

Deep Learning: an efficient tool for making sense of massive seismological datasets

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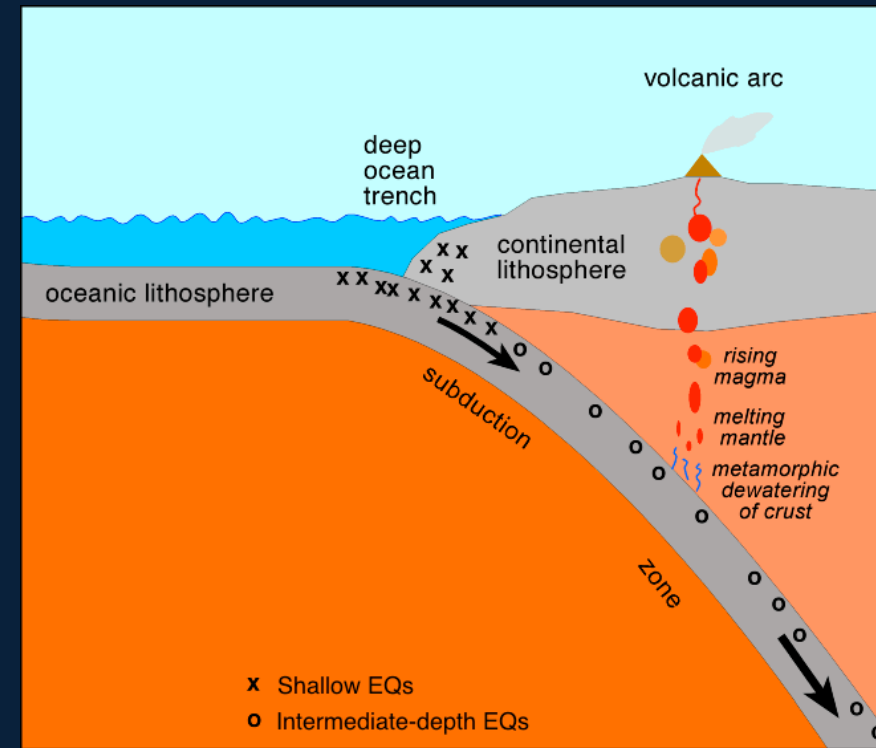
PHD STUDENT [EARTH, ATMOSPHERIC AND PLANETARY SCIENCES]

In collaboration with German Prieto and Laurent Demanet

Subduction zones

WHAT CONTROLS THE STRUCTURE OF INTERMEDIATE-DEPTH SEISMICITY IN SUBDUCTION ZONES?

