Data-Driven Discovery of Earth GeoDynamical in the Pacific Northwest

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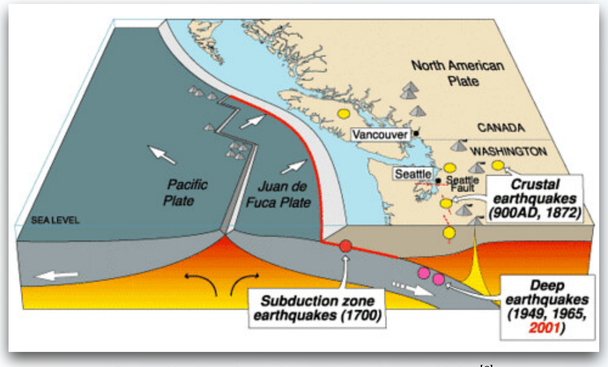
Background

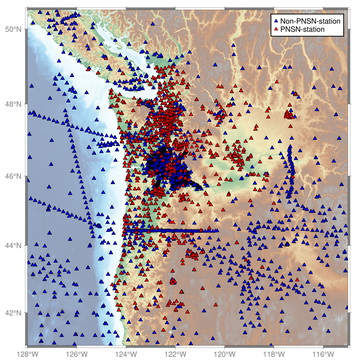
- ***The Pacific Northwest (PNW)*** is a particularly unique region in that it has a long record of seismicity (since the 1970s) and quite varied origins of crustal deformation, subduction- zone processes, volcanism, and surface processes.
- Earthquake catalogs gather important source characteristics of the past earthquakes. Seismologists rely heavily on accurate and comprehensive catalogs to do research like travel time tomography, full waveform inversion, seismic hazard characterization to establish active faults, and monitor seismicity to improve early earthquake warning. Manually processed catalogs usually are accurate, but impractical due to the time-intensive labor limits their completeness, especially as the seismic networks experience rapid growth.



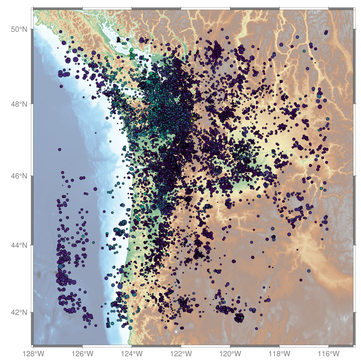
Cascadia Earthquake. Figure from USGS[6].

Data

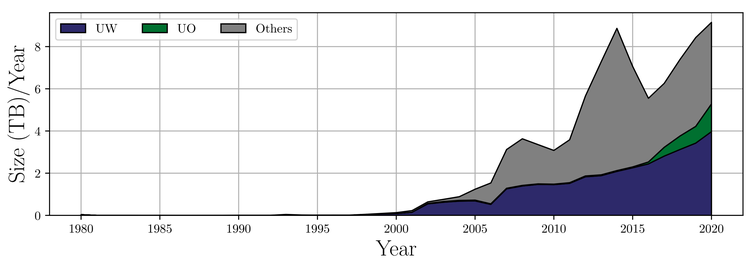
- We downloaded all seismic recording available at *Incorporated Research Institution for Seismology Data Management Center (*IRIS DMC[5]*)*, and focus on data of three-component seismometers sampled at 100Hz .
- Data are indexed with databases system for faster access.
- Metadata of 60 temporary and permanent seismic networks, and 100k earthquake events are stored in an XML format.



PNW seismic networks



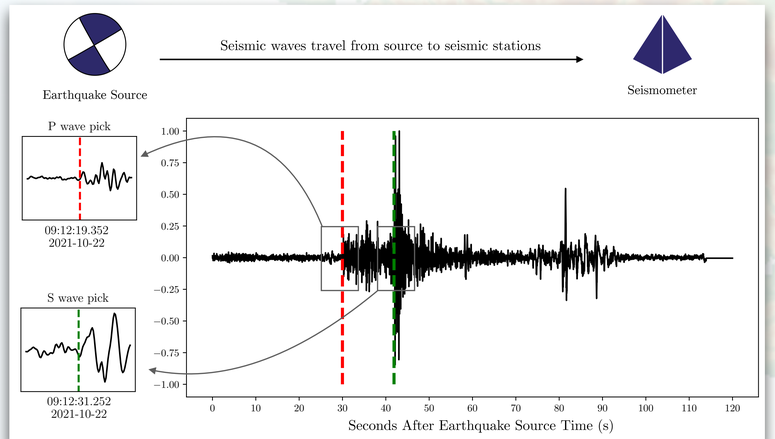
PNW earthquakes (1980-2020)



PNW seismic data availability by year at IRIS DMC[5].
Total sizes are UW (34TB), UO (4TB), and Others (50TB).

Method

- Curate PNW dataset from 20 years of earthquake records from UW seismic network.
- Retrain ***Earthquake Transformer*** model using this dataset.
- Refine and improve data on existing earthquake catalog.
- Todo: Earthquake detection, phase picking, and event classification on continuous waveform of other PNW seismic network.



