Applying the Taiwan Transformer Shaking Alert Model to Regional Earthquake Early Warning

- An AI EEW model for Taiwan seismic network
- Case study on M>6 events intensity estimation
- Interpretable AI for feature extraction on waveforms

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Regional EEW System

Detection Range

It covers a larger geographical area and predicts intensity with a greater distance from the earthquake epicenter.

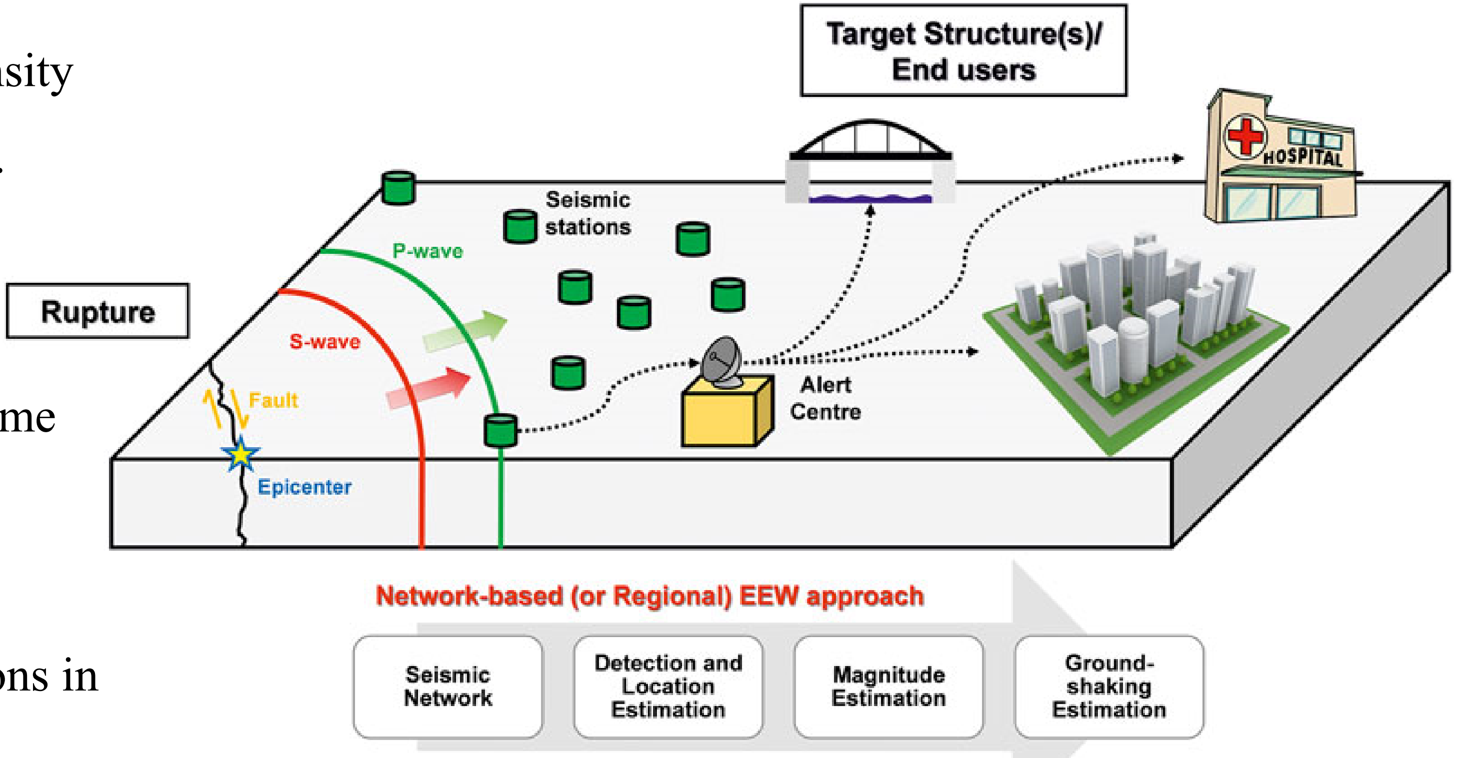
Optimization tasks

1. Increasing accuracy of intensity prediction
2. Reducing EEW processing time makes the lead time longer and the warning blind zone narrower

Challenges

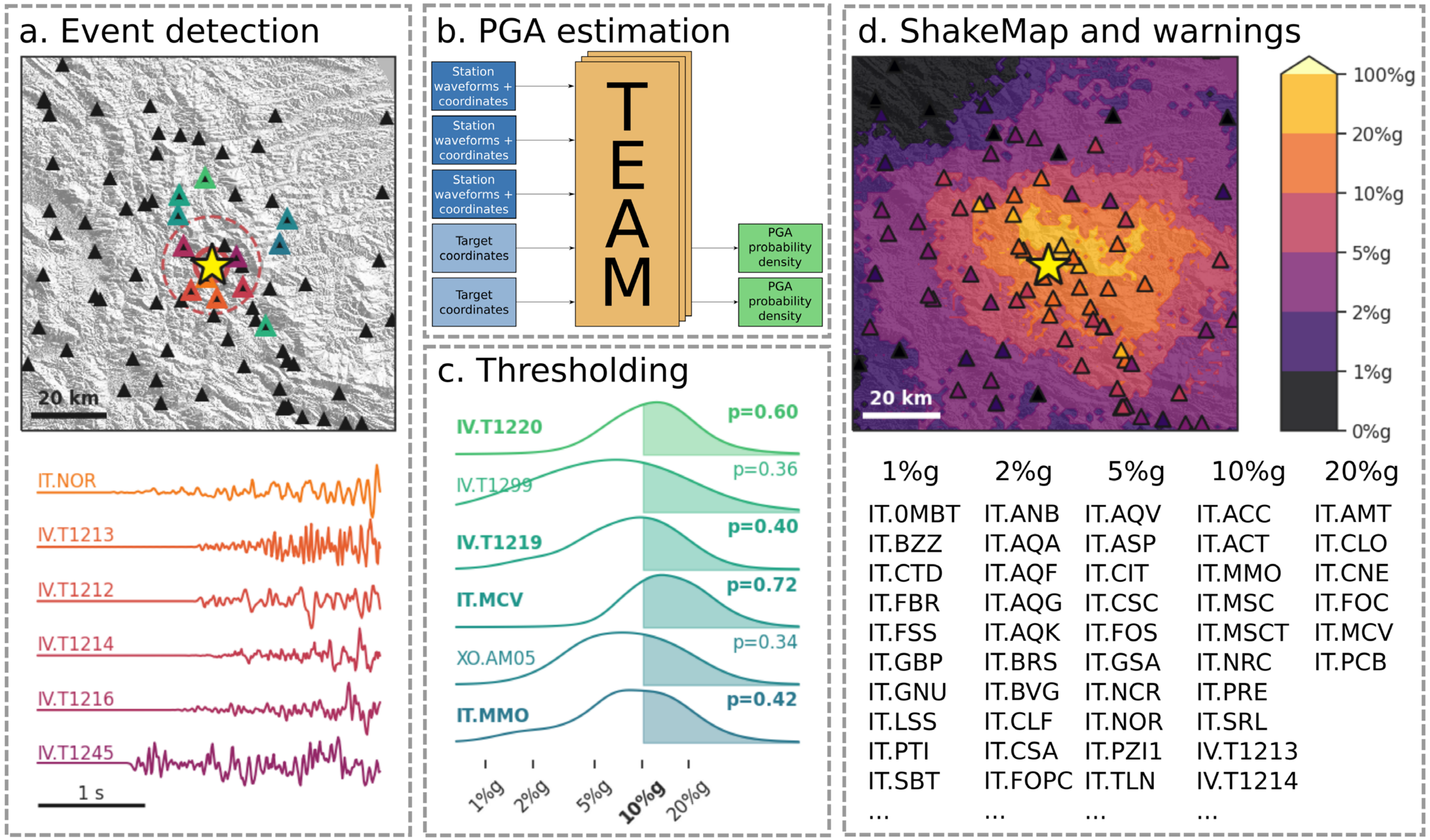
1. There are uncertainties due to simplified assumptions in the source parameters (magnitude, location).

