Building a seismic event classifier in the Pacific Northwest using AI

Distinguishing Earthquakes, Explosions & Surface Events

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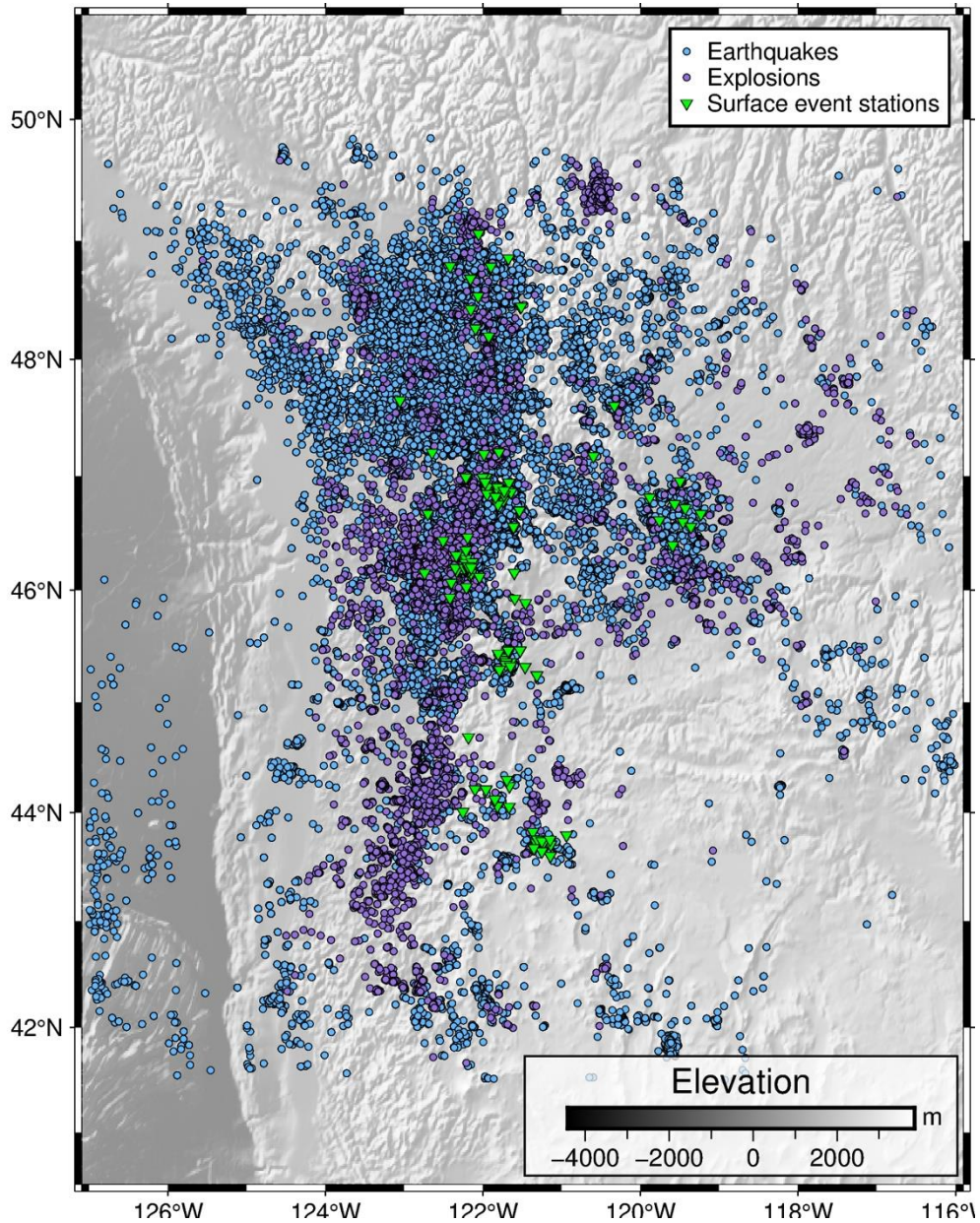
2025 CRESCENT Machine Learning Technical Short Course

PNSN
Pacific Northwest Seismic Network

USGS
science for a changing world

Why do we need a seismic event classifier in the Pacific Northwest?

