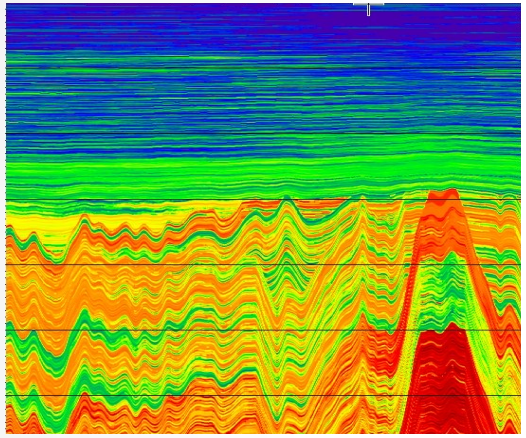
# Data-based choice of the training dataset for the numerical dispersion mitigation neural network

K. Gadylshin, V. Lisitsa, D. Vishnevsky, K. Gadylshina
Institute of Mathematics SB RAS
Institute of Petroleum Geology and Geophysics SB RAS

# NDM-net

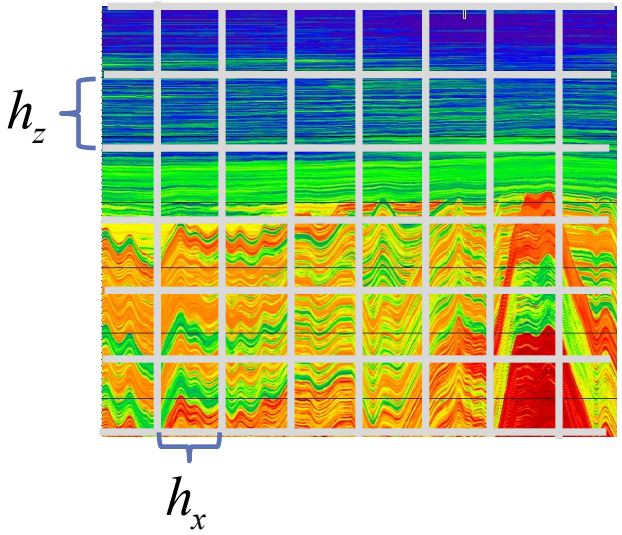


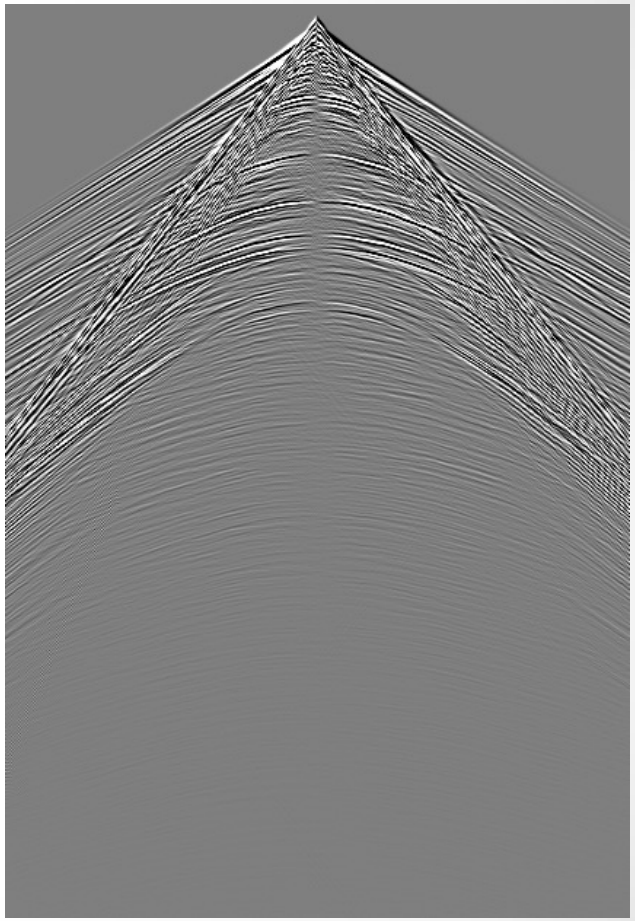
+

$$\rho \vec{u}_{tt} - \nabla \cdot \sigma = 0$$

$$\varepsilon = 0.5(\nabla \vec{u} + \nabla \vec{u}^T)$$

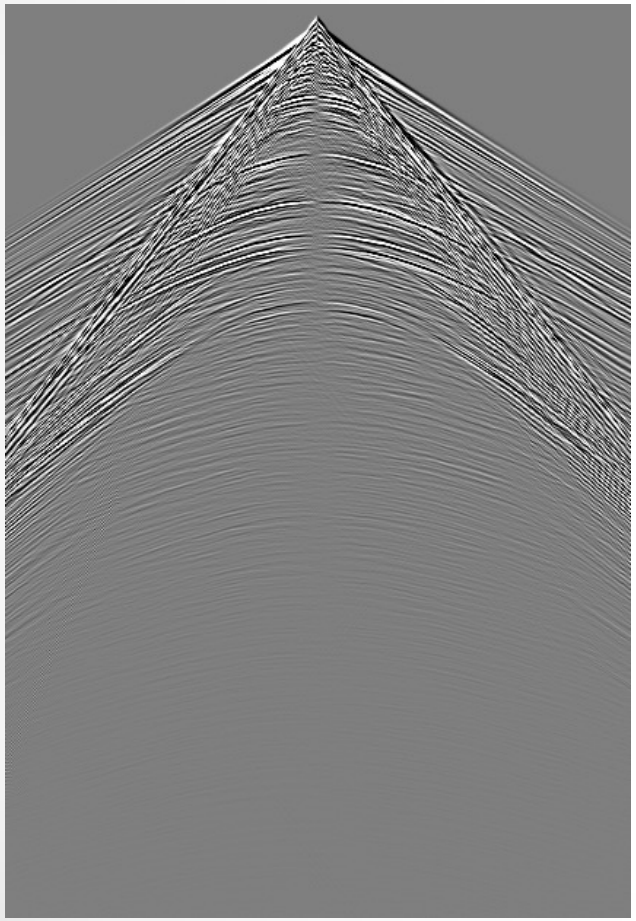