2. Miss or false alarms from offshore events result from a larger uncertainty of the earthquake location



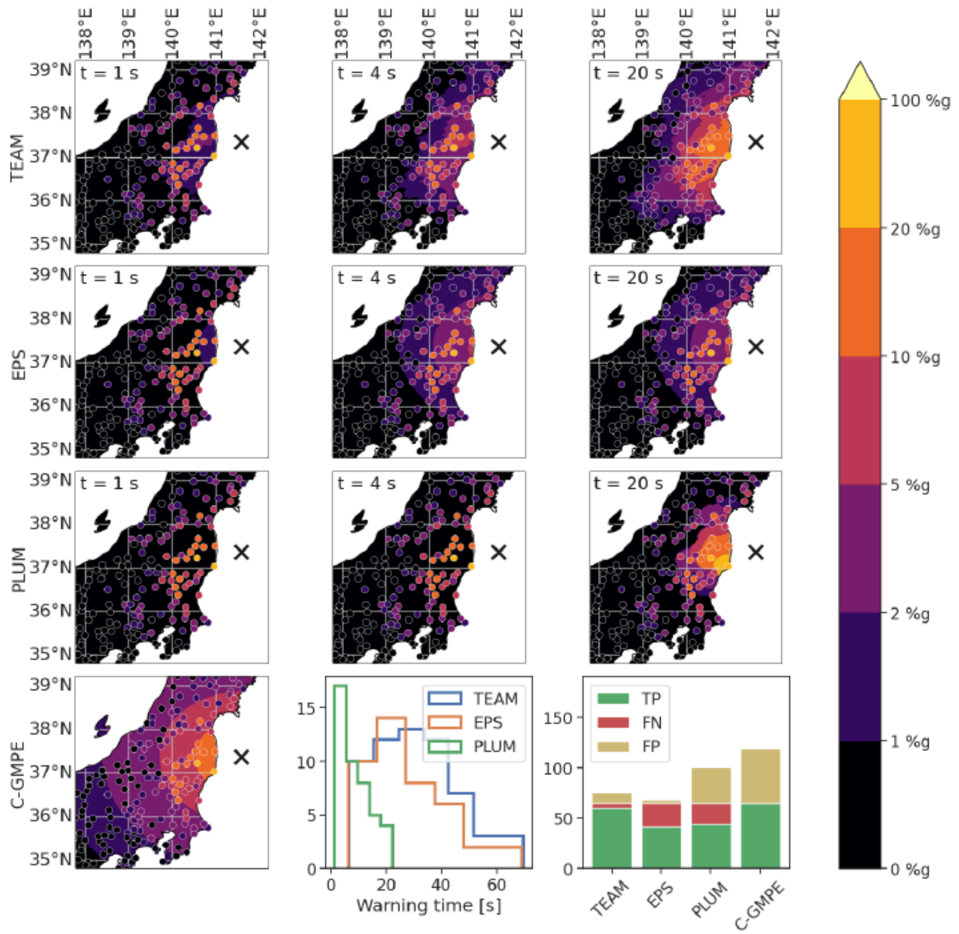
Zuccolo et al., 2021

An application of AI in EEW



Transformer Earthquake Alerting Model (TEAM)

2016 Fukushima earthquake with a magnitude of 7.6



Münchmeyer et al., 2021

Data

Seismic network: TSMIP

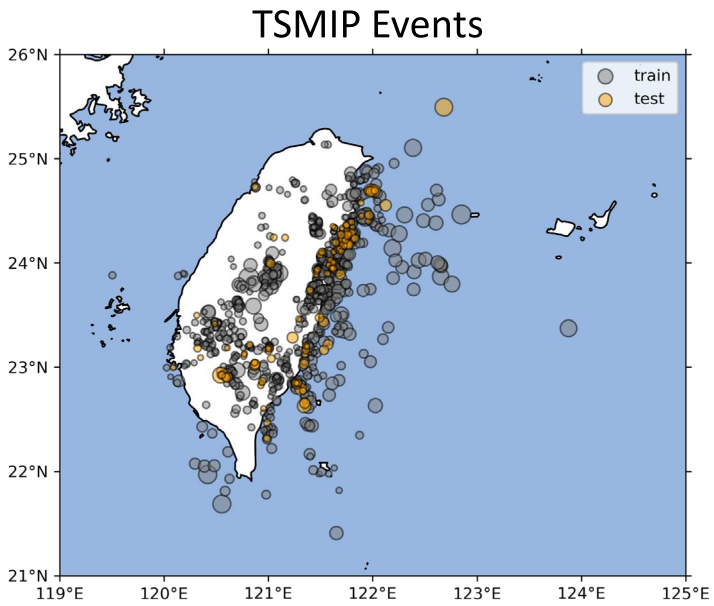
Period: 1999~2019

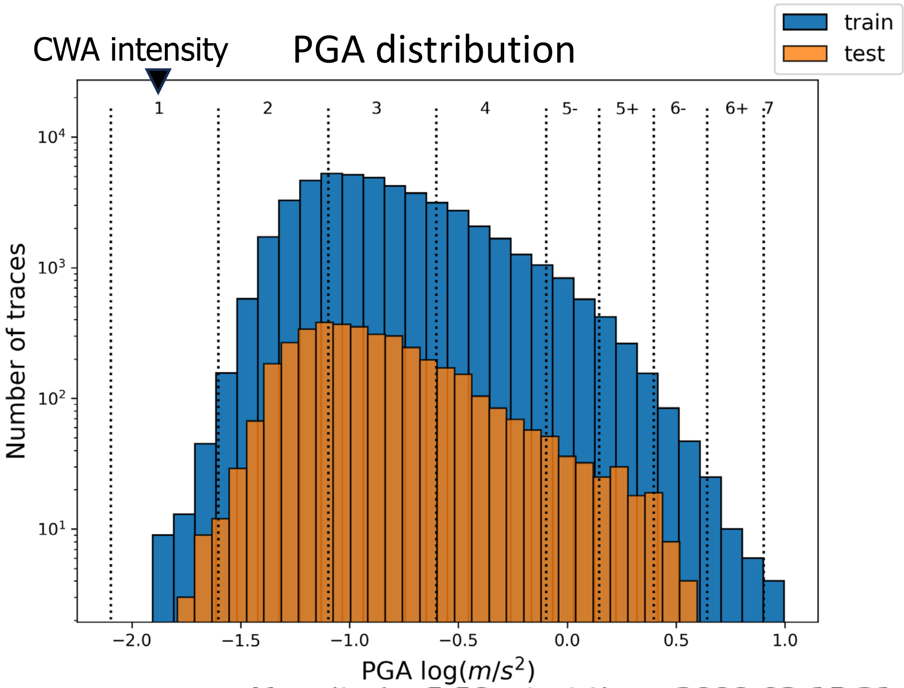
Magnitude: 3.5~7.3

Number of events: 1259

Test data: data in 2016 (129 events)

