Detection and location of local seismicity in Croatia using machine learning

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Motivation

Earthquake detection and phase picking are crucial steps in the analysis of earthquakes

Earthquake catalog

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Increased number of seismic stations available → Large amount of data →  → Earthquake catalog

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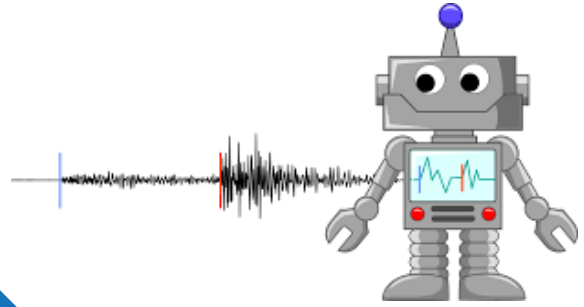

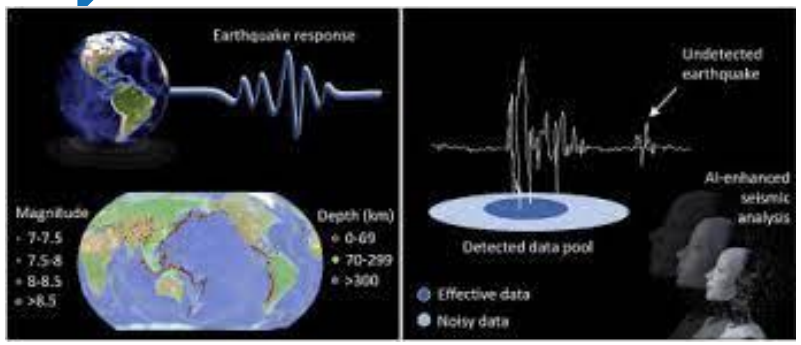

→ Earthquake catalog

Petrinja earthquake series

M_L 5.0 earthquake on December 28, 2020

M_L 6.4 earthquake on December 29, 2020

In the two years of this earthquake series, human analysts picked a total of:

- 16,000 earthquakes < M_L 2.0
- 1528 earthquakes 2.0 < M_L < 2.9
- 156 earthquakes 3.0 < M_L < 3.9
- 17 earthquakes 4.0 < M_L < 4.9
- 2 earthquakes 5.0 < M_L < 5.9
- 1 earthquake M_L > 6.0

Seismic network grew from few instruments in the epicentral area to more than 50 instruments in ~ 150 km radius from the epicentre

EQTransformer

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Earthquake transformer—an attentive deep-learning model for simultaneous earthquake detection and phase picking

S. Mostafa Mousavi, William L. Ellsworth, Weiqiang Zhu, Lindsay Y. Chuang & Gregory C. Beroza

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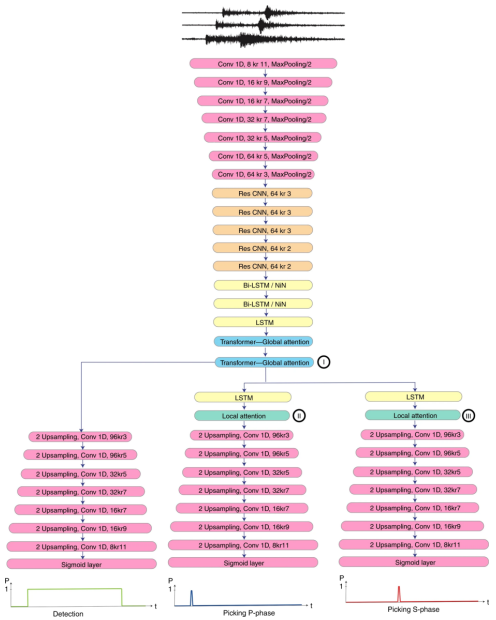
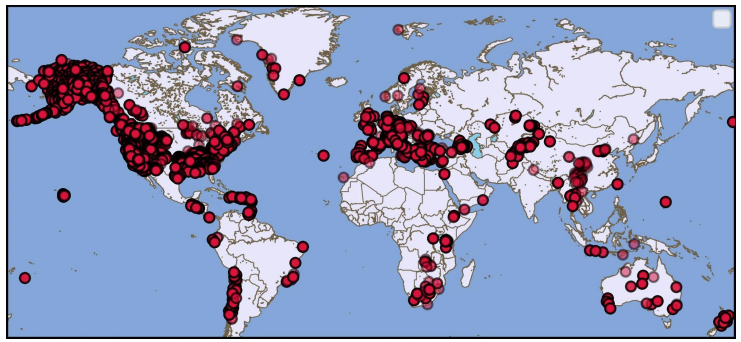
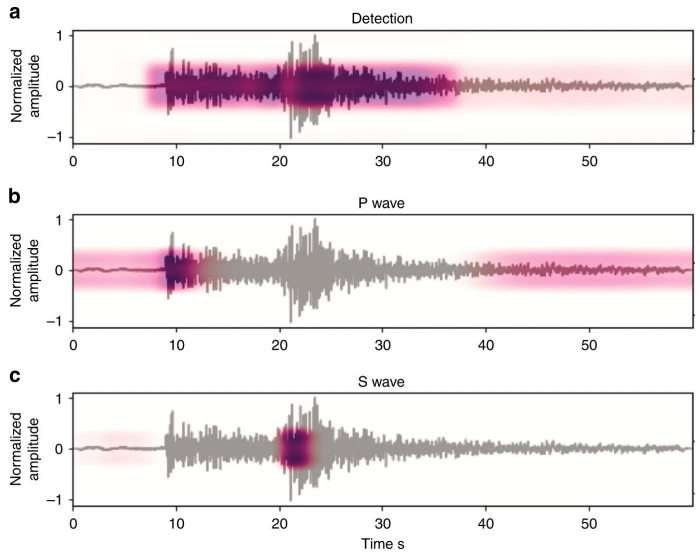




STEAD global training database



Attention framework

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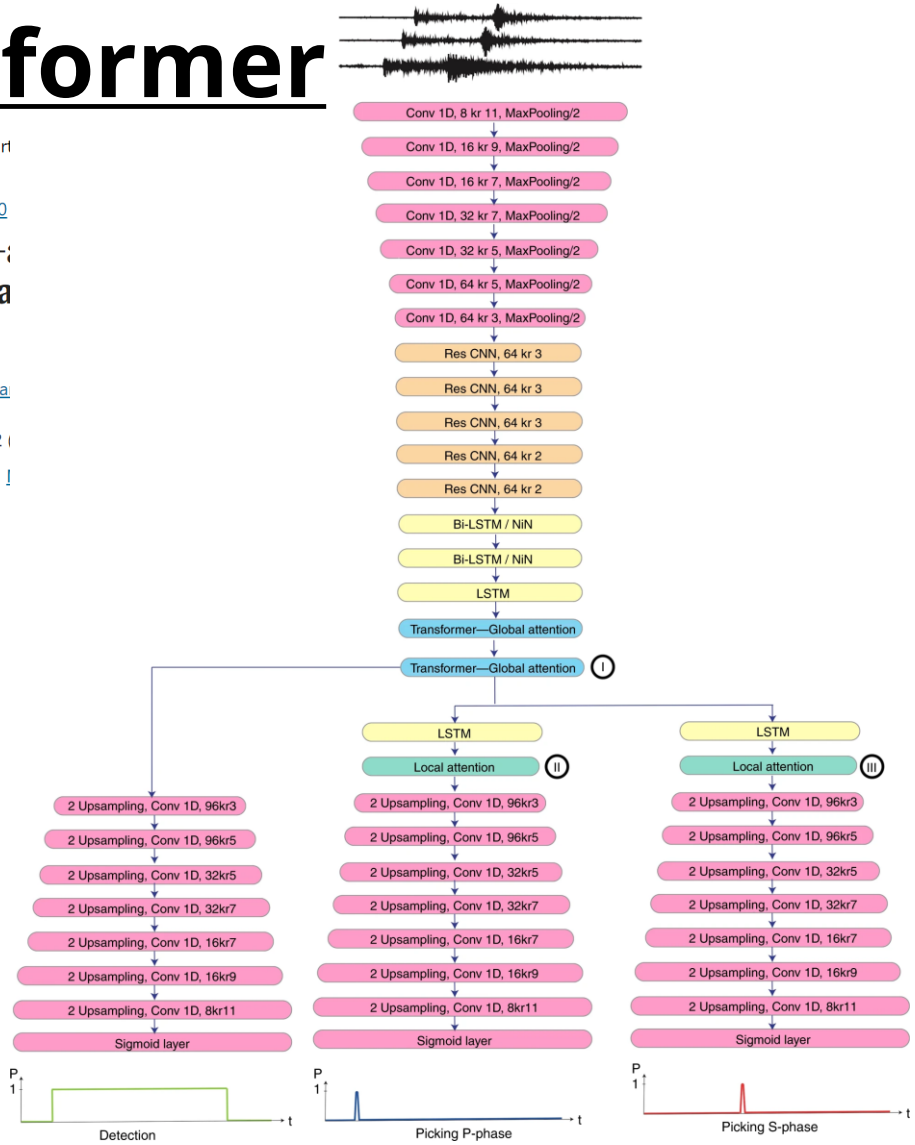

