

Deep learning based phase picking on seismological IMS stations

Steinberg, Andreas; Gaebler, Peter

Federal Institute for Geosciences and Natural Resources (BGR))



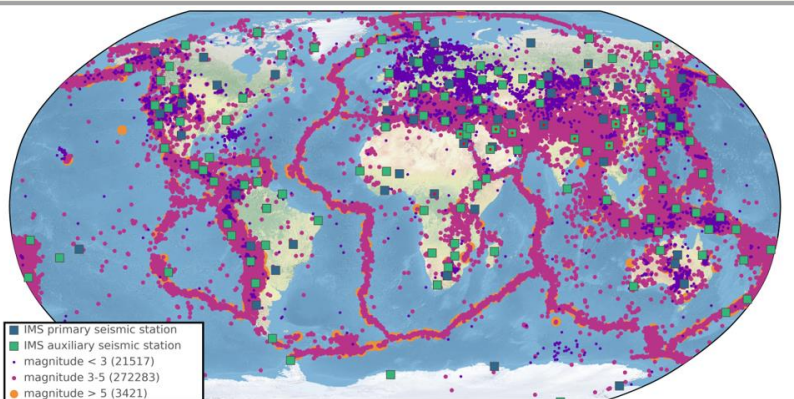
INTRODUCTION AND MAIN RESULTS

We train new IMS data based seismic phase pickers from both EQTransformer and PhaseNet architectures. Phase picking is a necessary step before event localization and characterization and deep learning based models have been proven to perform well at this task. PhaseNet and EQTransformer are two prominent state-of-the-art phase picking algorithms that have been retrained on several different datasets. Waveform data from primary and auxiliary stations is used in the training and evaluation. For training we use good quality picks from REB events between 2013 until 2023. We evaluate the performance with other ML Phase picking models in comparison with unseen evaluation REB phase picks and manual phase picks.

Dataset and model training

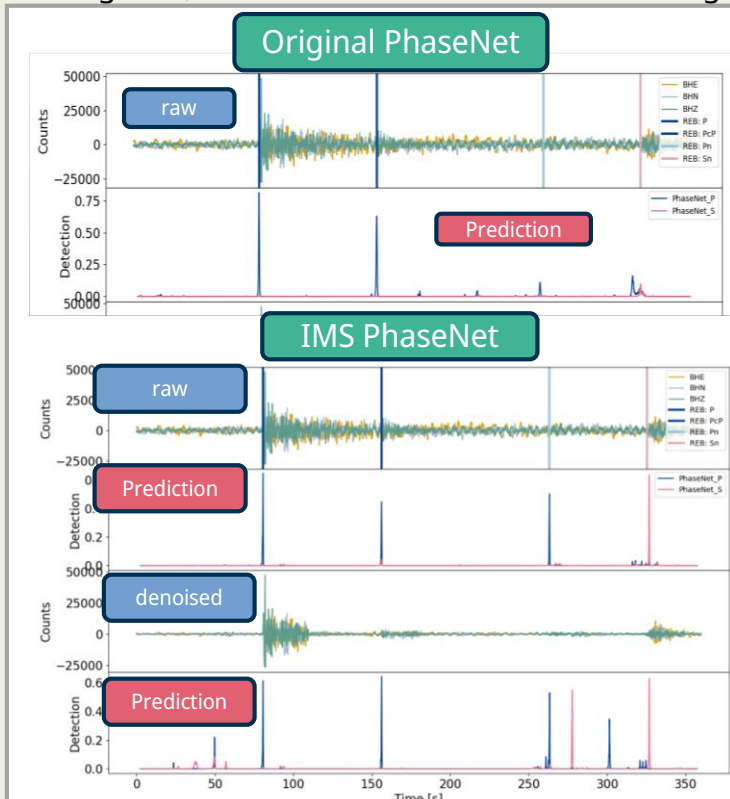
[We train new phase pickers based on the PhaseNet architecture and a database of 20 years listed in the earthquake catalog of BGR. The models are trained and evaluated with manual phase picks of BGR analysts. We compare the performance of the newly trained models by also applying other pre-trained PhaseNet and EQTransformer based phase pickers on unseen data. We determine if existing pre-trained models can satisfactorily be used out of the box for phase picking on waveforms of the GRSN.

