Use of multi-GPU architecture for real-life seismic modeling

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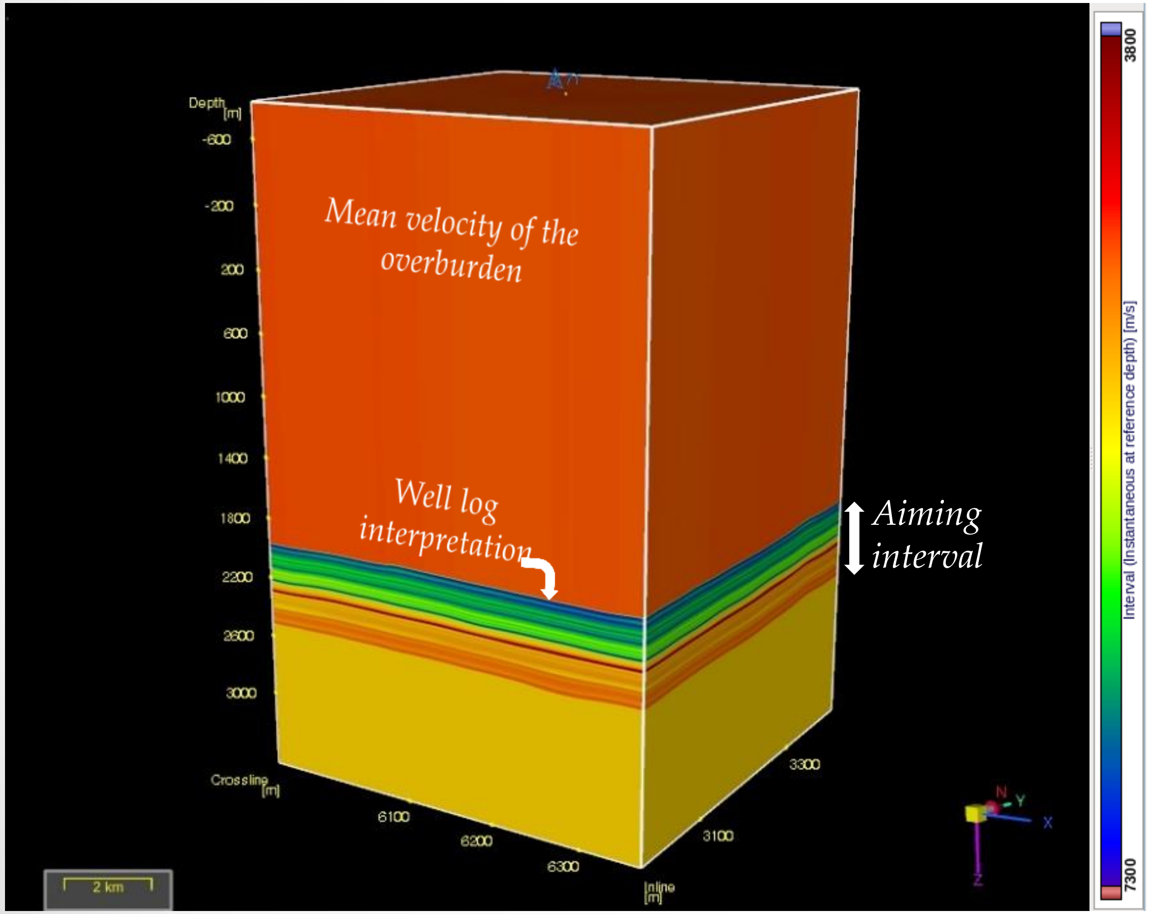
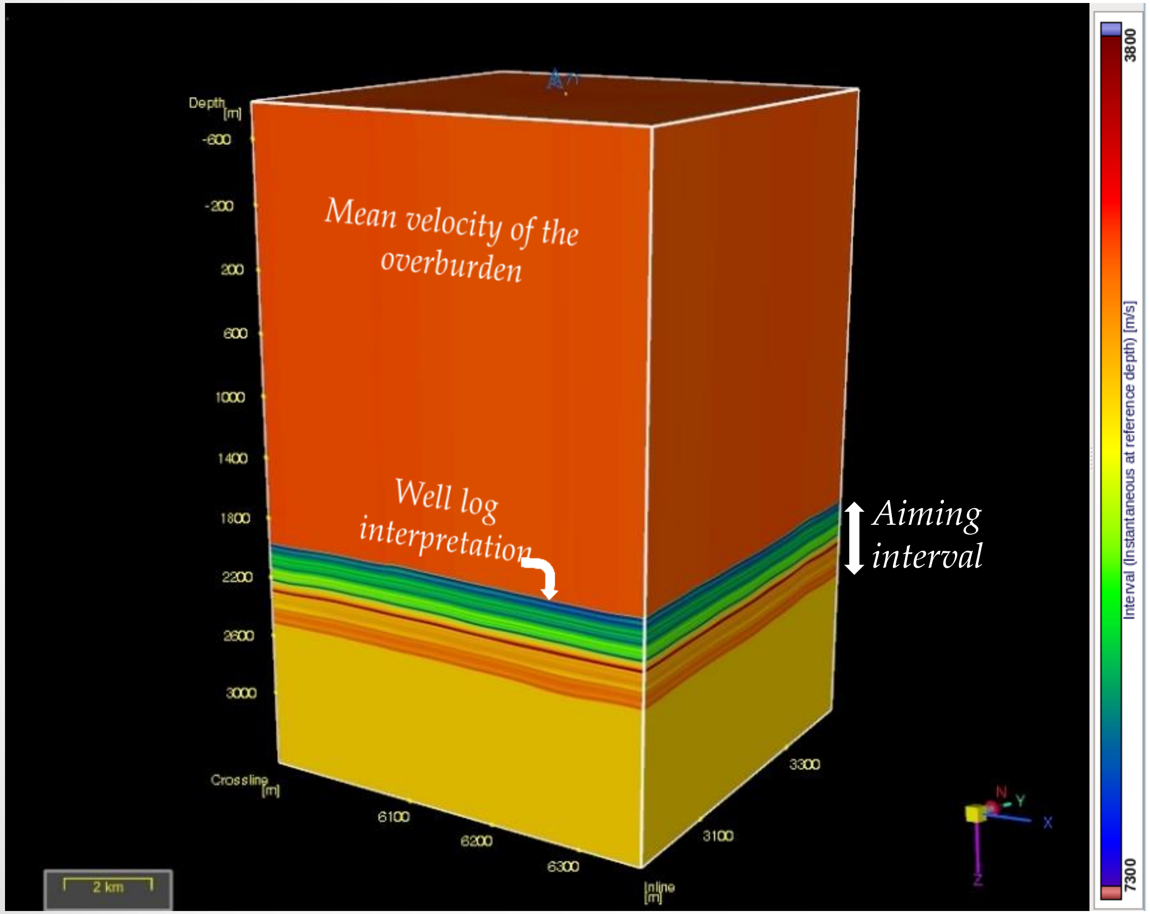
Outline