Huge Diversity of Seismic Sources



Subduction Zone

microseismicty

Intraplate seismicity

Low frequency tremors

Megathrust earthquakes

20 volcanoes

Volcanic seismicity

Glacier seismicity

Deep Long Period Seismicity

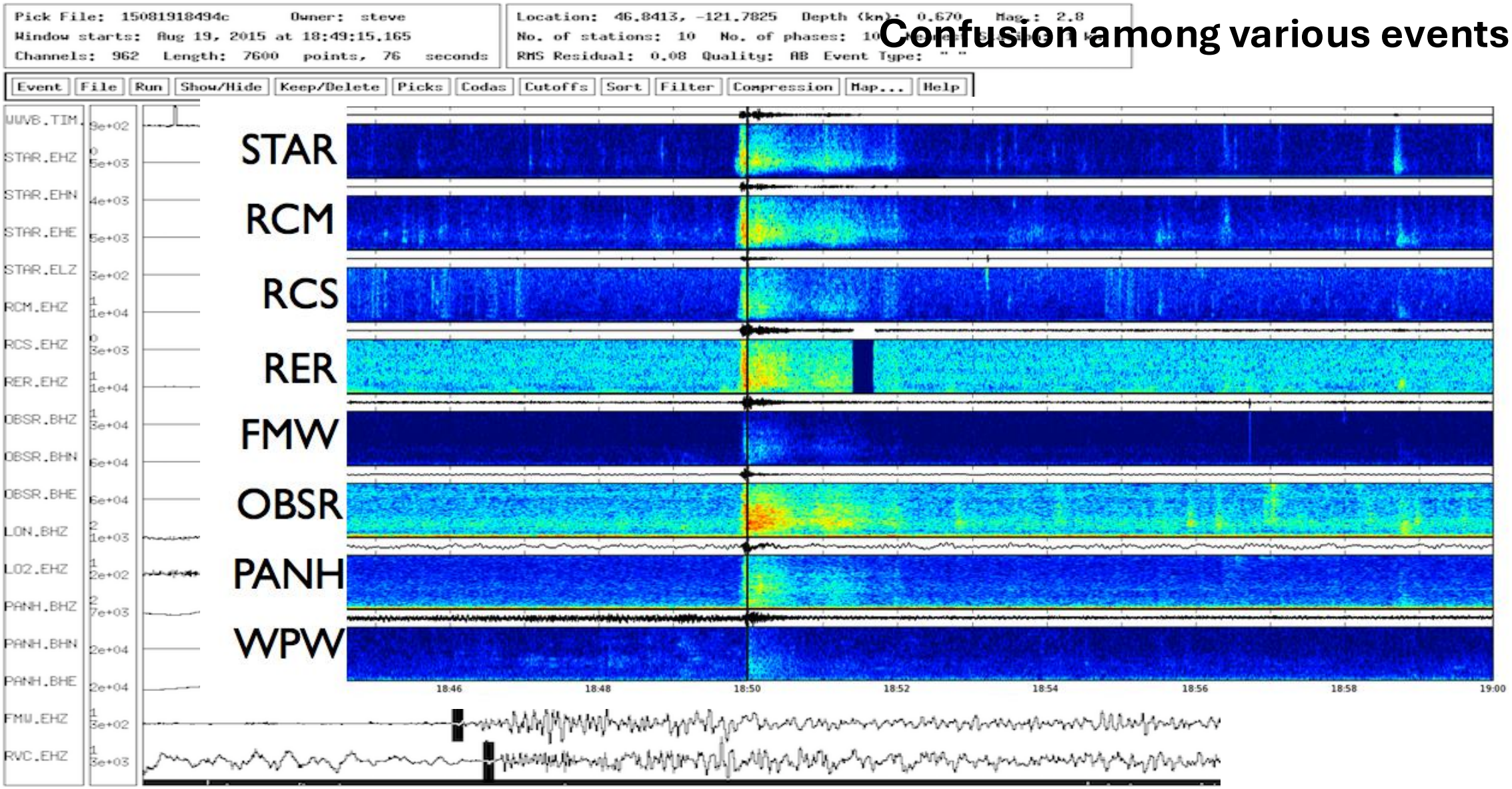
Surface events

Several quarries

Active source experiments

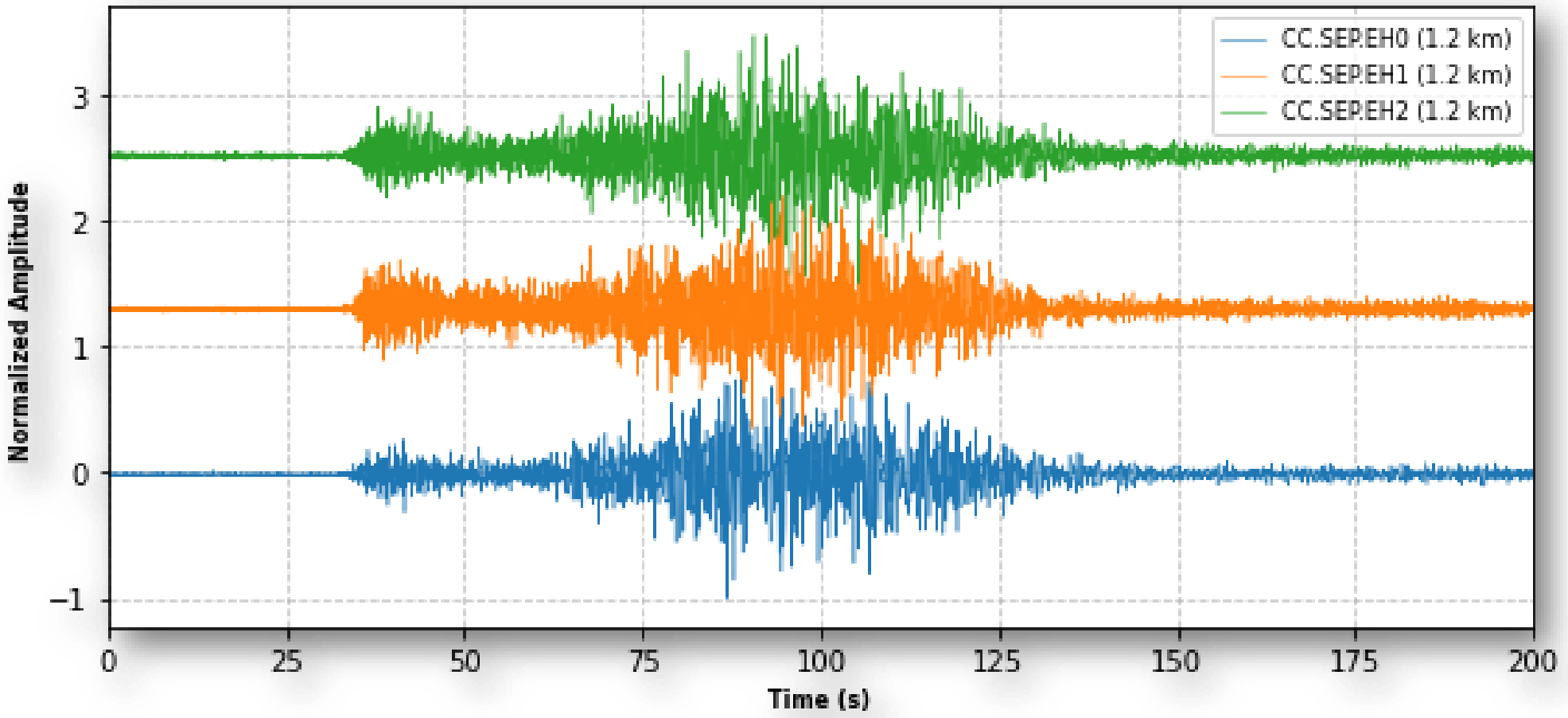
Magnitude 3.2 earthquake ??

Confusion among various events



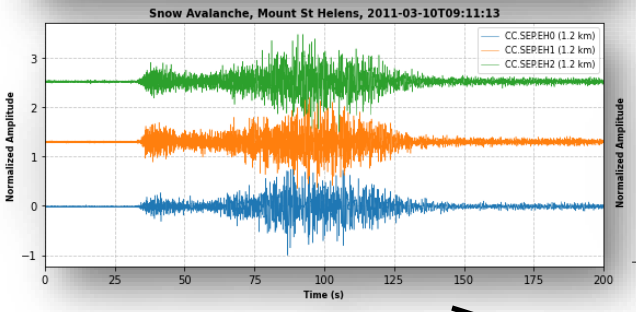
Rainier Rockfall

What is this event?

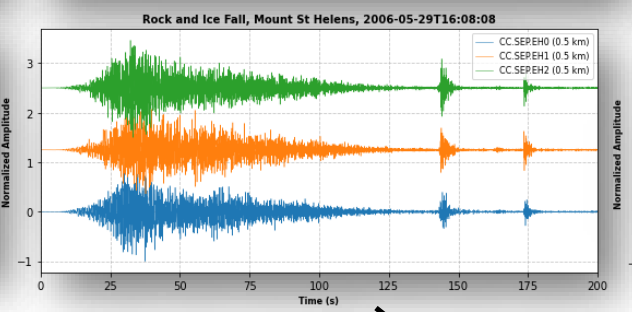


Current State of Monitoring

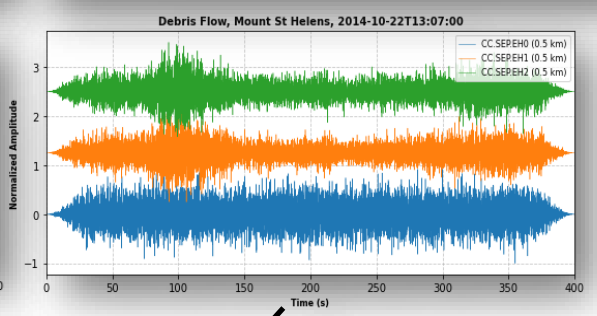
Snow Avalanche



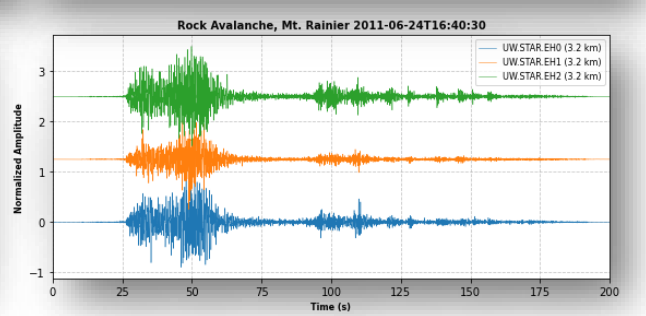
Rock and Ice Fall



Debris Flow



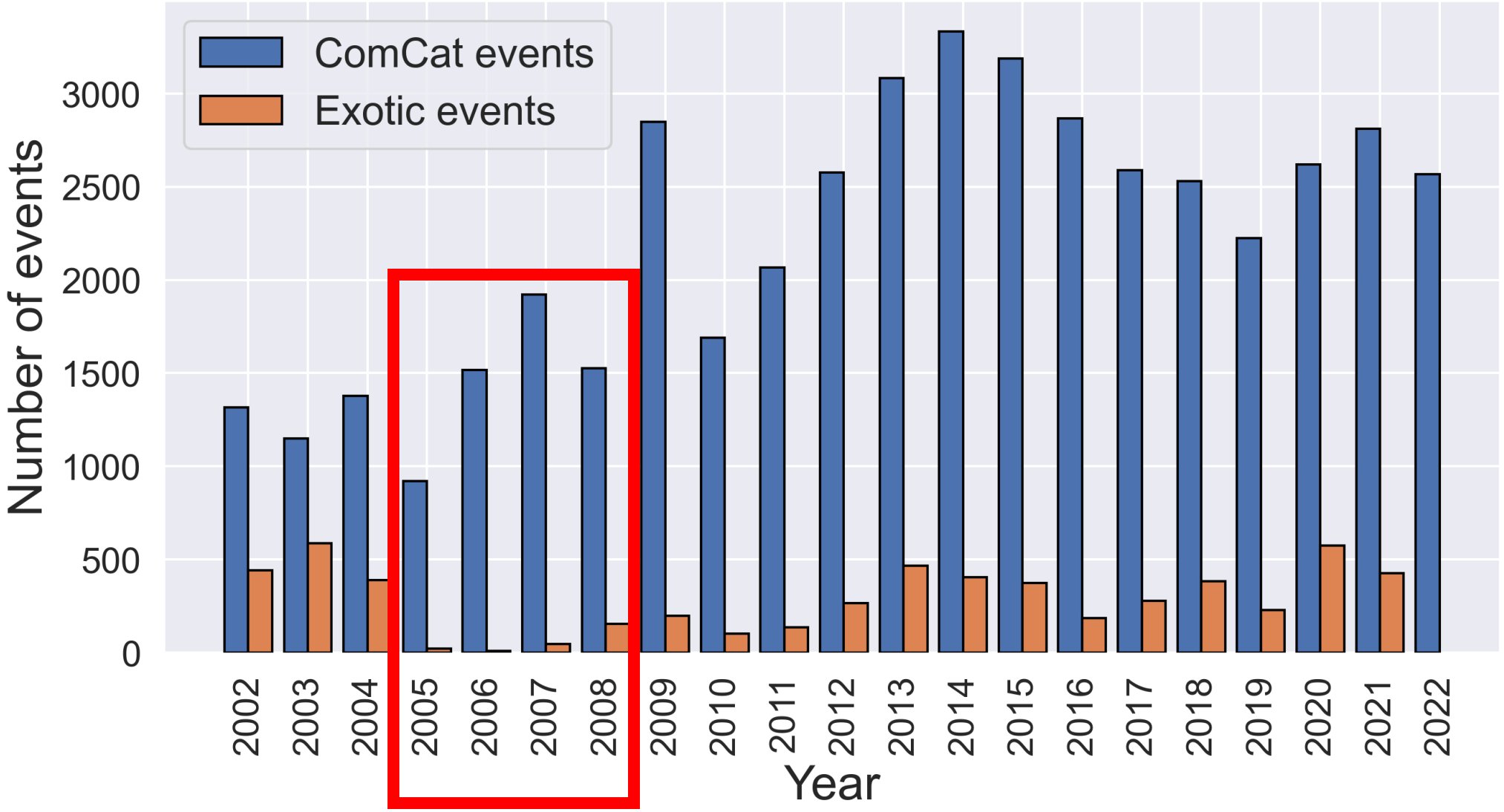
Rock Avalanche



Surface event

Over 9k Unidentified surface events in the PNSN catalog and this number is continuously increasing …

Current State of Monitoring



Ni et al. (2023)

To assist analysts in their decision

Confusing events, low mag, low snr

Why do we need a seismic event classifier in the Pacific Northwest?

