INSIGHTS FROM THE FIRST IN-RIVER DAS DEPLOYMENT

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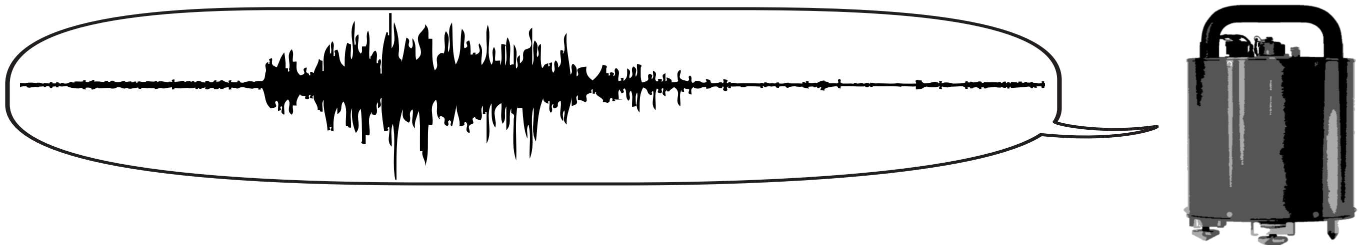
Surface processes produce and transport mass fluxes throughout Earth's surface systems.

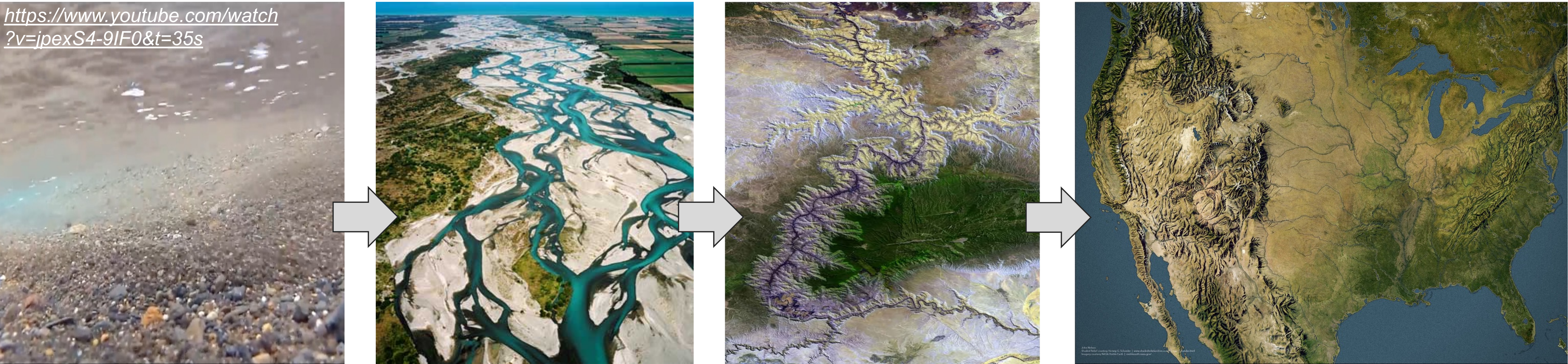
Mass fluxes govern the rates and patterns of erosion that control landscapes and hazards.

Our ability to characterize and predict fluvial processes is often limited by disconnections across scales

Fluvial monitoring can be challenging due to process **stochasticity**, **spatial heterogeneity** and **inaccessibility.**

Seismo-acoustic data provide continuous records with high resolution and broad spatial coverage.





Flow hydraulics controls sediment transport: one of the greatest monitoring challenges in fluvial geomorphology

Jinsha River, China
Wikipedia Commons: jpeg.ly/hbCJ

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Seismo-acoustic surrogate methods

Hydrophones

Challenges:

Plate geophones may be cost prohibitive.

DAS?

Seismic data integrate signals over large scales—signal inversion for individual processes (sediment vs water) is an ongoing challenge.

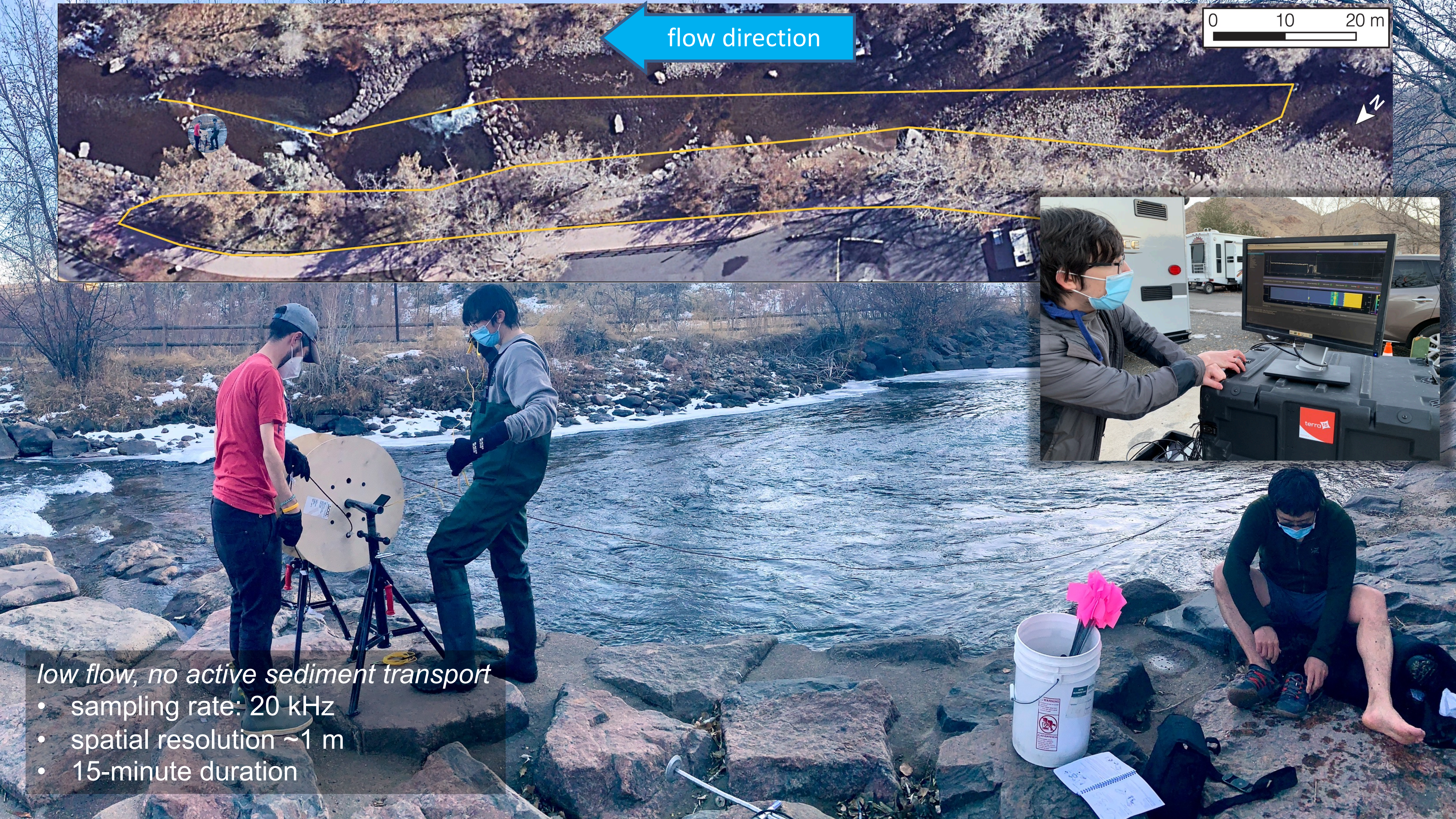
Hydrophone data is highly sensitive to localized conditions—signal interpretation is site-specific and requires extensive calibration.

December 6, 2020:

We threw a distributed acoustic sensor (DAS) in a creek

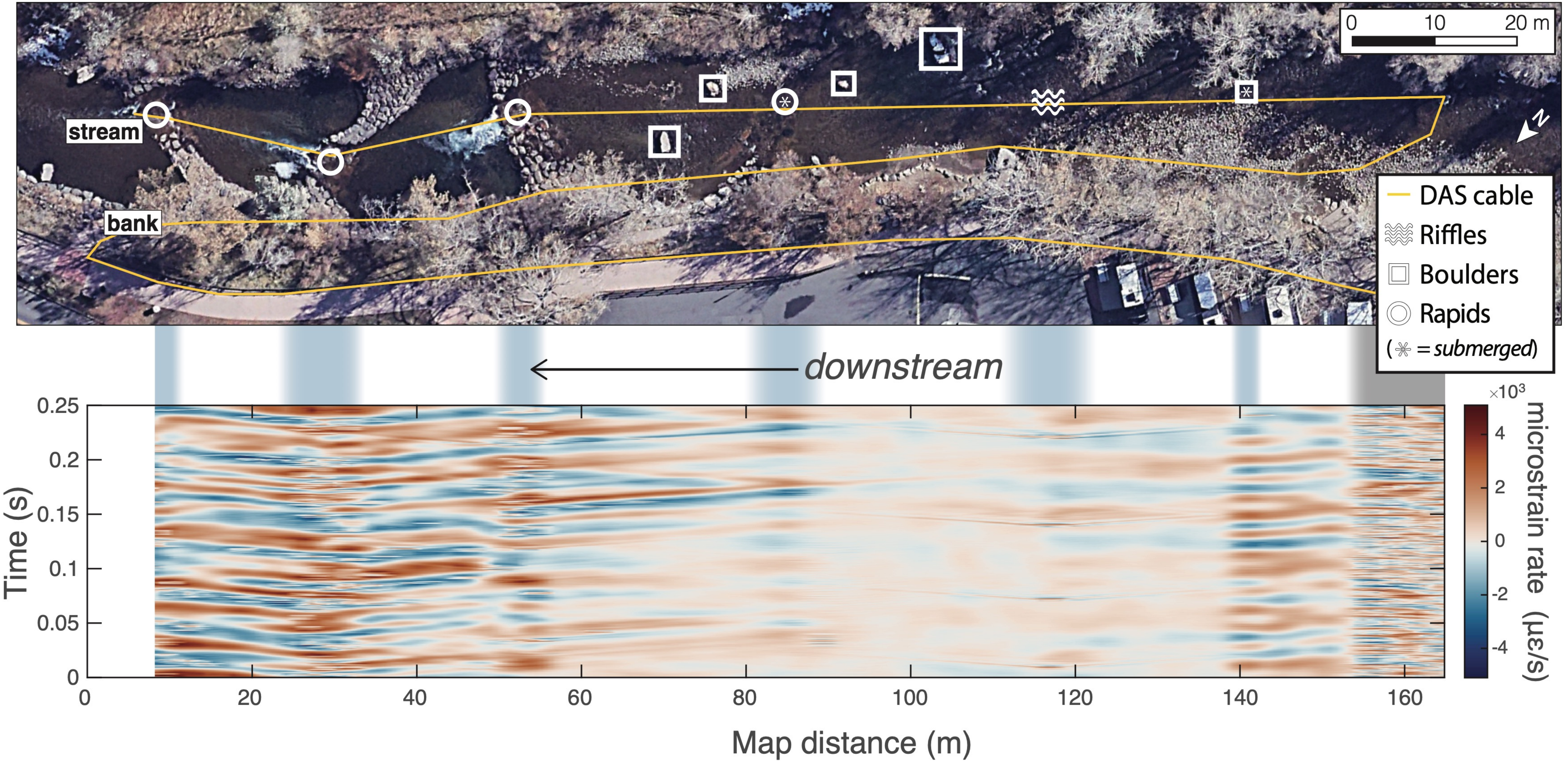
Collaborators:

