Mt Meager DAS Experiment

- Mt Meager is a geologically active volcano in British Columbia
- There have been several landslides, most recently in 2010
- There is potential for building a geothermal energy plant
- Landslides and rockfalls present a hazard for both local communities and any potential geothermal site
- Hazards are often associated with glaciers, so monitoring glacial activity is of interest as well
- Could Distributed Acoustic Sensing be used to monitor this activity ?
- Jan Dettmer and others at the University of Calgary secured funding for a DAS survey on Mt Meager in 2019

The Mt. Meager DAS Experiment

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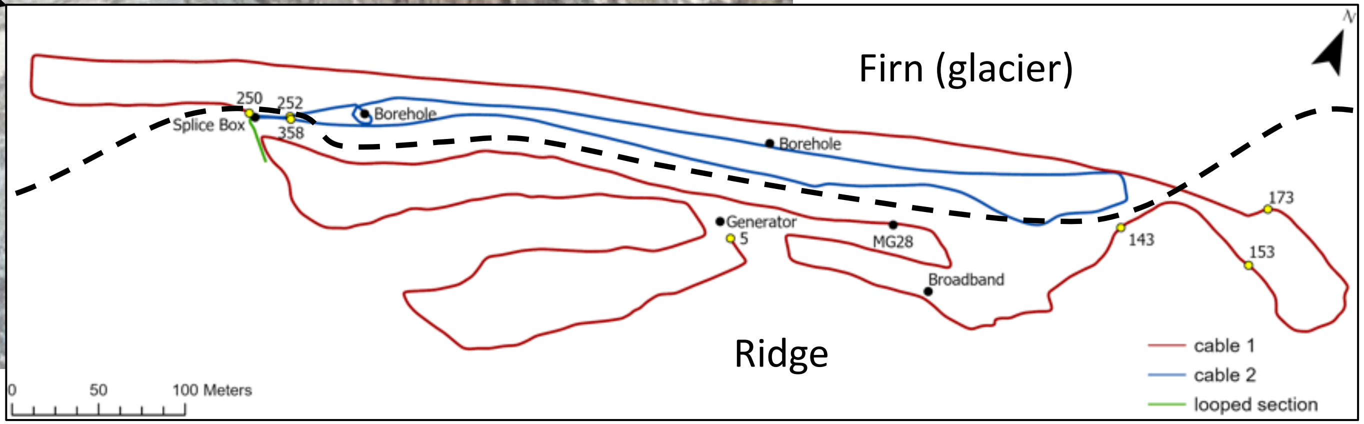
Mt. Meager

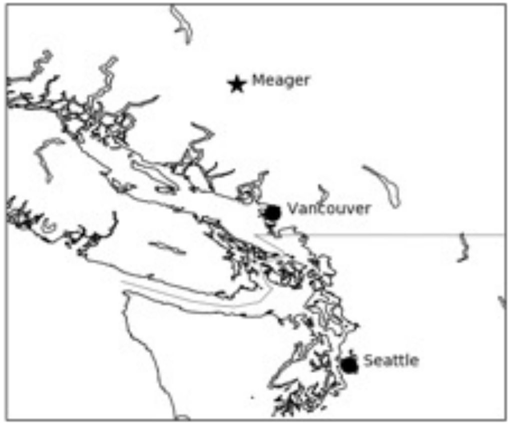
- Active volcano in the Garibaldi range
- High geothermal potential
- Massive landslides [50 Mio m^3 in 2010]

DAS Experiment

- 3 km cable along Meager ridge at 2100 a.s.l.
- Sep.-Oct. 2019



Cable layout on Meager ridge



Location of Mt. Meager


Mt Meager
DAS Layout
Meager Glacier
Image Landsat / Copernicus
Image © 2021 CNES / Airbus
© 2021 Google
Image © 2021 Maxar Technologies
145 m
1985
Google Earth
Imagery Date: 8/5/2019 50°37'43.74" N 123°29'10.95" W elev 1954 m eye alt 2.39 km

Mt Meager DAS Cable Layout

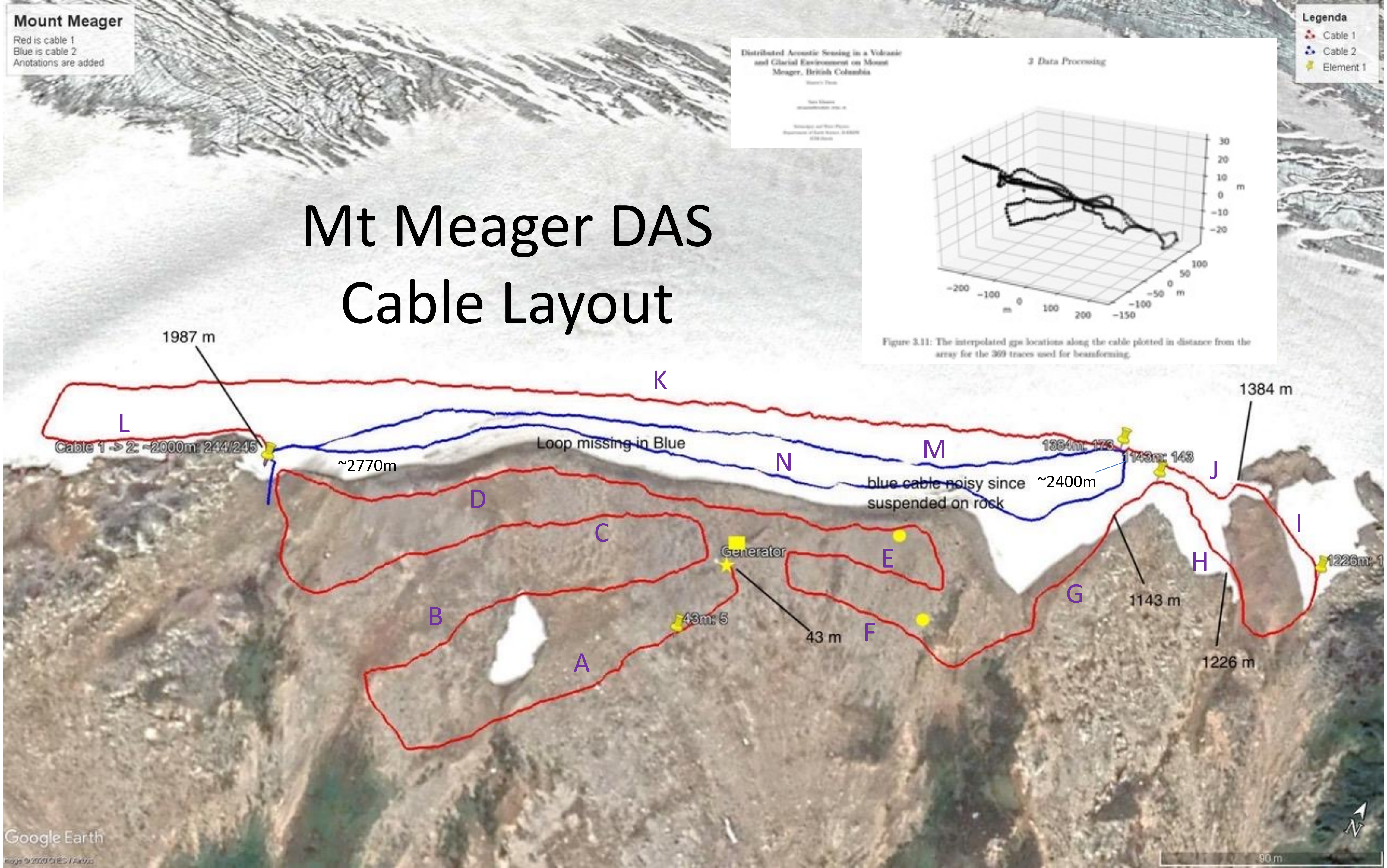


Figure 3.11: The interpolated gps locations along the cable plotted in distance from the array for the 369 traces used for beamforming.