- **phase picks:** 2.55 million; **phases:** P*- and S*-
- Waveforms acquired 60s before and 60s after REB phase pick
- Time: between 2013-2020 and 2021-2022; NK tests excluded
- 15 % withheld for validation; stored as HDF5



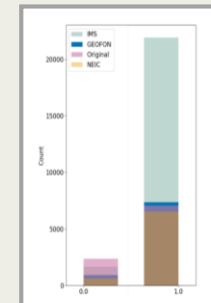
Qualitative comparison

Comparison between the original PhaseNet and the retrained IMS model for teleseismic distances. Original and PhaseNet perform similar, however the IMS model also detects the collapse ~8 minutes after the test. Original PhaseNet has false identification of Pg phase as S phase, the IMS model is correct, however shows multiple false detections. We use the Denoiser from Steinberg et al, 2024 to check the effect of denoising.



Quantitative comparison

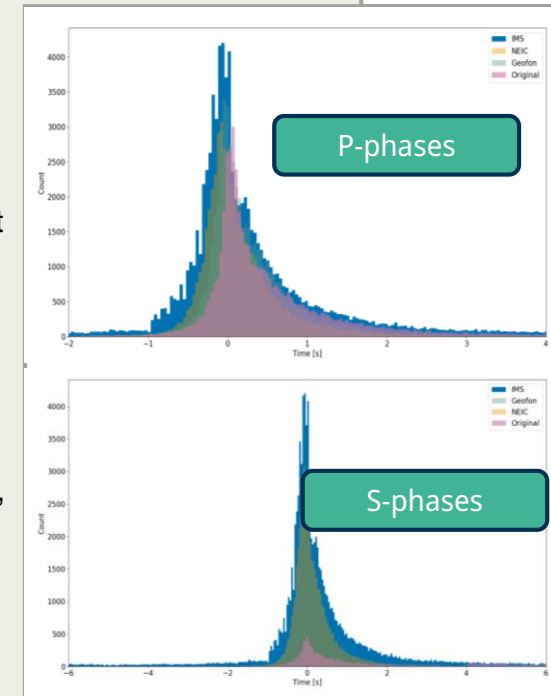
We conduct a quantitative analysis of the performance of pickers on the shown dataset with REB events from >2022, which have not been used in the training. The dataset consists of 909165, 600k P and S picks from 38593 Events.