Max Bezada, University of Minnesota
Ge Jin, Colorado School of Mines
Claire Masteller, Washington University in St. Louis
Matt Siegfried, Colorado School of Mines
Aleksei Titov, Colorado School of Mines
Bill Tate, University of Minnesota


flow direction
0 10 20 m
N
low flow, no active sediment transport
• sampling rate: 20 kHz
• spatial resolution ~1 m
• 15-minute duration

Roth et al (in prep)

Raw DAS waveform data show **strain rate** along the creek (submerged section only)



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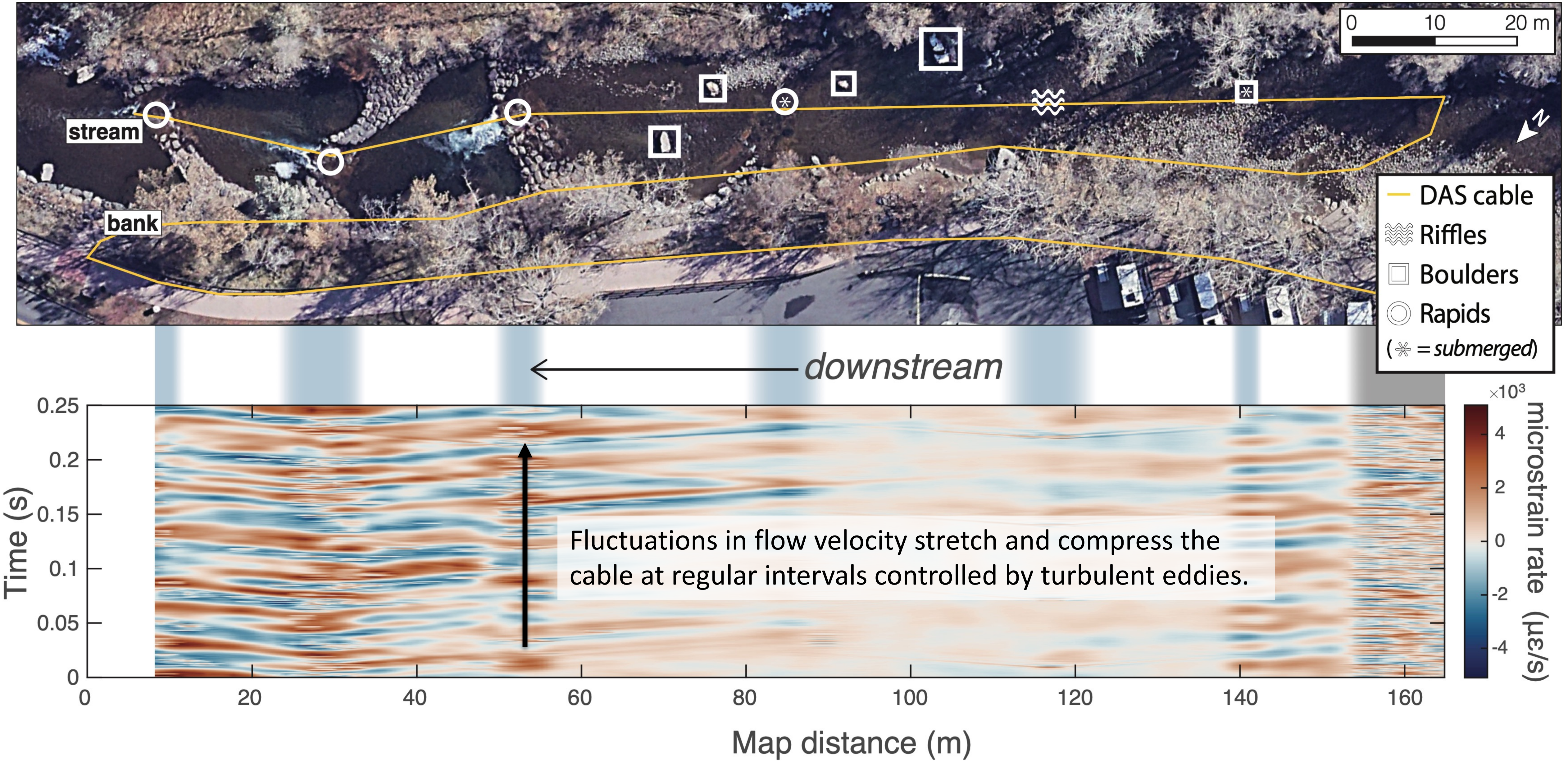

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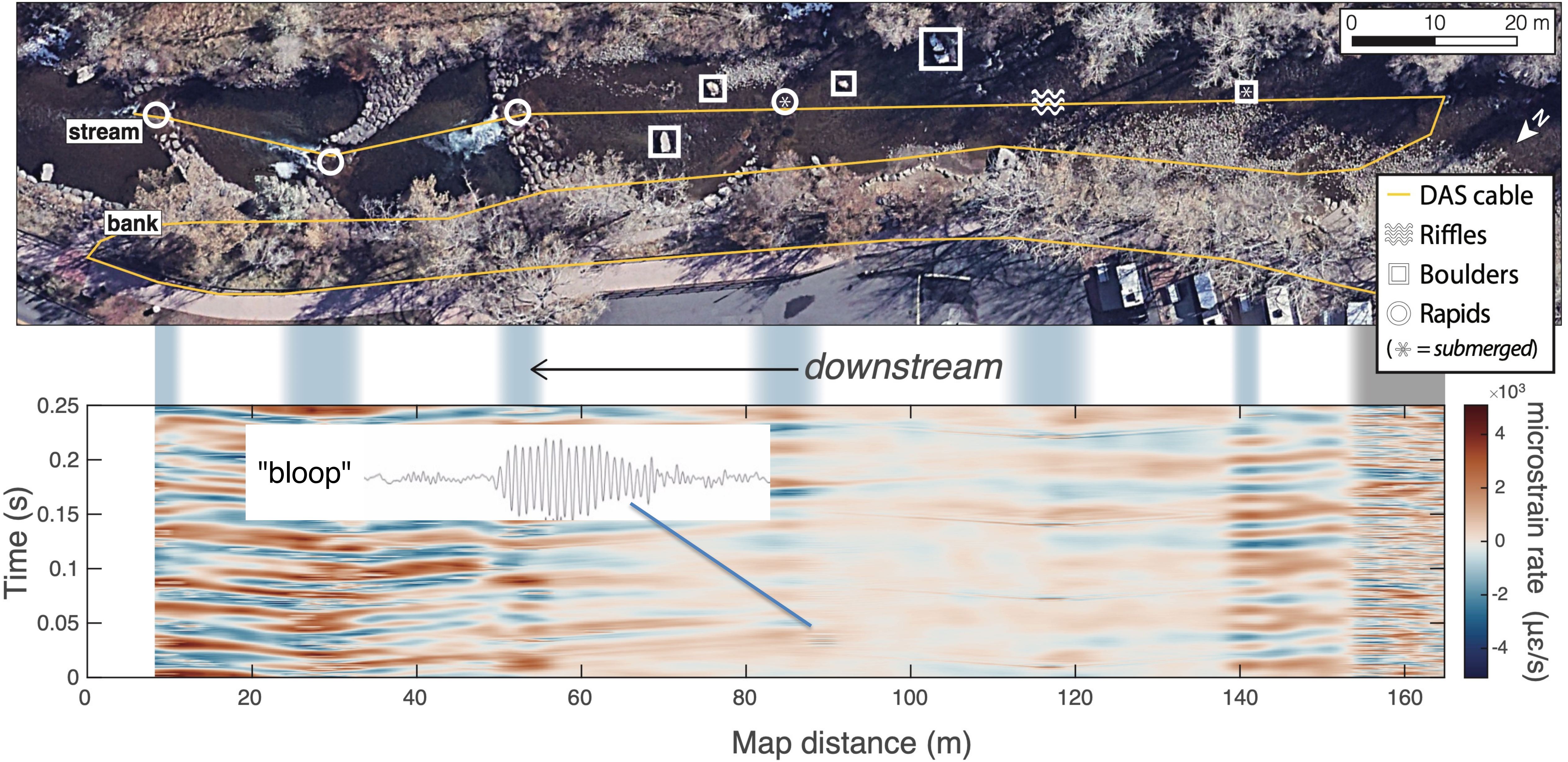

Roth et al (in prep)