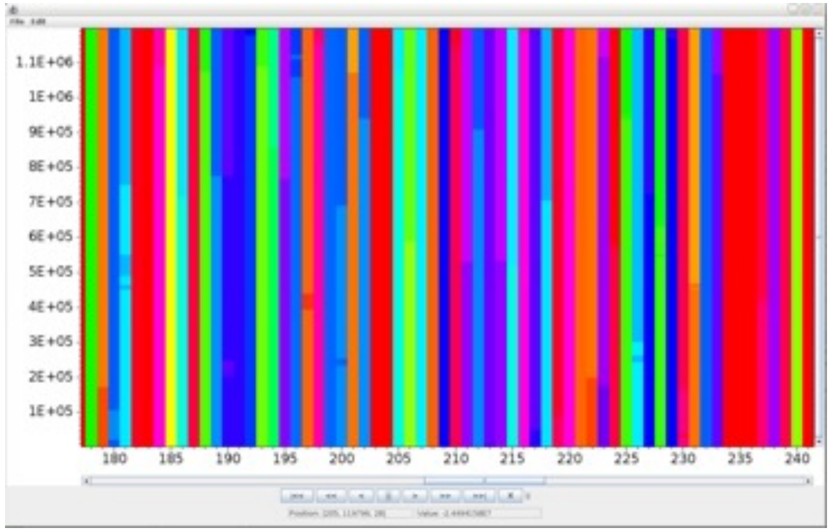
Mt Meager DAS Acquisition

- A single mode ”standard” fiber was laid out on a ridge near Mt Meager near the source of a glacier in September 2019
- DAS data was acquired for one month
- Since the sample rate is 1 msec, and there are 380 “channels”, this data set is LARGE
- One day of recording is 1000 msec/sec * 86400 sec/day * 380 = 3.28e10 samples per day
- With 4 bytes per sample, the data volume is 4*8.64e7 = 122 GB per day
- Data was acquired for a month, so the total data volume is 30*122 GB = 3.67 TB

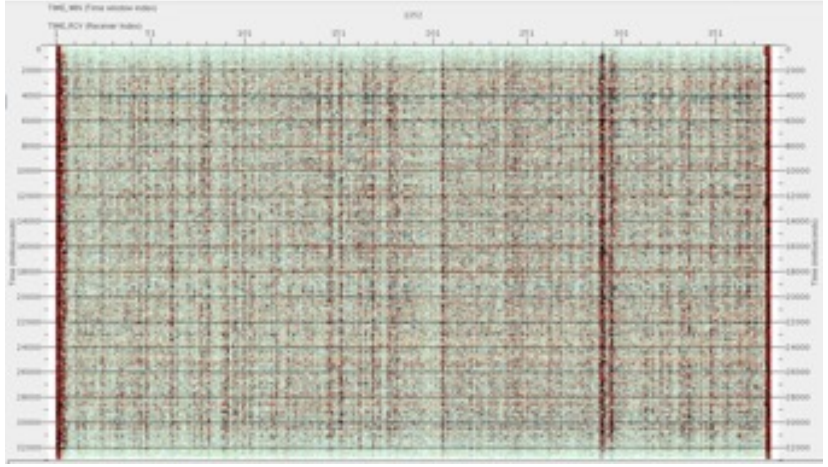
Mt Meager DAS Data Processing

- Data were loaded from U Calgary storage servers to AWS
- We used the Linux AWS Command Line Interface: `aws s3 cp *.h5 s3://glacier-das`
- 1 Day, 82 files, 0.75 GB per file, 56 GB total, transferred at 1 minute per file
- Raw data is converted to scaled differential phase in windowed time
- Total conversion and transfer elapsed time was 2 hours
- The compressed JavaSeis dataset is ~10 GB