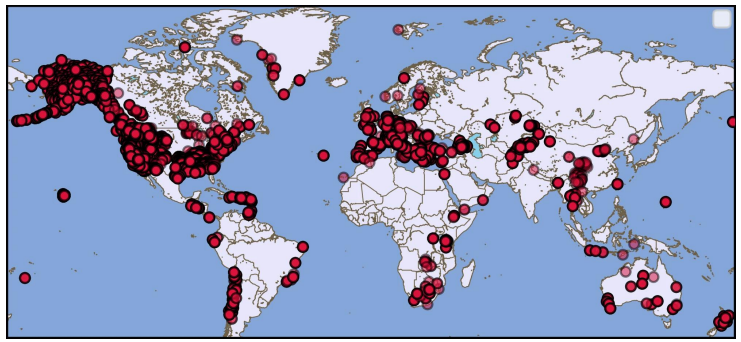

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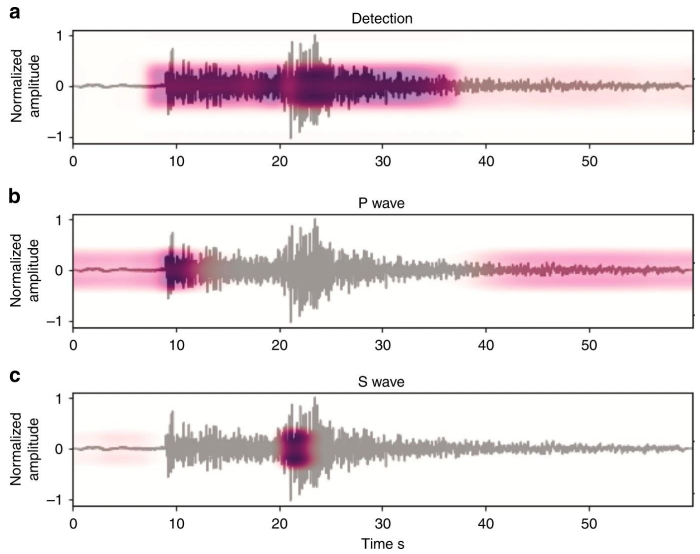

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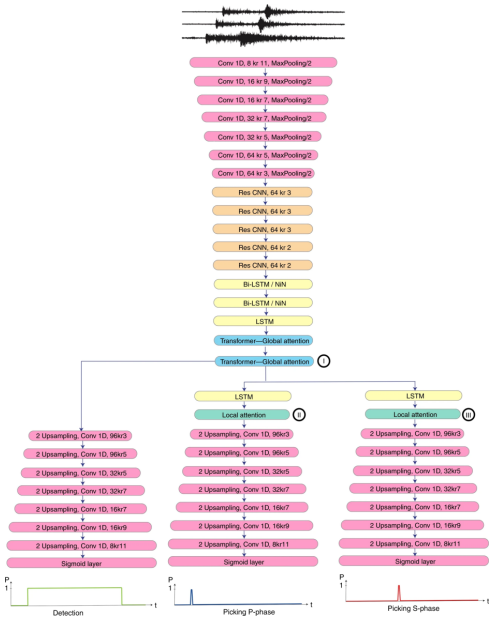

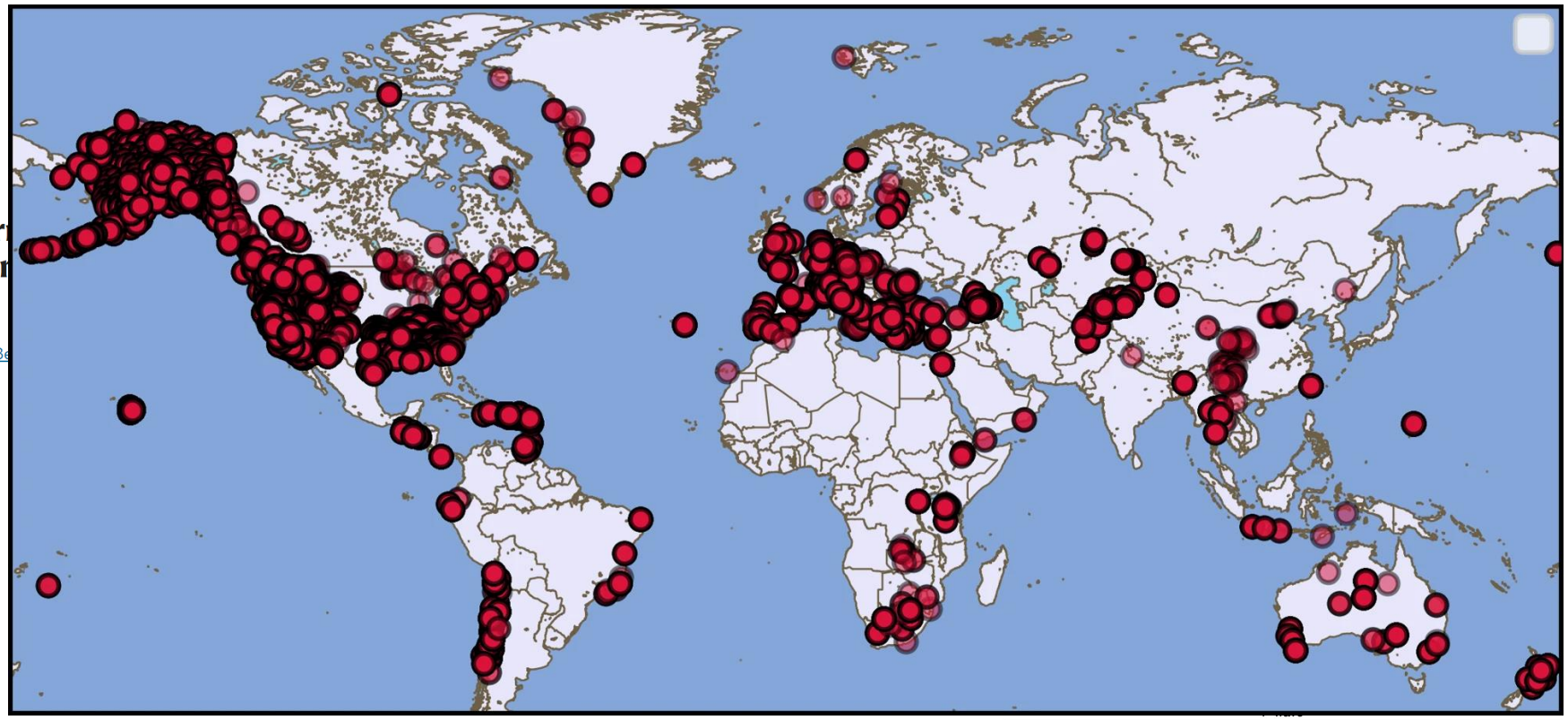

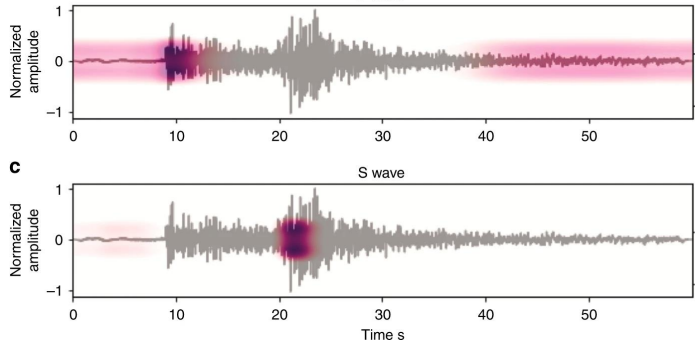

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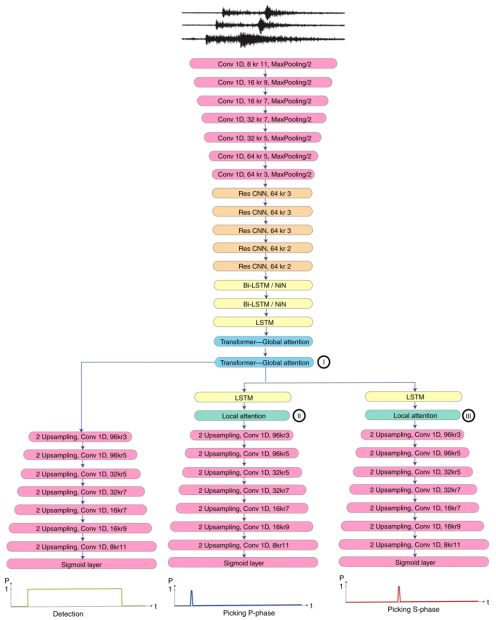

