dark* fiber optic networks

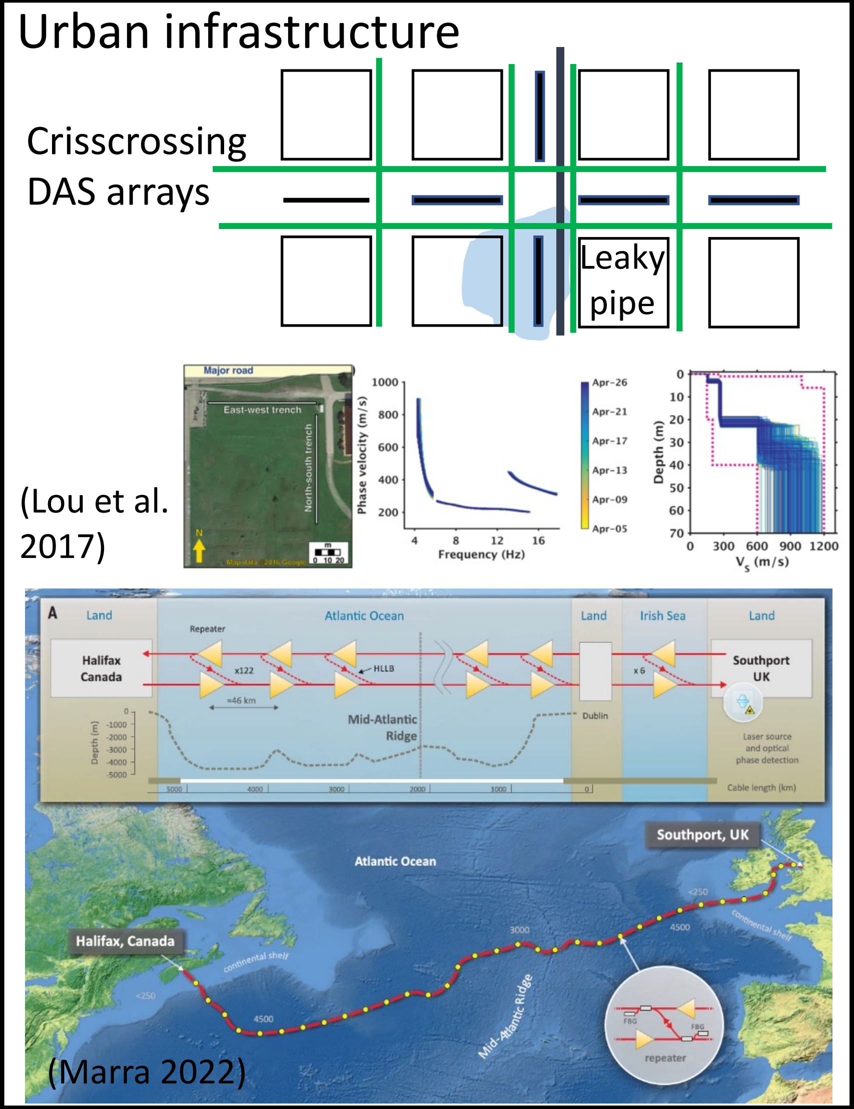
  ⇒ allows for multi-directionally monitoring in urban areas.

- High-density arrays

  ⇒ permits the creation of high-resolution site characterization maps (based on surface wave analyses)

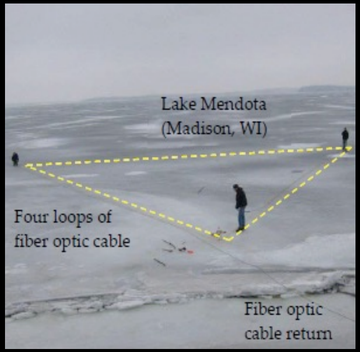
- Interferometry and Internet Communication Developments

  ⇒ exiting new opportunities for engineering and science



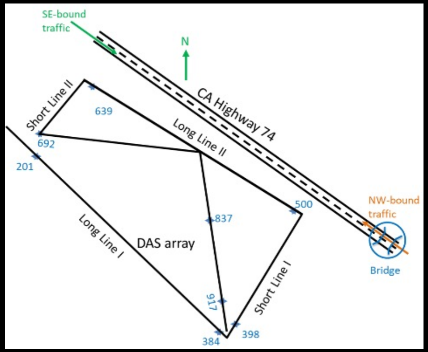
DAS Projects at UW-Madison

Frozen Lake Mendota, Madison WI (Mar. 2012)



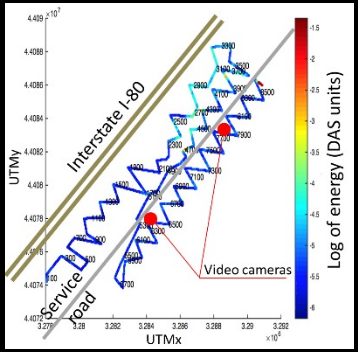
~300-m array - Loose tube and tight buffered cables melted into the lake ice

Garner Valley, So. California (Set. 2013)



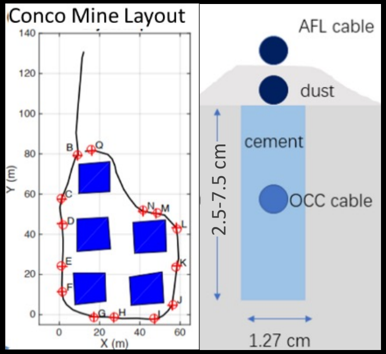
~1500-m array - Tight buffered tactical cable trenched and covered about 0.3 m into the sediment

Brady Hot Springs, West Nevada (Mar. 2016)



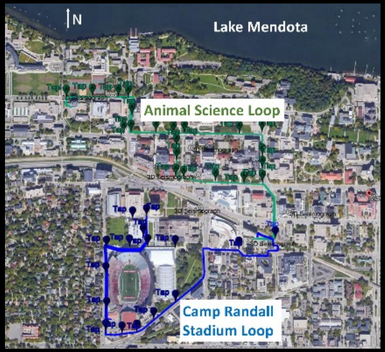
~8700-m array - Tight buffered tactical cable trenched and covered about 0.45 m into the sediment

Lafrange-Conco Mine, No. Illinois (Jun. 2017)



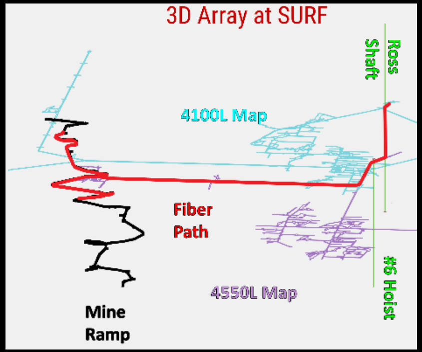
~600-m array - Tight buffered tactical cable cemented into a rock grove, covered with debris, and laid on the surface

Madison Dark Fiber, Madison, WI (Nov. 2019)



~4000-m and 3000-m arrays
Dark fiber in communication conduits across two different paths in campus

SURF Homestake Mine (May 2022/Feb 2023)



~4000-m – array along the drifts and ramps of the underground mine/research lab

Funded by NSF, DOE, MSHA, US Air Force, UW-Madison / Thanks to Silixa and Optasense

DAS Projects at UW-Madison

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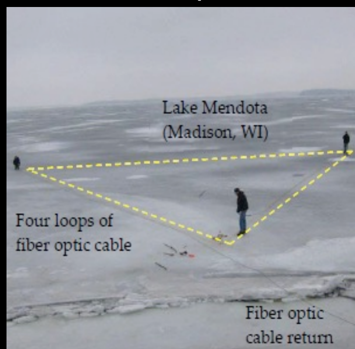