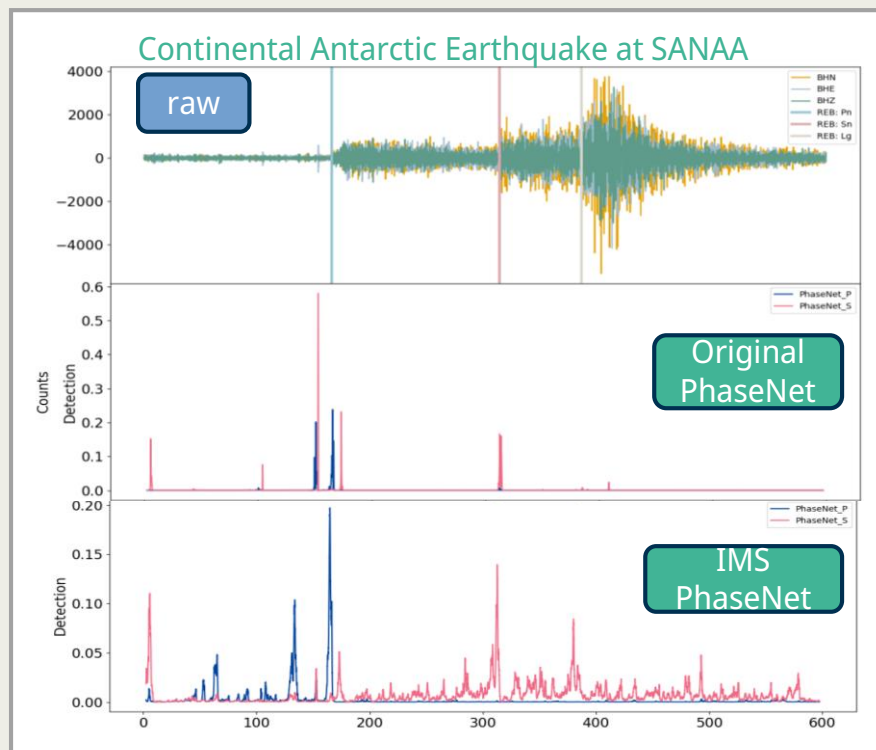
Conclusions

The model and dataset will be made available. PhaseNet performs better on IMS data in comparison to EQT. IMS PhaseNet model performs best in comparison to Original, Geofon and NEIC models. Geofon model is the second best (freely available via seisbench).

Retraining ML pickers specifically for the IMS dataset is strongly recommended based on the results of this study.



