AI-powered Earthquake Data Denoising

Data Science Lab 2024
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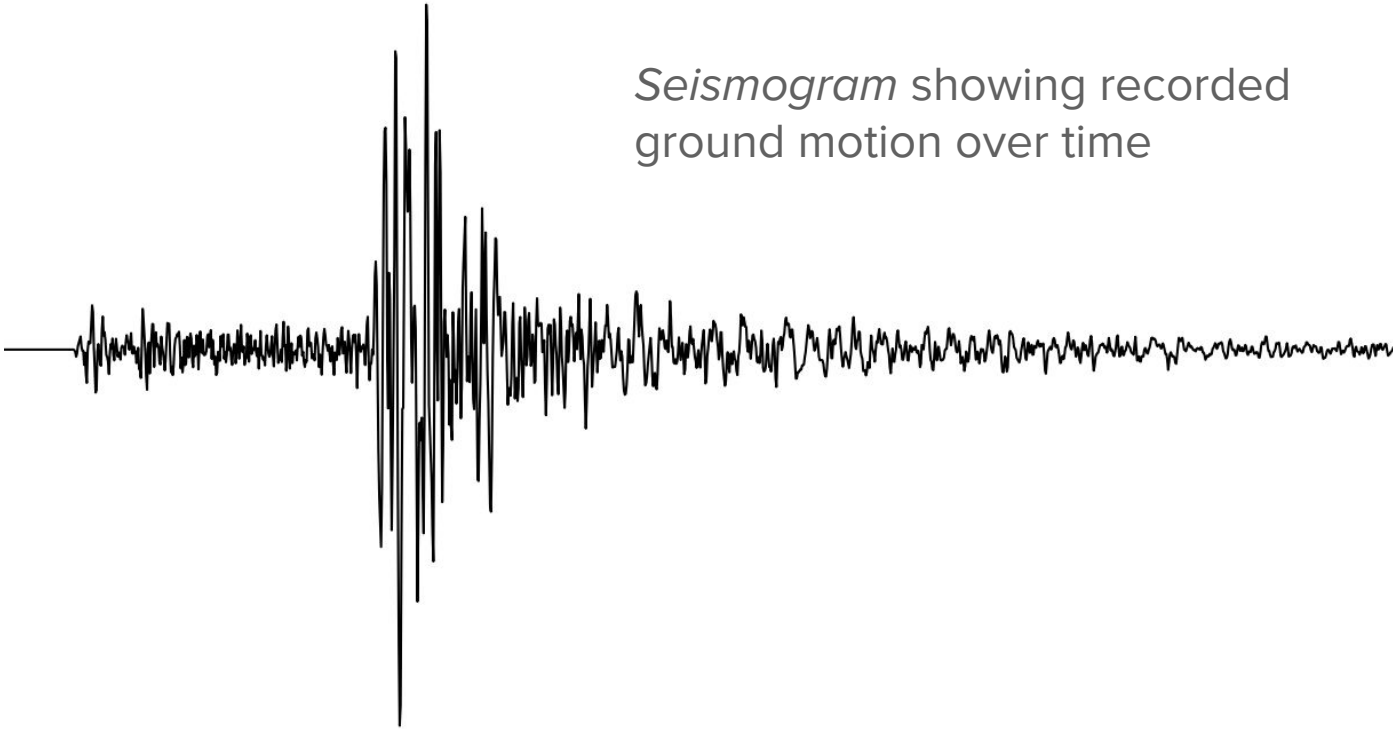
ETH Zurich

- Organisation
- Intro: earthquakes and their recordings, key parameters
- Swiss seismic network and earthquakes
- Data set
- Task & Evaluation

