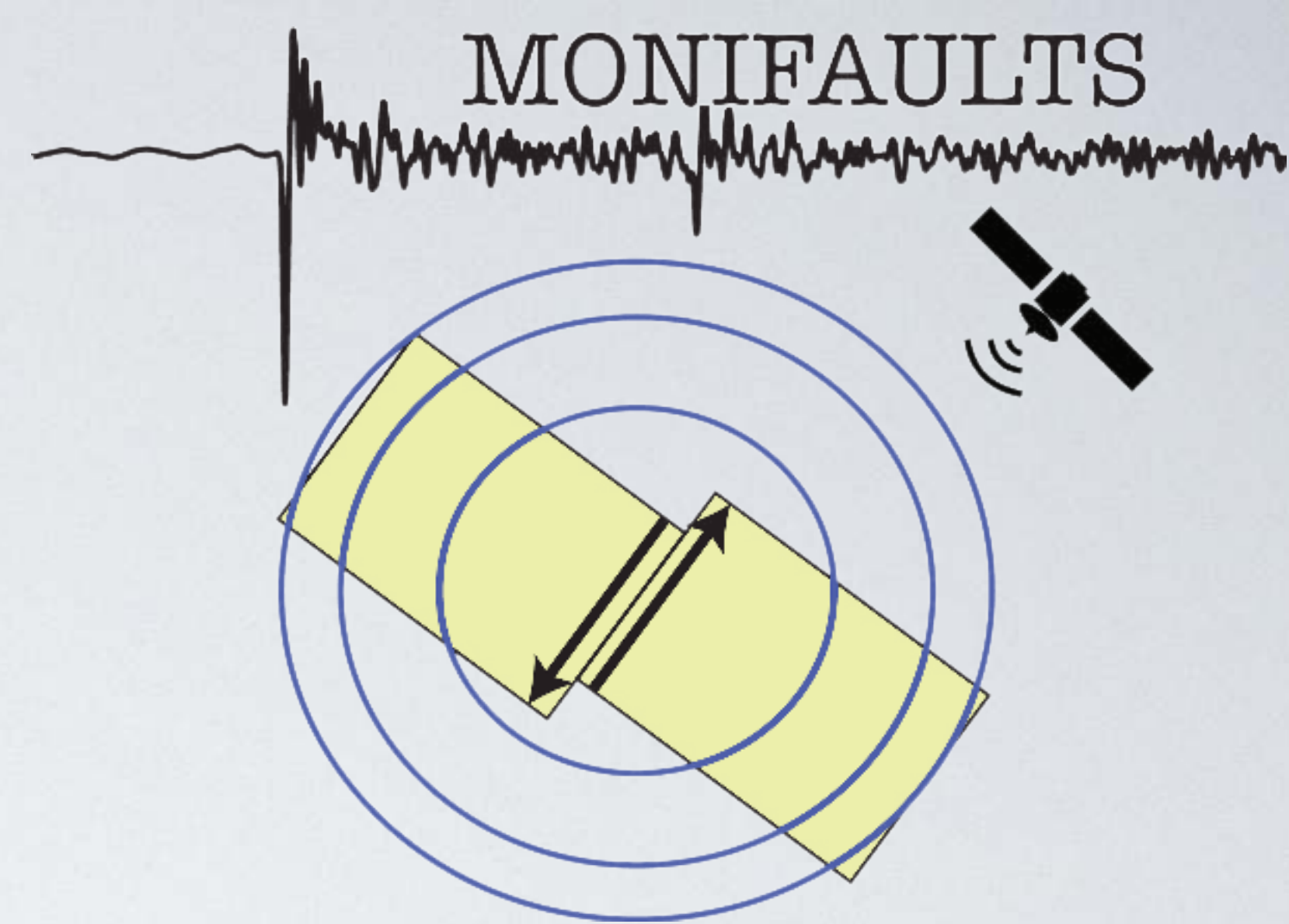




European Research Council  
Established by the European Commission



# Extending near fault earthquake catalog using convolutional neural network and single-station waveforms

Josipa Majstorović, Sophie Giffard-Roisin and Piero Poli

Institut des Sciences de la Terre, Université Grenoble Alpes

Journée utilisateurs GRICAD 2020

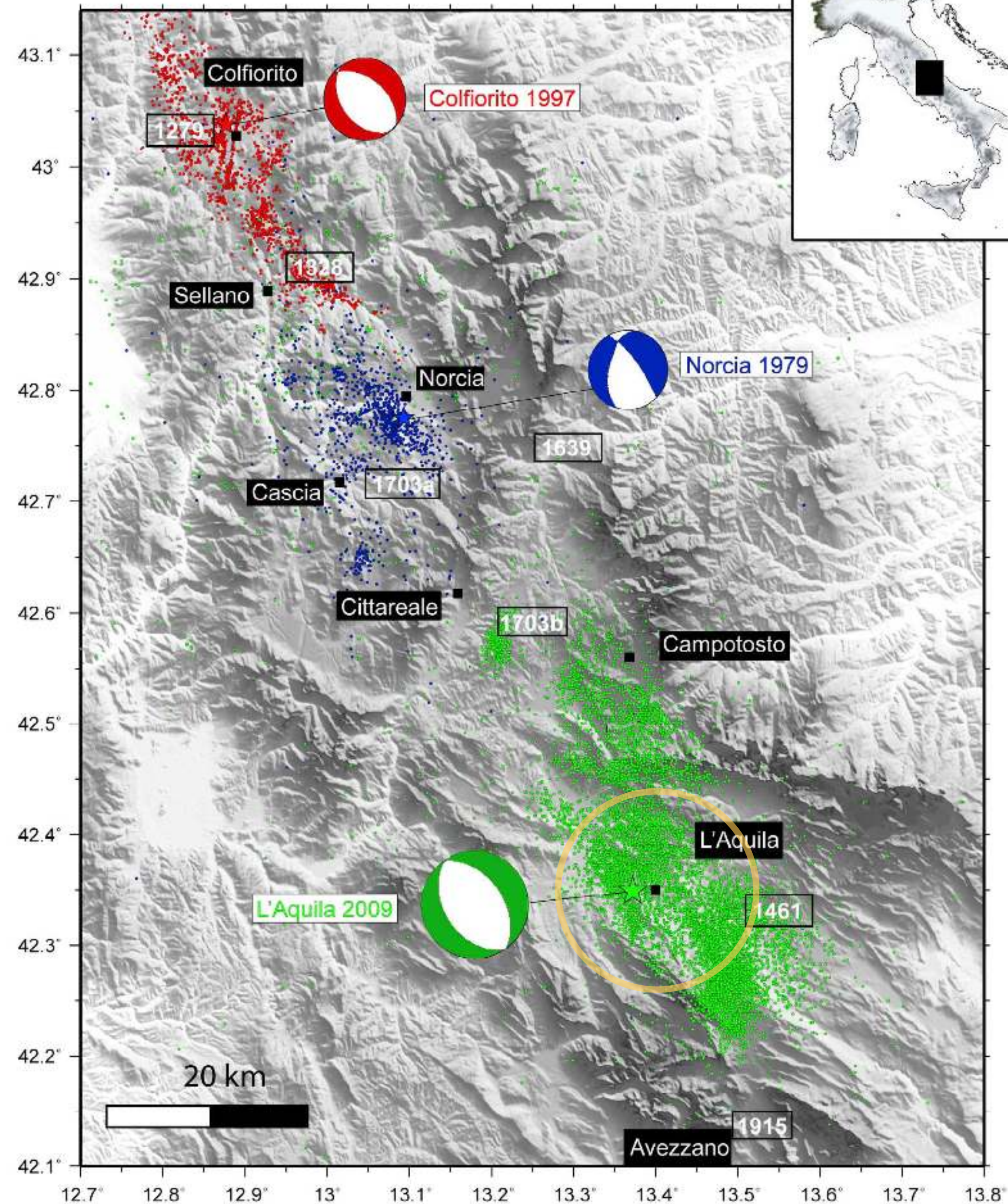
2-3 November 2020 Grenoble

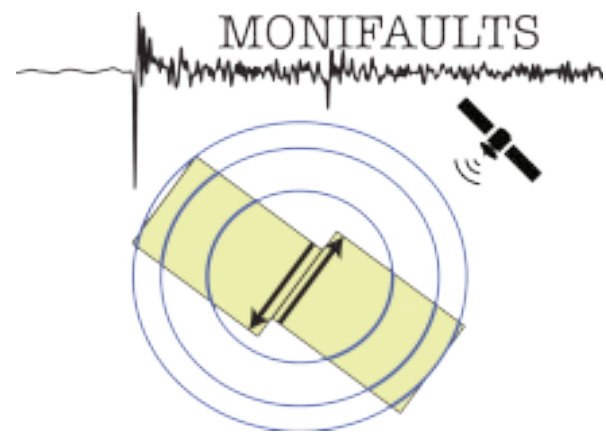
# Introduction & Study area



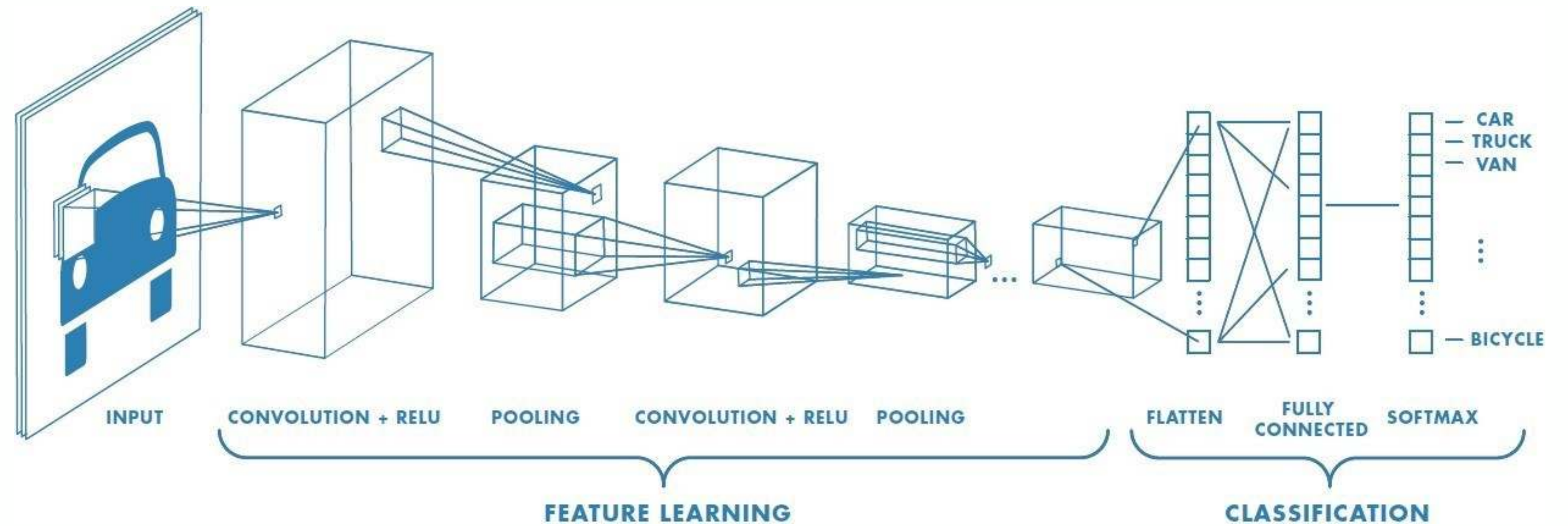
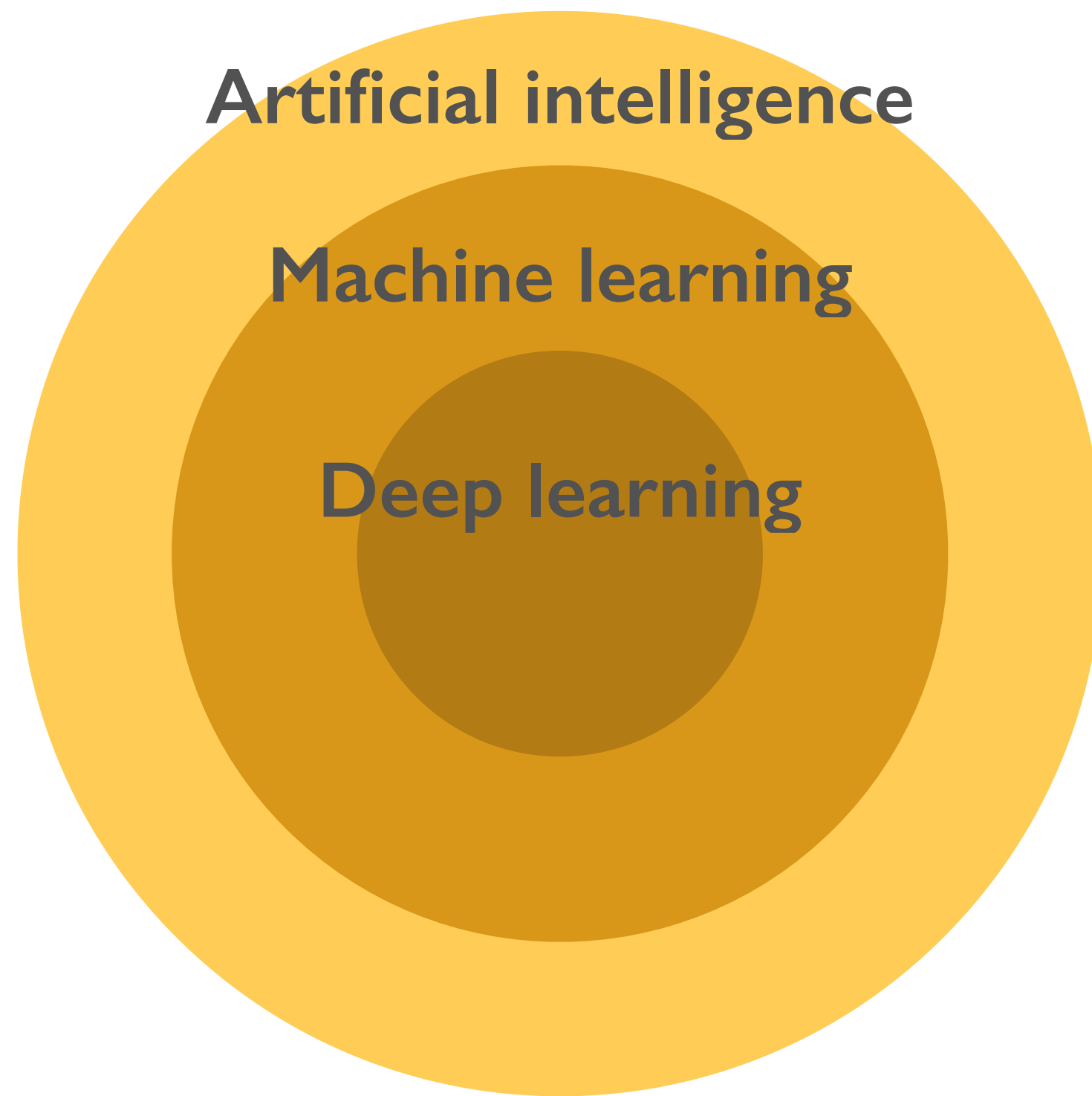
- Extending a near fault earthquake catalog to study local seismicity (eg. sessional effects).
- Main focus is L'Aquila earthquake (Mw 6.3) that occurred on April 6th 2009, 01:32 UTC right beneath the city of L'Aquila (Abruzzo region).