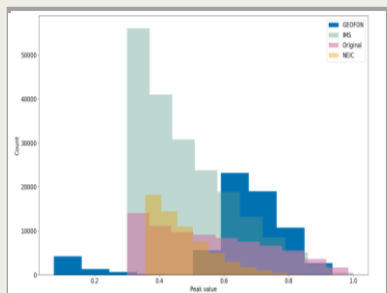
Another case Examples and certainty



- Magnitude 4.6, 2016-09-04 16:24
- 79.984°S 41.753°E; Distance: ~6000km

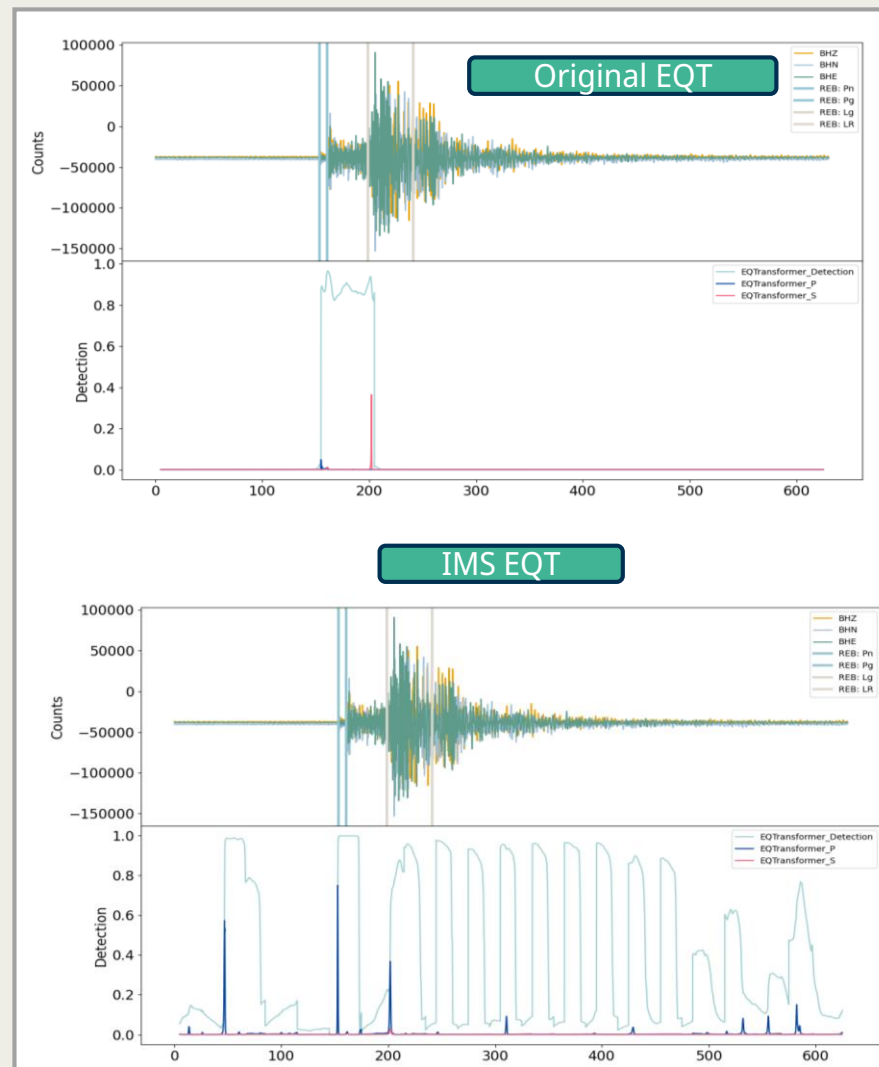
Certainty of predictions

- IMS model produces lower peak values
- ➔ Implies lower certainty and higher “noise” predictions but similar to original
- ➔ Geofon model has strong prediction confidences



EQT

Local earthquake in the Lubin area M3.0, 5km depth 2023-07-08 05:18:59

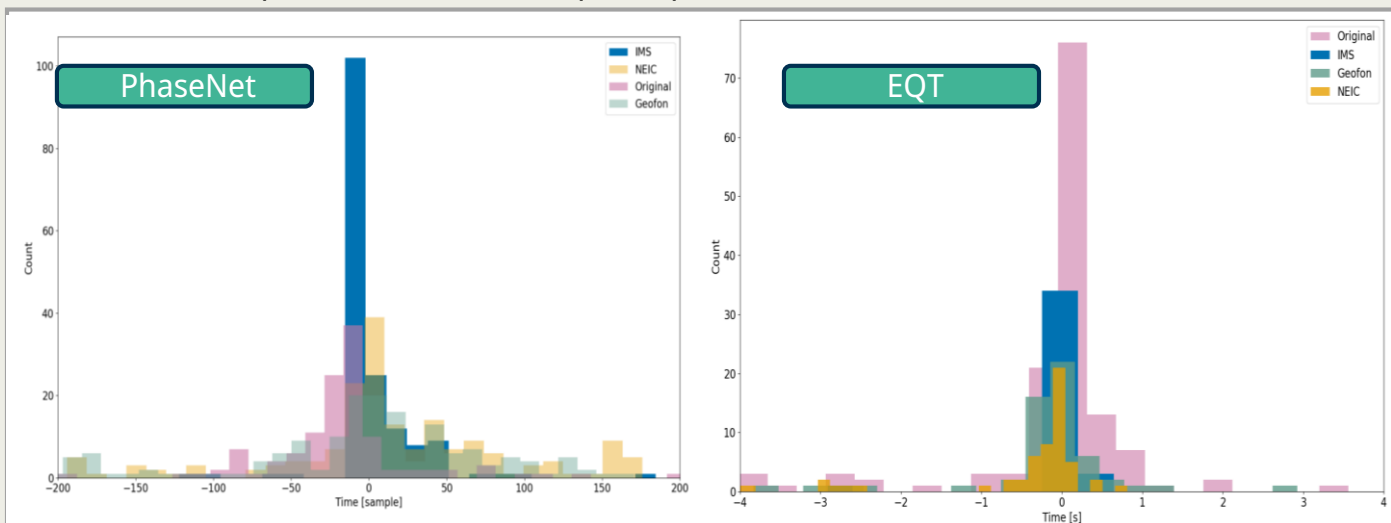
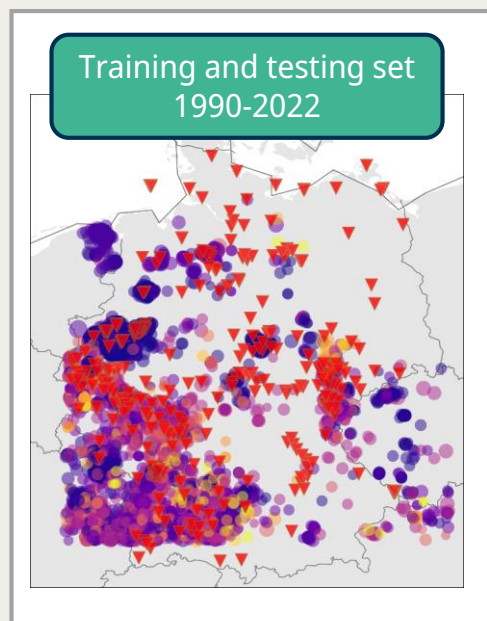