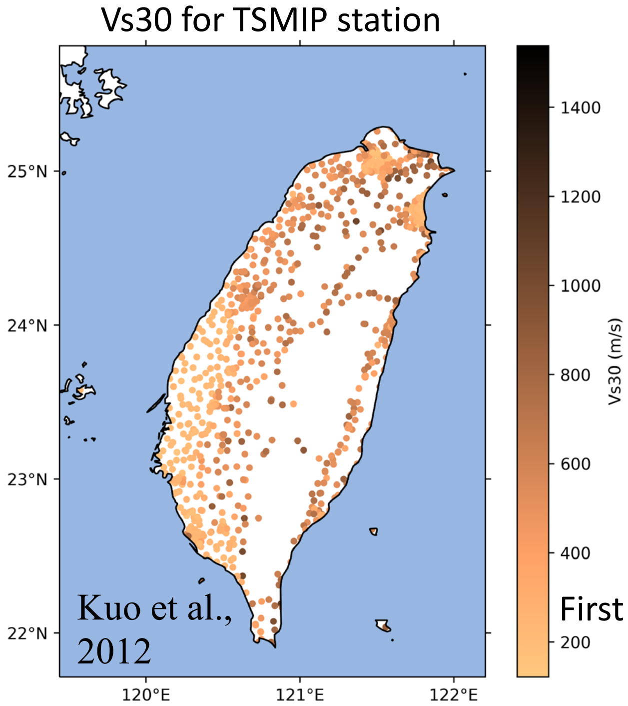
Site effect parameter: Vs30

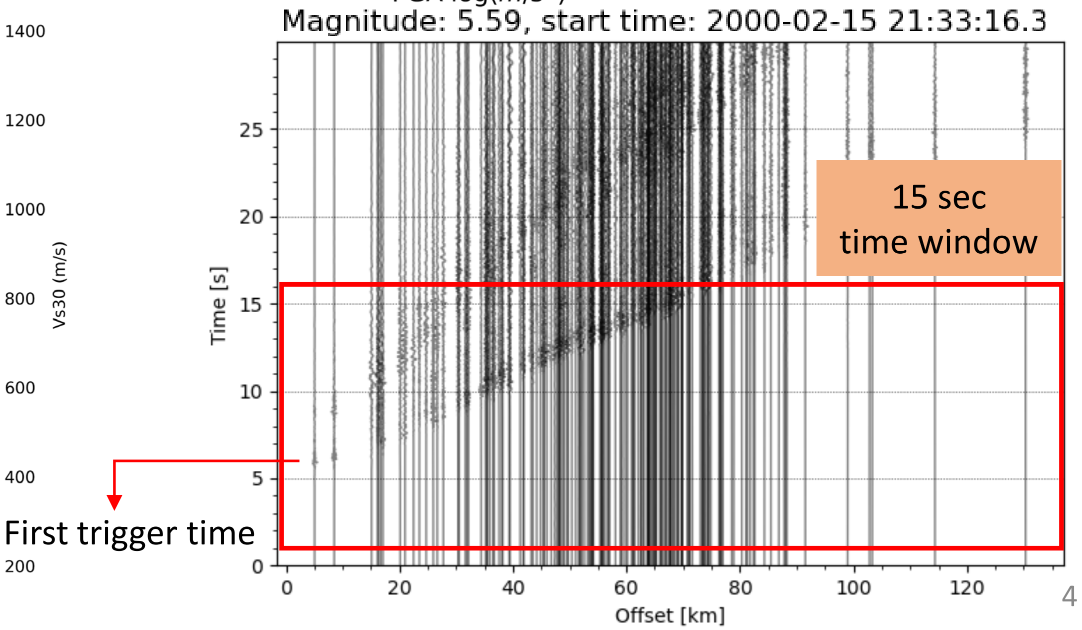




Model Inputs

1. 15 seconds 3 channels triggered traces
2. Triggered station location, Vs30
3. Target station location, Vs30
4. PGA (for training)





Model Architecture

Feature extraction:

Recognize complex features in seismic waveforms

Feature combination:

Build relationship between waveforms and stations

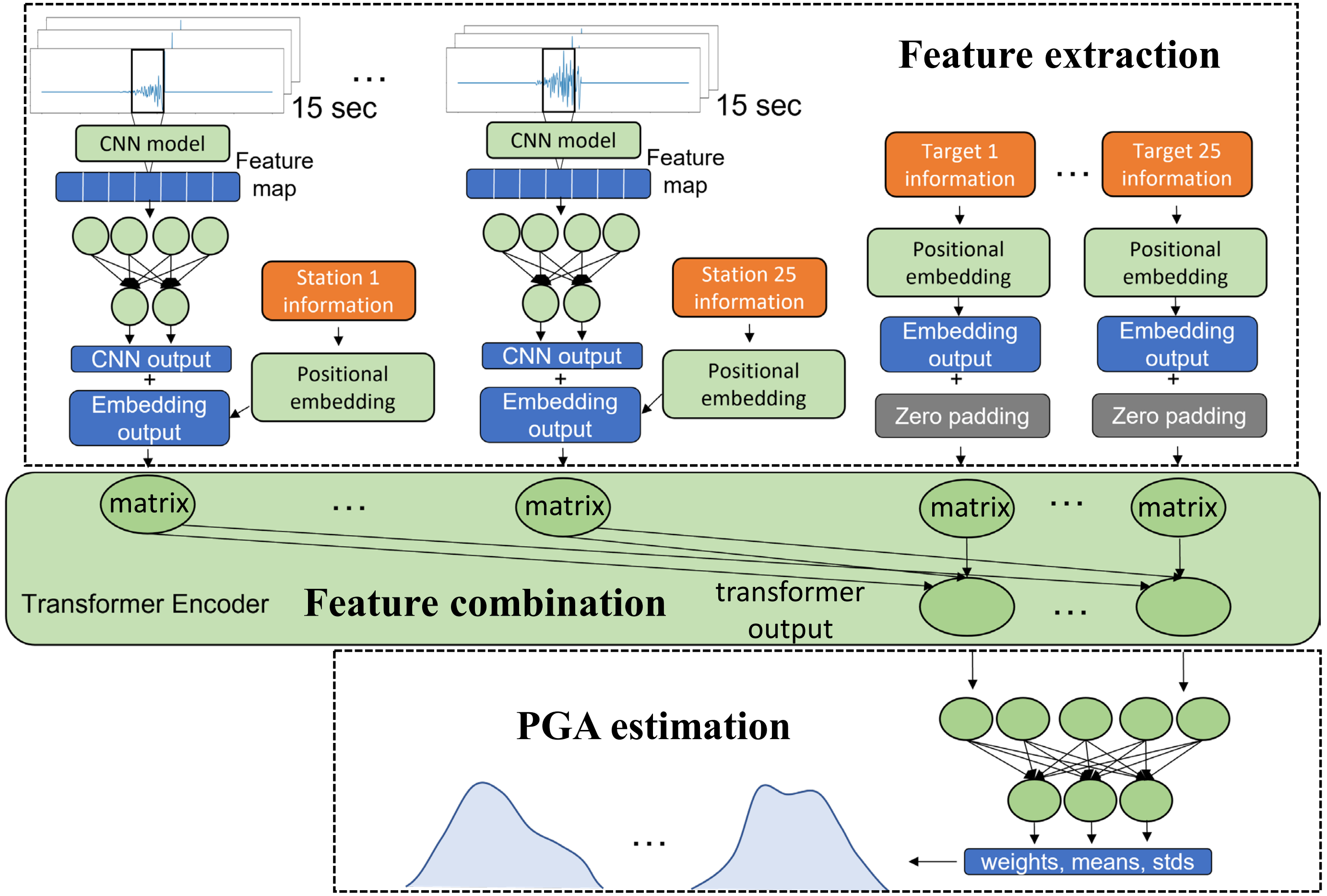
PGA estimation:

Produce PGA probability densities for target locations

Thresholding:

Issue warning when exceedance probability surpasses a predefined probability threshold

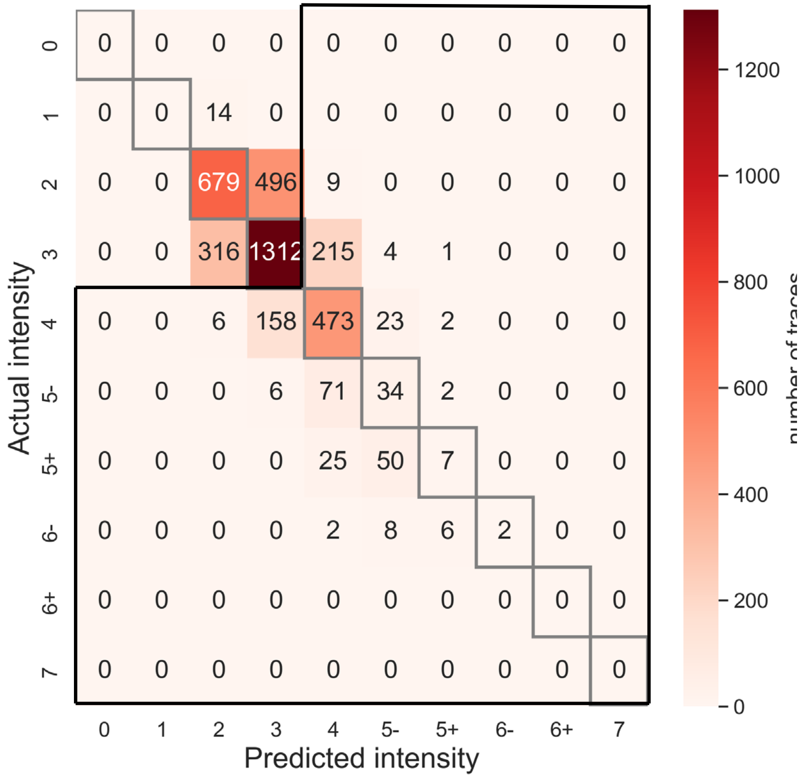
The Taiwan Transformer Shaking Alert Model (TTSAM)