$$\sigma = C\varepsilon$$



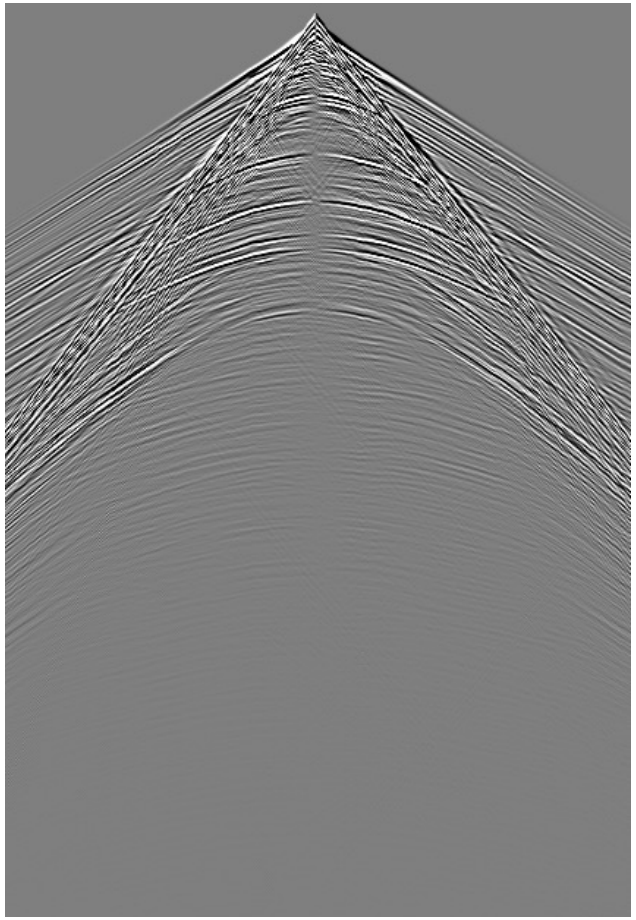



# Numerical dispersion

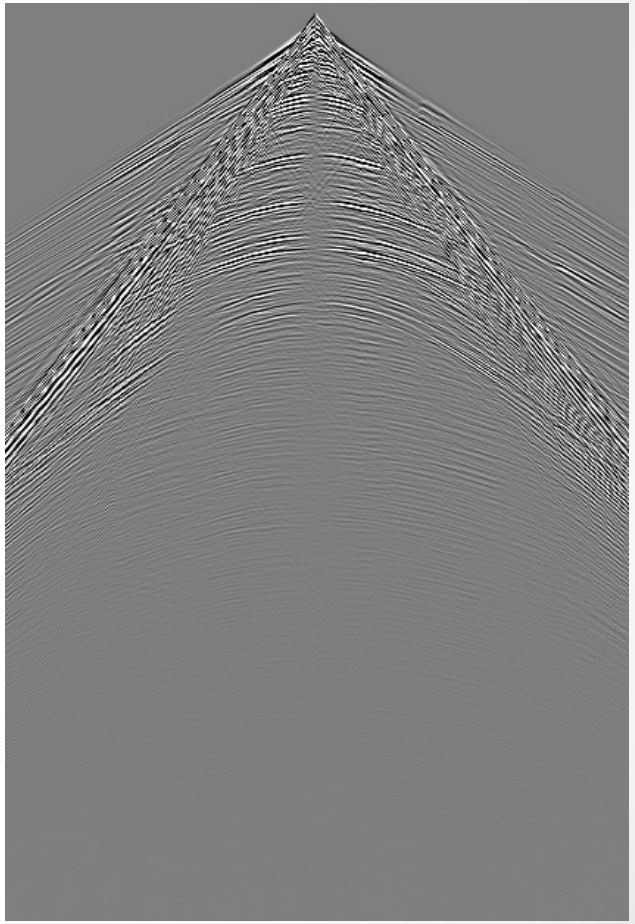
ux h=2.5m



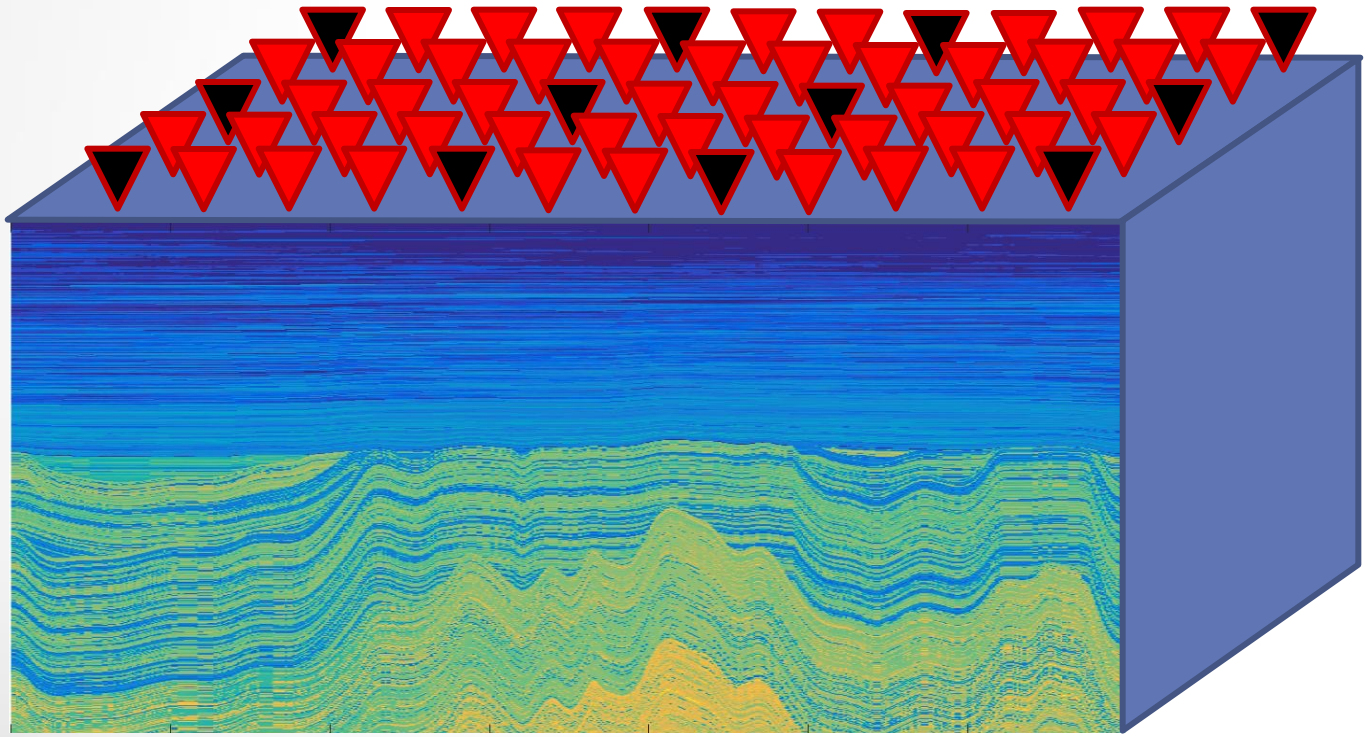
ux h=10m



difference

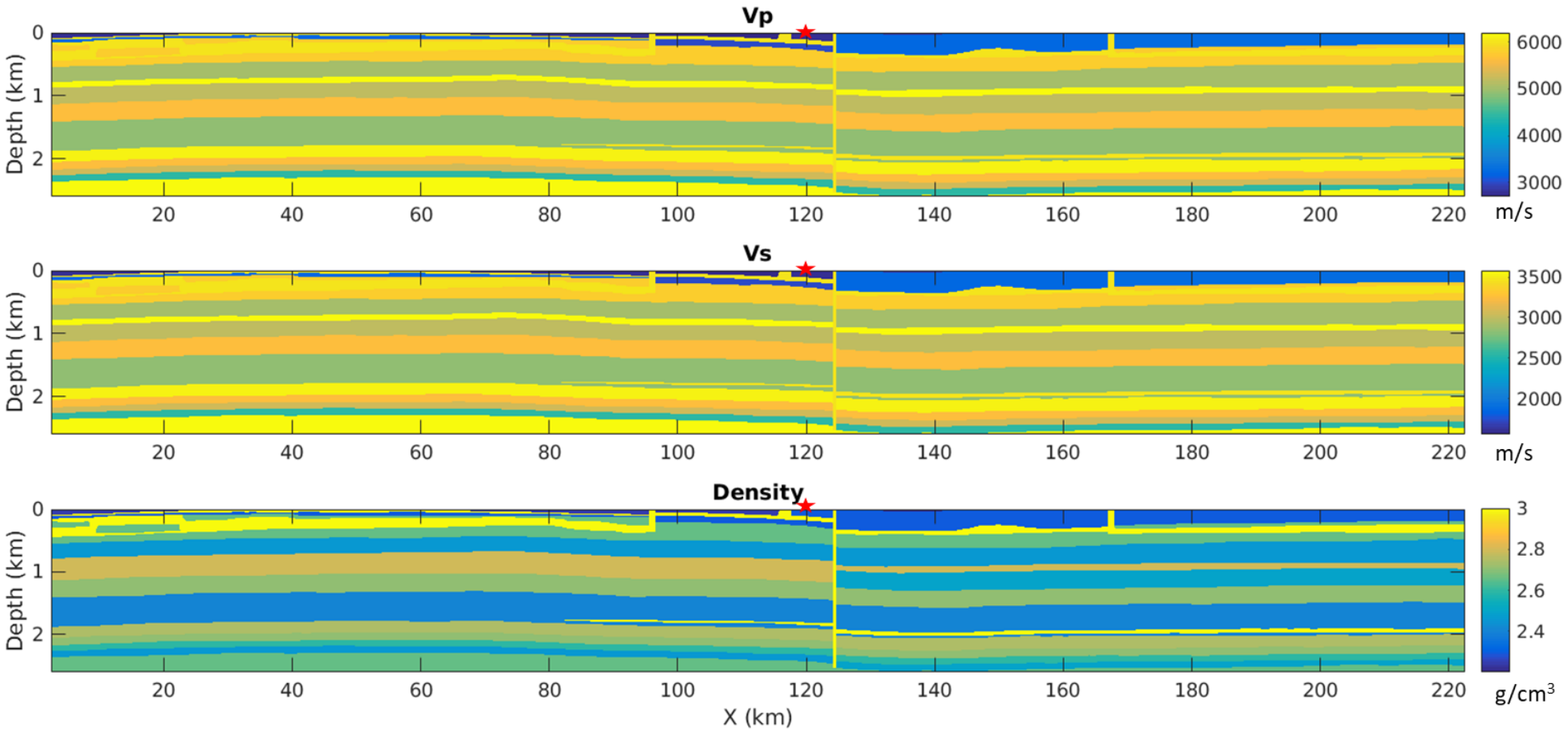


# NDM-net



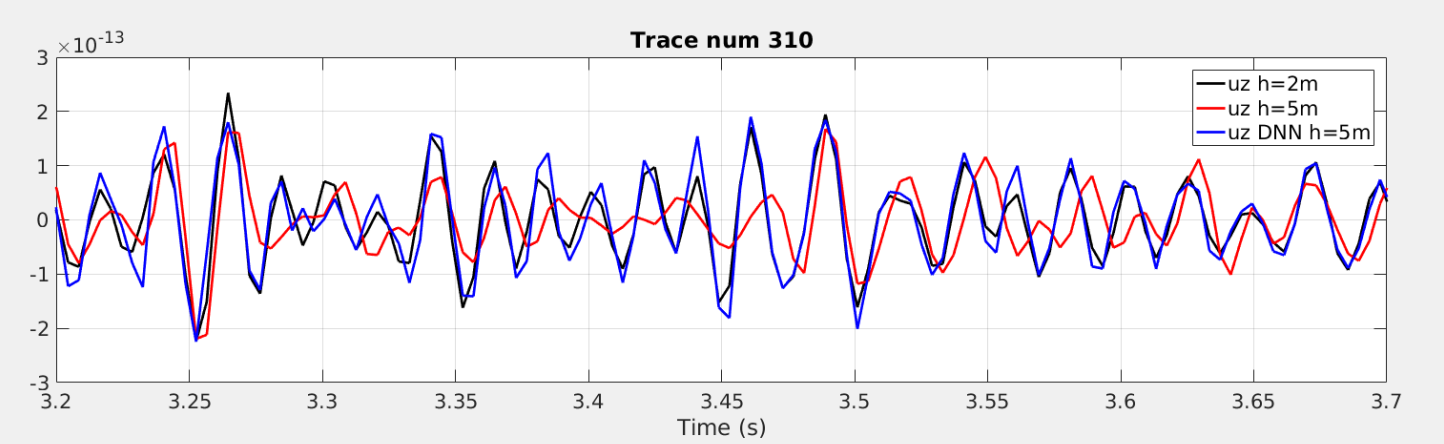
1. Compute **all** common-shot gathers using **coarse grid**
2. Compute **several** common-shot gathers using **fine mesh** – the training dataset
3. Train the NDM-net
4. Correct the solution for all common-shot gathers