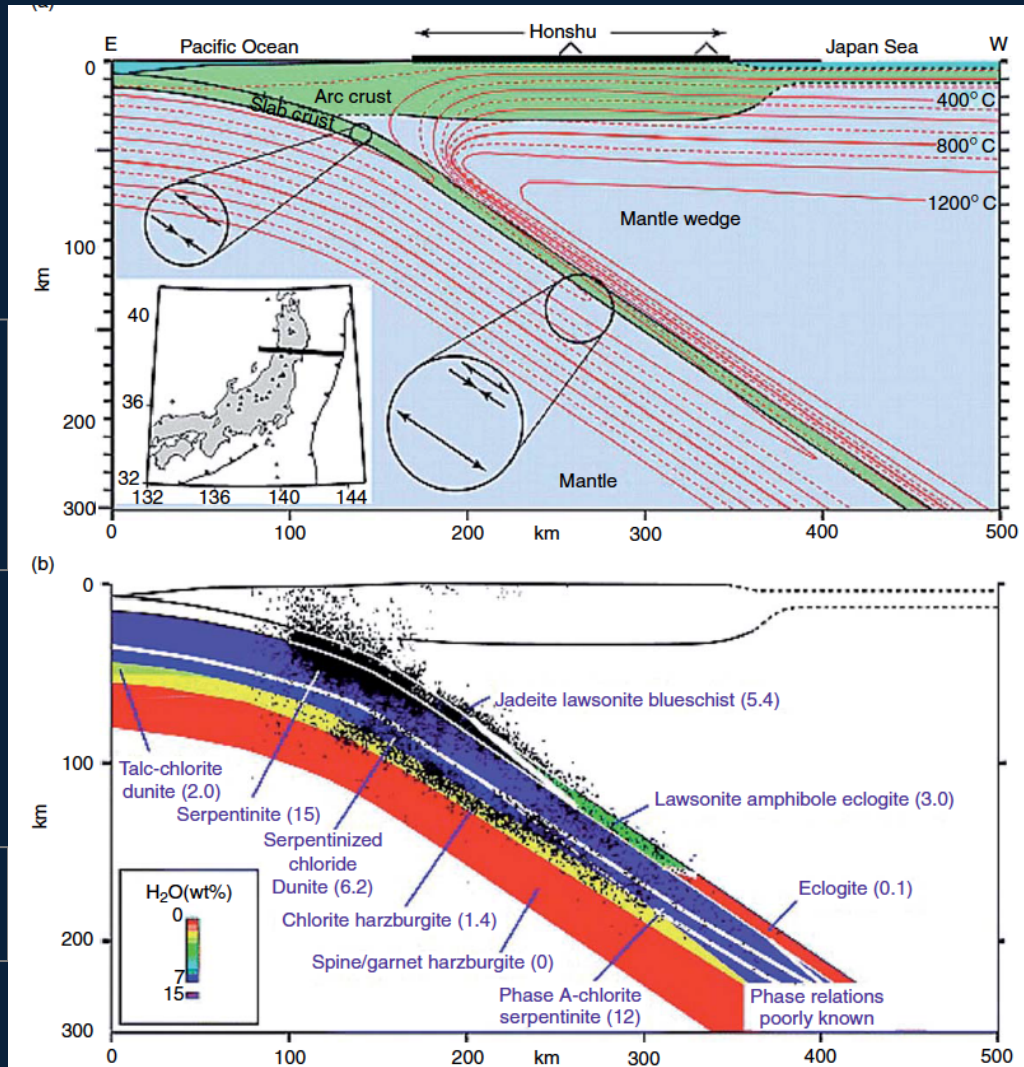
- Tectonic Environment
 - *Composition?*
 - *Water content?*
 - *Temperature?*
- Intermediate Depth Earthquakes
 - *Mechanism is not well constrained*
- Machine Learning
 - *Can Machine Learning help us?*
 - *We need a global perspective!*
 - *ML algorithms are only as good as the data we feed into them ...*