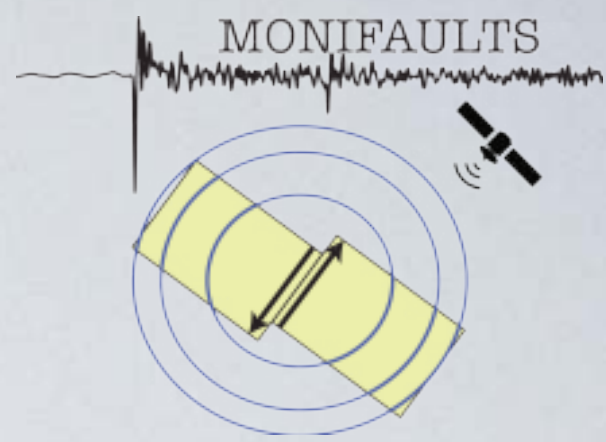
*Chiaraluce et. al., 2011*



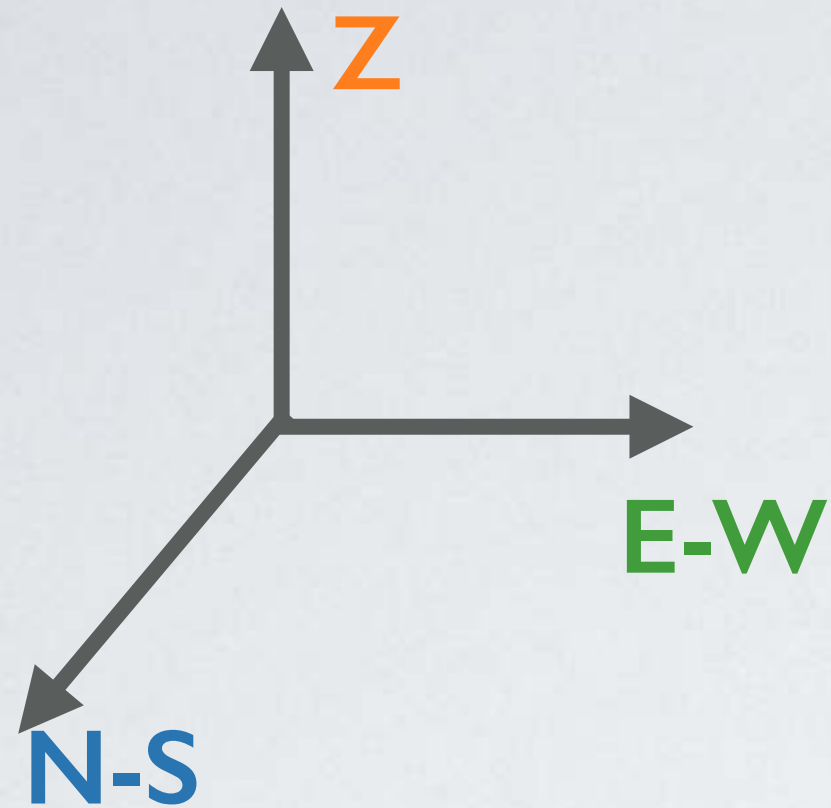


Convolutional Neural Network (CNN) is a supervised learning algorithm.

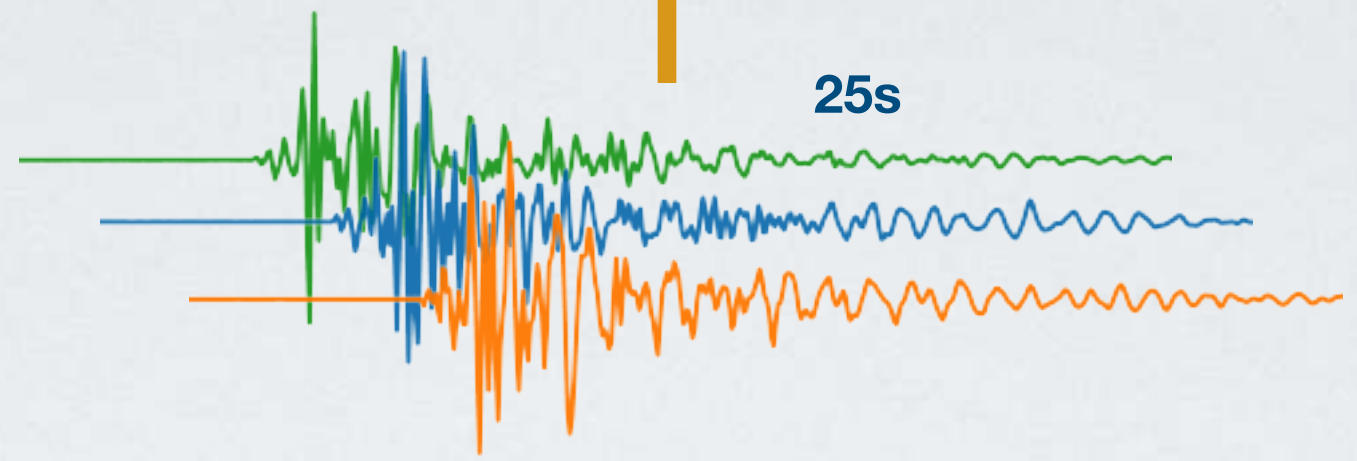




Data and preprocessing



The first input layer in CNN



Time series

Database of events

1. Catalog of earthquakes

- Local
- Regional
- Tele-seismic

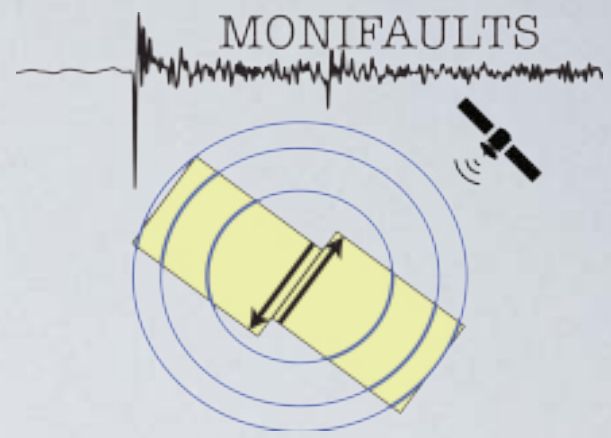
2. Seismograms

Three component seismograms (broad band) from **1990 to 2019** recorded at **AQU (42.354, 13.405)** station near city of L'Aquila, central Italy.

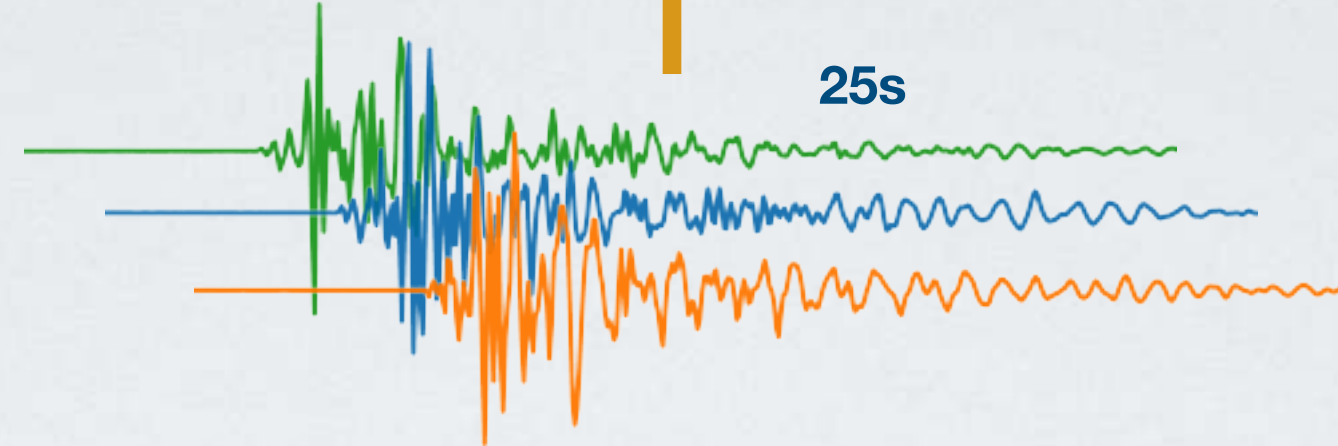
How to build a good database of the events to distinguish the local events?



