Identifying Unrecorded Seismicity in Eastern Scotland

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Probing **I**nto the **C**rust **T**hrough eastern **S**cotland

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PICTS field seismometers were deployed for a year between Summer 2022 and Summer 2023 at **ten locations in Aberdeenshire, Perthshire and Angus** (**Figure 1 inset**). Collected data was analysed using **machine-learning based pickers**, which were then associated into events using the GAMMA associator. The focus was on pre-trained, readily available models to assess their **validity for studying areas with little or no known seismicity.**
Additionally, **new models are currently being trained (Figure 2)**, using known events and human-annotated phase arrivals, to see if they can provide more accurate event detection

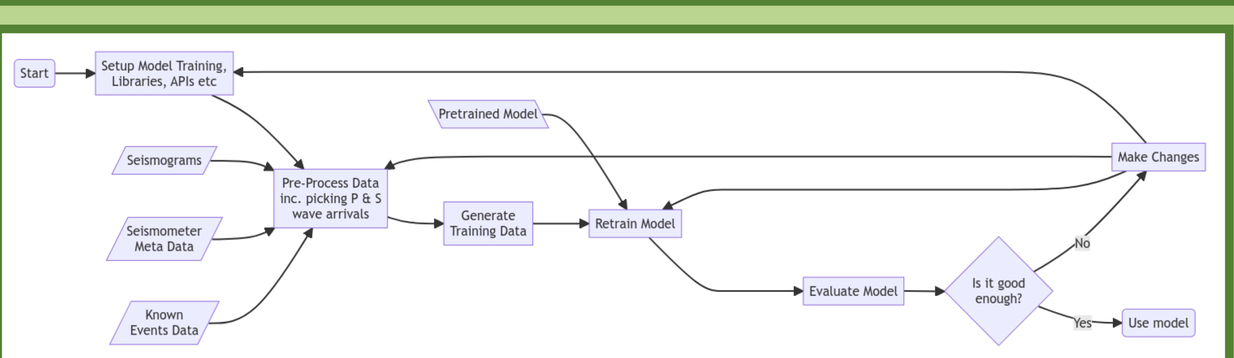

Figure 2. Flowchart illustrating model training process

We found that **bandpass filtering 2-8 Hz consistently improves model predictions** for known events as compared to unfiltered waveforms (Figure 3) on noisier data. Furthermore, on filtered data, **EarthquakeTransformer** (pre-trained on the *original* dataset included in the Seisbench API) **seems to perform better than PhaseNet**, which includes a degree of false positives (Figure 3).

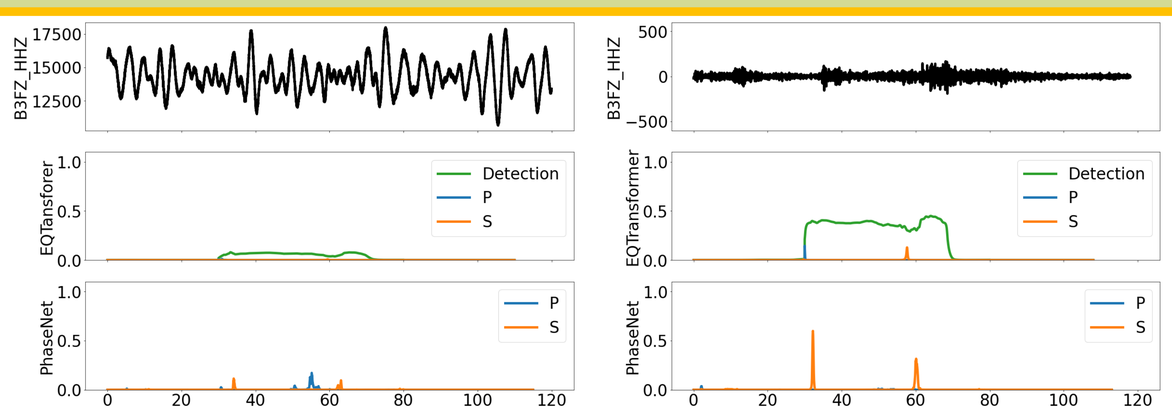

Figure 3. Z-channel waveforms from a PICTS station (B3FZ) and model probability functions. Right panels show unfiltered data, left panels show bandpass-filtered data (2-8 Hz)

When retraining ML picker models using PICTS data (Figures 2 and 4), we found that **using travel-time models (TauPy) alone to generate P & S wave arrival times produced inferior models.** Initial indications are that **models retrained on PICTS data using manually picked arrival times will likely outperform existing pretrained models** for applications in this geographic region. A side benefit to manual picking is that anomalies for further investigation have been discovered, such as abnormal wave travel times.