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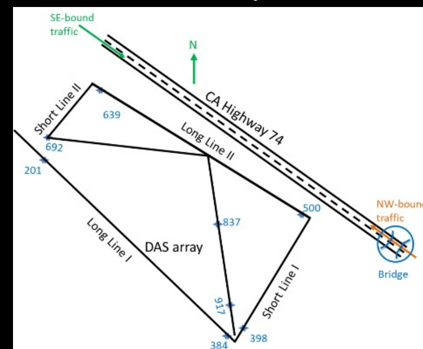

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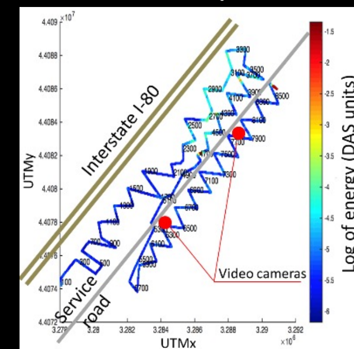
Brady Hot Springs, West Nevada (Mar. 2016)



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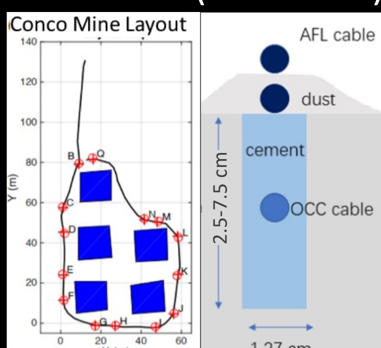

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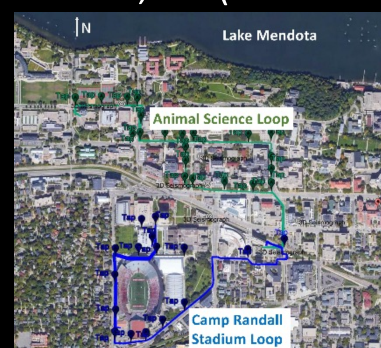

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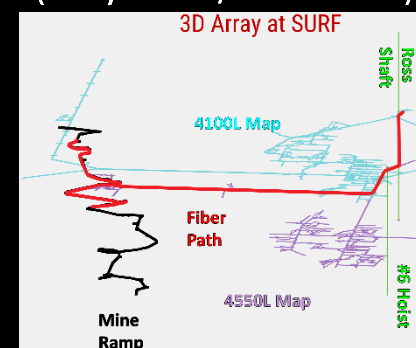
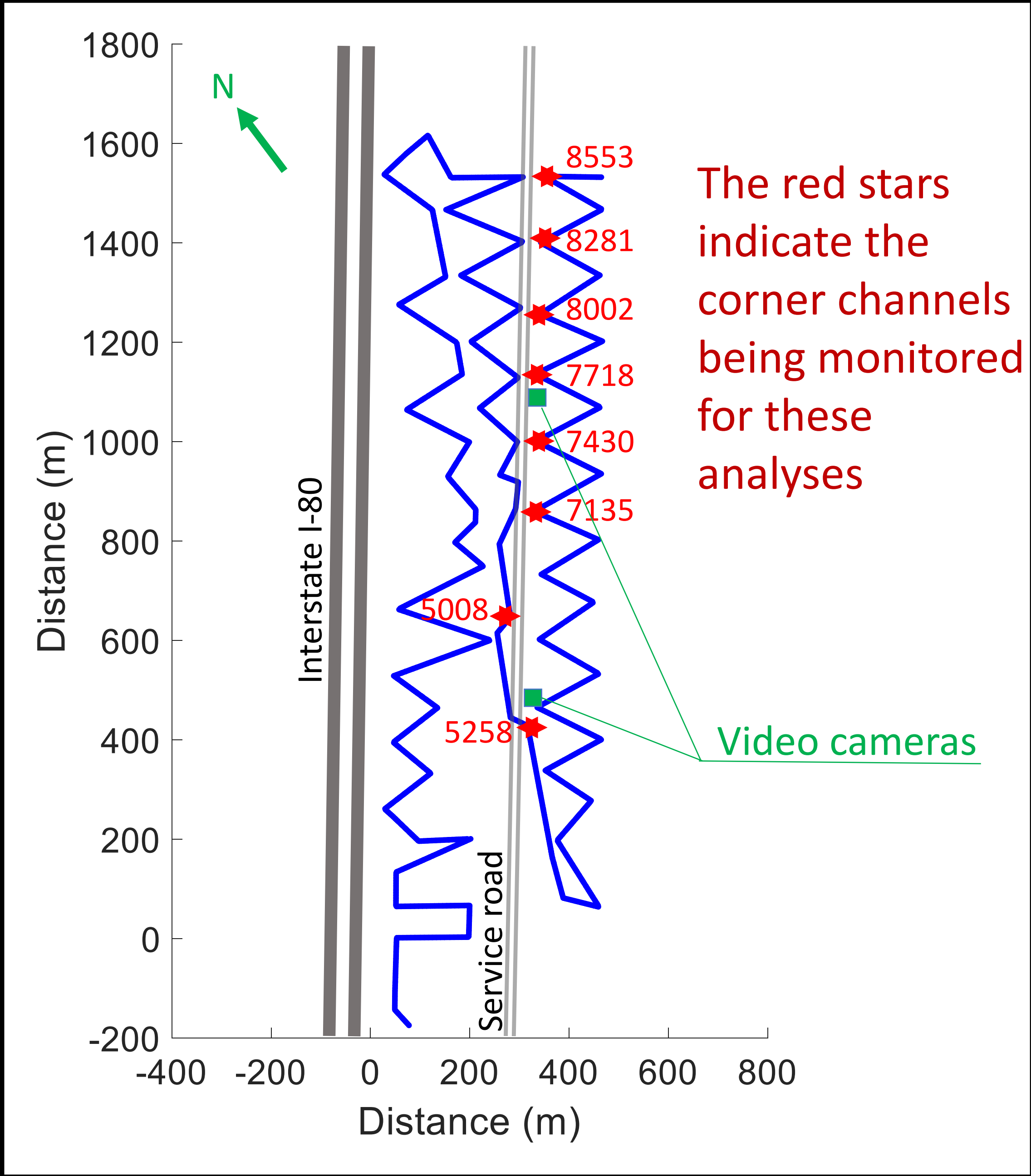