Locating them not always possible

Developing a surface event catalog

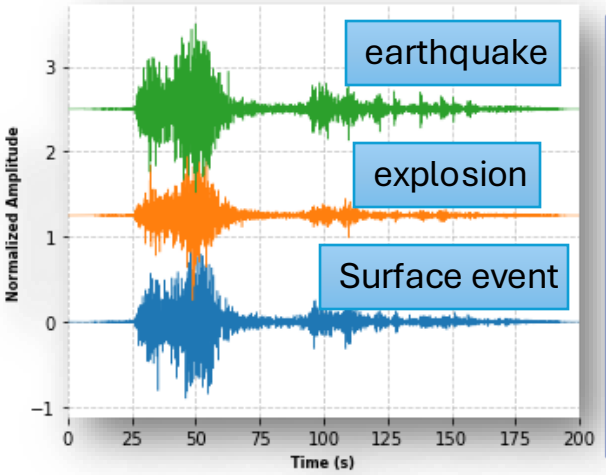
Huge number of unreviewed events

STA/LTA cannot detect emergent events

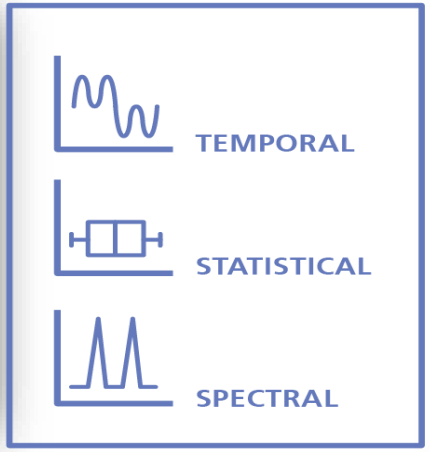
How to build a seismic event classifier using AI?