Organisation

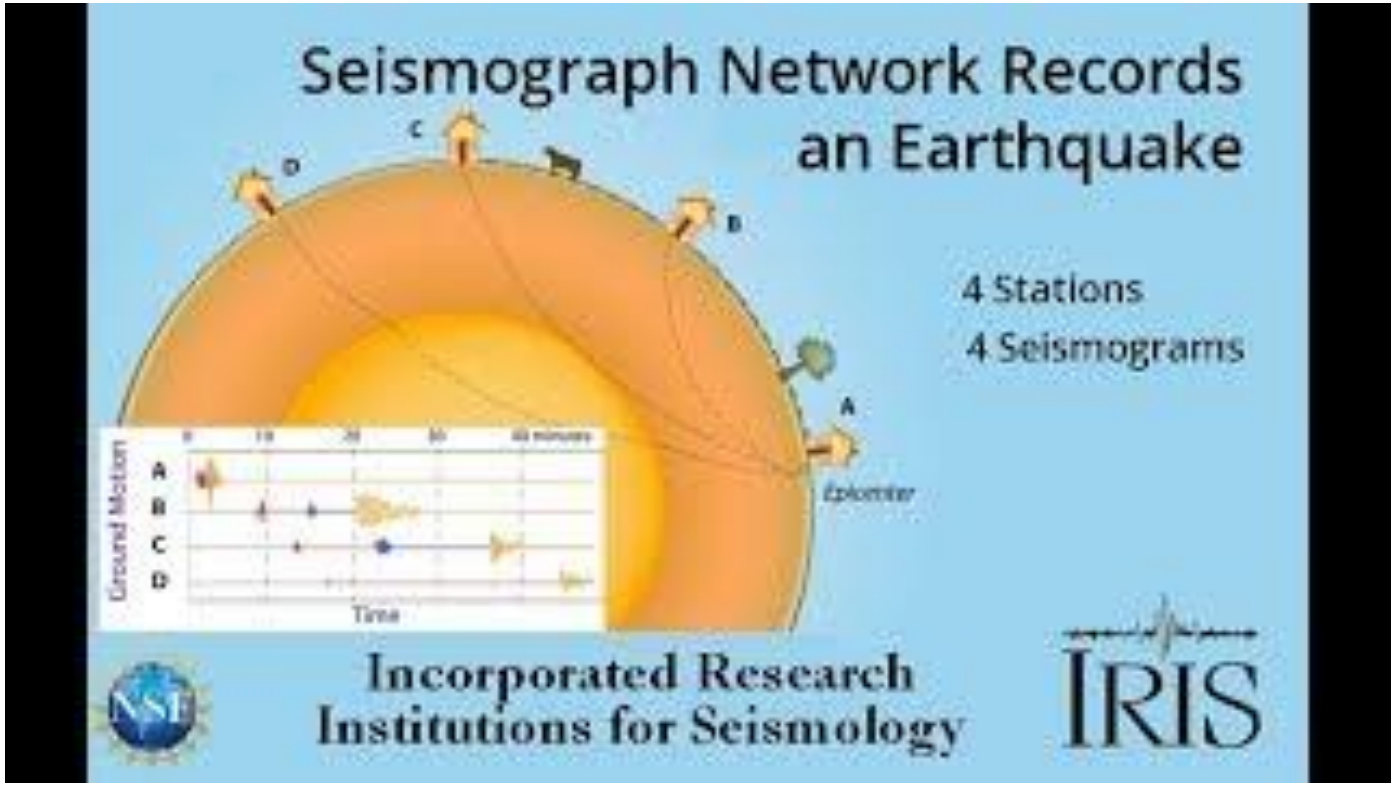
Intro

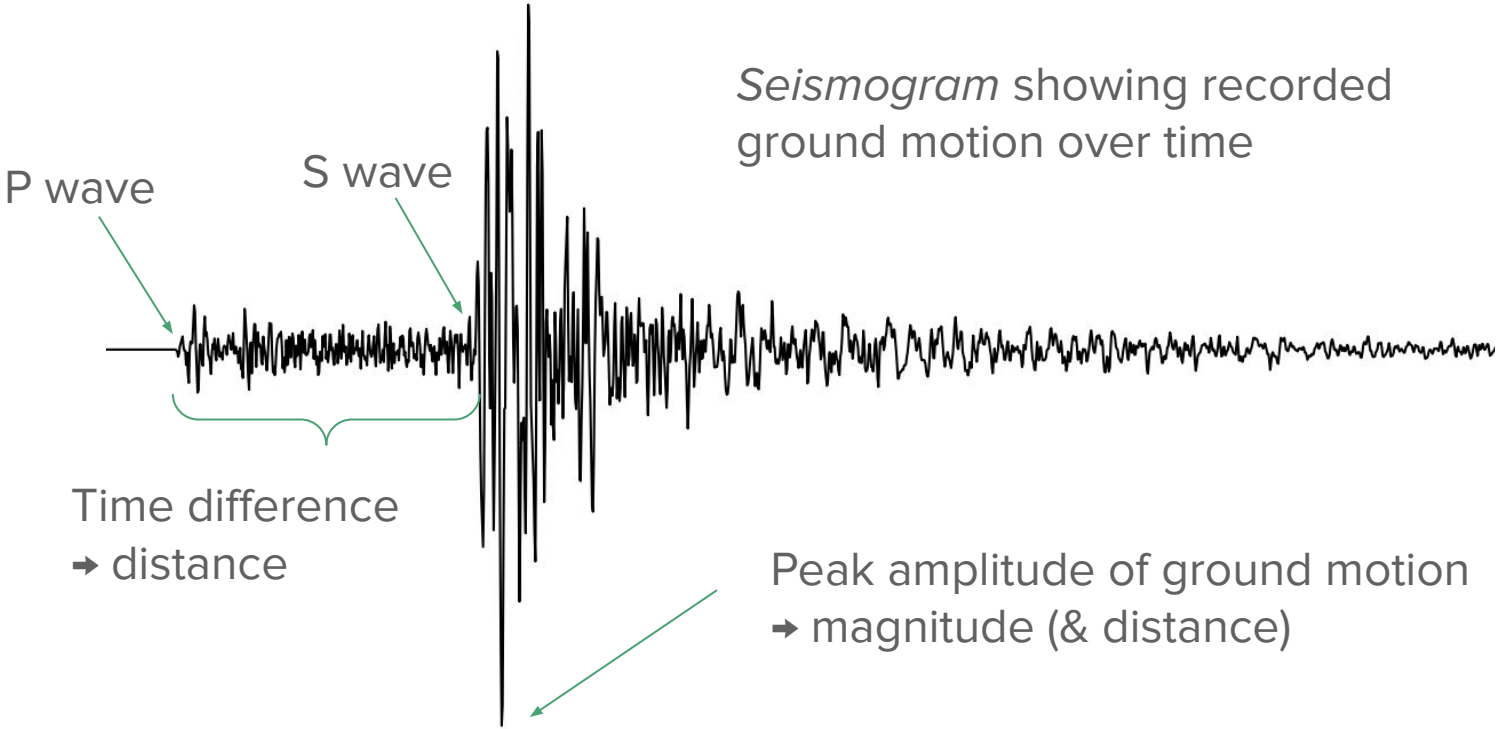
Earthquake data



Seismogram showing recorded ground motion over time

Earthquake recordings



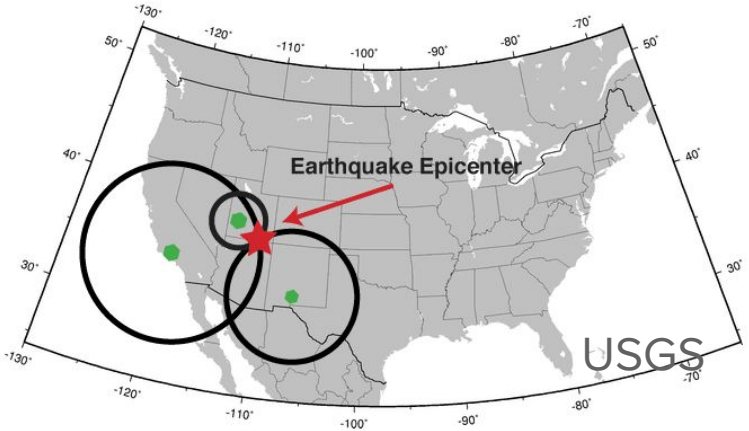

P wave
S wave
Seismogram showing recorded ground motion over time
Time difference
➔ distance
Peak amplitude of ground motion
➔ magnitude (& distance)