# An example

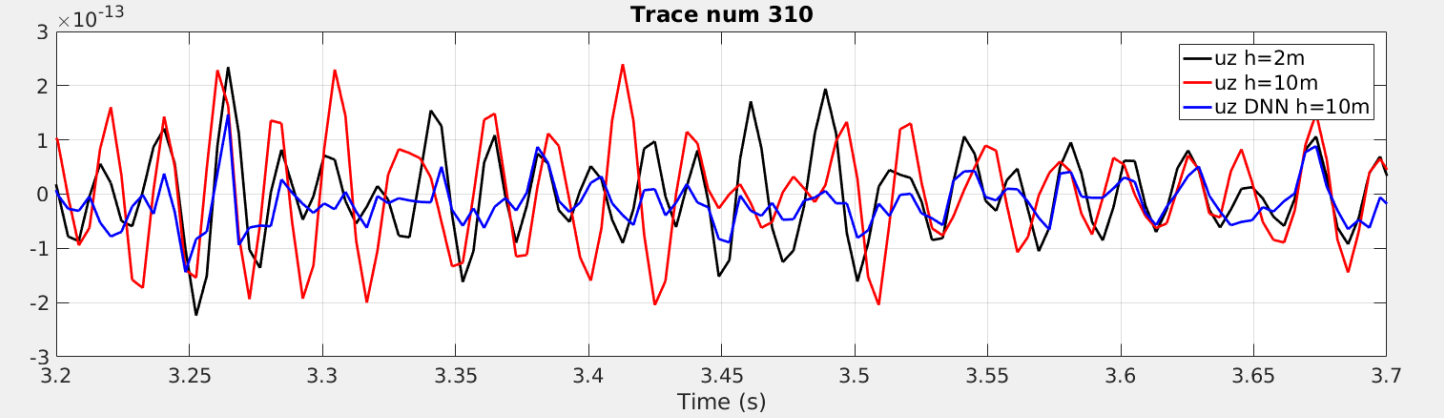

Vp
Depth (km)
0
1
2
20
40
60
80
100
120
140
160
180
200
220
6000
5000
4000
3000
m/s
Vs
Depth (km)
3500
3000
2500
2000
m/s
Density
Depth (km)
3
2.8
2.6
2.4
g/cm3
X (km)

# Numerical dispersion mitigation

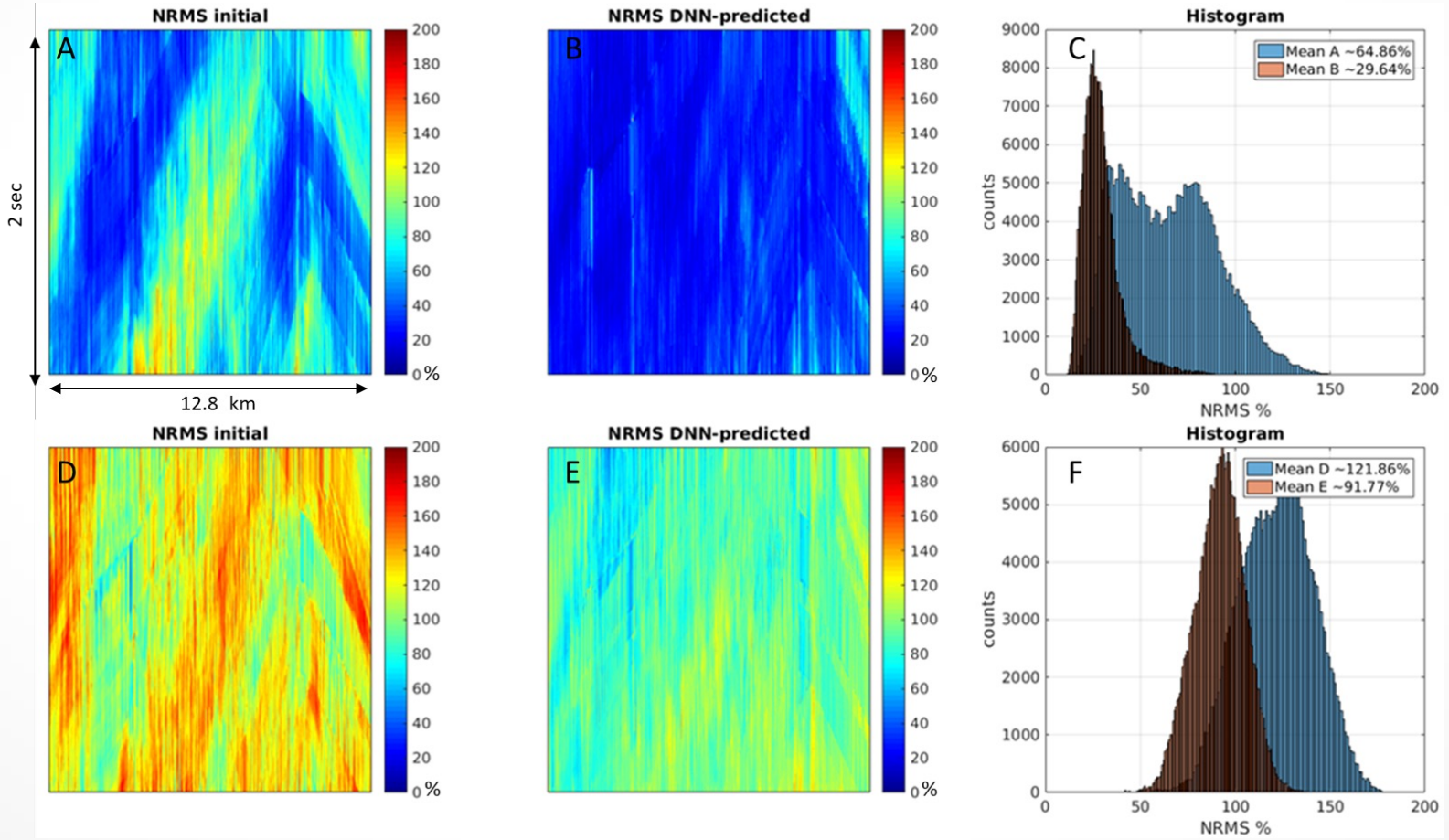
h=5 to h=2




h=10 to h=2

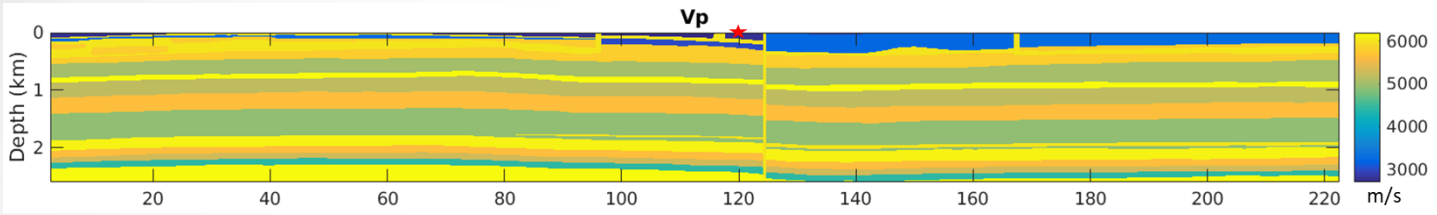


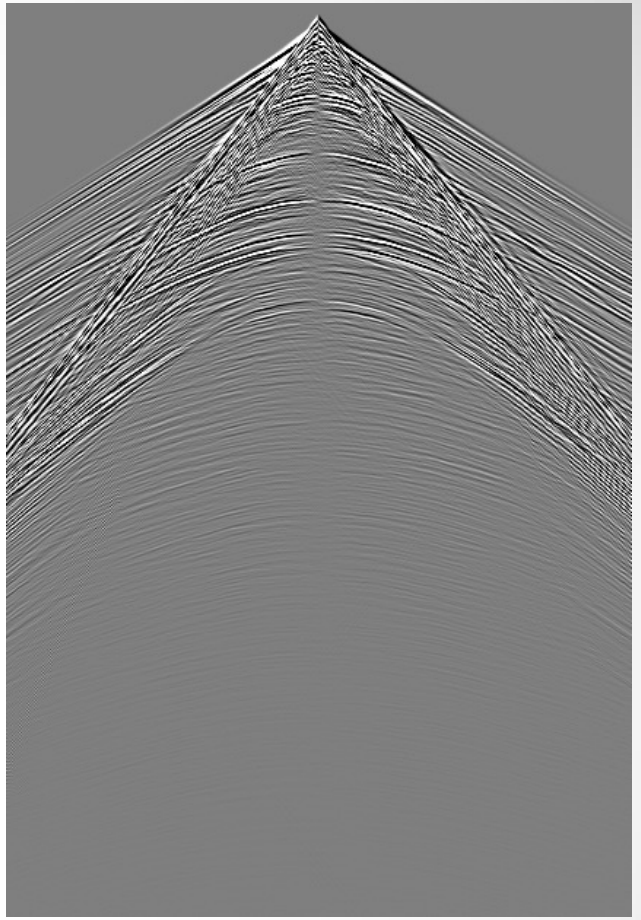
# NRMS


NRMS initial
A
2 sec
12.8 km
200
180
160
140
120
100
80
60
40
20
0 %
NRMS DNN-predicted
B
Histogram
C
Mean A ~64.86%
Mean B ~29.64%
counts
NRMS %
D
E
F
Mean D ~121.86%
Mean E ~91.77%

# Speed-up

1900 sources



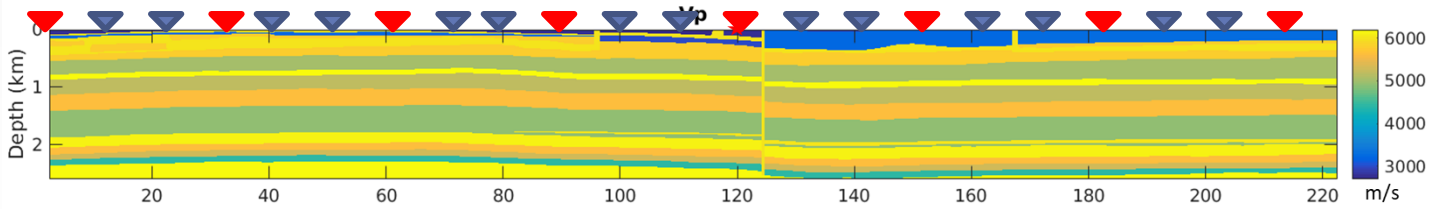



Simulation of the entire dataset:
2x2 м – 23 hours
5x5 м – 2.3 hours
10x10 м – 0.6 hours

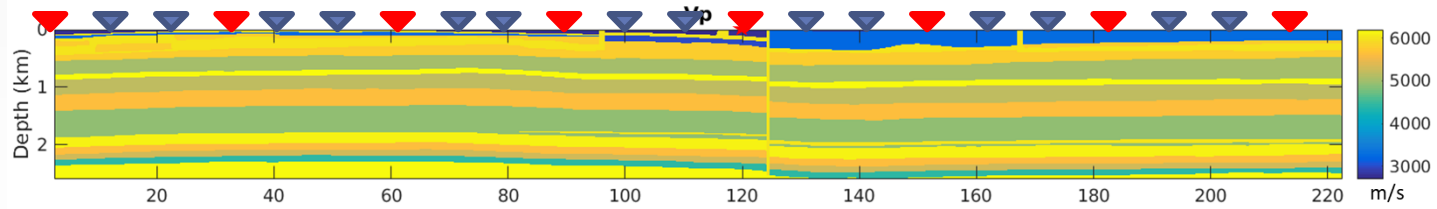
Number of shots in
the training dataset – 190
Training time – 40 min
Correction time – 0.1 seconds per shot