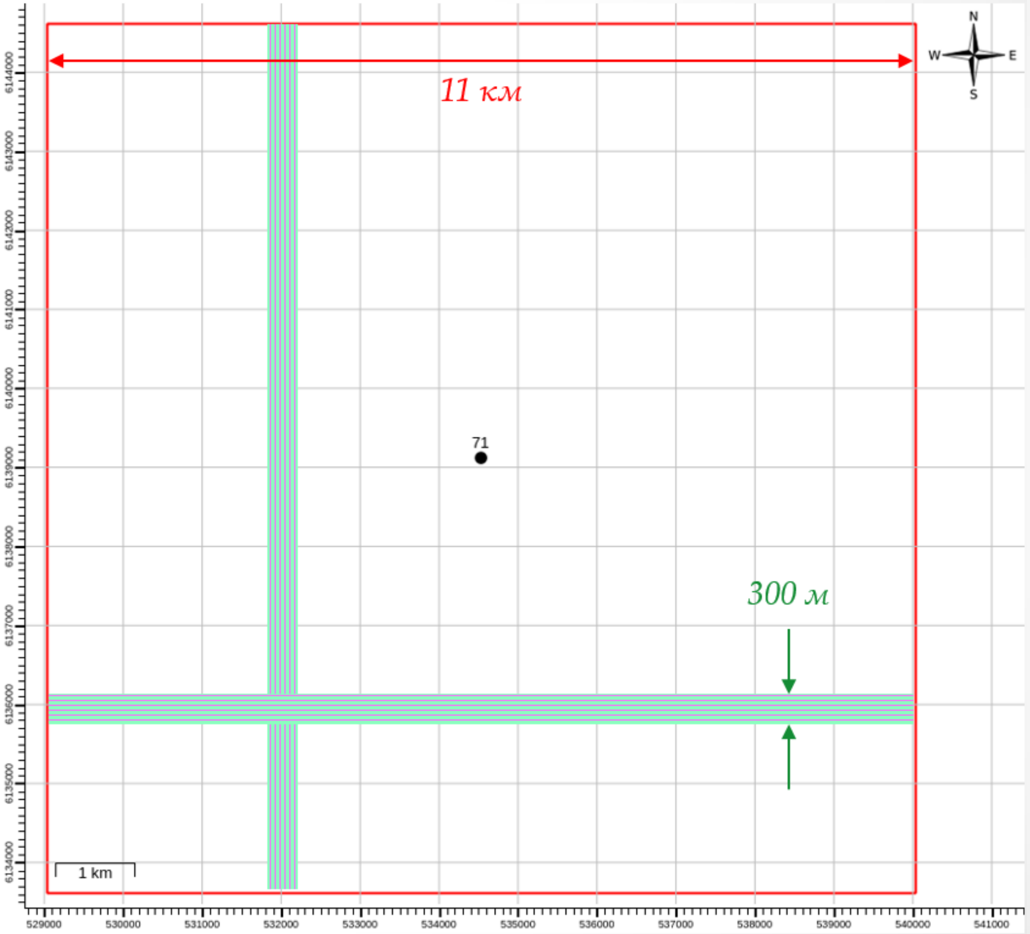
- Statement of the problem
    - Geology
    - Mathematics
- HPC implementation
- Results of simulation
- Conclusions