Data and preprocessing



The first input layer in CNN



25s

Time series

Database of events

1. Catalog of earthquakes

2. Seismograms

INGV catalog  
USGS for  $M > 4.5$   
Valoroso et. al., 2013

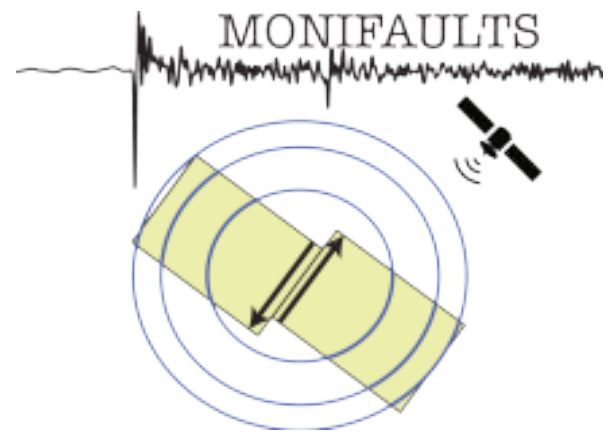
**~500k**

Selection process

**~65k  
accepted  
earthquakes**

# Data and preprocessing

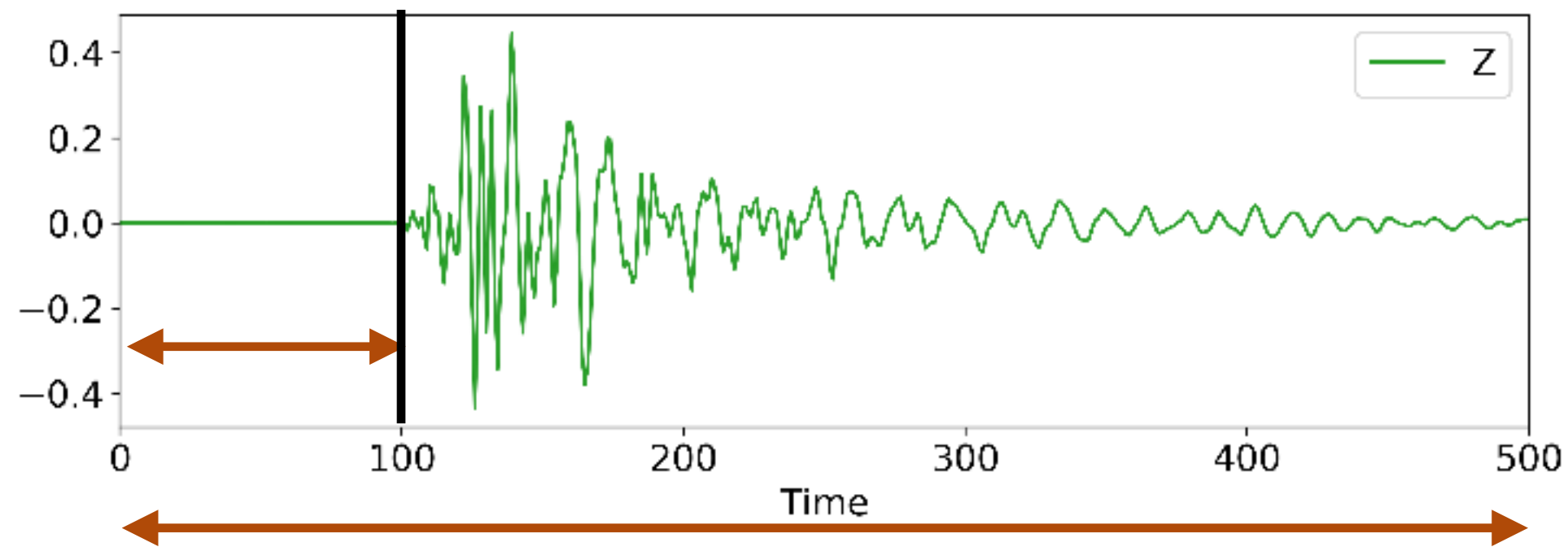
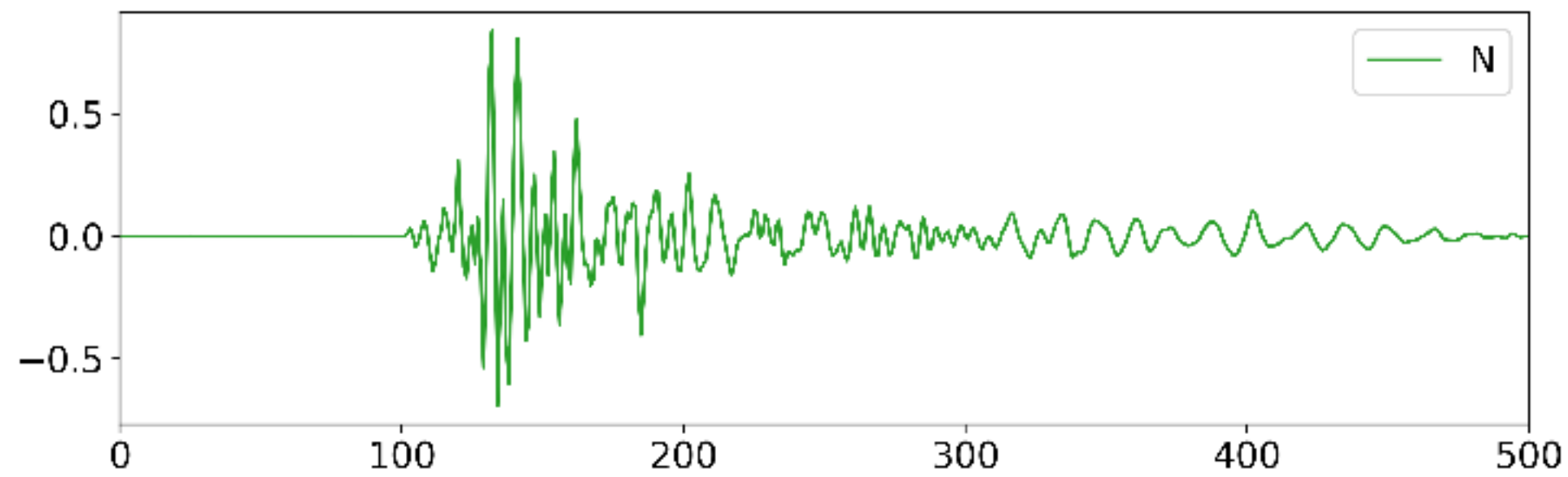
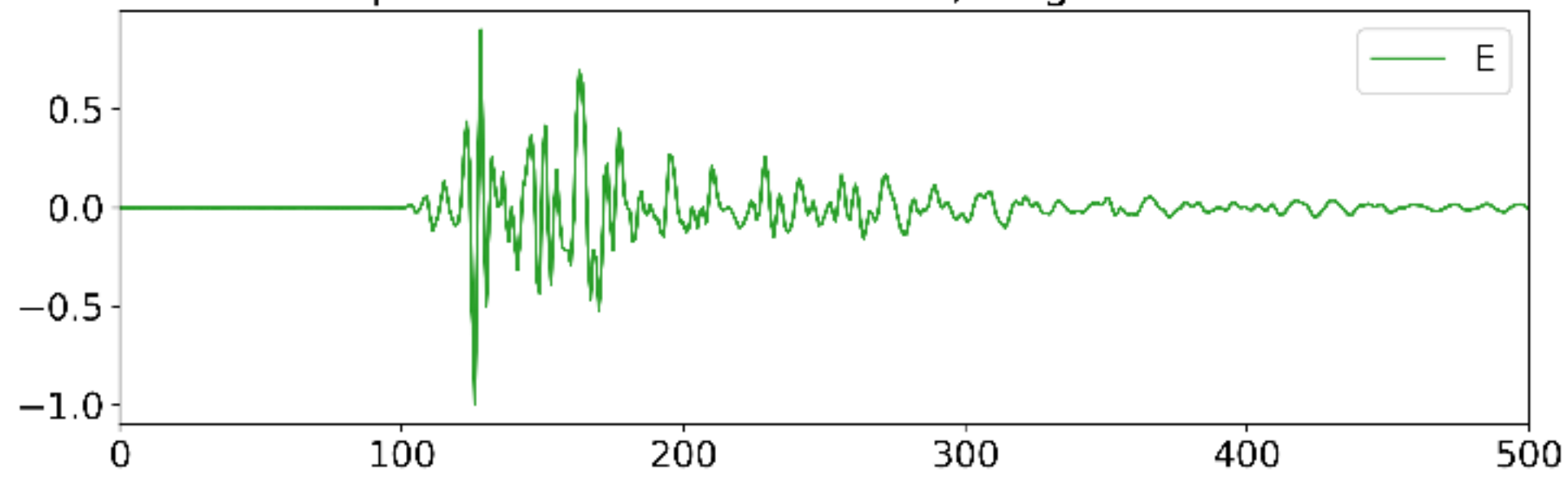
## Database of events



positive sample

~65k

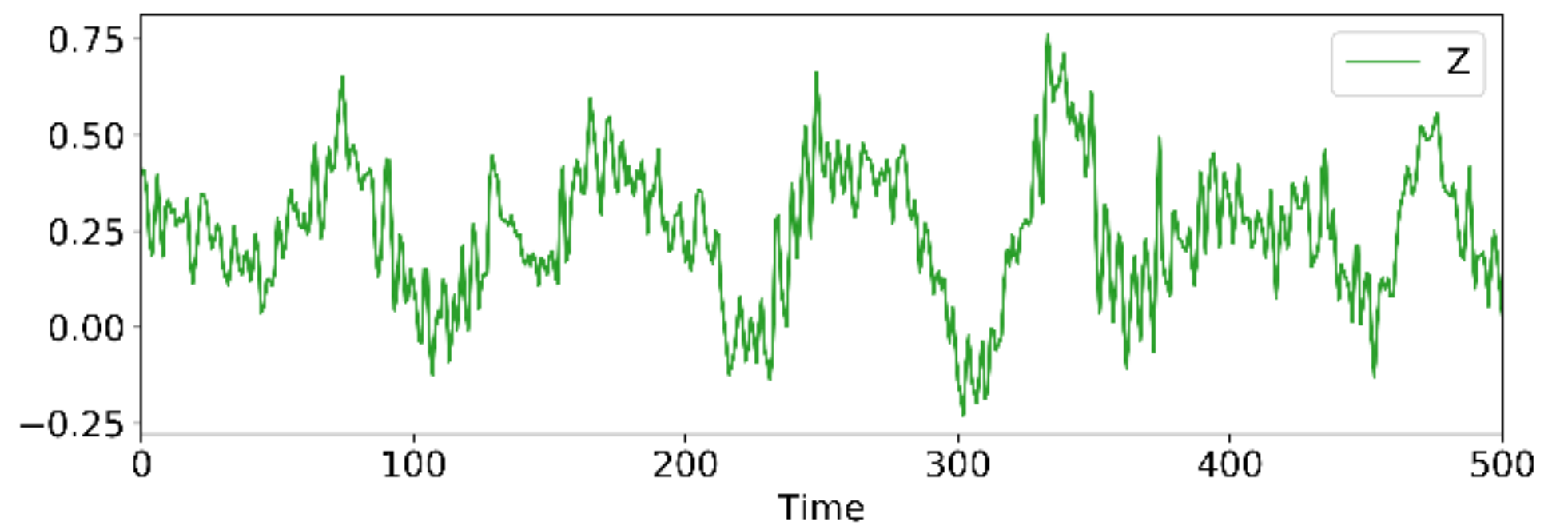
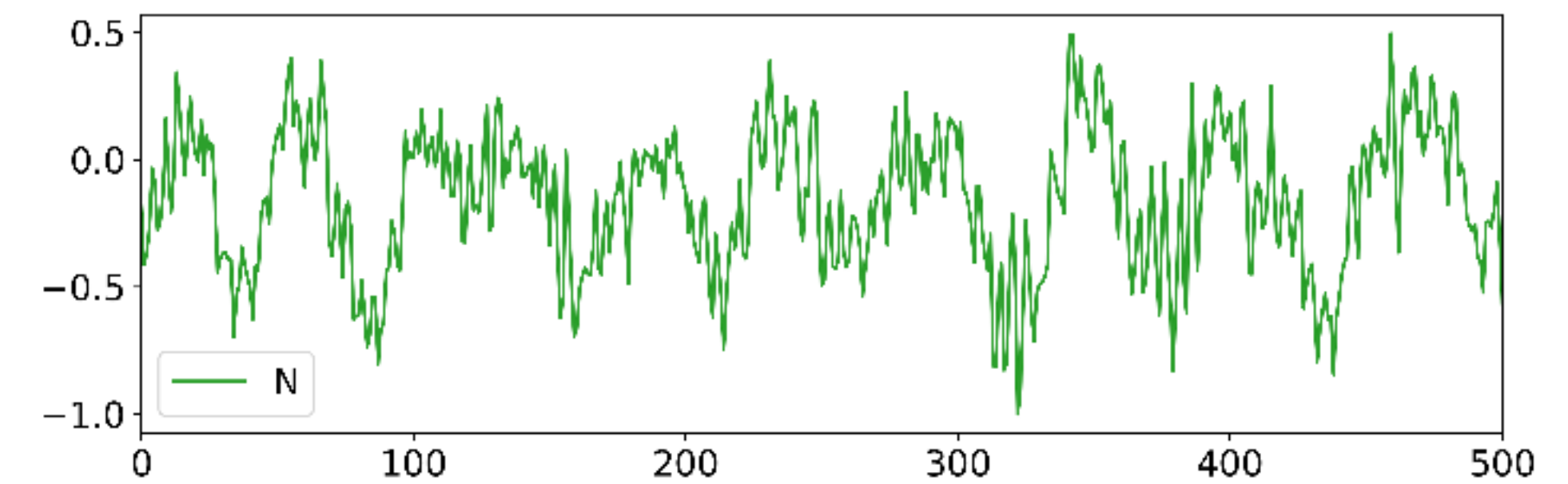
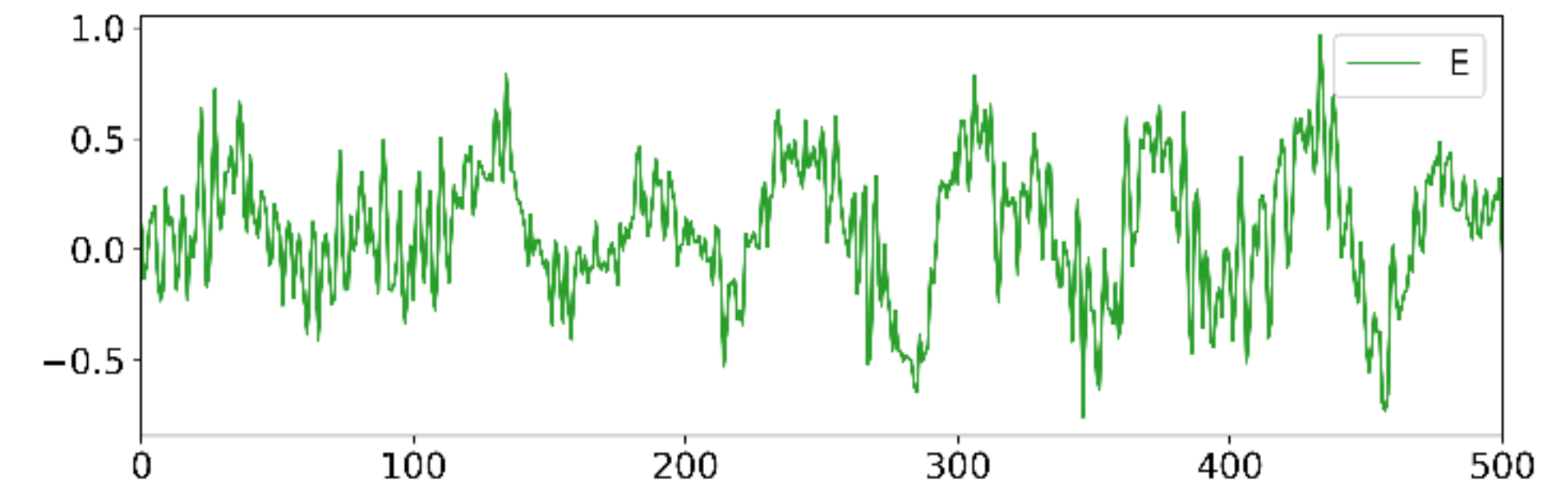
Epicentral distance: 8.17km, Magnitude: 2.7



25

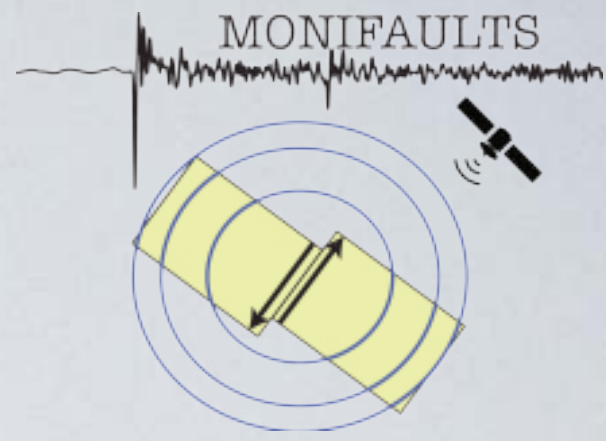
negative sample

~65k



6

# Proposed framework



Two-stage pipeline using 1D convolutional neural networks (CNN) for earthquake detection and characterisation.