~4000-m – array along the drifts and ramps of the underground mine/research lab

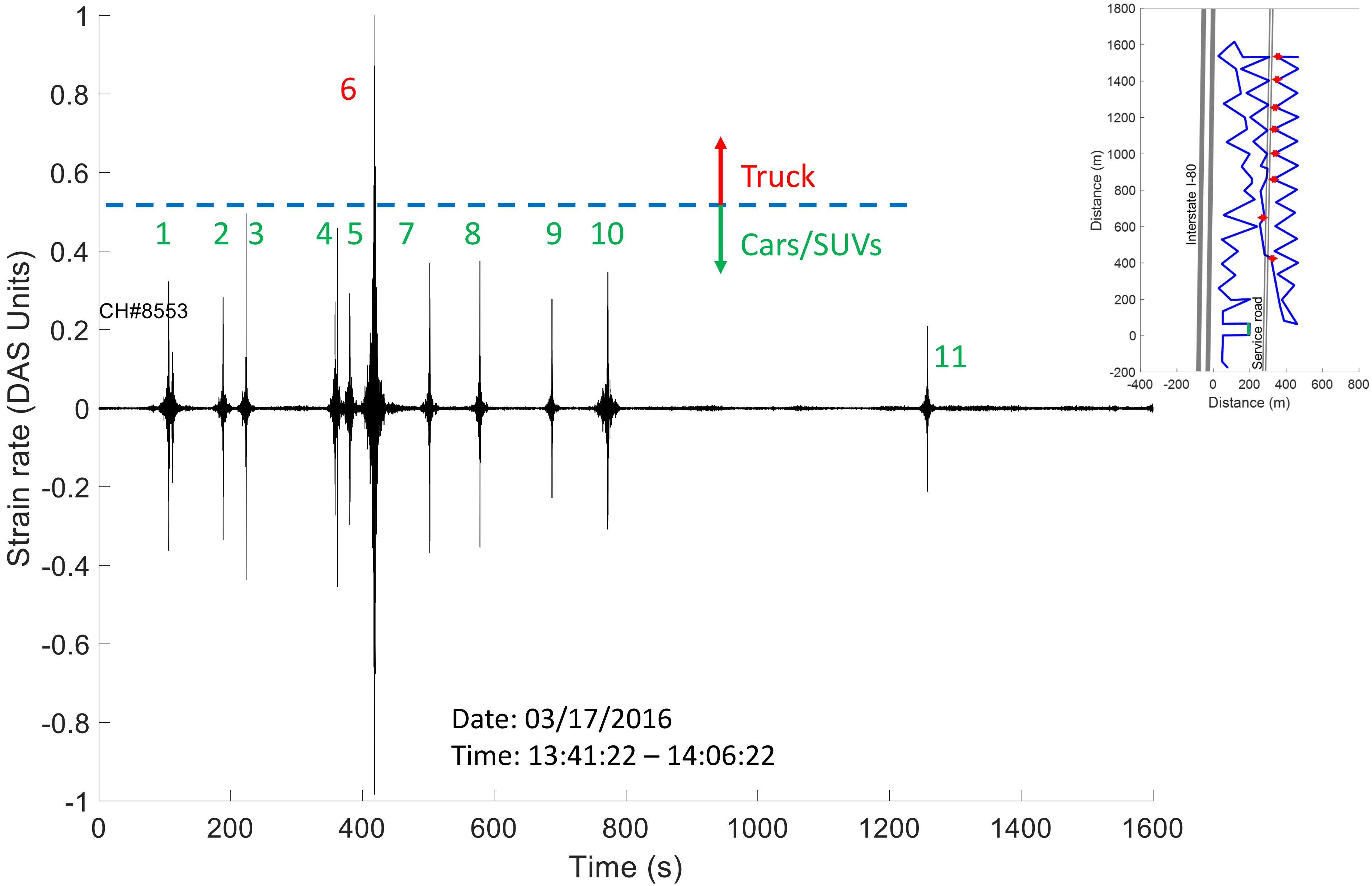
Funded by NSF, DOE, MSHA, US Air Force, UW-Madison / Thanks to Silixa and Optasense

Brady Hot Springs - DAS Array

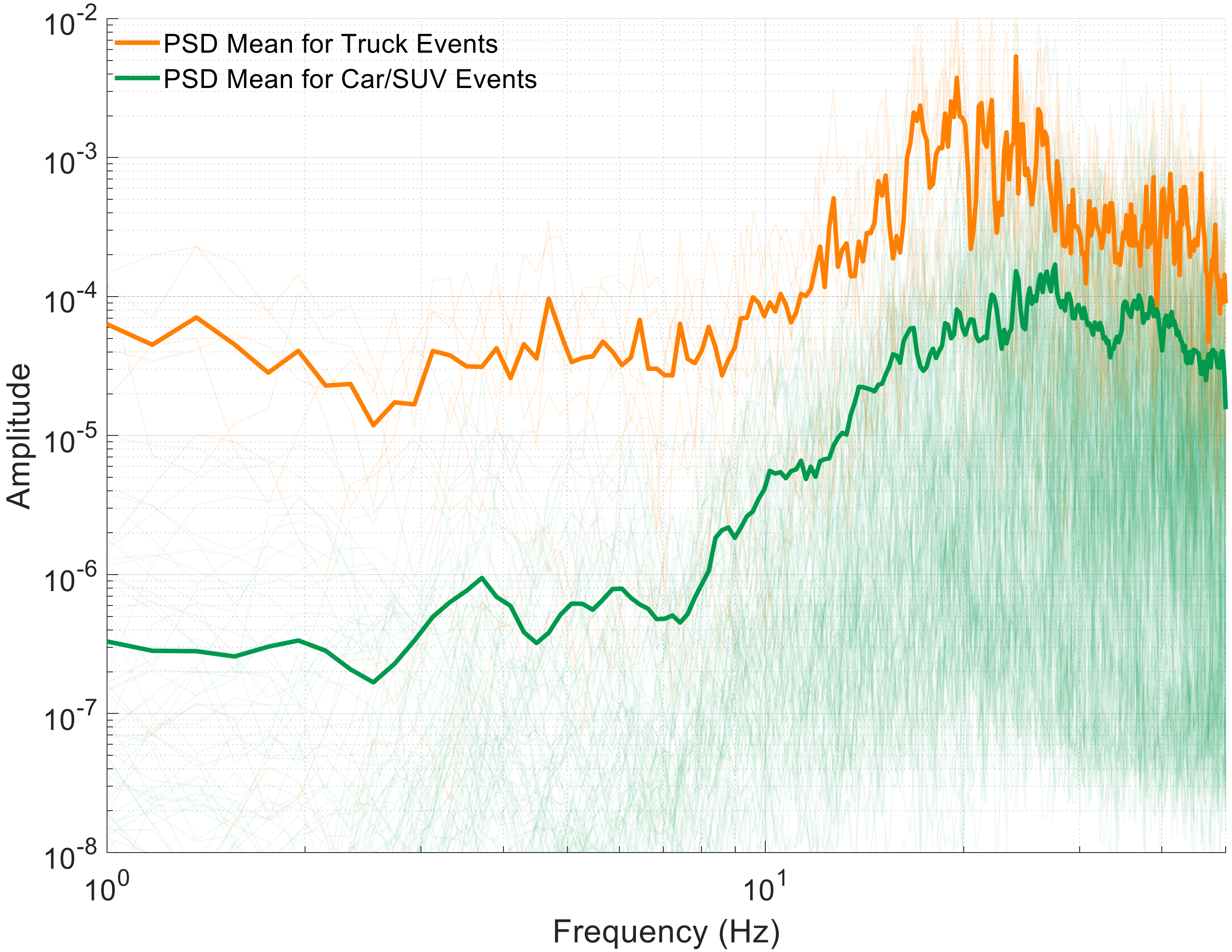
- 8700-m long DAS and DTS array was trenched to a depth of about ~0.4 m to actively and passively image a geothermal field.
- Traffic was monitored during the 6 AM to 7 AM “rush” hour along the service road to a diatomaceous mine.
- Cameras were set up to image the passing traffic.