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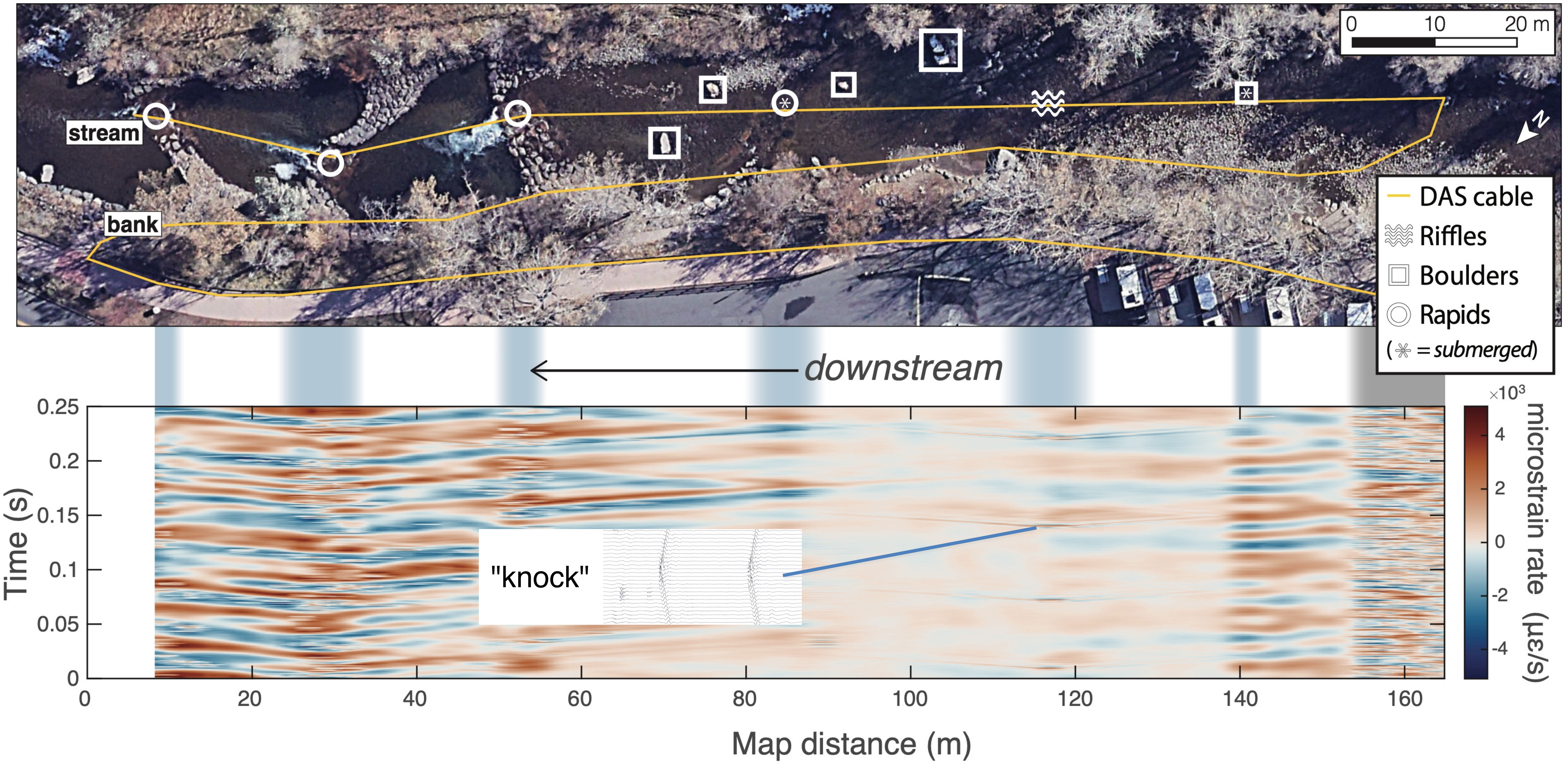
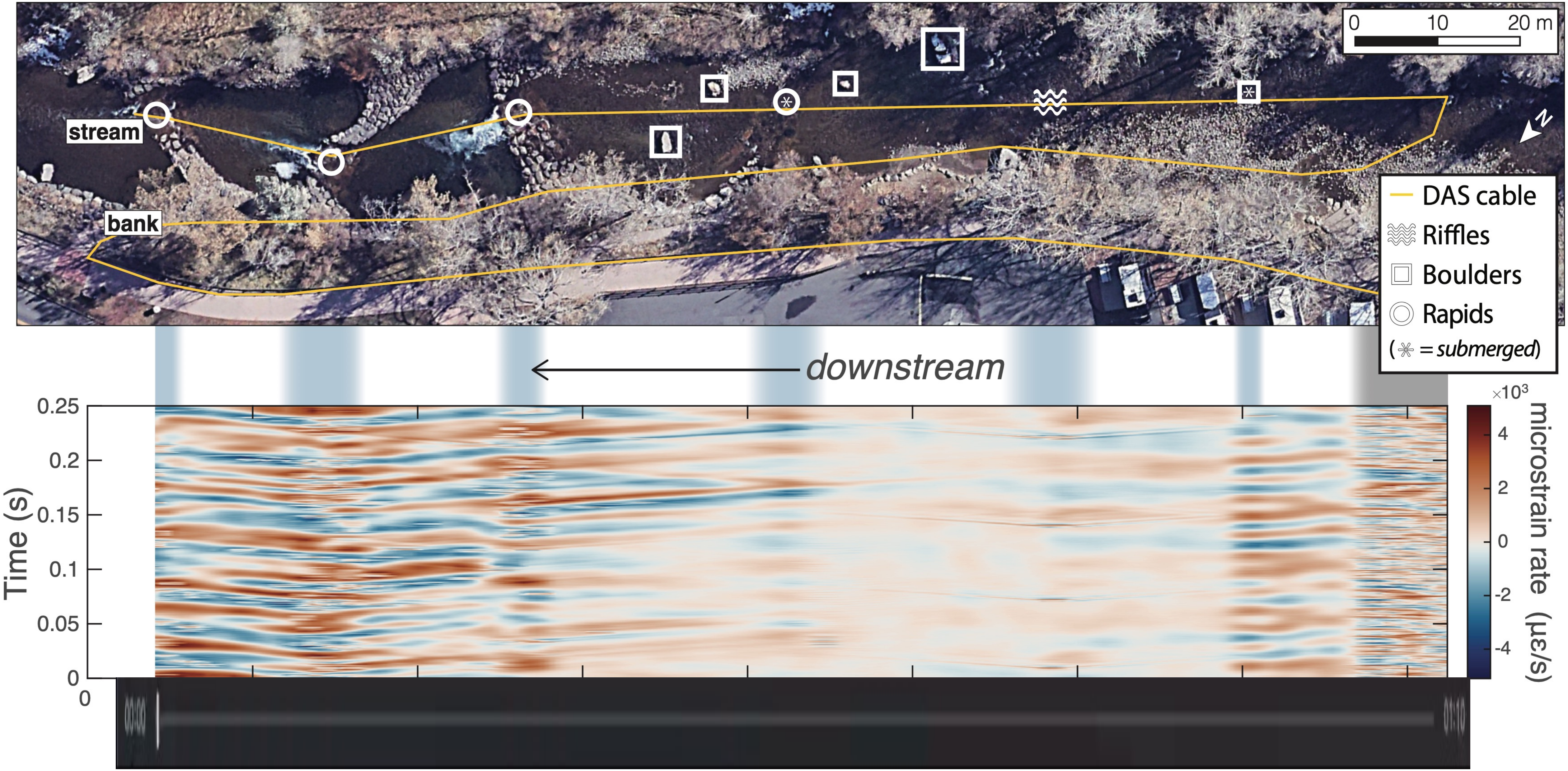
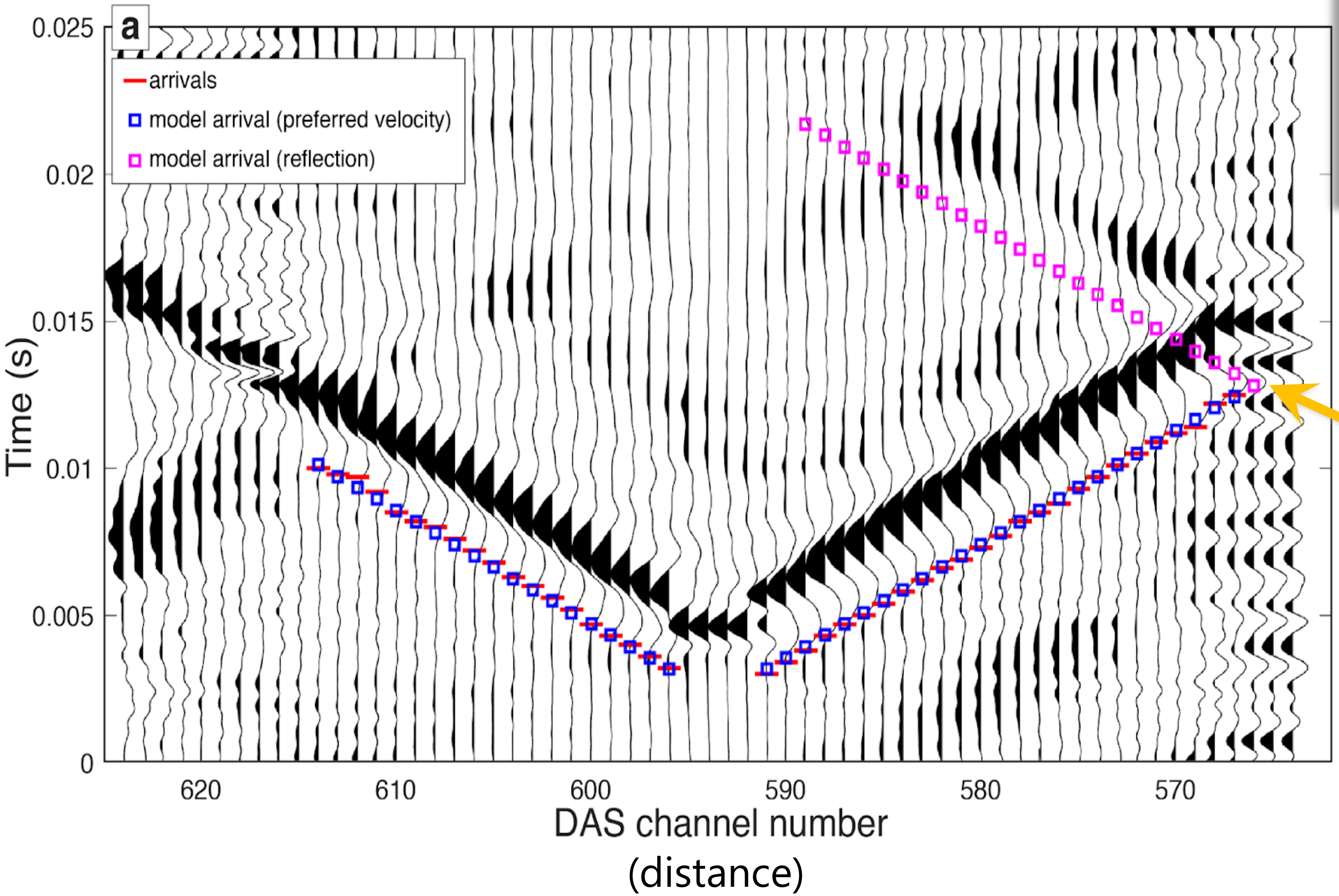


Audio conversion of DAS signals

Spliced consecutive 0.3-second segments of strain rate from each in-creek DAS channel along the creek