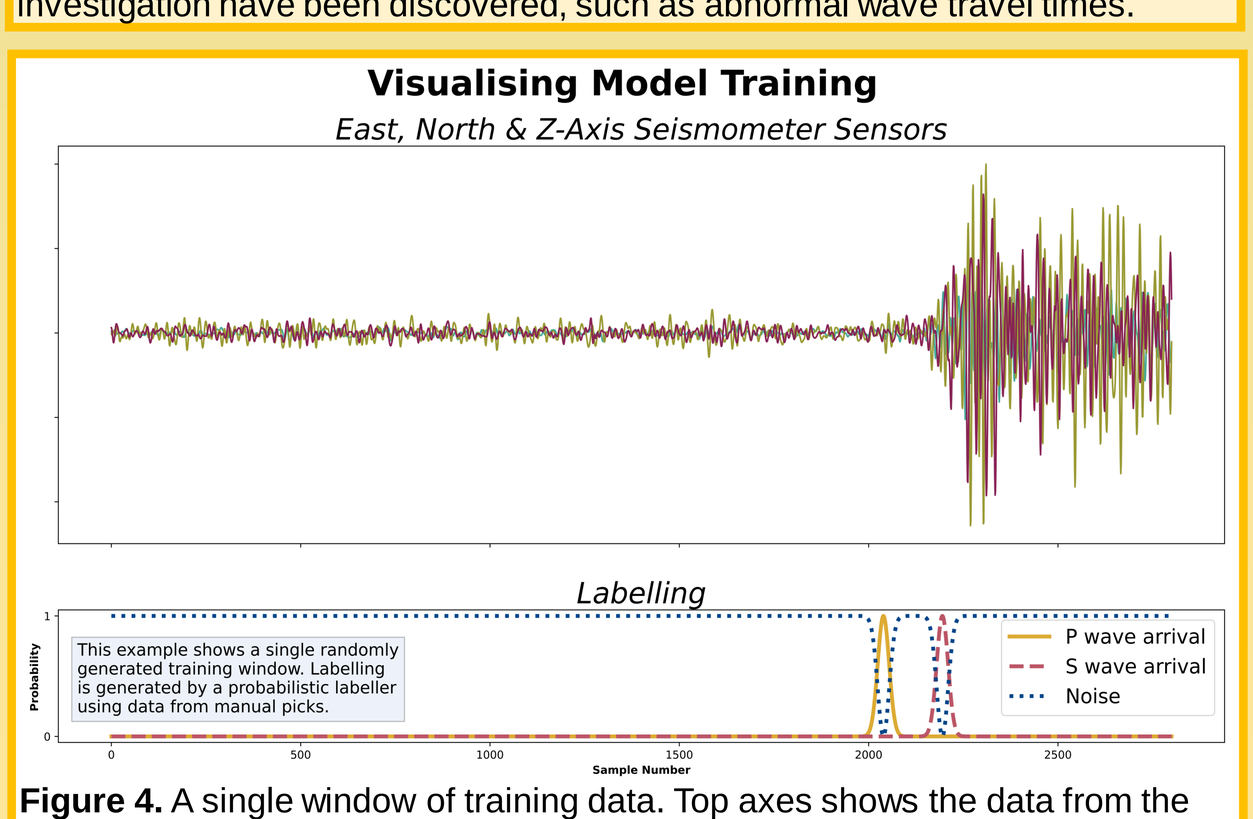

Figure 4. A single window of training data. Top axes shows the data from the seismometer, with bottom axes showing the training labelling for the data

Limited testing was also done with ML based denoising; **DeepDenoiser was found to have a slightly detrimental effect on model pick accuracy** when applied to the target data.

Our Training Code

https://github.com/dgc-proton/PICTS_ML

Seismic activity in Scotland is limited to the West of the country **(Figure 1)**. The **Highland Boundary Fault (HBF)** is of particular interest, as it stretches from SW to NE Scotland. **HBF does express seismicity in its Western portion, but not the Eastern**. As part of the PICTS project, an array of ten seismometers was deployed in Eastern Scotland, on both sides of HBF, to identify any unrecorded seismic events.