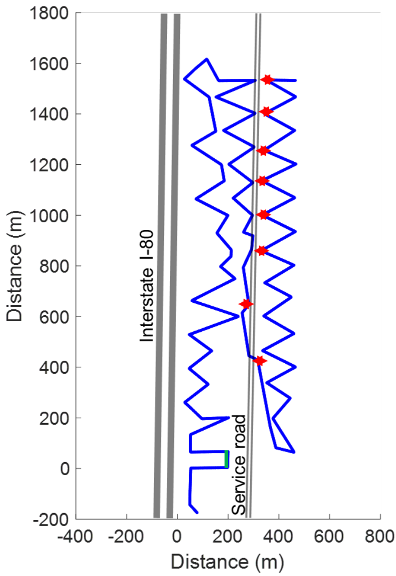


Brady Hot Springs – Vehicle Identification



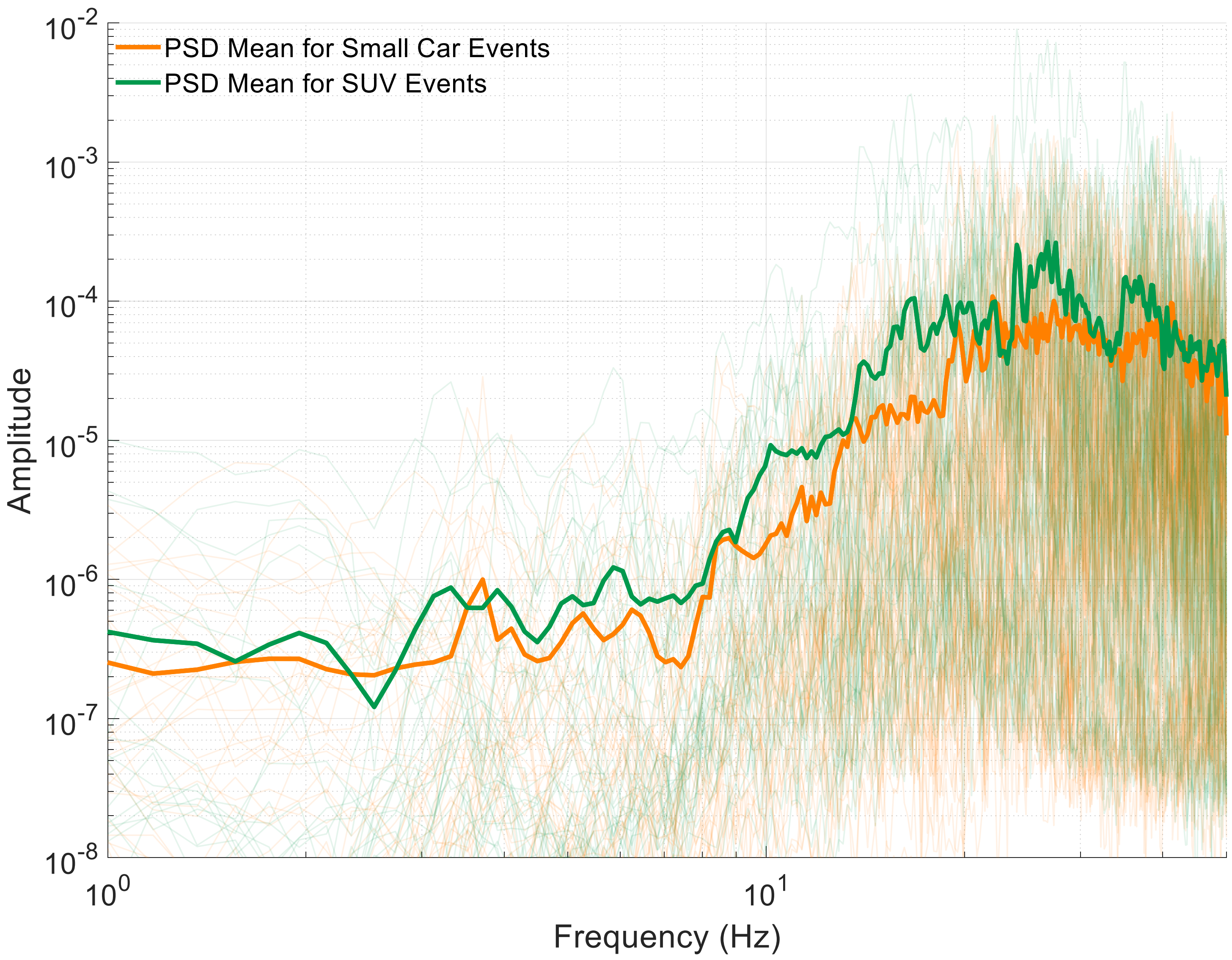
Energy Density – Truck vs. Cars/SUVs

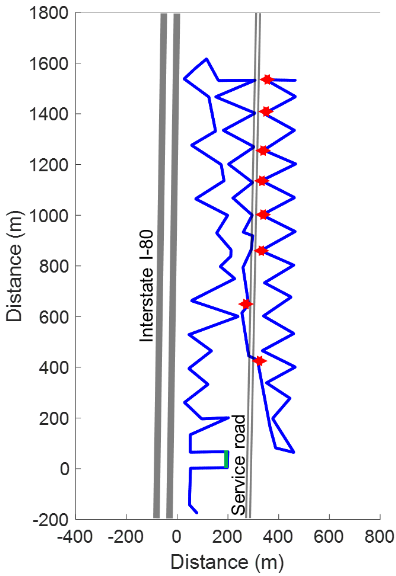




Analyses: Esra Ak

Energy Density – Truck vs. Cars/SUVs

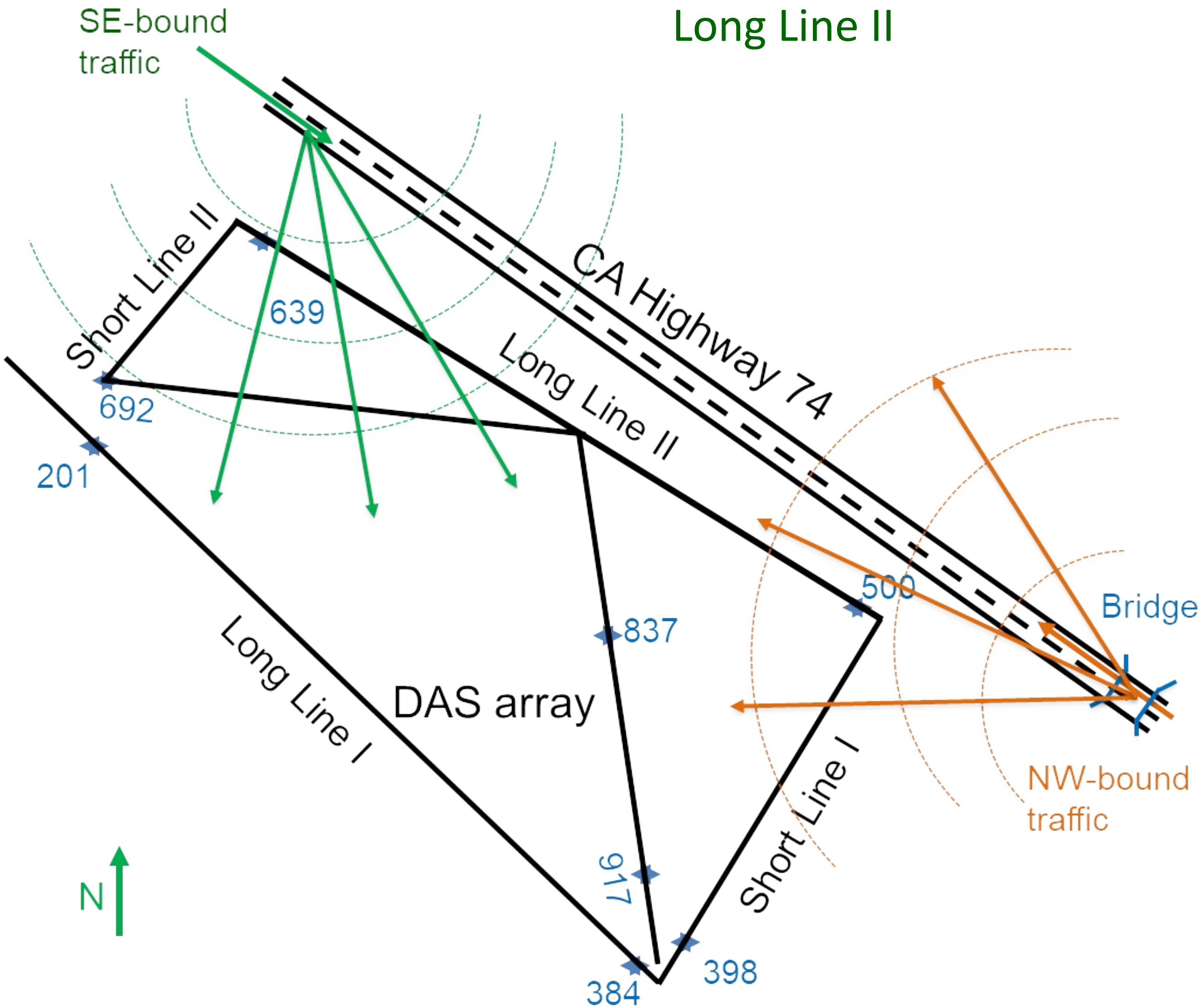




Analyses: Esra Ak

Traffic Data – Roadways Surface Analysis

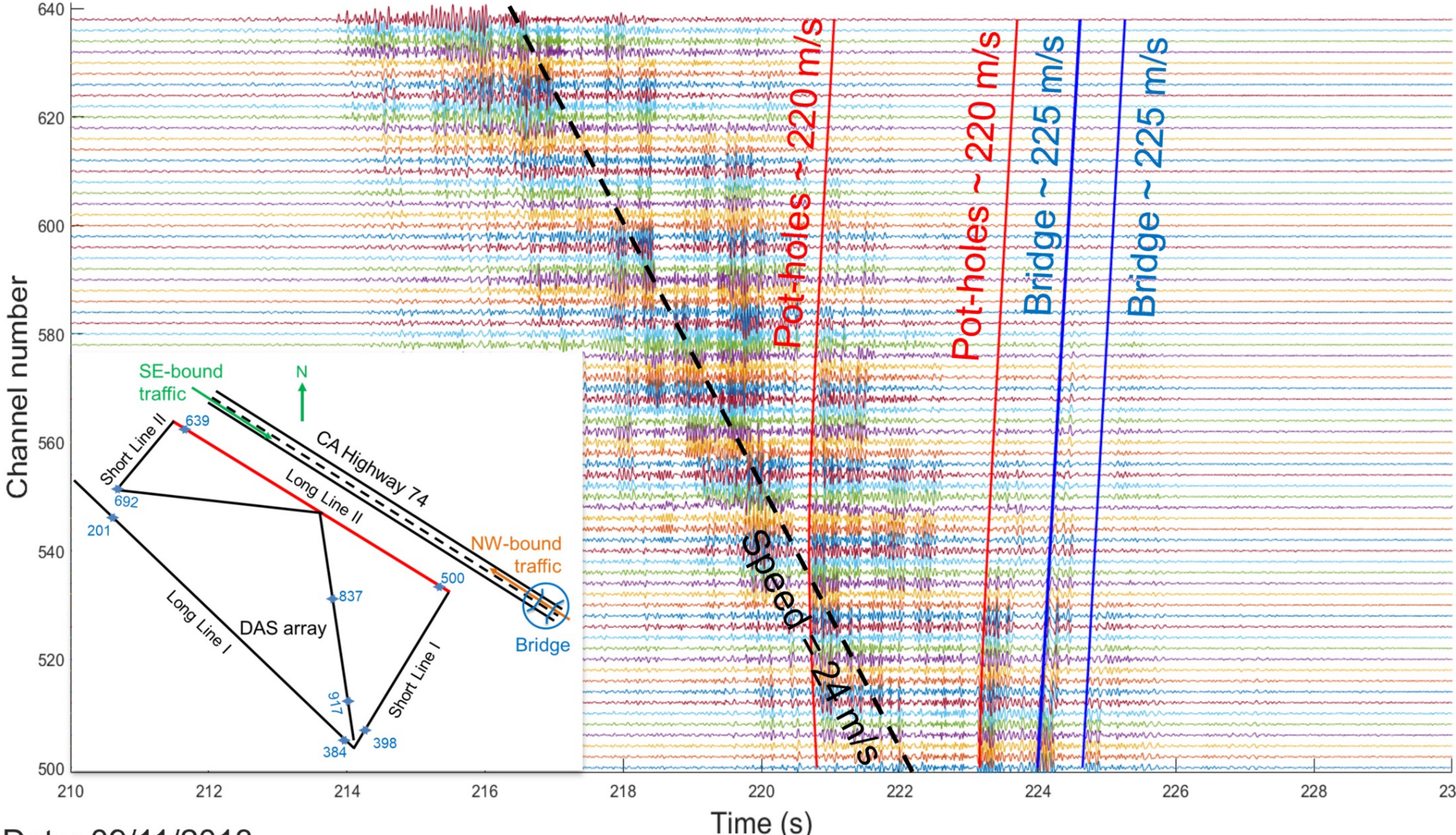