"Knocking" signal most likely the cable whacking against the bed

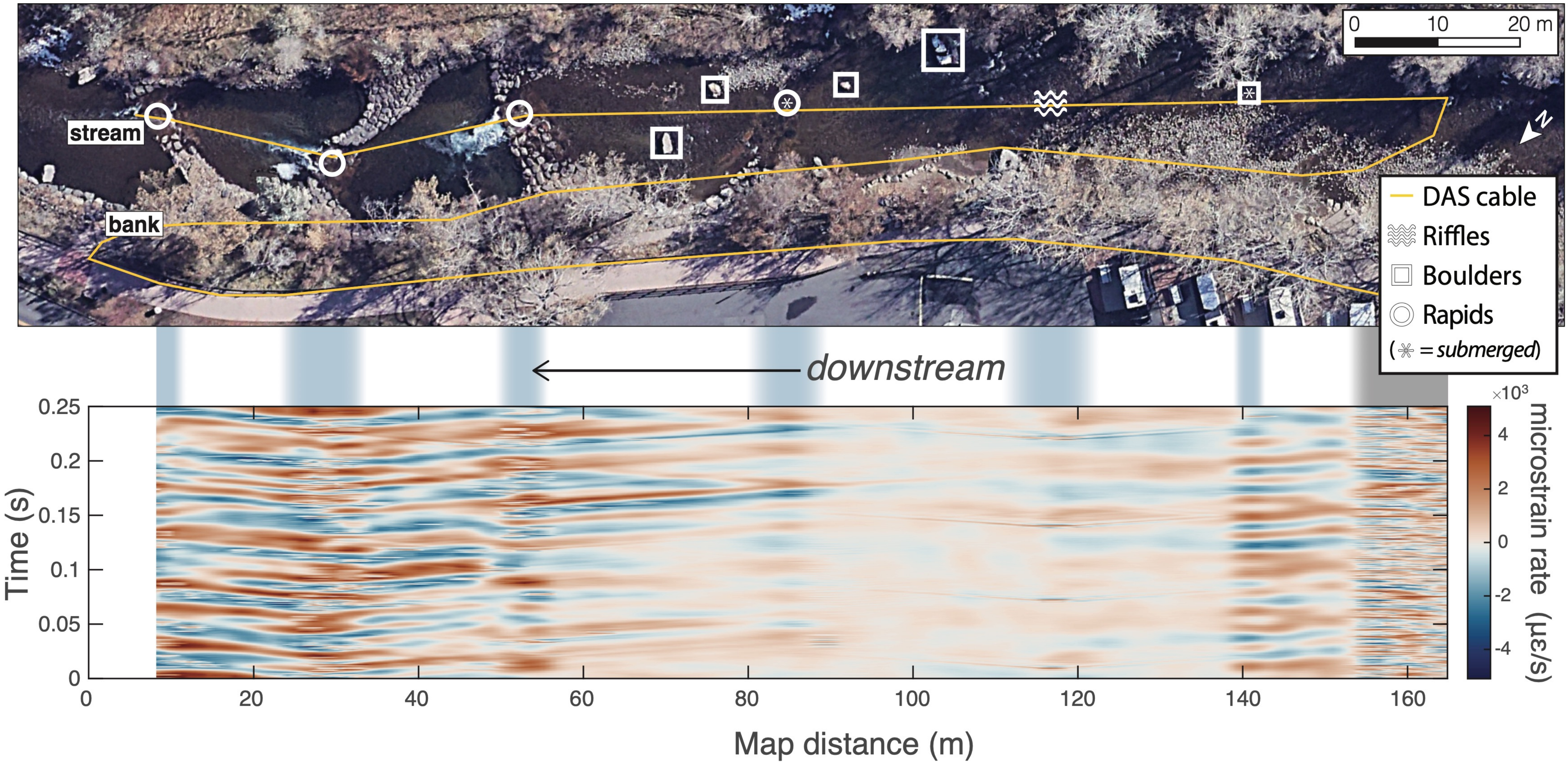


82 "knocking" events analyzed via arrival time grid search

- **Signal propagates at >2000 m/s**
  (speed of sound in water is ~1450 m/s)
- **Nearly complete signal reflection at the submerged boulder upstream**

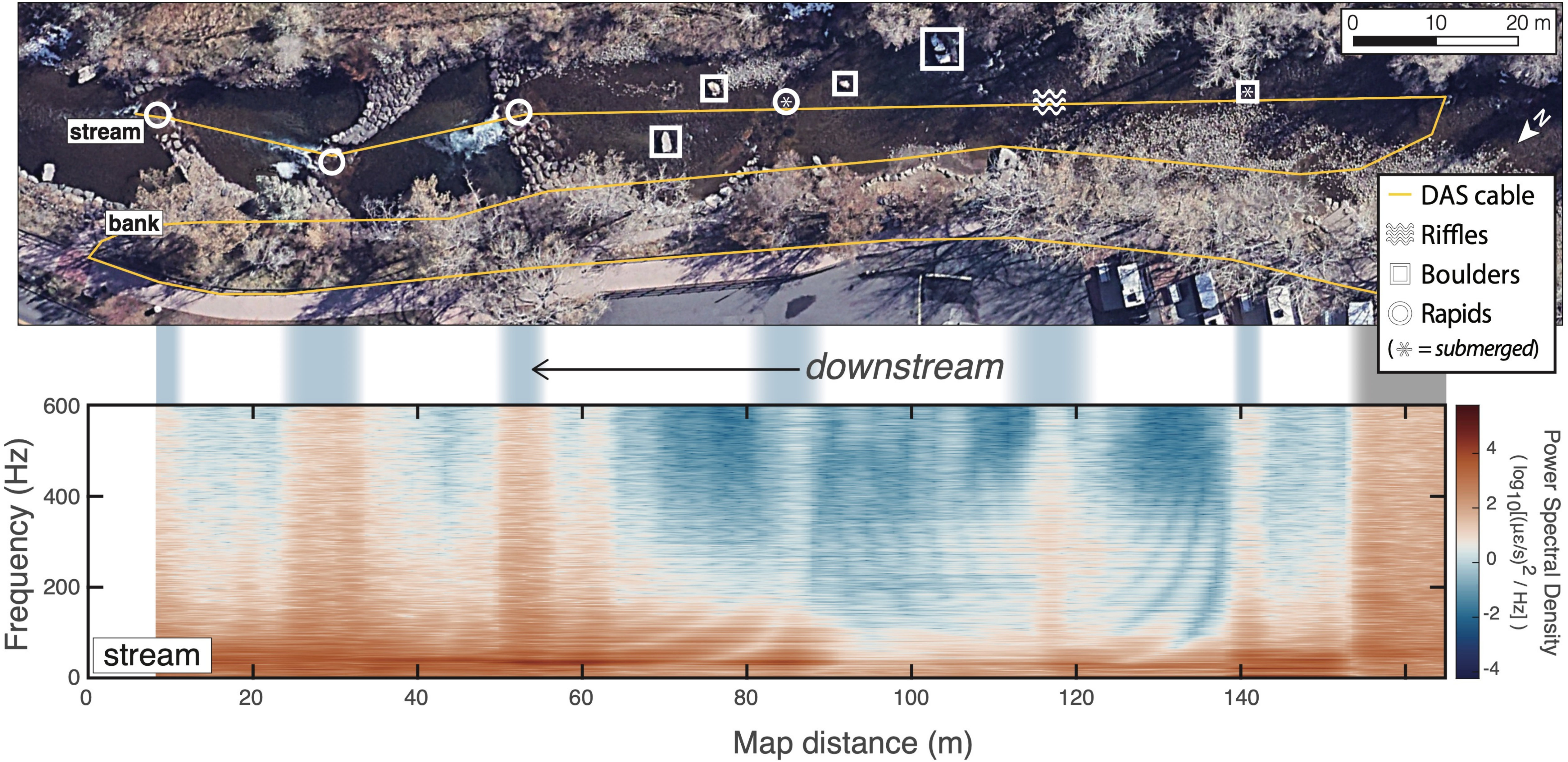
→Signals are propagating through the cable itself

Roth et al (in prep)

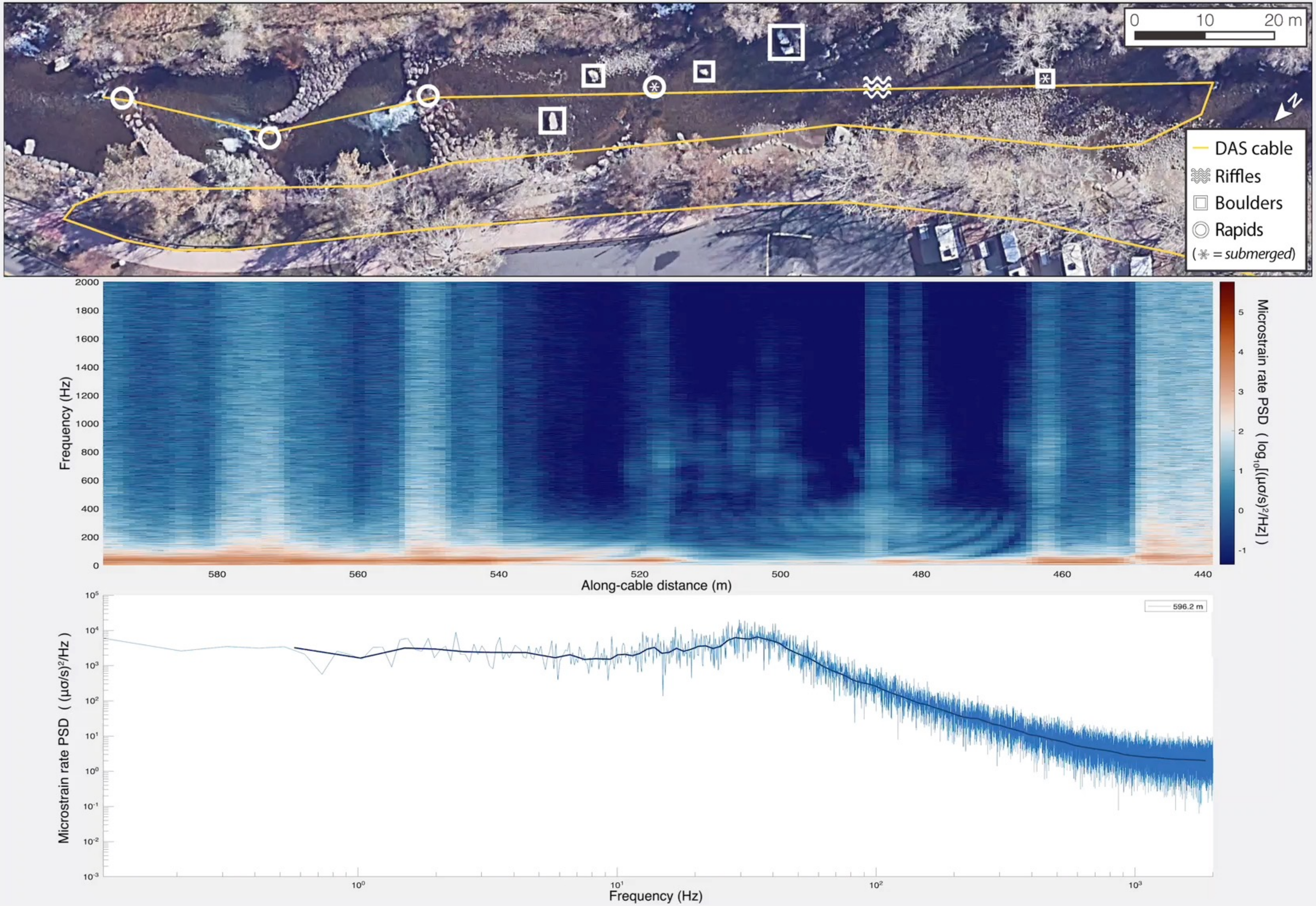


Roth et al (in prep)