Raw integer data



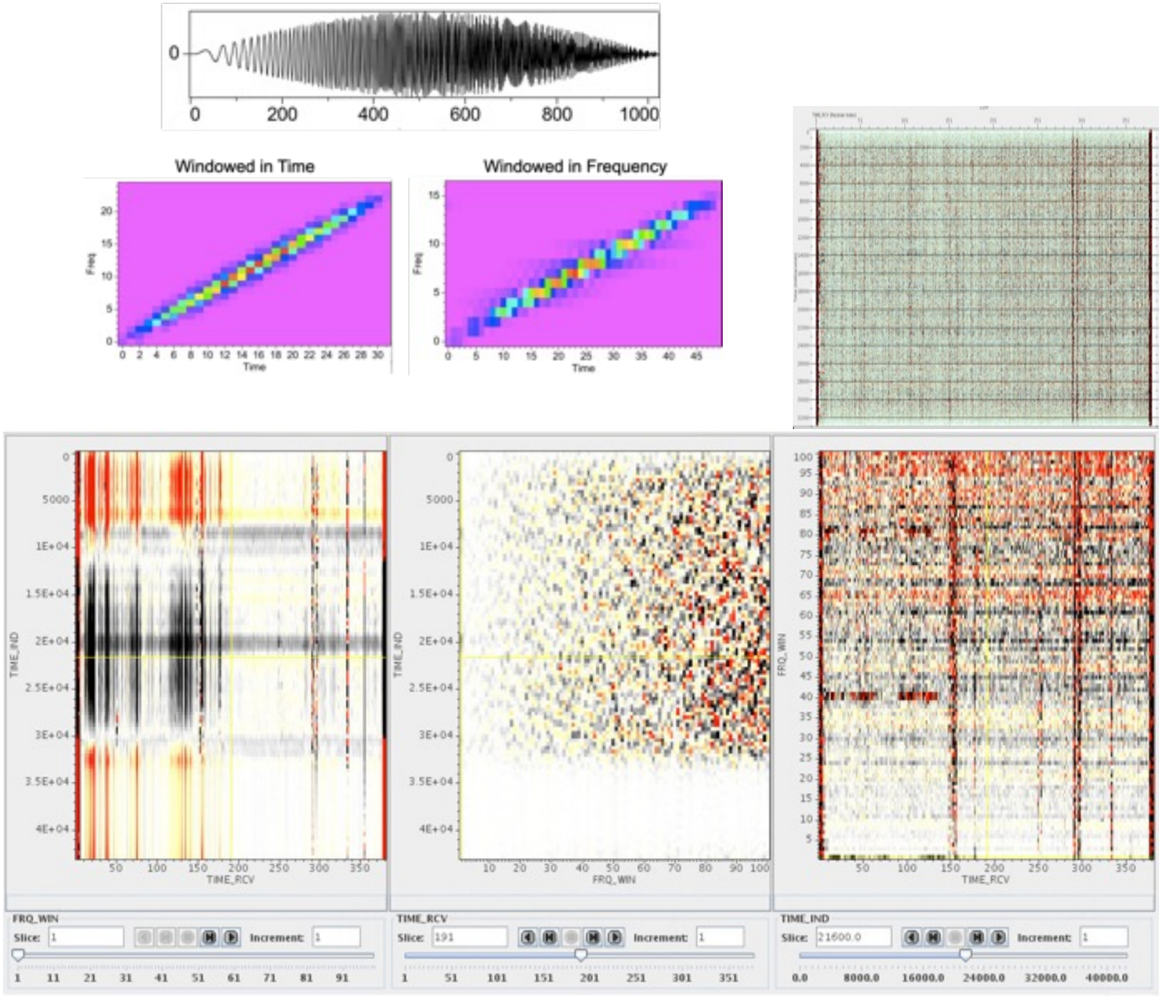
Scaled differential phase



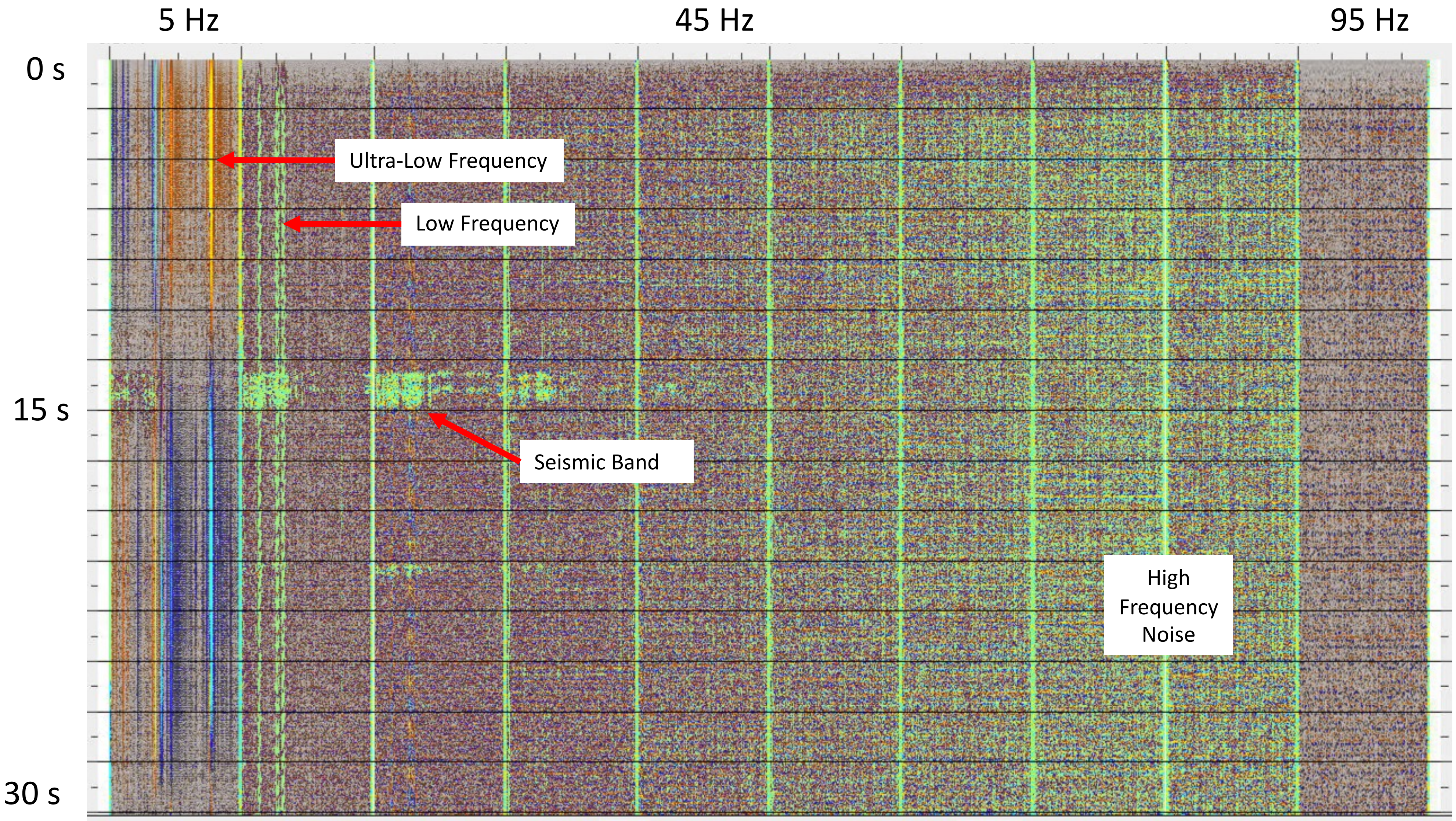
Multi-Scale Decomposition

- Based on the Generalized Windowed Transform (GWT, Mosher 2011)
- Framework for wavelet style transforms that avoid sub-band aliasing
- Real to real transform in "Frequency Bands"
- Mathematical coupling between sub-bands retains ALL frequencies

GWT: Sparsity With Minimal Artifacts



Meager DAS Time-Frequency Decomposition

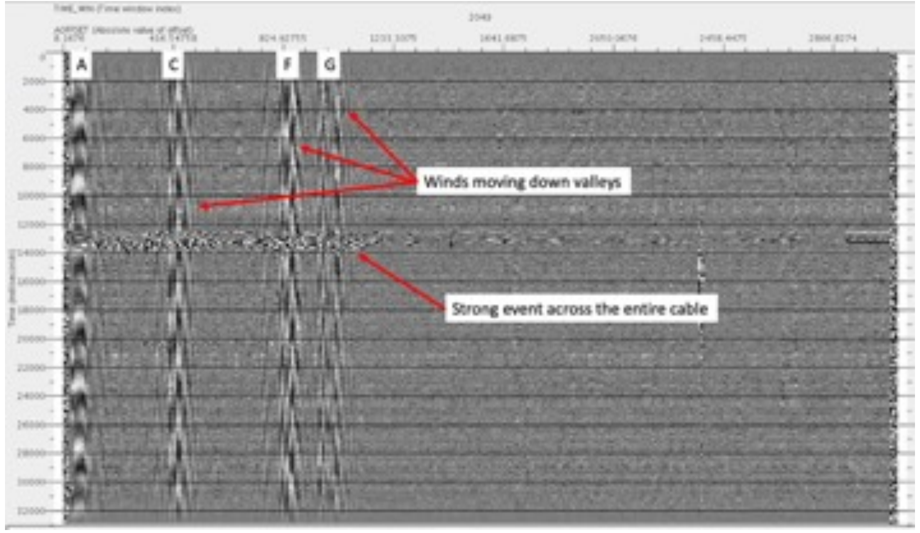


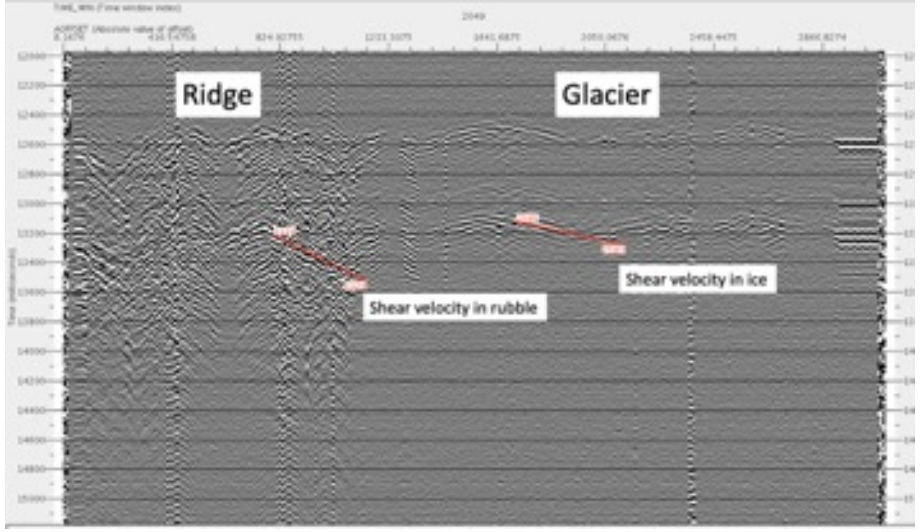
Mt Meager DAS Experiment – Seismic Events

- Numerous seismic events are observed on the 2019 Mt Meager DAS dataset
- The largest energy appears to be surface waves traveling in the near surface at expected shear velocities
- Geophone recordings co-located with the DAS cable in space and time are consistent with Rayleigh wave particle motion
- Most observed events originate on the glacier but increase significantly in amplitude as they propagate across ridge and slope
- Events cluster in specific locations on the glacier and ridge

Numerous Seismic Events in the 5-50 Hz Band

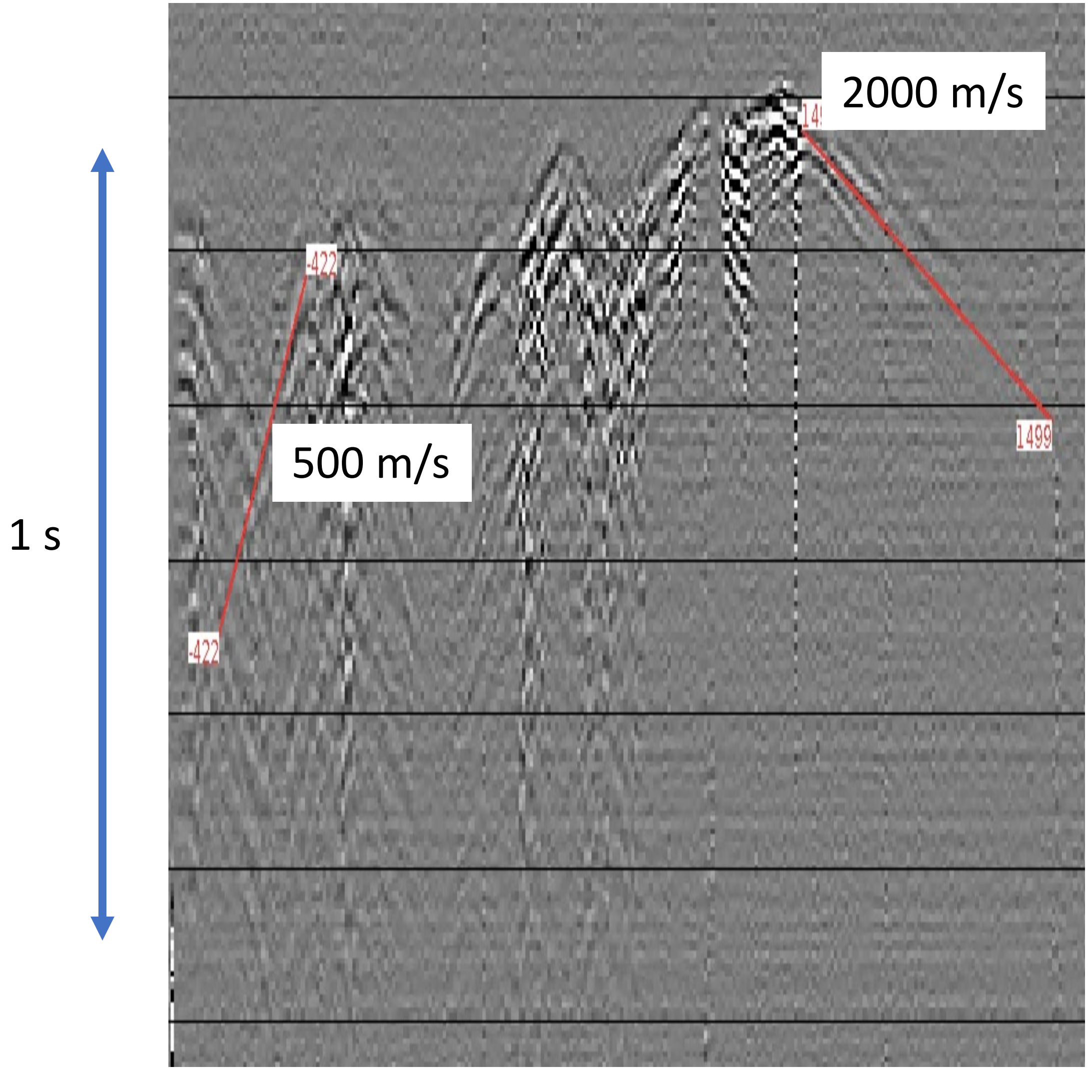
- We see low frequency wave trains in valleys with 1-5 m/s velocity
- Events that occur on all channels
- Complex waveforms traveling at near surface shear velocities
- Events appear to originate on the glacier and on the slopes
- No confirmed tele-seismic events have been found