A vehicle hitting a pothole would be felt as a point along Long Line II



Garner Valley (So. California): ~700-m rectangular deployment monitored with 10-m gauge length using iDAS interrogator

A vehicle hitting the *'bump at the end of the bridge'* would be felt as a surface wave along Long Line II. The recorded velocity would be lower than the real surface wave group velocity due to misalignment.

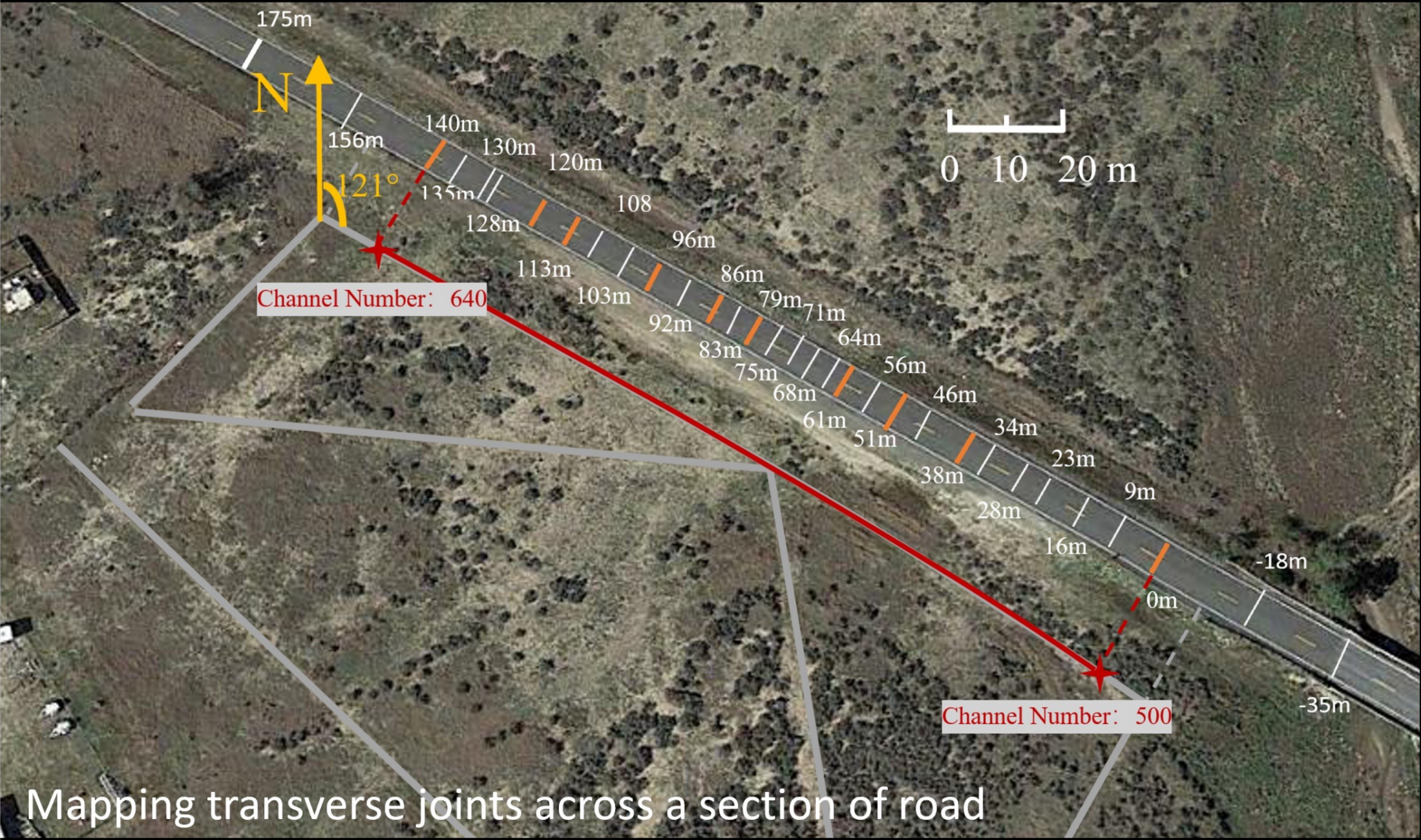
Vehicle Event: Roadways Surface Analysis