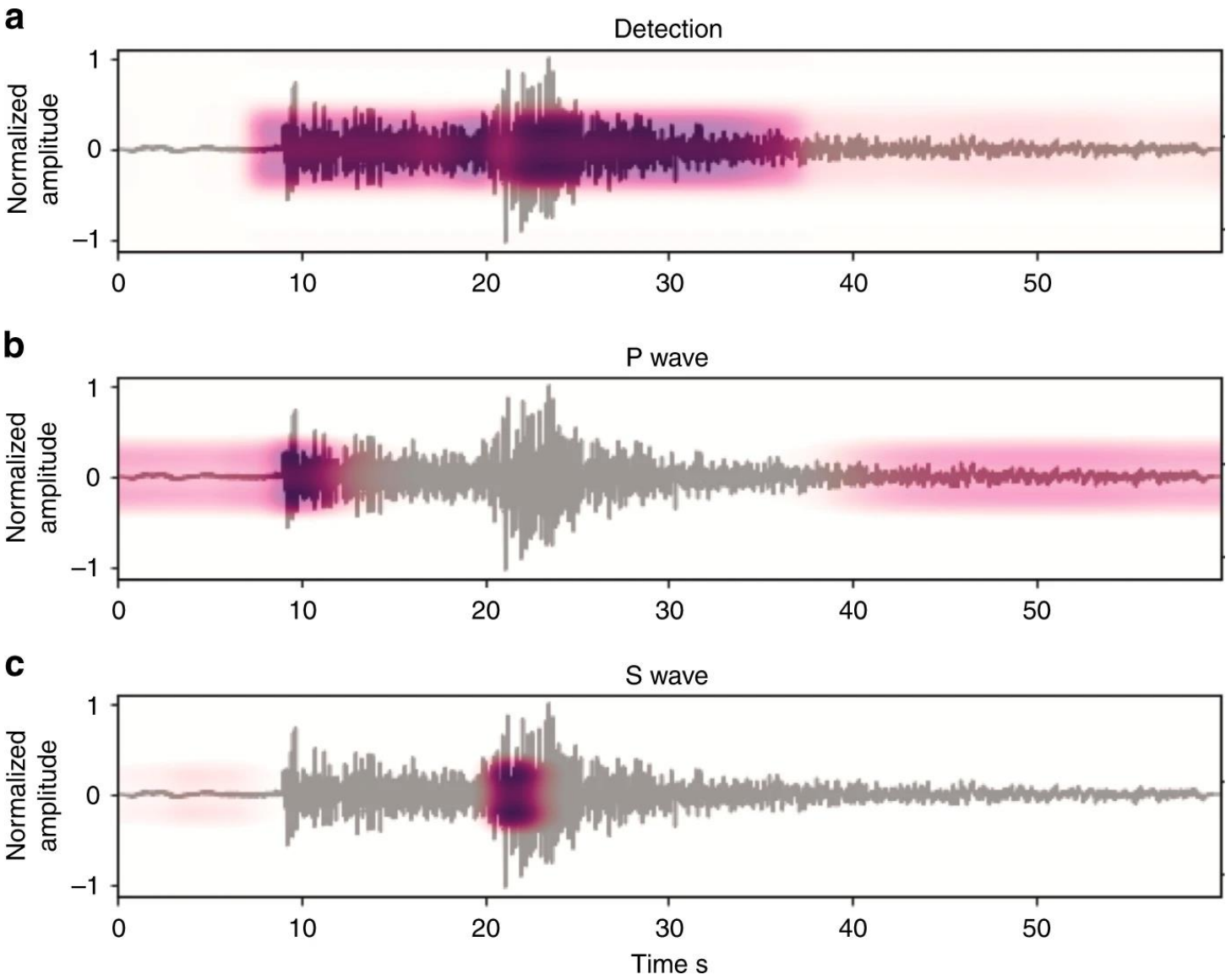

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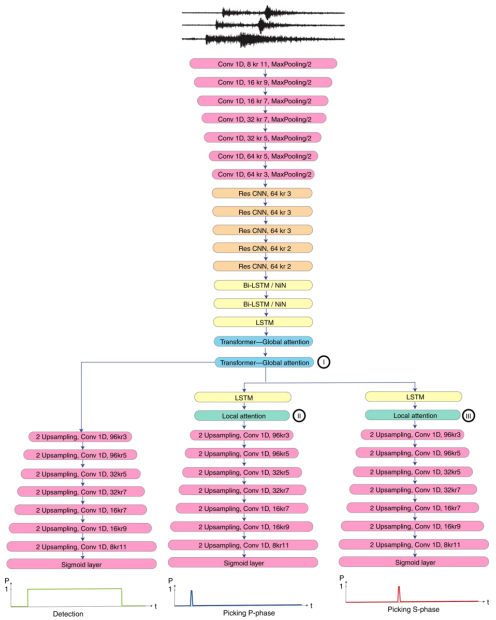
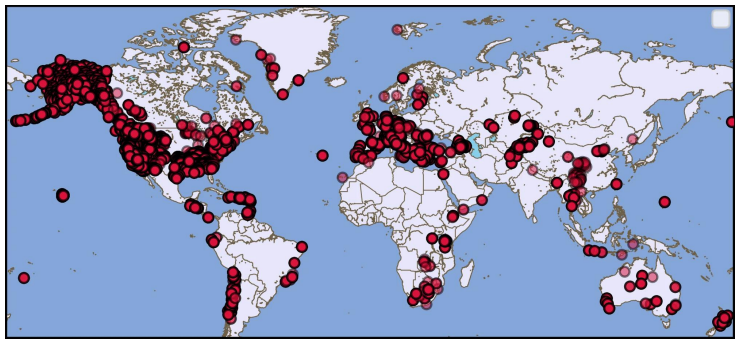


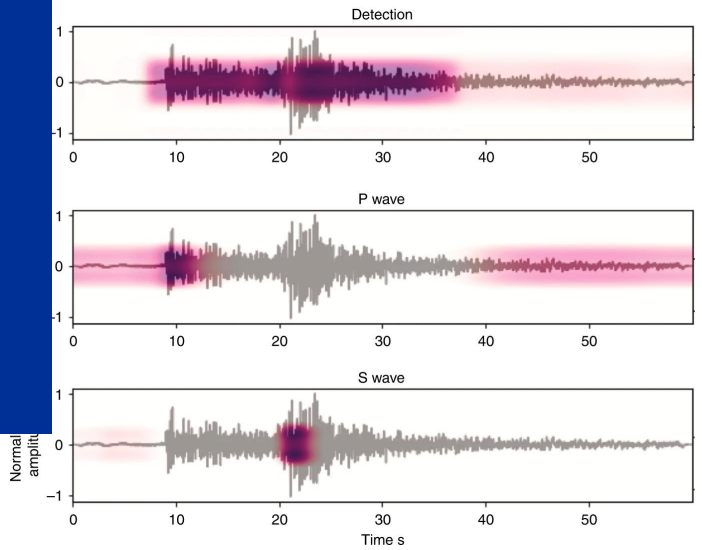
EQTransformer used on 9 weeks of data from January 1, 2021 – March 4, 2021

EQT detection parameters:

- Detection probability: 60%
- P probability: 40%
- S probability: 30%



STEAD global training database

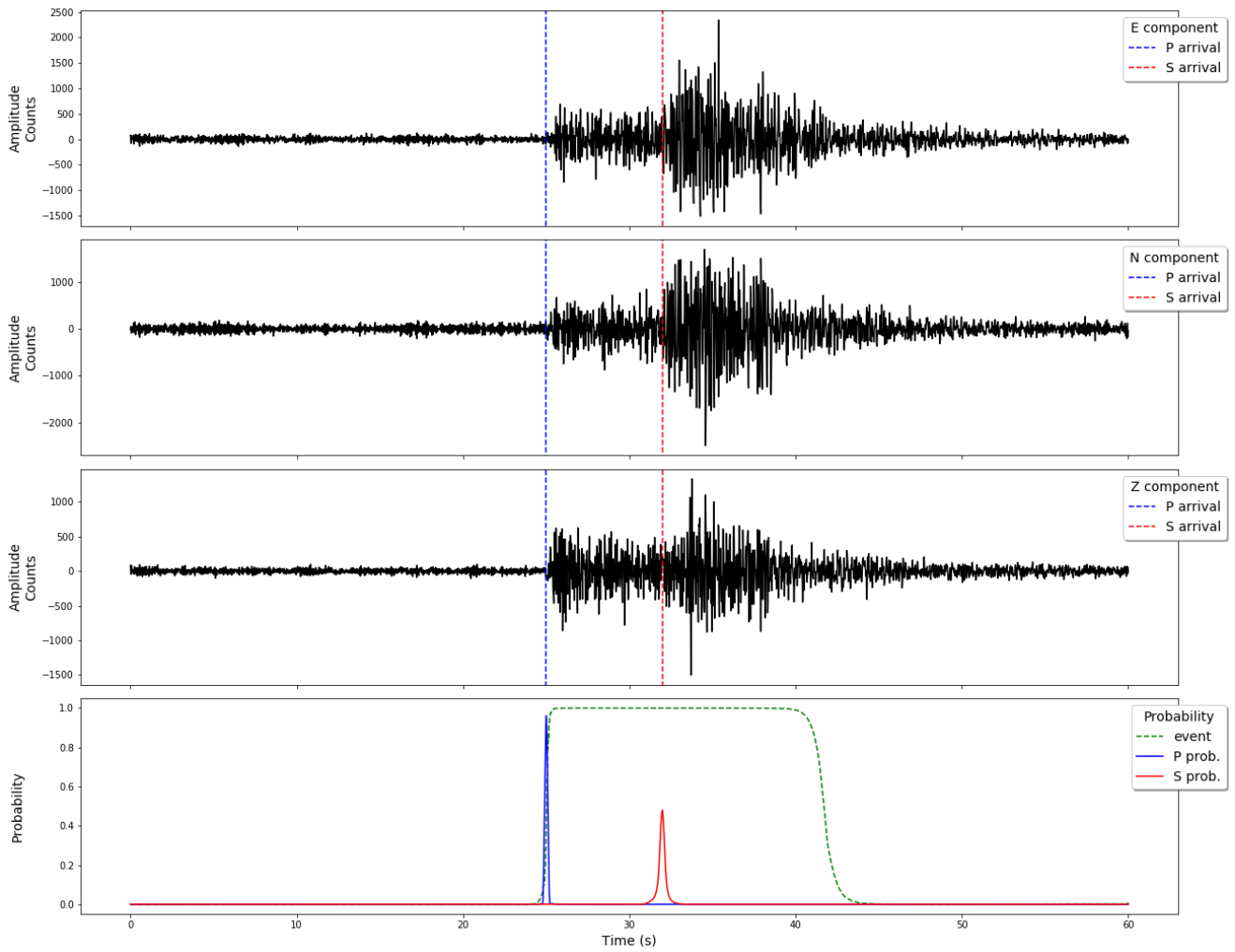


Attention framework

EQTransformer

For week between January 15 and January 21 and for station PTJ:

- Human: 291 P phase, 362 S phase arrival times
- EQT: 3316 P phase, 2526 S phase arrival times