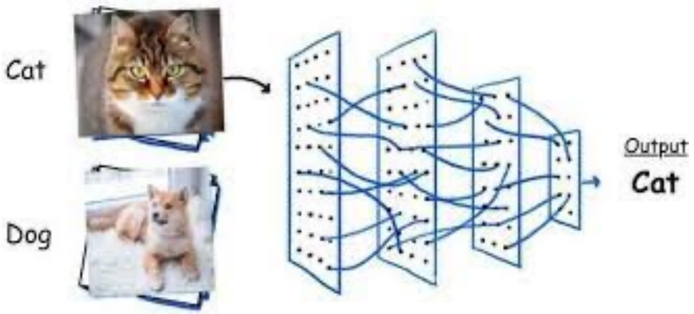
DAS Seismic Event Detection

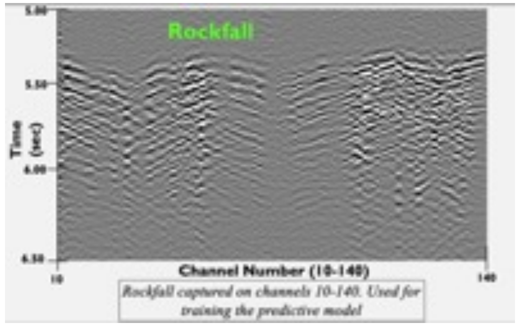
- Seismic Event Observations
  - Velocities 500 m/s on ridge and 2000 m/s on glacier for 5-50Hz data
  - Consistent with expected surface wave velocities in rocky soil and ice
  - Simple waveform on ice
  - Complex waveforms on ridge and slope
- Seismic Event Detection
  - Calculate seismic attributes
  - A training set of 10 second windows manually classified as event/no event
  - Rank attributes using machine learning
  - Create catalog of windows with events

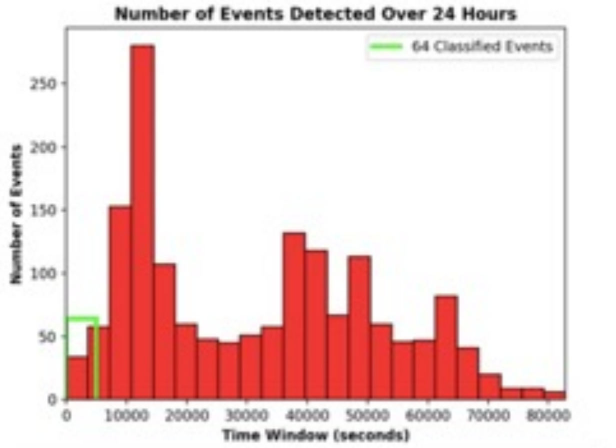


Deep Learning Example: DAS Event Detection

- The Cat vs Dog Tutorial
- VGG16 Deep Learning Network with Transfer Learning
- Train using events labeled by experts
- Predicted 900 events using a full day of recording
- Matches performance of human experts
- Work done by undergrad for senior thesis



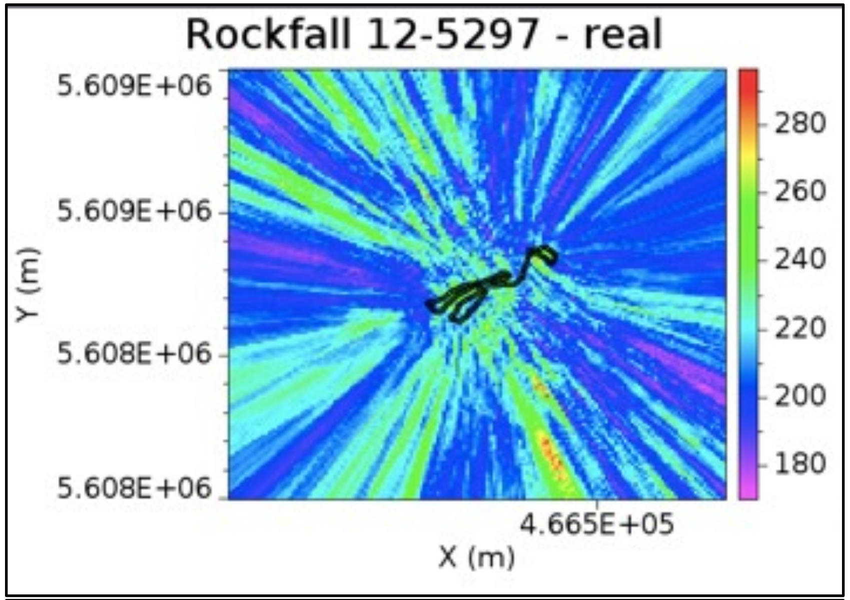


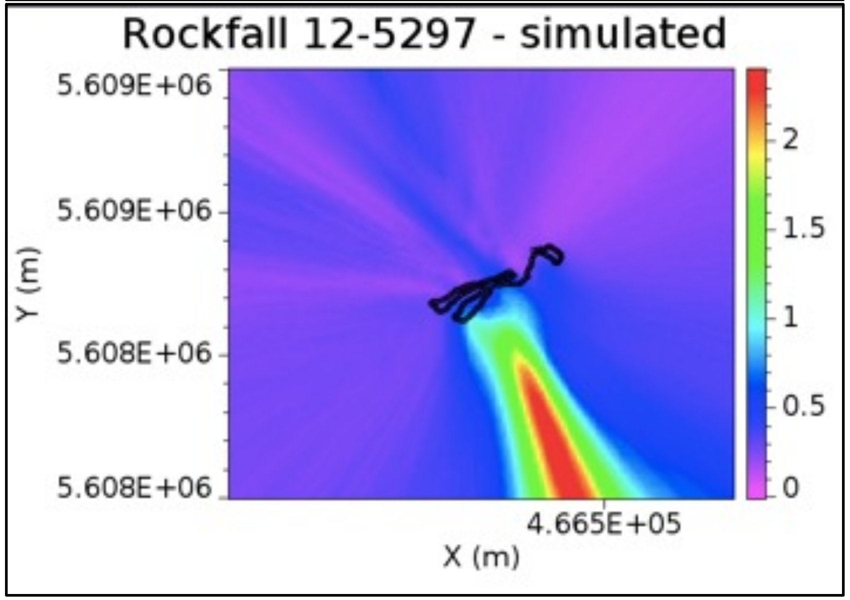


Number of energy events detected by the neural network from 8640 frames over 24 hours on day 11

DAS Event Location

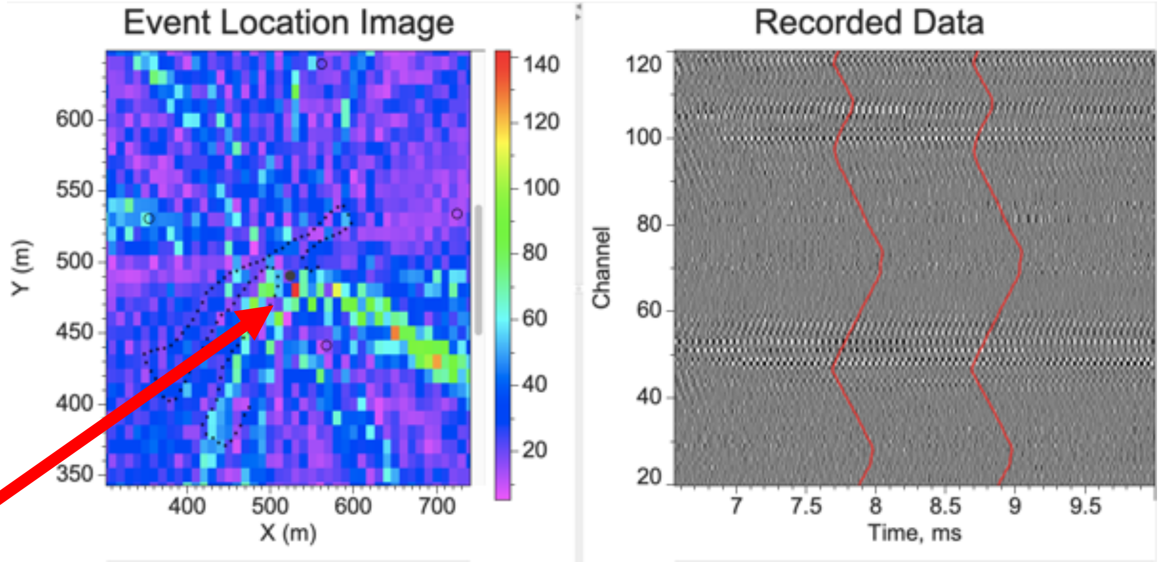
- Interferometry / Migration
  - Create an image grid of possible source locations
  - For each image point, calculate travel-times for all channels
  - Shift all channels by the travel time
  - Stack over a time window
  - Assign the RMS energy of the summed trace to the image grid cell
  - Visualize in map view
- Validation
  - Pick a source location from the real data image
  - Create a simulated seismogram for the assumed source
  - Compare images from real and simulated data