Date: 09/11/2013

Local time: 20:24:19 – 20:39:19

Surface Road Quality Summary

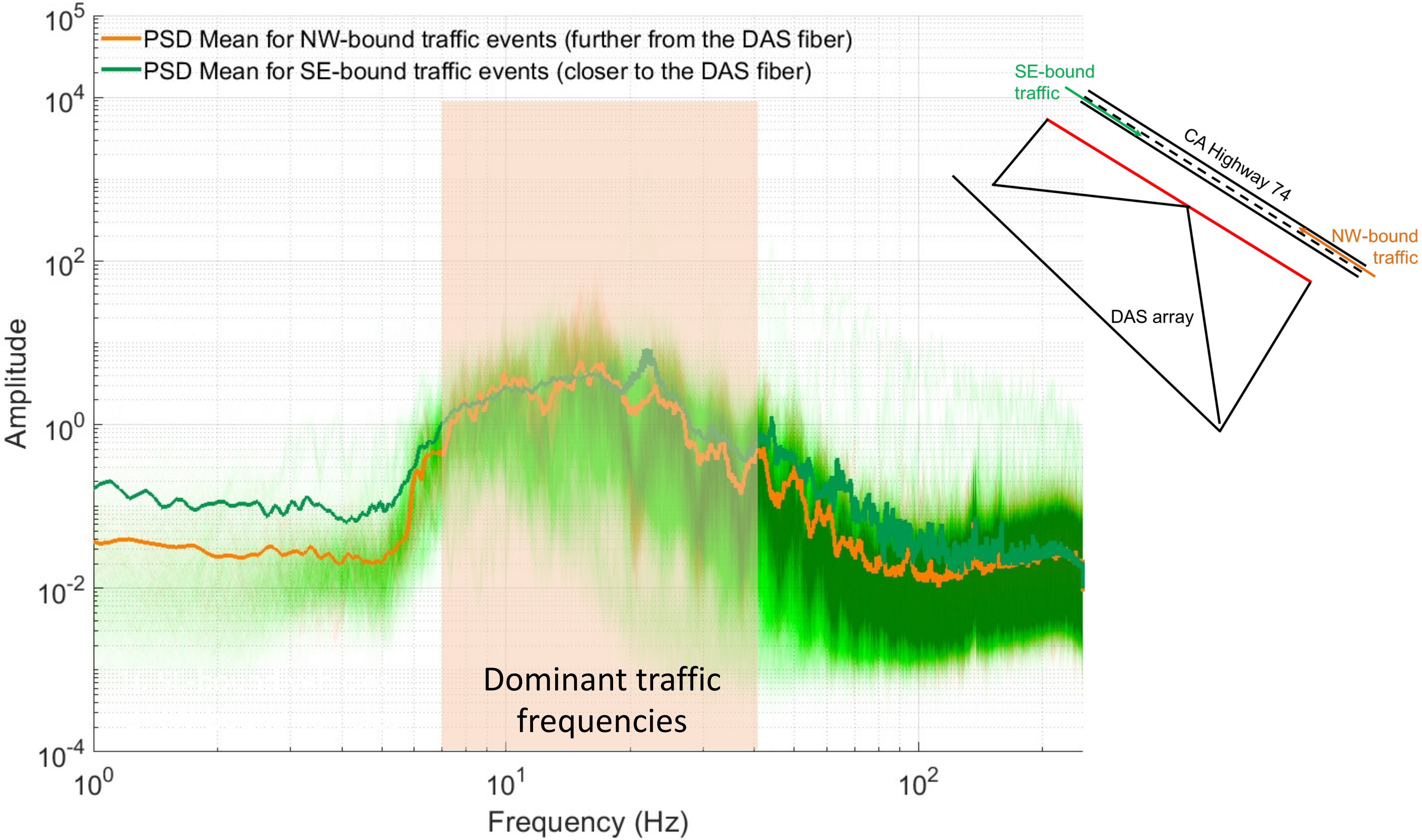


Mapping transverse joints across a section of road

Only achievable with a dense sensing array.