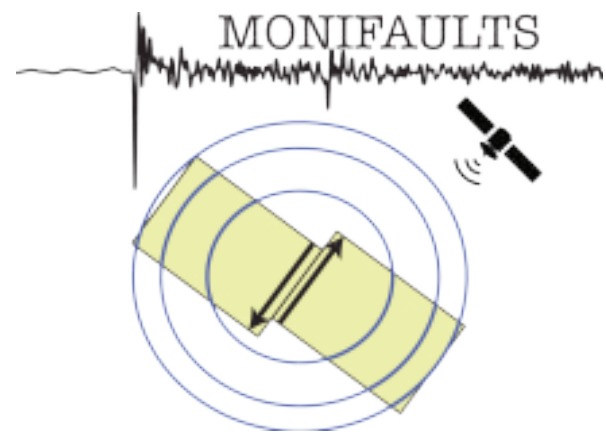
Dividing the original database in three parts:

**Training 80%**  
**Validation 10%**  
**Evaluation 10%**

Distance  
<10, >10 km

Magnitude  
<1, 1-2, 2-3, >

# Proposed framework



The grid search is performed for the best combination of the CNN hyperparameters.

Tests	Description	Parameters
2	Architecture	Deep and shallow CNN
2	Optimisation algorithms	SGD and ADAM
3	Learning rate	1e-5, 1e-3, 1e-2
2	Momentum	0.2, 0.9
2	Mini-batch size	128, 512
Fixed	Epochs	Early stopping

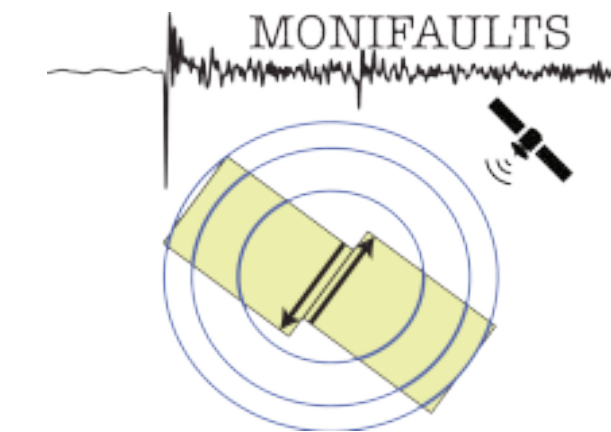
**TOTAL 48 tests**

	DEEP CNN								SHALLOW CNN							
	128				512				128				512			
	SGD		ADAM		SGD		ADAM		SGD		ADAM		SGD		ADAM	
1E-05	T1	T3	T13	T15	T2	T4	T14	T16	T25	T27	T37	T39	T26	T28	T38	T40
1E-03	T5	T7	T17	T19	T6	T8	T18	T20	T29	T31	T41	T43	T30	T32	T42	T44
1E-02	T9	T11	T21	T23	T10	T12	T22	T24	T33	T35	T45	T47	T34	T36	T46	T48
	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9

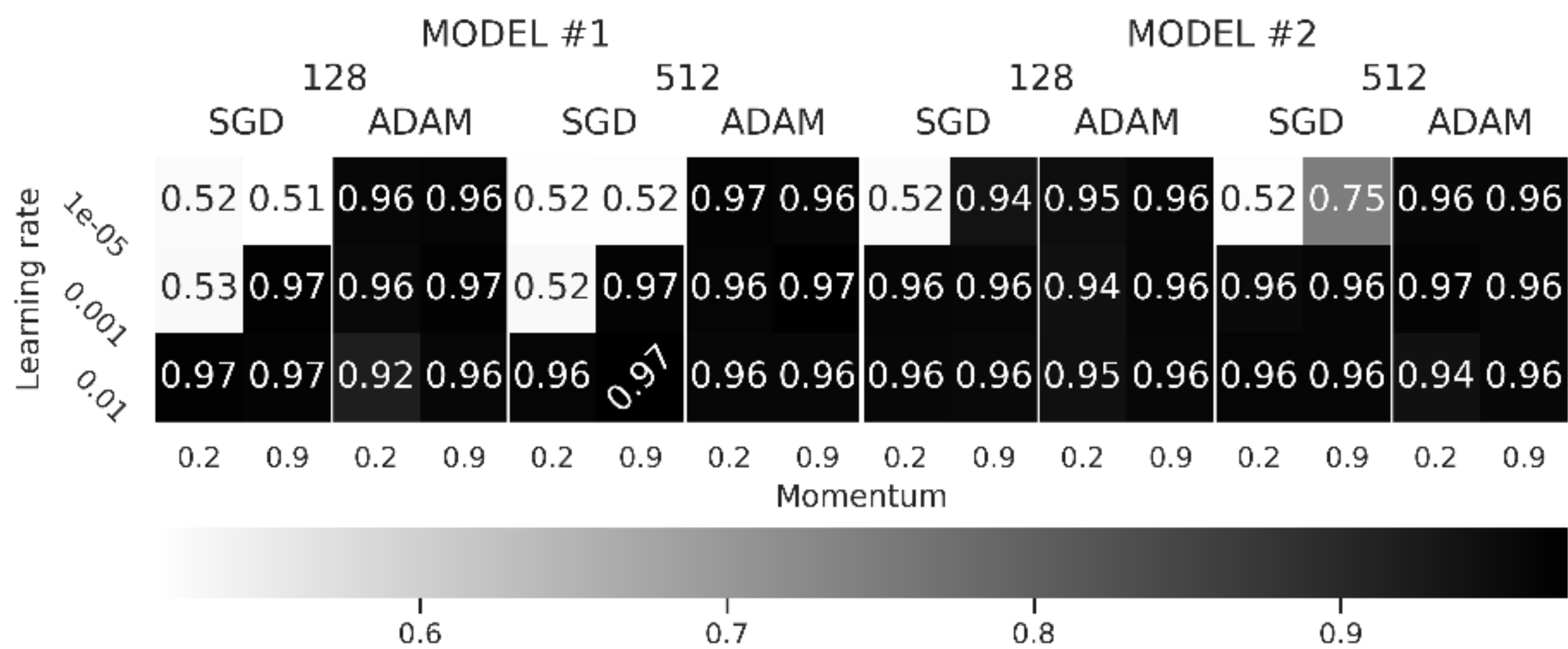




# CNN detector

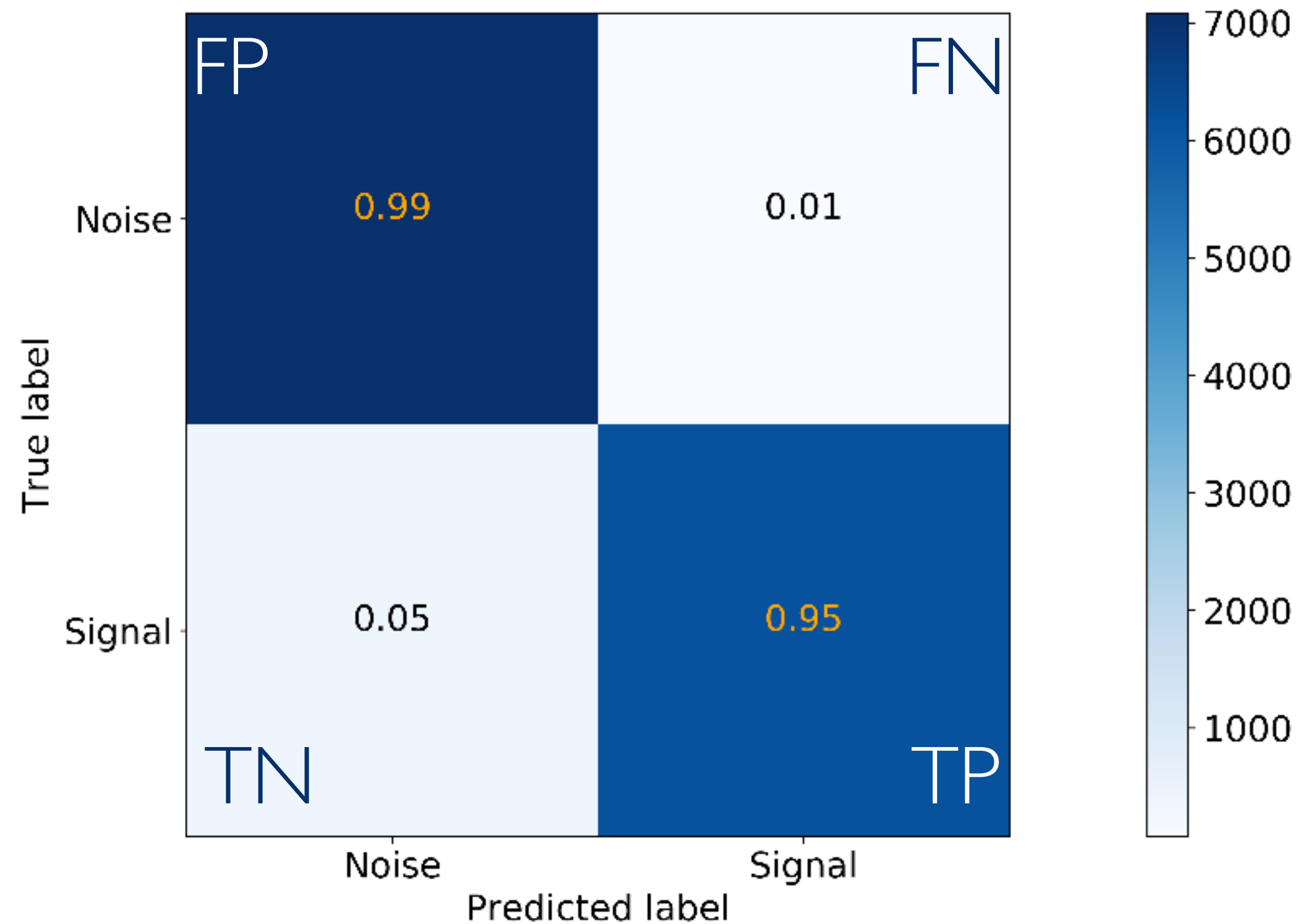


## Training + validation



Deep architecture  
 SGD optimisation algorithm  
 1e-2 learning rate  
 0.9 momentum  
 512 mini-batch