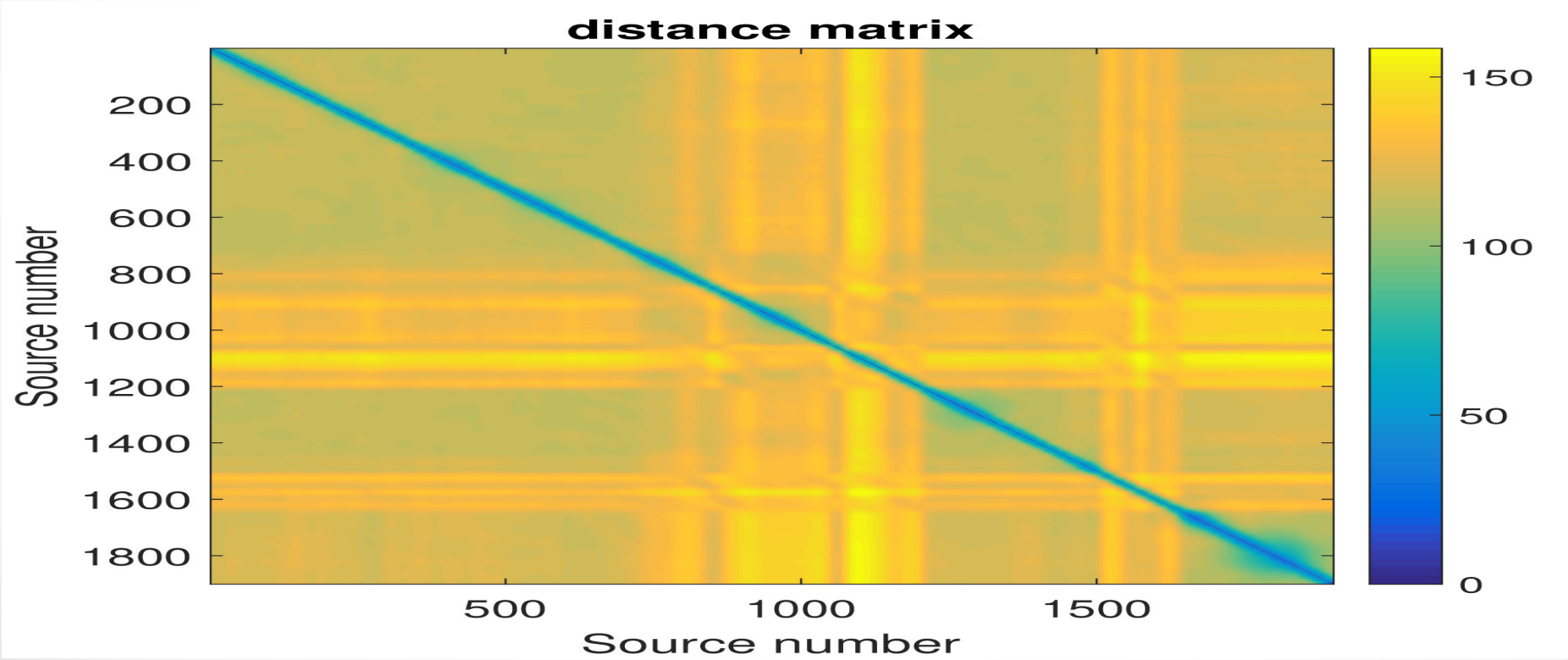
Time **f-d + NDM-net**:
Entire dataset on 5 m grid: 3 hours
Generation of the training dataset:
2.3 hours
Training: 0.6 hour
**In total: 6 hours**