30-second average spectrograms provide a **spatially continuous snapshot** of the flow-generated **hydroacoustic spectrum**

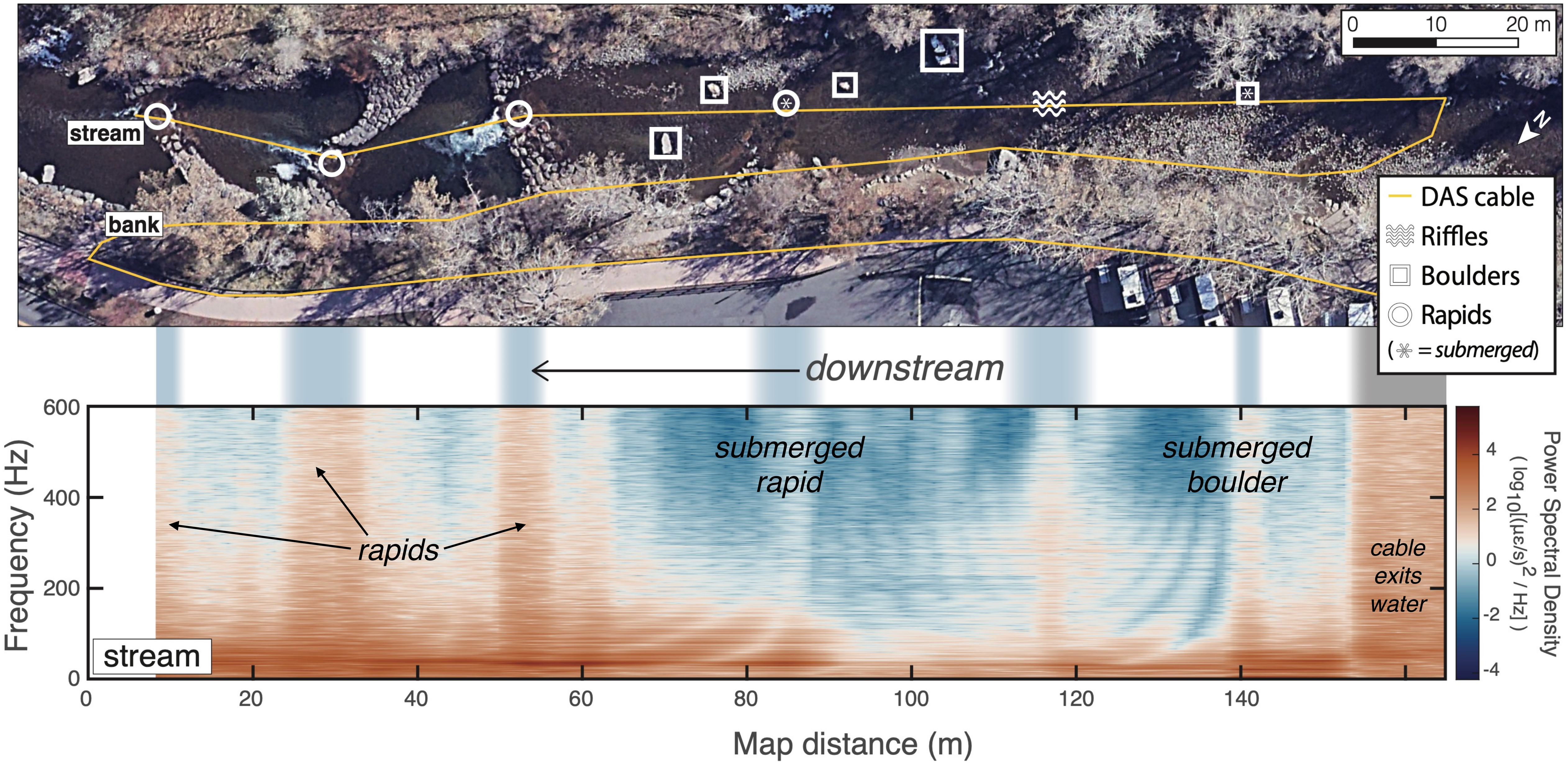


Roth et al (in prep)



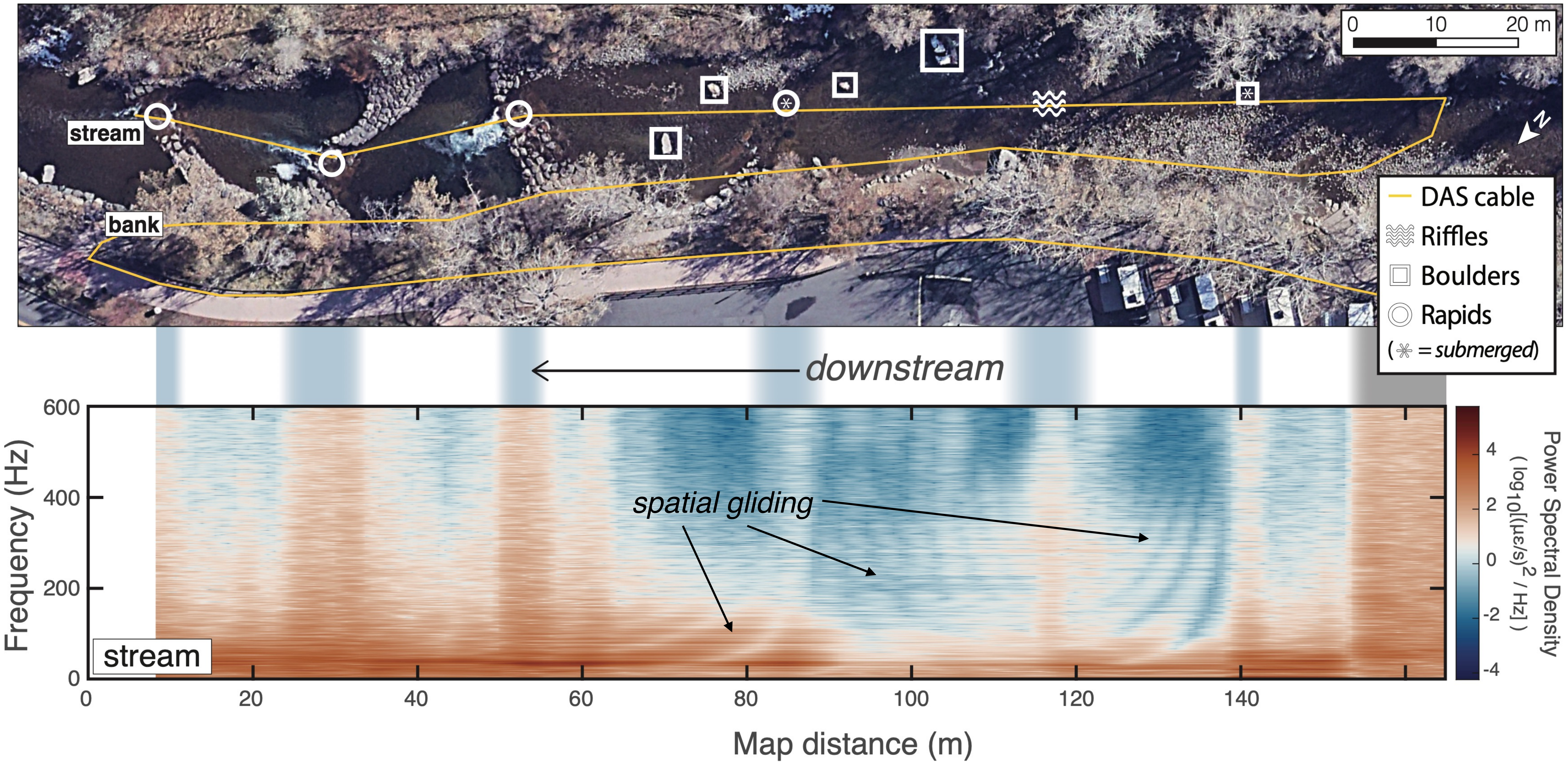
Roth et al (in prep)

Broadband acoustic peaks are associated with turbulence



Roth et al (in prep)

