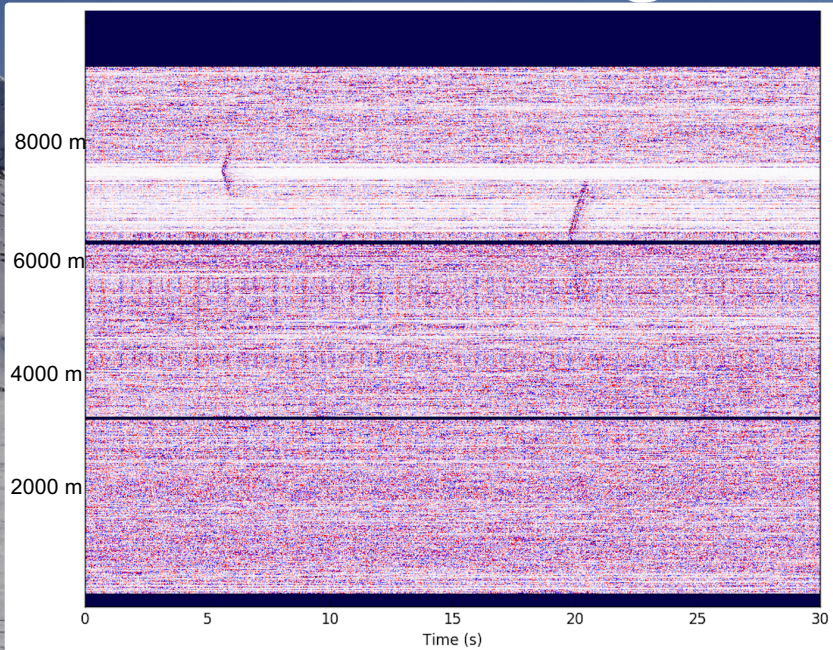
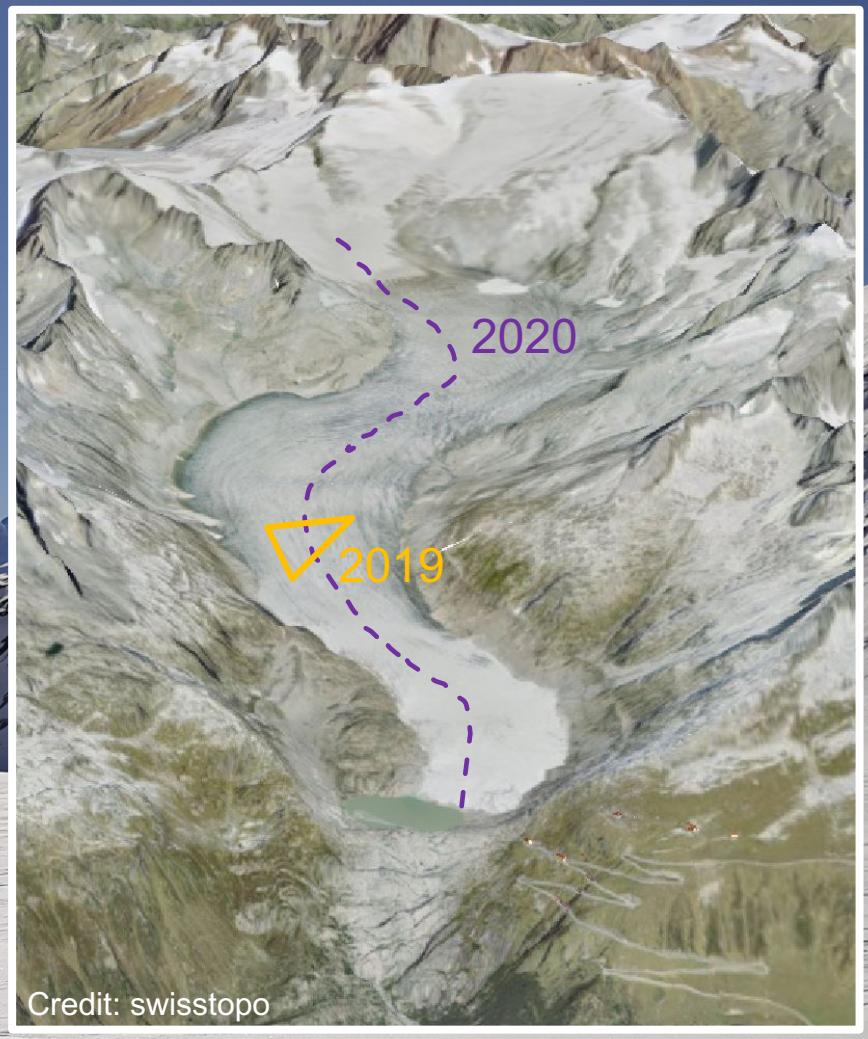
Capturing Glacier-Wide Cryoseismicity With Distributed Acoustic Sensing

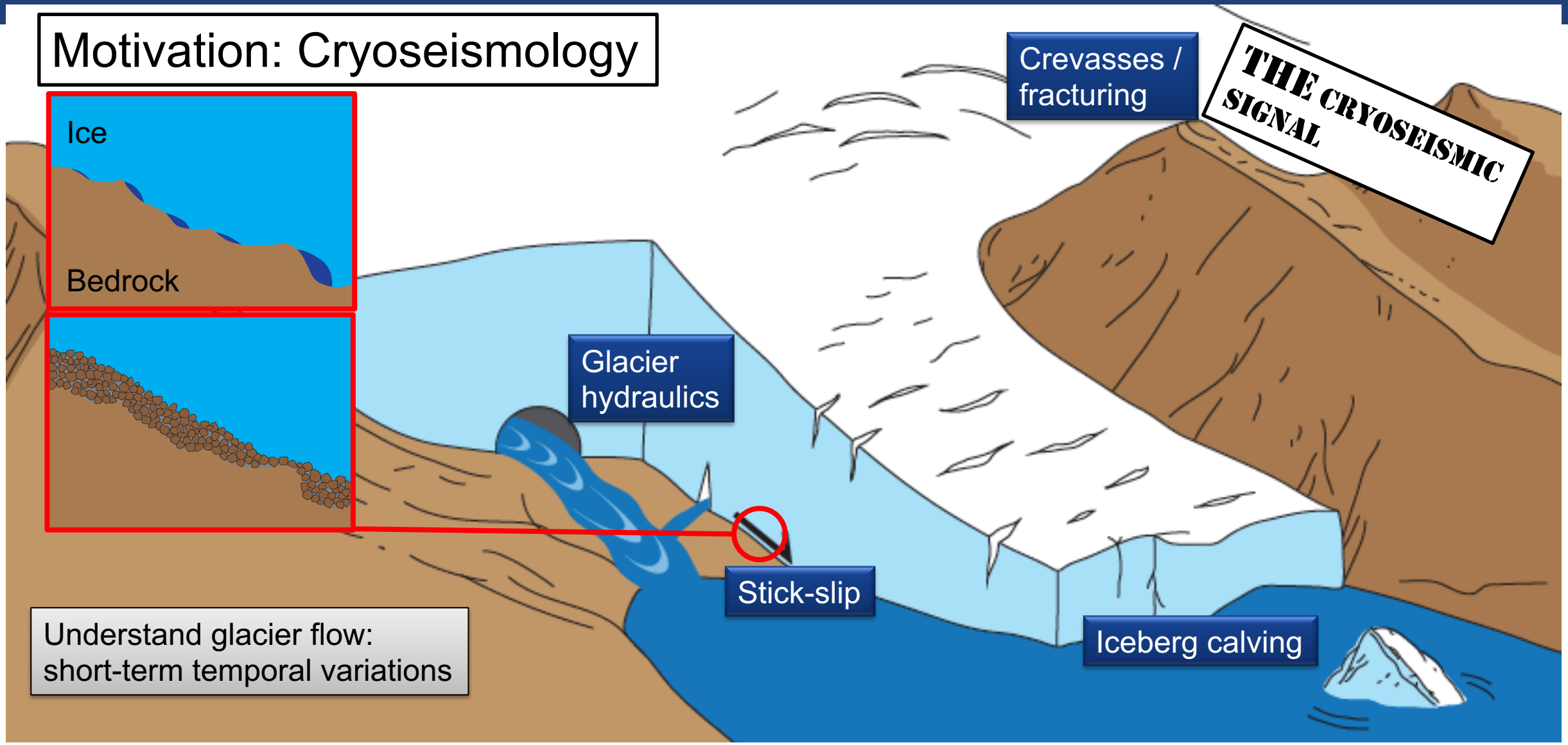






Fabian Walter, Patrick Paitz, Andreas Fichtner, Pascal Edme, Wojciech Gajek, Bradley P. Lipovsky, and Eileen Martin