# Matrix of NRMS

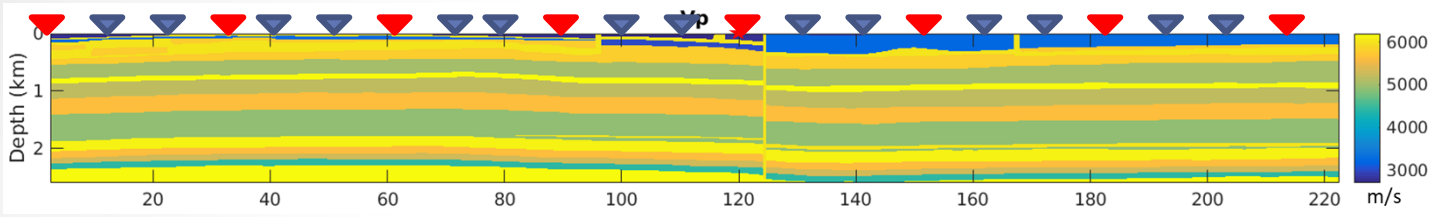


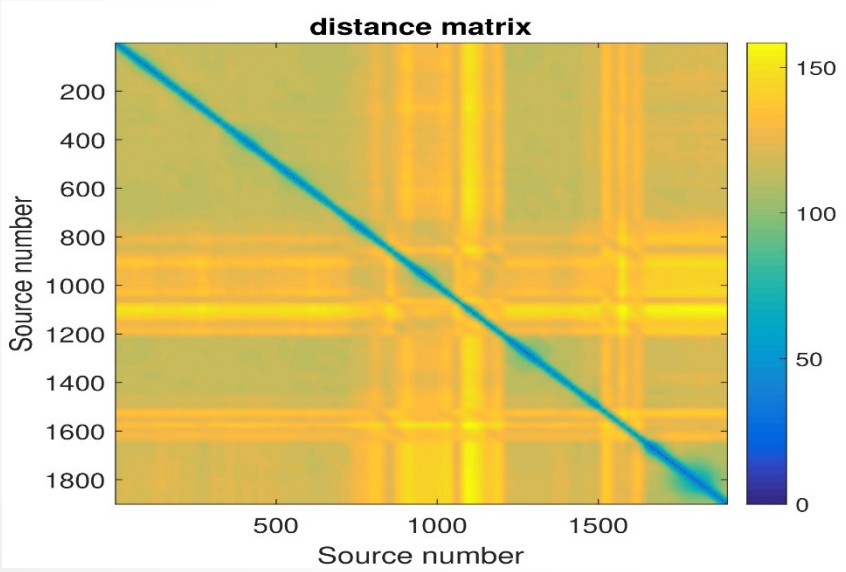
# Matrix of NRMS

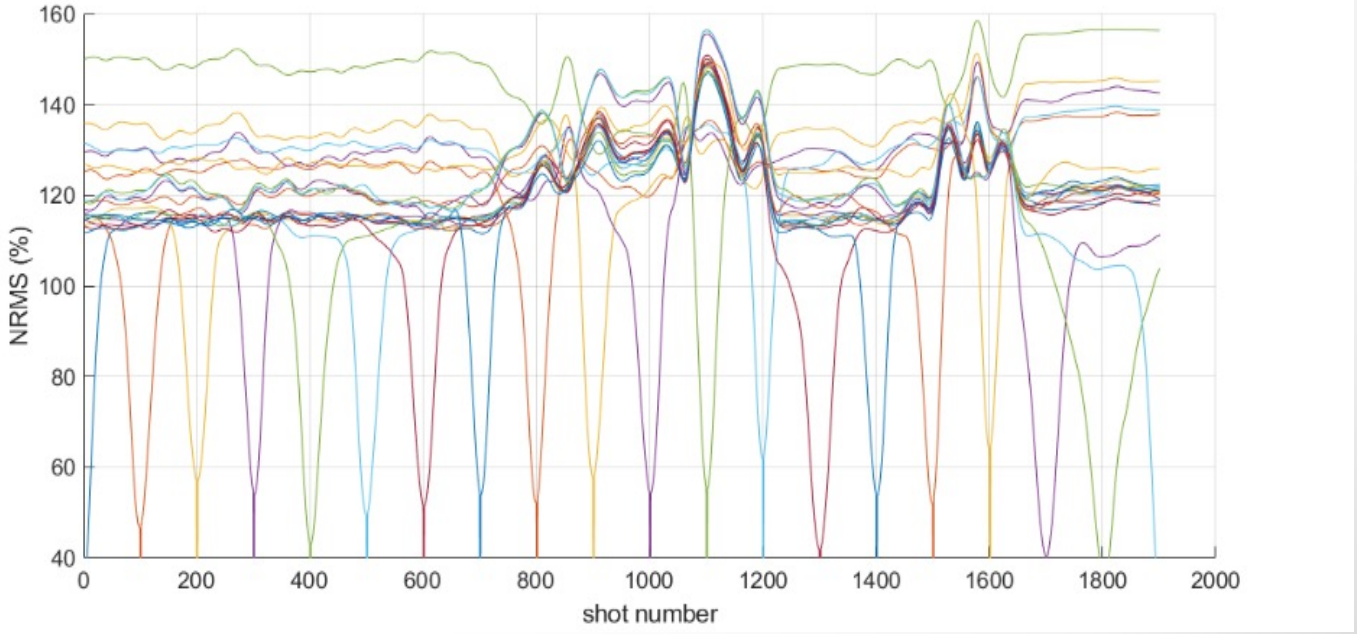


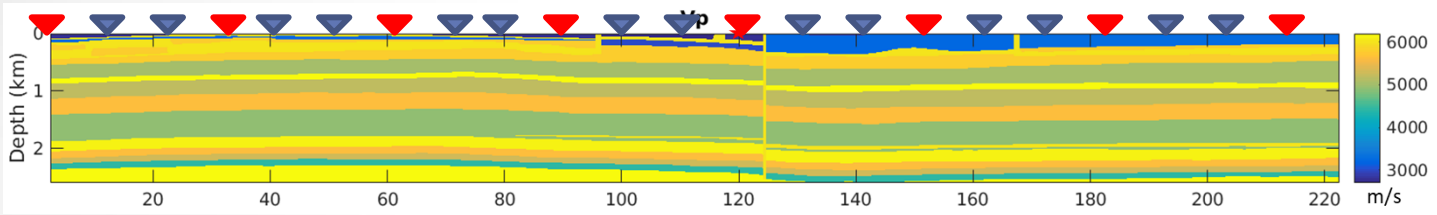
# Matrix of NRMS



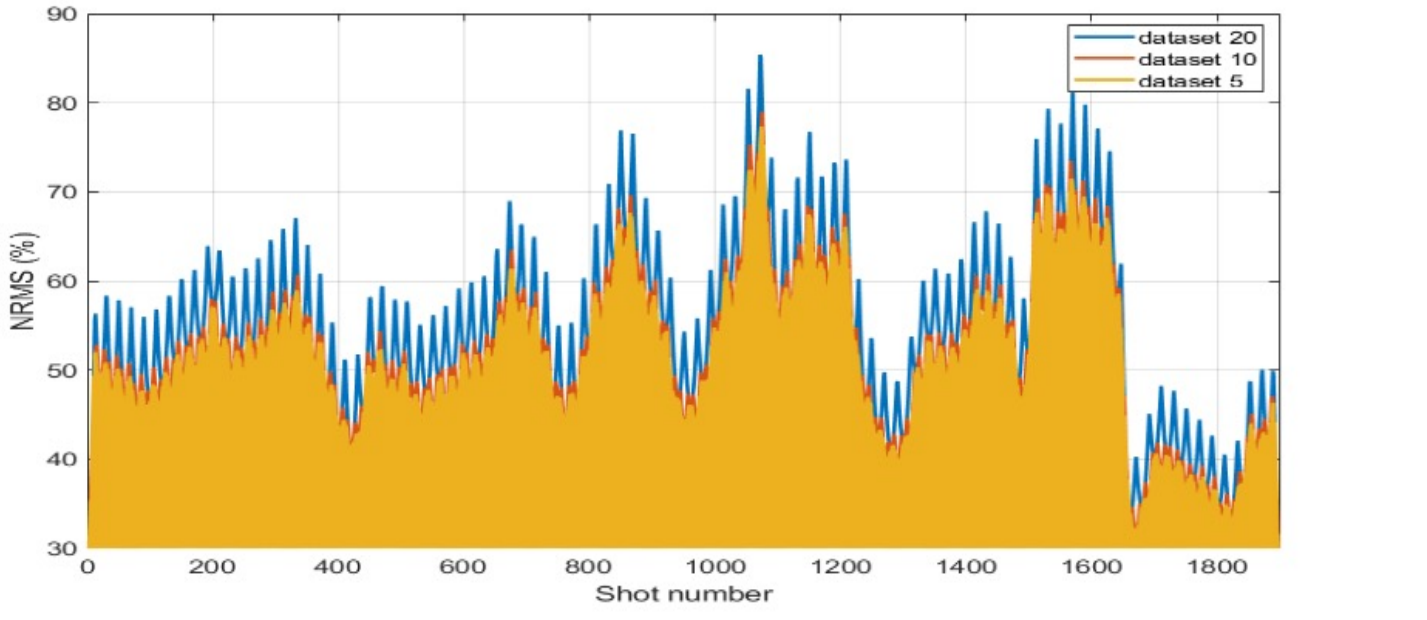



# NRMS distance to the training dataset

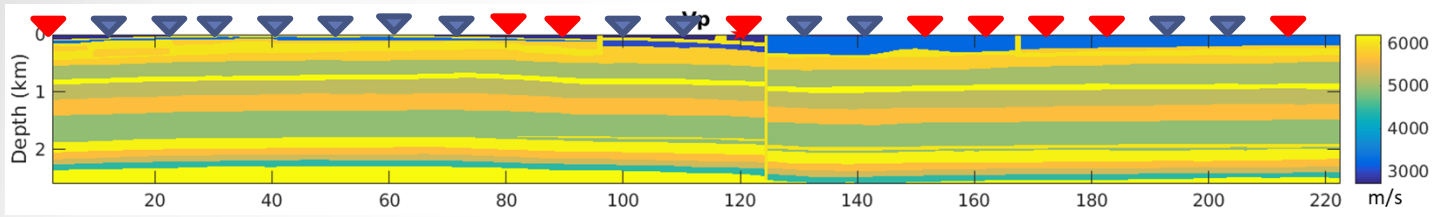



$$d_j = \min_t NRMS(f_t, f_j)$$

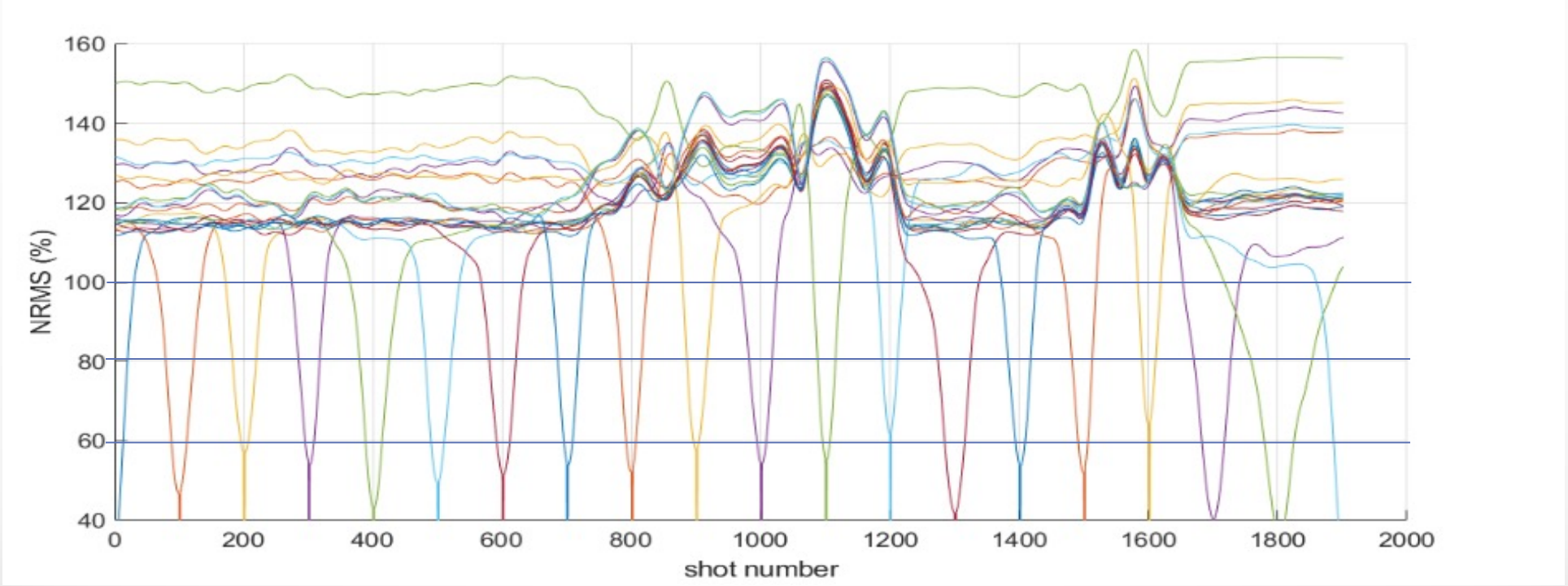
| Training dataset | (min) | NRMS | Speed-up |
|---|---|---|---|
| 5% | 32 | 44% | 4.5 |
| 10% | 40 | 29% | 3.6 |
| 20% | 43 | 23% | 2.6 |