Probability density functions of PGA

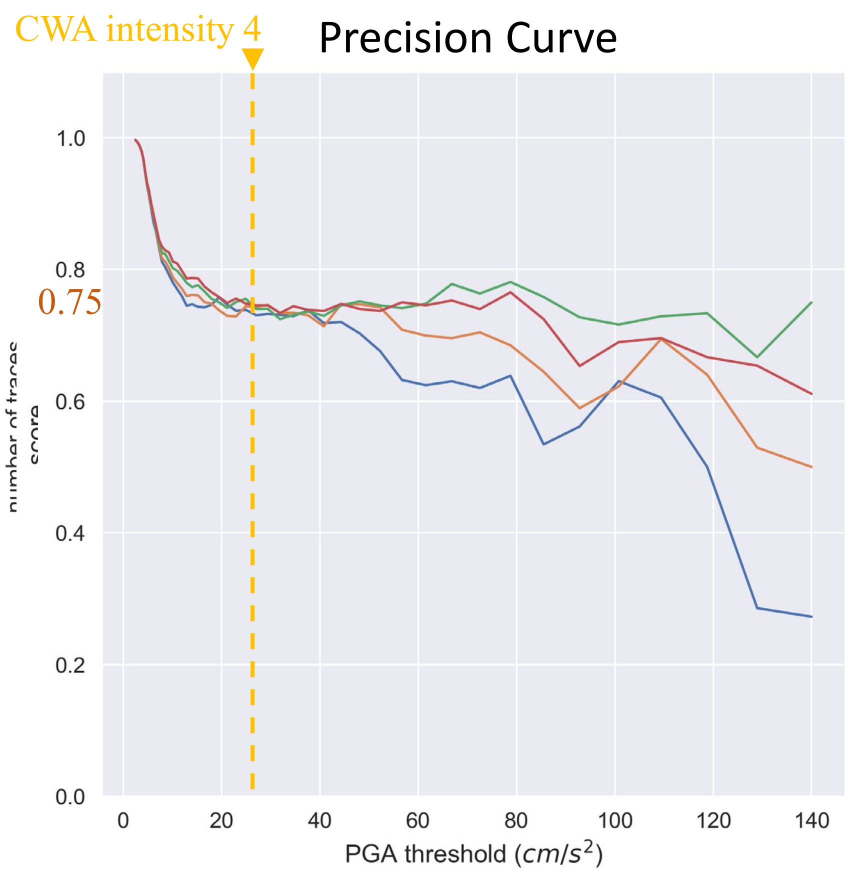
Intensity Performance

Intensity Confusion Matrix

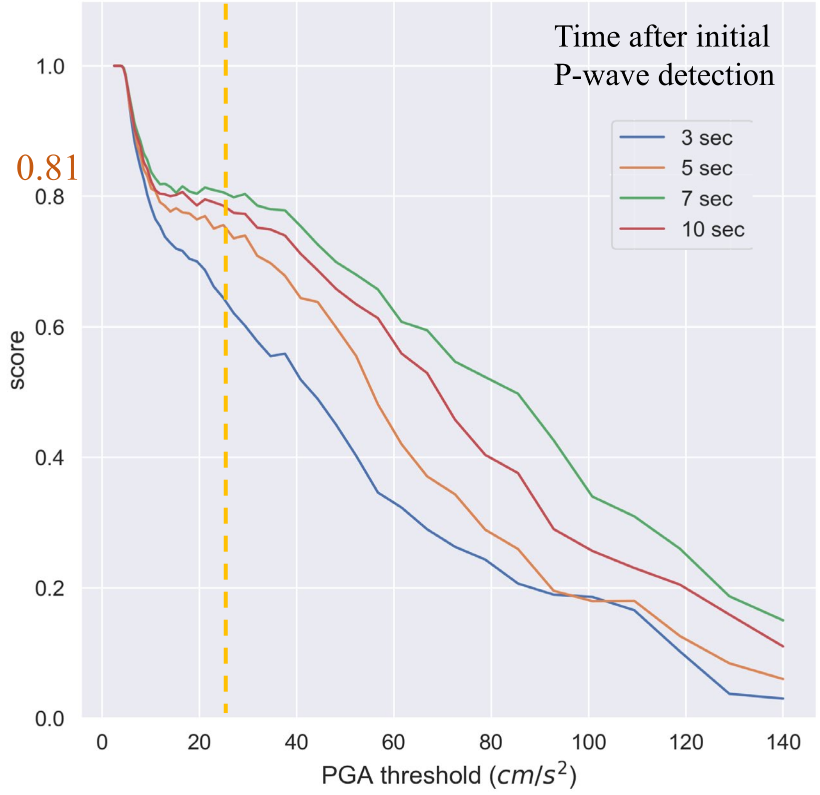


CWA intensity 4

Precision Curve

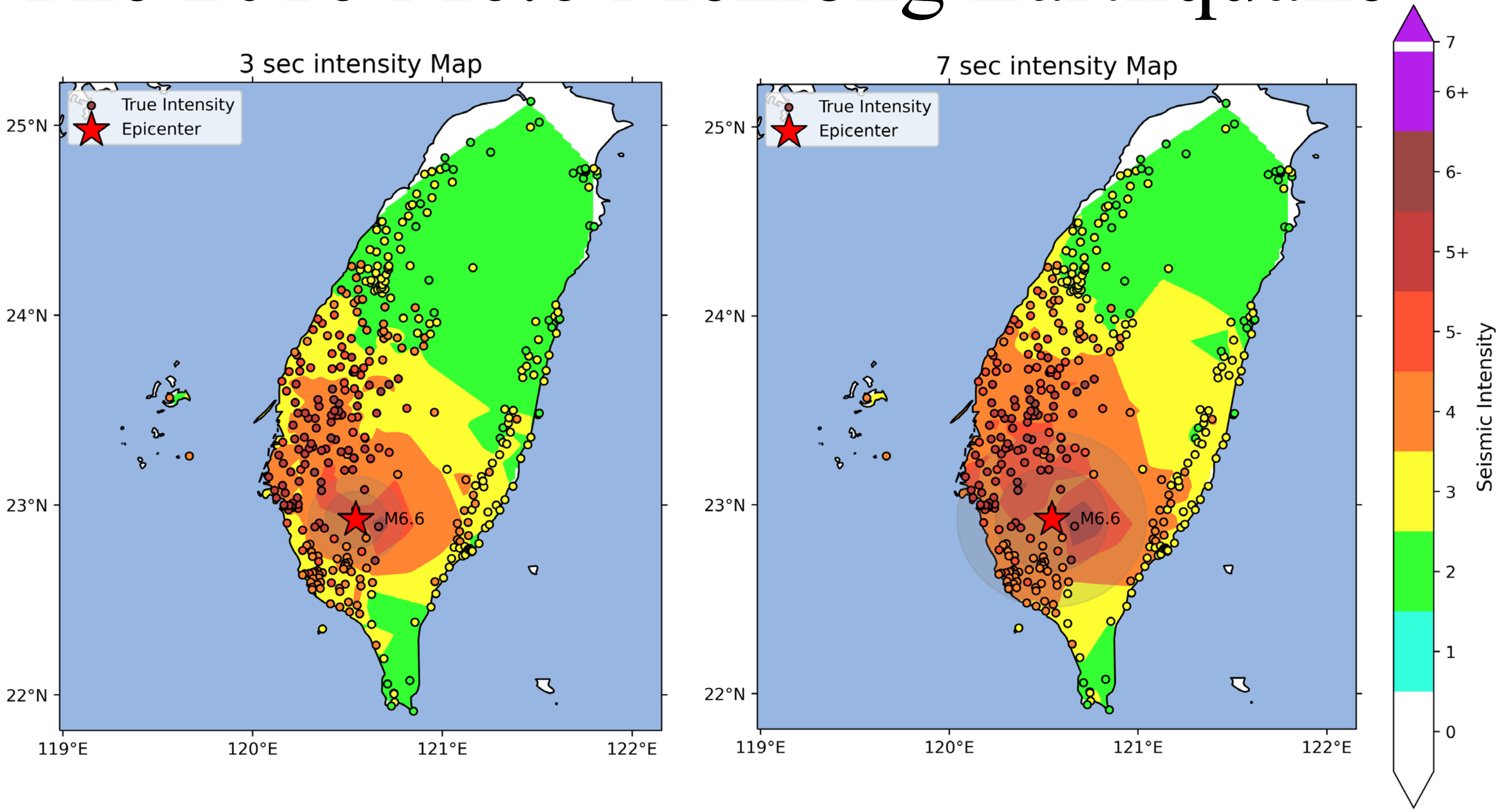


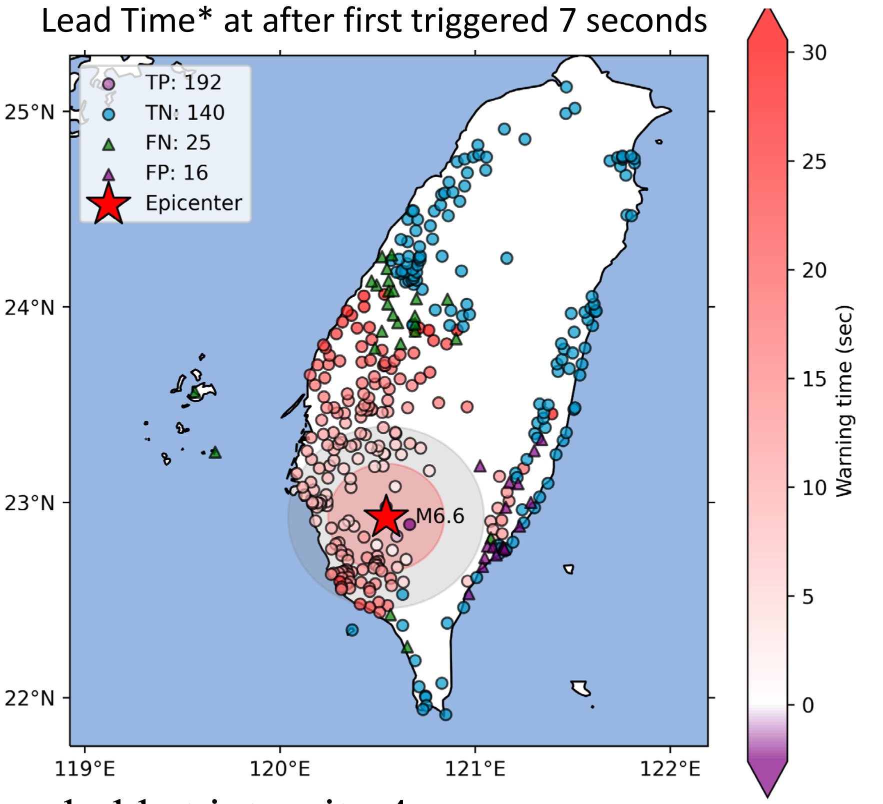
Recall Curve



- 64% of predictions accurately match the true intensity.
- 94% of the data exhibit intensity deviations within ±1 level.
- Adjustable warning thresholds to accommodate varying sensitivities to seismic motion for various end-users