Geological model

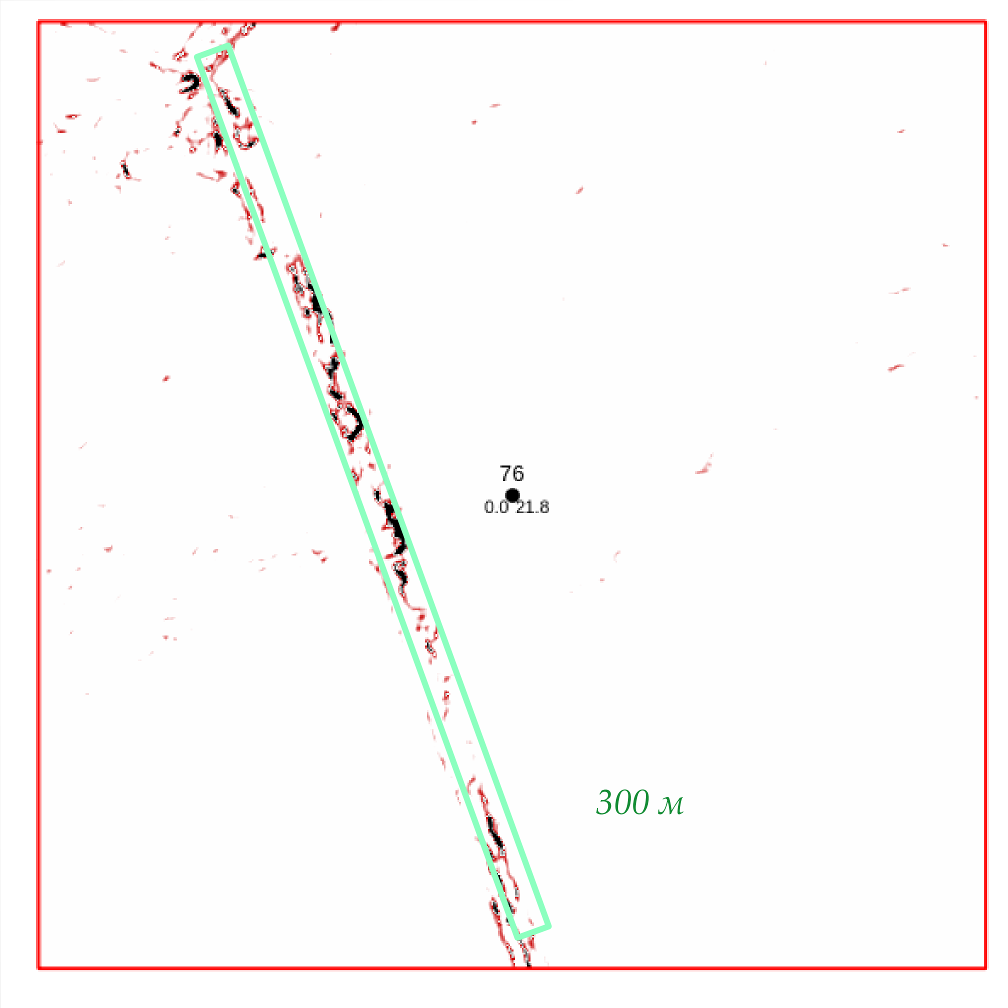


Geological model

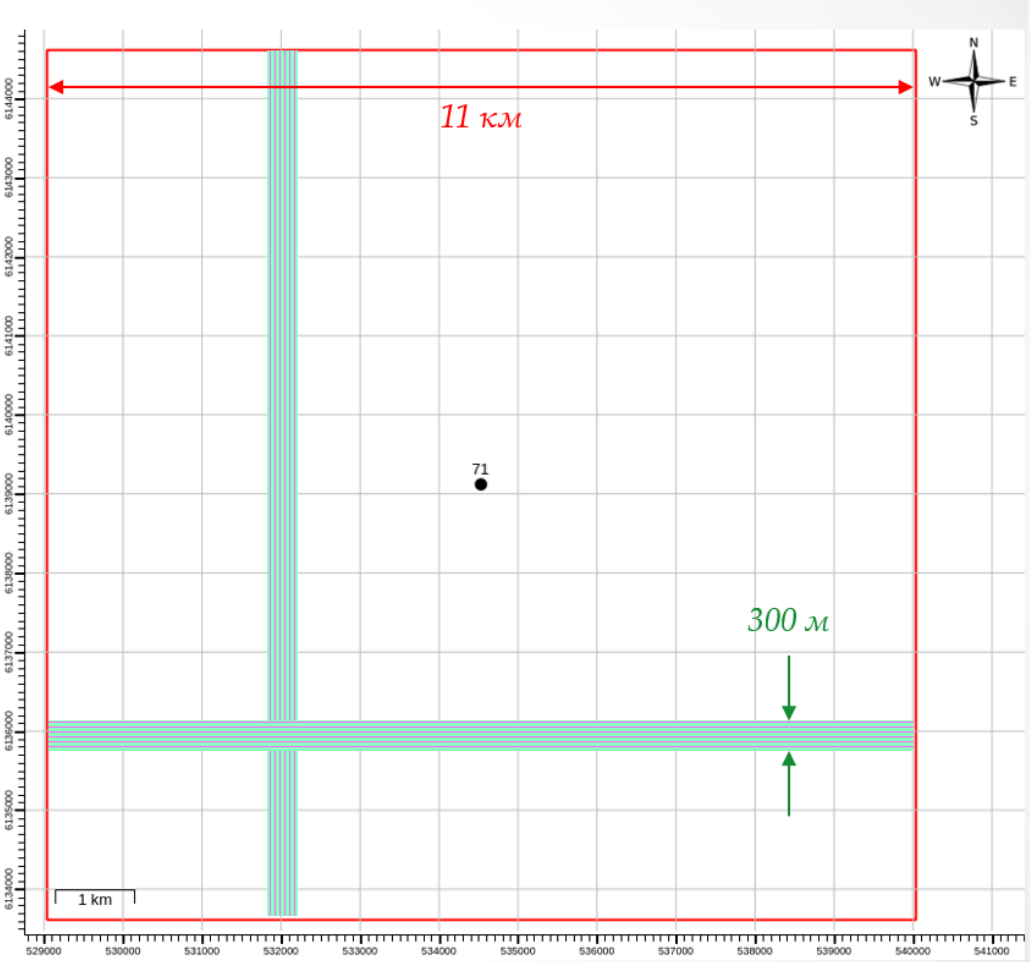