## Evaluation



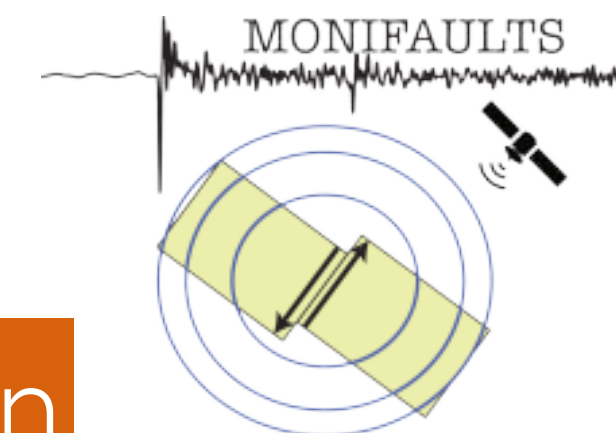
**Accuracy 97%**



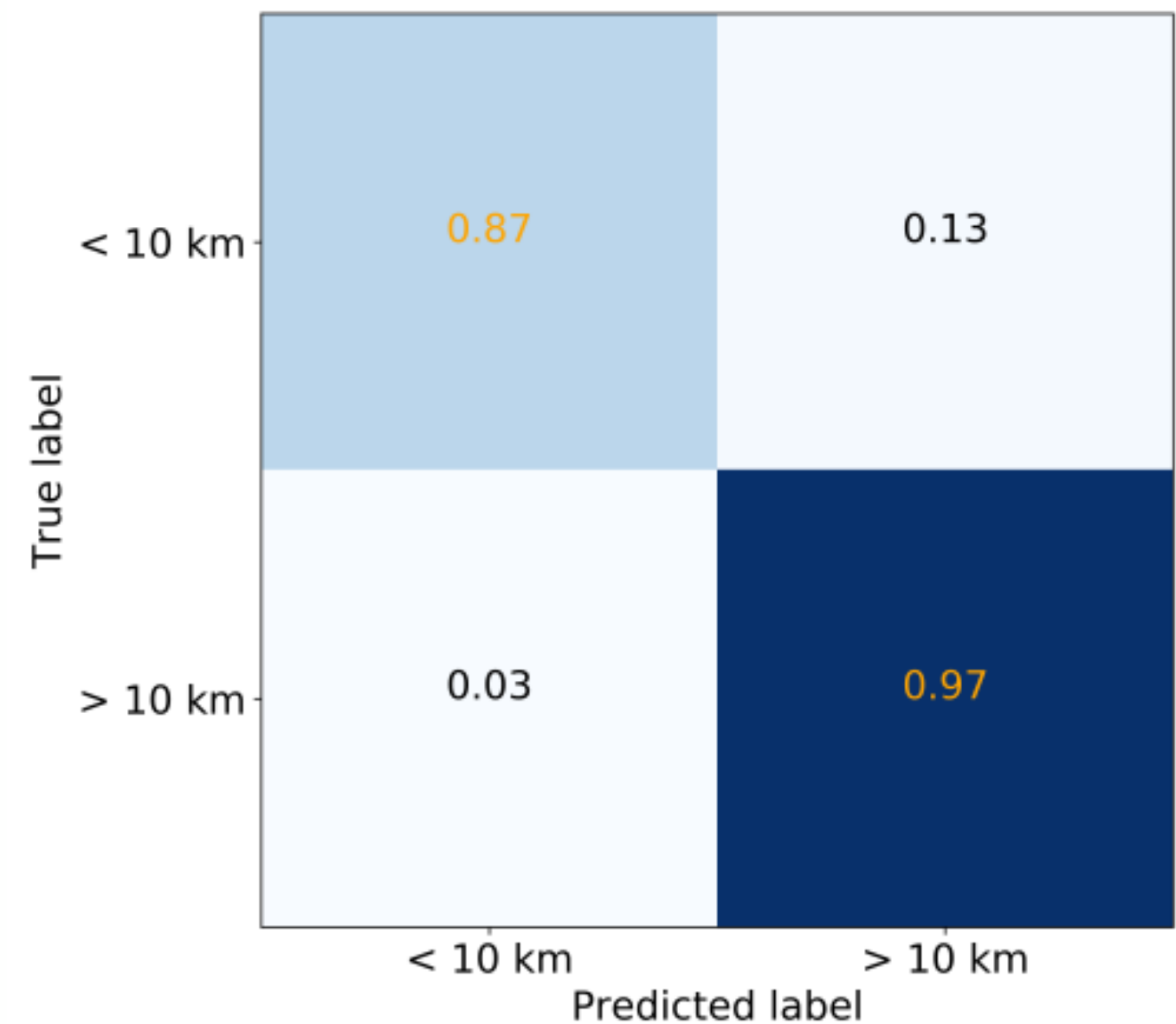
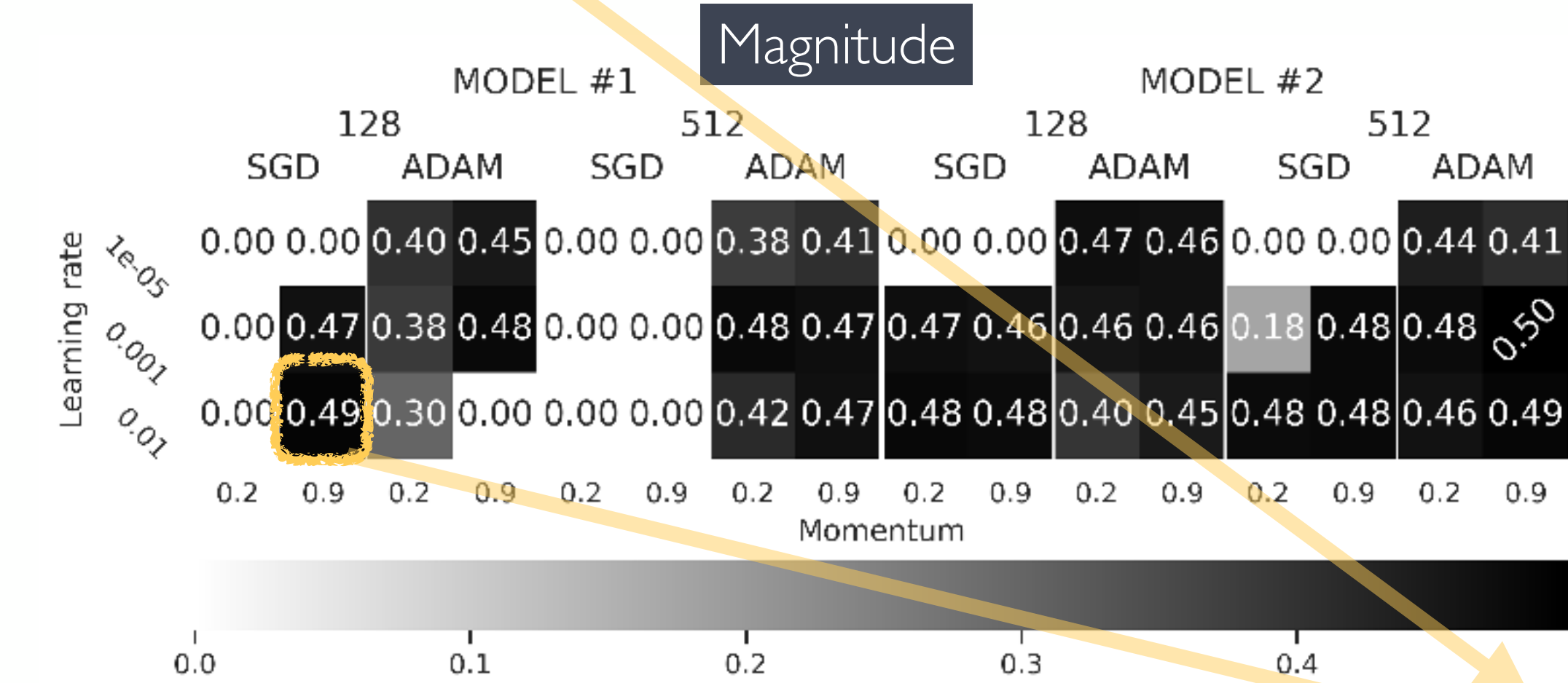
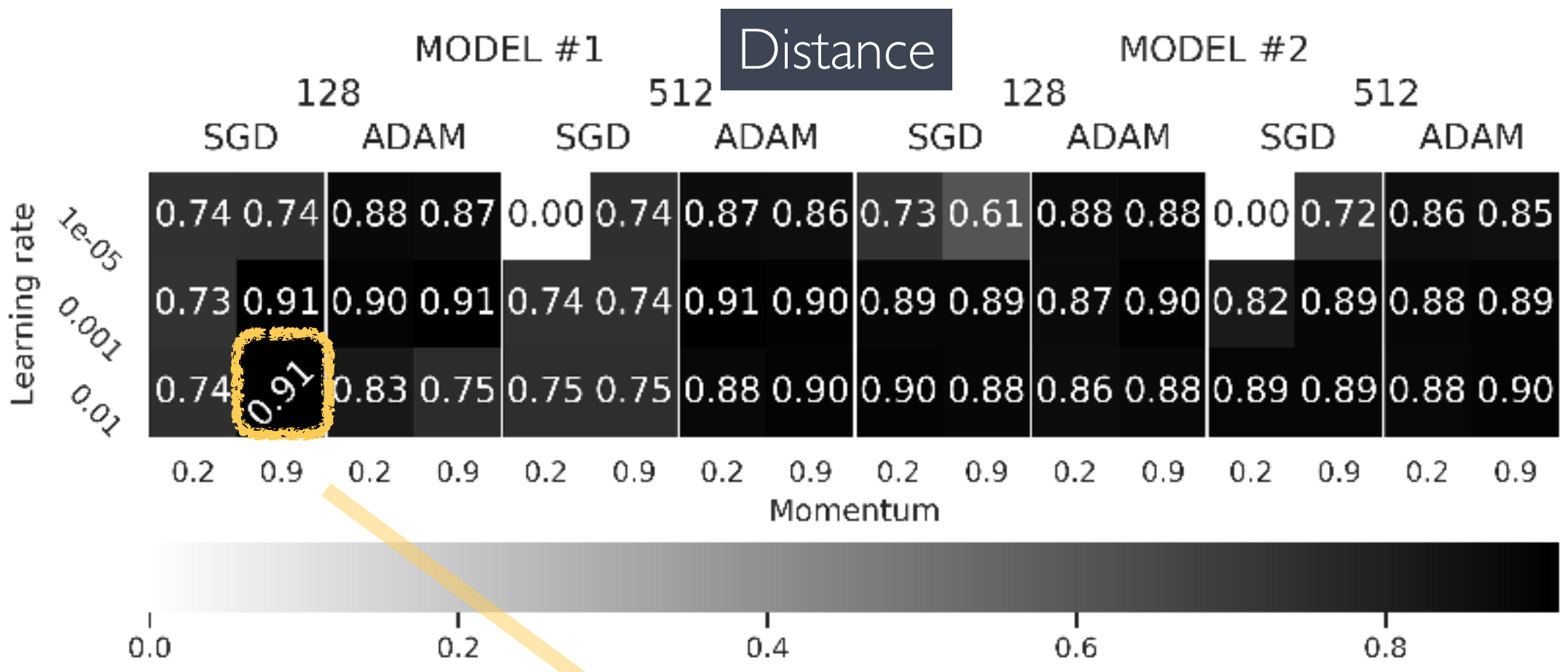
# CNN labelling

Distance  
<10, >10 km

Magnitude  
<1, 1-2, 2-3, >

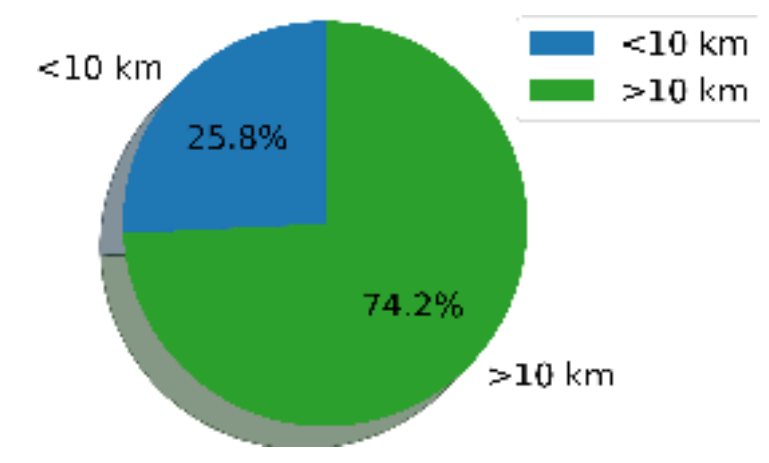


## Training + validation

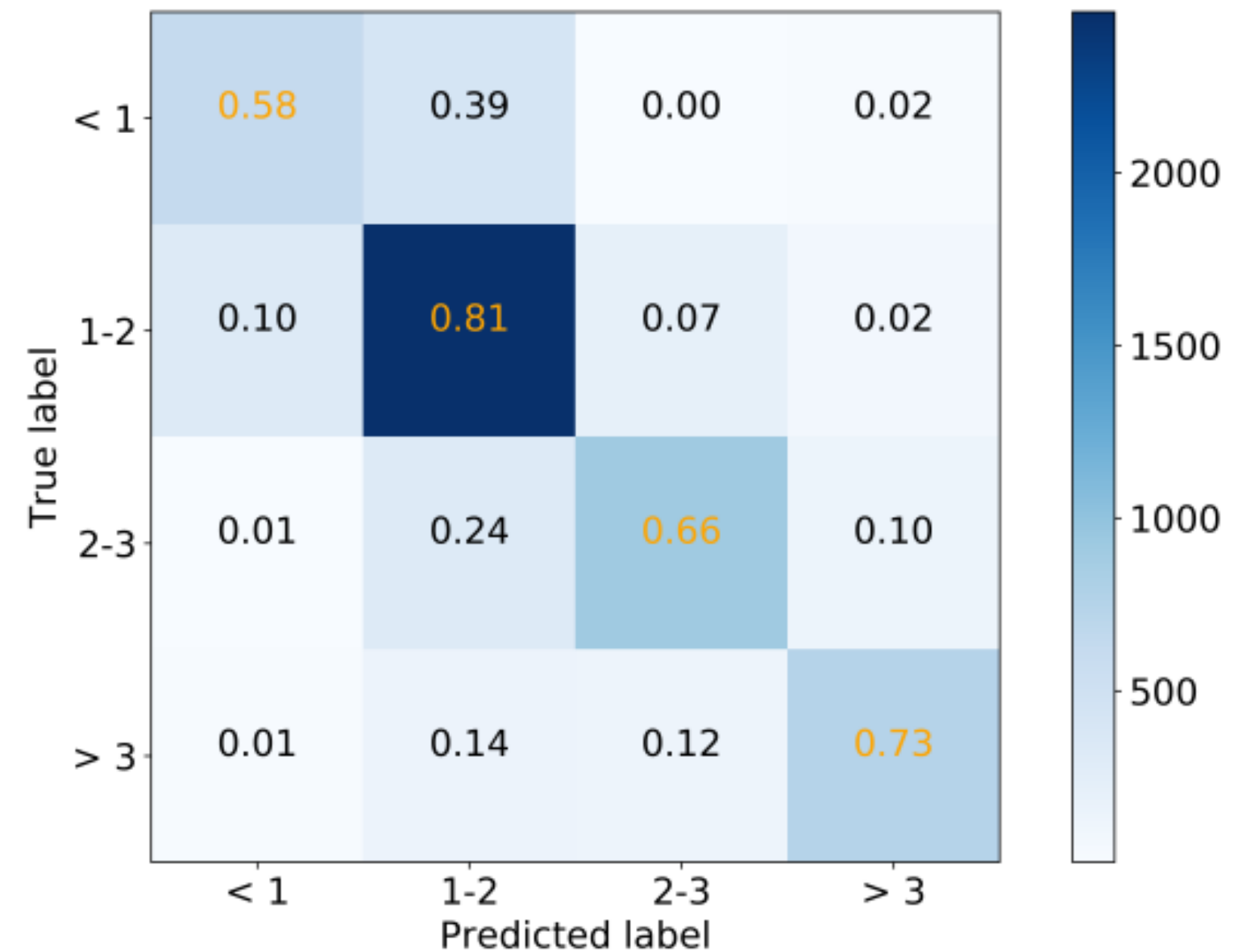


## Evaluation

Distance accuracy 94%



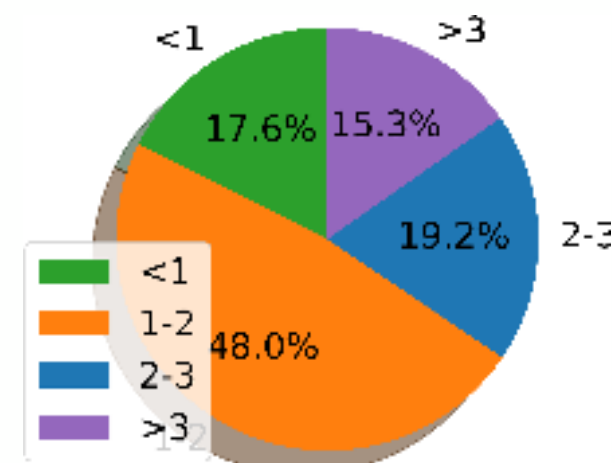
Magnitude accuracy 72%



Deep architecture  
SGD optimisation algorithm  
1e-2 learning rate  
0.9 momentum  
128 mini-batch