EQ Locations to Constrain Mechanism

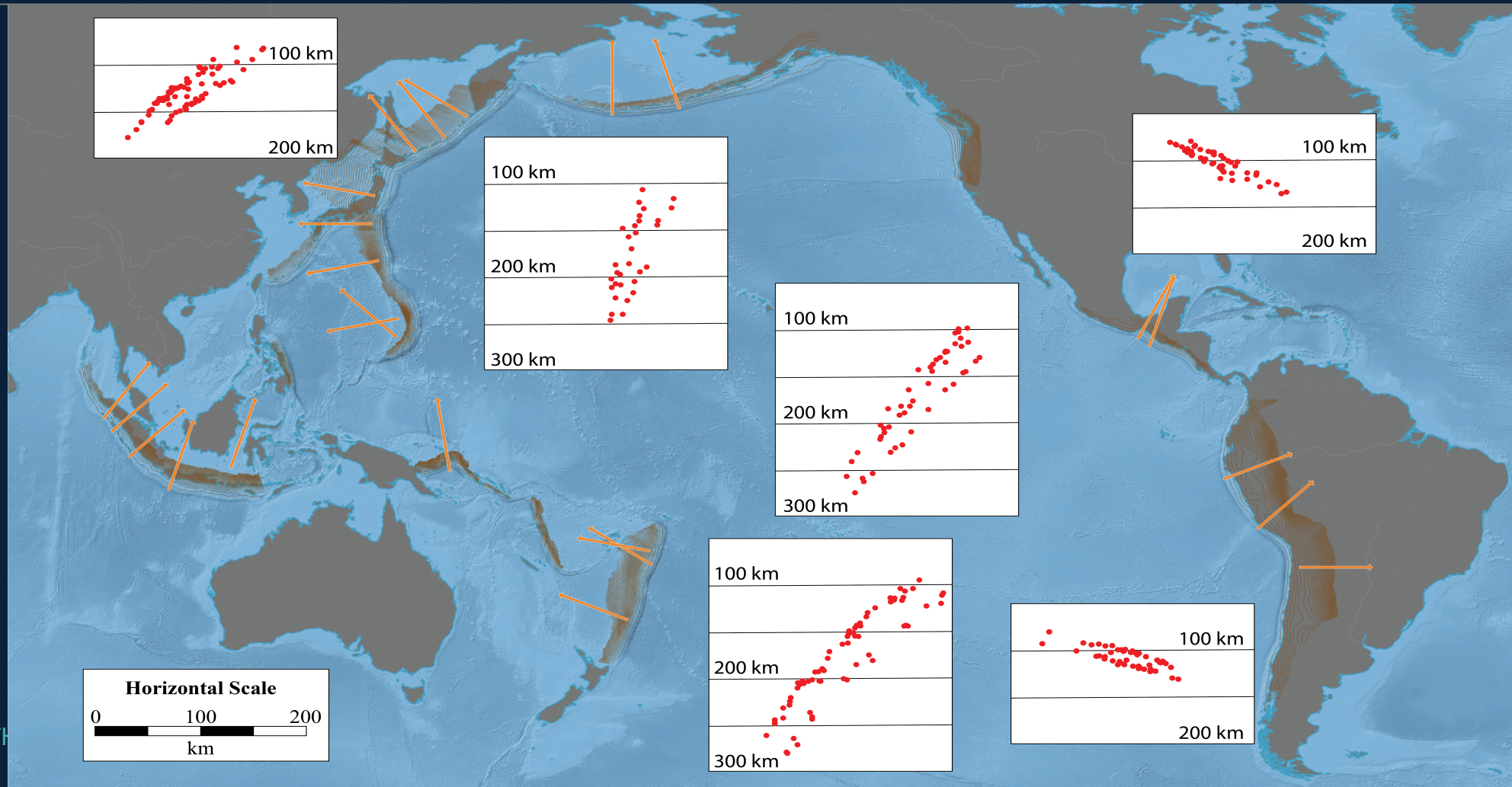
DOUBLE SEISMIC ZONES AND
DEHYDRATION EMBRITTLEMENT

HOUSTON, 2007; HACKER ET AL, 2003



A Big Data Problem!

- OVERWHELMED WITH DATA: CONTINUOUS RECORDINGS AT THOUSANDS OF SENSORS WORLDWIDE. PETABYTES OF TIME-SERIES DATA.
- HOW CAN WE QUICKLY EXTRACT USEFUL INSIGHTS FROM THEM??





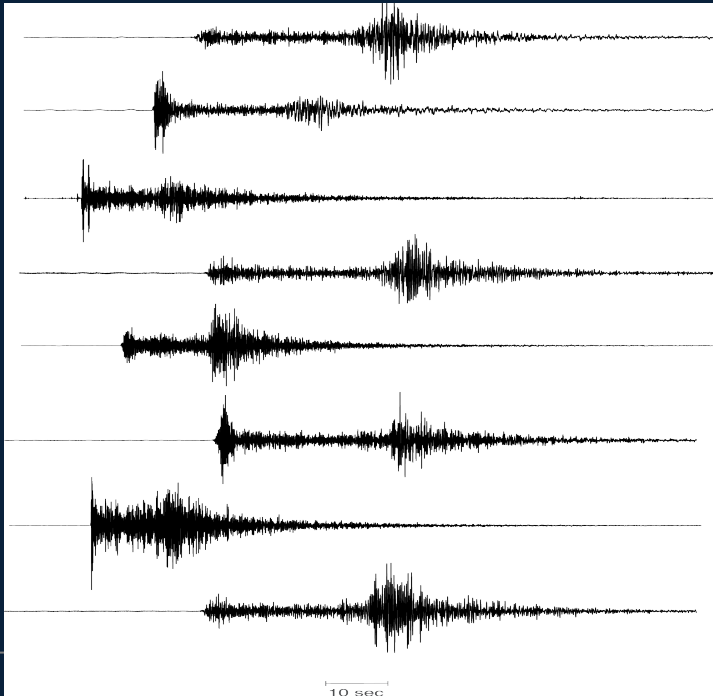
Machine Learning

CONVOLUTIONAL NEURAL NETWORKS

Detection

NETWORK ARCHITECTURE

- 16 convolutional layers.
- 1 fully connected layer.