Developing a seismic event classifier

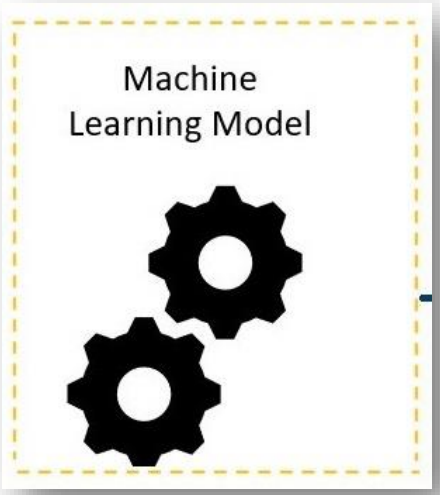
1. Labeled Dataset

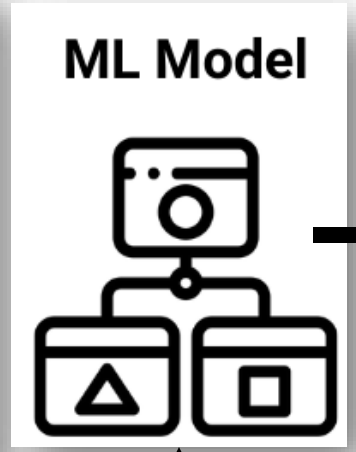


2. Feature Extraction

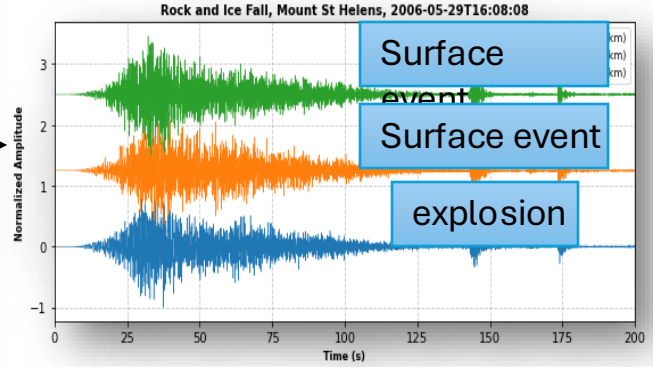


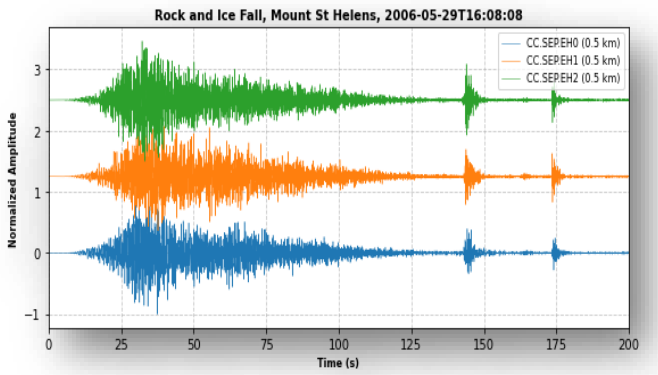
3. Model Training





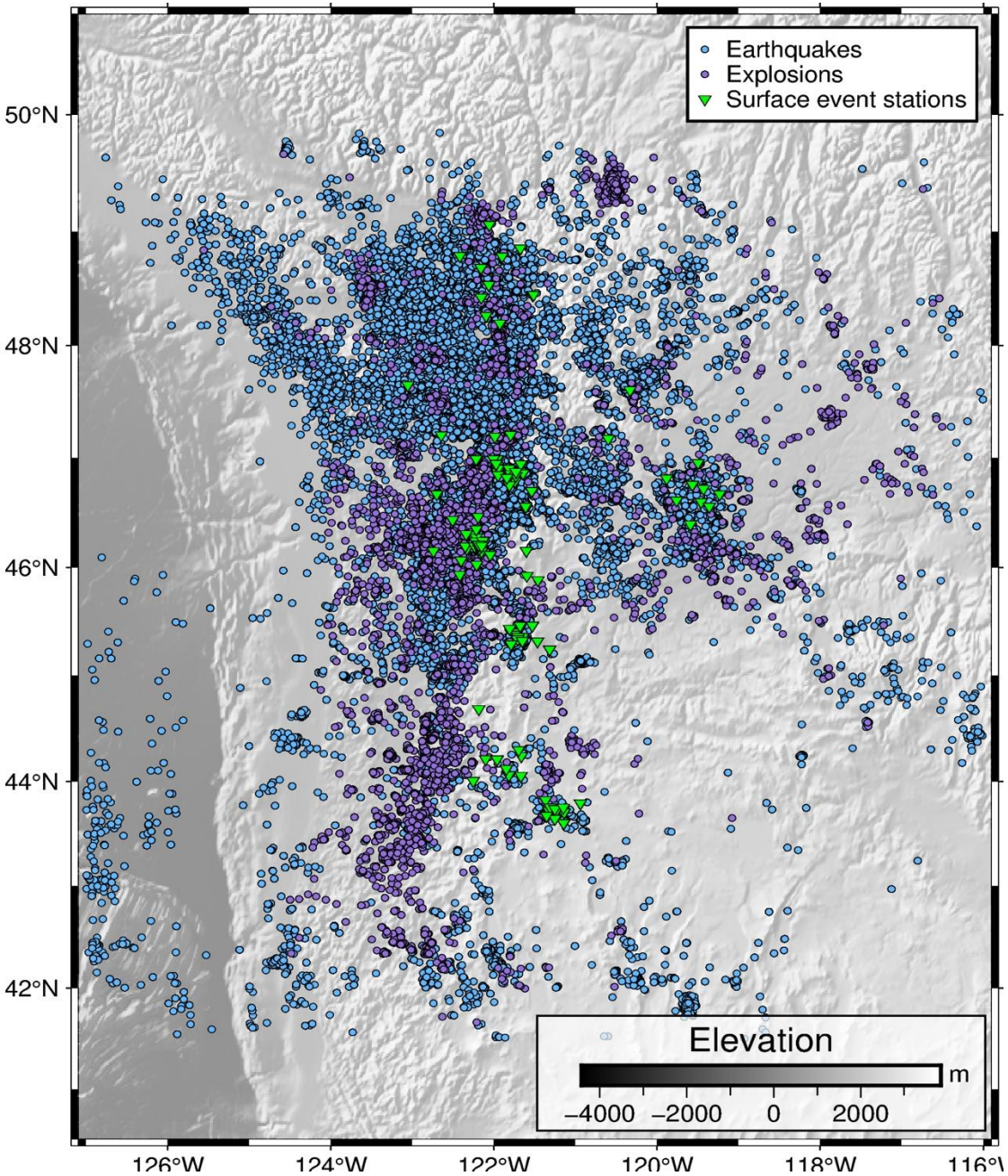
4. Model Evaluation

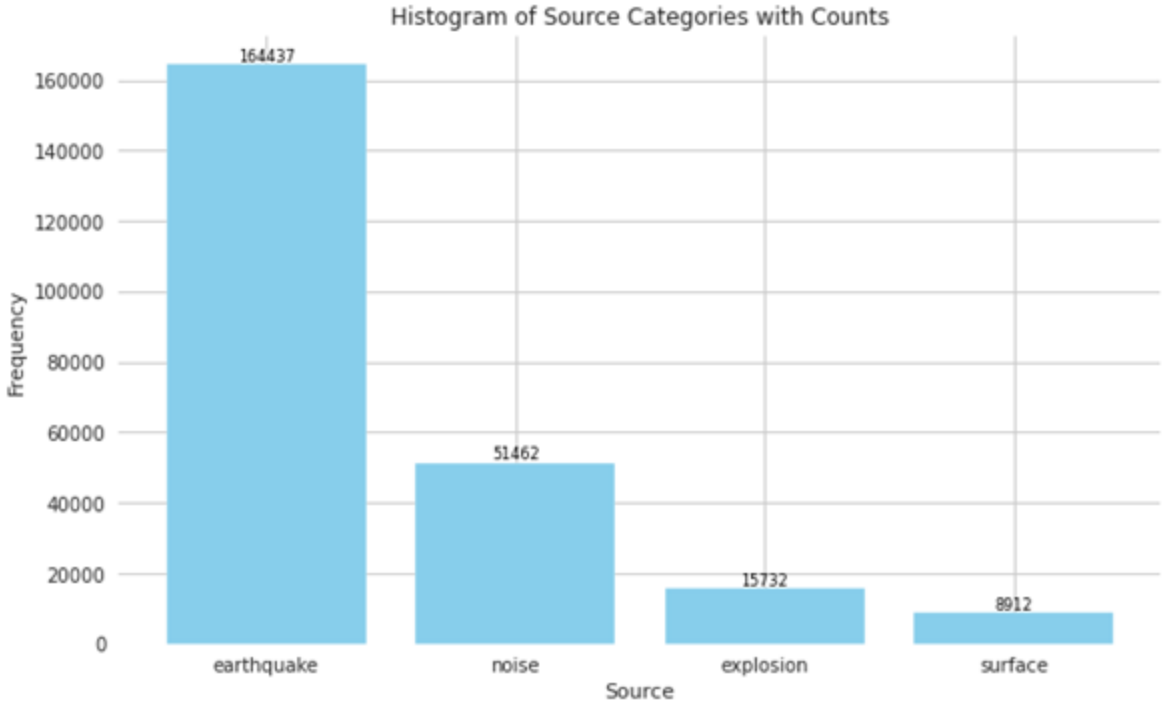




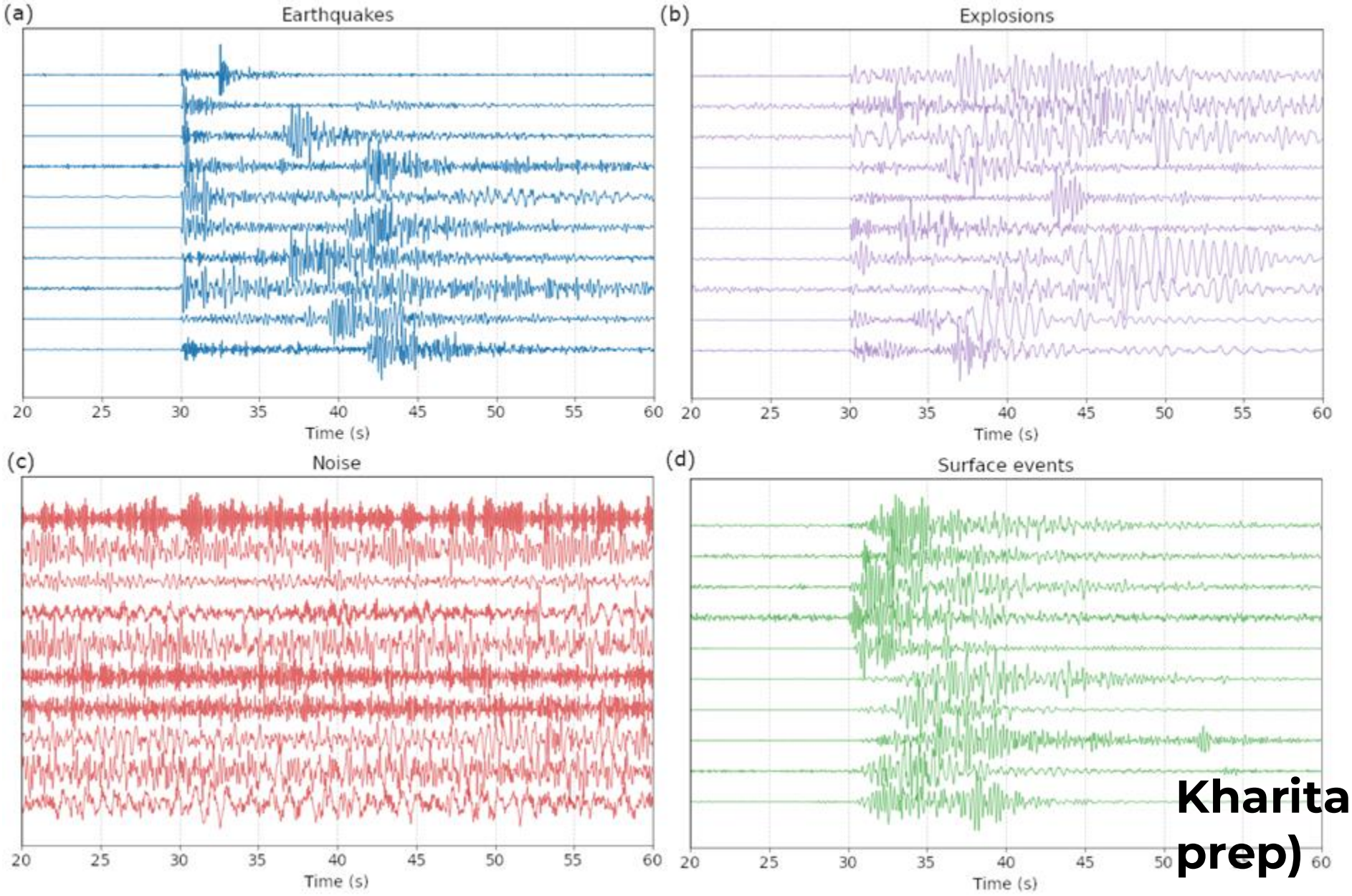
Unlabeled Test data

1. Labeled Dataset





The PNW curated data set has diverse source types, with mainly Earthquakes, Explosions, and Surface events



Kharita et al. (in prep)