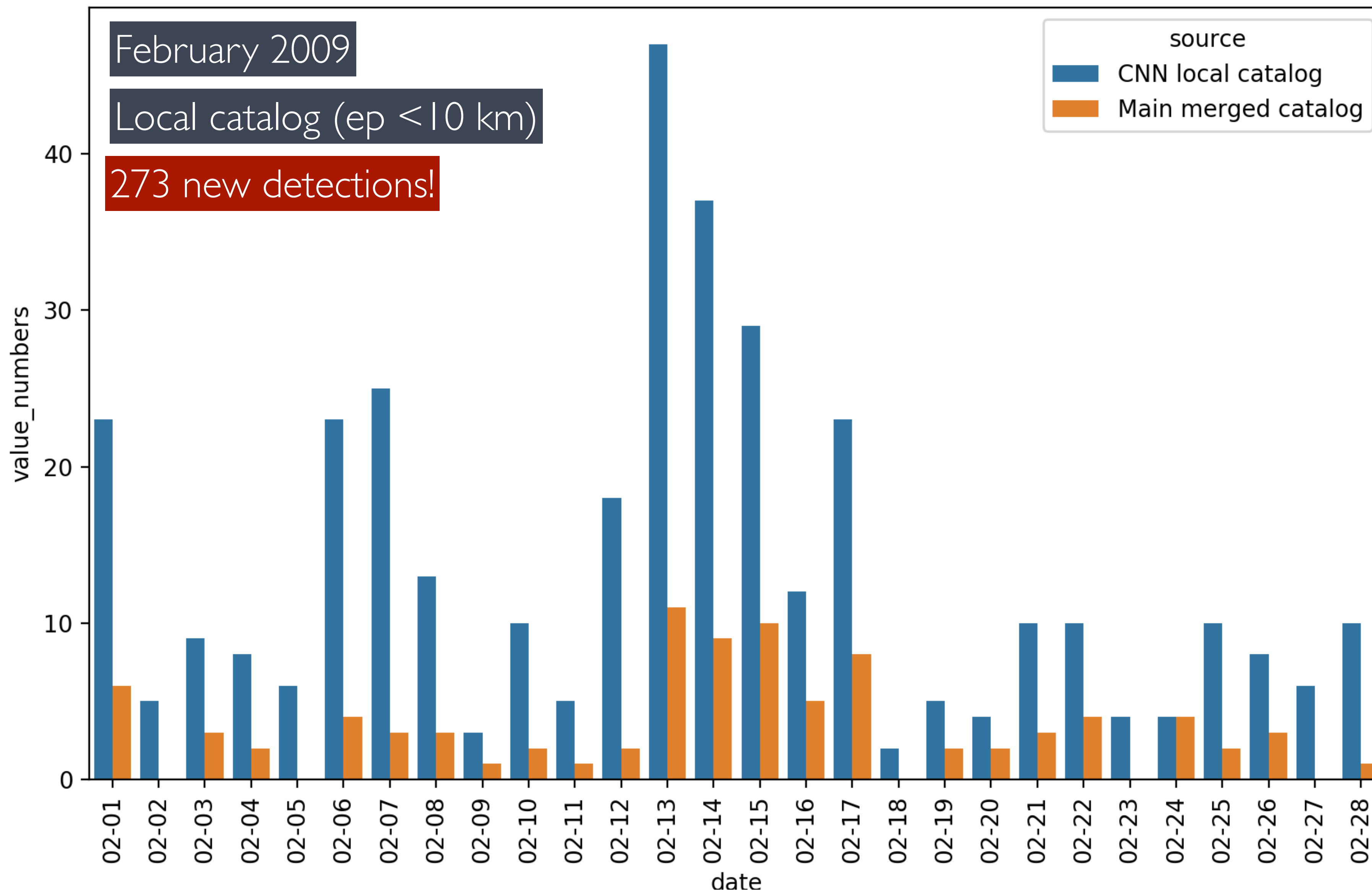
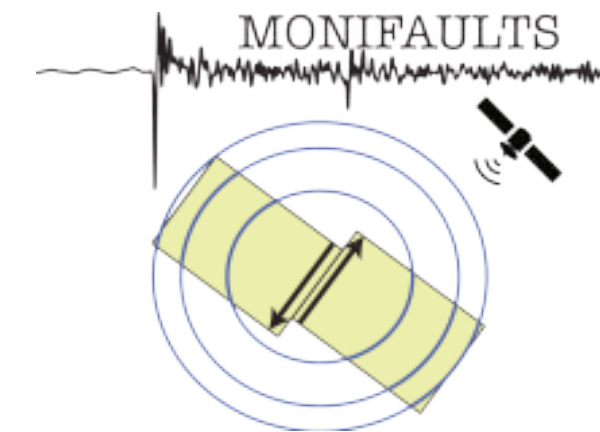
## Test II

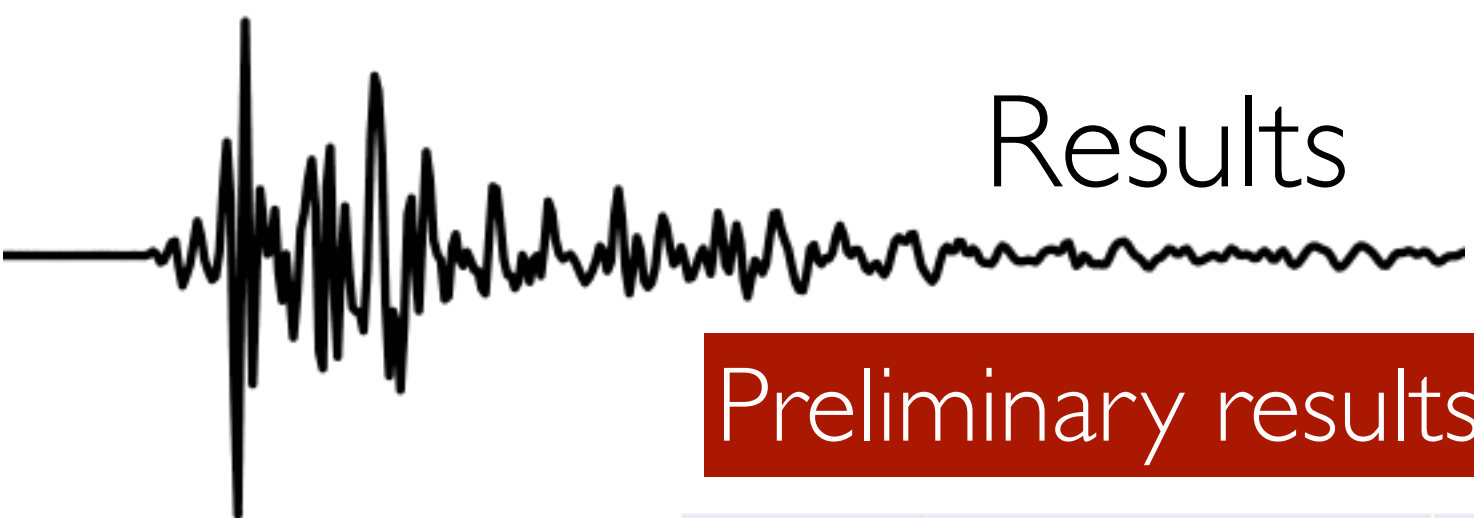
10



# Results

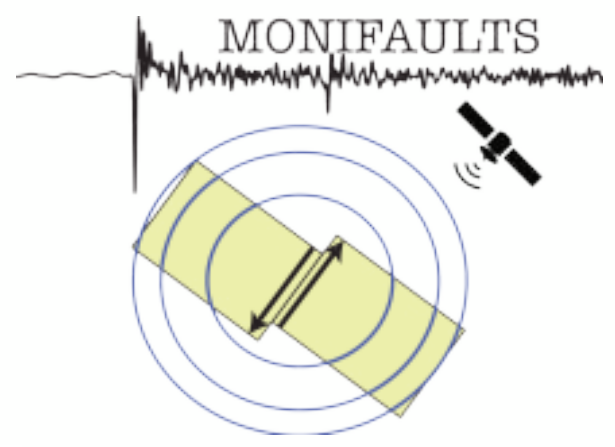
# Continuous data



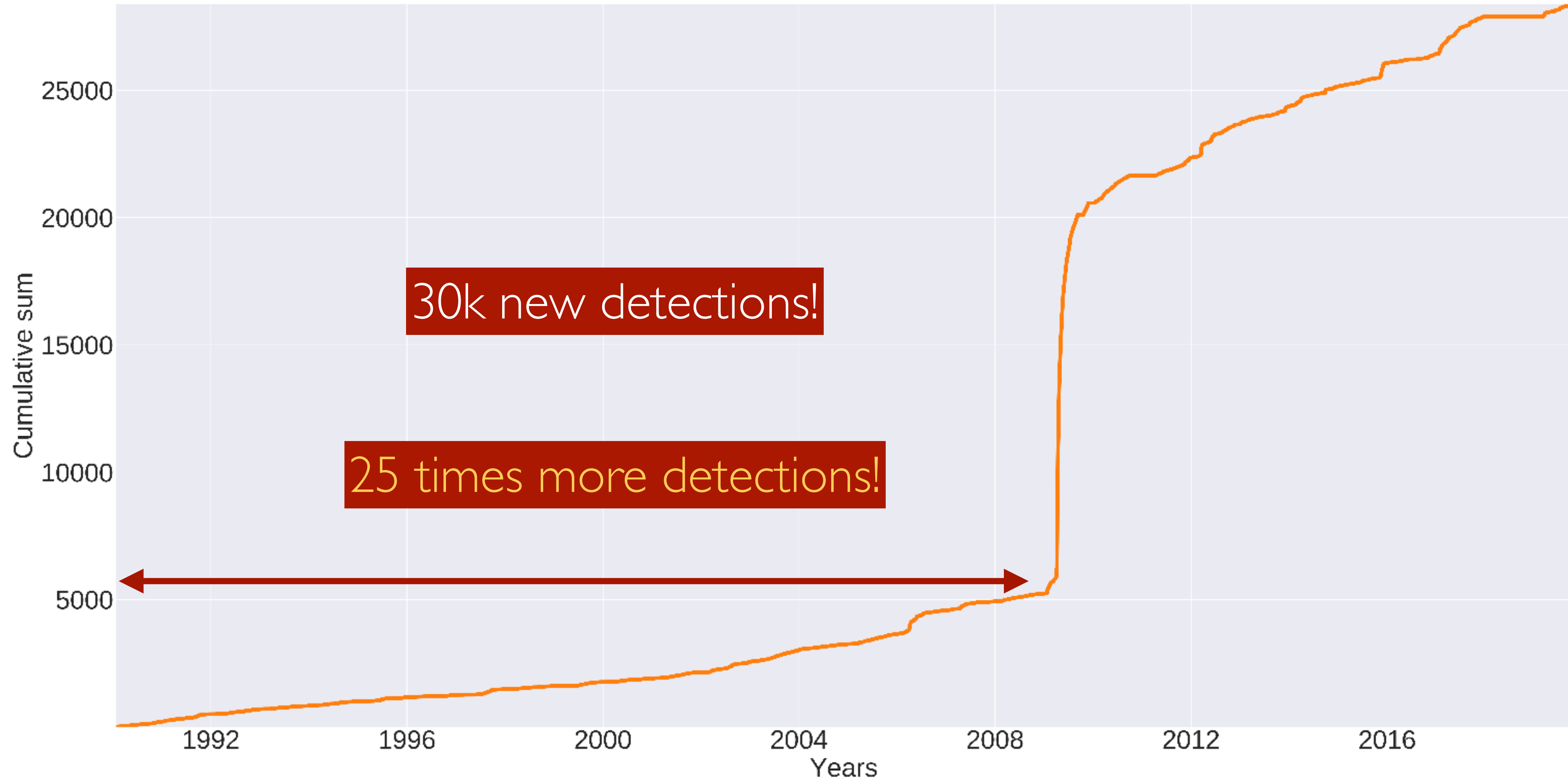


Continuous data

Local catalog (ep < 10 km)



Preliminary results!