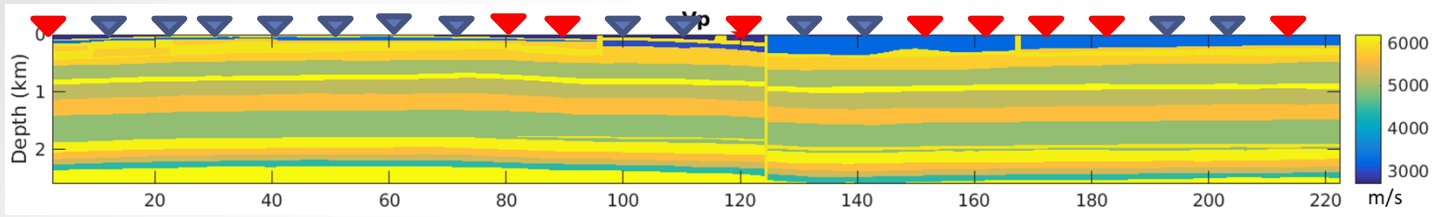
# Training dataset with fixed NRMS



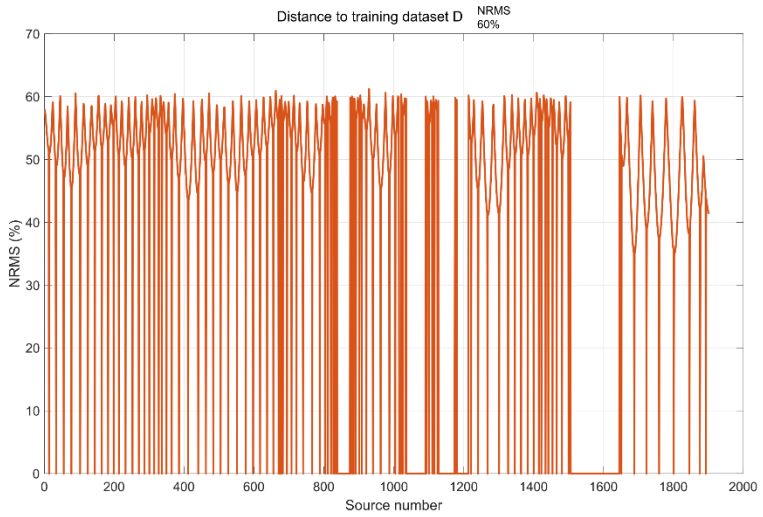

$$D = \max_j d_j = \max_j \min_t NRMS(f_t, f_j) \leq ?$$

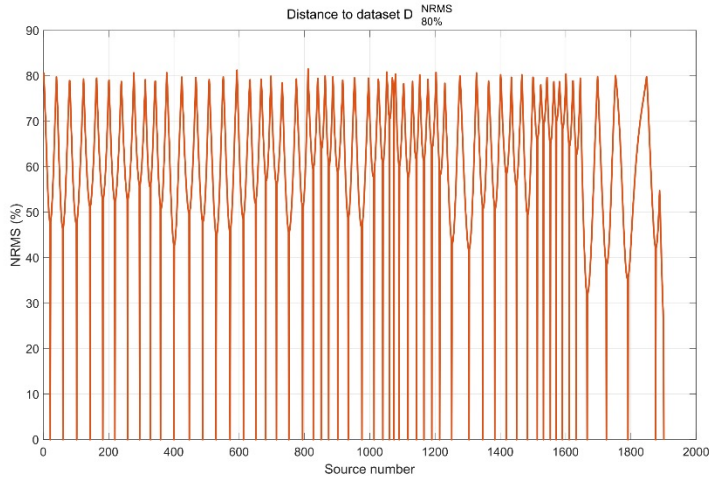


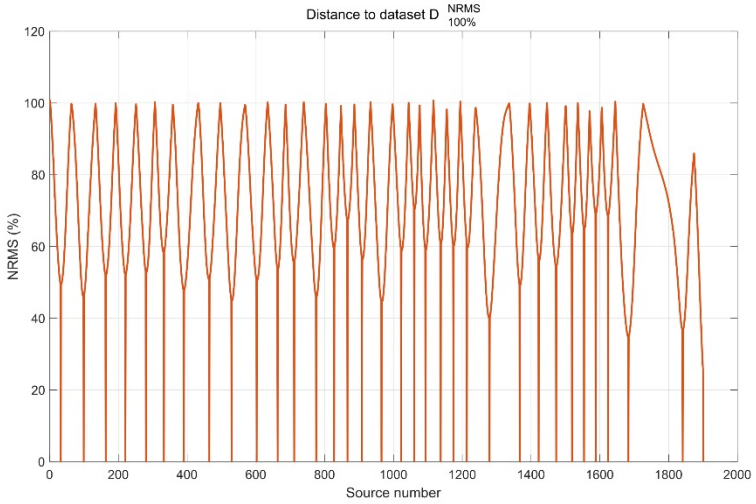
# Training dataset with fixed NRMS



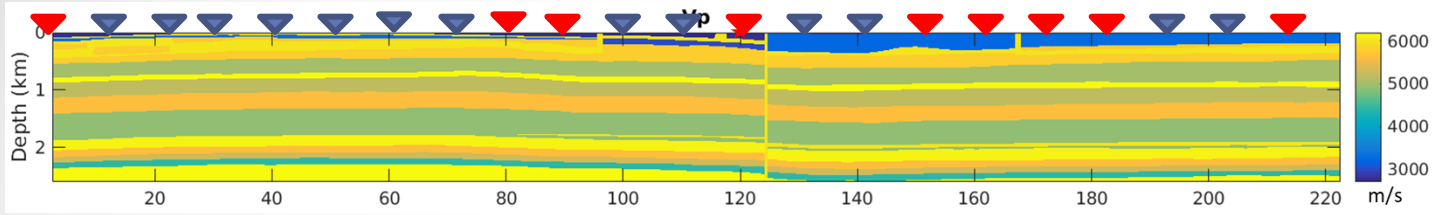

$$D = \max_j d_j = \max_j \min_t NRMS(f_t, f_j) \leq ?$$



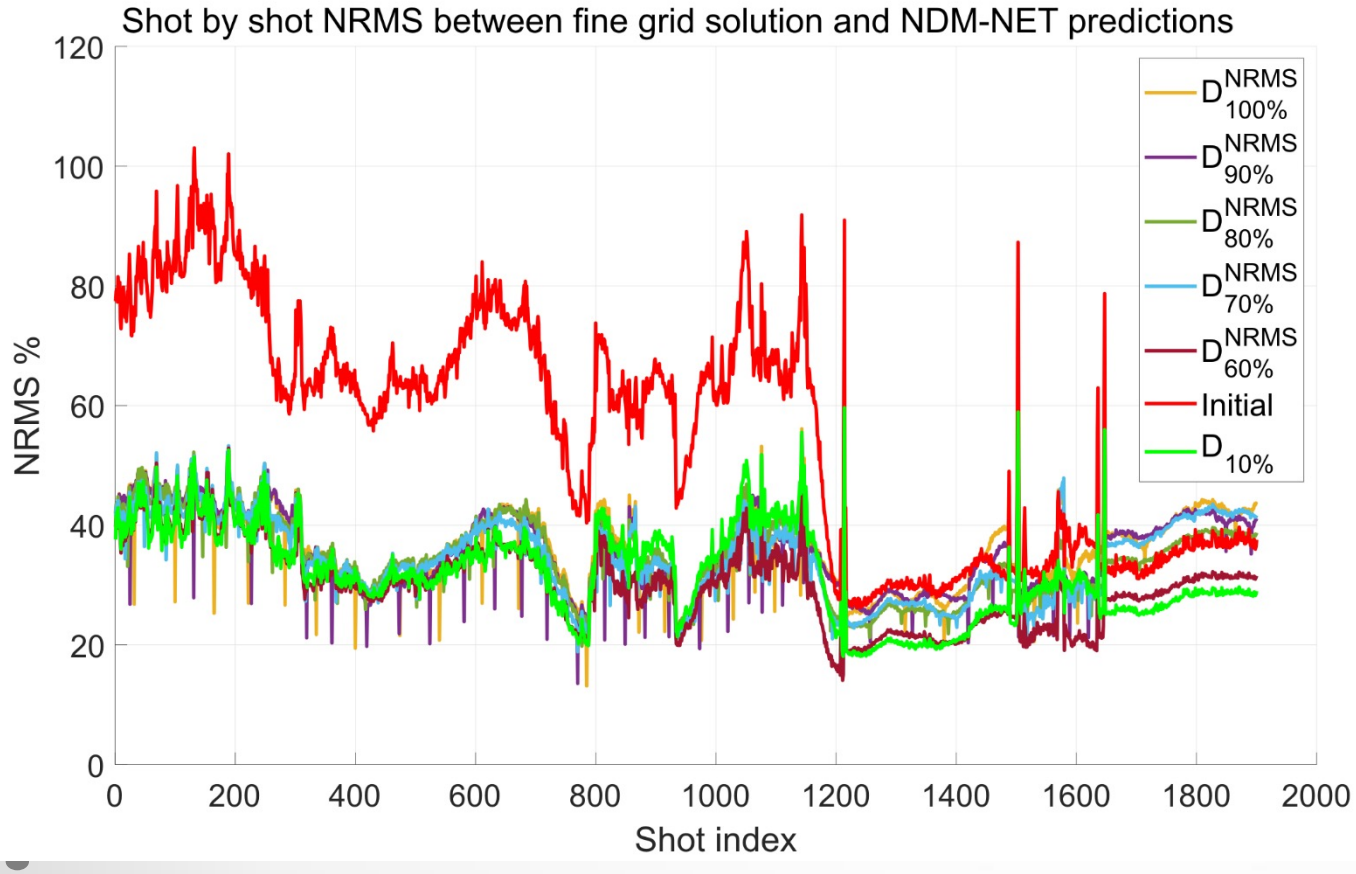



# Training dataset with fixed NRMS

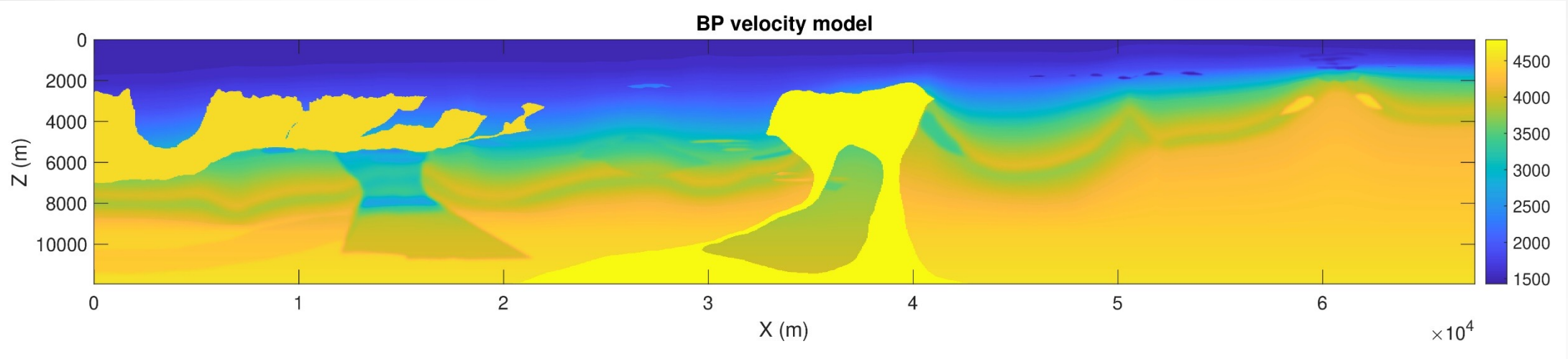



$$D = \max_{j} \min_{t} NRMS(f_t, f_j) \leq ?$$

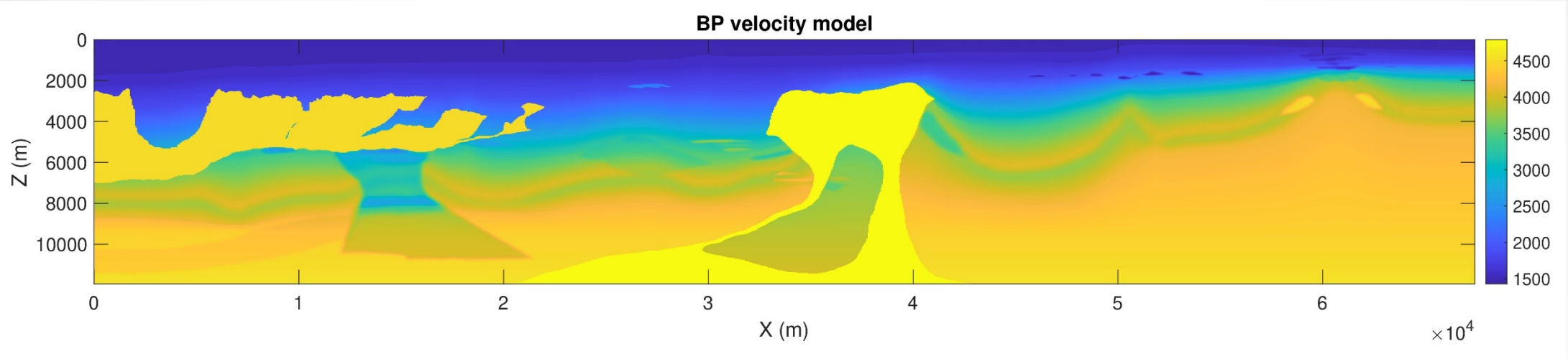


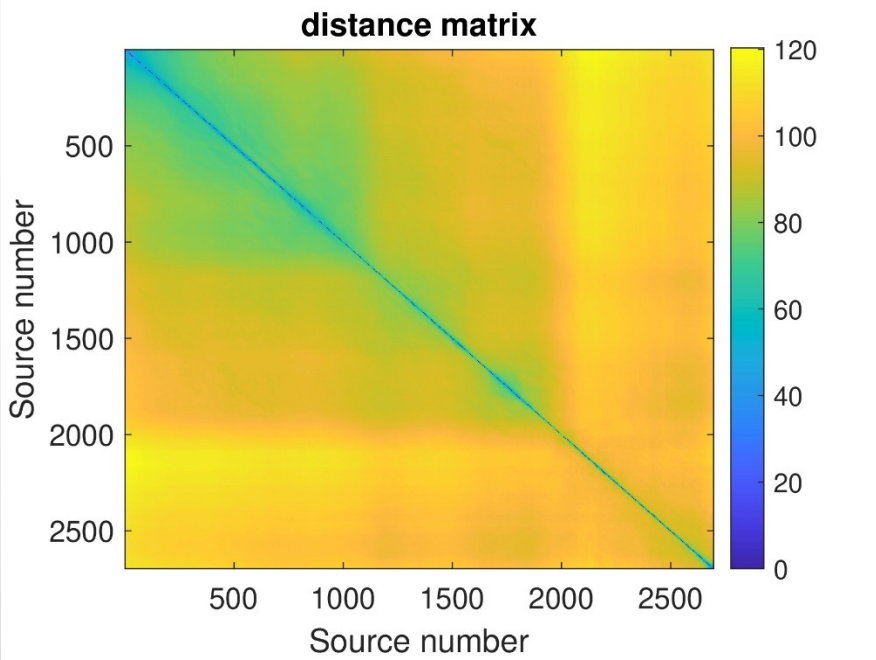

| Dataset | Number of sources | NRMS |
|---|---|---|
| 60% | 414 | 30,28% |
| 70% | 109 | 34,69% |
| 80% | 56 | 35,11% |
| 90% | 43 | 35,68% |
| 100% | 34 | 36,26% |
