MIT EARTH RESOURCES LABORATORY
ANNUAL FOUNDING MEMBERS MEETING 2019

Earth Resources Laboratory

# A Deep Learning Architecture for Earthquake Detection and Seismic Phase Identification

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# Subduction Zones?

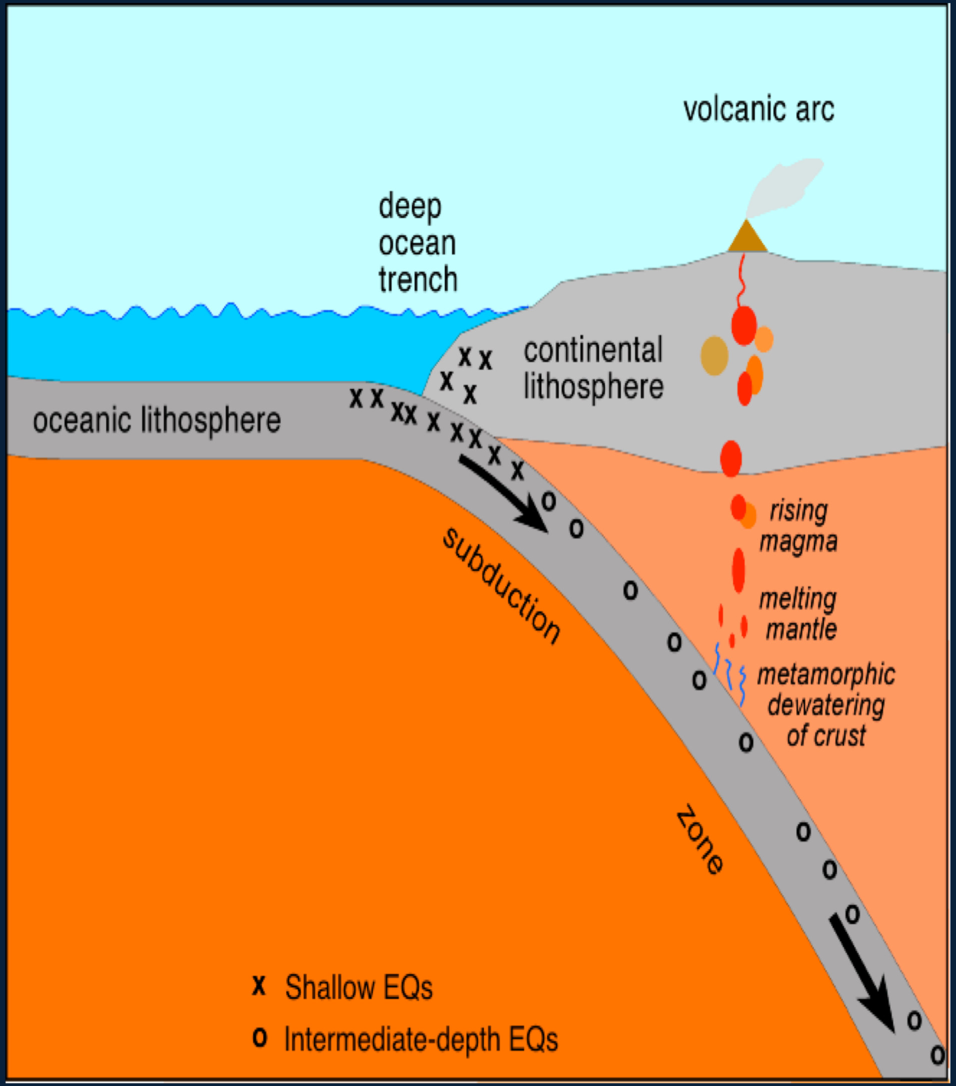
Earthquakes between

| | |
|---|---|
| 50-300 km | Intermediate-Depths |
| >350-700 km | Deep |

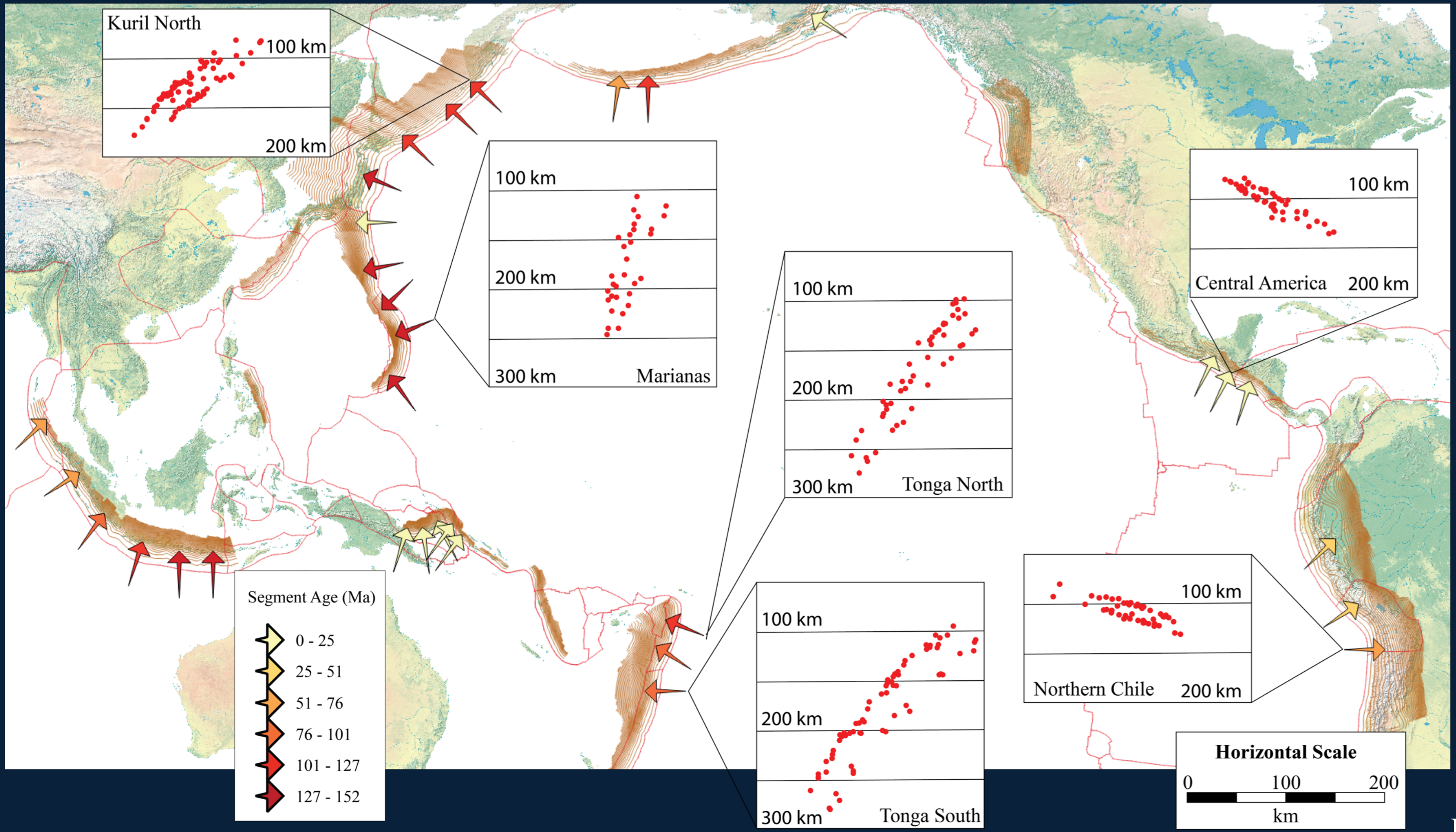
Due to high T-P, brittle rheology is not guaranteed.

Composition?
Water content?
Temperature?

**Mechanism is not clear**



# Characterizing Seismicity along Double Seismic Zones




**Largest Double Seismic Zone (DSZ) catalog**
**32 slab segments, 10-150 Ma.**
**DSZ everywhere**

Florez and Prieto, 2019

# Earthquake Detection

- Traditional Detection methods rely calculating the energy in a seismogram:

$$\frac{Energy\ in\ Short\ term\ window}{Energy\ in\ Long\ Term\ Window}$$

- Work well only when SNR > 5.0

- Similarity based methods: Require a set of known templates, which are correlated against a continuous stream of data.

- However, in seismic catalogs we have millions of labelled data points!