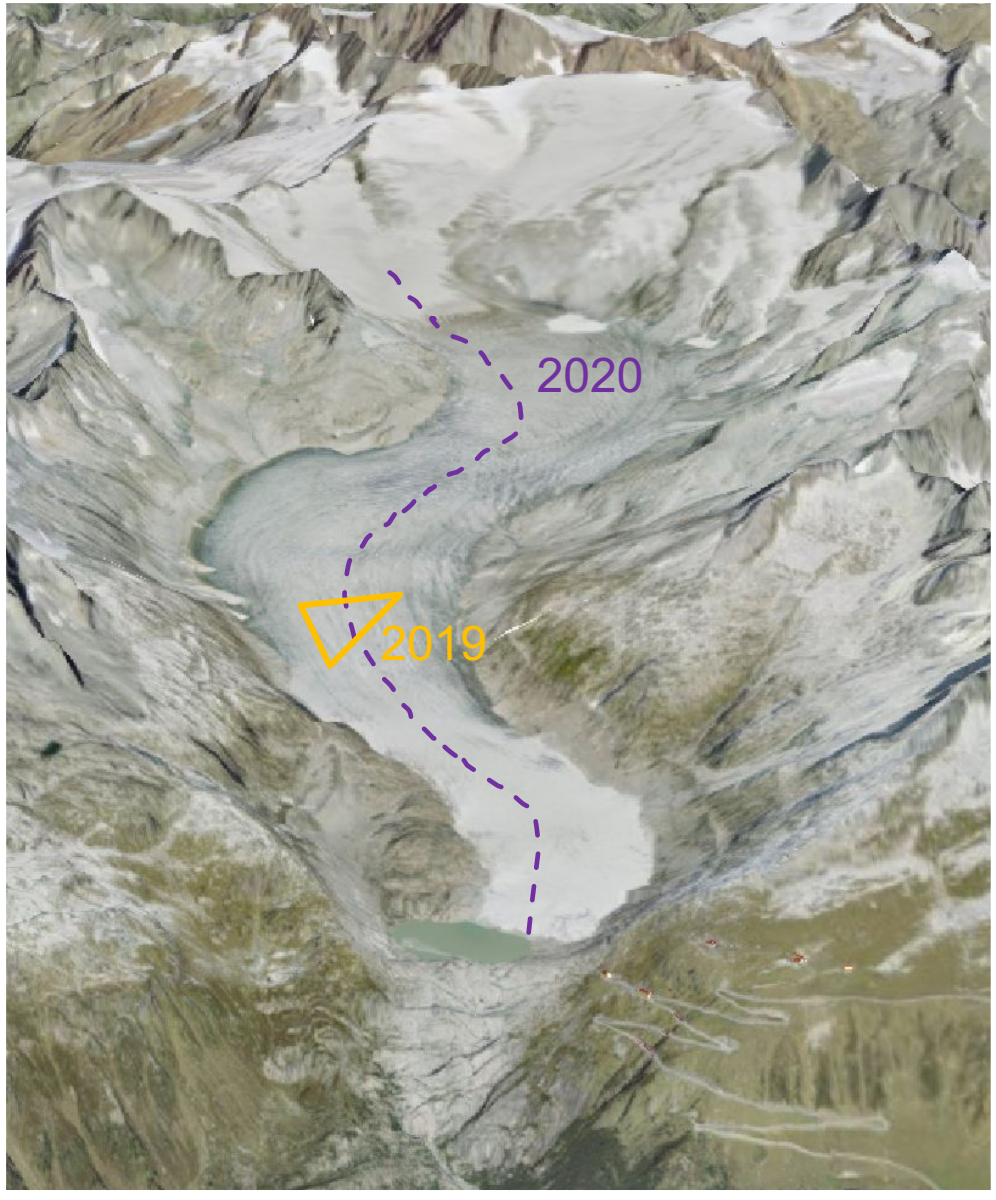
Motivation: Cryoseismology

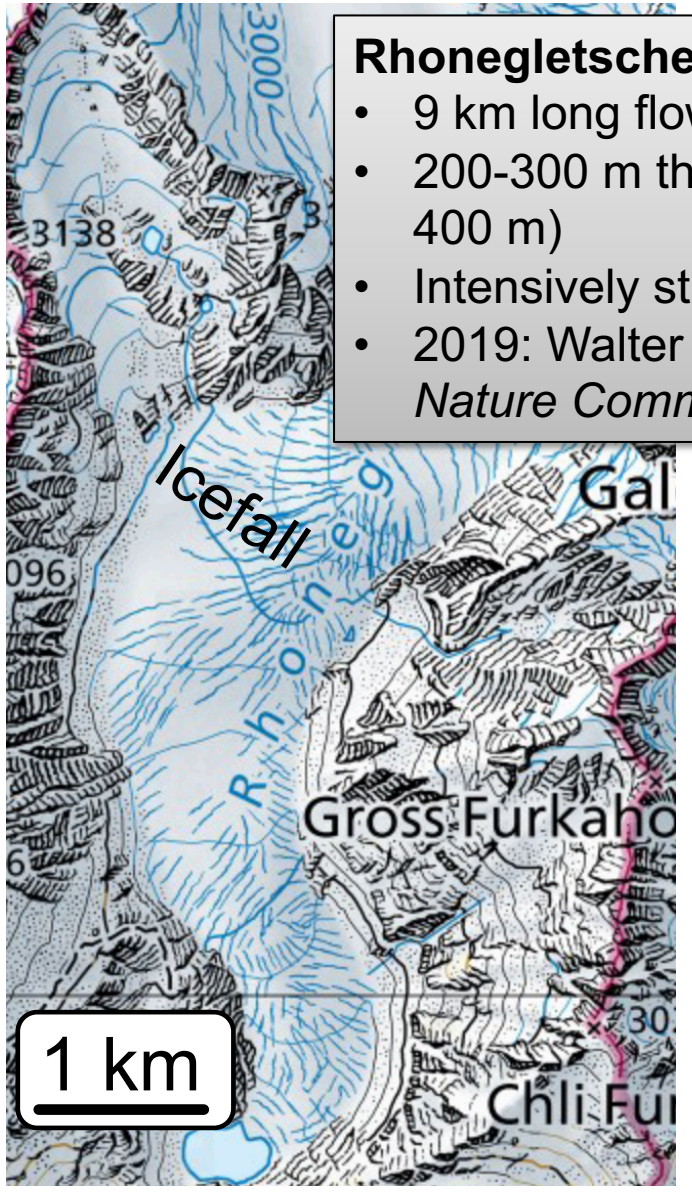


Understand glacier flow:
short-term temporal variations

Modified from Larose et al., 2015, in *Journal of Applied Geophysics*

2 DAS Experiments on Rhonegletscher, Switzerland





Rhonegletscher

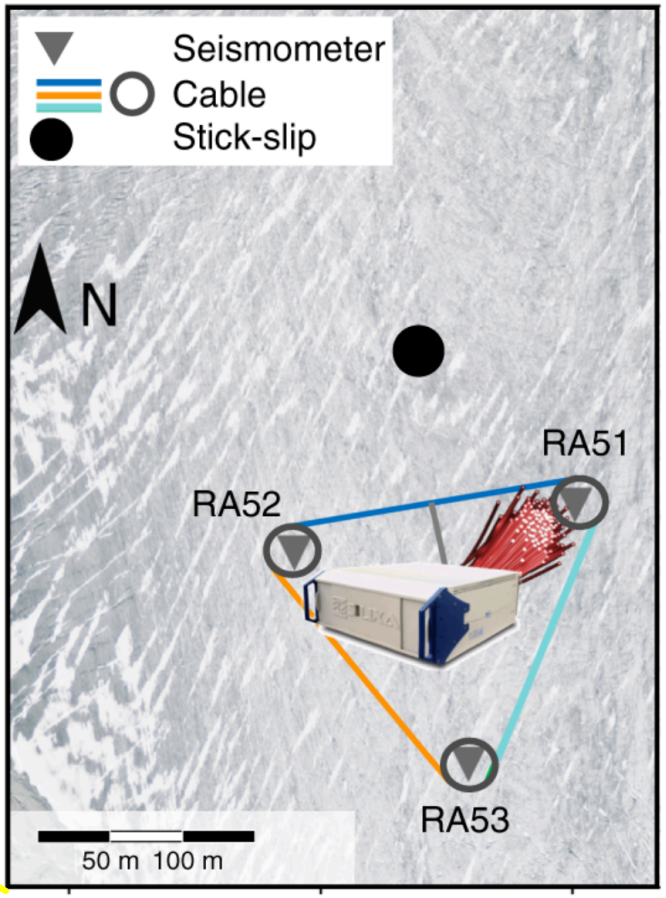
- 9 km long flowline
- 200-300 m thick (max up to 400 m)
- Intensively studied
- 2019: Walter et al., 2020 in *Nature Communications*

Credit: swisstopo

Cable Installation

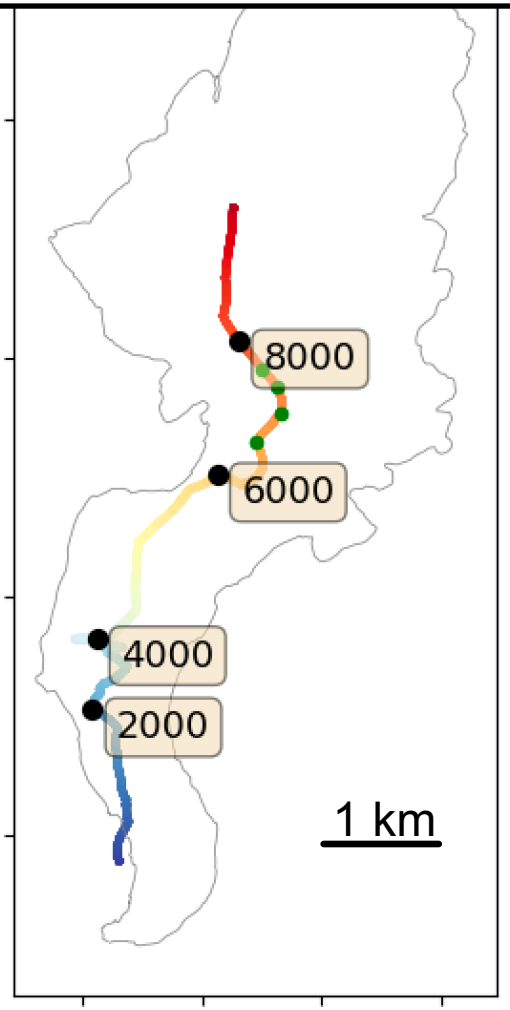






2019 Winter Campaign
- 1 km long cable
- 5 days
- Published (*NatComm*, 2020)

2020 Summer Campaign
- 9 km long cable
- 1 month
- Data mining ongoing



Winter 2019

Summer 2020
(snow-covered
accumulation area)