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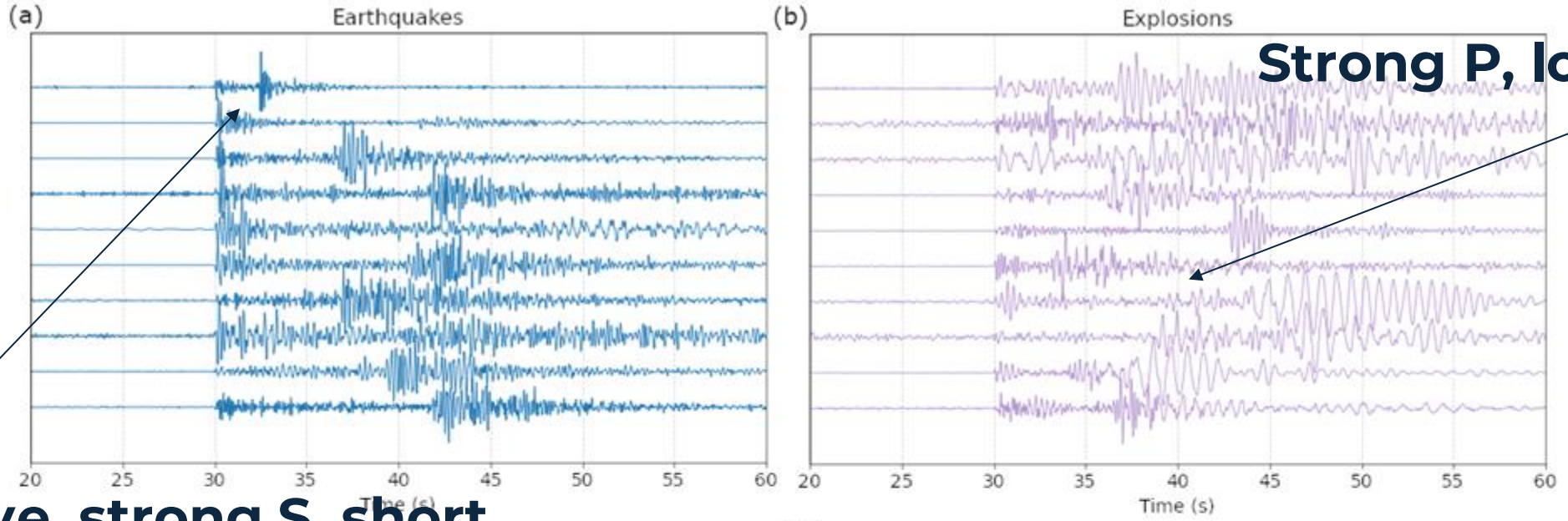
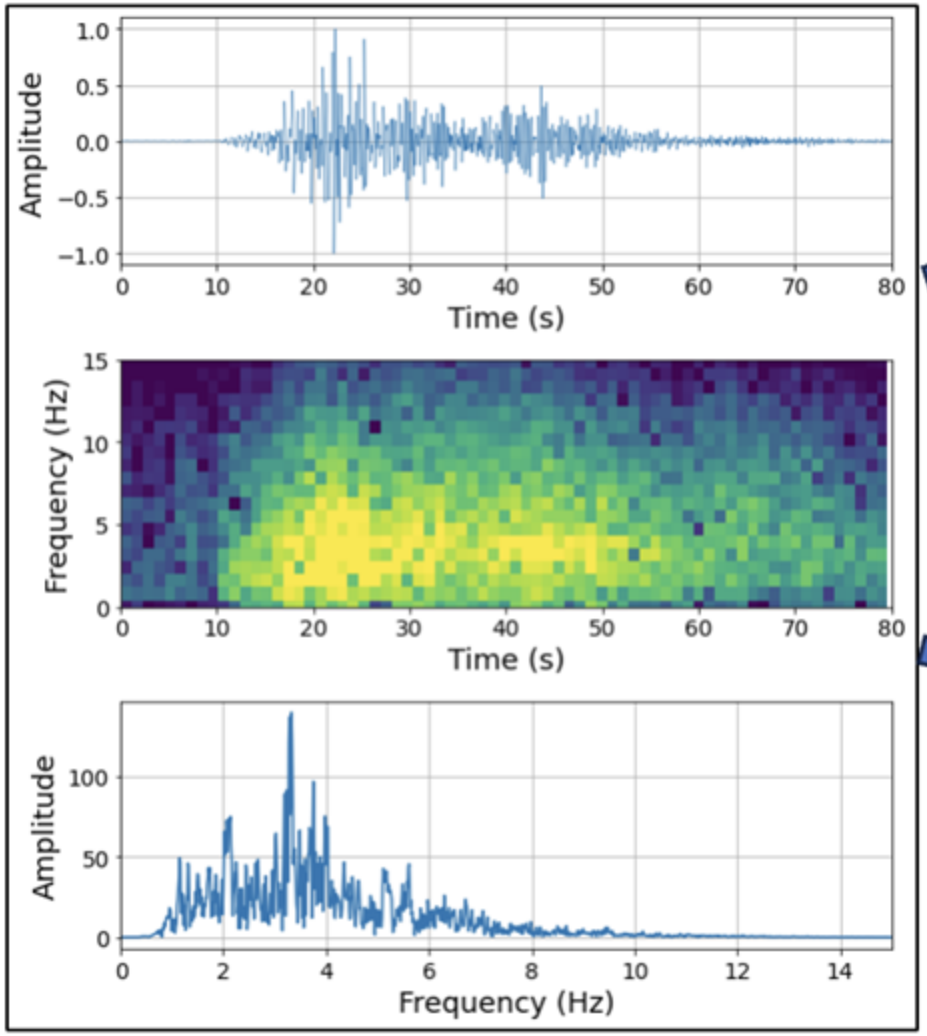


Kharita et al. (in prep)

Event Discrimination using Machine Learning



Classic ML Algorithms

Feature extraction
- Tsfel
- Tsfresh
- Physics based features

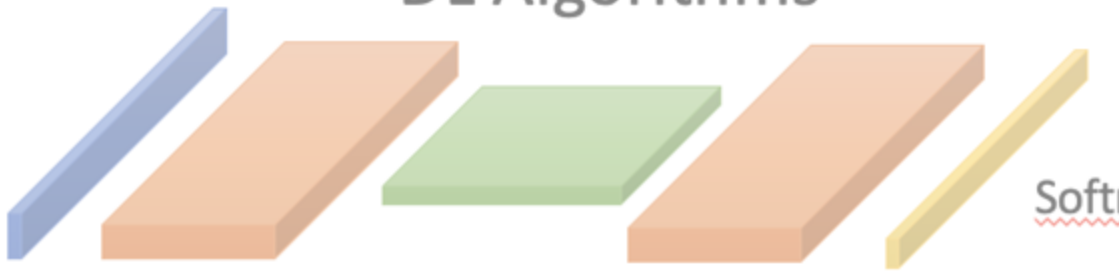
Feature Selection
- PCA
- T-SNE
- ICA
- RFE

ML Algorithms
- SVM
- RF
- LR
- KNN

Feature engineering

Training

DL Algorithms

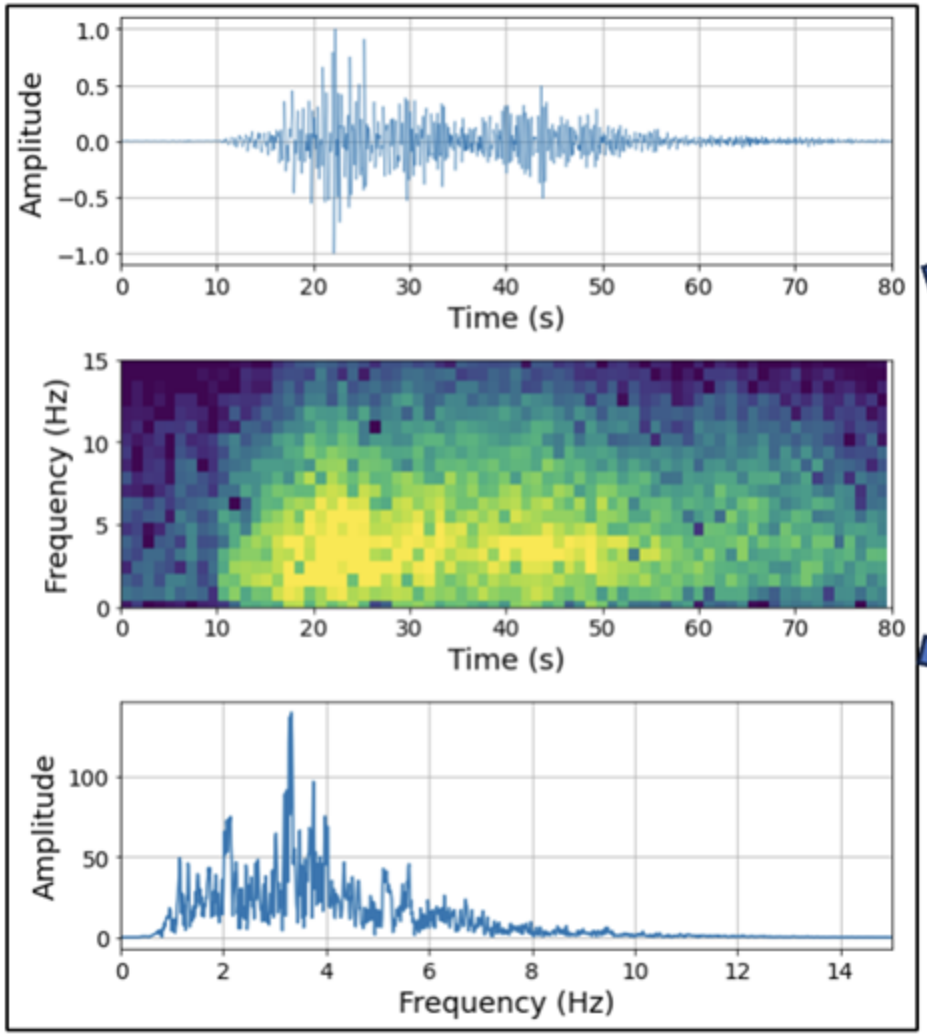


Automatic Feature Learning

- Eq
- Exp
- No
- Su

Kharita et al. (in prep)