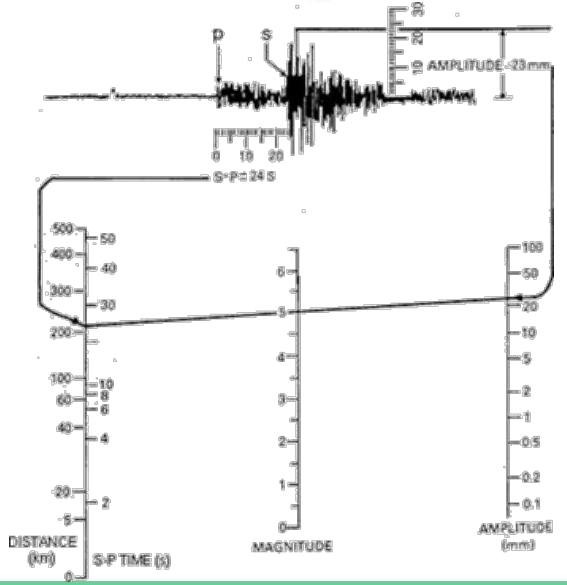
Earthquake - Key Parameters

Location (hypocentre) - triangulation using time difference of P and S arrivals from several stations

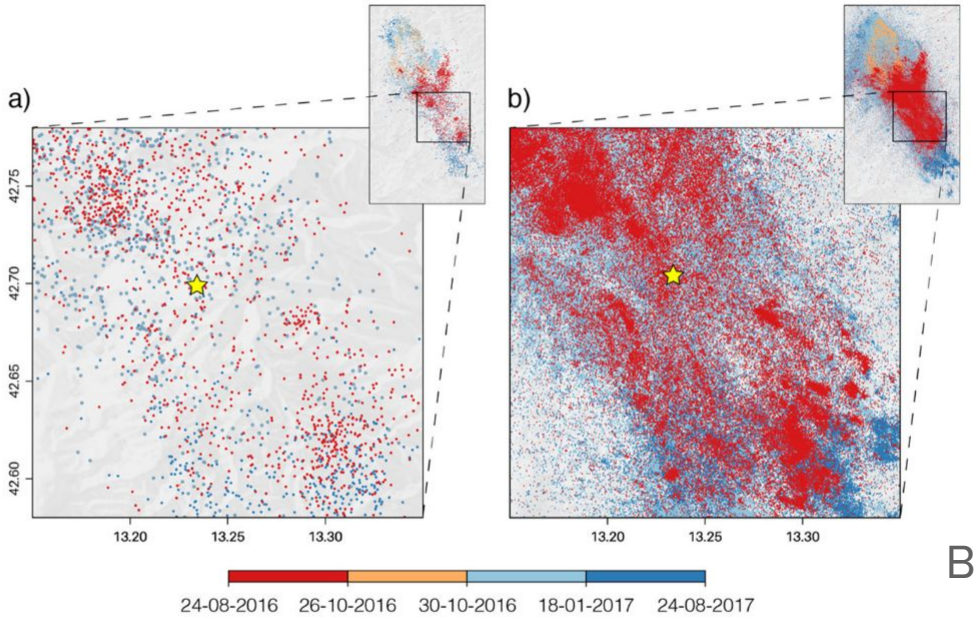
Strength (magnitude): estimated from recorded peak amplitude and distance to quake

(simple methods)