The 2016 M6.6 Meinong Earthquake





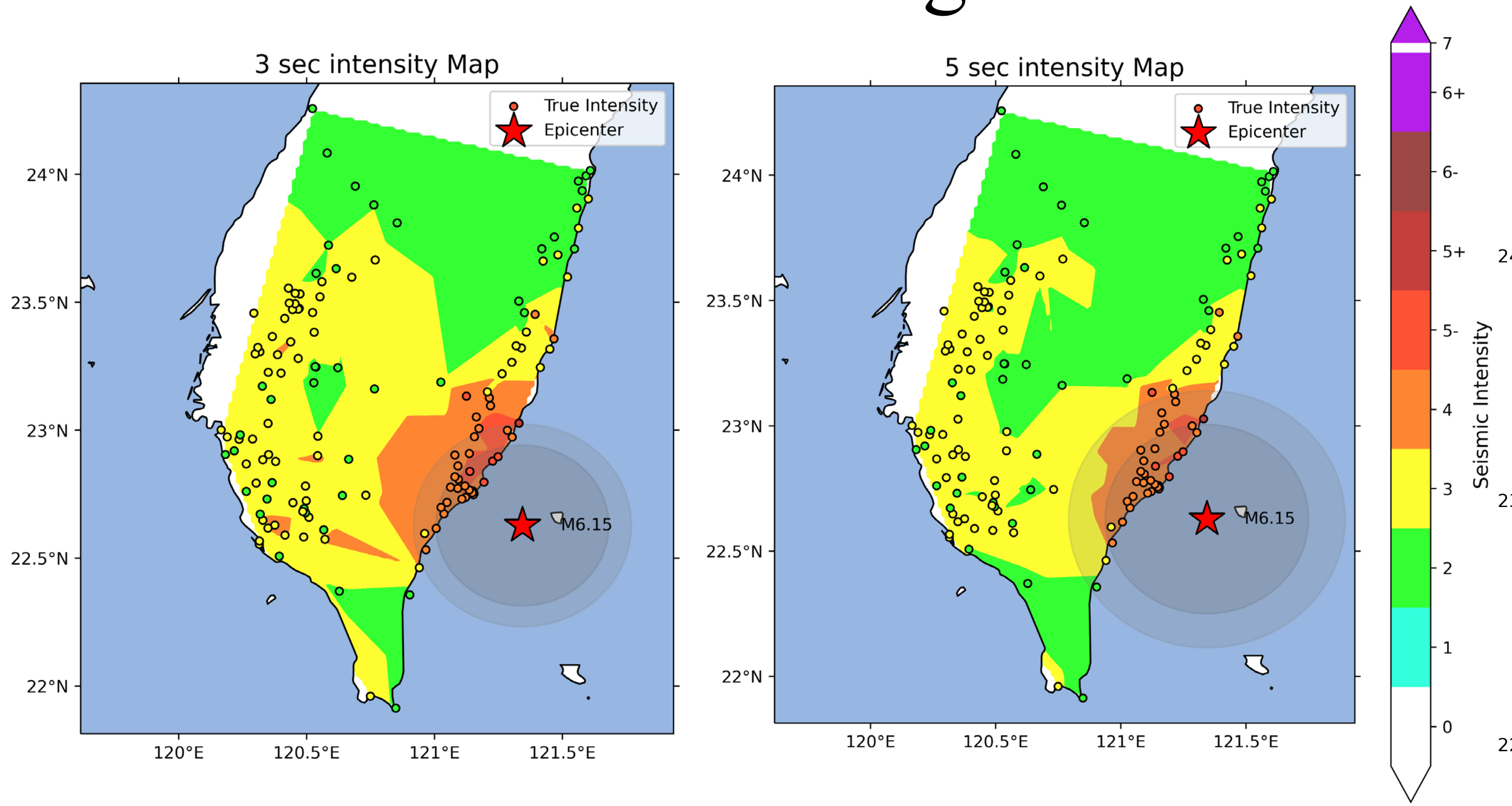
- The TTSAM starts estimating intensity after 3 seconds of initial P-wave detection.
- The TTSAM effectively identifies 80% of the area with intensity 4 and above after 7 seconds.

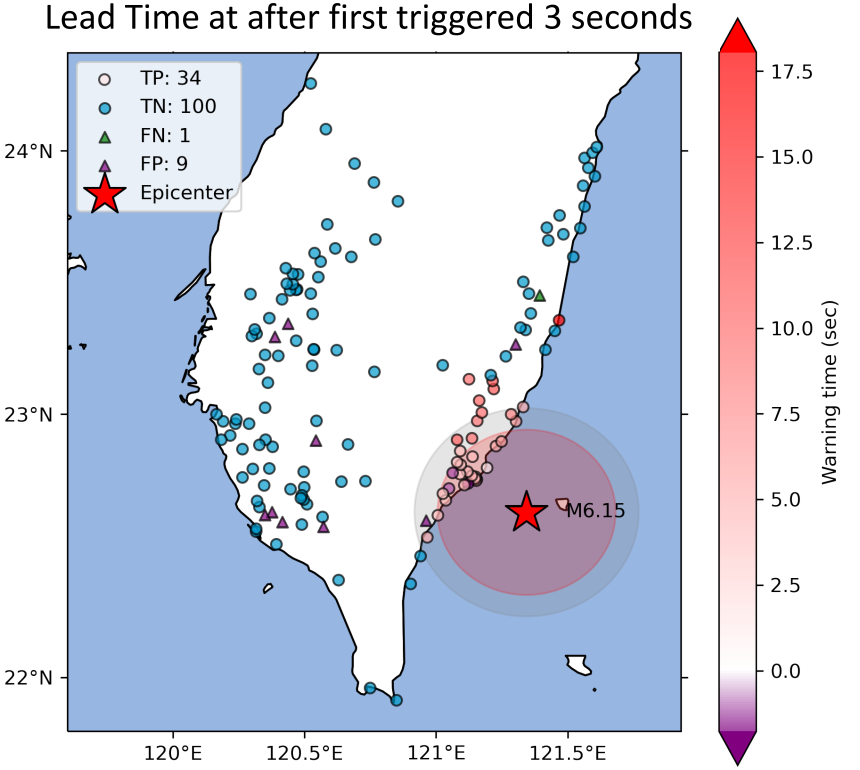
Set warning threshold at intensity 4

- Precision: 0.92 and recall: 0.88 (at the 7th second)
- Average lead time: 16 seconds