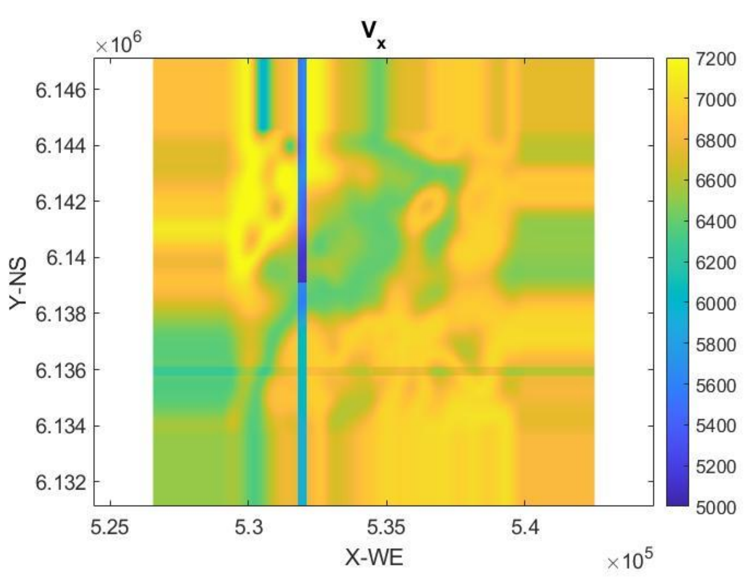
Geological model

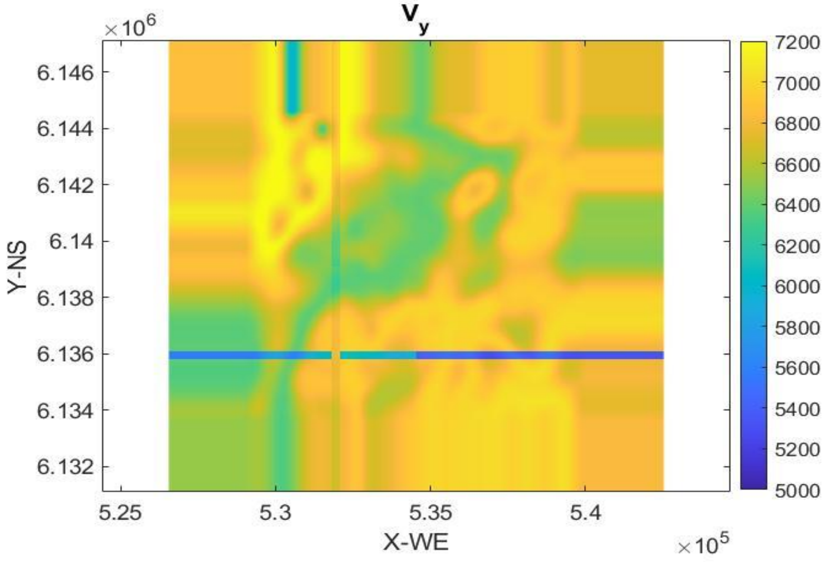