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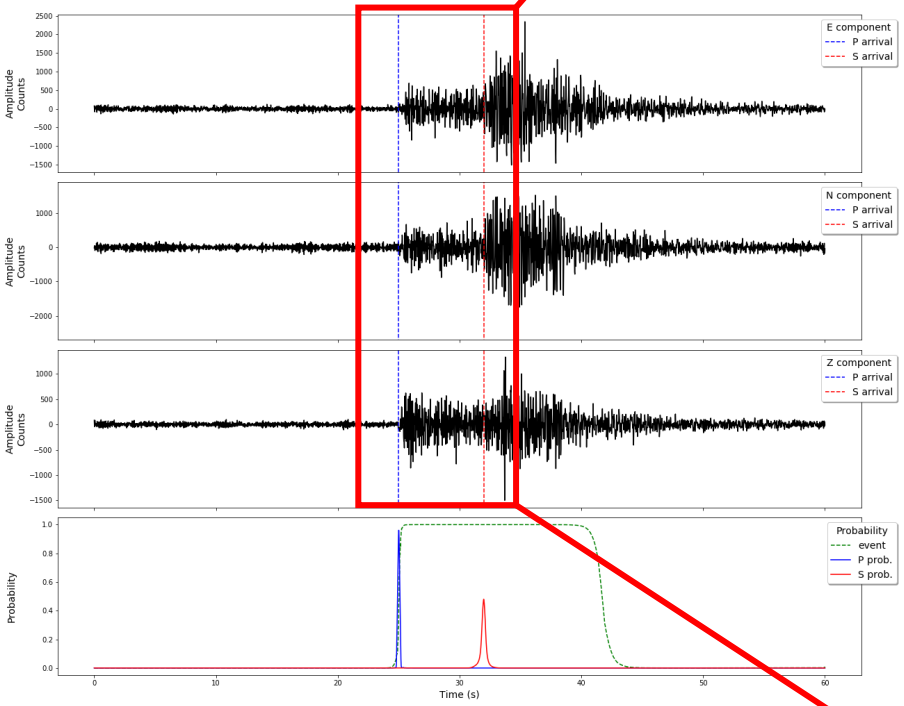
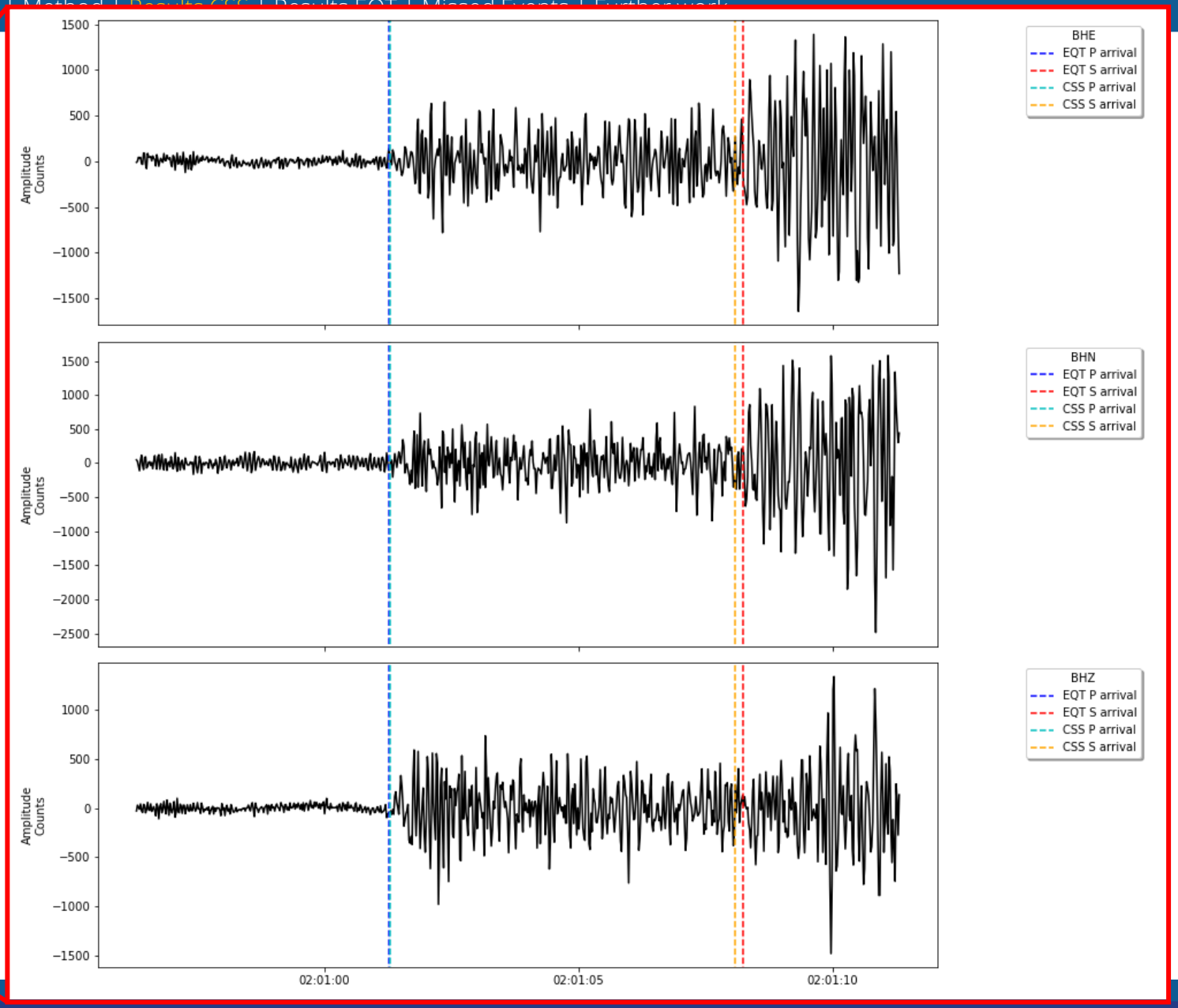
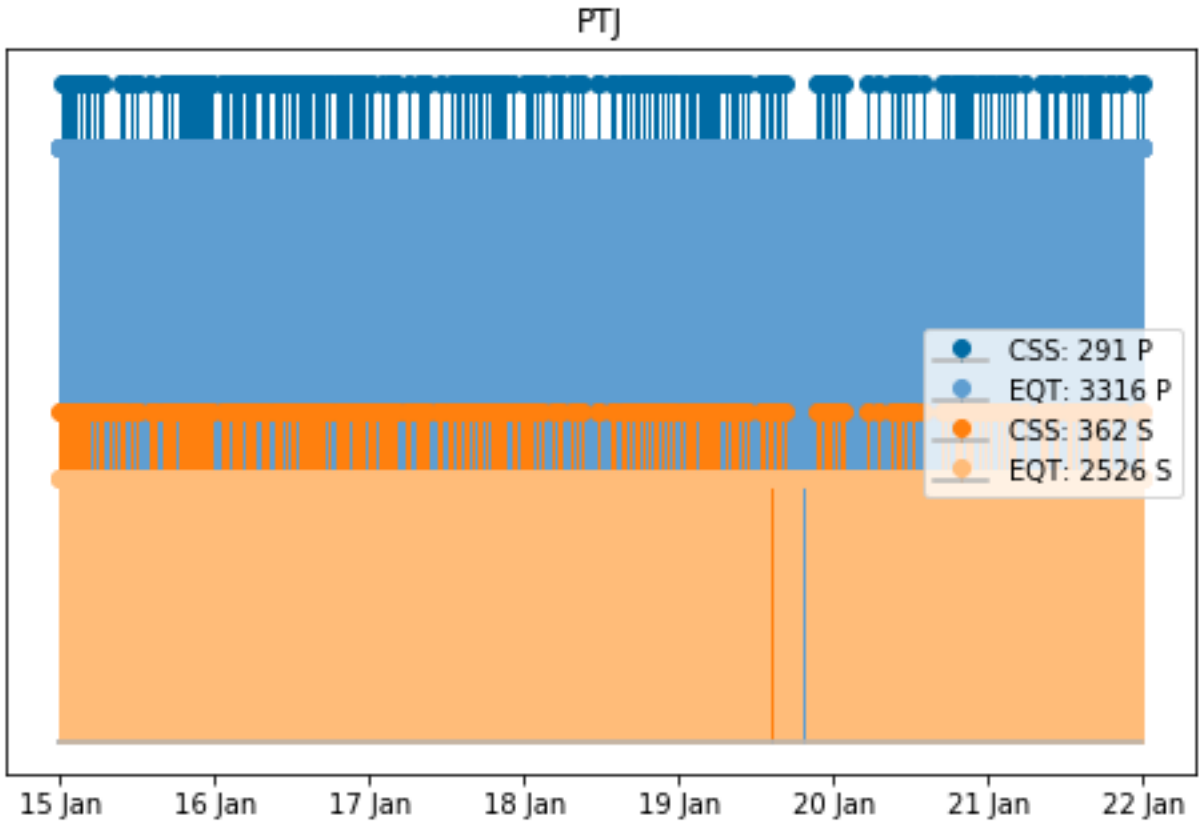
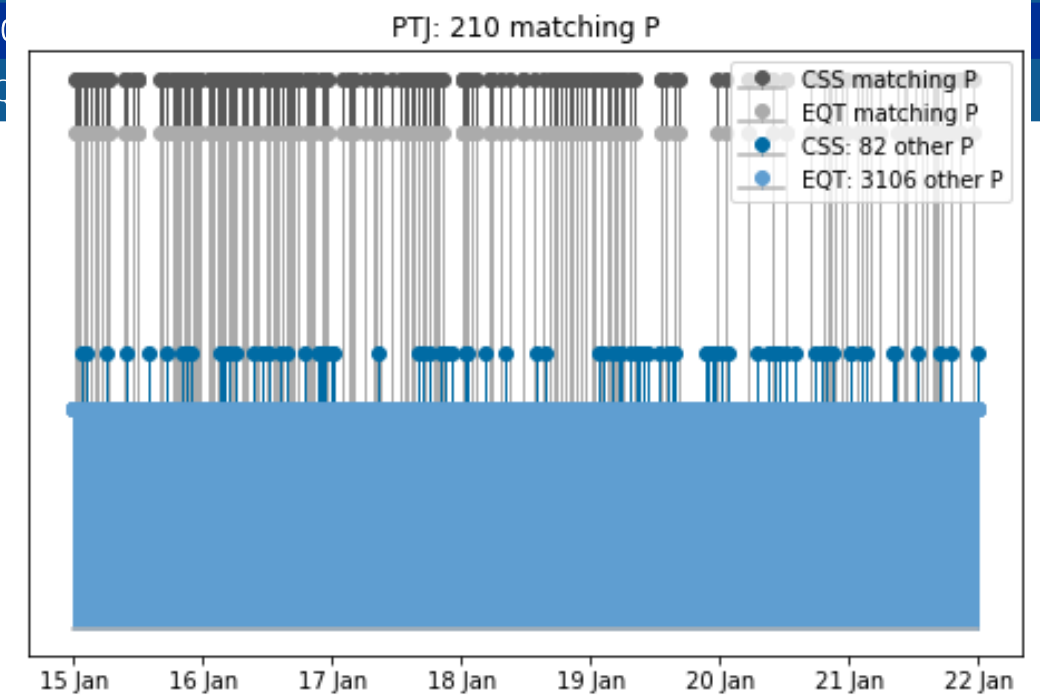
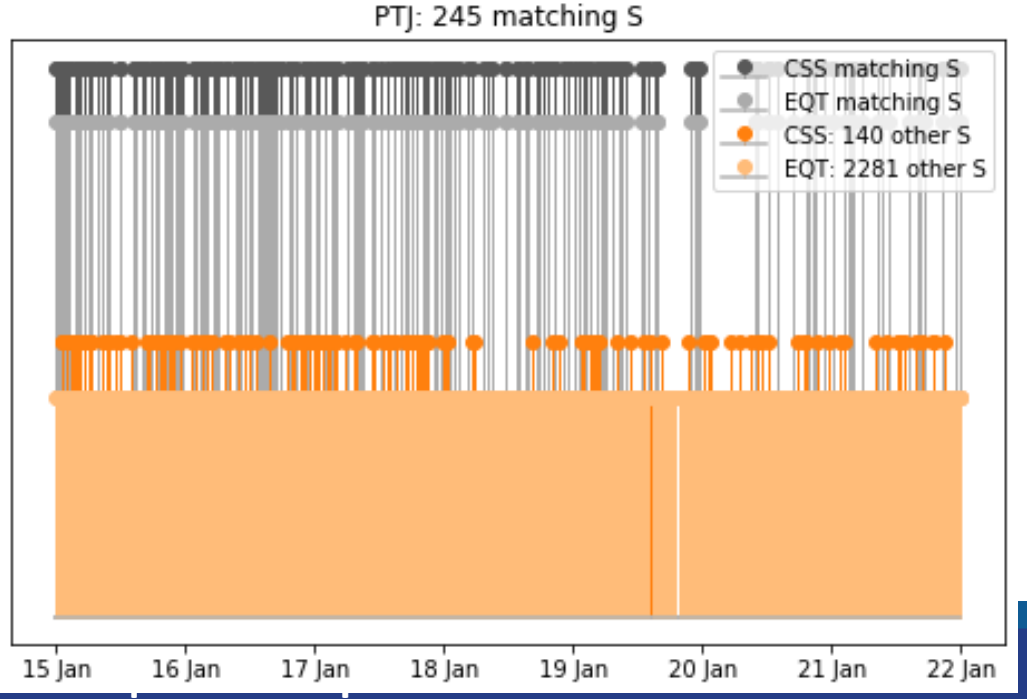