| | | |
| Eq 10 | 191 | 31,91% |

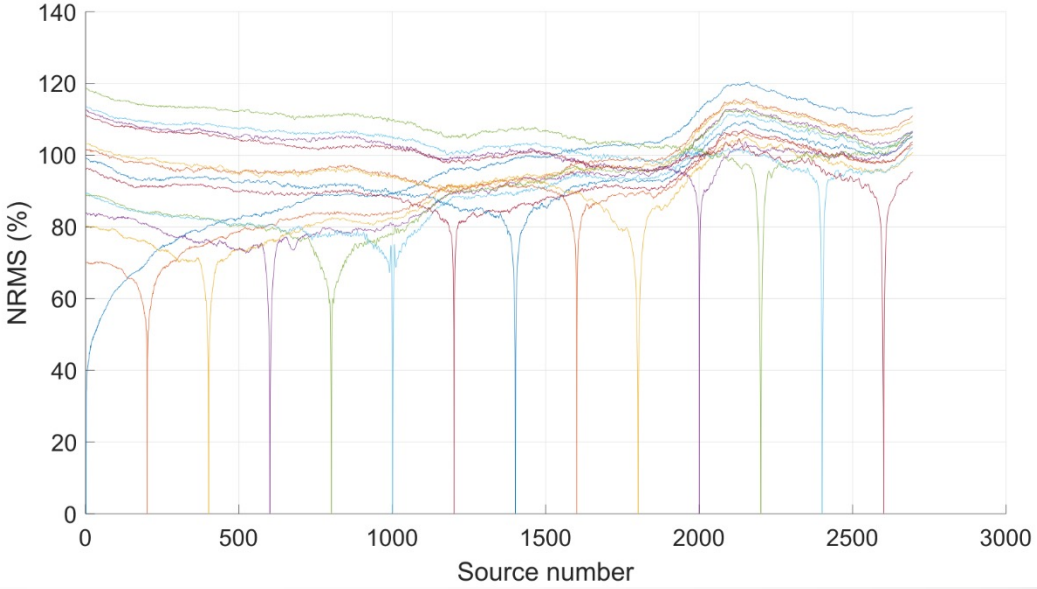
# BP model


BP velocity model
Z (m)
0
2000
4000
6000
8000
10000
0
1
2
3
4
5
6
X (m)
×10^4
4500
4000
3500
3000
2500
2000
1500

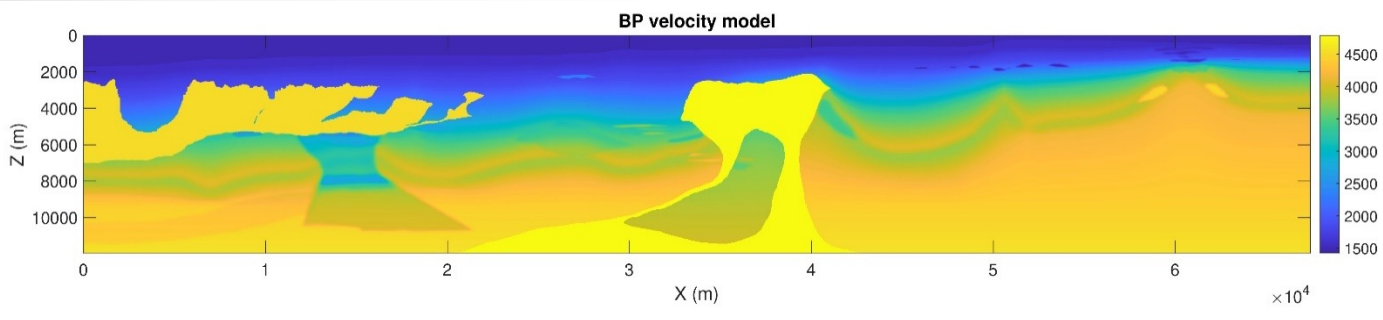
# BP model


BP velocity model
Z (m)
X (m)
×10^4
0
2000
4000
6000
8000
10000
0
1
2
3
4
5
6
4500
4000
3500
3000
2500
2000
1500


distance matrix
Source number
Source number
500
1000
1500
2000
2500
120
100
80
60
40
20
0

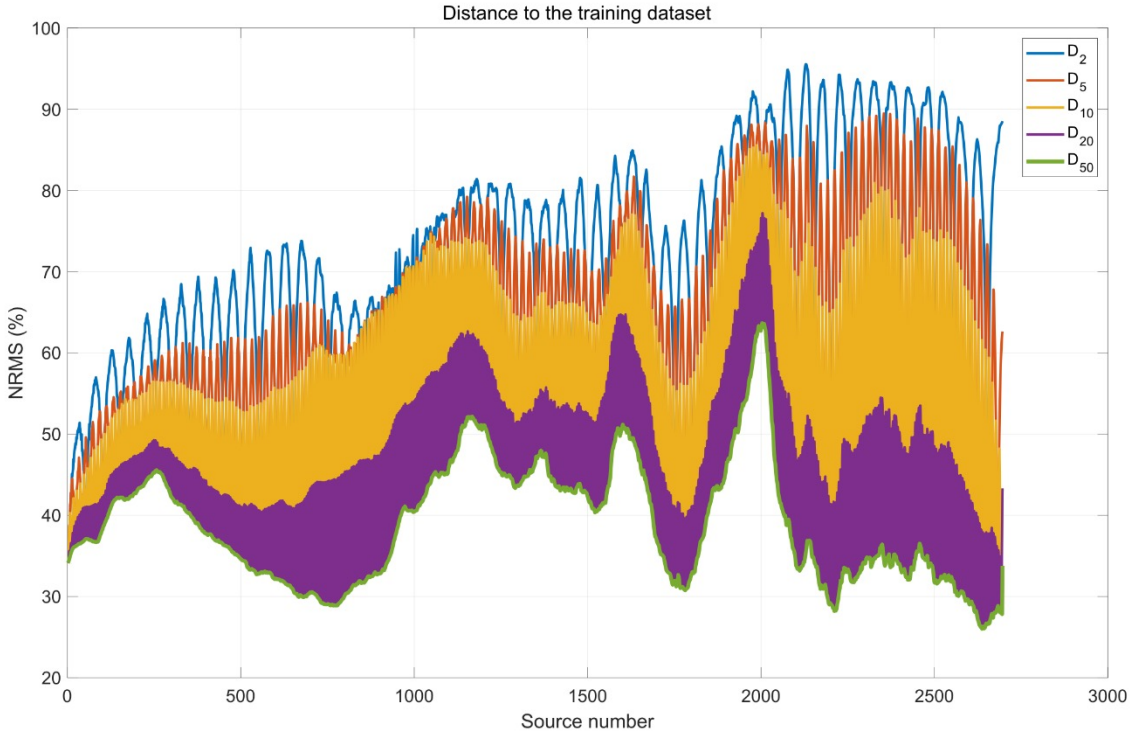

NRMS (%)
Source number
0
20
40
60
80
100
120
140
0
500
1000
1500
2000
2500
3000

# BP model

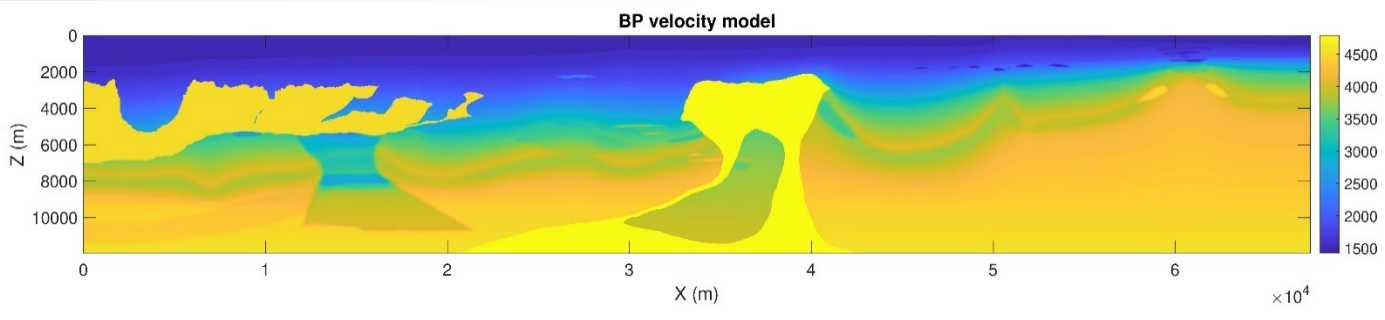



$$d_j = \min_t NRMS(f_t, f_j)$$

| Training dataset | Number of source | NRMS |
|---|---|---|
| 2% | 55 | 50% |
| 5% | 135 | 44% |
| 10% | 270 | 40% |
| 20% | 540 | 37% |
| 50% | 1348 | 31% |