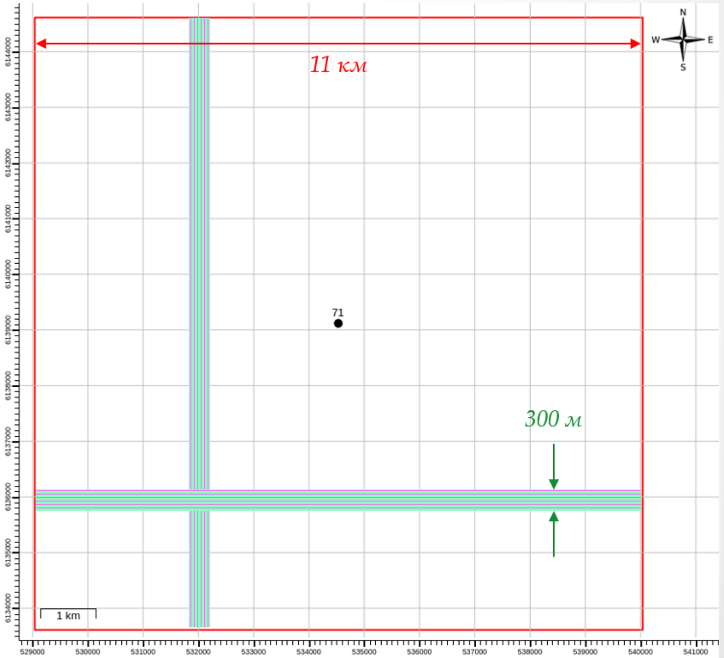
Example of the fracture corridors geometry