Improvements thanks to ML methods

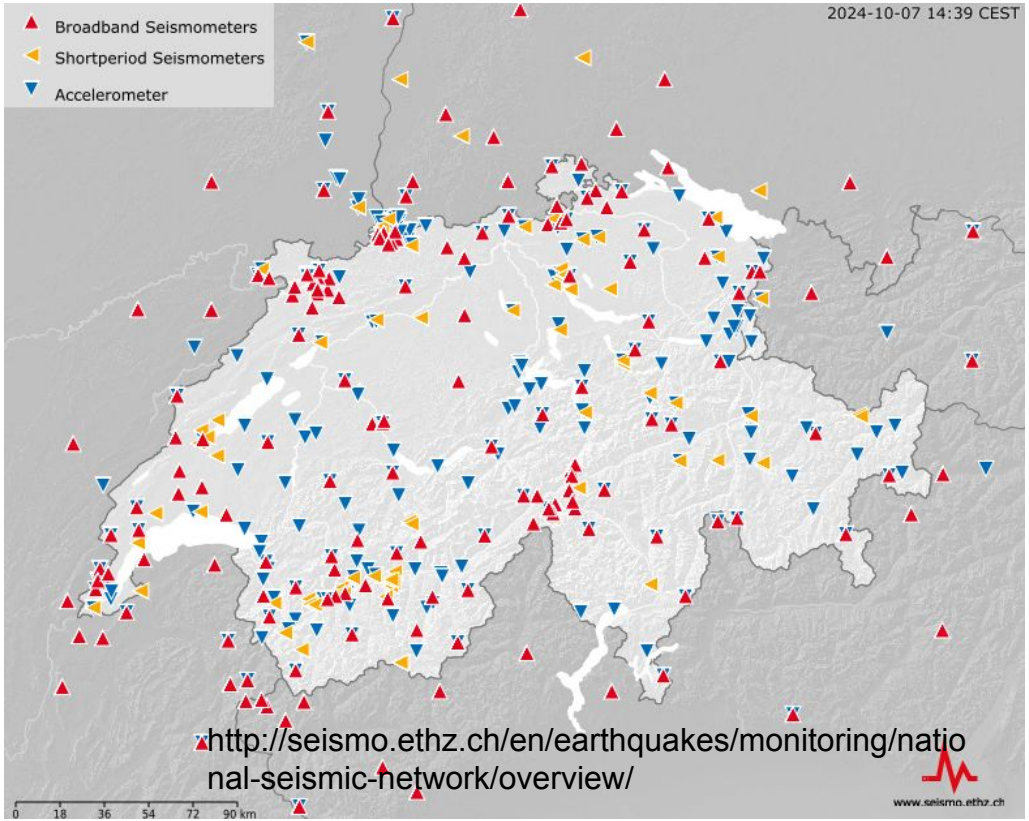


Beroza et al. (2021)

Fig. 1 A year of seismicity in the epicentral area of the 2016 $M = 6.0$ Amatrice earthquake (star) in Italy color coded by time of occurrence. a Real-time catalog, available at http://cnt.rm.ingv.it/ and (**b**) machine-learning catalog[16] are shown for event magnitudes above their respective magnitude of completeness[12,16] Mc = 2.2 and Mc = 0.5.

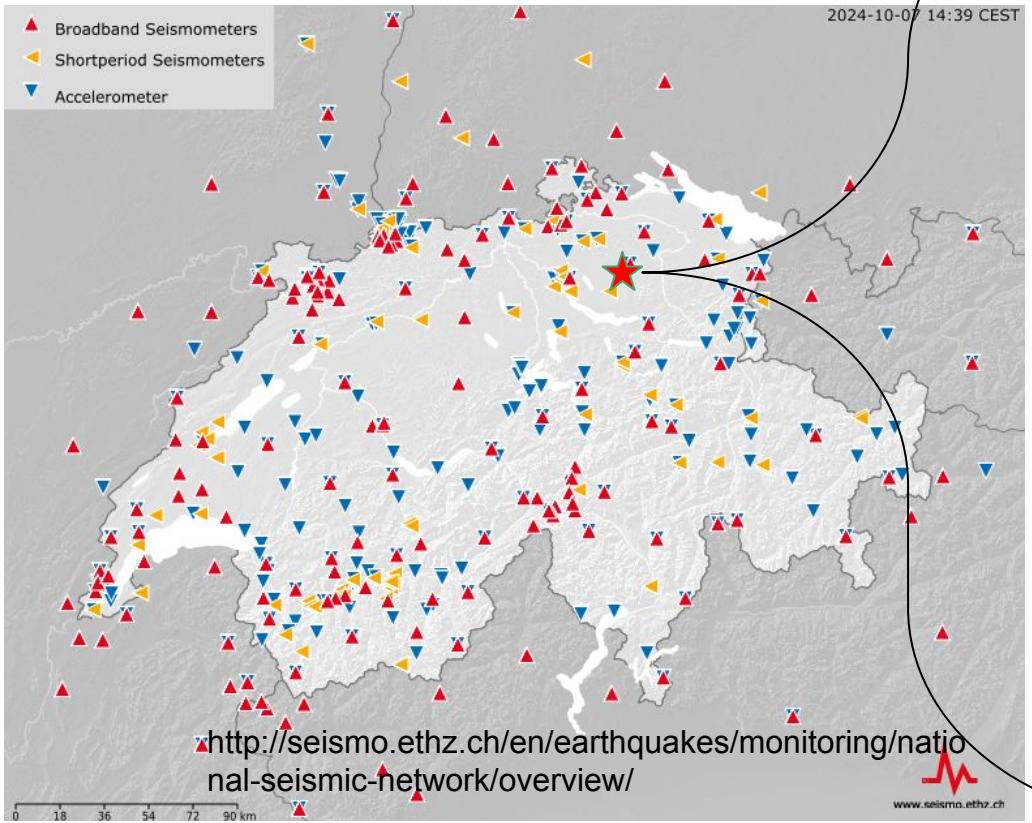
Swiss seismic network and earthquake recordings

Swiss Seismic Network



http://seismo.ethz.ch/en/earthquakes/monitoring/national-seismic-network/overview/

Typical Earthquake recording



http://seismo.ethz.ch/en/earthquakes/monitoring/national-seismic-network/overview/