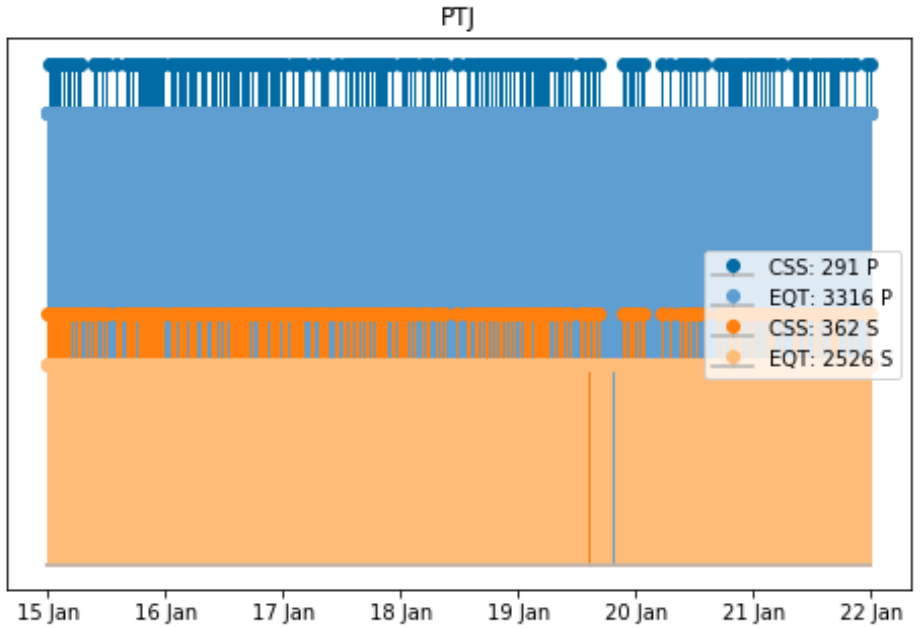
EQTransformer

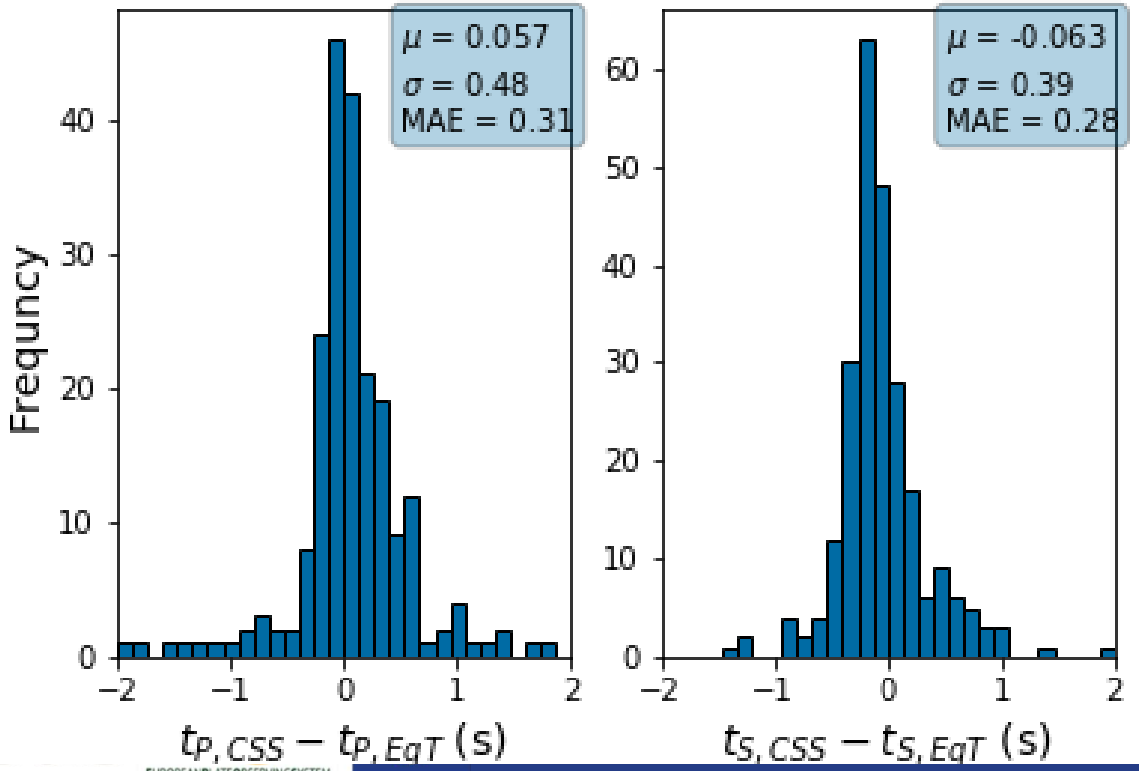


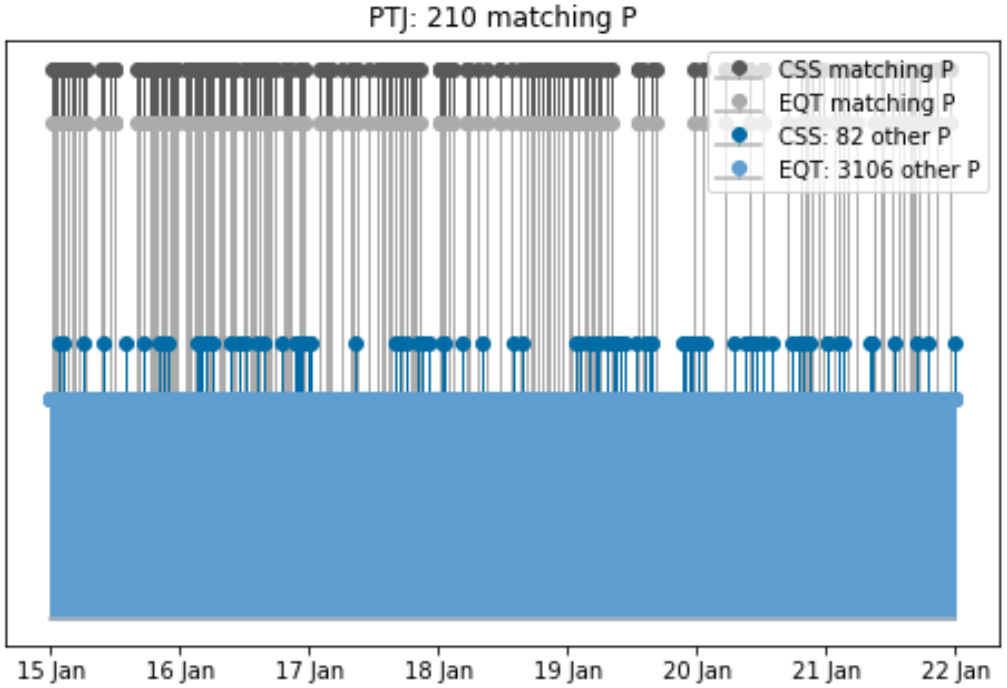


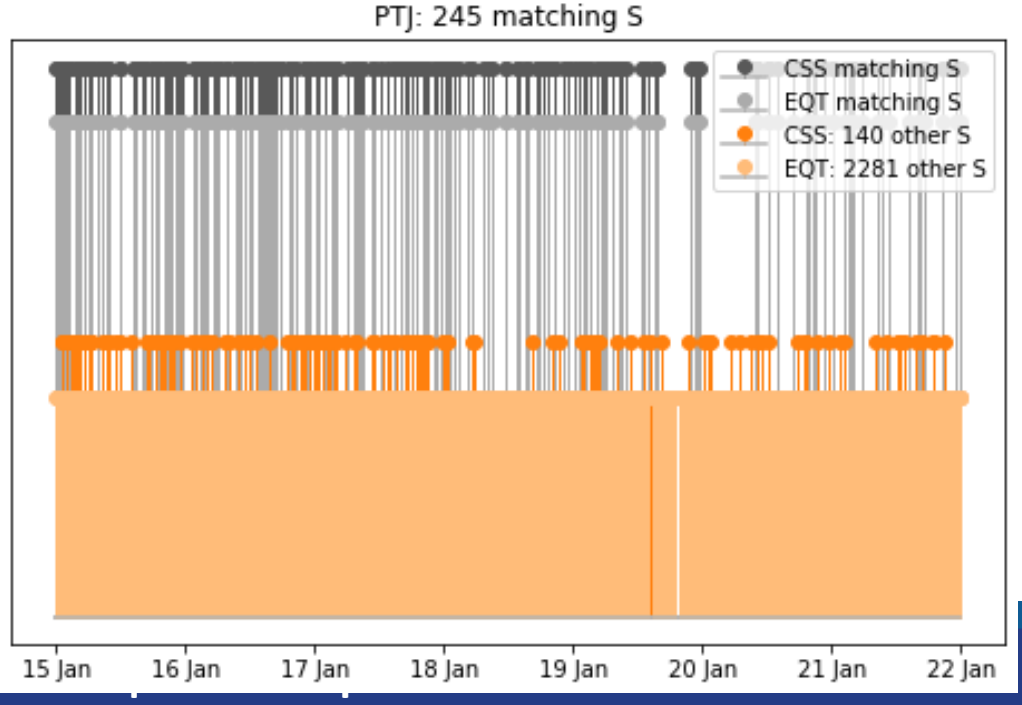


EQTr


PTJ
CSS: 291 P
EQT: 3316 P
CSS: 362 S
EQT: 2526 S
15 Jan
16 Jan
17 Jan
18 Jan
19 Jan
20 Jan
21 Jan
22 Jan


μ = 0.057
σ = 0.48
MAE = 0.31
μ = -0.063
σ = 0.39
MAE = 0.28
Frequncy
$t_{P,CSS} - t_{P,EqT}$ (s)
$t_{S,CSS} - t_{S,EqT}$ (s)

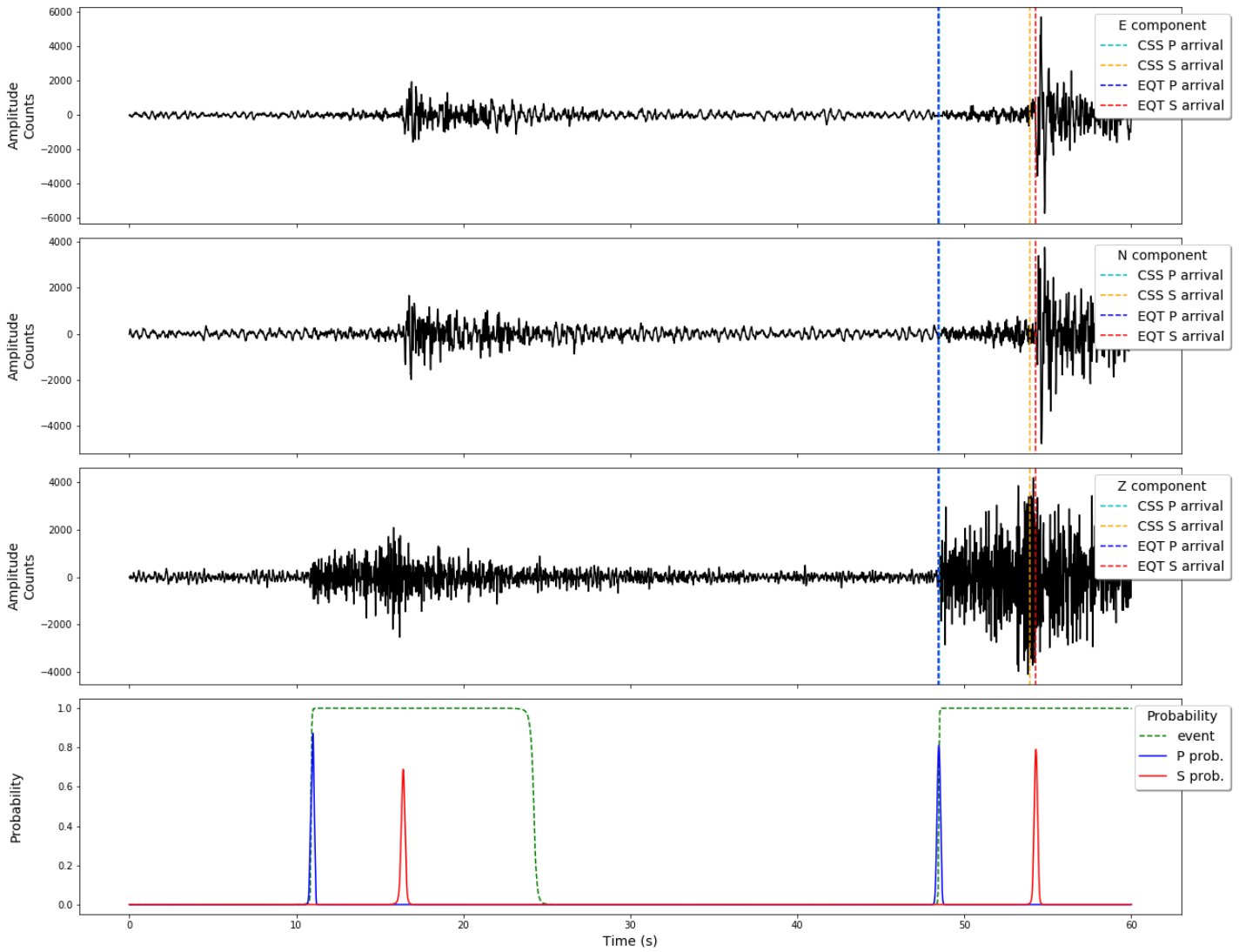

PTJ: 210 matching P