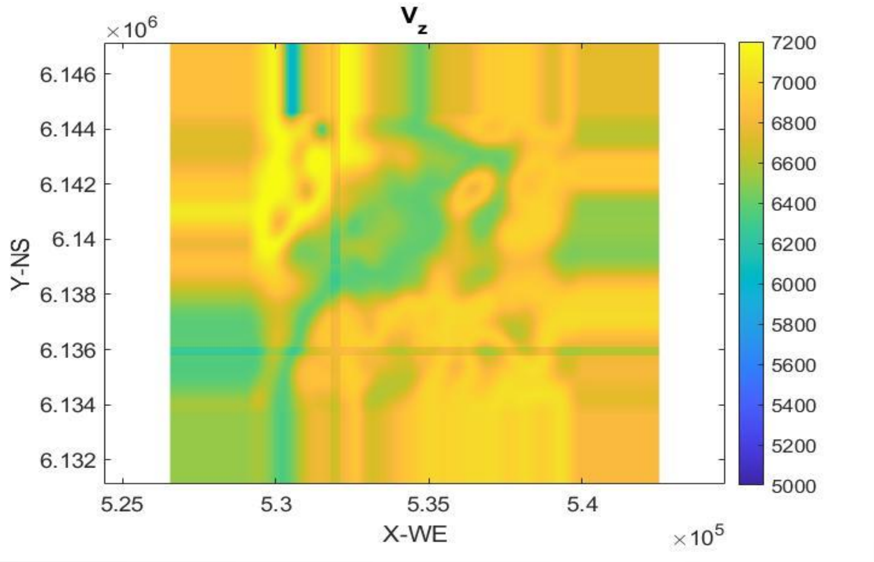


Geological model





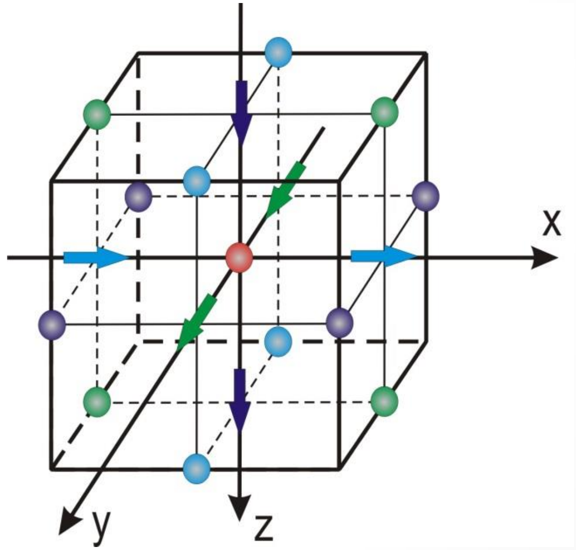




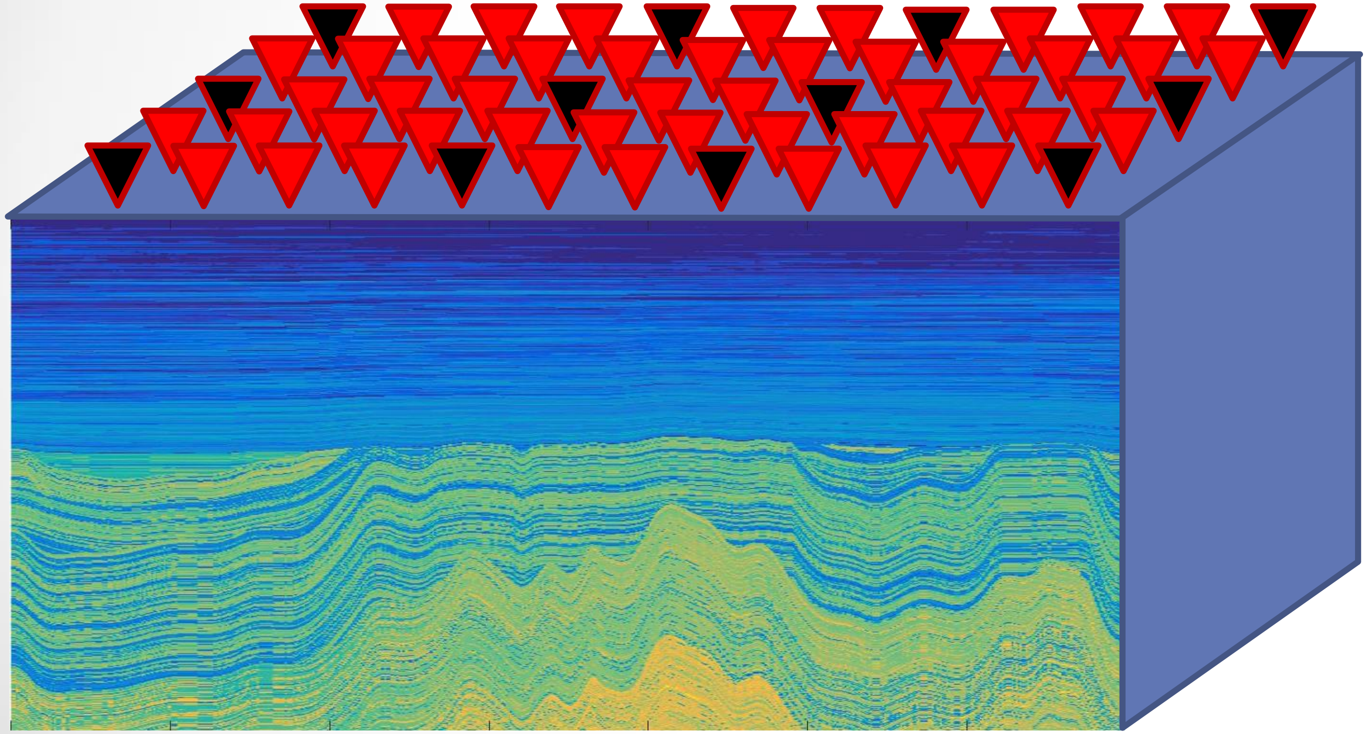
Finite-difference approximation

$$\rho \frac{\partial u}{\partial t} = \nabla \cdot \sigma, \quad \frac{\partial \varepsilon}{\partial t} = \frac{1}{2}\left(\nabla u + \nabla u^T\right), \quad \sigma = C\varepsilon$$

$$\begin{pmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \sigma_{yz} \\ \sigma_{xz} \\ \sigma_{xy} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} & c_{13} & 