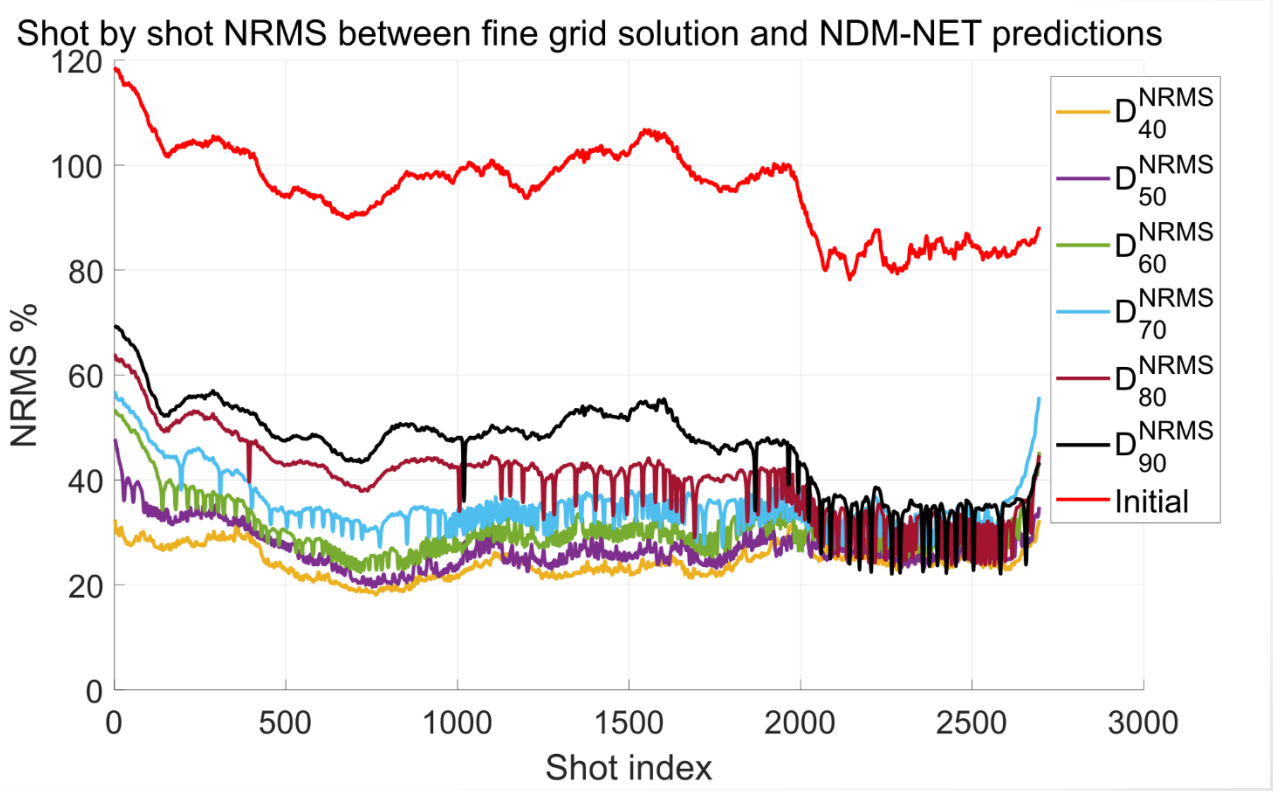


# BP model

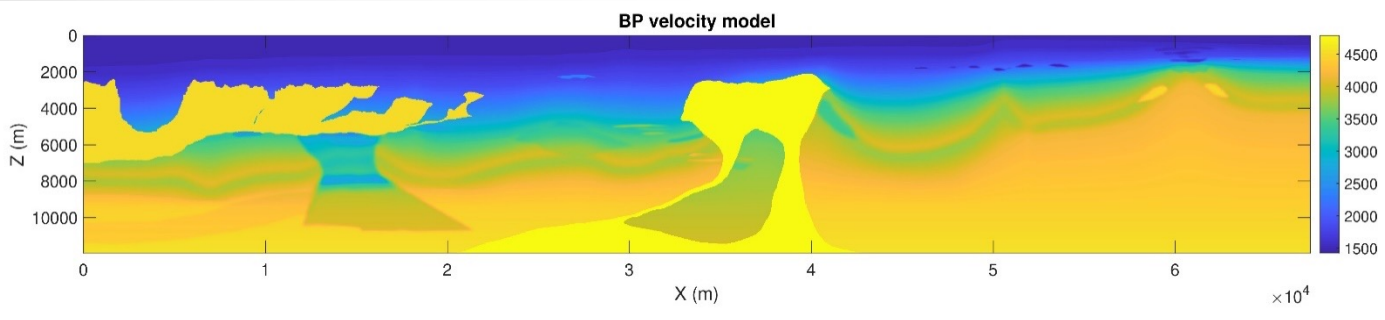



$$D = \max_{j} \min_{t} NRMS(f_t, f_j) \leq ?$$

| Training dataset | Number of sources | NRMS |
|---|---|---|
| NRMS 90% | 27 | 46% |
| NRMS 80% | 90 | 41% |
| NRMS 70% | 216 | 35% |
| NRMS 60% | 425 | 31% |
| NRMS 50% | 794 | 27% |
| NRMS 40% | 1672 | 24% |



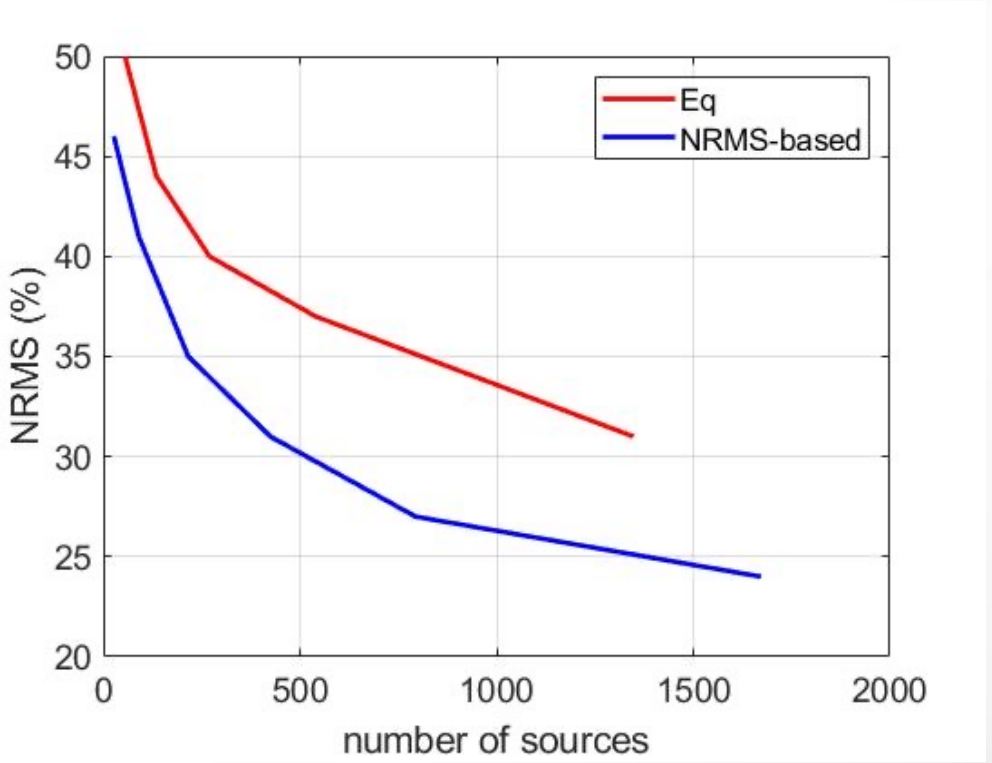
# BP model




$$D = \max_{j} \min_{t} NRMS(f_t, f_j) \leq ?$$

| Training dataset | Number of source | NRMS |
|---|---|---|
| 2% | 55 | 50% |
| 5% | 135 | 44% |
| 10% | 270 | 40% |
| 20% | 540 | 37% |
| 50% | 1348 | 31% |

| Training dataset | Number of sources | NRMS |
|---|---|---|
| NRMS 90% | 27 | 46% |
| NRMS 80% | 90 | 41% |
| NRMS 70% | 216 | 35% |
| NRMS 60% | 425 | 31% |
| NRMS 50% | 794 | 27% |
| NRMS 40% | 1672 | 24% |



# Conclusions

- Machine learning may be an efficient tool to speed-up seismic modelling even if a naïve strategy to training dataset construction is used.

- If the training dataset is constructed to preserve a certain NRMS level between the training dataset and the entire dataset, the number of shots in the training dataset may be further reduced.

# Thank you for your attention!