Gliding bands through run-riffle sequence



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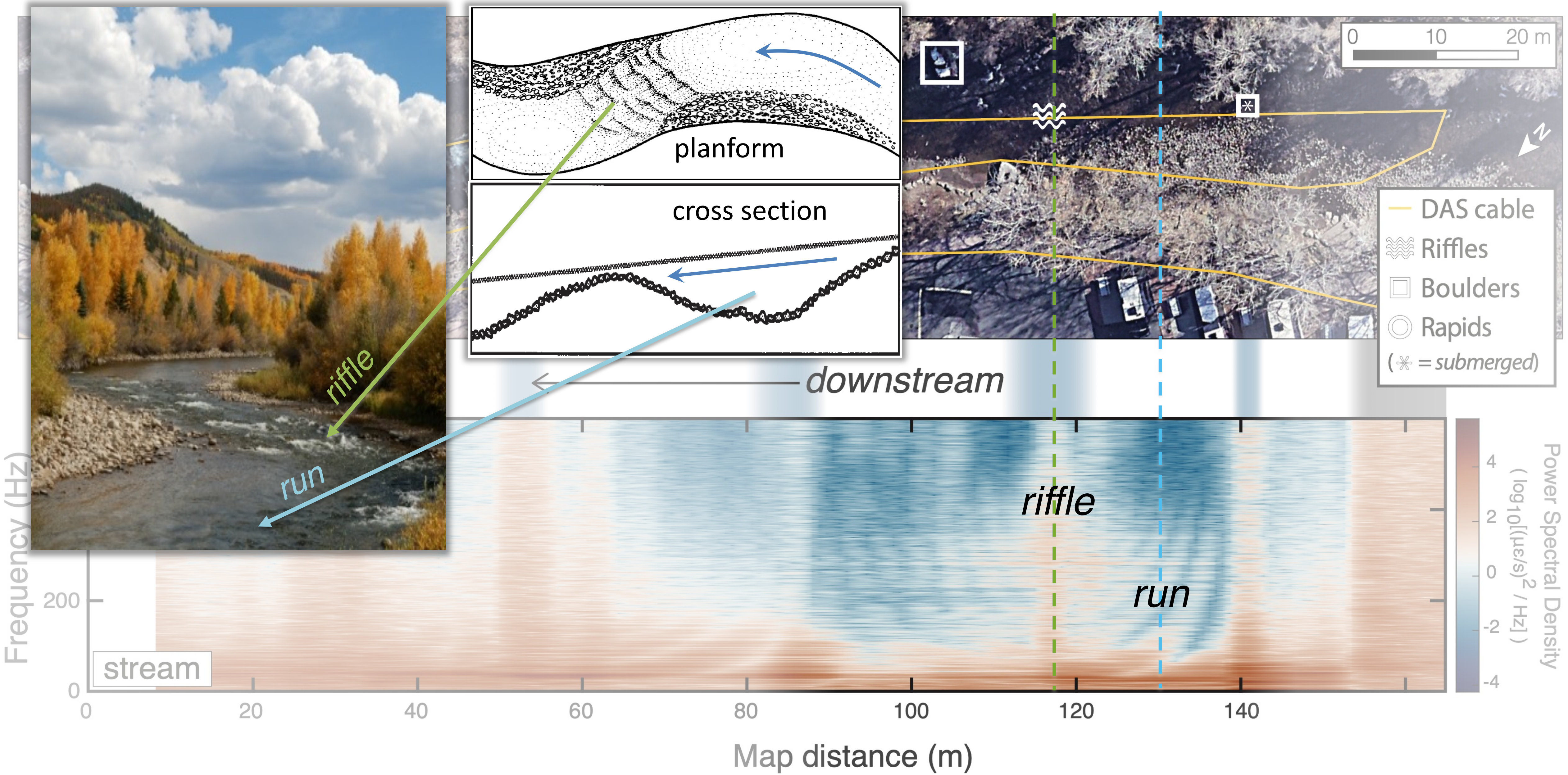
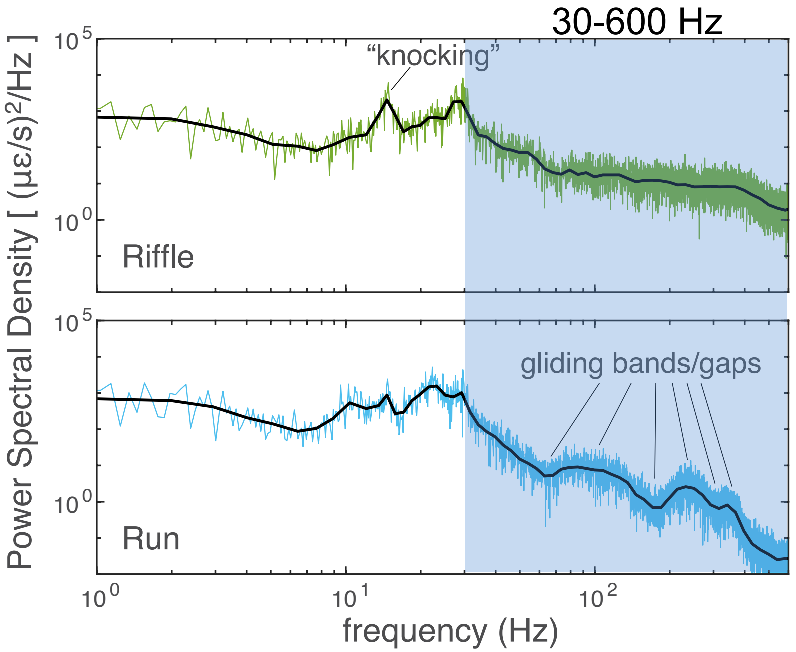
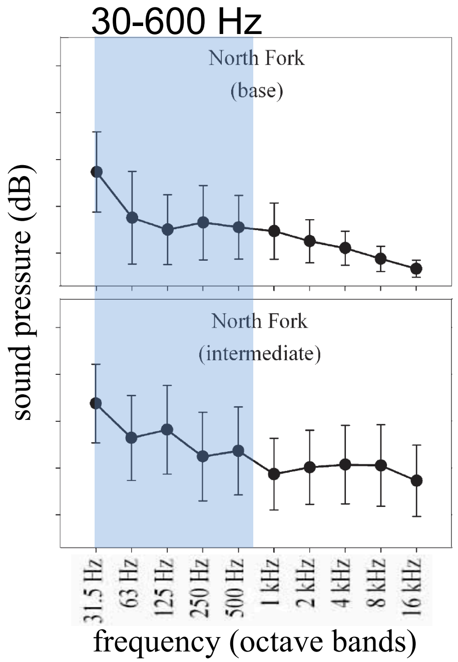


Roth et al (in prep)

Spectra are broadly consistent with low resolution observations from single hydrophones.



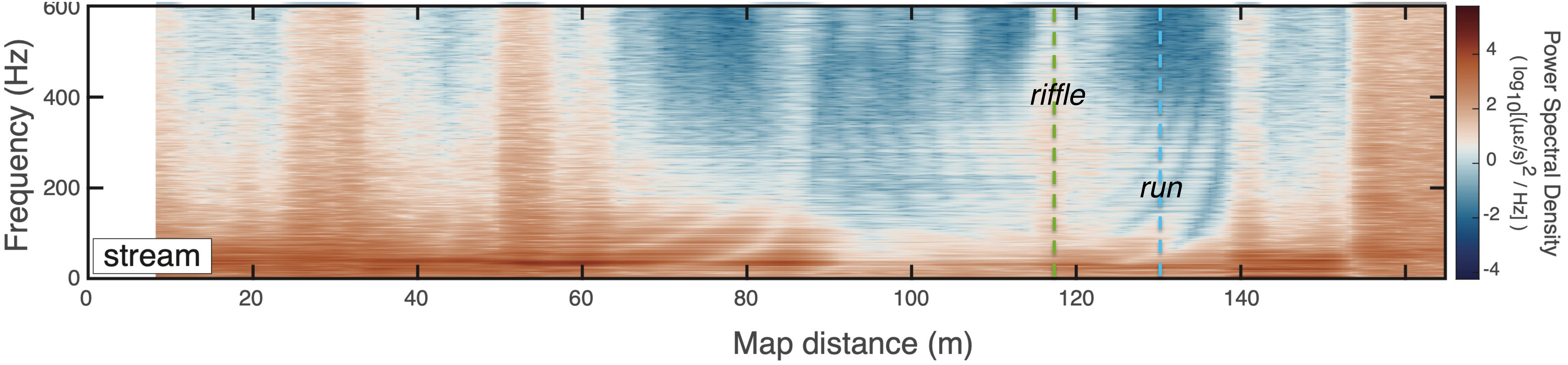


low flow depth

higher flow depth

Development of spectral complexity at more laminar, intermediate flow levels?

Tonolla et al., 2011

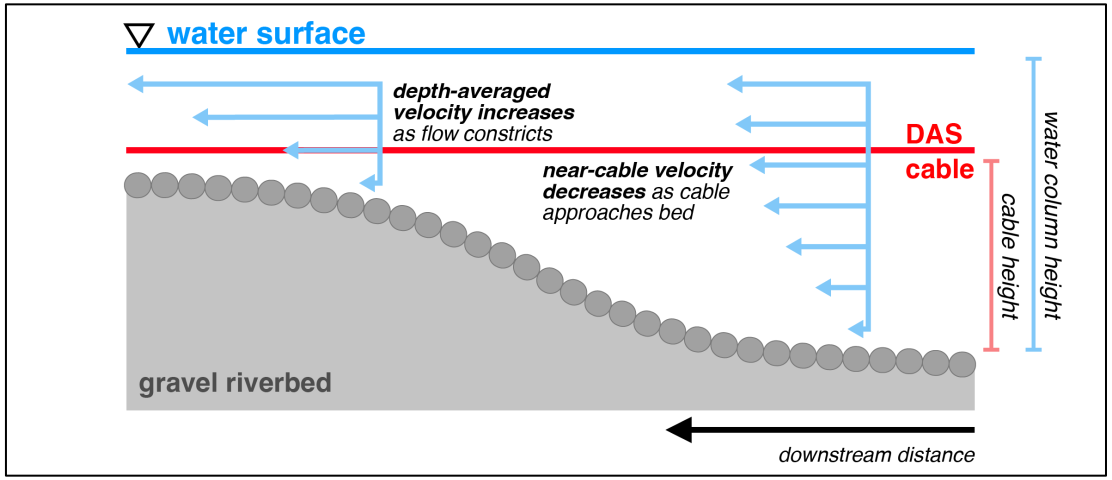


Roth et al (in prep)

What causes gliding and banding?

Knocking analysis demonstrated constant propagation velocity in cable →*gliding is not caused simply by changing tension along the cable*

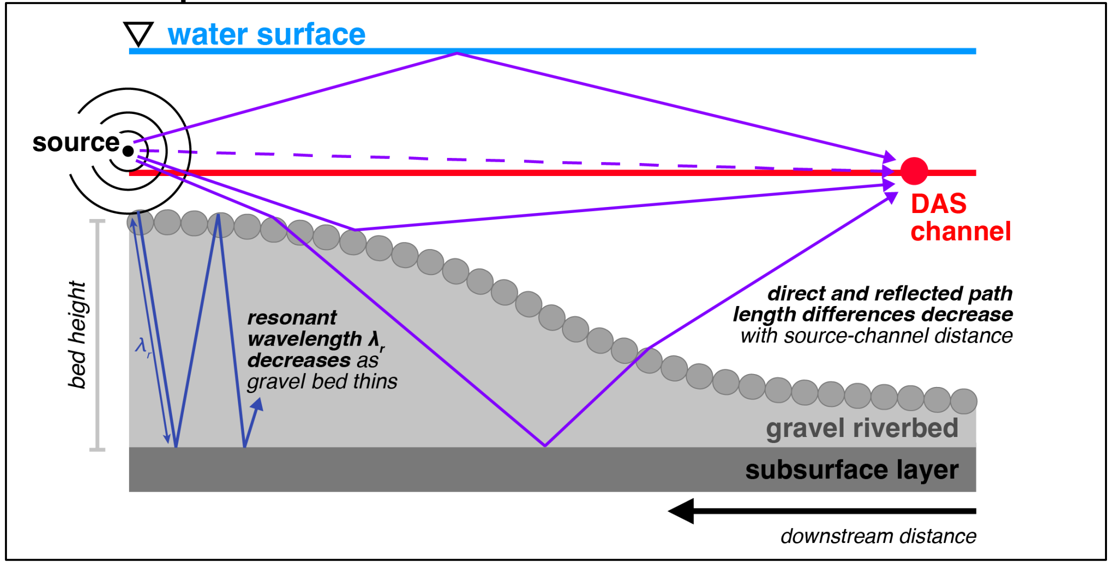
Spatially variable flow hydraulics



Spatially variable flow velocity immediately around the cable?