- Comparison between the original EQT and the retrained IMS EQT model. Original EQT shows correct first arrival identifications. The IMS EQT only predicts the first arrival correctly and has false detections.
- EQT seems to generally perform worse in comparison to PhaseNet for IMS data

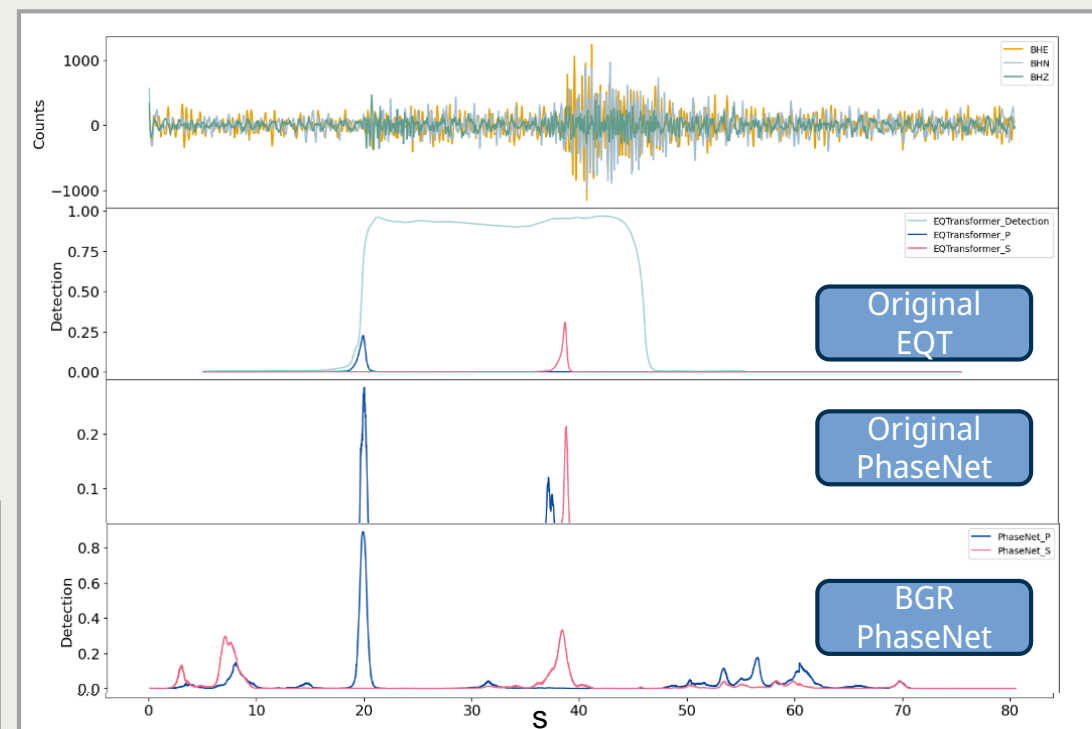
Application to local seismicity in Germany

BGR catalog of 804 earthquakes and explosions >M2 in 2023 in Germany.

- ~ 60k events from 1990 to 2022 (10k earthquakes, 17k induced events, other explosions)
- **phase picks:** 578.685 phases: Pg, Pn- and Sg, Sn-phases of networks: BQ, GQ, GR, HS, KQ, LE, RN, SX, TH, YA, Yd, Total 502 stations
- Waveforms are acquired 10s before and 10s after manual BGR phase pick
- Random shift in waveform start time of up to 5s and random 15 % of events withheld for testing
- Validation with 2135 events between 2023-2024 (552 earthquakes) in total 21414 phase picks



Waveforms from the first Nord Stream explosion (UTC 00:03) on 26th September 2022 at the local German station PEEM. A BGR data based trained PhaseNet is applied and compared to other models.



The original EQT and original PhaseNet models find the correct phases, but the original PhaseNet also finds a non-existent P-phase arrival just before the Sg-phase arrival.