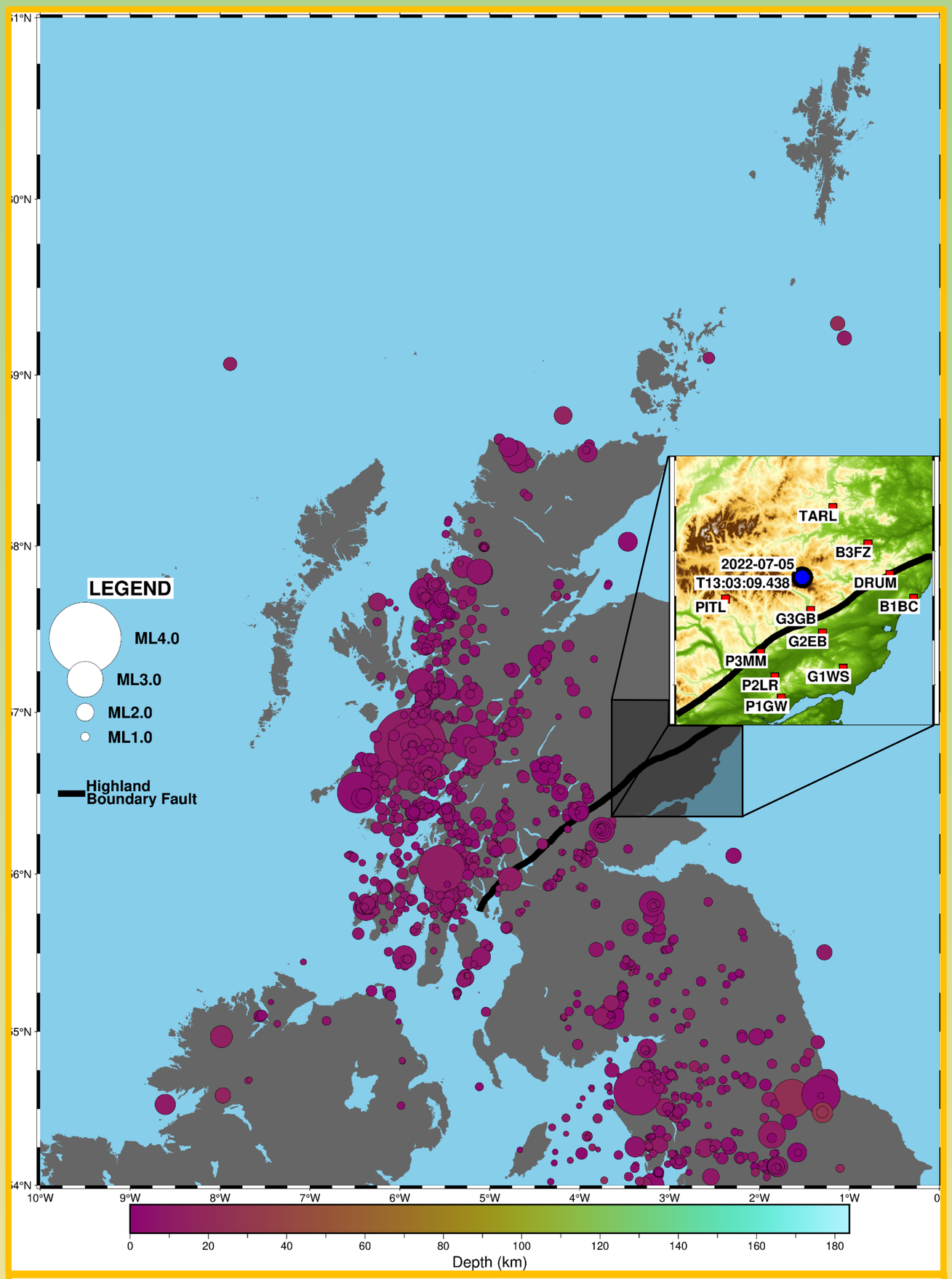

Figure 1. Map of earthquakes recorded by BGS between July 2013 and July 2023, showing depth and local magnitude. HBF marked by a black line. Locations and names of PICTS stations, as well as a potential unrecorded event on inset.

Figure 5. Filtered E-channel waveforms and spectrograms from a PICTS station (B3FZ), a RaspberryShake station (R92E0, Stonehaven), and a permament BGS seismometer (DRUM, Drumochty Mains).

The GAMMA associator ran on ML model picks has **found multiple potential events**. However, one, which occurred on July 5 2022 stands out as potenially local (**Figure 1 inset**), as the **signal length (~40s) is similar to other local earthquakes**, and the **spectrograms show more high-frequency signals** as compared to teleseismic events (Figure 5). This event is clearly present on multiple PICTS and non-PICTS stations, **and the time of the event does not match any known events**.