8x9000 Matrix

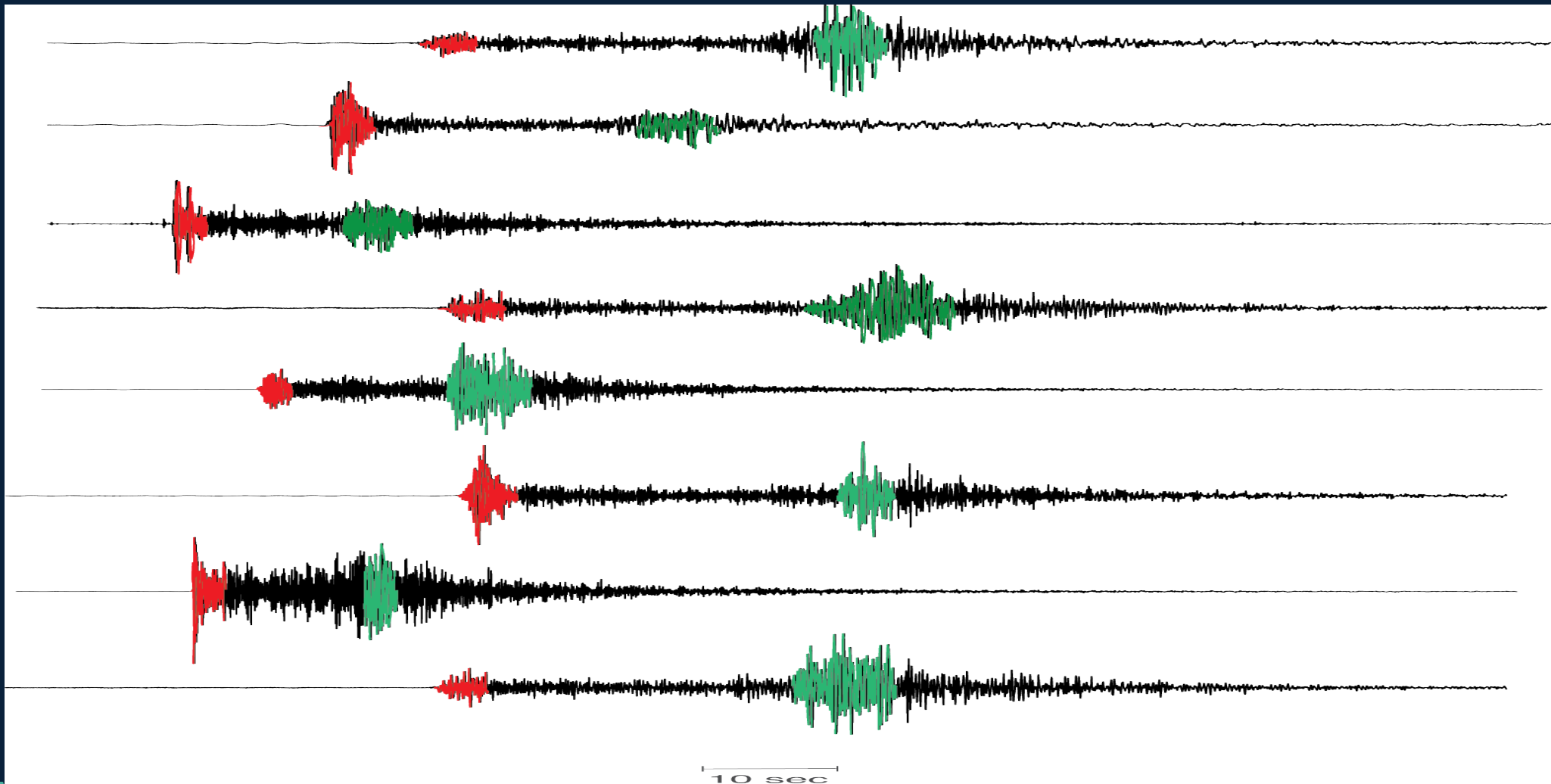
CLASSIFICATION PROBLEM

Three classes:

- P and S wave in at least 3 station
- P wave in at least 5 stations
- Other.