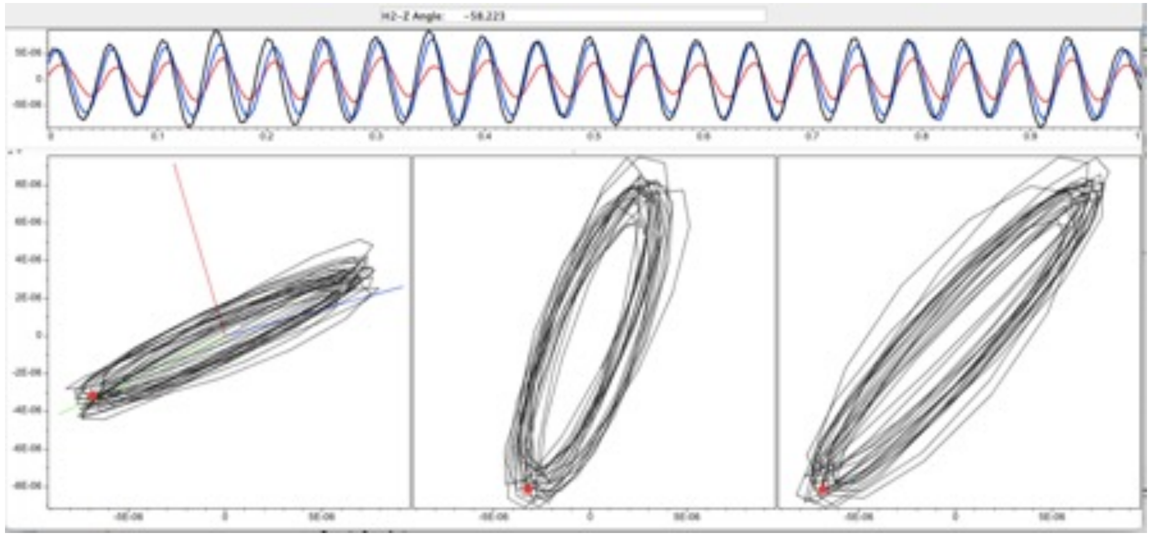


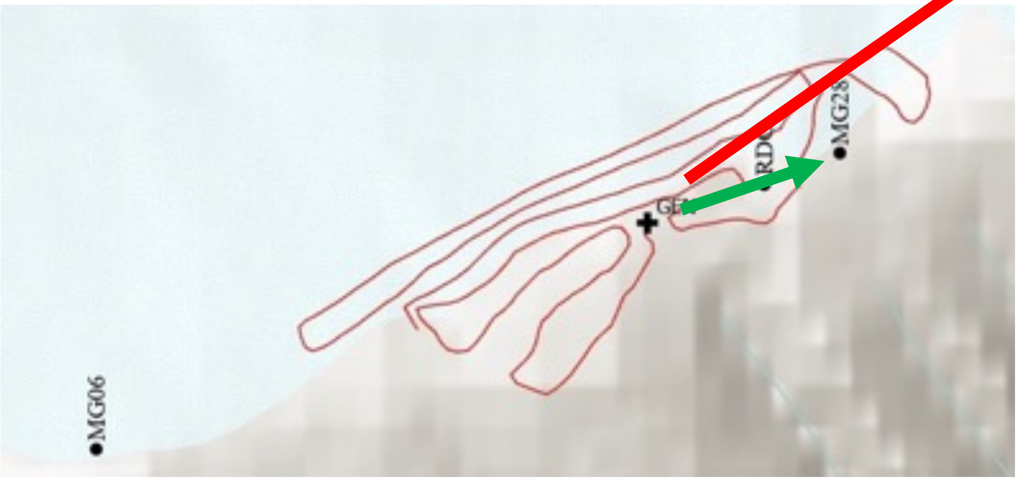


Generator “signal” provides calibration

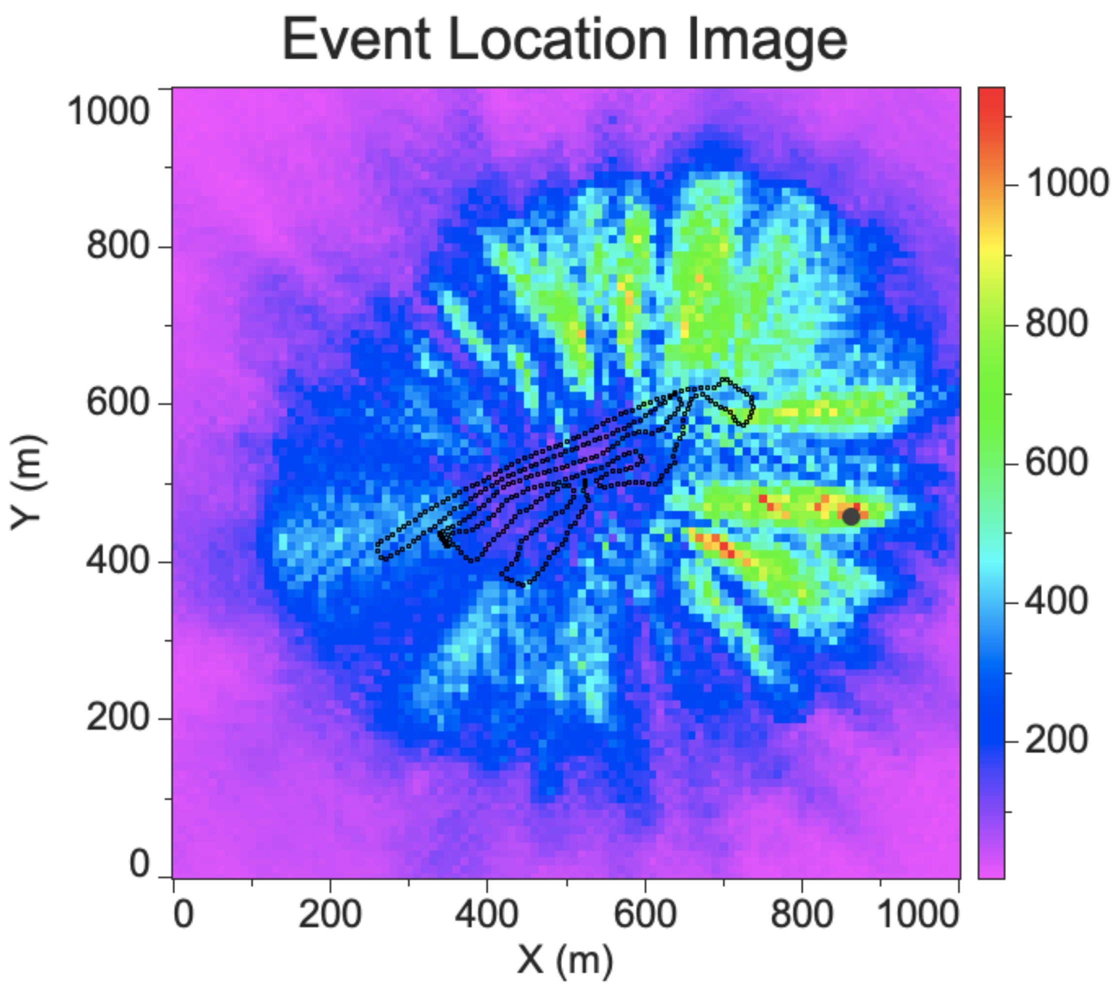
- Event location coincides with generator location using 500 m/s
- MG28 Sees the same energy
- Prograde elliptical motion
- Aligned with propagation direction