CSS matching P
EQT matching P
CSS: 82 other P
EQT: 3106 other P
15 Jan
16 Jan
17 Jan
18 Jan
19 Jan
20 Jan
21 Jan
22 Jan


PTJ: 245 matching S
CSS matching S
EQT matching S
CSS: 140 other S
EQT: 2281 other S
15 Jan
16 Jan
17 Jan
18 Jan
19 Jan
20 Jan
21 Jan
22 Jan

EQTransformer

Week between January 1 and January 6 and for station RUGV:

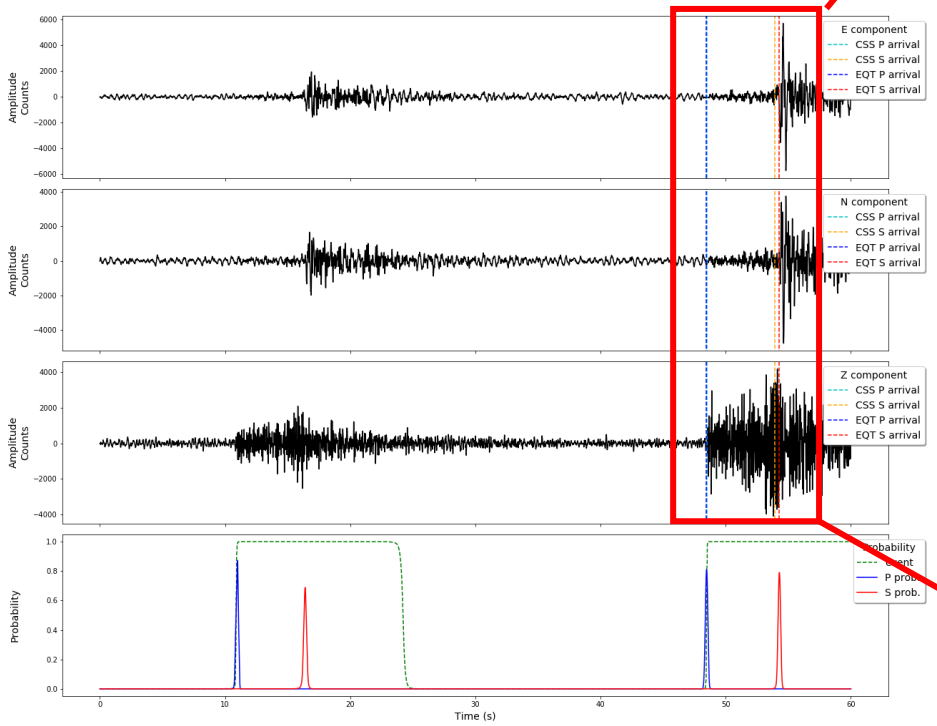
- Human: 492 P phase, 431 S phase arrival times
- EQT: 5925 P phase, 3890 S phase arrival times