# Training Data

Japan

- Subset of 82,654 high quality  hypocenters
- 640,232 P-wave picks
- 152,215 S-wave picks

Northern Chile

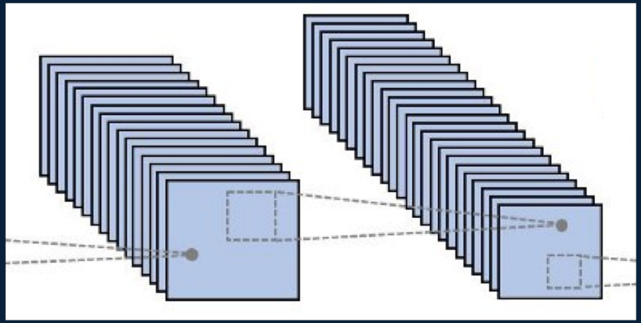
- Subset of  10,014 high quality  hypocenters
- No Analyst picks avaible for training
- 68,134 P-wave detections using templete matching
- 54,890 S-wave detections using template matching

Southern California:

- 878,232 P-wave picks
- 538,232 S-wave picks

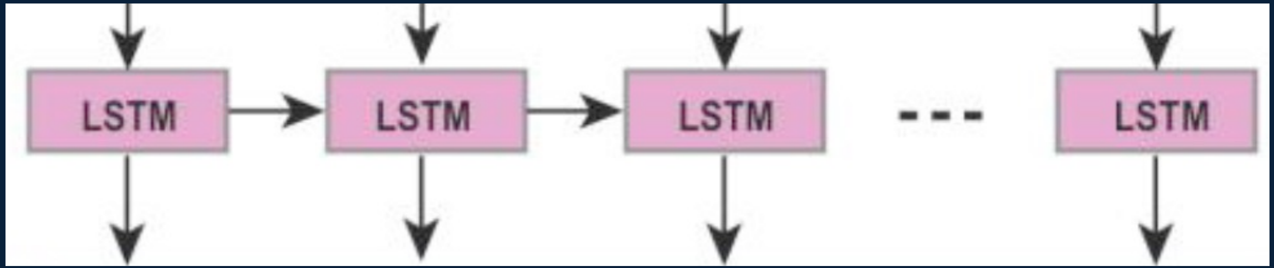
# Phase Detection

- 6 Convolutional Layers

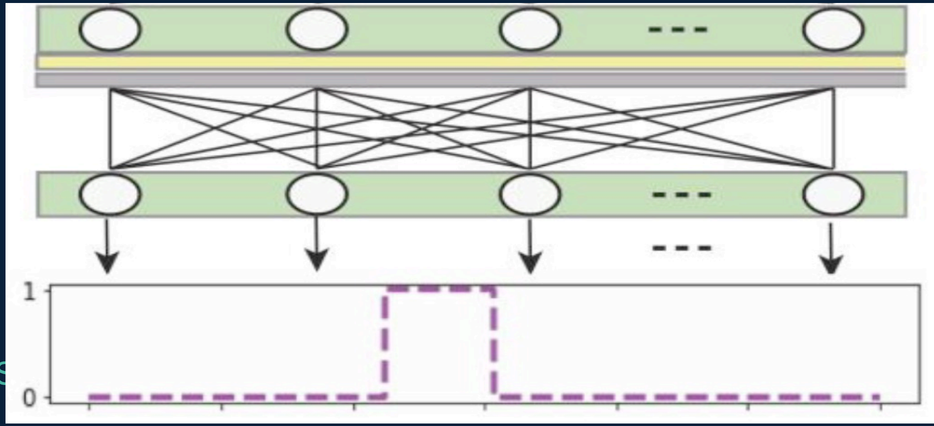


- 2 Long Term Short Term Memory layers (LSTM)

Recurrent Neural Network:

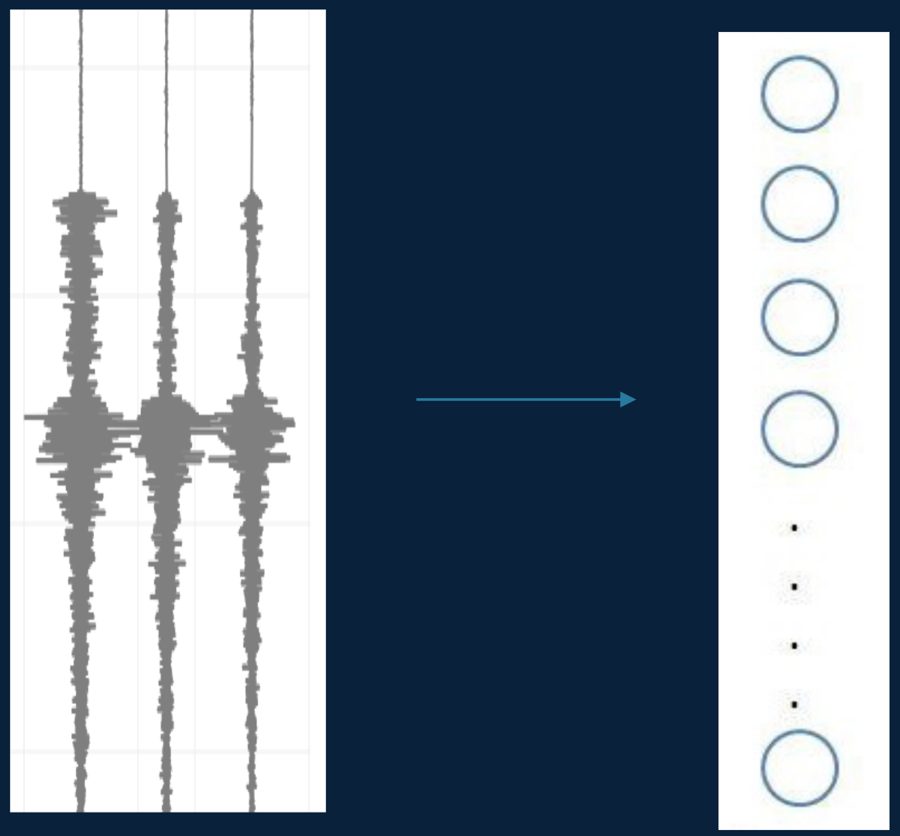



- 2 Dense Layers:



# Phase Detection

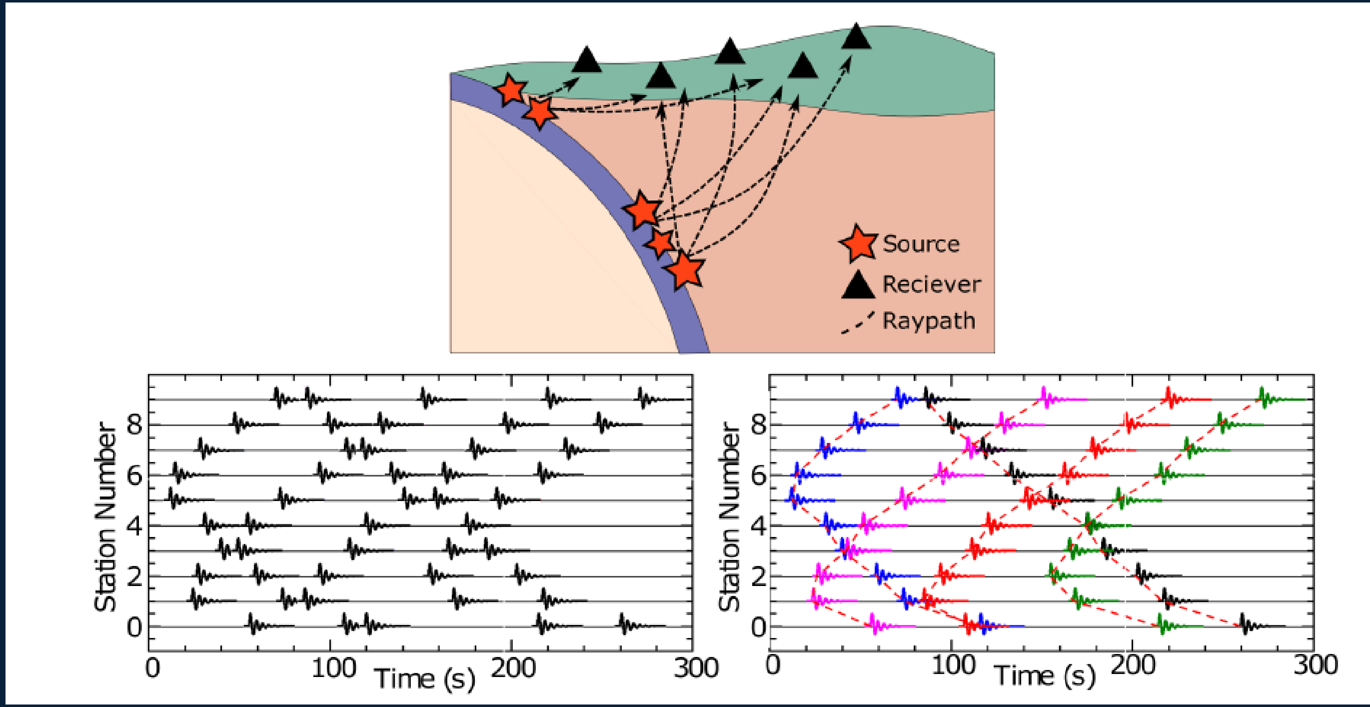
- Input: 3 Component waveforms:



- A prediction for each time sample

# Phase Association

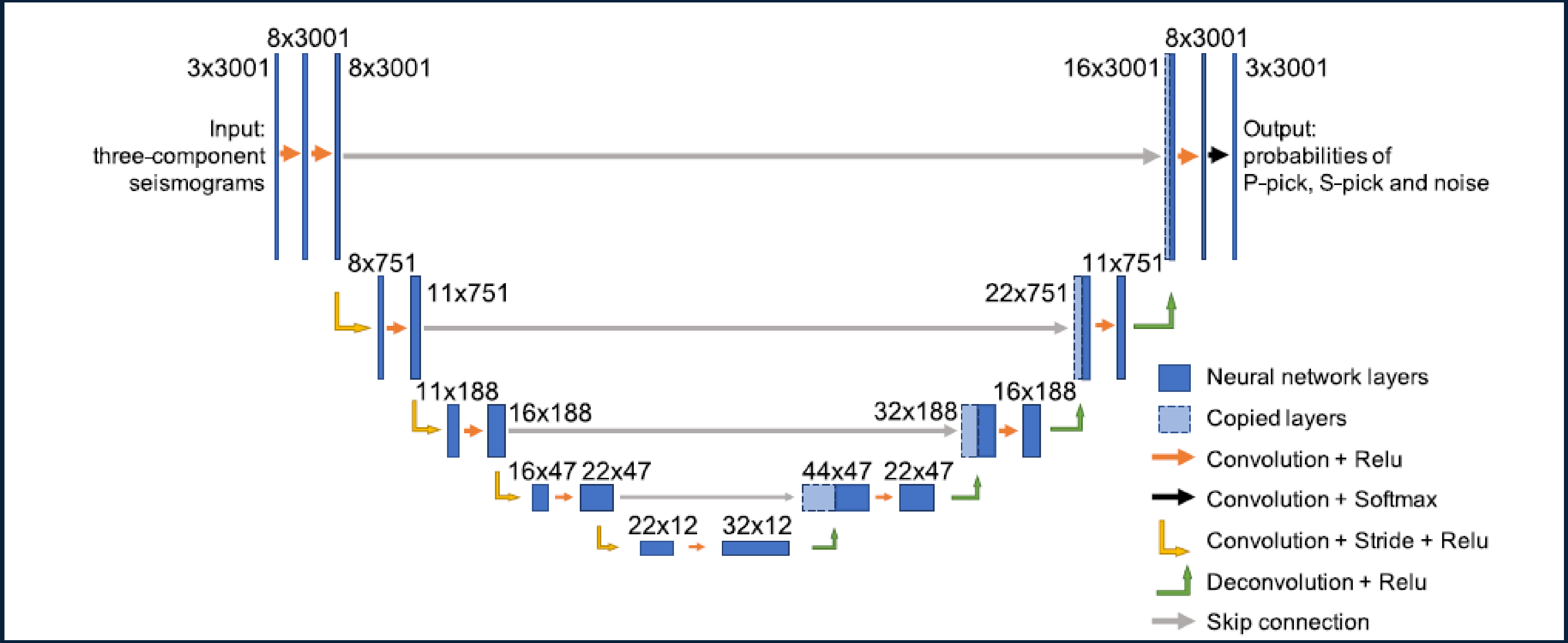
- Scalable and grid free method using RNNs