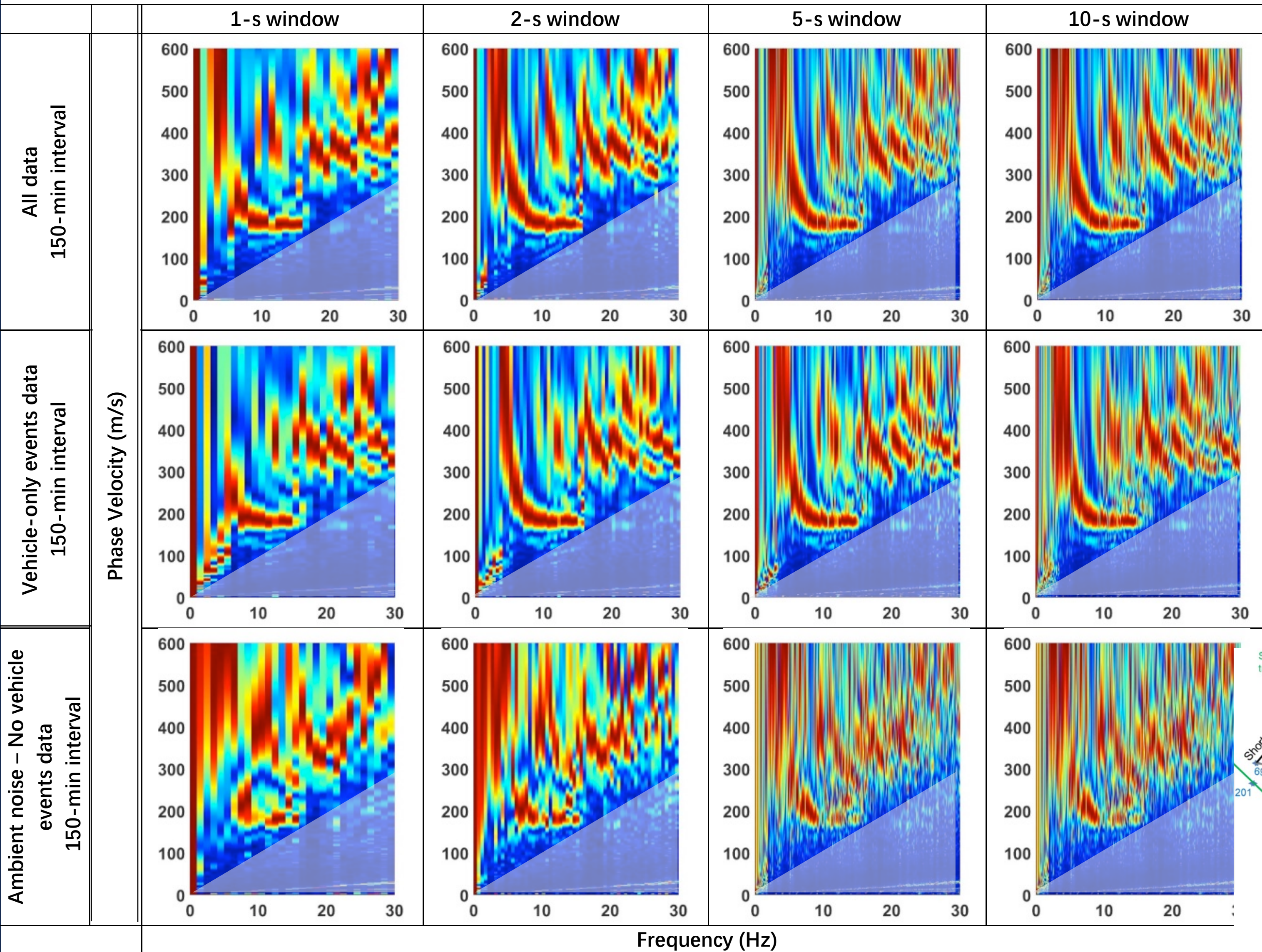
Analyses: Siyu Lu

Power Spectral Density - Different Travel Directions



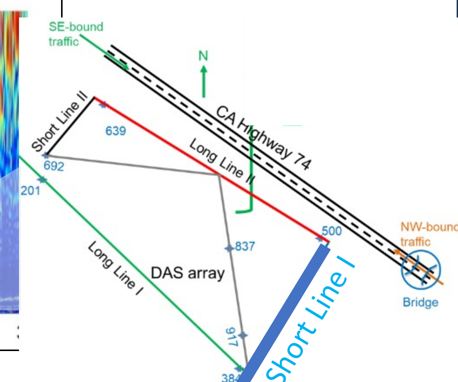
Vehicle Events as Seismic Sources

Dispersion Curves along Short Line I



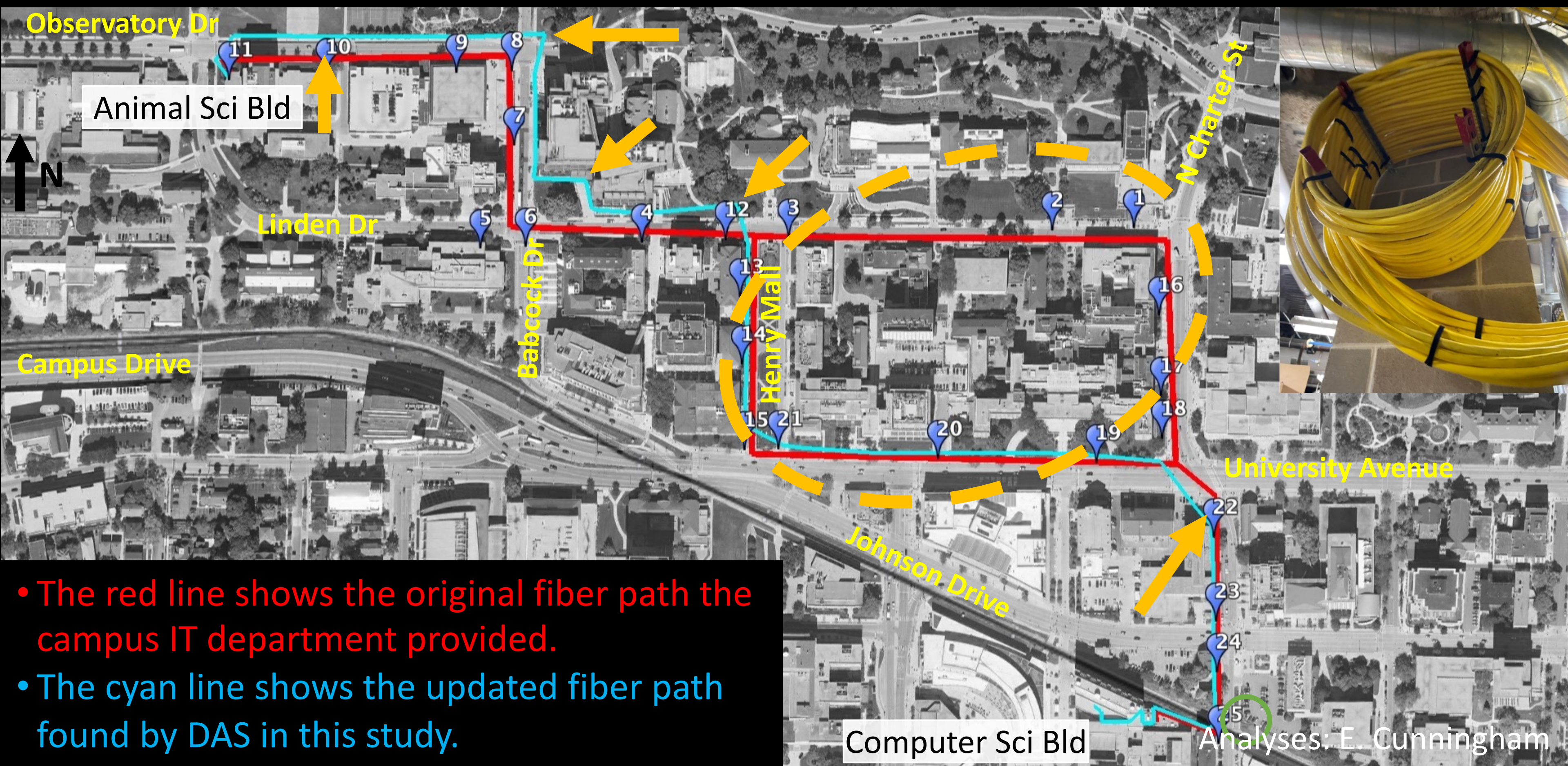
Grayed area: Wavelength < gauge length (10 m in this case)

Other constraints:
Dean et al. (2016)
Vantessel et al. (2022)



Dark Fiber in an Urban Environment

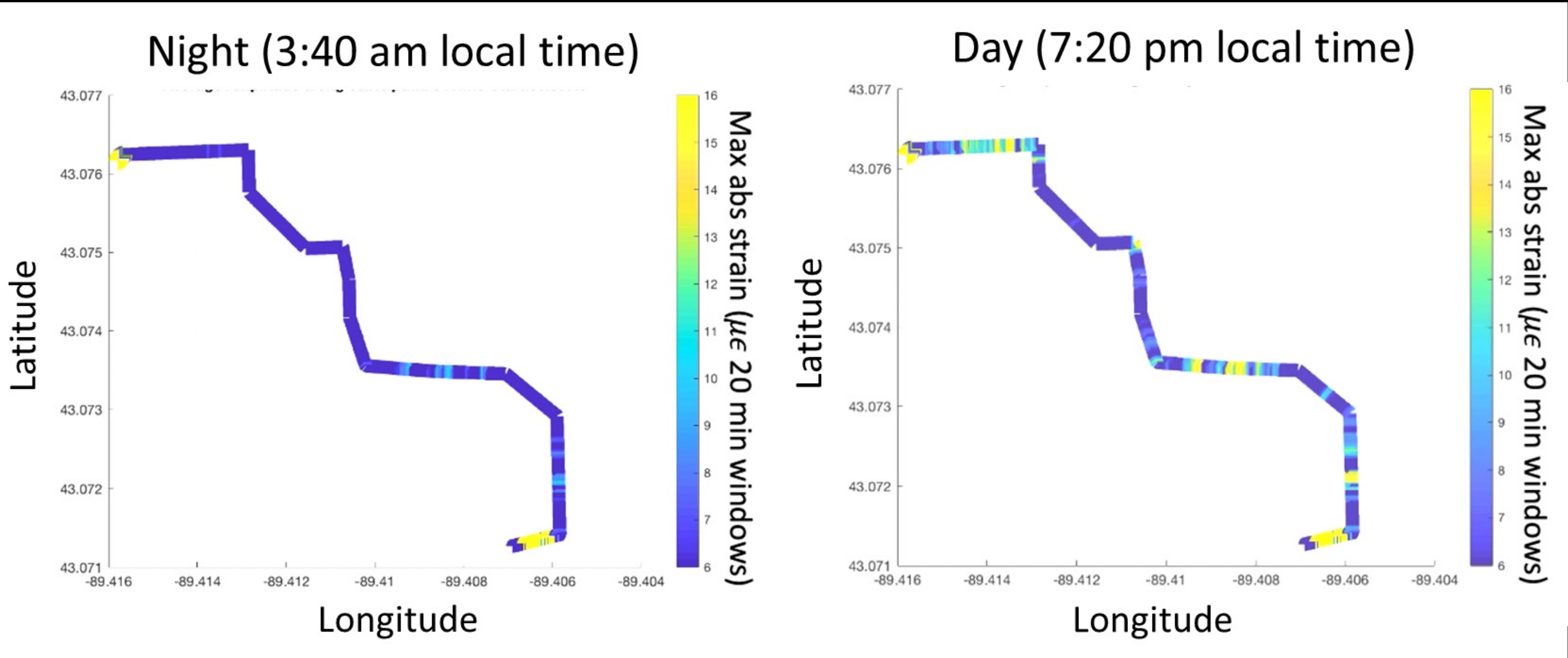
- About a week of Silixa iDAS surveys on a ~4000-m dark fiber route from the Compute Sci to the Animal Sci Buildings.
- DAS cable mapping with tap testing showed IT route maps were incorrect.
- DAS cable mapping located 25% more fiber than the reported map distance.