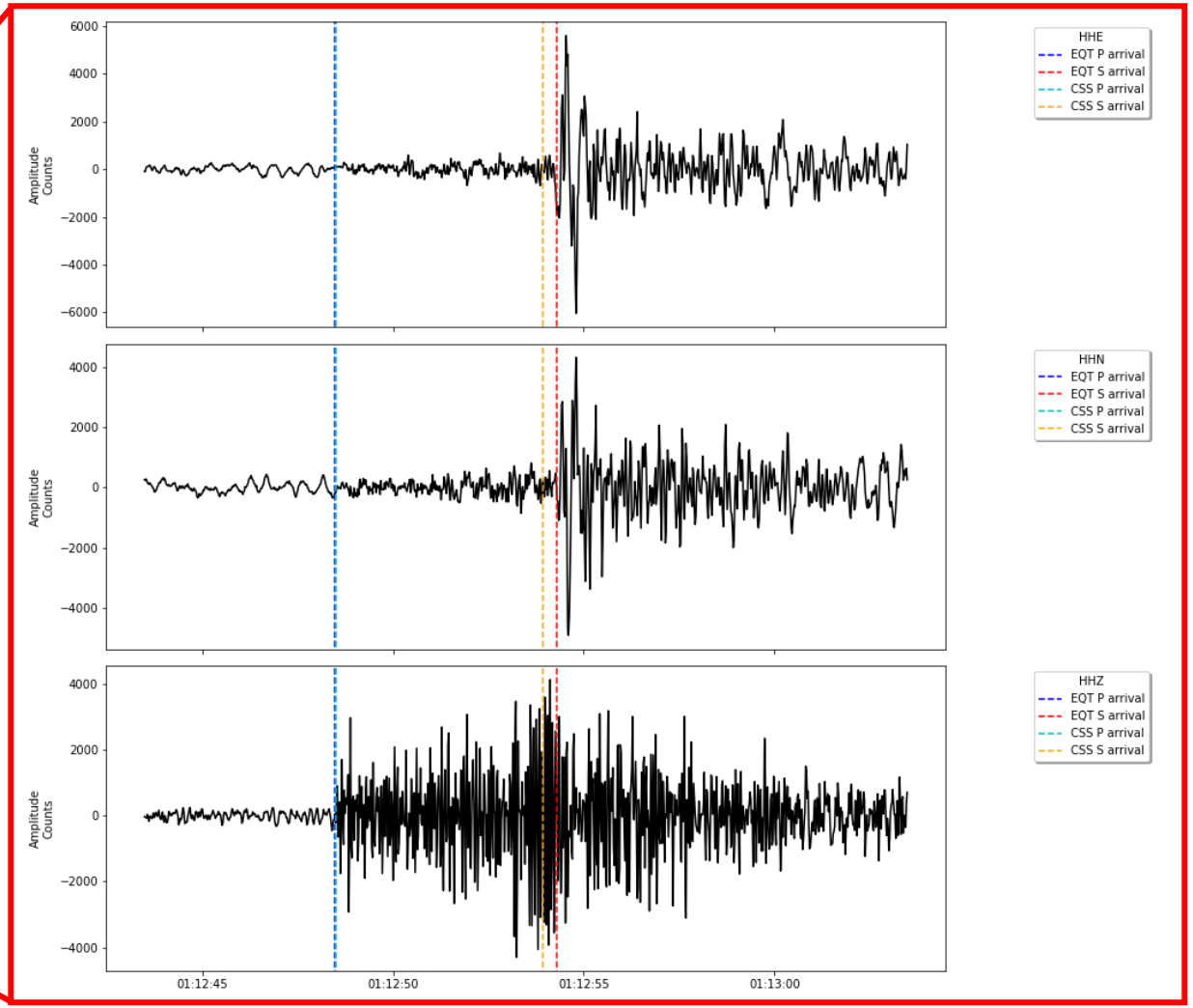


EQTransformer

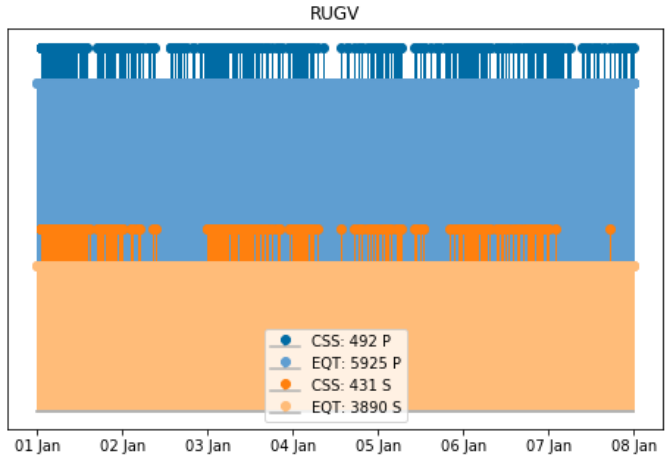
Week between January 1 and January 6 and for station RUGV:

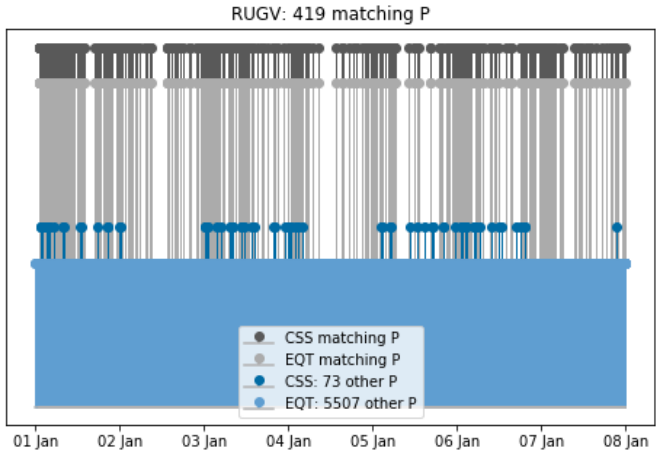
- Human: 492 P phase, 431 S phase arrival times
- EQT: 5925 P phase, 3890 S phase arrival times