10 cm deep trench

Melt-in several cm

W. Gajek, M. Chmiel

Summer 2020
(snow free ablation area)



- Slight melt-in
- Crevasses, melt streams: locally poor coupling, noise

M. Chmiel

ETH zürich

Cable Transport



Helicopter transport to glacier, but then …

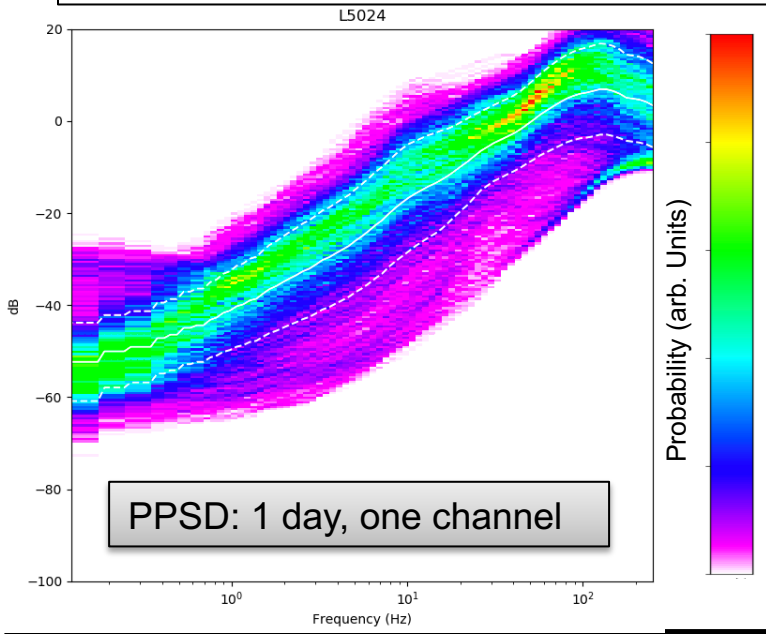


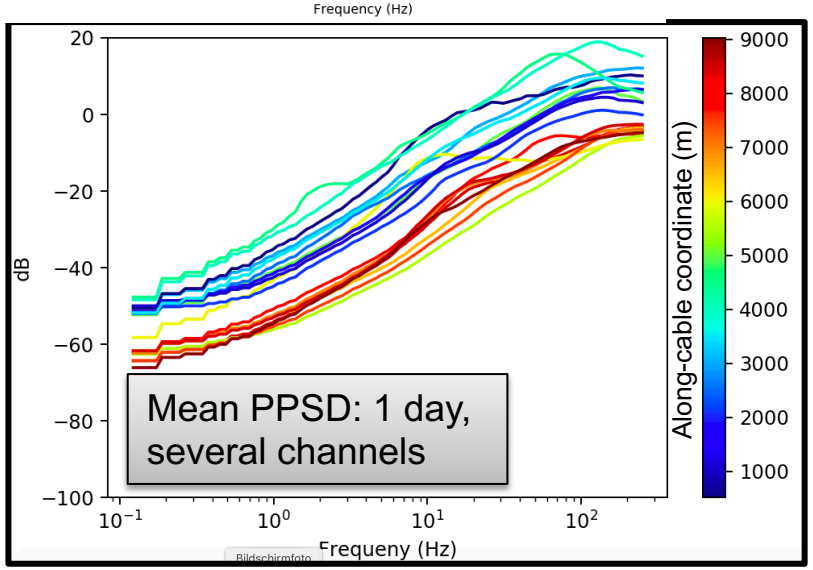


Splicing in the field was necessary.

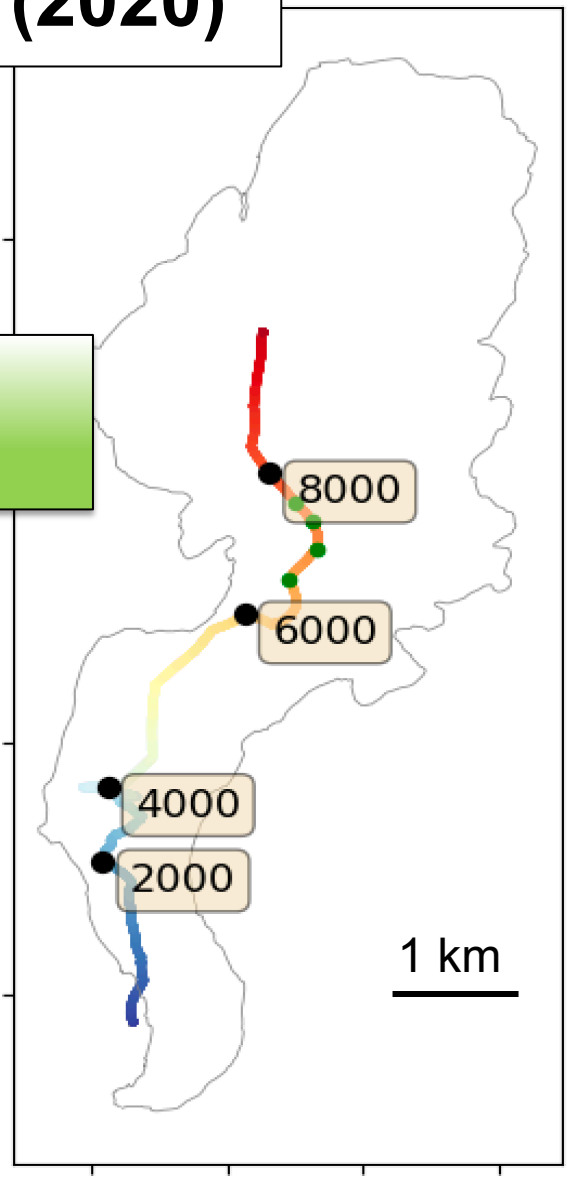
Photos: W. Gajek

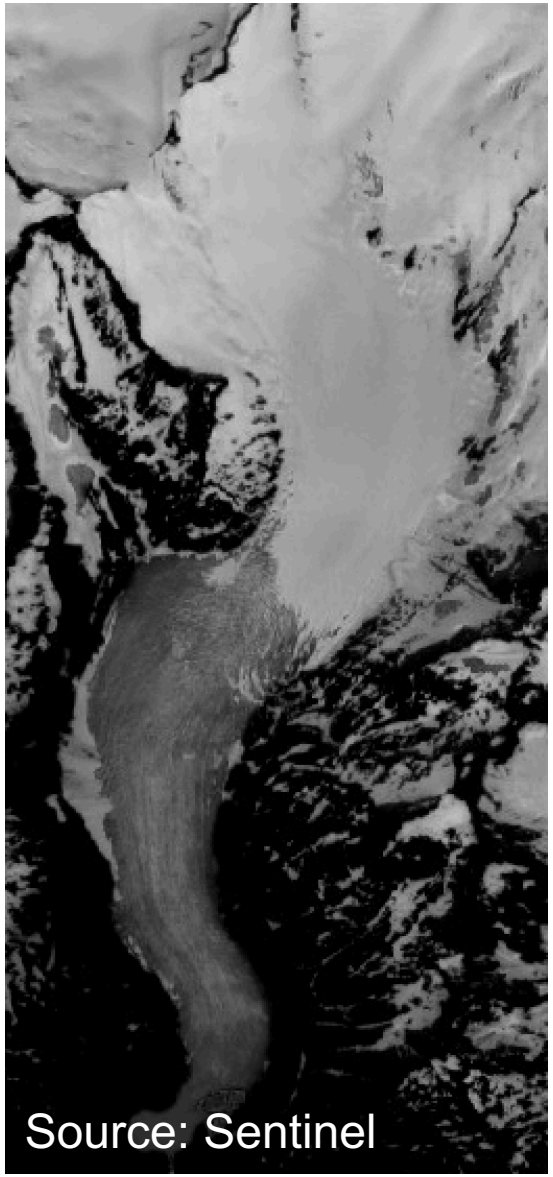
Spatial Variations in Seismic Noise (2020)