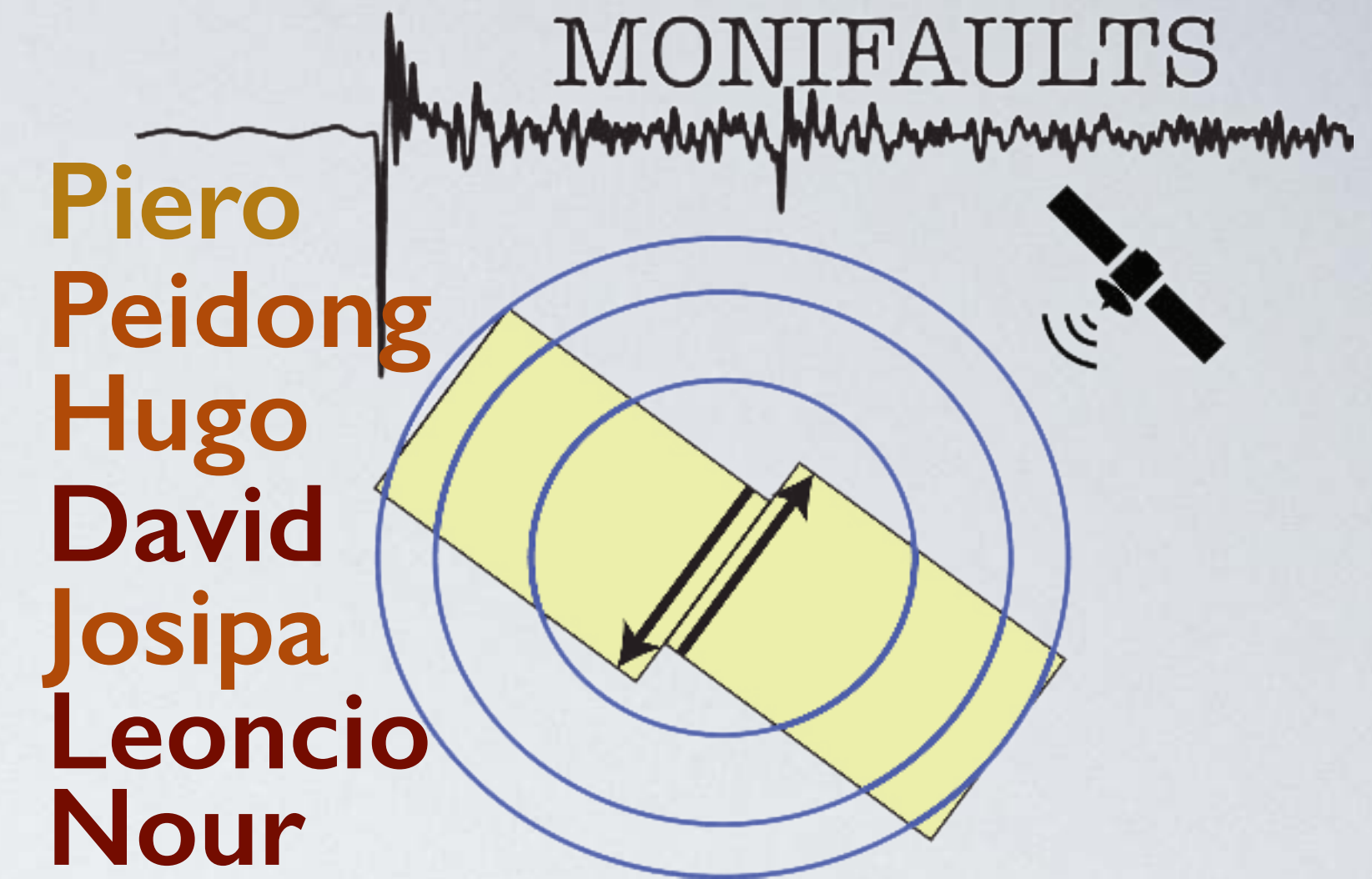
Data, codes, clusters...

ISTerre cluster

```
majstorj@ist-oar:/data/projects/monifault$ ls  
data david hugo josipa larino leoncio nour peidong piero
```

CIMENT

```
(base) majstorovicj@f-dahu:/summer/monifault$ ls  
data david hugo josipa larino leoncio nour peidong piero
```



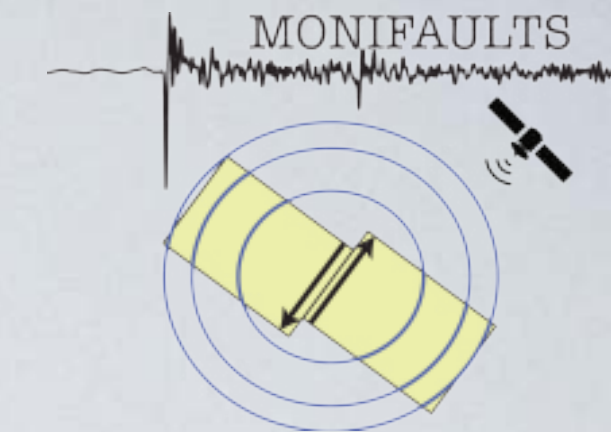
Piero  
Peidong  
Hugo  
David  
Josipa  
Leoncio  
Nour

December 2019 - newbie

Thank you  
sos-calcul-gricad!



Data, codes, clusters...



### ISTerre cluster

```
majstorj@ist-oar:/data/projects/monifault$ ls  
data david hugo josipa larino leoncio nour peidong piero
```

Mount this folder on my laptop.

### Ciment

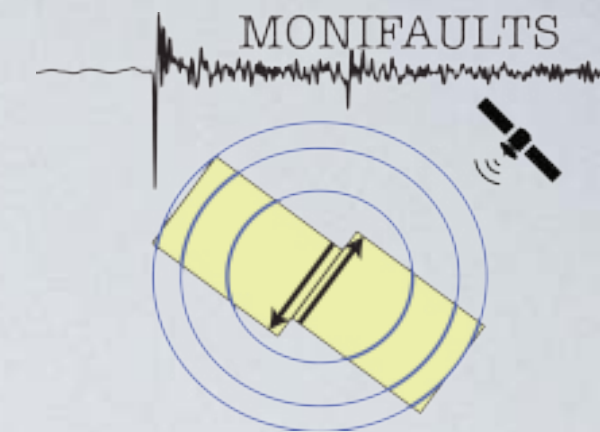
```
(base) majstorovicj@f-dahu:/summer/monifault$ ls  
data david hugo josipa larino leoncio nour peidong piero
```

Codes, results 100 Gb



~ 30 years of three component seismograms for 1 station

AQ1
AQ2
AQ3
276 Gb
AQ4



## Stages of the framework

1. Building an extensive catalog

ISTerre (CPU)

2. Extracting positive and negative samples

ISTerre (CPU)

3. CNN training and validation

Dahu (GPU)

4. CNN evaluation

ISTerre (CPU)

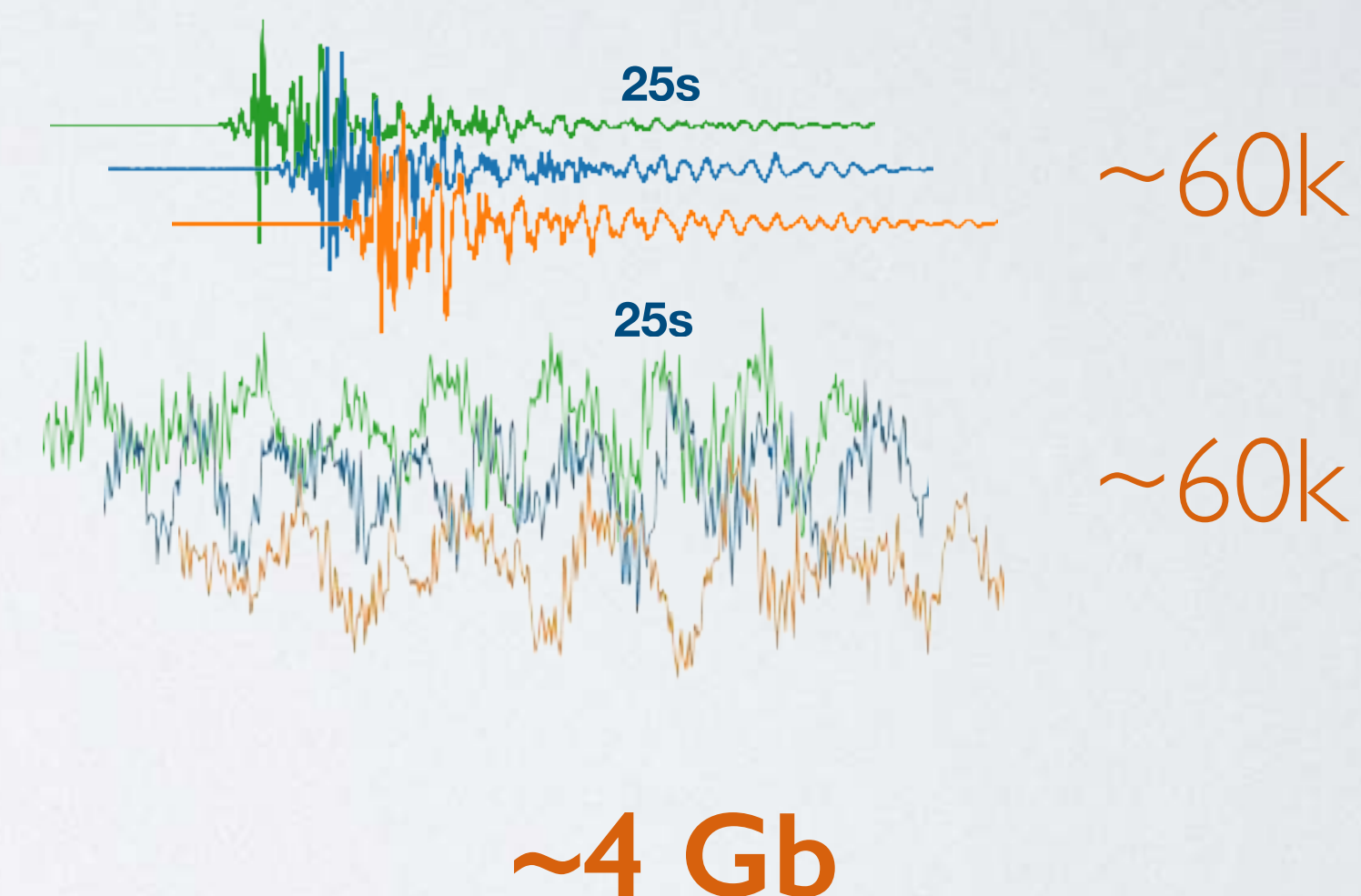
5. Running CNN on continuous data

Dahu (GPU)

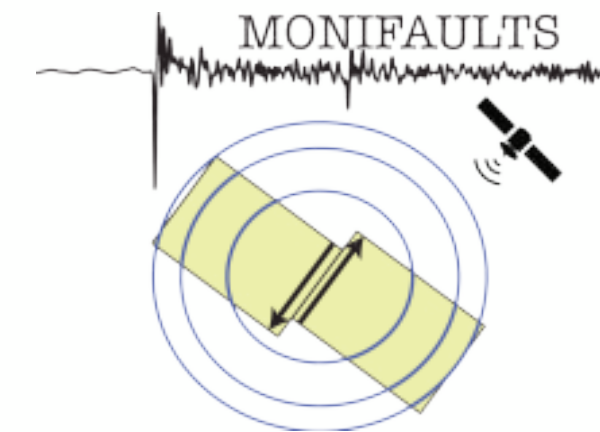
6. Extracting local events

ISTerre (CPU)

→ Samples are .txt files



Data, codes, clusters...