Sorted by distance

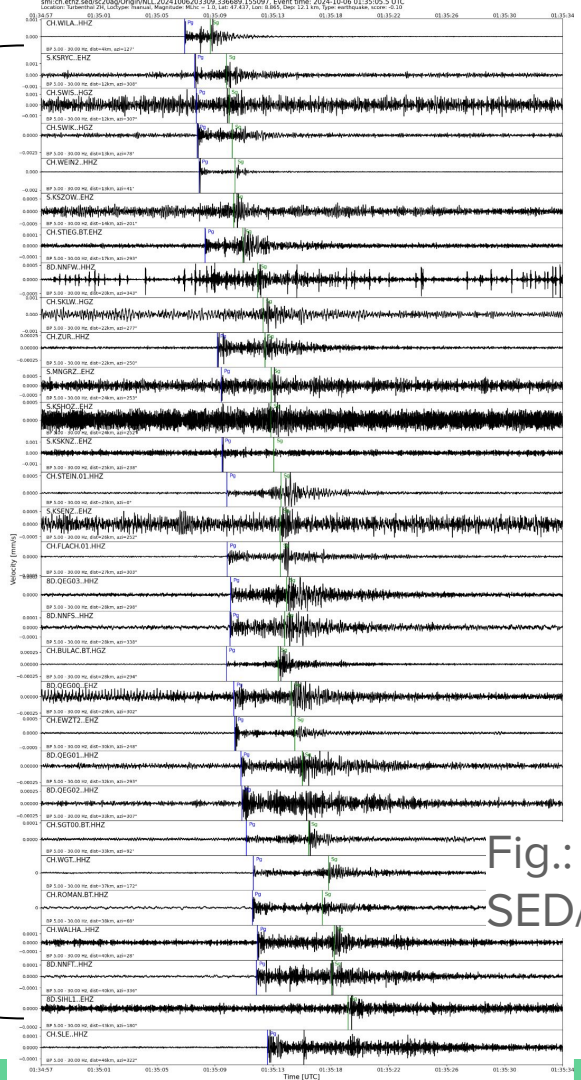
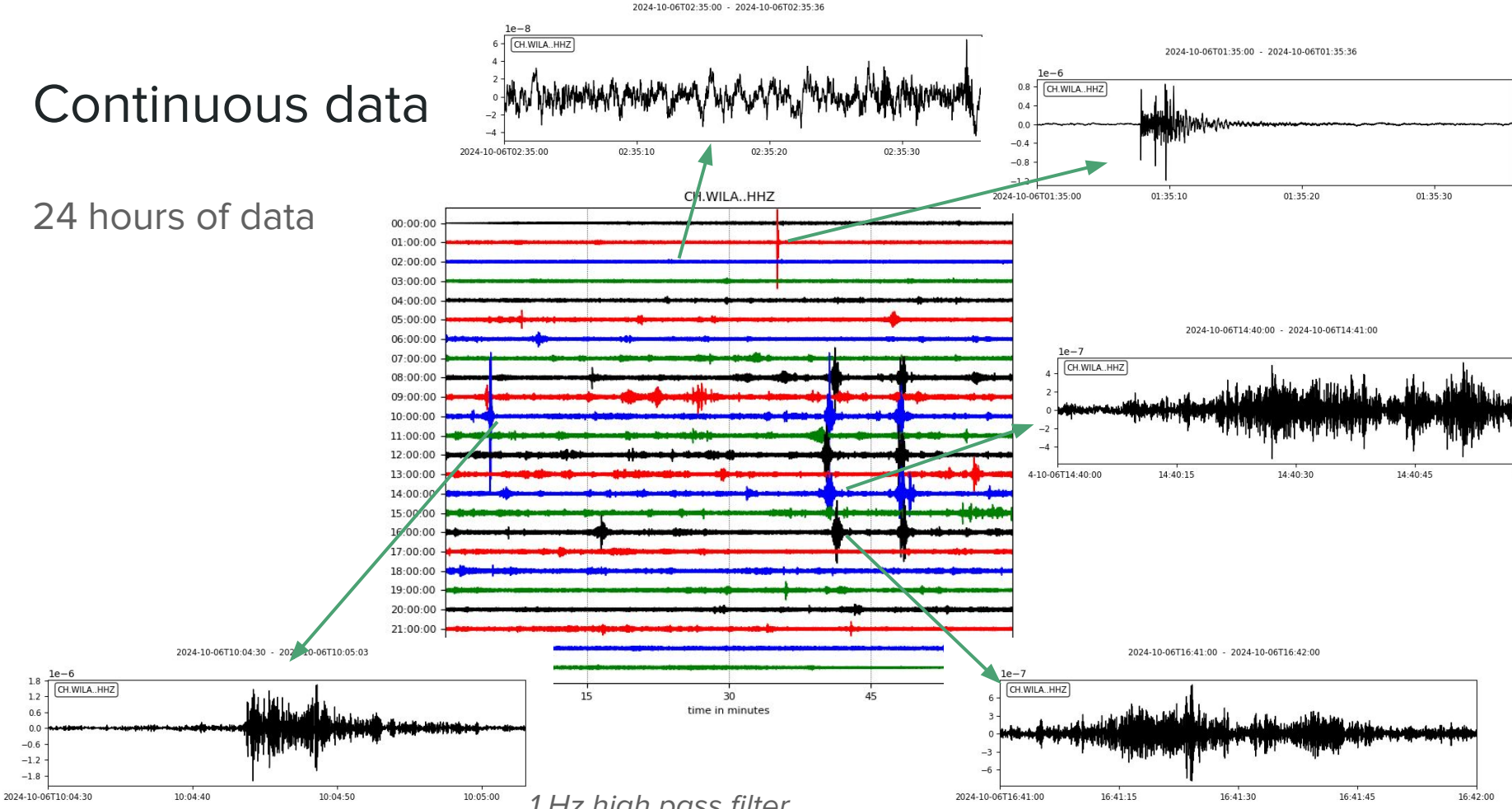


Fig.: SED/ETH

Continuous data

24 hours of data



1 Hz high pass filter

Data set

Data set

3 components:

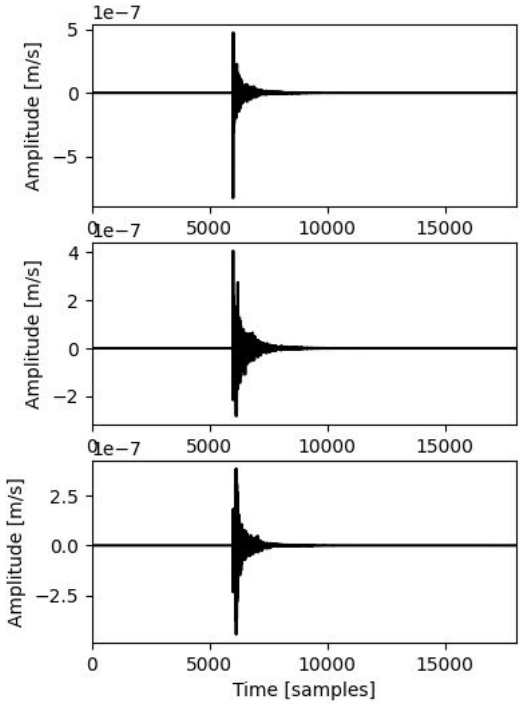
Up-Down

North-South

East-West

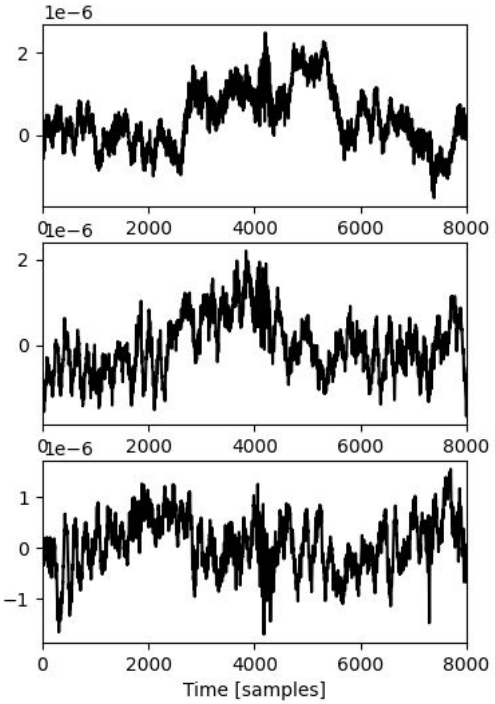
Event signals

(snippets of 180 seconds, 100 samples-per-second)



Noise signals

(snippets 80 seconds, 100 samples-per-second)



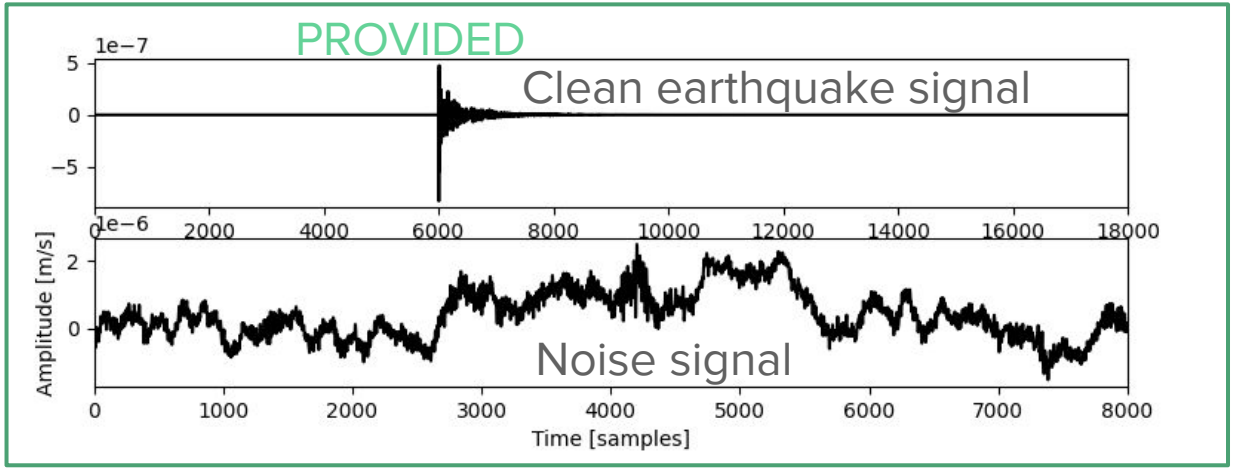
Data set

Event signals

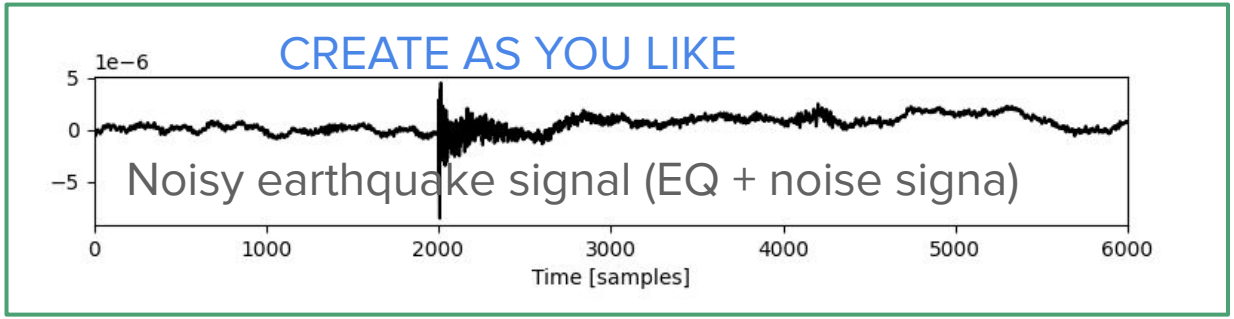
(snippets of 180 seconds, 100 samples-per-second, sps, P-wave always at 60s)

Noise signals

(snippets 80 seconds, 100 sps)



Noisy earthquake signal (e.g. 60 seconds snippet, 100 sps)