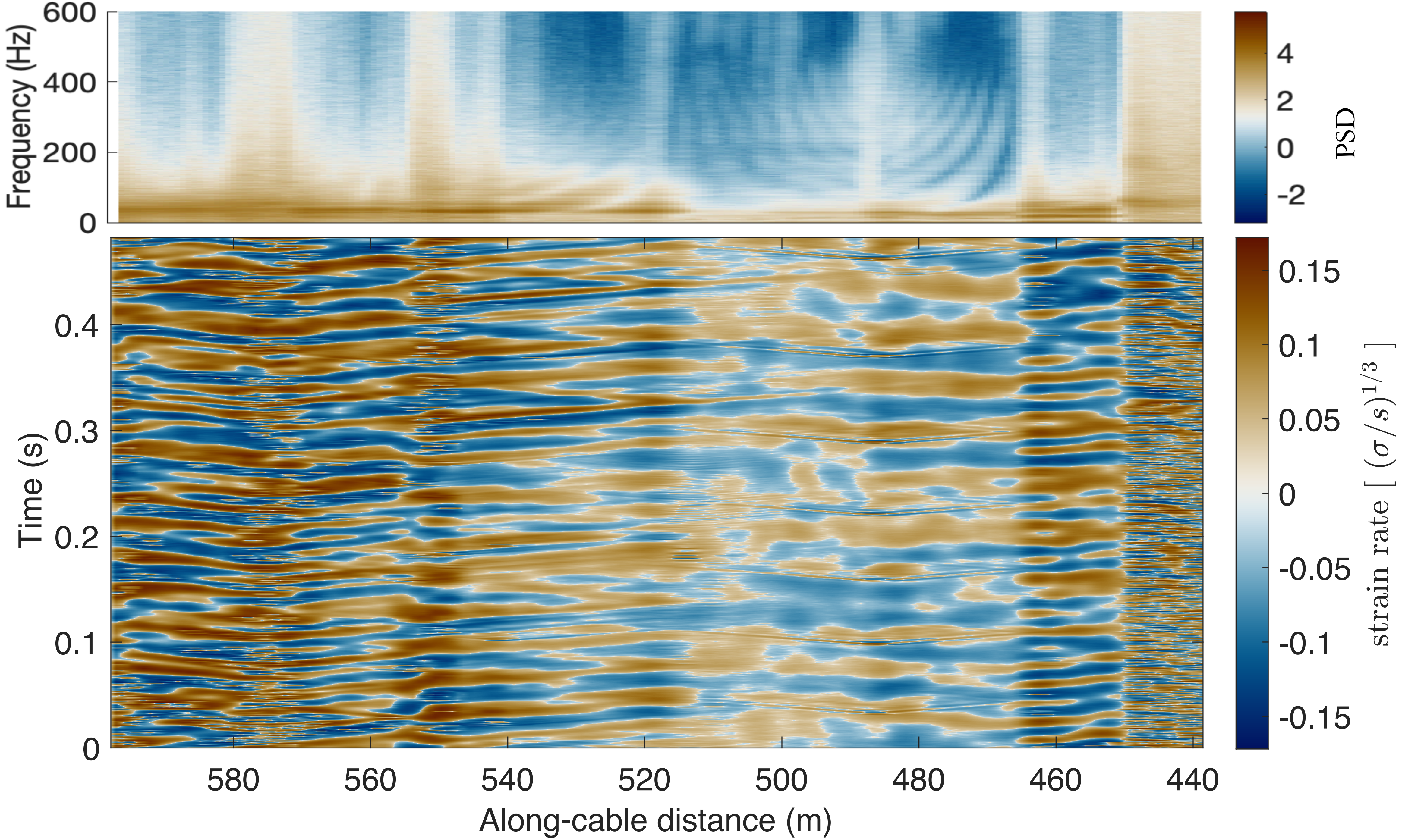
(Unknown mechanism for multiple spectral bands.)

Wave phenomena



Wave phenomena involving constructive or destructive interference with reflections?

(Could produce gliding spectral peaks or bandgaps.)

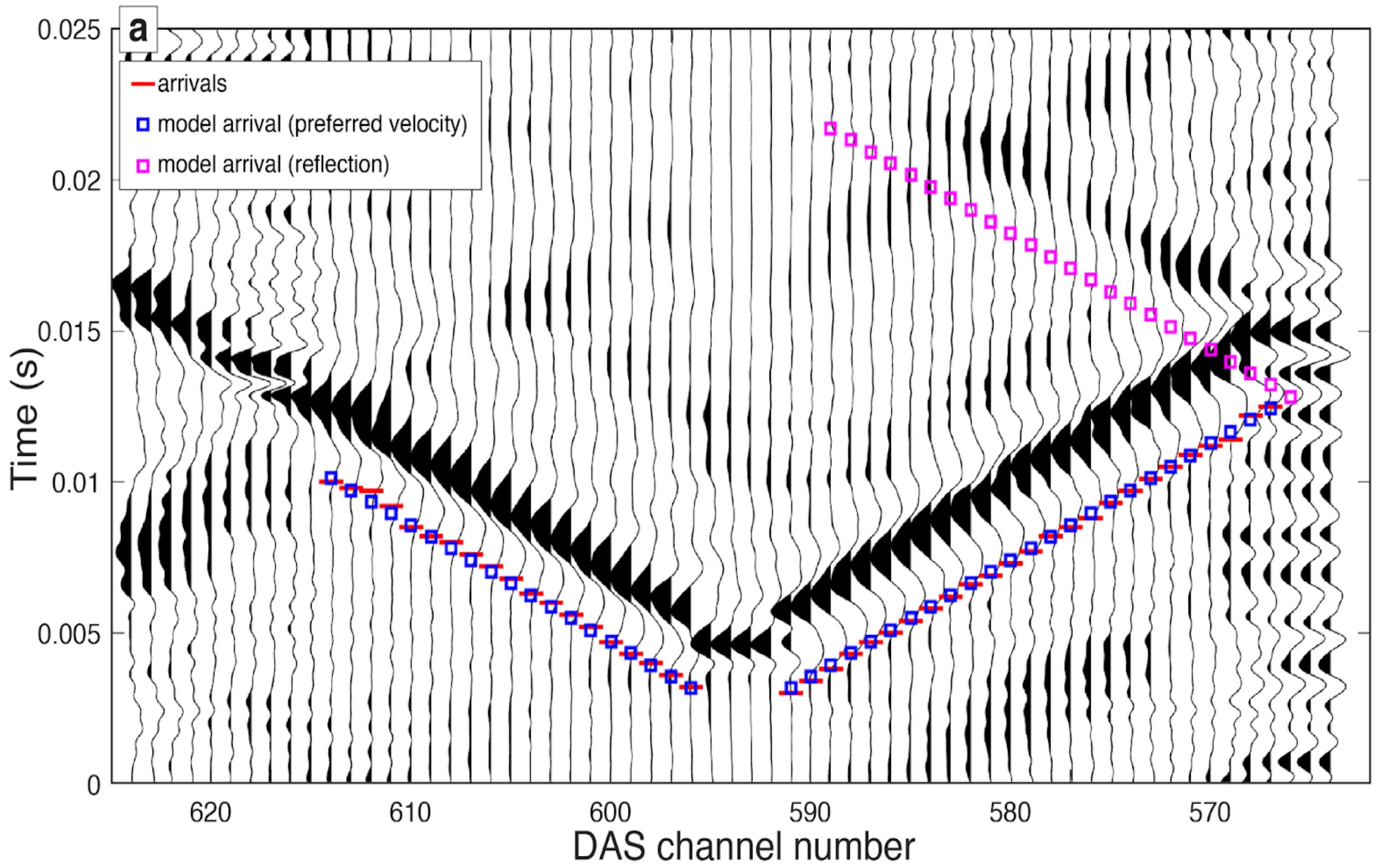


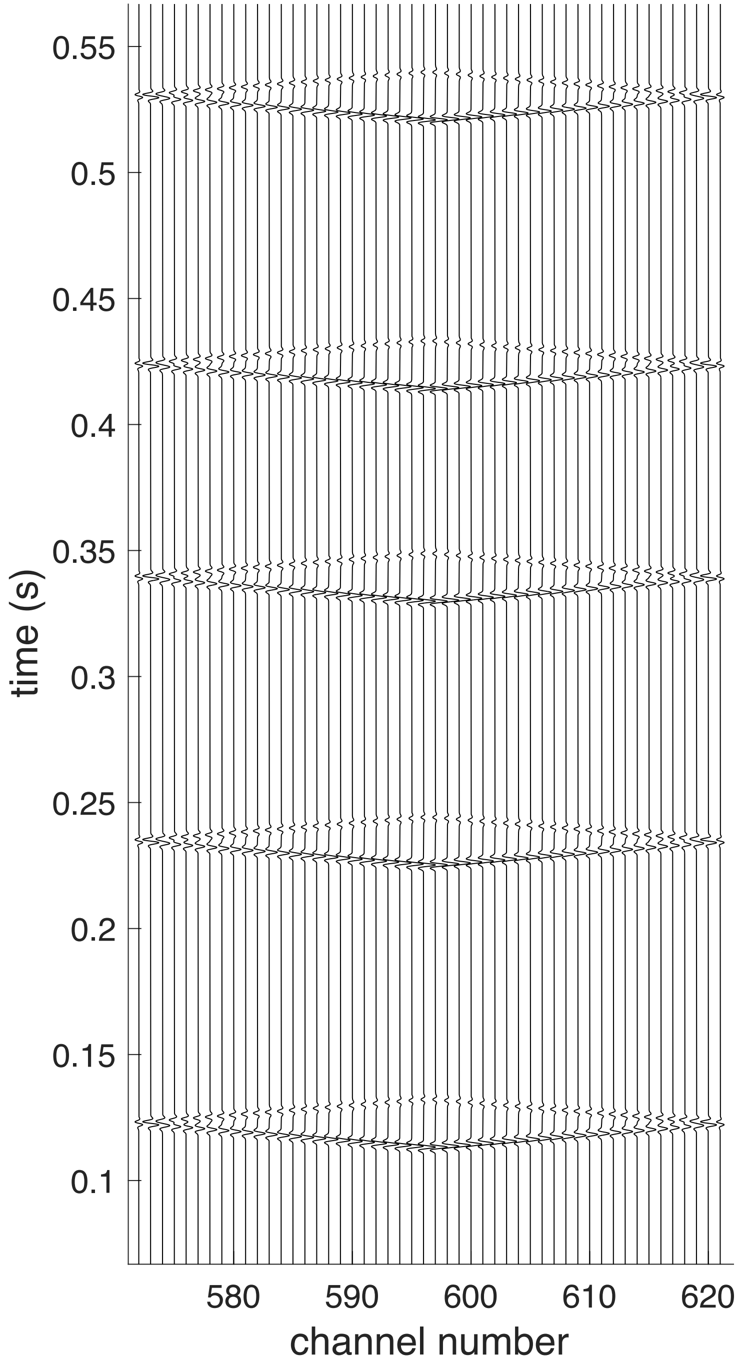
Frequency (Hz)
600
400
200
0
PSD
4
2
0
-2
Time (s)
0.4
0.3
0.2
0.1
0
strain rate [$(\sigma/s)^{1/3}$]
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
580
560
540
520
500
480
460
440
Along-cable distance (m)