*Lead time: the time between PGA and issuing warning

The 2016 M6.15 Taitung Offshore Earthquake



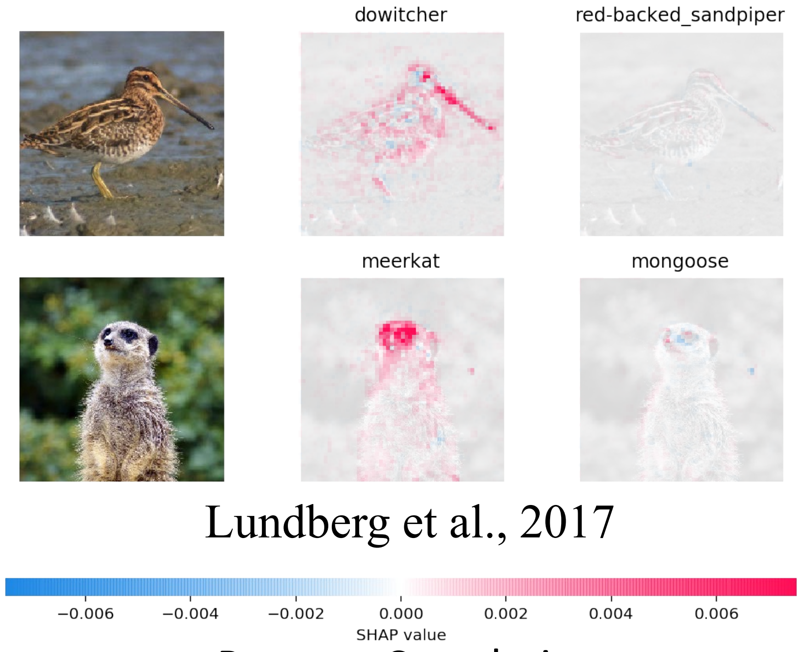


- The TTSAM precisely estimates the area with strong intensity after 3 seconds of initial P-wave detection.
- Precision: 0.80 and recall: 0.97 (at the 3rd second)

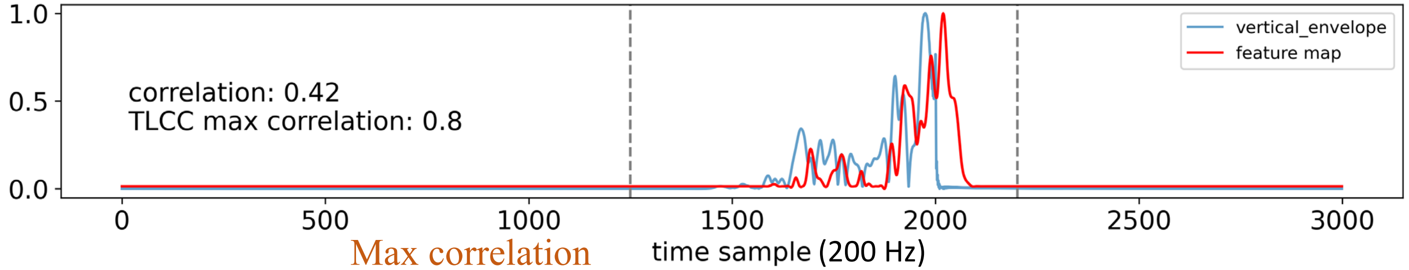
- Corrections are applied to assess the intensity of seismic activity in distant areas at the 5th second.
- Average lead time: 7 seconds

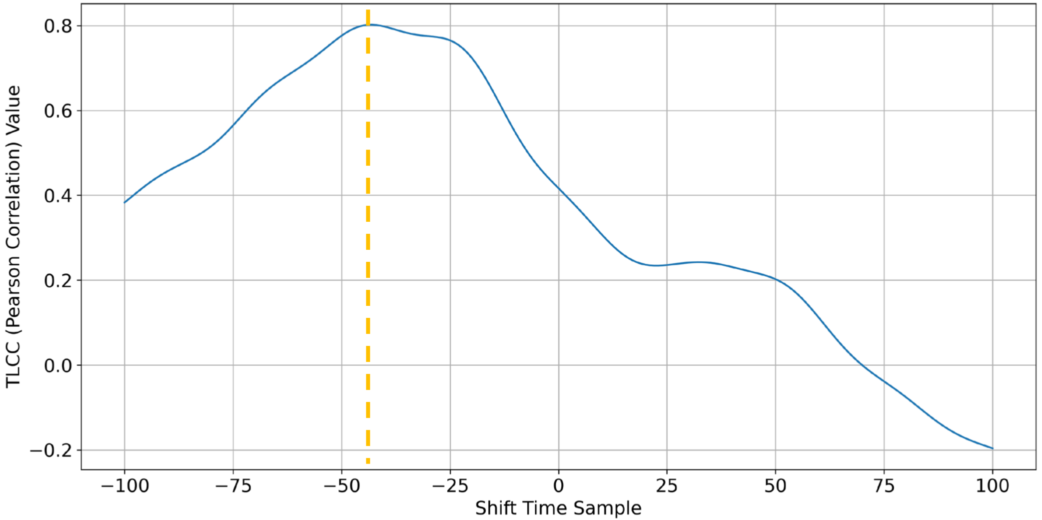
Interpretable Feature Extraction

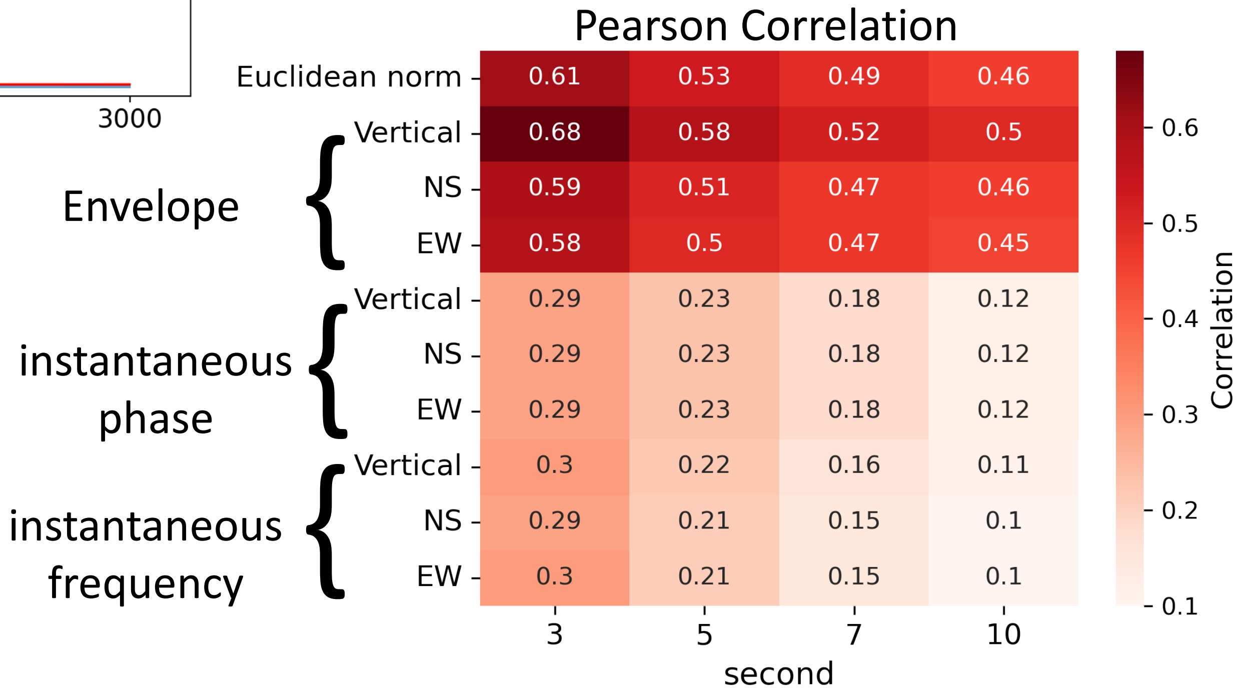
- We use TLCC (Time Lagged Cross Correlation) to quantify the correlation between waveform feature map and physical parameters.
- Highest correlation: 3-second vertical of waveform envelope