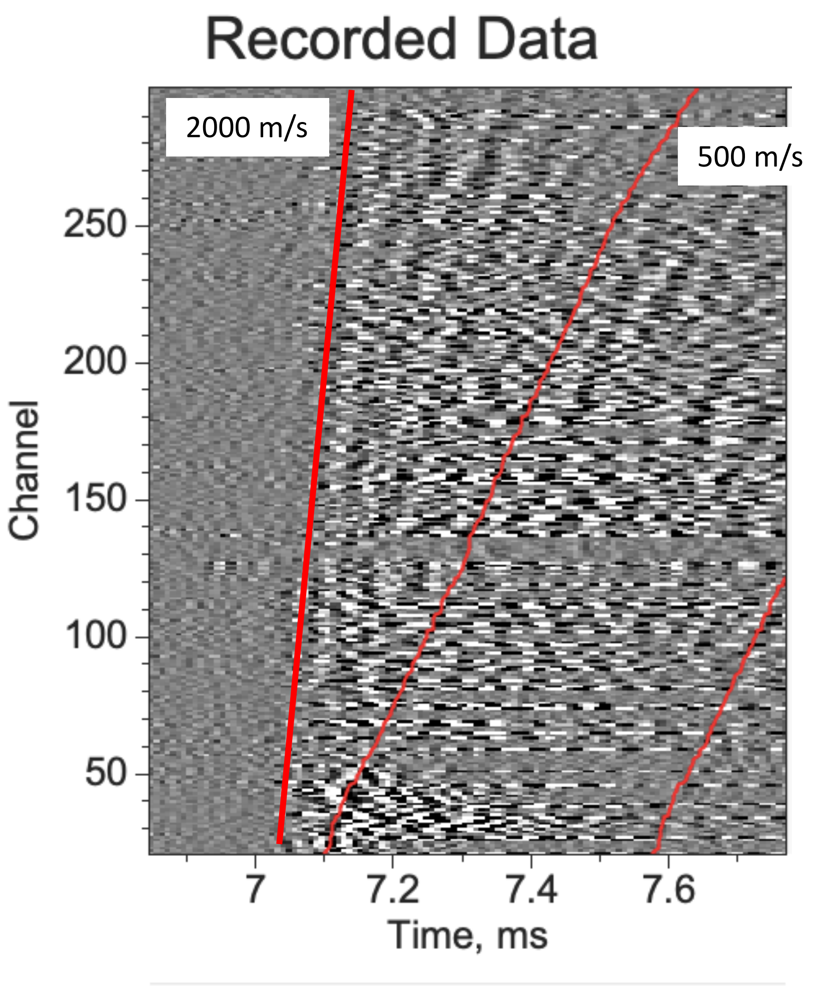






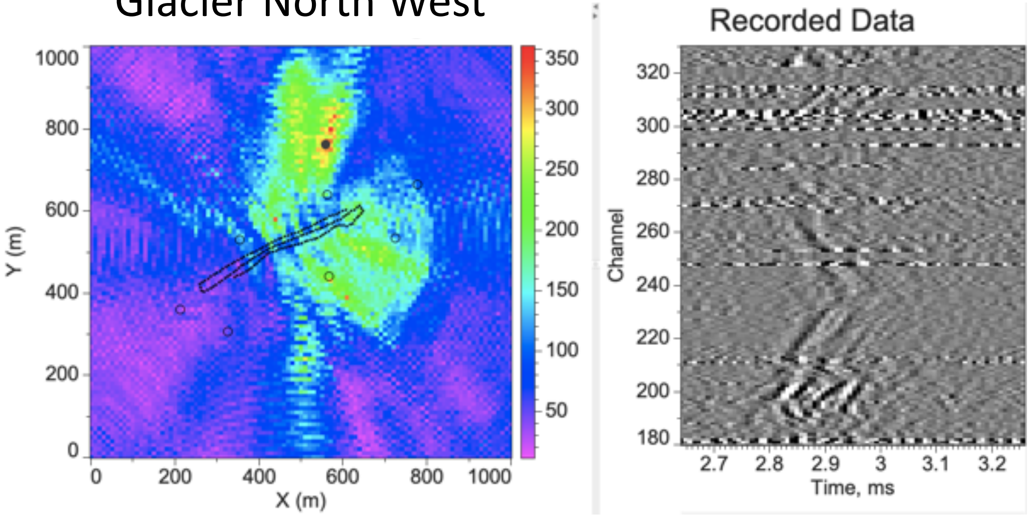
Locations complicated by velocity contrast