- The red line shows the original fiber path the campus IT department provided.
- The cyan line shows the updated fiber path found by DAS in this study.

Dark Fiber in an Urban Environment

Dark Fiber Cable Sensitivity Inferred from Noise Analysis



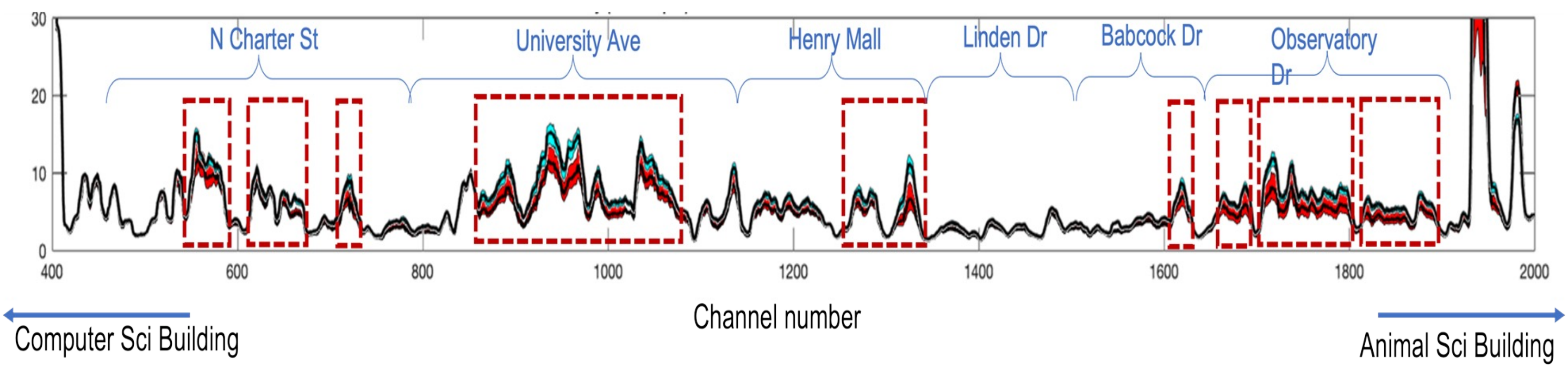
The maximum absolute strain value for 20-min periods for each channel along the fiber route. High-sensitive fiber channels show low values of maximum absolute strain at night (top) and high values of maximum absolute strain during the day due to campus activities.

Analyses: E. Cunningham

Dark Fiber in an Urban Environment

Dark Fiber Cable Sensitivity Inferred from Noise Analysis

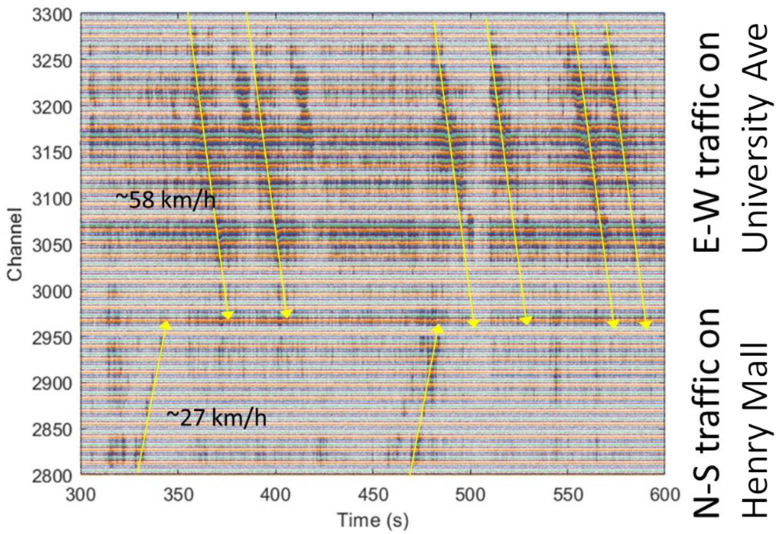
Red 11 pm to 6 am max abs strain for 30 s intervals
Cyan 11 am to 5 pm max abs strain for 30 s intervals



Maximum absolute strain values for 30-sec periods are calculated for each channel along the fiber. The 'day' values are in red, and the 'night' values are in cyan, with the mean for each series shown with a black line.

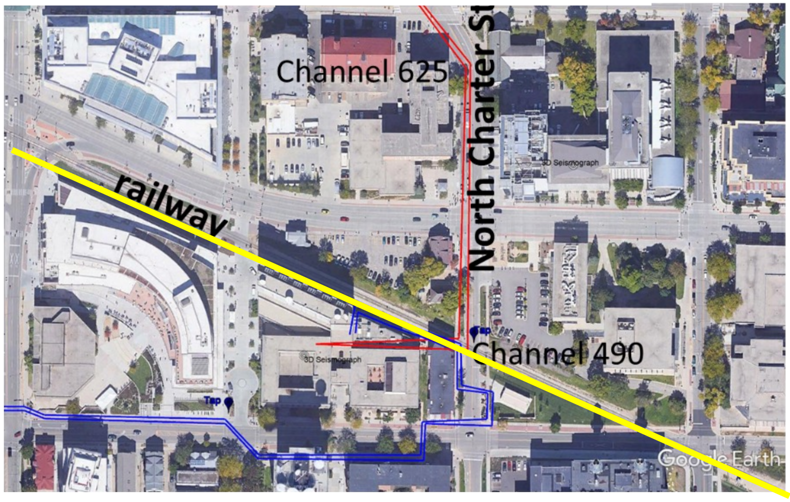
Dark Fiber and Campus Activities

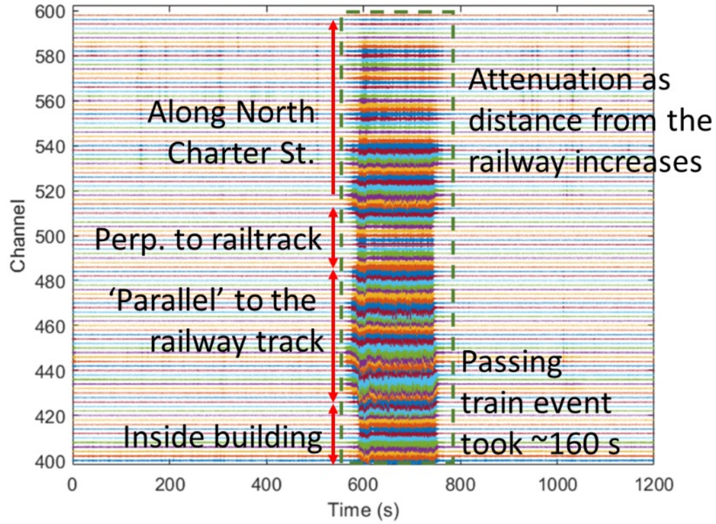
Vehicular Traffic



Records were collected on 20191105 215619 UTC.

Railway Traffic





Records were collected on 20191106 214249 UTC.

Challenges and opportunities for adoption in engineering practice

- Interrogators’ cost and availability – improving!
- Gauge length – DAS - geophysics (long range and large gauge length) vs. OFDR - NDE (short range and small gauge length).
- Challenges application of HVSR due to the strong DAS directivity.
- Incredibly large data sets – but properly designed monitoring methodologies can control it.
- Yet, DAS arrays (and the use of arrays of opportunities) have the potential to revolutionize infrastructure monitoring by allowing high spatial resolution and high dynamic range.