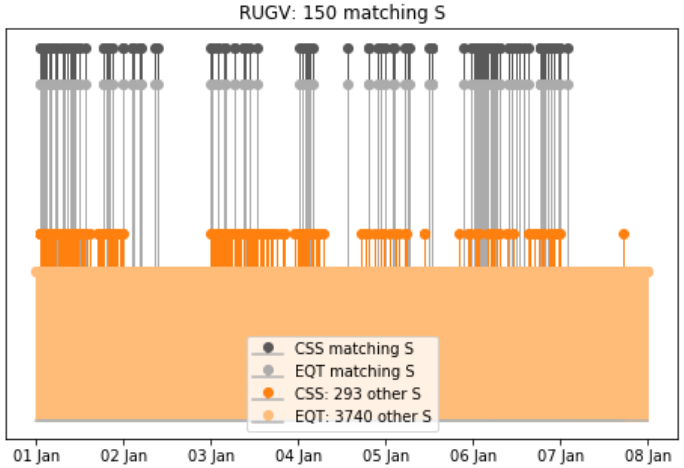


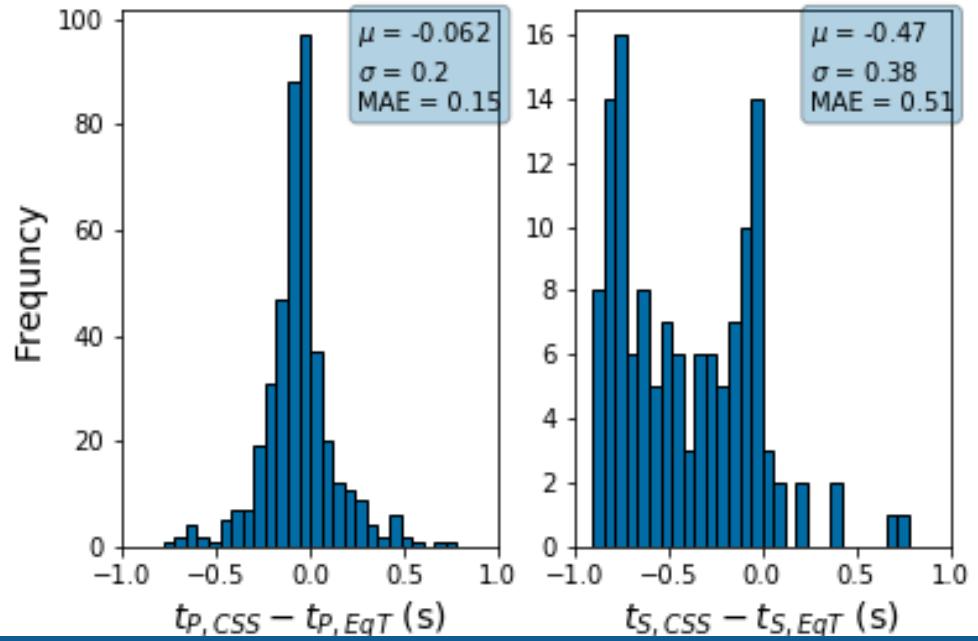


EOTransformer









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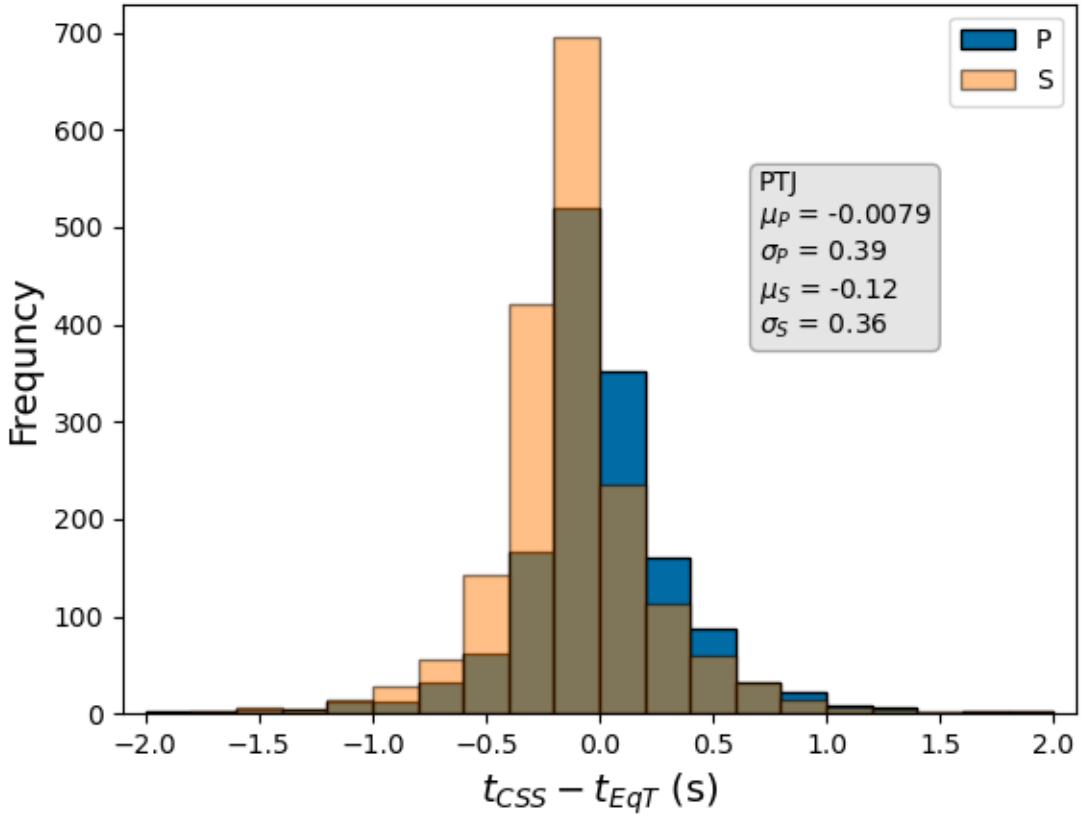

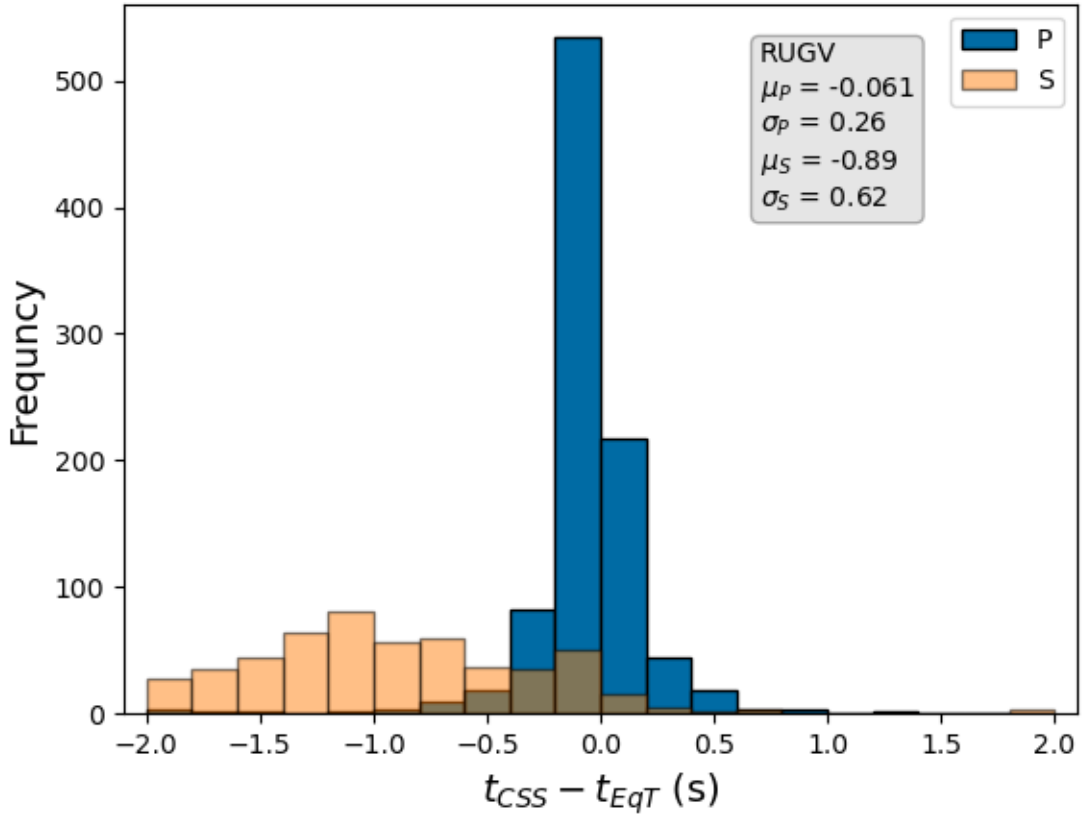

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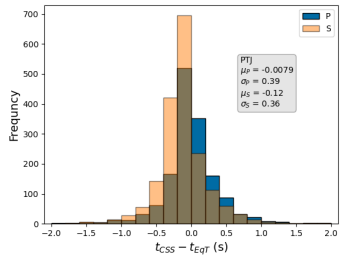

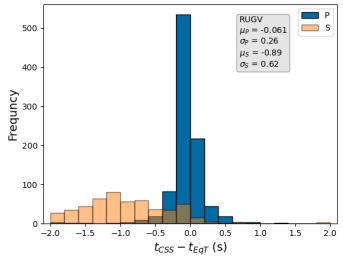

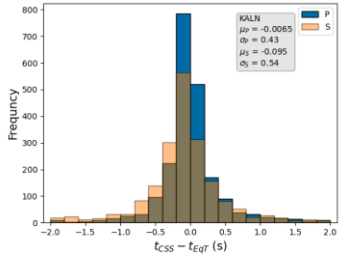

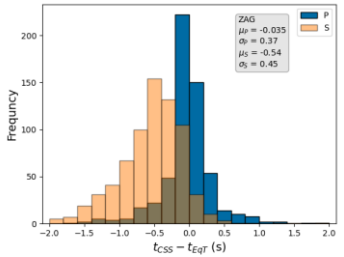

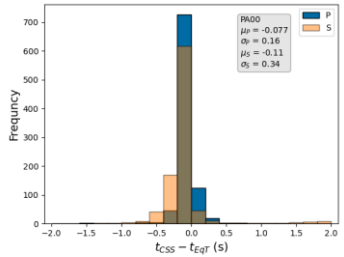

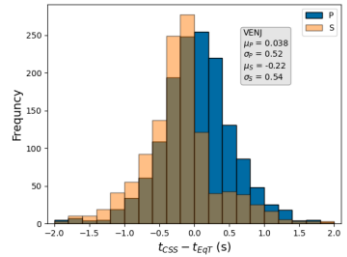

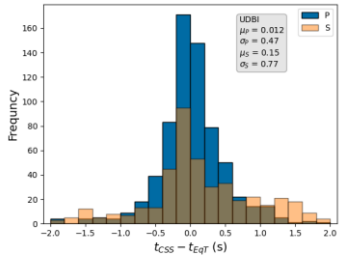

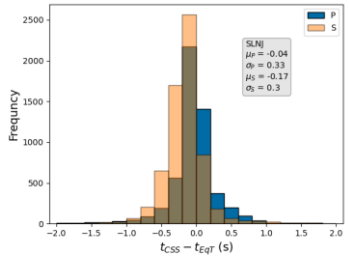

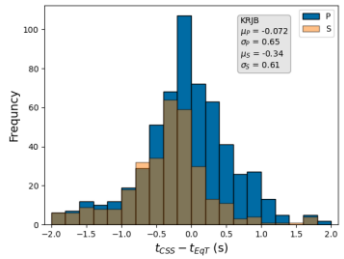

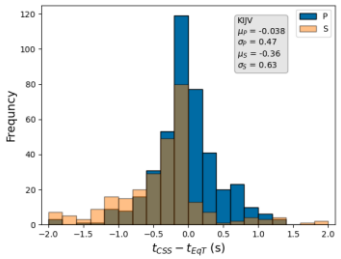

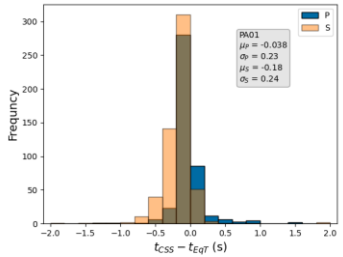

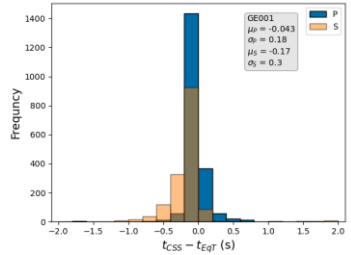

Further work

Find False Positives from EQT output
Find events that human analyst registered as an earthquake and EQT did not
Calculate uncertainties of EQT results
Create training dataset based on local seismicity in Croatia and then run the detection again
Compare results with other ML algorithms (PhaseNet)