Precision: 96.2 %

CNN training: Template matching



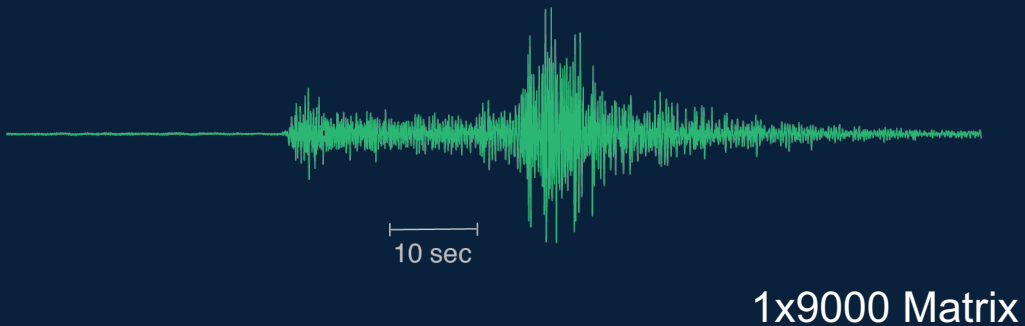
■ Data Augmentation

- Mute 1 arrival.
- Mute 2 arrivals.
- Randomly stretch the amplitude of 1 or 2 arrivals.
- Apply a small Random offset to randomly selected arrivals.
- Apply scaling factor to randomly selected arrivals.
- Can increase labeled data by a factor of a 100.

Picking

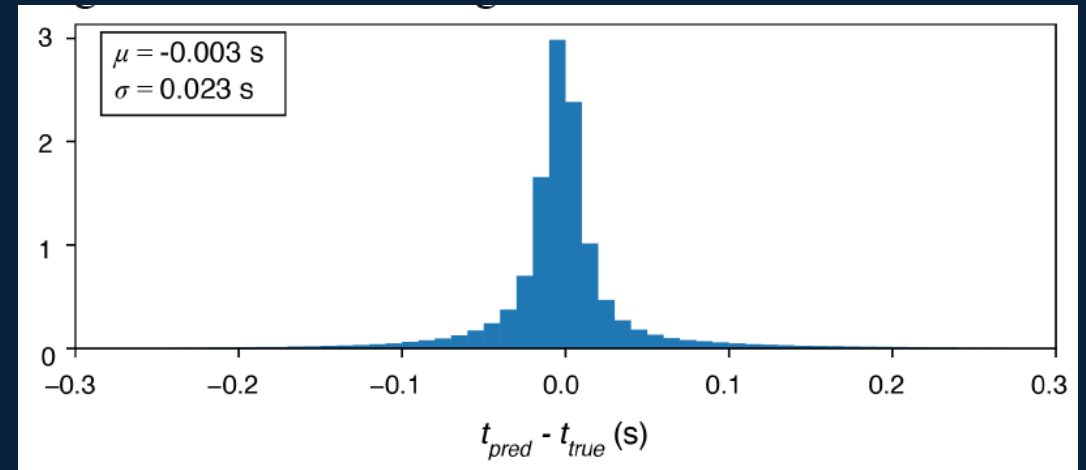
NETWORK ARCHITECTURE

- 8 convolutional layers.
- 2 fully connected layers.