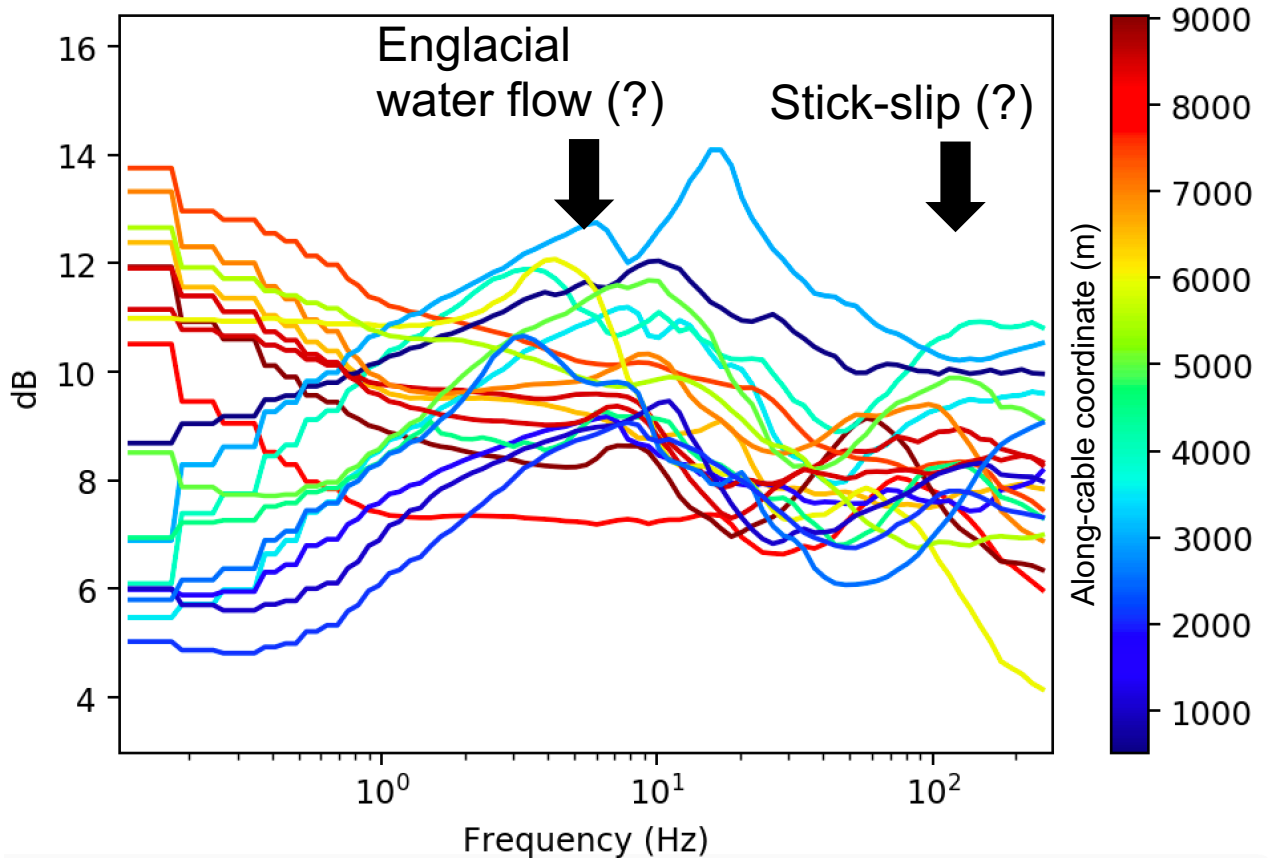


Snow dampens noise (ca. 20 dB)!

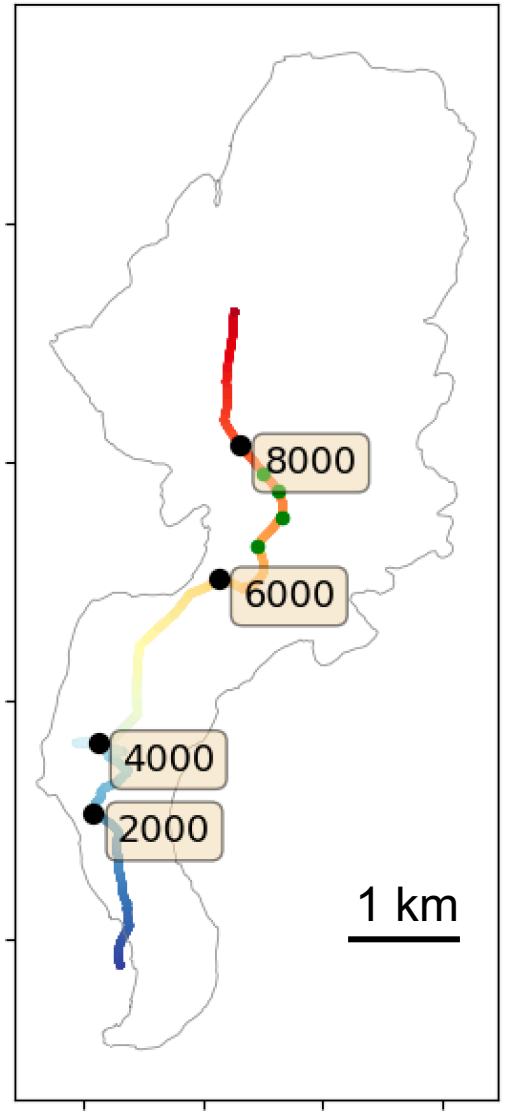


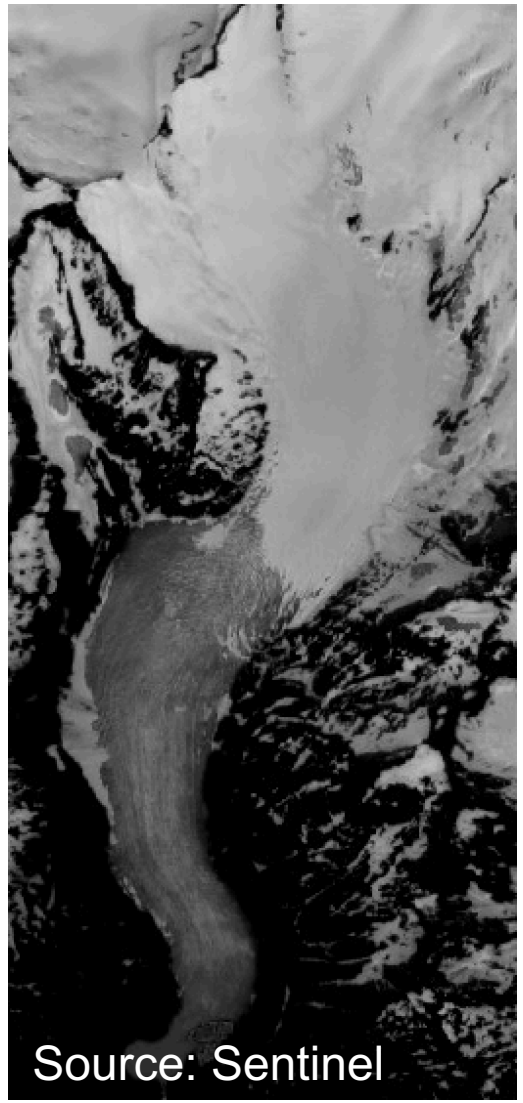


Daily Noise Standard Deviation (2020)

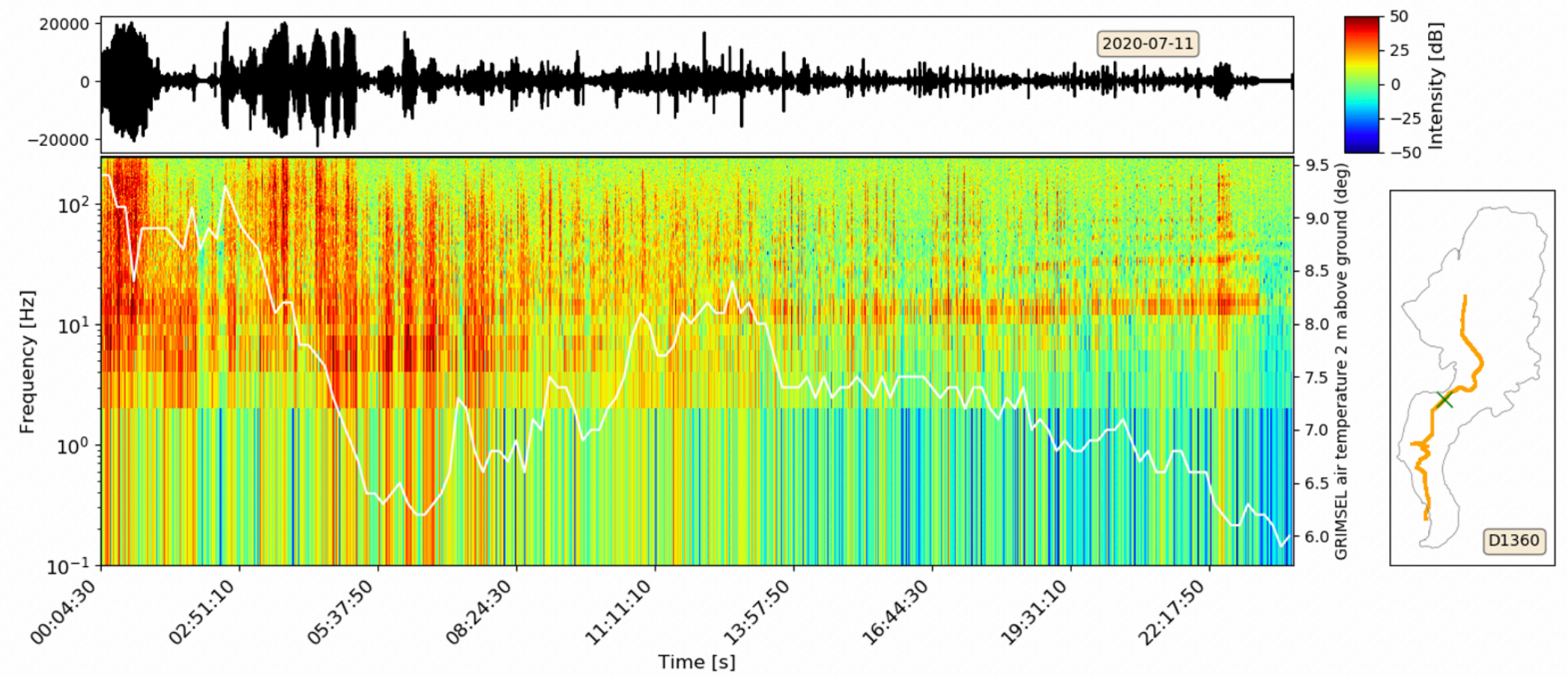


Snow dampens noise (ca. 20 dB)!