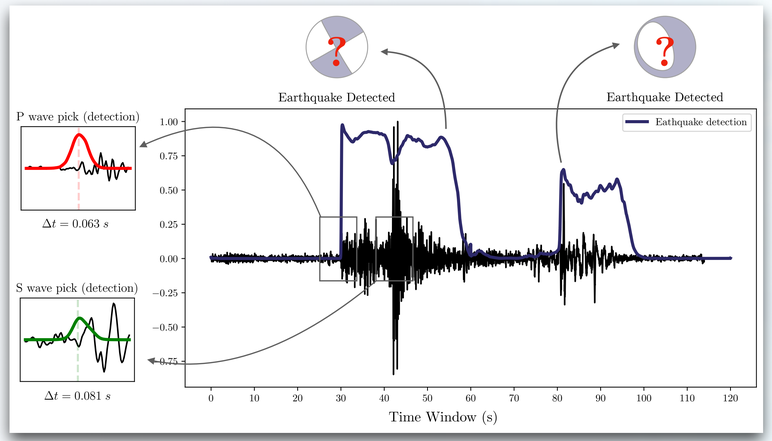
Ground motion recorded at seismic stations when an earthquake happens.

- Looks at events in PNSN[4] catalog between year 2000 and 2020, with magnitude>0.
- The PNW dataset contains 103k waveforms, P and S manual picks.
- Use ground motion record 50s before, and 100s after earthquake origin time.
- Retrain the model with the parameters pre-trained with global earthquake dataset STEAD[3].
- Single RTX 3090, batch size 512.

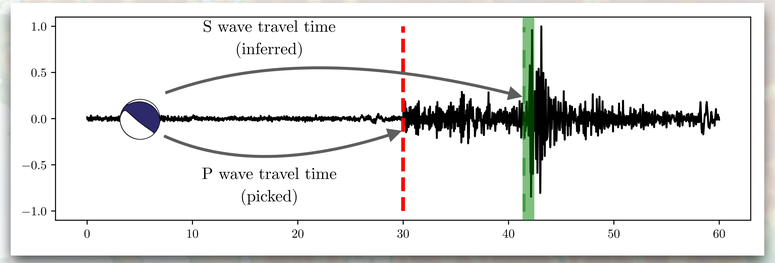
Train ↓

Earthquake Transformer[2]

Predict ↓



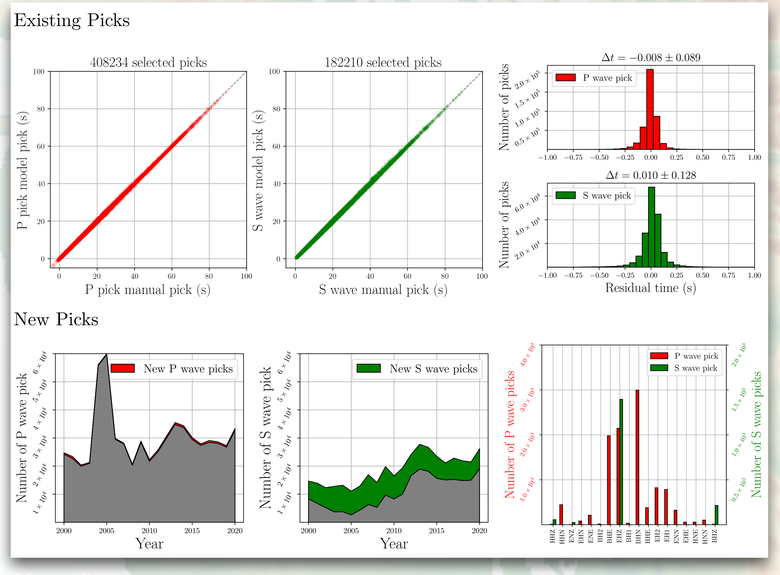
Prediction of Earthquake Transformer.



Inferred S wave travel time from P wave travel time.

Results

- Retraining the model with PNW data is necessary compared to using weights trained with data from a different region.
- Database system is accelerating the data streaming rate. For prediction on 20 years of earthquake catalog, it takes 11 hours of computation with 15 cores, 100% GPU, and 50 MB/s data streaming rate (from data server to computing server).
- Very small bias (less than 1 data point) and variant compared to manual picks for both P and S wave.
- Limited number of new P wave picks found (reasonable), but S wave picks are almost doubled compared to existing catalog.



Next Step…

- Check the quality of new P and S wave picks.
- Apply this model to more PNW stations and networks.
- Do prediction on continuous waveform.
- Predict on off-shore seismic stations and networks.

Reference

1. *Woollam, J., Münchmeyer, J., Tilmann, F., Rietbrock, A., Lange, D., Bornstein, T., Diehl, T., Giunchi, C., Haslinger, F., Jozinović, D., Michelini, A., Saul, J., & Soto, H. (2021). SeisBench—A Toolbox for Machine Learning in Seismology. ArXiv:2111.00786 [Physics].*
2. *Mousavi, S. M., Ellsworth, W. L., Zhu, W., Chuang, L. Y., & Beroza, G. C. (2020). Earthquake Transformer—An attentive deep-learning model for simultaneous earthquake detection and phase picking. Nature Communications, 11(1), 3952.*
3. *Mousavi, S. M., Sheng, Y., Zhu, W., & Beroza, G. C. (2019). STanford EArthquake Dataset (STEAD): A Global Data Set of Seismic Signals for AI. IEEE Access, 7, 179464–179476.*
4. *Pacific Northwest Seismic Network: https://www.pnsn.org*
5. *Incorporated Research Institutions for Seismology Data Manage Center: https://ds.iris.edu/ds/nodes/dmc/*
6. *United States Geological Survey: https://www.usgs.gov*