REGRESSION TASK

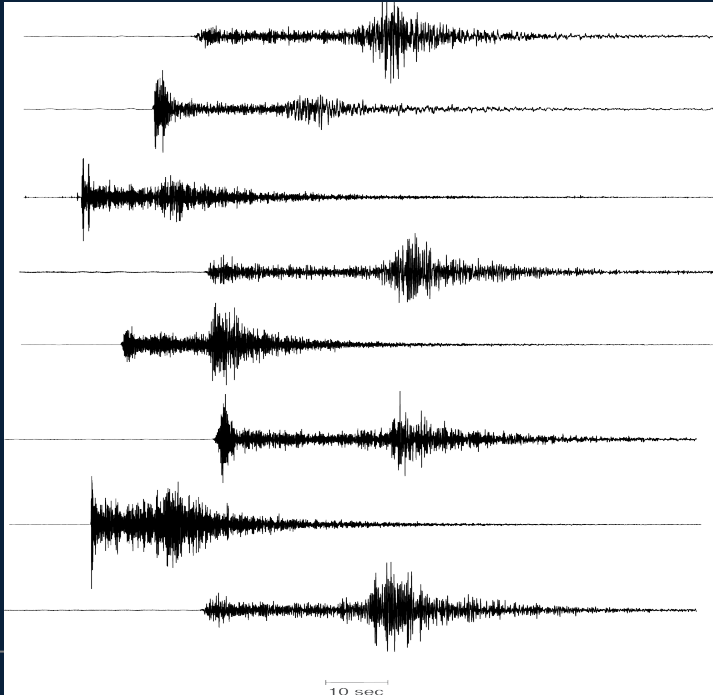
Precision: 98.1 %



Magnitude Estimation

NETWORK ARCHITECTURE

- 16 convolutional layers.
- 2 fully connected layers.