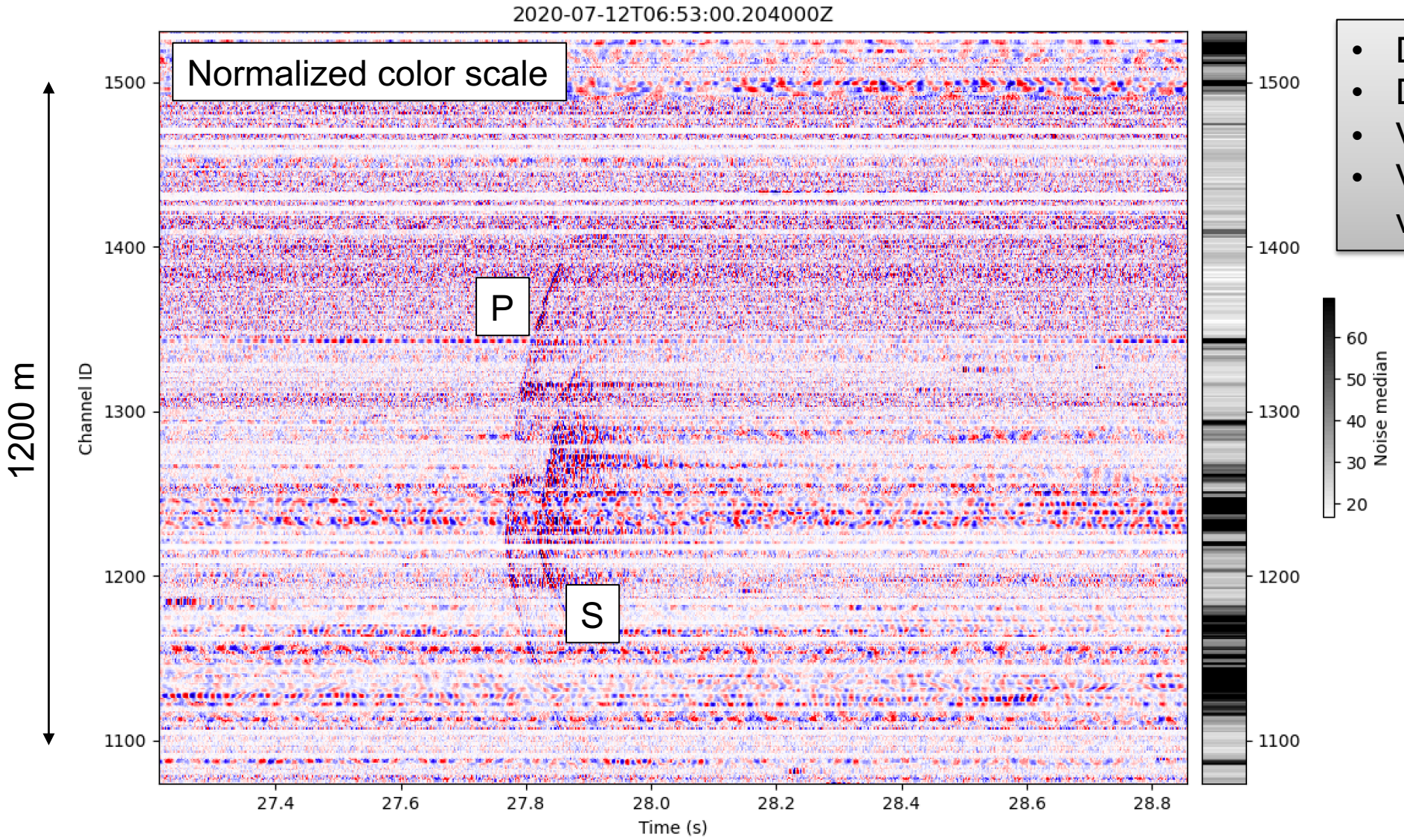




Noise Spectrogram (see also movie)

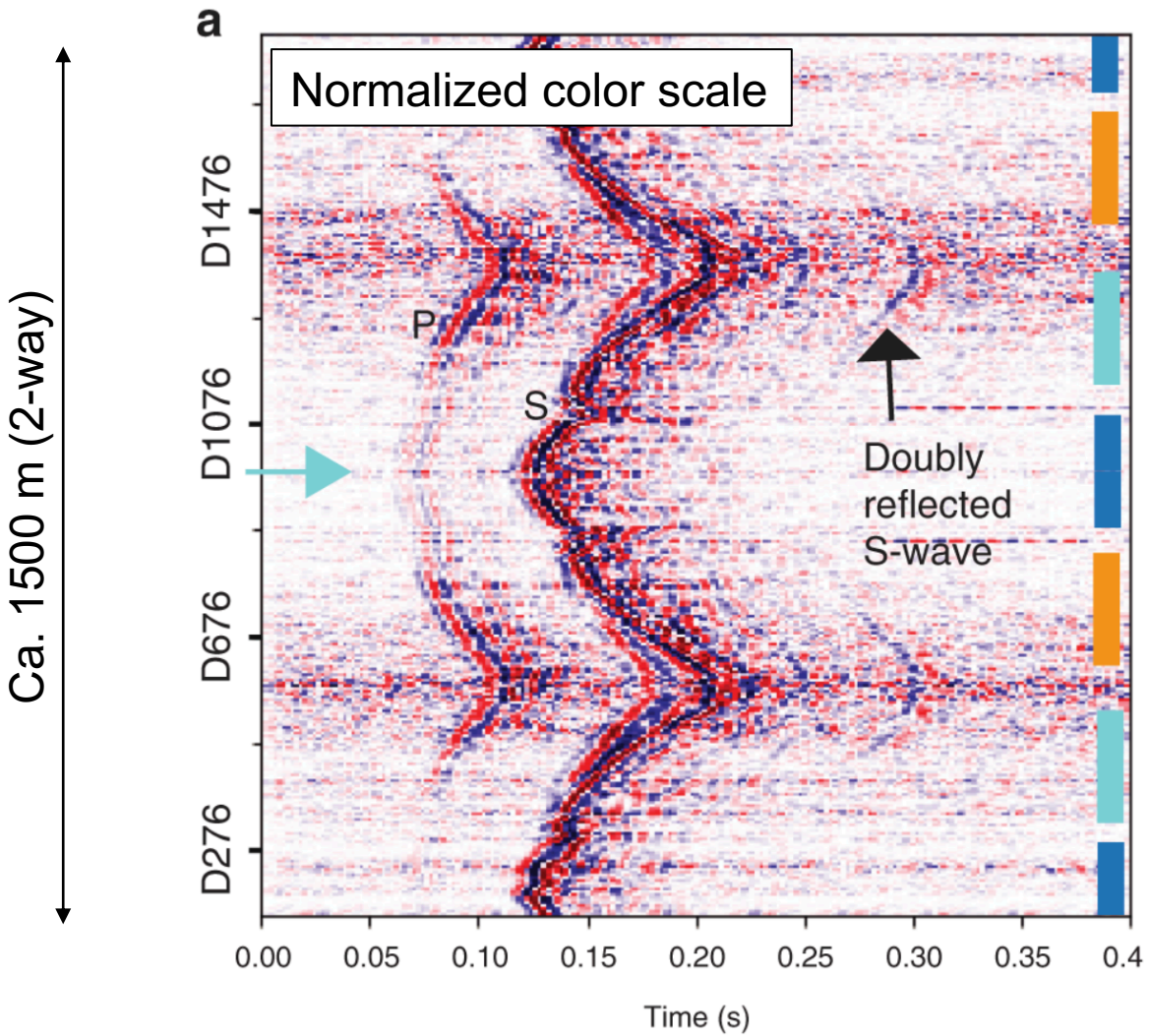


Stick-Slip Icequake Signal (2020)



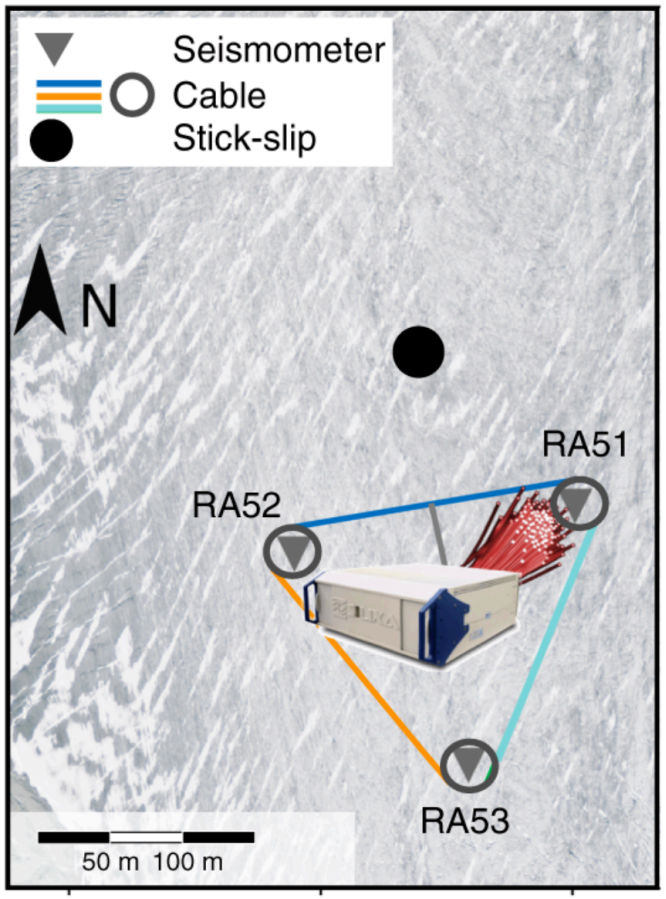
- Deep (basal) source
- Dominant P- and S-arrivals
- Visible over 100s of meters
- Variable channel noise: variable detectability