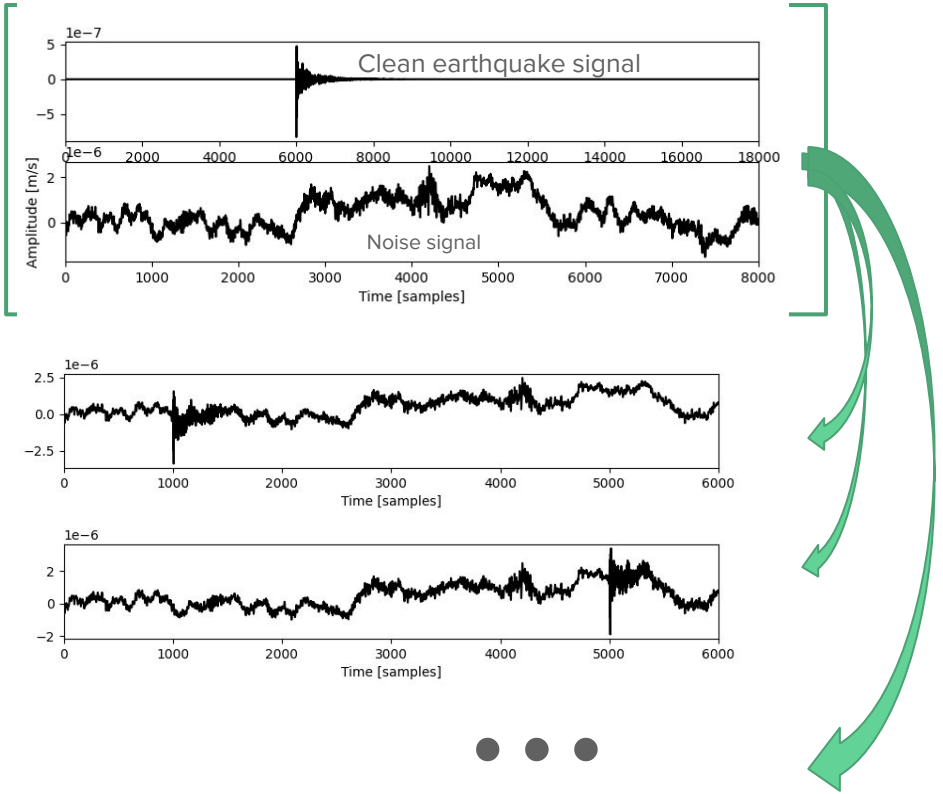
Data set

Event signals

~25k

Noise signals

>25k

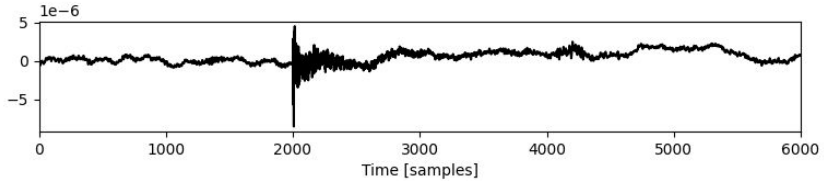


Noisy earthquake signal

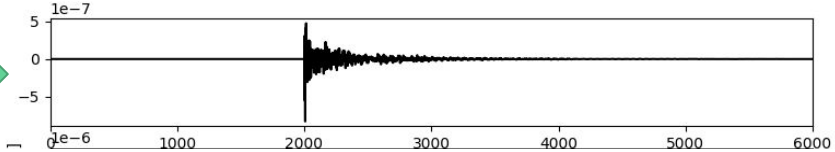
XX combinations of event and noise signals (with variations in signal-to-noise ratio = relative amplitude of earthquake and noise signals, position of EQ signal in time window,....)

Task

Noisy earthquake signal
(EQ + noise signal)



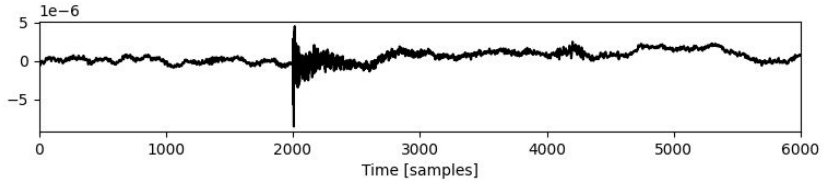
Denoised earthquake signal



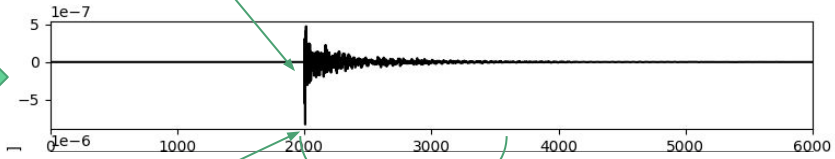
Evaluation - comparing denoised to true/clean EQ signal

Onset of EQ signal

Noisy earthquake signal
(EQ + noise signal)



Denoised earthquake signal



Waveform similarity

Peak amplitude

Benchmarking against conventional tools (digital filter) and existing DL denoiser

Where to start?

MarsQuakeNet: A More Complete Marsquake Catalog Obtained by Deep Learning Techniques

Nikolaj L. Dahmen, John F. Clinton, Men-Andrin Meier, Simon C. Stähler, Savas Ceylan, Doyeon Kim, Alexander E. Stott, Domenico Giardini

Seismic Signal Denoising and Decomposition Using Deep Neural Networks

Publisher: IEEE Cite This PDF

model available for baseline comparison

Weiqiang Zhu · S. Mostafa Mousavi · Gregory C. Beroza All Authors

Approaches from other fields, time series decomposition?