Event Discrimination using Machine Learning



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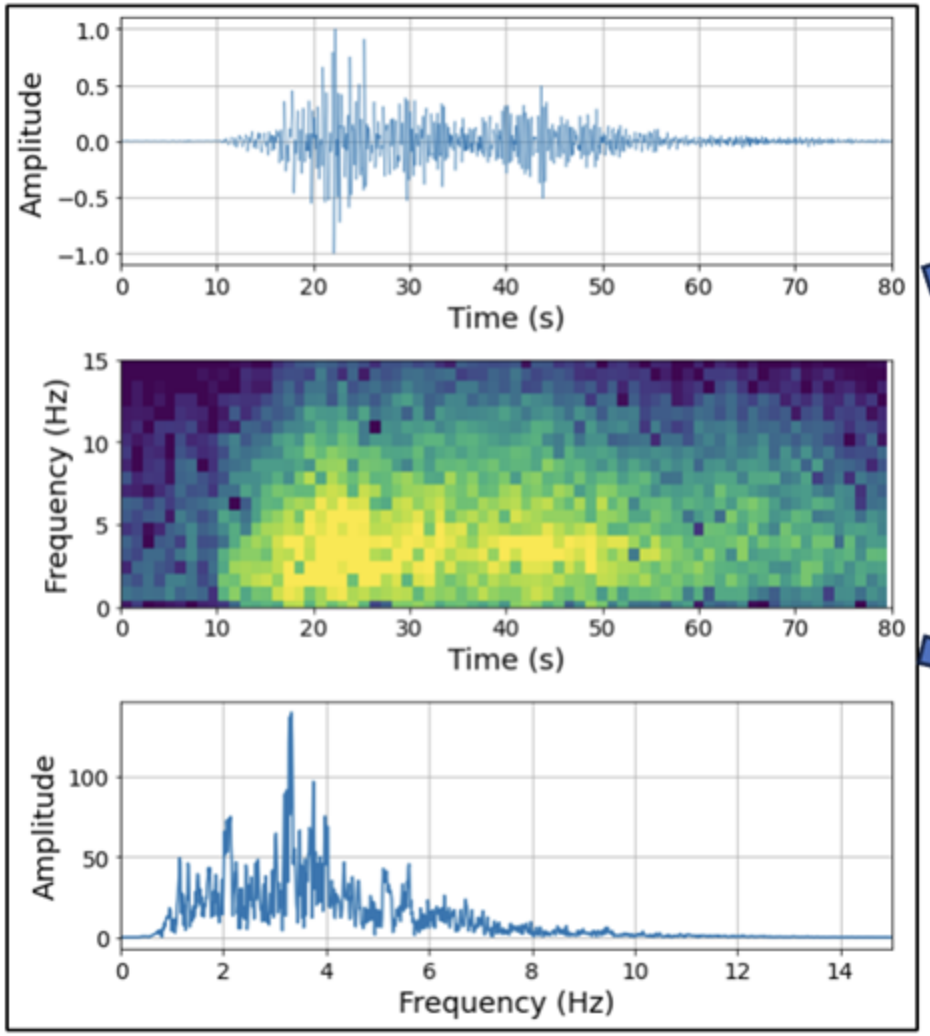

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Feature engineering

Training

Much of ML in environmental seismology uses Random Forest

DL Algorithms

Automatic Feature Learning

Eq

Exp

No

Su

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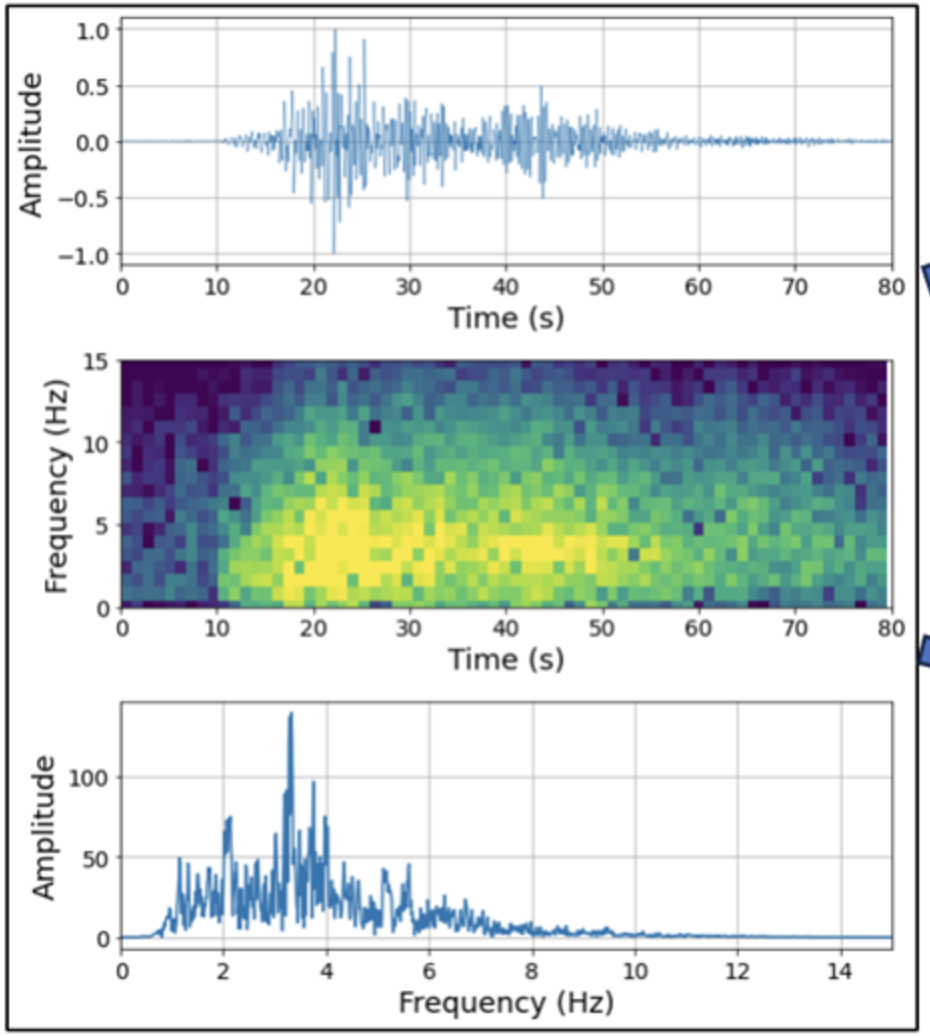
Event Discrimination using Machine Learning



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ML Algorithms
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Feature engineering

Training

DL Algorithms

Much of ML for earthquake catalog building uses Deep Learning

Automatic Feature Learning

- Eq
- Exp
- No
- Su

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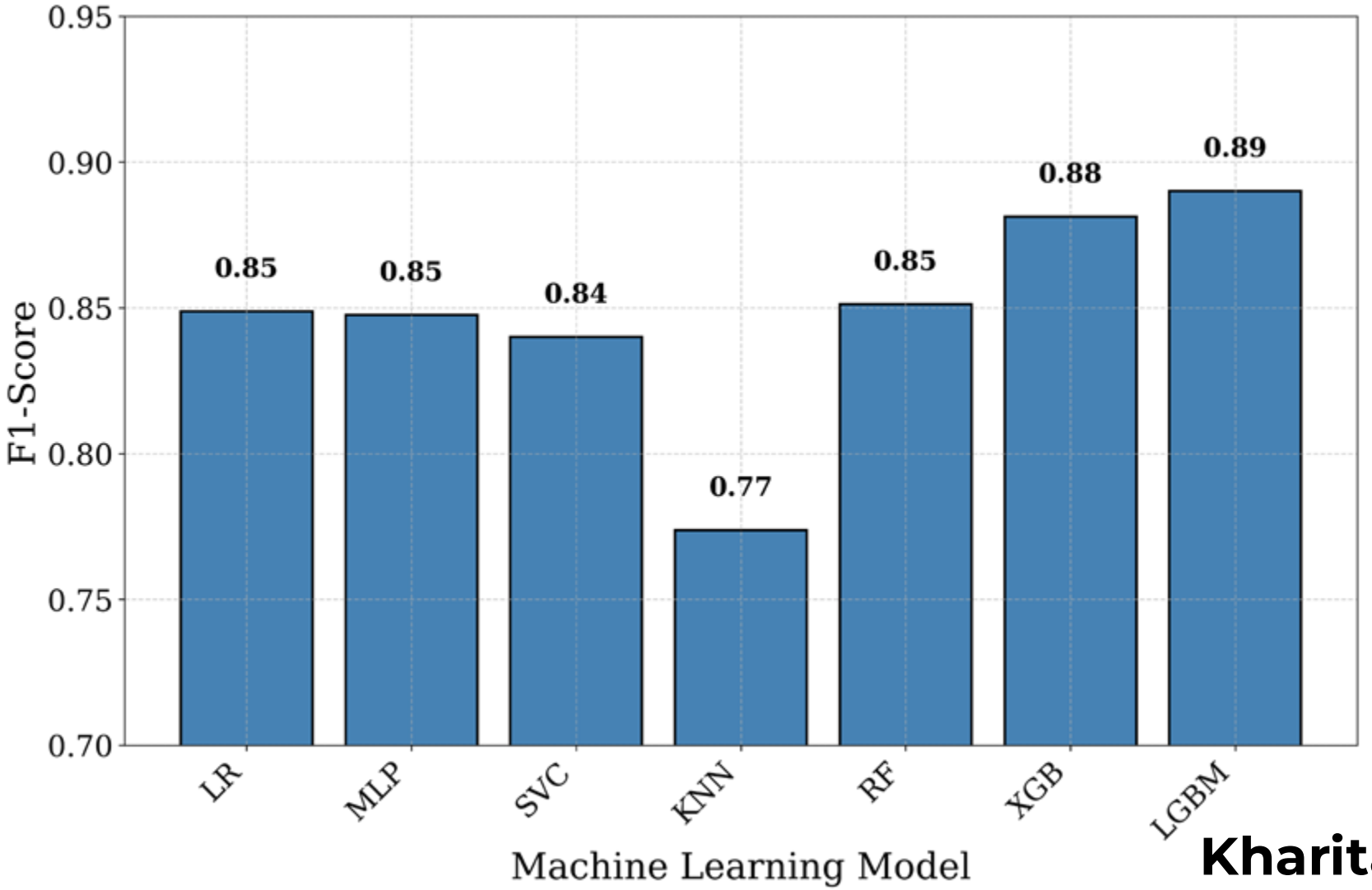
Classic Machine Learning:

Decision-Trees-based models always win



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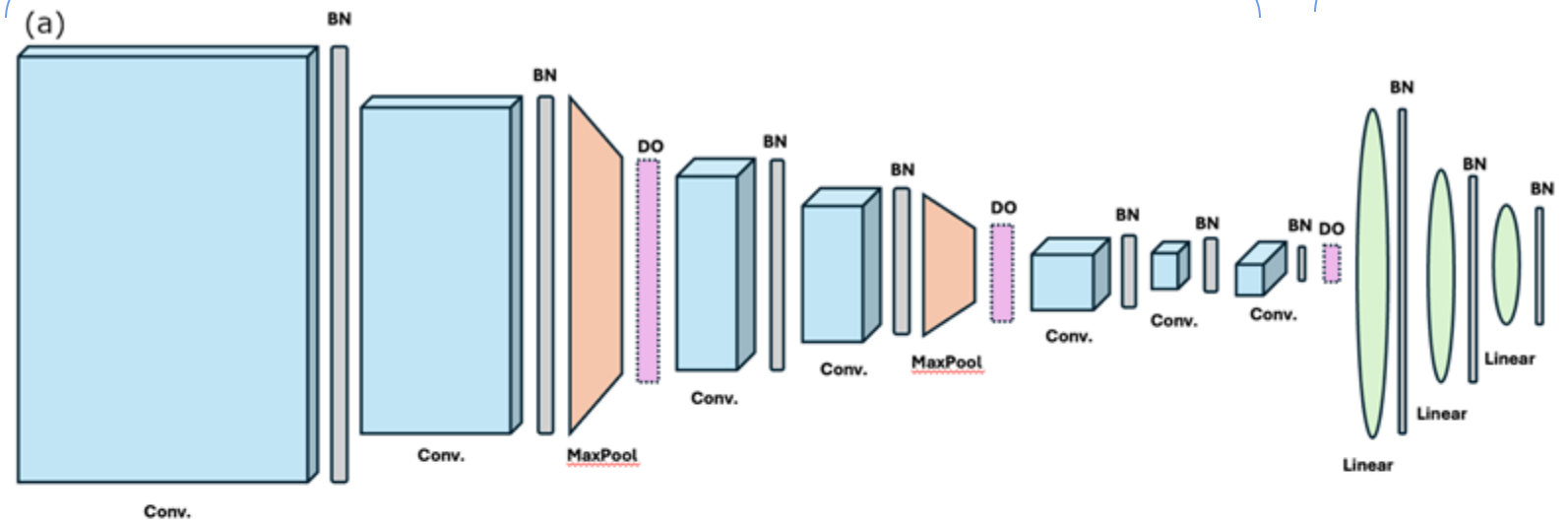
Deep Learning: CNNs are great and simple for classification

Feature extraction

classifier

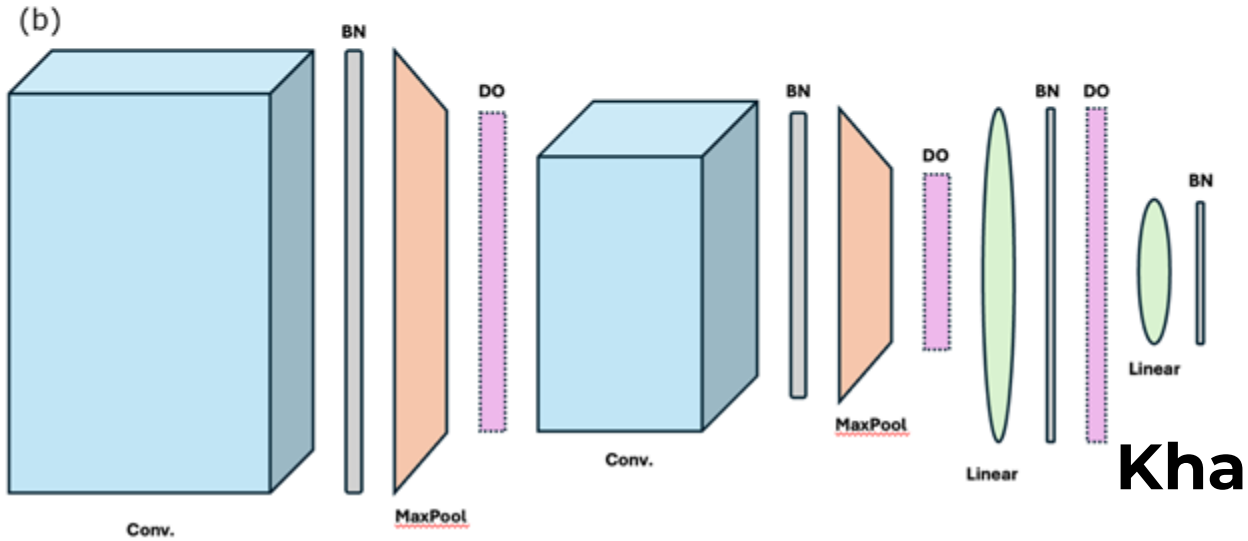
Long skinny

QuakeXNet



Shallow & wide

SeismicCNN



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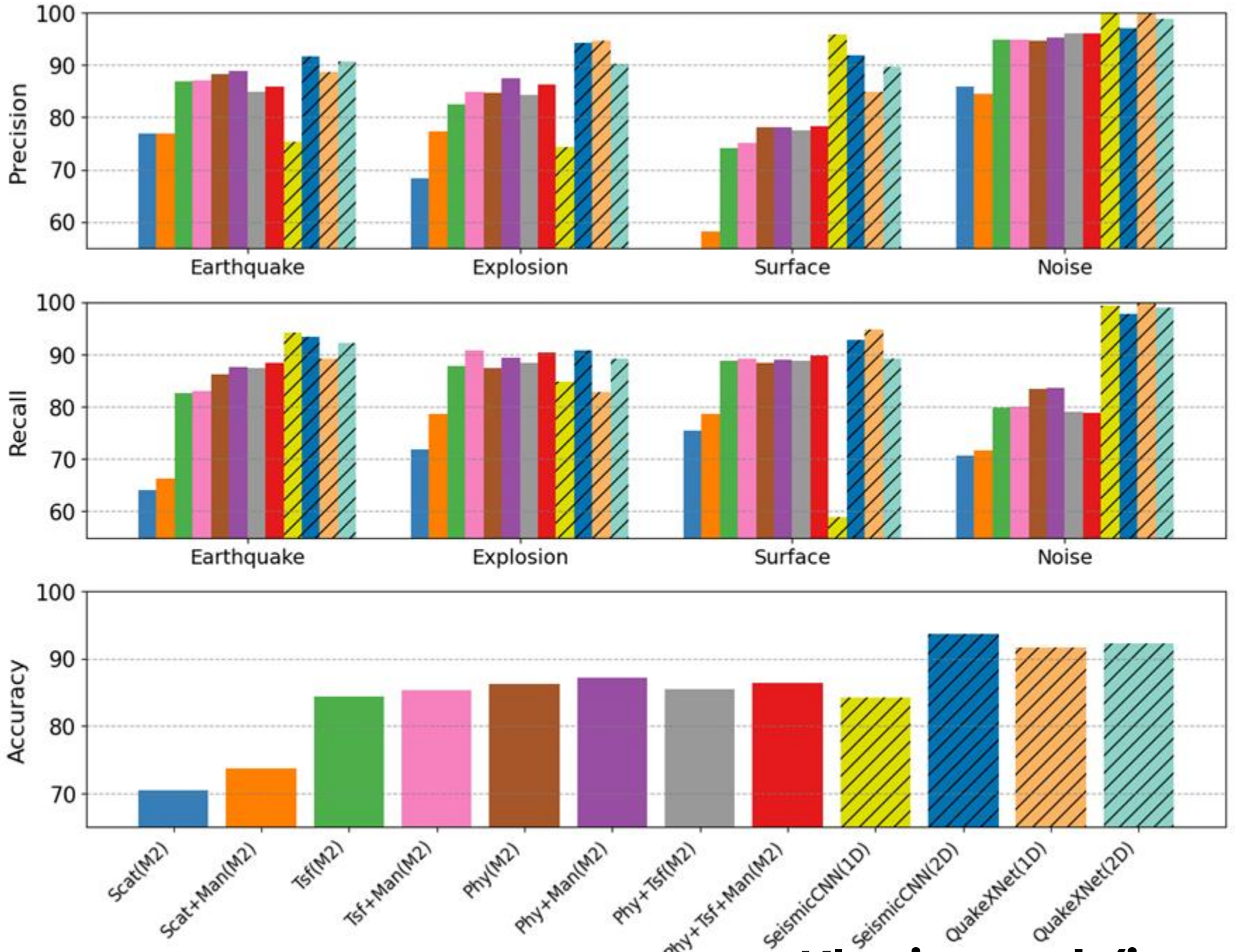
Performance