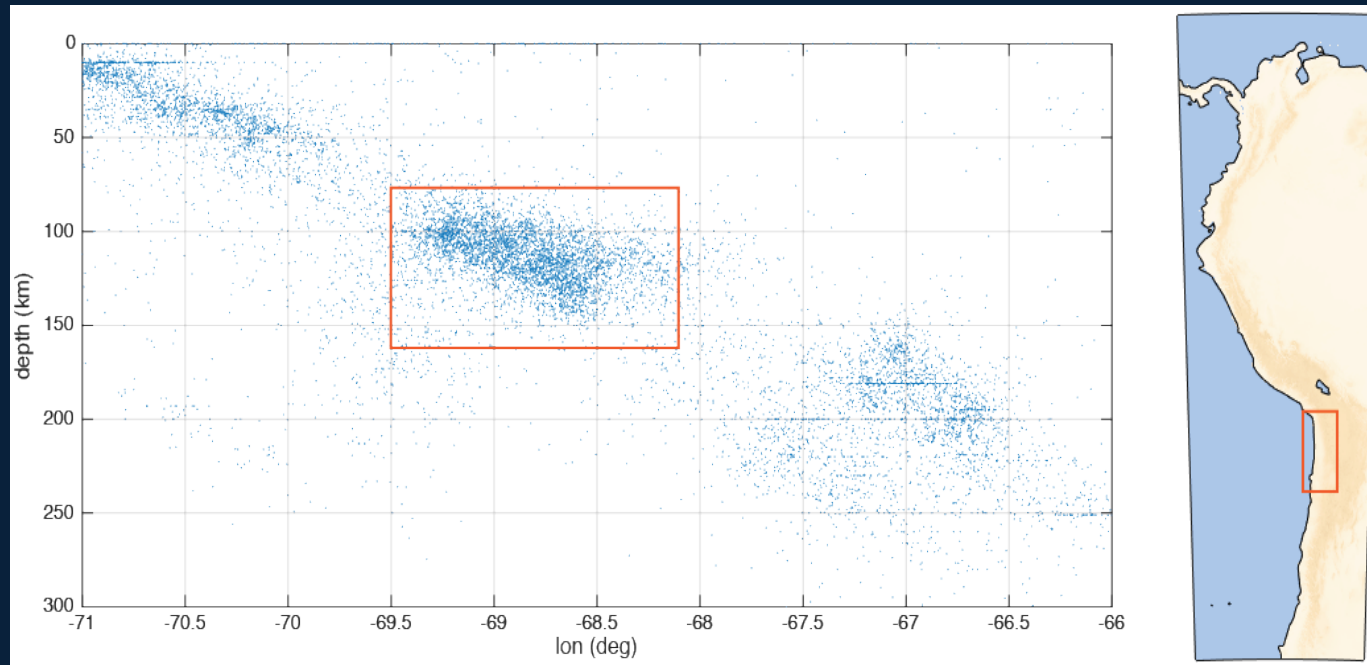
8x9000 Matrix

REGRESSION TASK

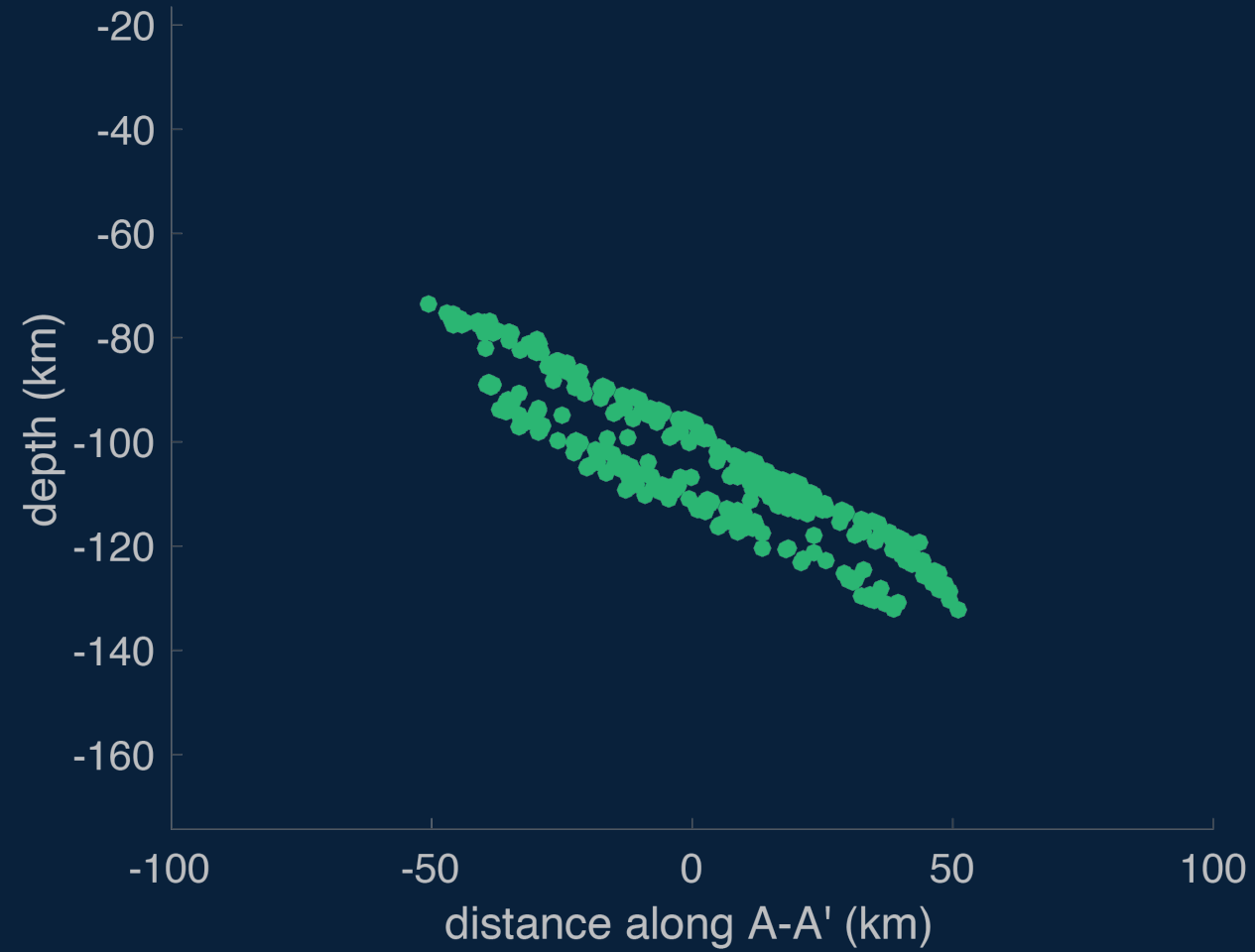
Precision: 78.4 %

How it Helps

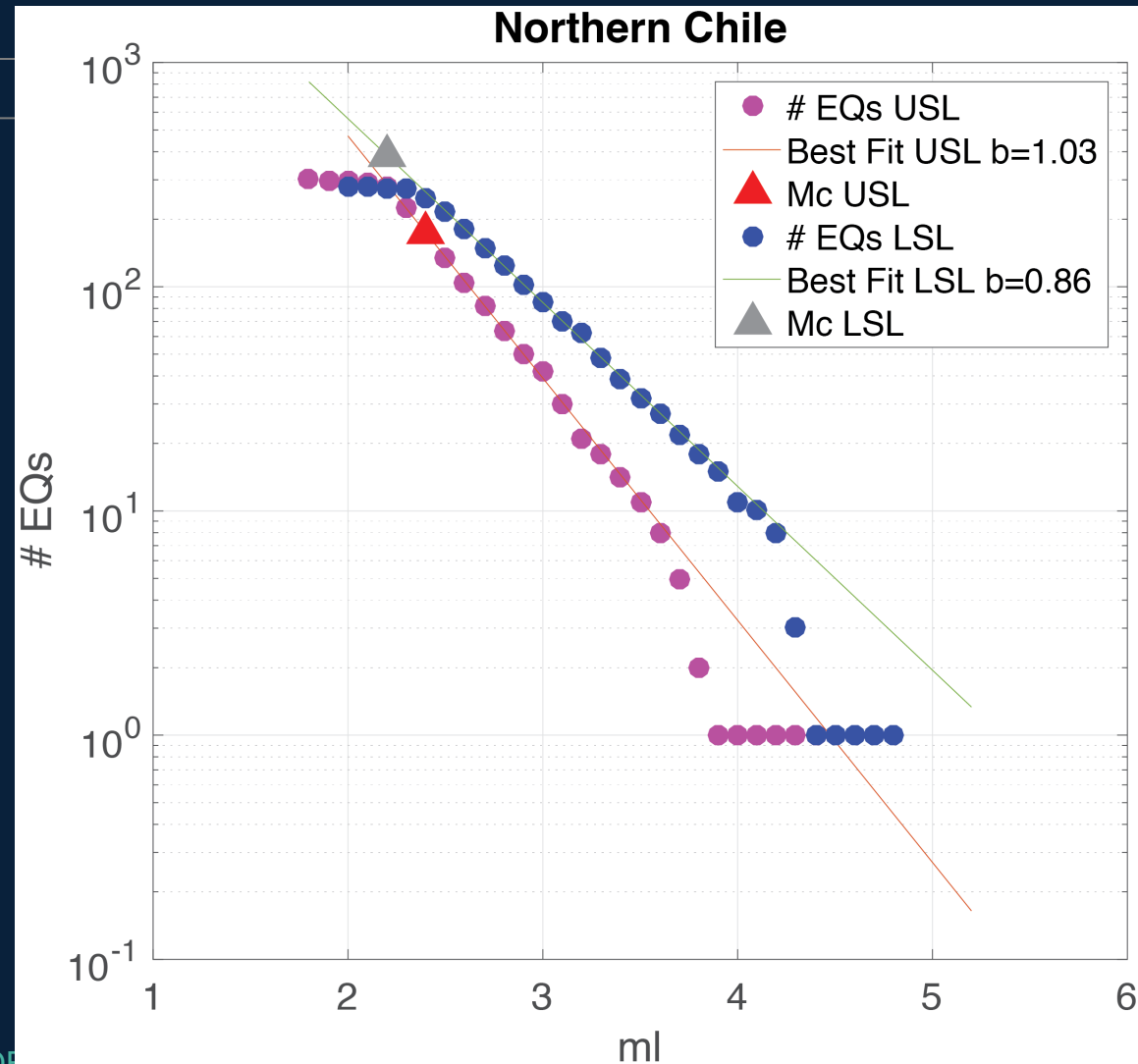
DEPTH CROSS-SECTION



CATALOG LOCATIONS SHOW NO DOUBLE-SEISMIC ZONE (DSZ)



Frequency-magnitude statistics



Conclusions

WHAT CONTROLS THE STRUCTURE OF INTERMEDIATE-DEPTH SEISMICITY IN SUBDUCTION ZONES?

- **Intermediate Depth Earthquakes**
 - *Significant differences between upper and lower planeMechanism is not well constrained*
- **Machine Learning**
 - *In many applications CNNs can replace template matching.*
 - *Data Augmentation the key problem.*
 - *Potential to get results in hours, rather than months*