Stick-Slip Icequake Signal: Details (2019)

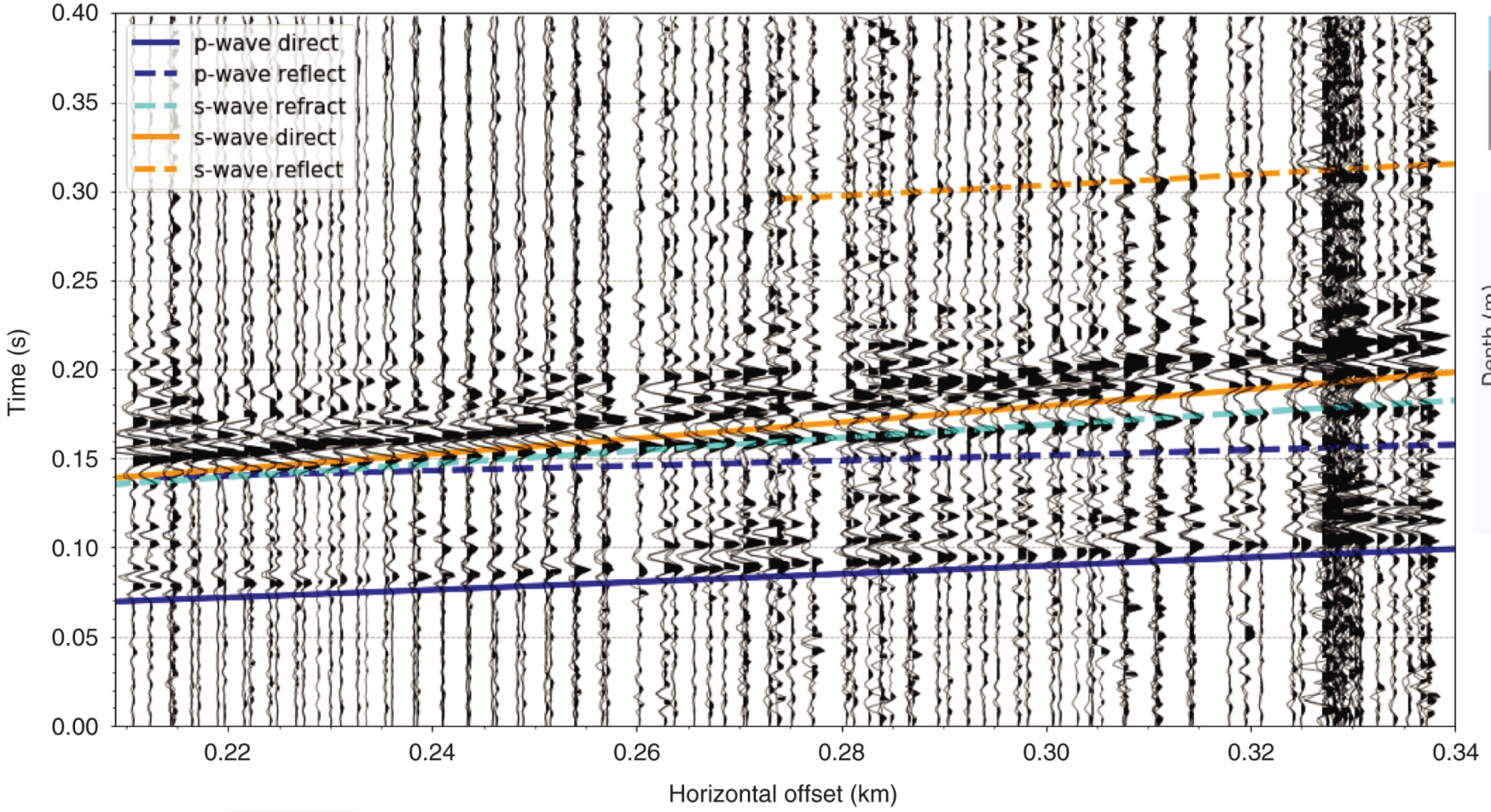


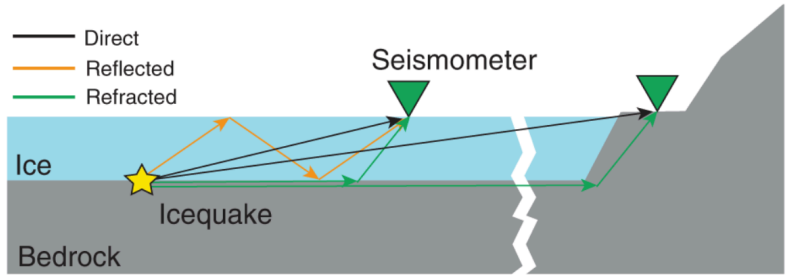
- Clear P- and S- arrivals
- Indirect phases

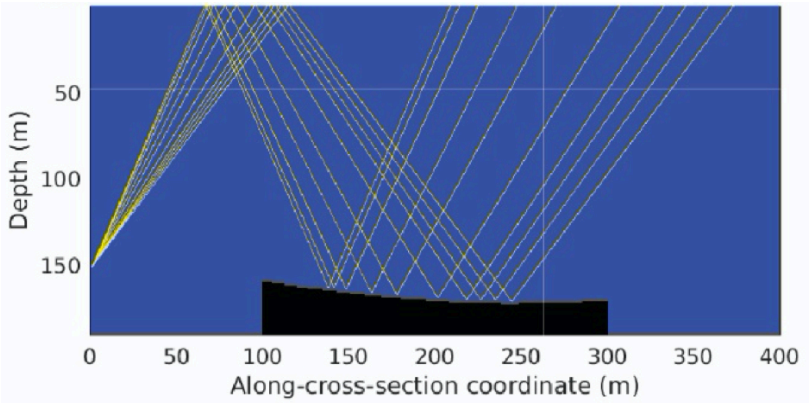
2019 Winter Deployment



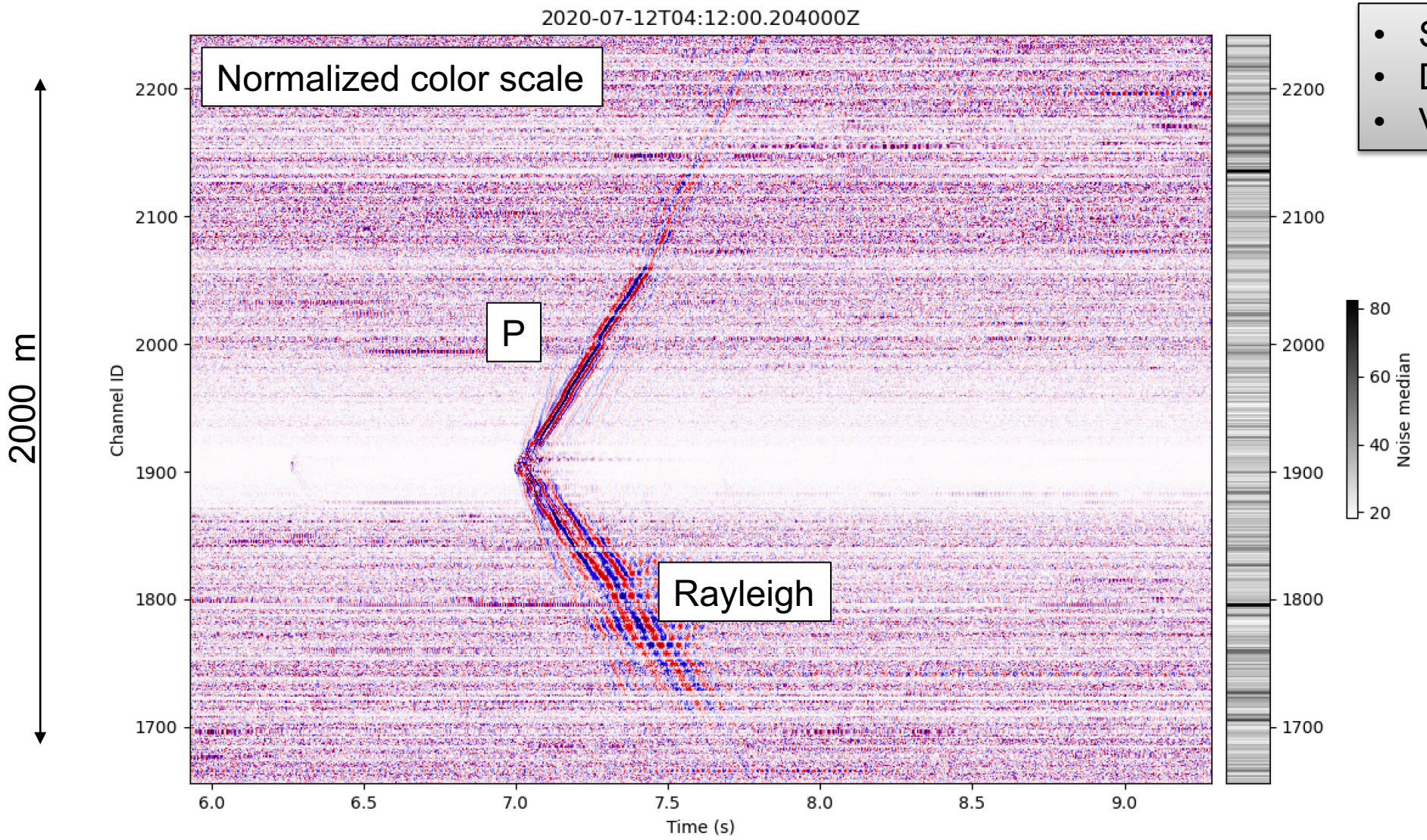
Stick-Slip Icequake Signal: Details (2019)