Lundberg et al., 2017

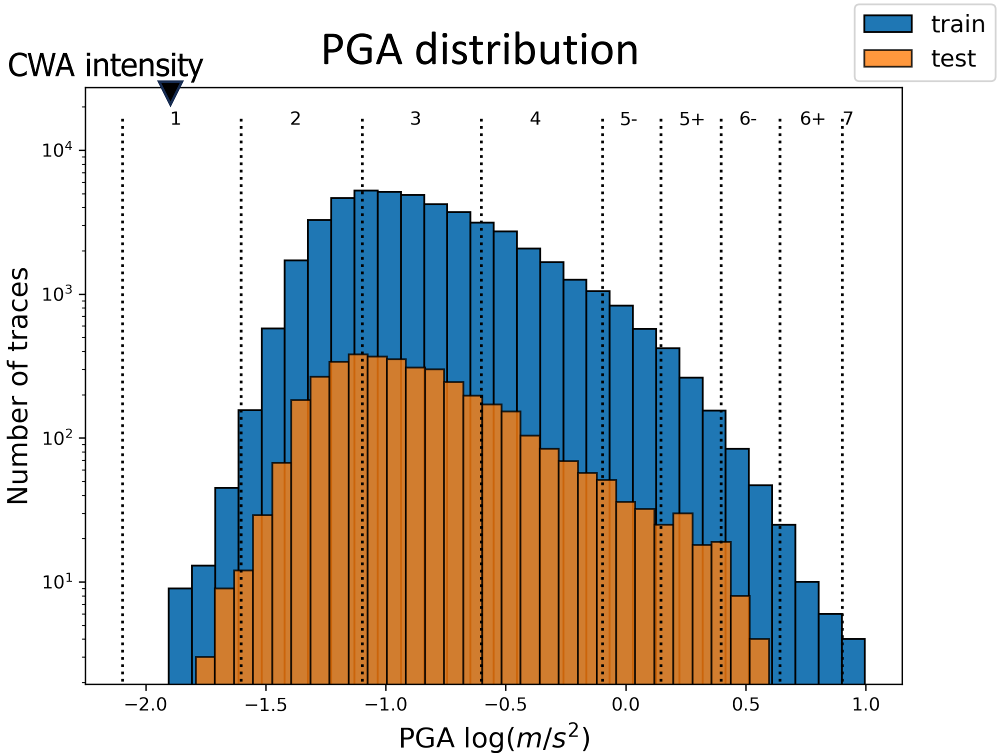






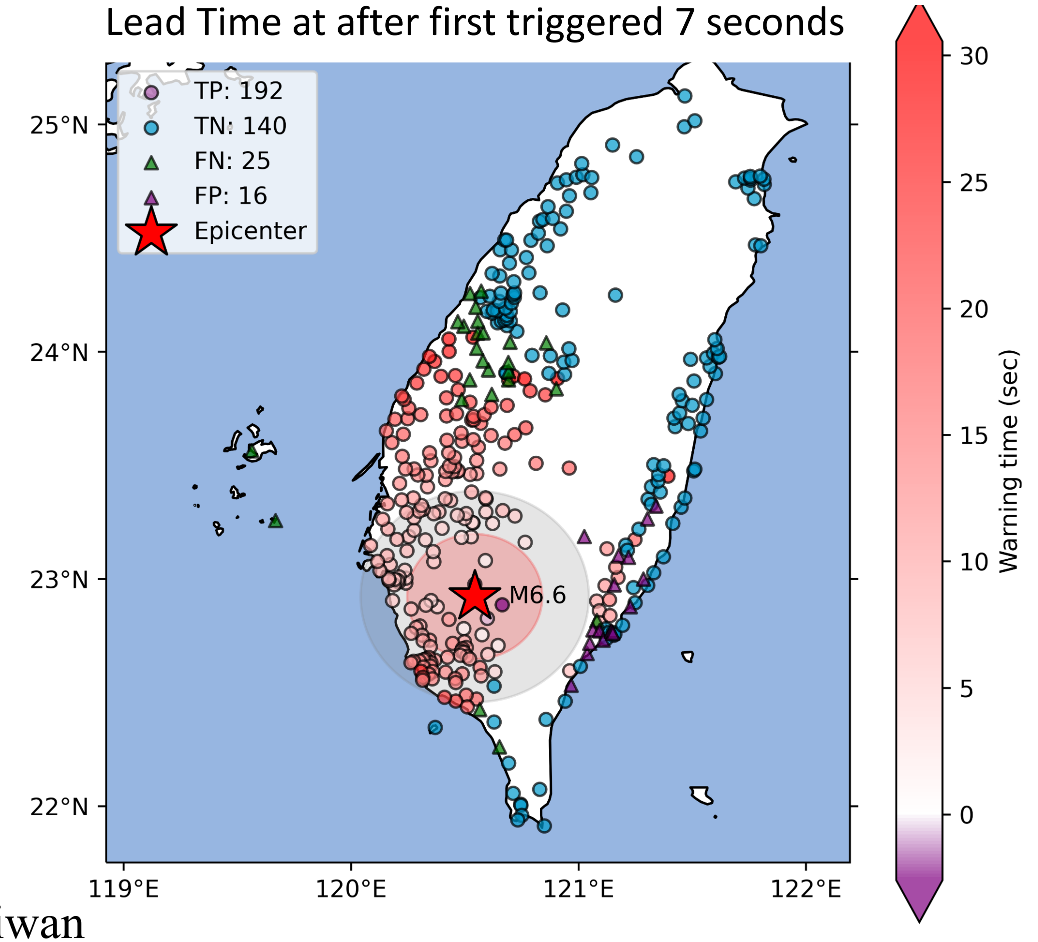
High Intensity Underestimation due to scarce data

- Accurate intensity estimation remains challenging for events with intensity levels of 5- and above.
- Introducing the Generative Network (GAN) to generate high-intensity data in Taiwan to assist model training.



Takeaways

- AI-based TTSAM achieves better compatibility with Taiwan's seismic station network than TEAM.
- Setting the alert threshold at intensity level 4, the model demonstrates a precision of 75% and a recall rate of 81%.
- For the Meinong and Taitung Offshore earthquakes, the warnings are issued 16 seconds and 7 seconds in advance, respectively.



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