CNN training and validation ~4 Gb

Grid search - 48 test

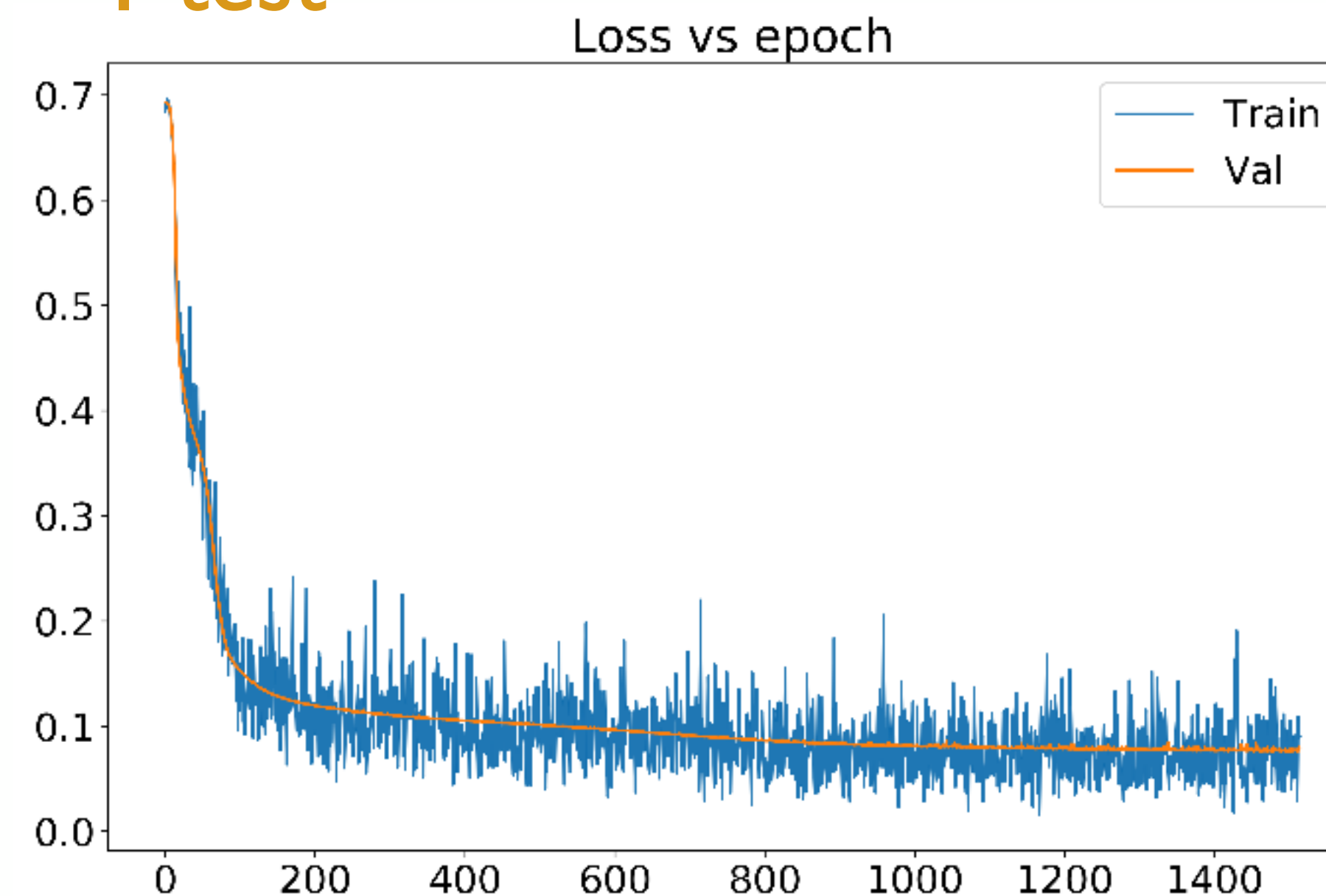
	DEEP CNN								SHALLOW CNN							
	128				512				128				512			
	SGD		ADAM		SGD		ADAM		SGD		ADAM		SGD		ADAM	
1E-05	T1	T3	T13	T15	T2	T4	T14	T16	T25	T27	T37	T39	T26	T28	T38	T40
1E-03	T5	T7	T17	T19	T6	T8	T18	T20	T29	T31	T41	T43	T30	T32	T42	T44
1E-02	T9	T11	T21	T23	T10	T12	T22	T24	T33	T35	T45	T47	T34	T36	T46	T48
	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9

I estimated that I need only 2 cores.

```
#!/bin/bash
#OAR -n run1gpu
#OAR -t gpu
#OAR -l /nodes=1/gpudevice=1/core=2,walltime=5:00:00
#OAR --stdout output_DET_JOB1_m2_n1_a1_o1_l1_t1_b1.out
#OAR --stderr output_DET_JOB1_m2_n1_a1_o1_l1_t1_b1.err
#OAR --project monifault
#OAR --notify mail:josipa.majstorovic@univ-grenoble-alpes.fr
```

Sending jobs in batches of 8.

I test



GPU: 5000 epochs ~ 3h30

There was a problem with the submission order:  
/nodes=1/gpudevice=1/core=2.

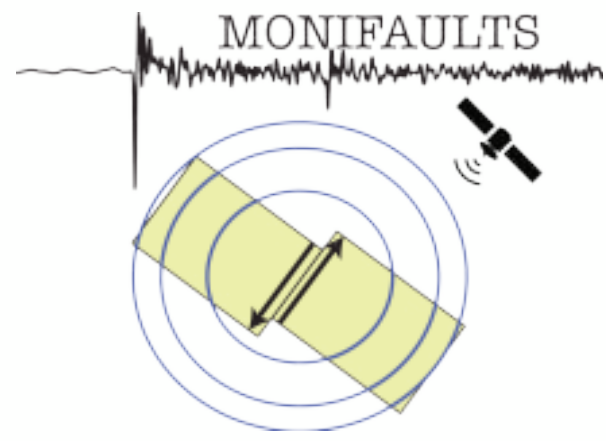




CNN training and validation

Distance  
<10, >10 km

Magnitude  
<1, 1-2, 2-3, >



I have/need to run grid search for a lot of different experiments!

Jobs = Experiments x 48

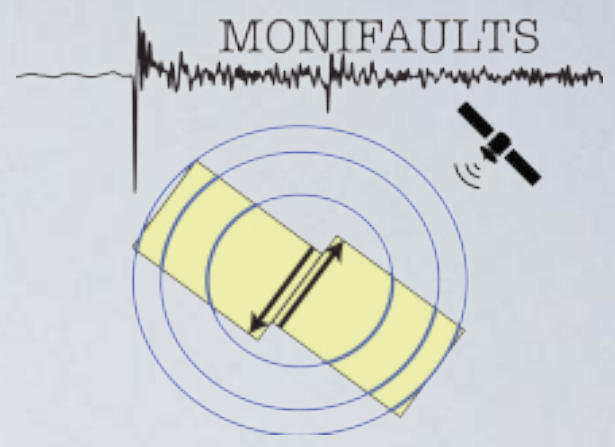
Option to automatically submit jobs in batches or individually.

Not elegant solution: small python script that checks the status of my submitted jobs.

Memory issue

Submission order of nodes, gpudevice, cores

Submission of many jobs

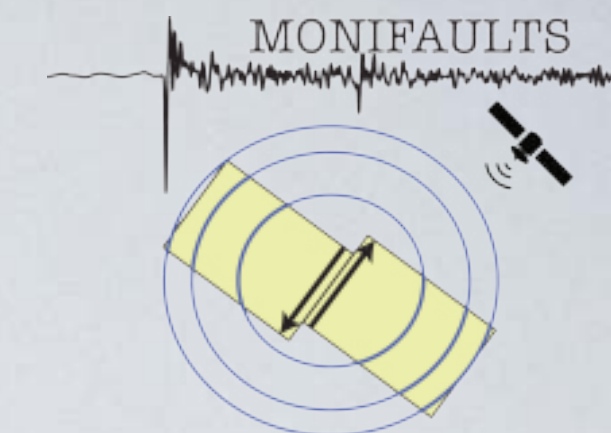


## Stages of the framework

1. Building an extensive catalog	ISTerre (CPU)
2. Extracting positive and negative samples	ISTerre (CPU)
3. CNN training and validation	Dahu (GPU)
4. CNN evaluation	ISTerre (CPU)
5. Running CNN on continuous data	Dahu (GPU)
6. Extracting local events	ISTerre (CPU)



Data, codes, clusters...

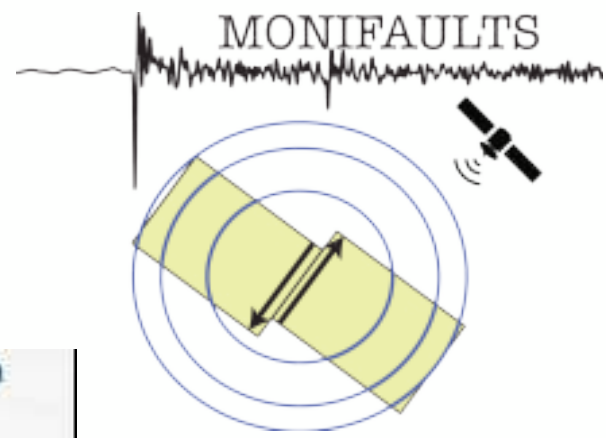


Folder	Days	5. Running CNN on continuous data	6. Extracting local events
AQ1 (1990-1994)	1528	~1h 10	~4 min
AQ2 (1995-1999)	1249	~1h	~3 min
AQ3 (2000-2009)	3391	~2h 30	~9.8 min
AQ4 (2010 - 2019)	2801	2h	~6.4 min



1 day ~2.5 s

# Data, codes, clusters...

A screenshot of the CIMENT Wiki Main Page. The page has a header with navigation tabs: "page", "discussion", "view source", and "history". The main content area is titled "Main Page" and "Welcome to the CIMENT Wiki". It contains a welcome message, a "Getting started" section with links to "General docs", "Clusters docs", "Grid docs", and "Admin docs", and a "Discussion lists" section. The left sidebar contains sections for "users", "administrators", "links", "search", and "tools". The footer includes a "Powered By MediaWiki" logo and a "Privacy policy" link.

147.171.176.96 talk for this ip address log in

page discussion view source history

## Main Page

### Welcome to the CIMENT Wiki

This wiki is intended to give useful informations about the Ciment clusters and grid and may be edited by every Ciment user (excepted protected pages that are maintained by the staff).  
For more information, please, visit the [official site](#).

### Getting started

- [General docs](#): In this section, you'll find docs and tutorials about common services of CIMENT.
- [Clusters docs](#): In this section, you may find docs about a particular cluster.
- [Grid docs](#): In this section, you'll find docs and tutorials about the Ciment GRID (CiGri) and related services such as the grid storage.
- [Admin docs](#): Here are some docs for CIMENT system administrators

### Discussion lists

Another source of informations are discussion lists. You are strongly encouraged to participate to the [ciment-users@univ-grenoble-alpes.fr](mailto:ciment-users@univ-grenoble-alpes.fr) list. Every Ciment users are automatically subscribed to this list. Other lists are available, such as lists specific to ciment *poles* or ciment *platforms*. They are hosted on the Université Grenoble Alpes server: <https://listes.univ-grenoble-alpes.fr/>

users

- [Main Page](#)
- [General docs](#)
- [Clusters docs](#)
- [Grid docs](#)
- [Support](#)

administrators

- [Admin docs](#)
- [CiGri middleware](#)
- [CIMENT operations](#)

links

- [Ciment](#)

search

tools

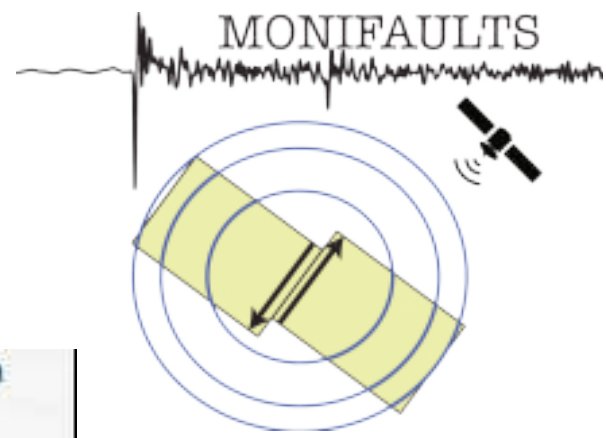
- [What links here](#)
- [Related changes](#)
- [Special pages](#)
- [Printable version](#)
- [Permanent link](#)

This page was last modified on 4 June 2019, at 13:38. This page has been accessed 123,805 times. [Privacy policy](#) [About CIMENT](#) [Disclaimers](#)

Powered By MediaWiki

I appreciate the effort of having the Wiki in English.

# Data, codes, clusters...

A screenshot of the CIMENT Wiki Main Page. The page has a header with navigation tabs: 'page', 'discussion', 'view source', and 'history'. The main content area is titled 'Main Page' and includes a welcome message: 'Welcome to the CIMENT Wiki'. Below this, it states: 'This wiki is intended to give useful informations about the Ciment clusters and grid and may be edited by every Ciment user (excepted protected pages that are maintained by the staff). For more information, please, visit the official site'. There are three sections: 'Getting started' with a list of links for 'General docs', 'Clusters docs', 'Grid docs', and 'Admin docs'; 'Discussion lists' with a paragraph about participating in the 'ciment-users@univ-grenoble-alpes.fr' list; and a footer with page modification and access statistics, and a 'Powered By MediaWiki' logo.

147.171.176.96 talk for this ip address log in

page discussion view source history

## Main Page

**Welcome to the CIMENT Wiki**

This wiki is intended to give useful informations about the Ciment clusters and grid and may be edited by every Ciment user (excepted protected pages that are maintained by the staff).  
For more information, please, visit the [official site](#).

### Getting started

- **General docs:** In this section, you'll find docs and tutorials about common services of CIMENT.
- **Clusters docs:** In this section, you may find docs about a particular cluster.
- **Grid docs:** In this section, you'll find docs and tutorials about the Ciment GRID (CiGri) and related services such as the grid storage.
- **Admin docs:** Here are some docs for CIMENT system administrators

### Discussion lists

Another source of informations are discussion lists. You are strongly encouraged to participate to the [ciment-users@univ-grenoble-alpes.fr](mailto:ciment-users@univ-grenoble-alpes.fr) list. Every Ciment users are automatically subscribed to this list. Other lists are available, such as lists specific to ciment *poles* or ciment *platforms*. They are hosted on the Université Grenoble Alpes server: <https://listes.univ-grenoble-alpes.fr/>

This page was last modified on 4 June 2019, at 13:38. This page has been accessed 123,805 times. [Privacy policy](#) [About CIMENT](#) [Disclaimers](#)

Powered By MediaWiki

Thank you for your attention!

I appreciate the effort of having the Wiki in English.