Deep Learning outperforms classic Machine Learning

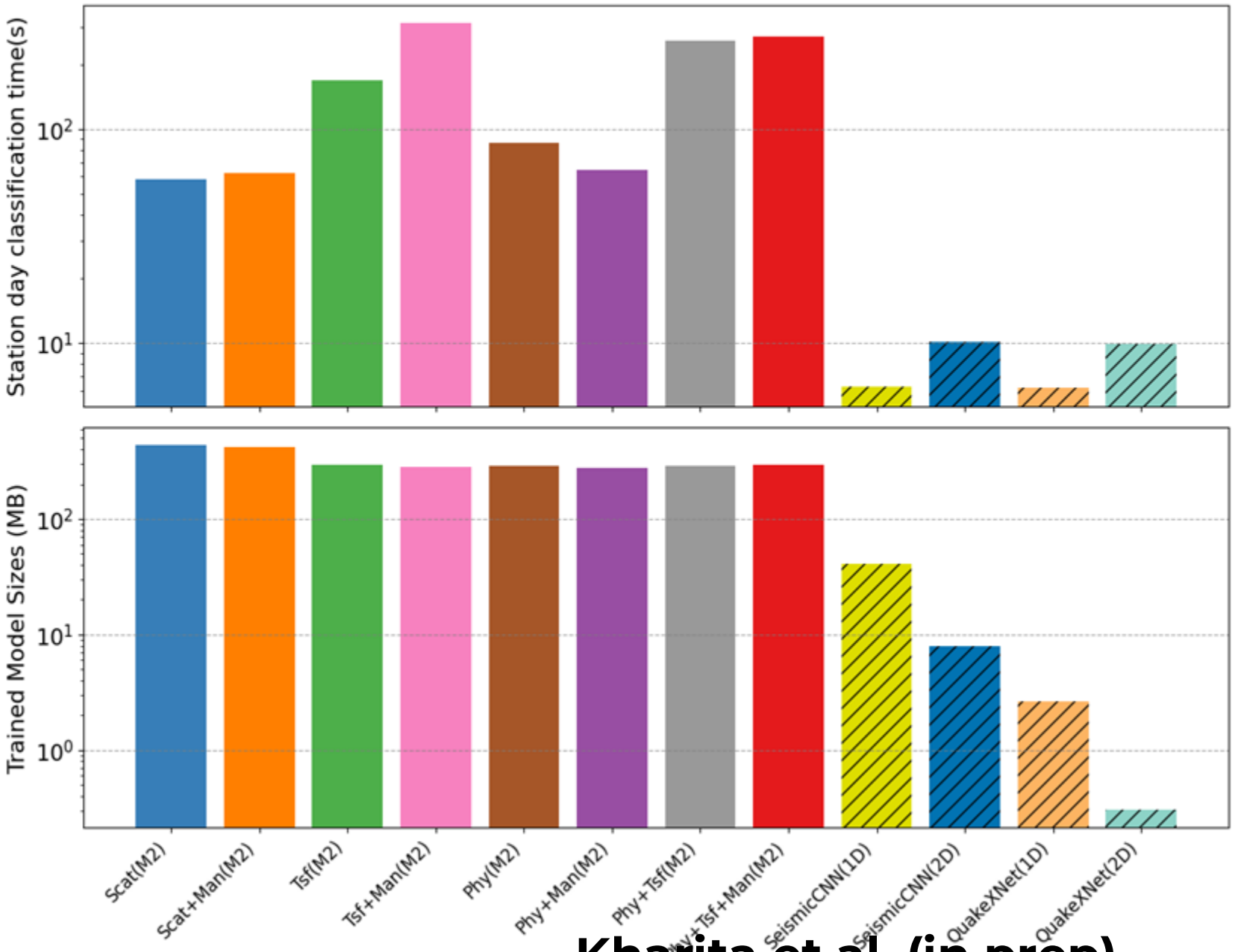
(on balanced data sets)



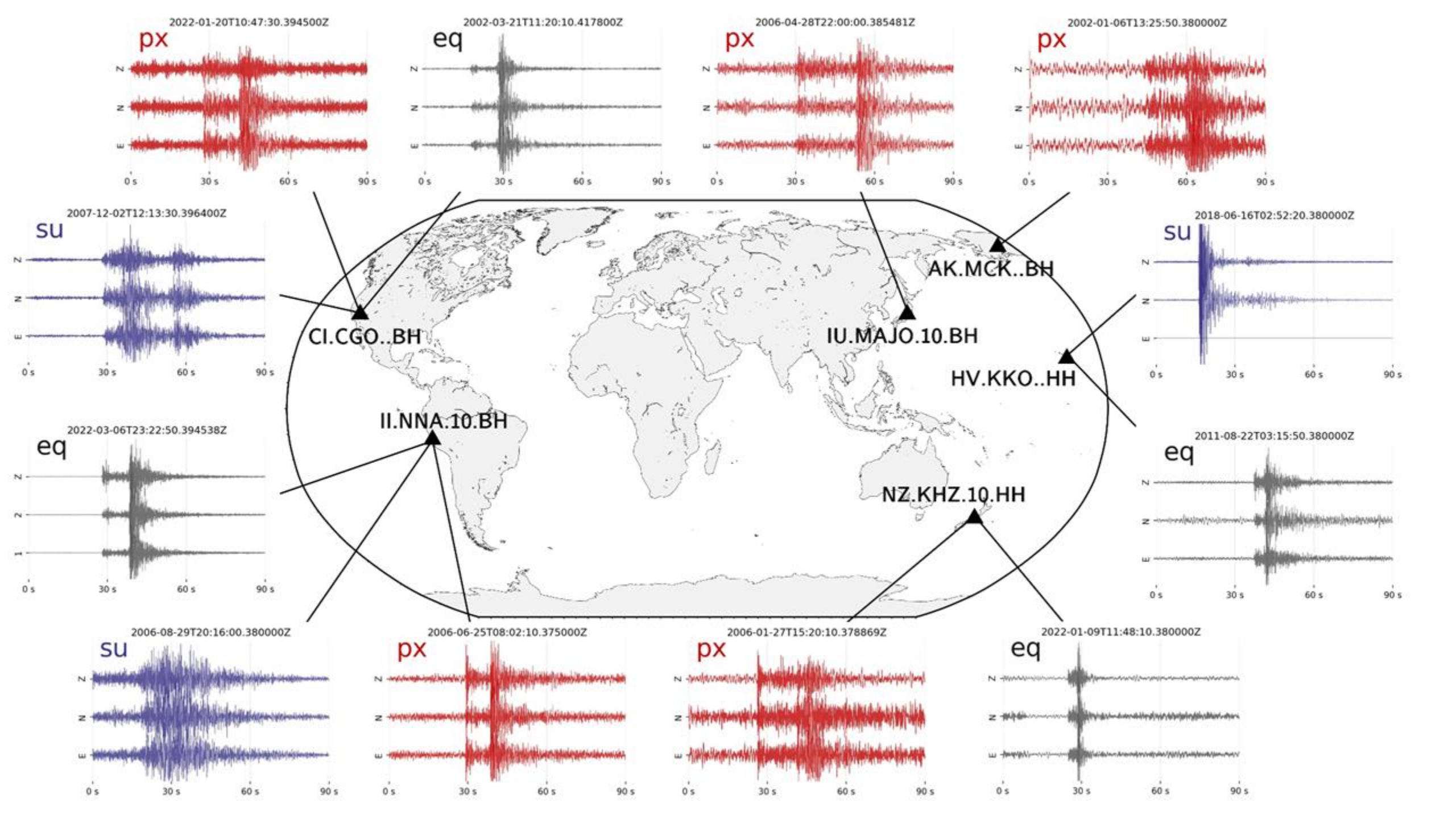
Kharita et al. (in

Computationa performance

Extracting features from time series takes much longer than DL inference.



Kharita et al. (in prep)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px
2007-12-02T12:13:30.396400Z
su
2018-06-16T02:52:20.380000Z
su
AK.MCK..BH
CI.CGO..BH
IU.MAJO.10.BH
HV.KKO..HH
II.NNA.10.BH
NZ.KHZ.10.HH
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eq
2011-08-22T03:15:50.380000Z
eq
2006-08-29T20:16:00.380000Z
su
2006-06-25T08:02:10.375000Z
px
2006-01-27T15:20:10.378869Z
px
2022-01-09T11:48:10.380000Z
eq
0 s
30 s
60 s
90 s

Thank you

https://github.com/Akashkharita/PNW_Seismic_Event_Classification

Future plans - Analyzing global detections, deploying in PNSN, Analyzing the generalizability