JOURNAL ARTICLE

A multitask encoder–decoder to separate earthquake and ambient noise signal in seismograms

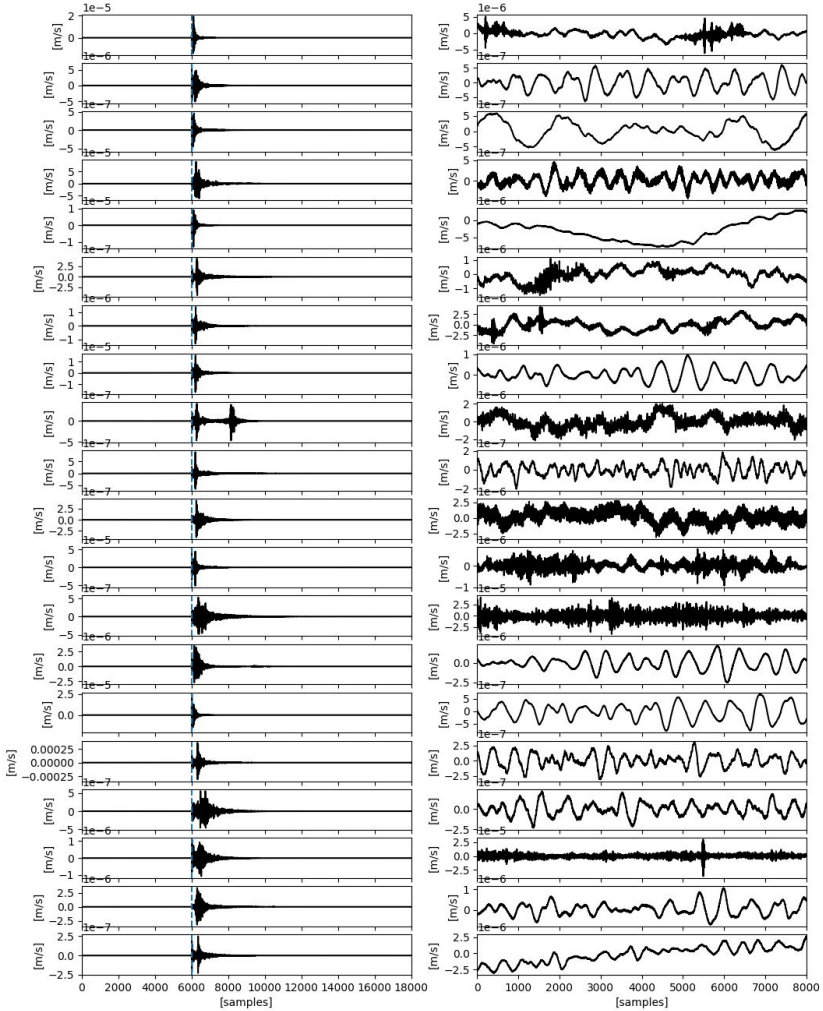
Jiuxun Yin, Marine A Denolle, Bing He Author Notes

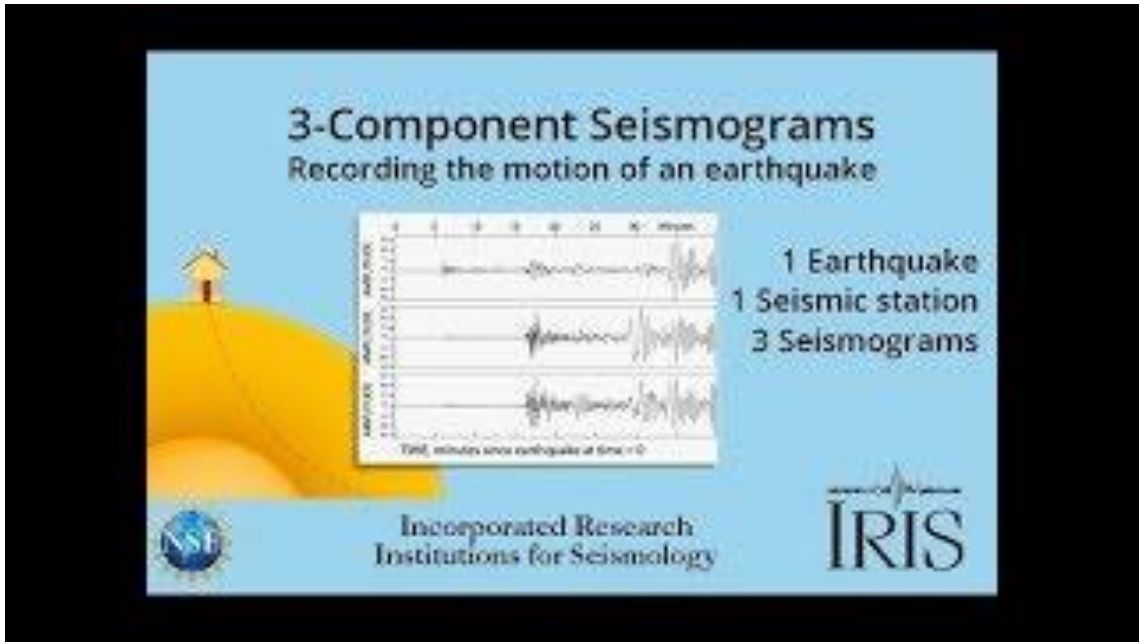
SEDENOSS: SEparating and DENOising Seismic Signals With Dual-Path Recurrent Neural Network Architecture

Artemii Novoselov[1], Peter Balazs[2], and Götz Bokelmann[1]

Cold Diffusion Model for Seismic Denoising

Daniele Trappolini[1,2], Laura Laurenti[1], Giulio Poggiali[3], Elisa Tinti[2,3], Fabio Galasso[4], Alberto Michelini[2], and Chris Marone[3,5]


[m/s]
[samples]
0 2000 4000 6000 8000 10000 12000 14000 16000 18000
0 1000 2000 3000 4000 5000 6000 7000 8000


3-Component Seismograms
Recording the motion of an earthquake
1 Earthquake
1 Seismic station
3 Seismograms
Incorporated Research
Institutions for Seismology
IRIS