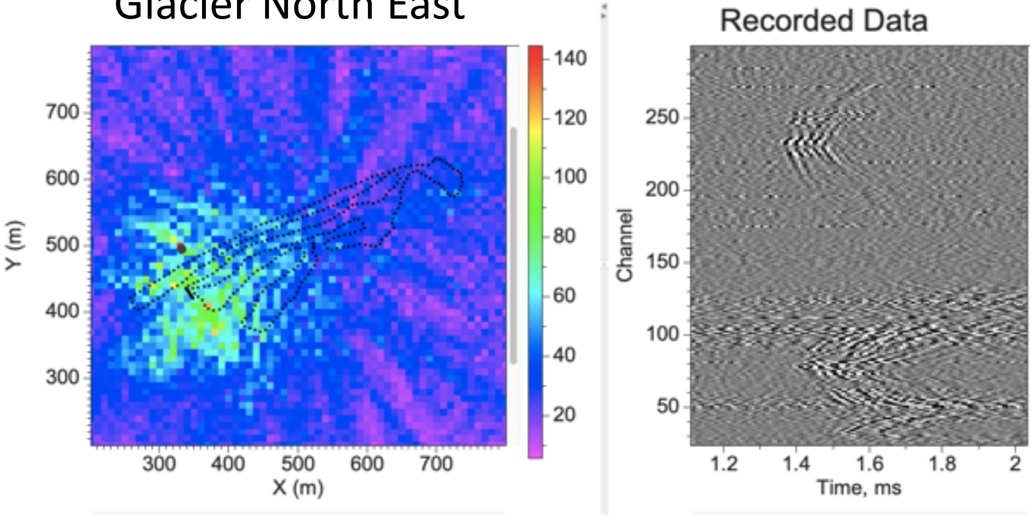


Events are clustered in a few spatial locations

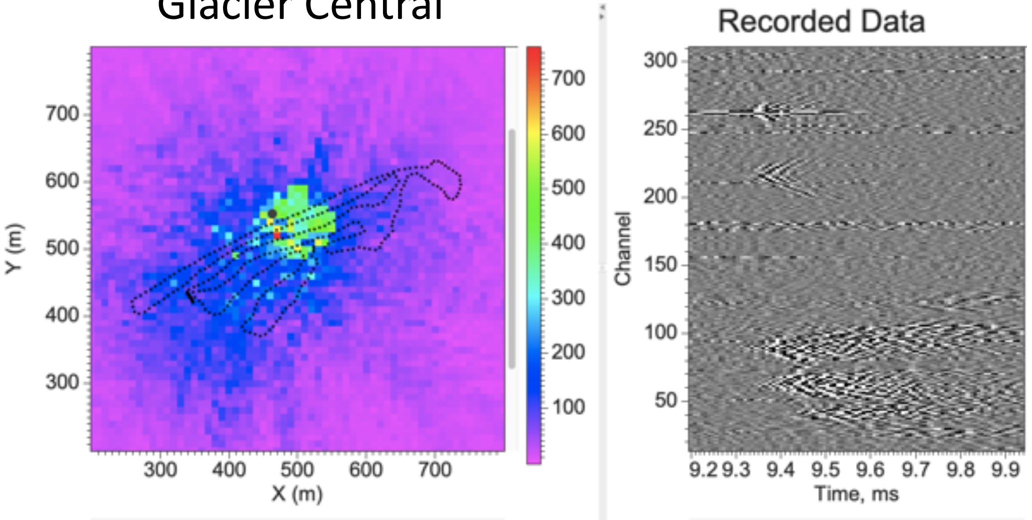
Glacier North West



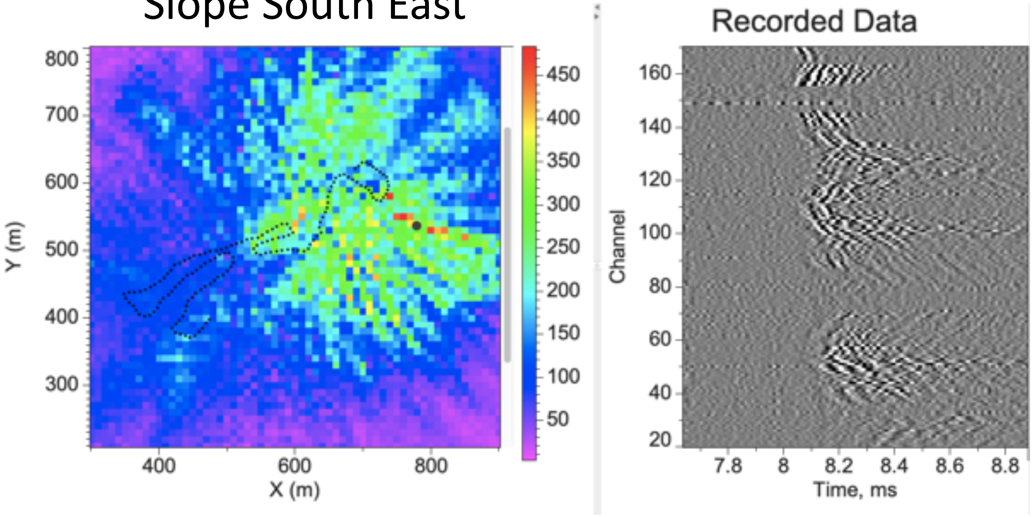
Glacier North East



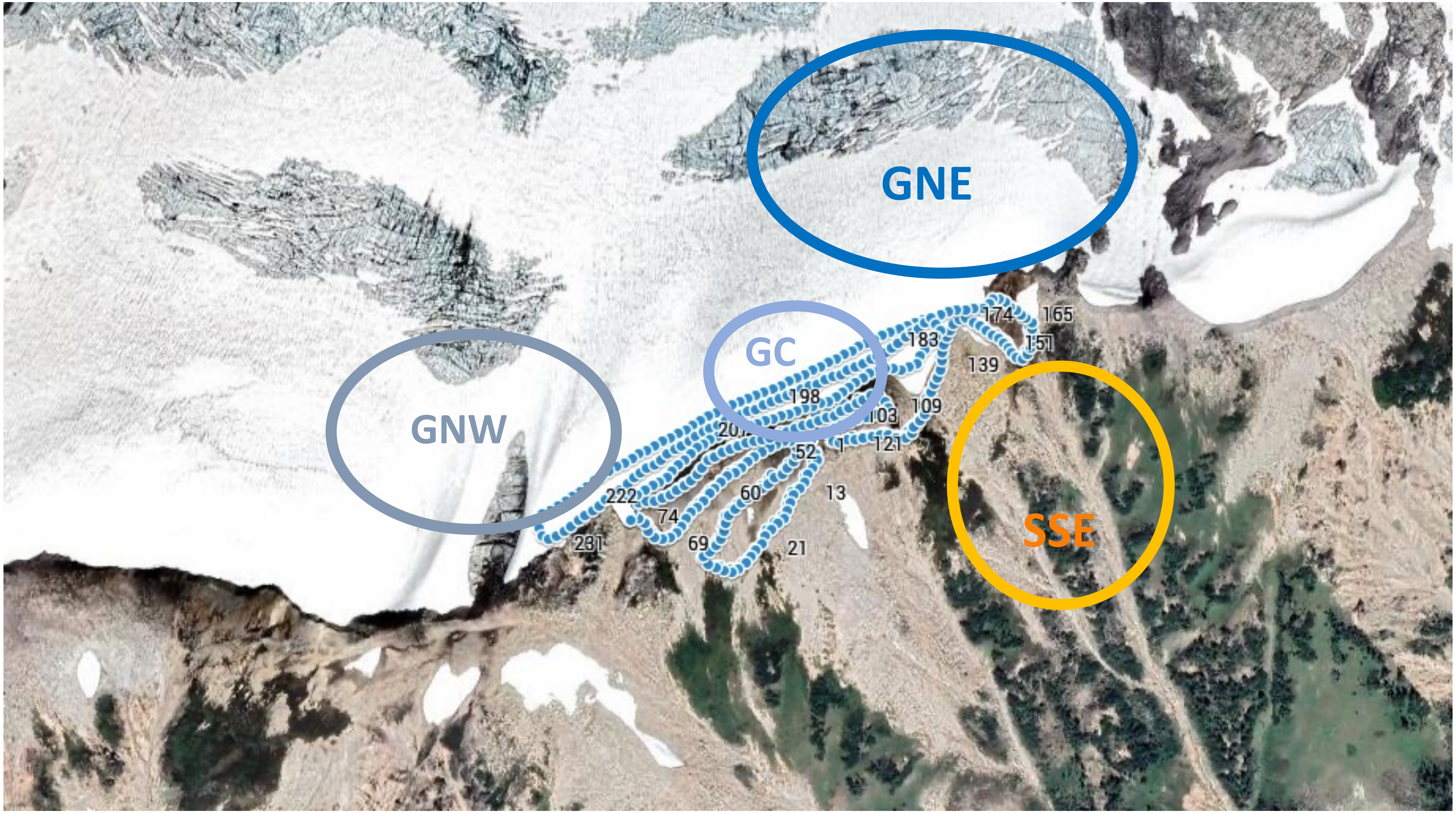
Glacier Central



Slope South East

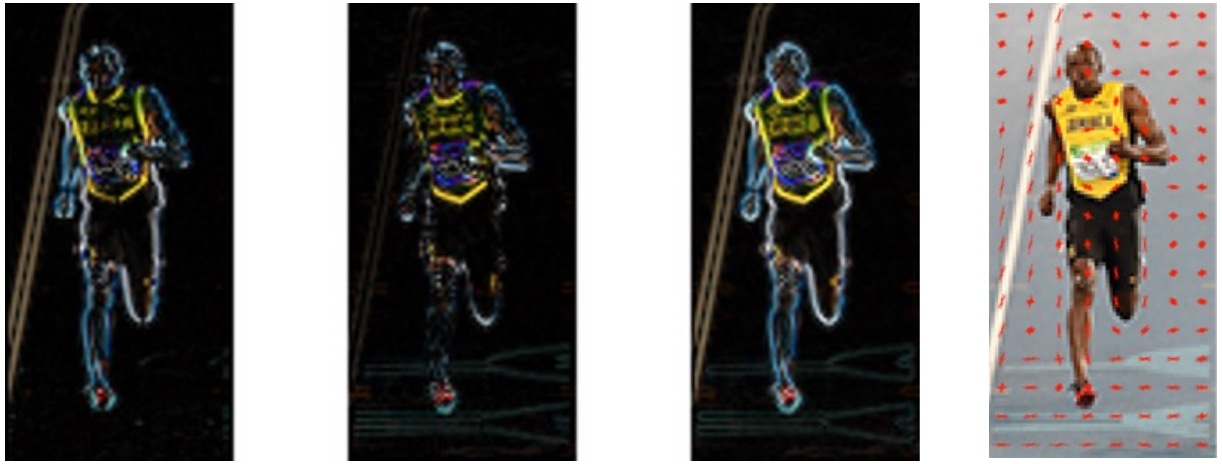


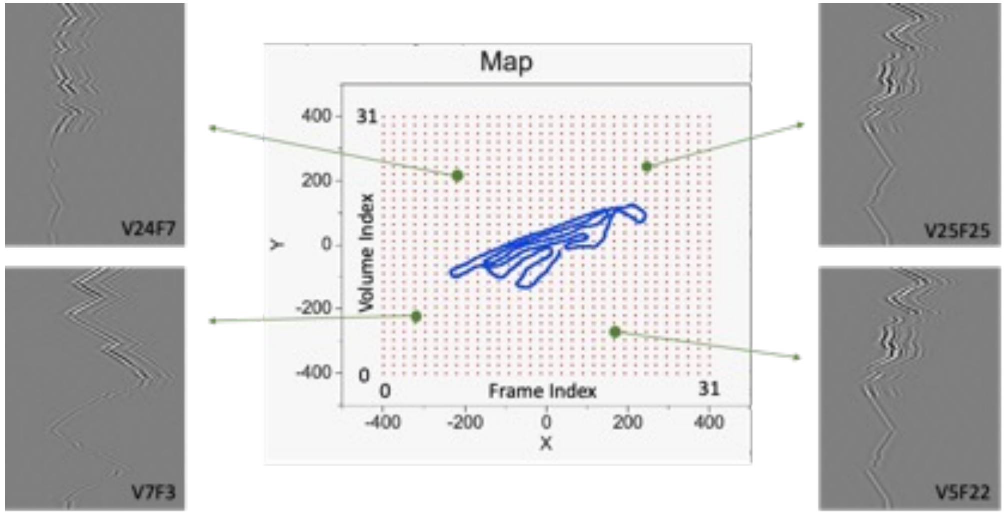
Event Cluster Locations – 29 Sep 2019



Machine Learning Based Event Location

- Focus on feature extraction
  - Extract features that make geophysical sense
  - Utilize existing ML algorithms
- Use synthetic data to guide feature extraction
  - Realistic synthetics with noise
  - Provides balanced dataset for training
- Rank feature importance
- Re-train on real data



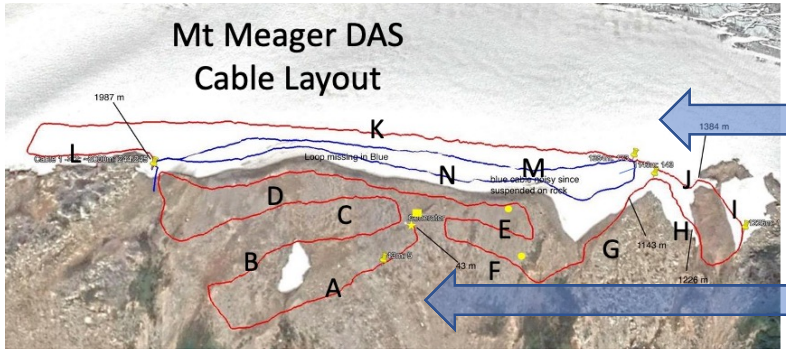


Initial Results

- Clean Synthetics:
  - Corner detection and Histogram of Gradient best features so far
  - XG Boost package with tuning provides best results
  - Start with 2 classes and increase number till it “breaks”
  - 16 classes with simple 4 x 4 tiling has > 90% true positives
- Synthetics with noise
  - Generated 0.1, 0.5, and 1.0 SNR examples
  - Will investigate how many classes can be resolved
- Real Data
  - Use features and metrics from synthetic data
  - Tune hyper-parameters and pre-processsing

Low Frequency Strain Monitoring

- DAS records strain changes down to DC
- Careful processing is required to retain this information
- Even a simple “box-car” windowing operation can damage low frequencies
- MoMacMo Multi-Scale DAS processing preserves low frequencies with high fidelity
- Here we show an example of the value of this information for monitoring low frequency strain changes at Mt Meager