Ross et al, 2019

# Accurate S Wave picking

- Unet Architecture



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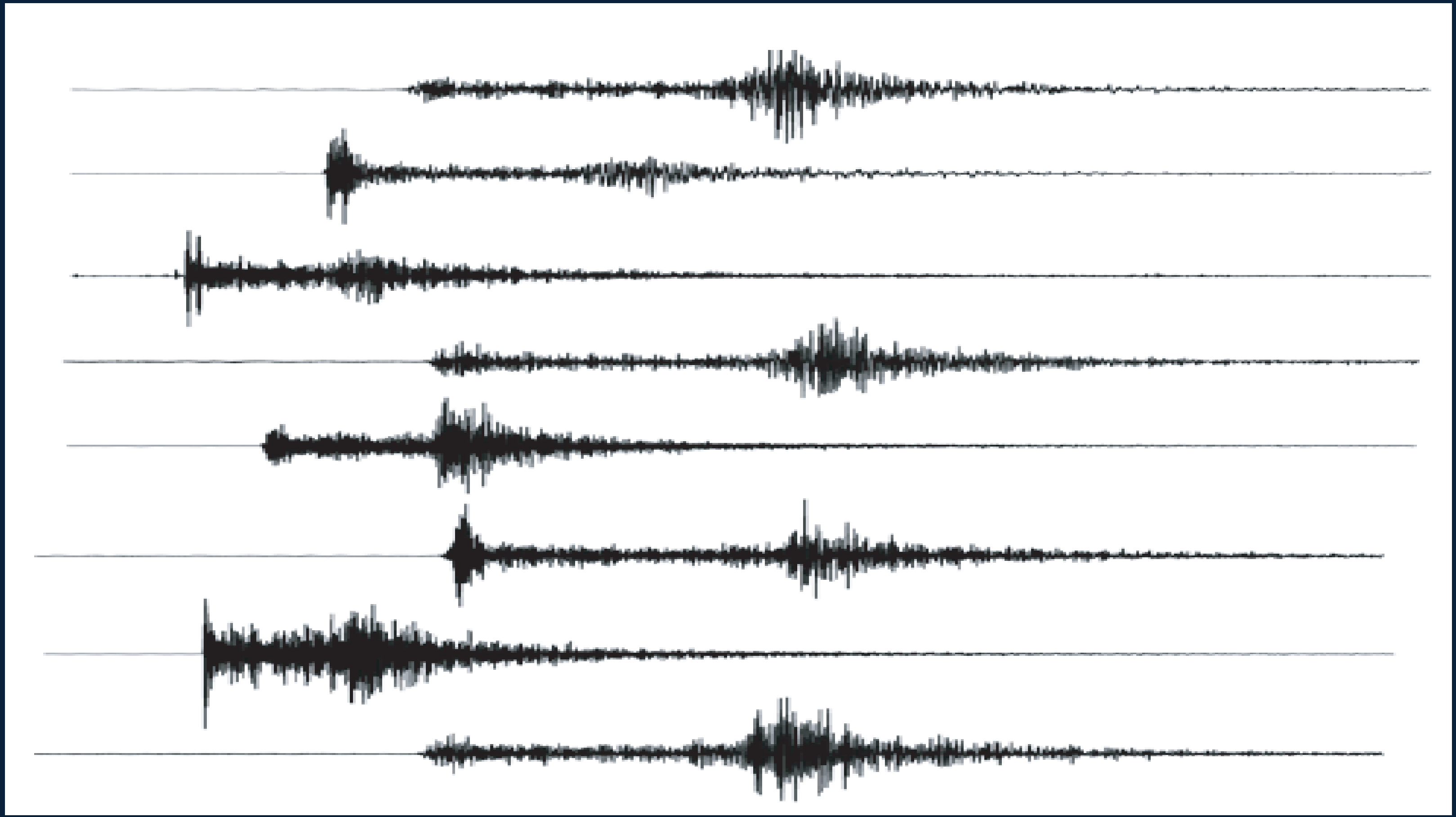
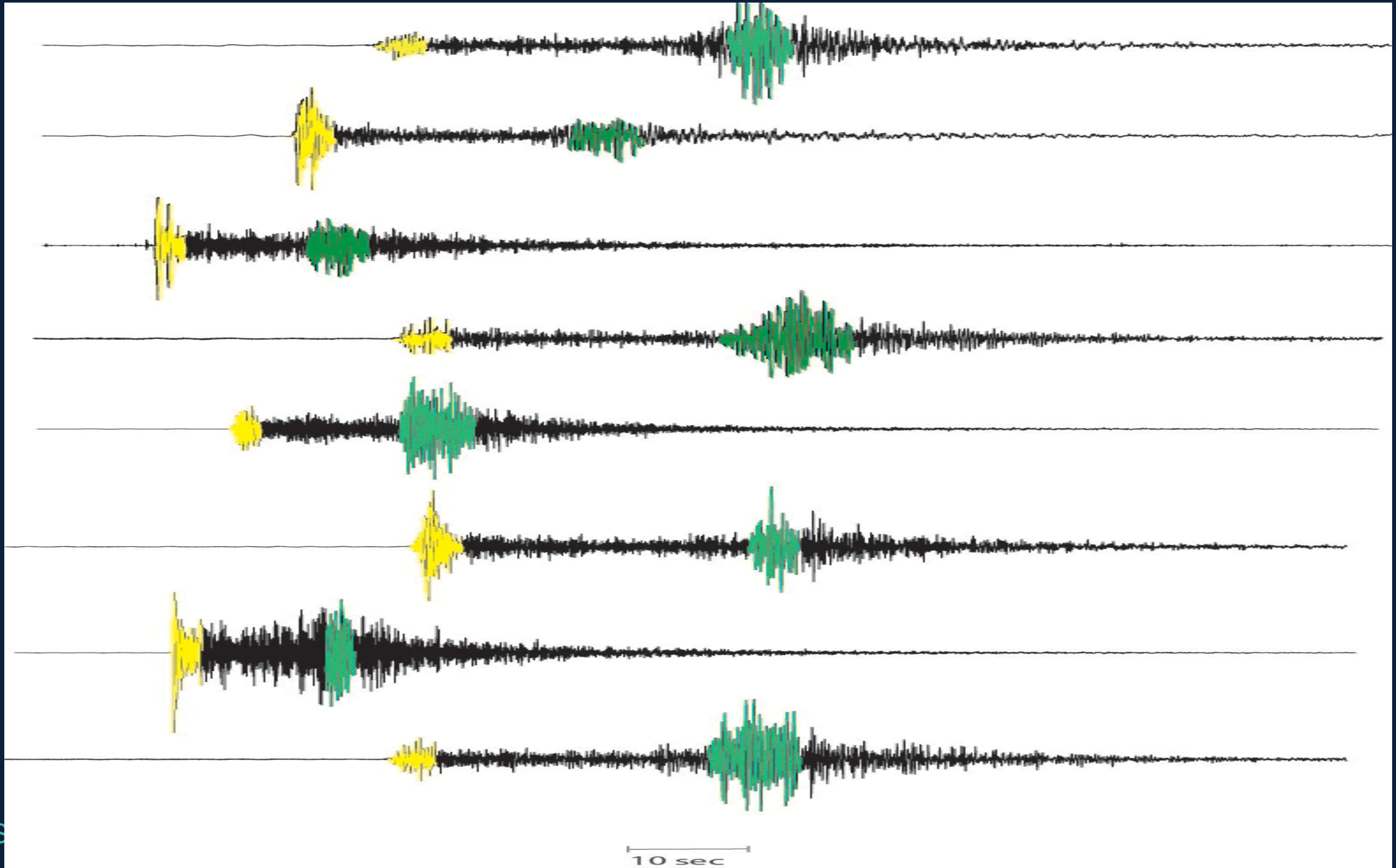
- Unet Architecture



# Accurate S Wave picking

- Unet Architecture



# Detection Results

$$\text{Precision} : P = \frac{T_{\mathrm{p}}}{T_{\mathrm{p}} + F_{\mathrm{p}}},$$

$$\text{Recall} : R = \frac{T_{\mathrm{p}}}{T_{\mathrm{p}} + F_{\mathrm{n}}},$$

- Precision P:  0.96
- Recall P: 0.89
- Precision S:  0.86
- Recall S: 0.78

# Results

- Comparison with template matching:

  Run For 1 month after 8.3 Mw, September 2015 Illapel EQ

  CSN:  421

  Template Matching:  2 891

  Deep Learning: 2 493