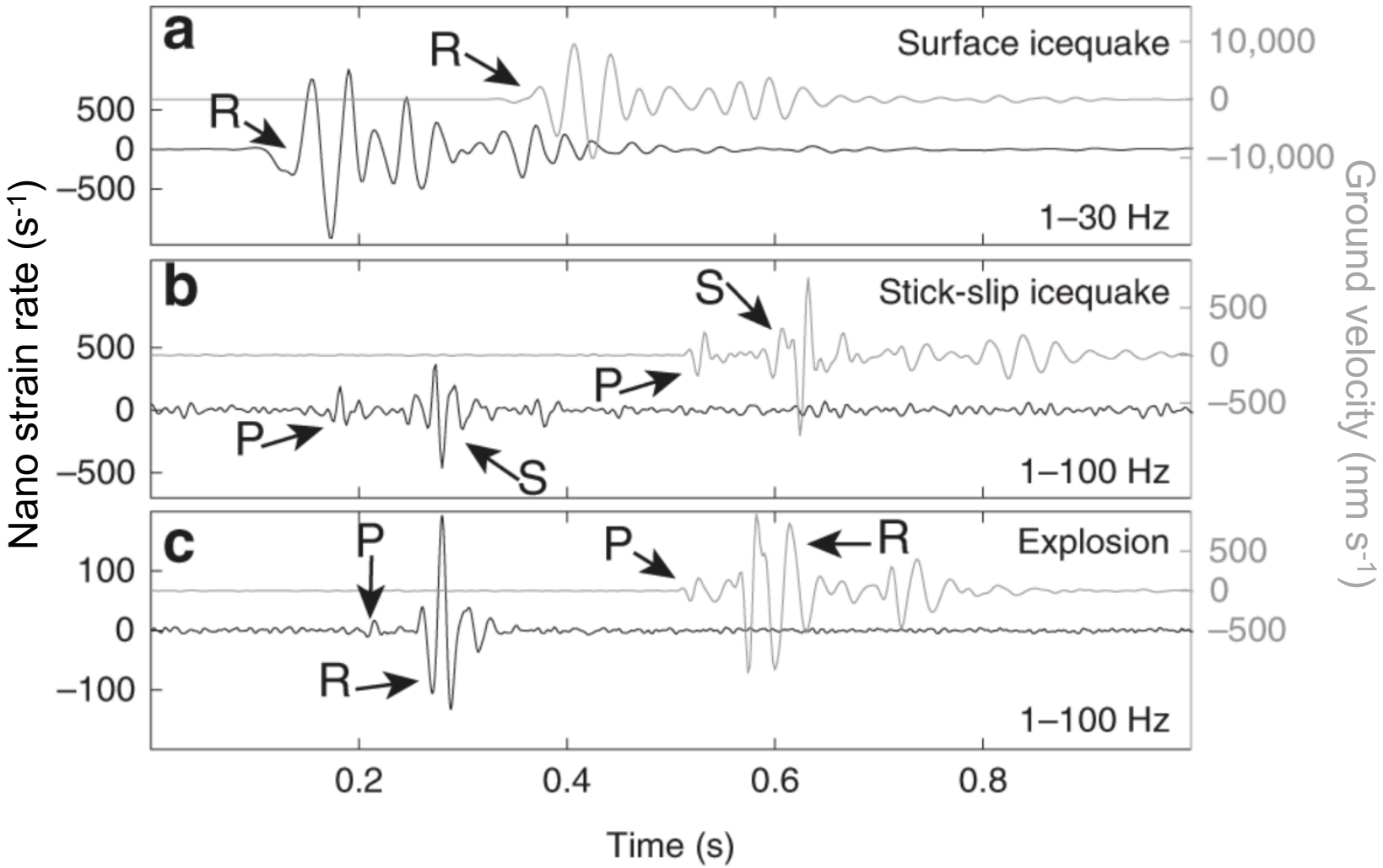


Surface Crevasse Icequake Signal (2020)

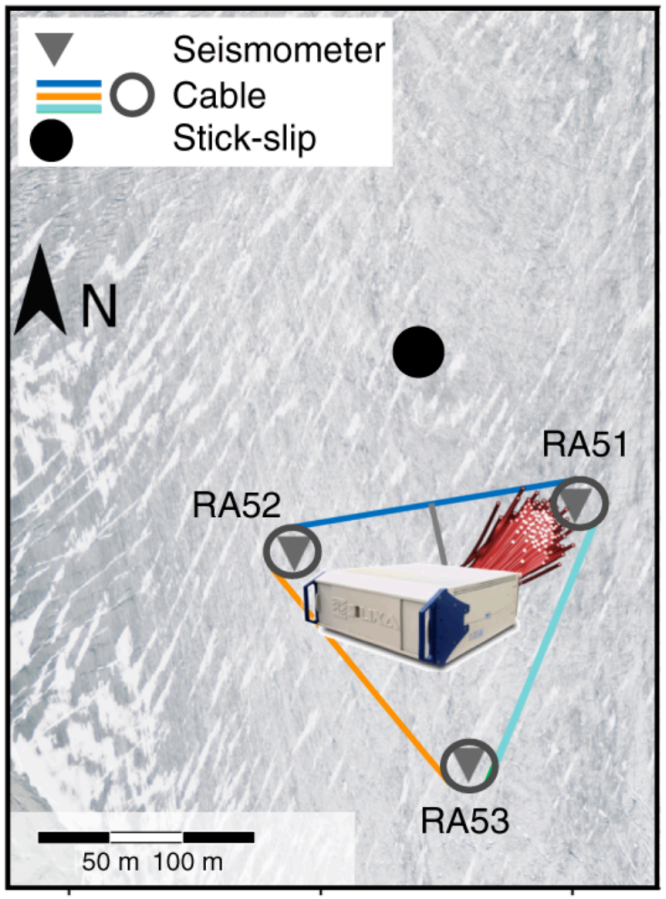


- Surface crevasse icequake
- Dominant Rayleigh arrival
- Visible over 1 kilometer