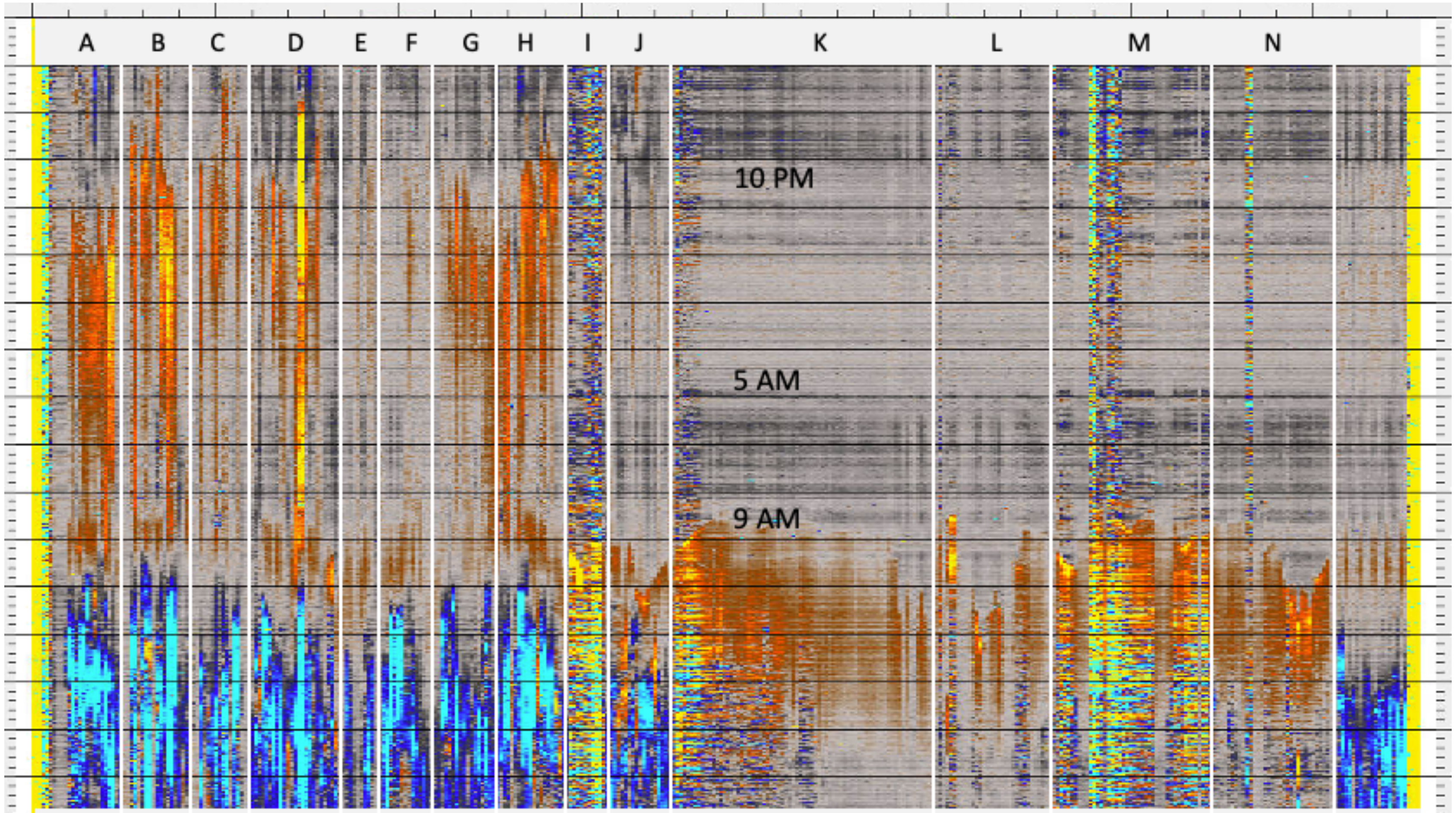


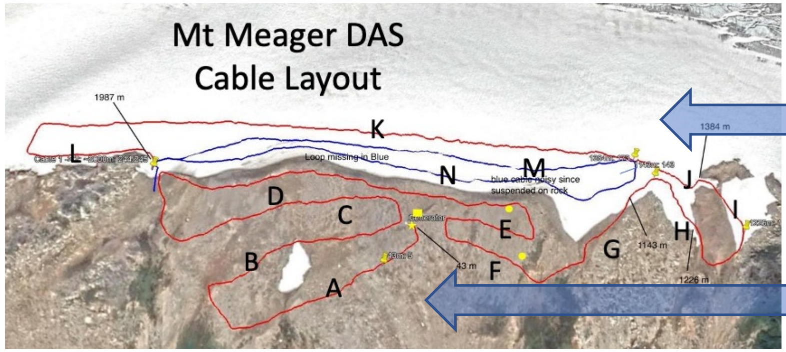
Glacier (K-N)

Ridge (A-J)

Low Frequency Strain

- Zero to 1 Hz
- Temp induced
- Warm = expansion
- Cold = contraction
- One UTC day
- Sunrise on glacier
- Wind on ridge





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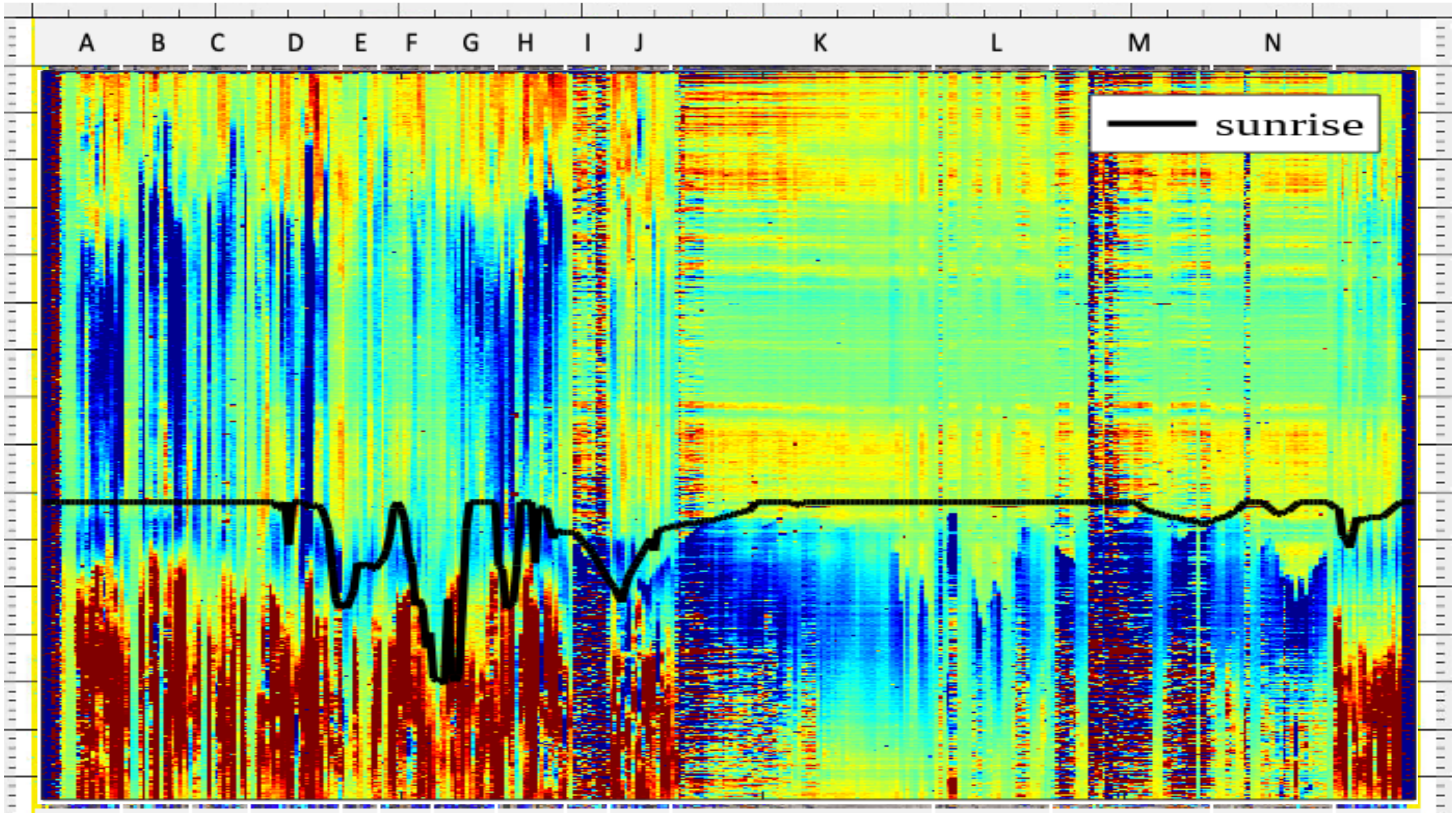

Future work

- Complete machine learning workflow for event location
  - Successful application to event detection
  - Current work focused on identifying attributes and classifications
- Create complete event catalog for all 29 days of recording
  - Time, location, magnitude
  - DAS and geophones
- Visualization of events in time and space
  - Time lapse displays of event locations in map view
- Correlation with microclimate and surficial processes
  - Time of day, sunrise, inferred temperature, glacial movement
  - Is there a predictive component we can identify ?