Roth et al (in prep)

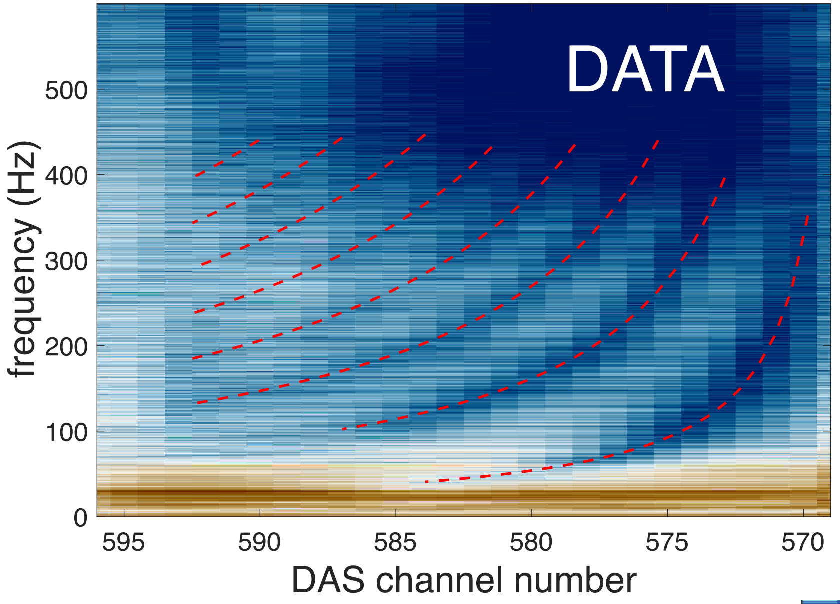
Synthetic ricker wavelet

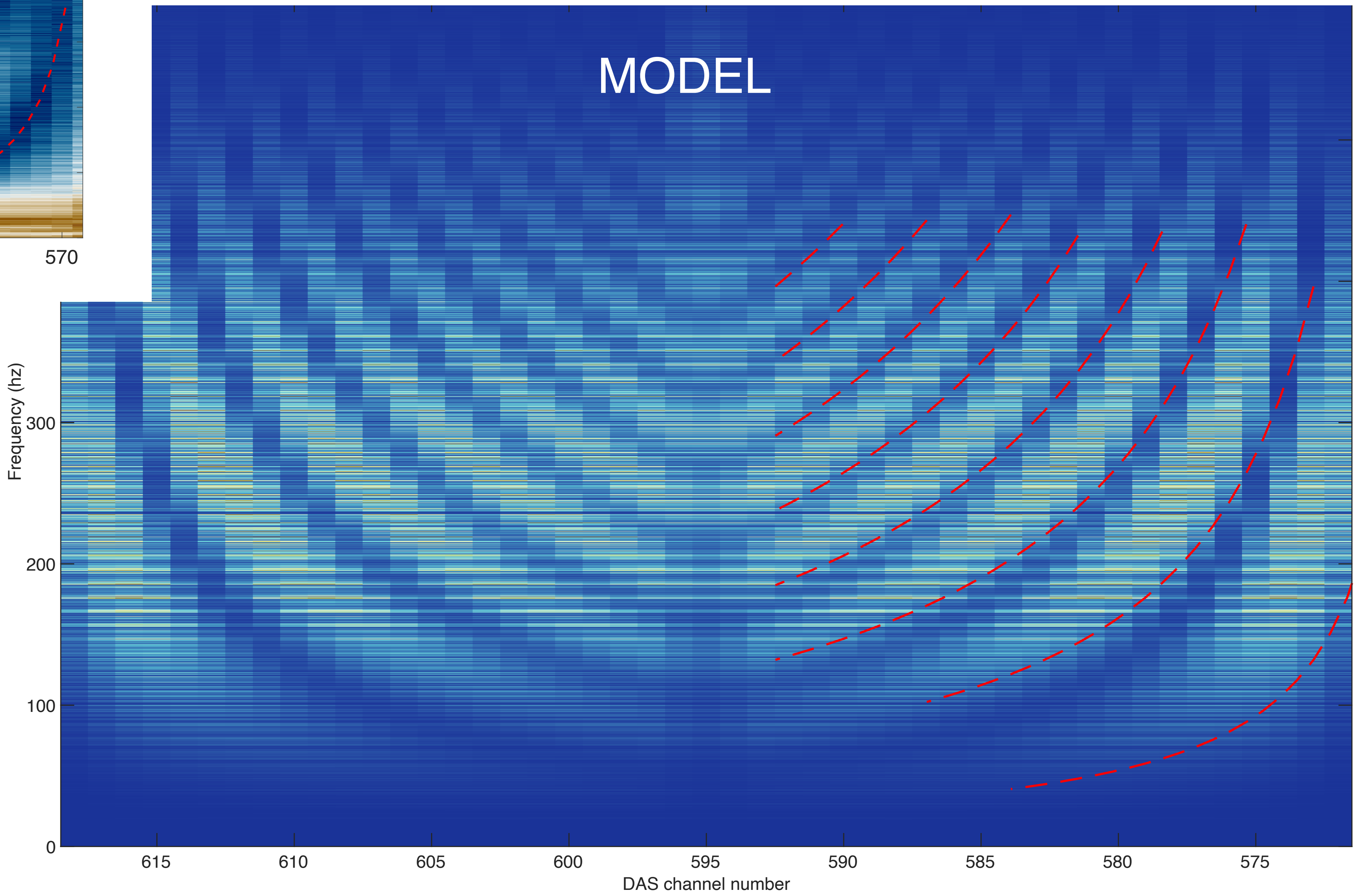
(approximately matching observed impulse width, interval, reflection locations, wavespeed, etc.)



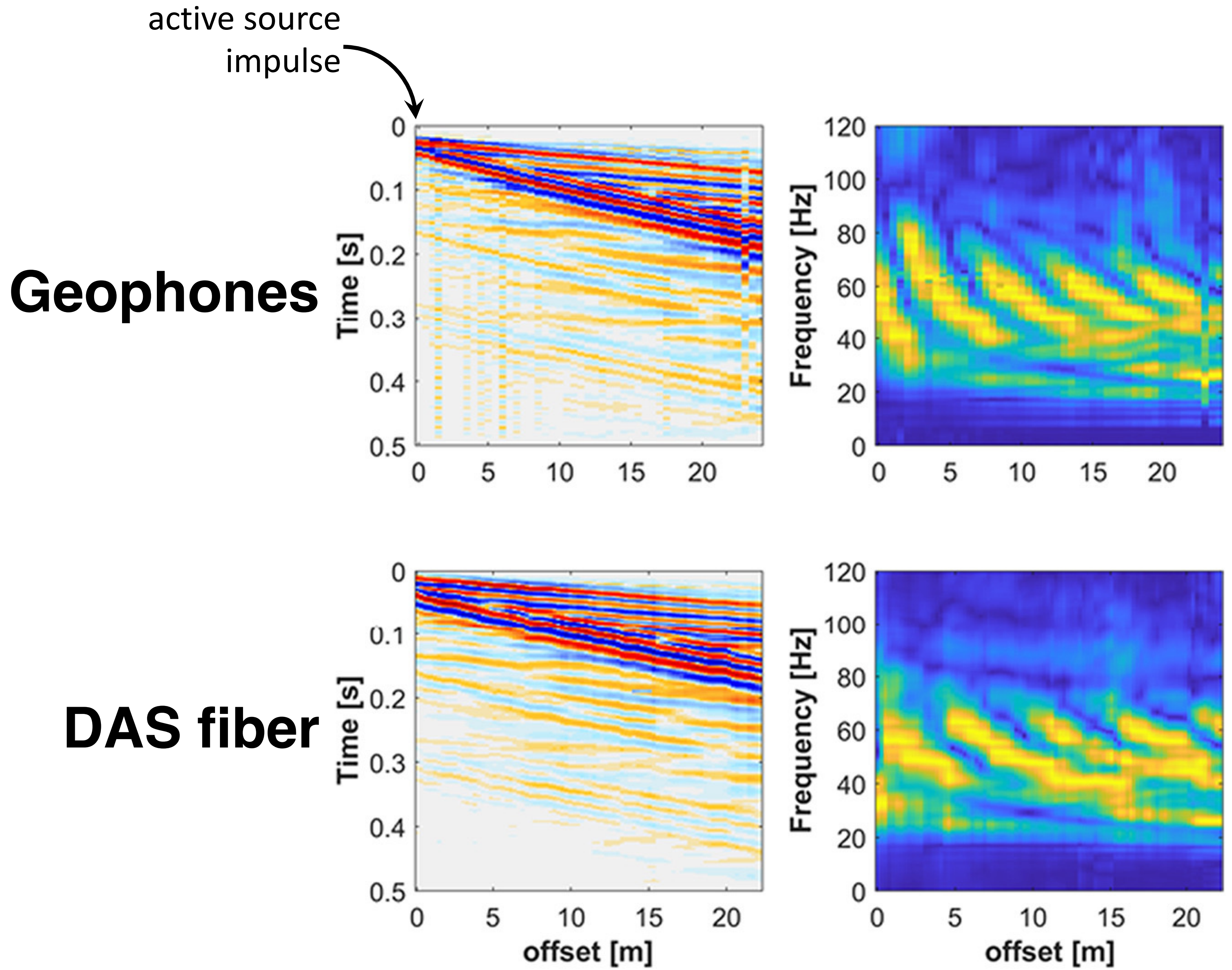


Synthetic ricker wavelet reproduces gliding bands





Gliding in spatial spectrogram results from reflected or overlapping impulse signals



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Assessment of Distributed Acoustic Sensing (DAS) performance for geotechnical applications

Matteo Rossi [a], Roger Wisén [b], Giulio Vignoli [c d], Mauro Coni [c]

Spatial gliding of impulse signals in a layered medium observed in both DAS and geophones.

Key points + open questions

- Spatially continuous snapshot of flow-generated hydroacoustic spectrum reveals localized flow hydraulics (consistent with low-resolution hydrophone observations).

- Spatial gliding in spectral bands caused by spatially variable impulse offset.
  - Do sediment-generated impulses produce gliding? (e.g., Thorne, 2014; Geay et al., 2017)
  - Is this a common occurrence in spatial spectrograms? (e.g., Rossi et al., 2022)
  - Could reflection, refraction, and interference phenomena or variation in near-cable flow hydraulics also produce spatial gliding in some settings? (e.g., Bouffaut et al., 2022)

- Can better constraints on fluvial signals from DAS enable inversion of hydrophone and seismometer data (e.g., deconvolve water + sediment)? → co-located deployments needed

- Best practices needed for cable deployment and anchoring.
  - Free
  - Anchored
    } *cable motion, reflections, resonances?*
  - Covered
  - Buried
    } *decoupled from fluid strain, attenuation, gliding in layered substrates??*