Different Icequake Waveforms



2019 Winter Deployment



Full day

2020 193 00:04
XS.D1256.50.ESN

2020 193 00:04
XS.D1264.50.ESN

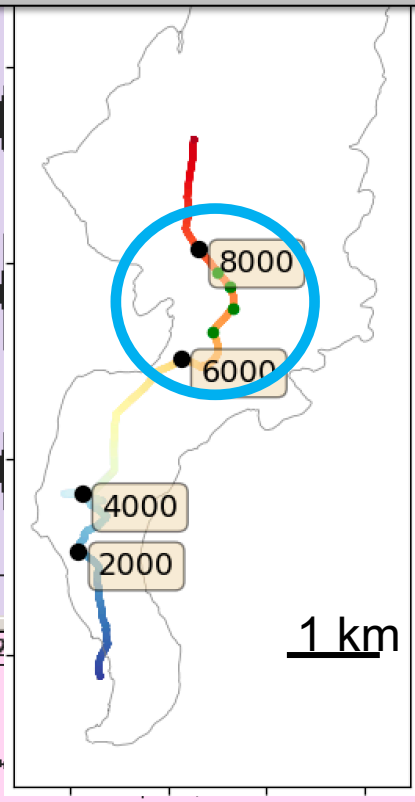
2020 193 00:04
XS.D1272.50.ESN

2020 193 00:04
XS.D1248.49.ESN

1-4 / 4

2020 193 00:04:30.203 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00

Record from accumulation zone



3 seconds

2020 193 00:04
XS.D1256.50.ESN
RMS = 1620
-6487
16217

2020 193 00:04
XS.D1264.50.ESN
RMS = 1895
-8949
11276

2020 193 00:04
XS.D1272.50.ESN
RMS = 218
-16690
11855

2020 193 00:04
XS.D1248.49.ESN
RMS = 320
-17025

2020 193 00:29:56.970 00:29:57.5 00:29:58.0 00:29:58.5 00:29:59.0 00:29:59.5

- Variable high-frequency noise
- No spatial correlation

Full day

XS.D1256.50.ESN

2020 193 00:04
XS.D1264.50.ESN

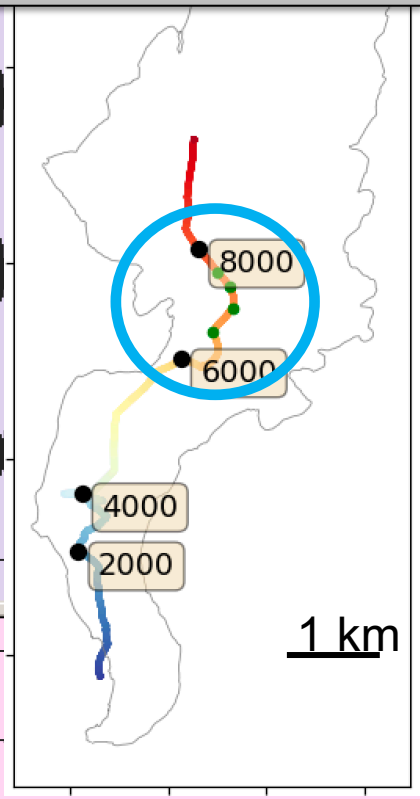
2020 193 00:04
XS.D1272.50.ESN

2020 193 00:04
XS.D1248.49.ESN

1-4 / 4

2020 193 00:04:30.203 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00

Record from accumulation zone



2 seconds

.203 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00

2020 193 00:04
XS.D1256.50.ESN
RMS = 392. -1384
3590

2020 193 00:04
XS.D1264.50.ESN
RMS = 479. -3086
9037

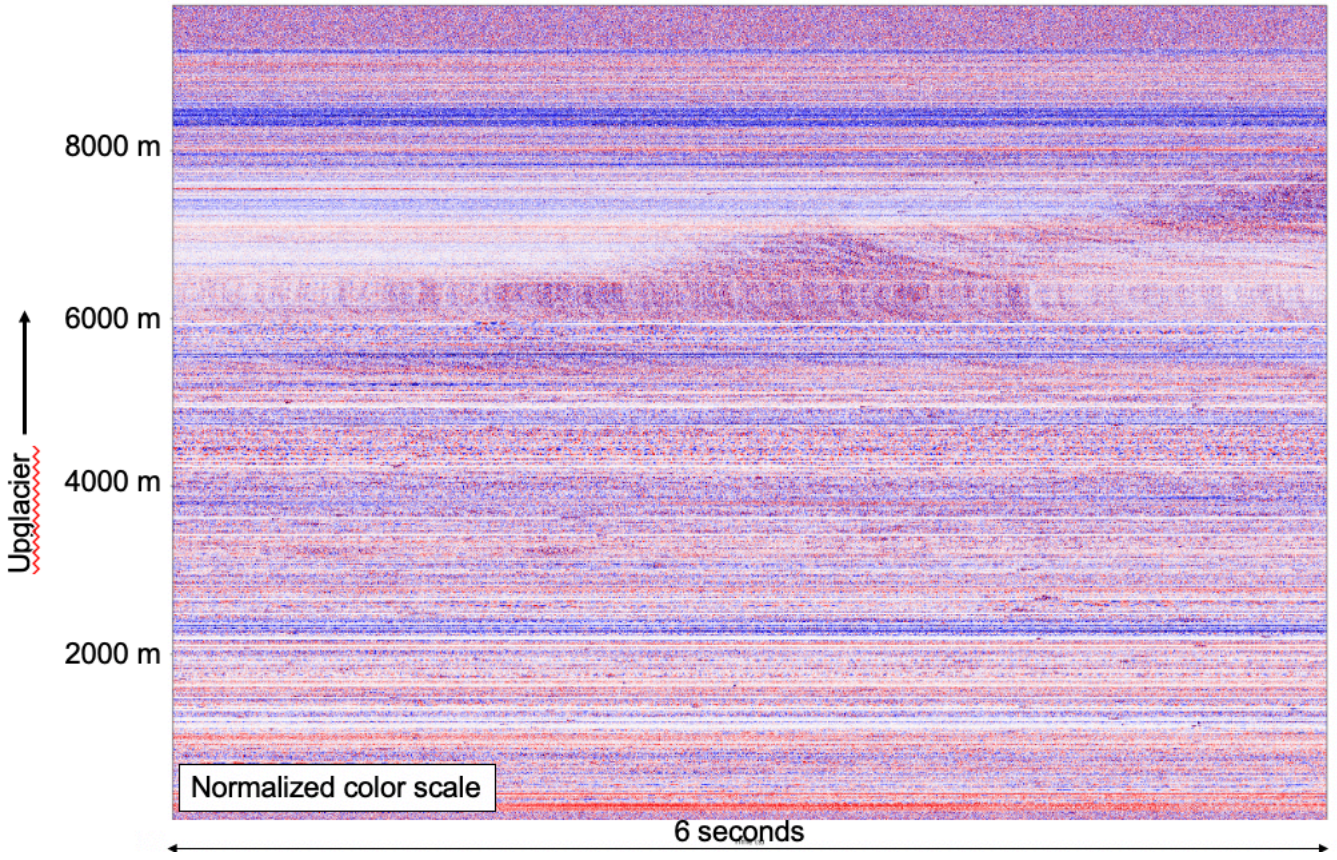
2020 193 00:04
XS.D1272.50.ESN
RMS = 93(-11097
3493

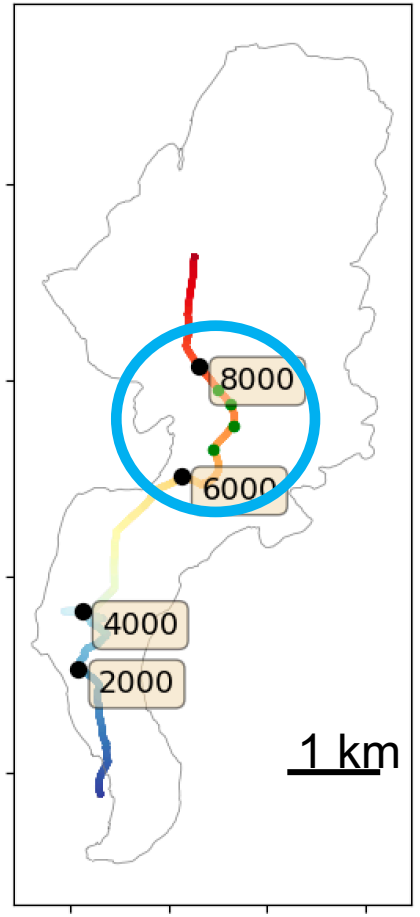
2020 193 00:04
XS.D1248.49.ESN
RMS = 417. -1291

2020 193 12:34:14.692 12:34:15.0 12:34:15.5 12:34:16.0

- Spatially coherent HF signals
- Basal (stick-slip) event

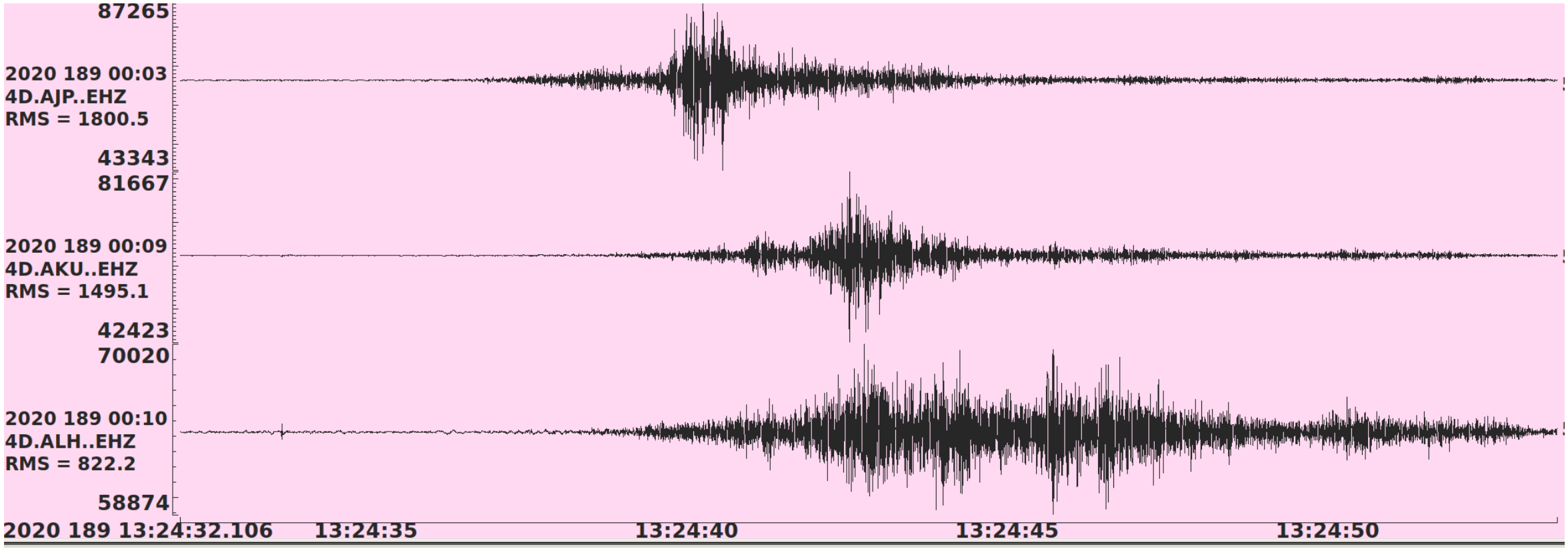
Migrating High-Frequency Tremor (2020)





Migrating High-Frequency Tremor: Geophone Ground Truth

Very high frequencies (near Nyquist)
- Stick-slip tremor?
- Anthropogenic (e.g. military jets)?



Low Frequency Waves (2020)