0 & 0 & 0 \\ c_{12} & c_{22} & c_{23} & 0 & 0 & 0 \\ c_{13} & c_{23} & c_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & c_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & c_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & c_{66} \end{pmatrix} \begin{pmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \varepsilon_{zz} \\ \varepsilon_{yz} \\ \varepsilon_{xz} \\ \varepsilon_{xy} \end{pmatrix}$$



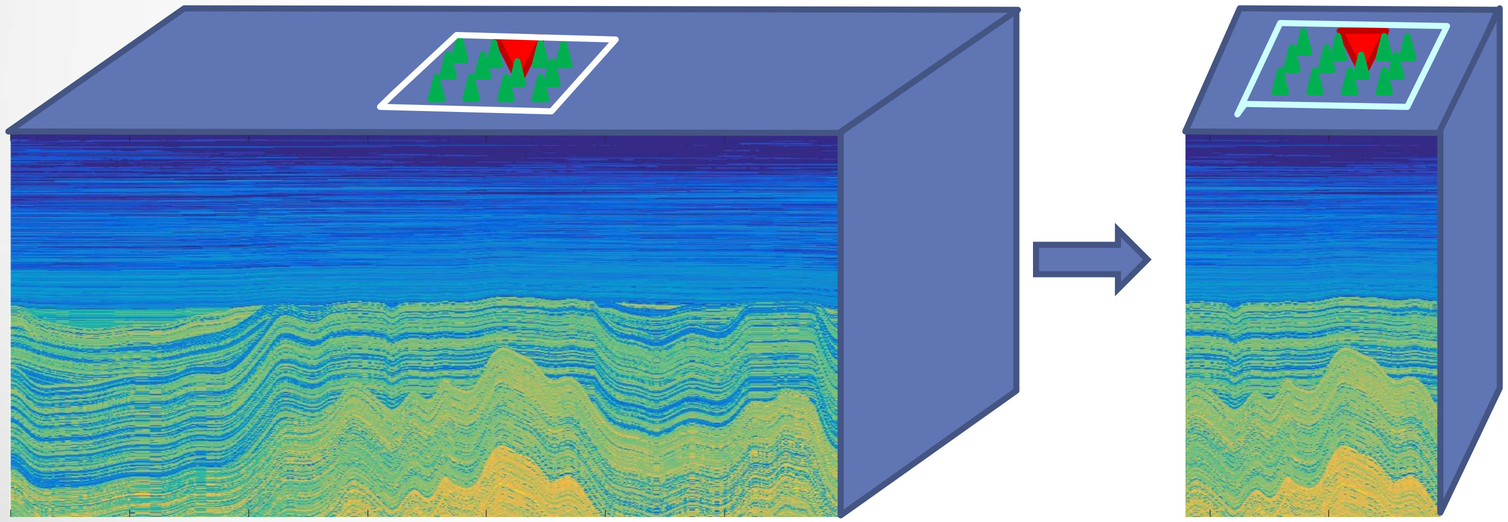
Seismic modeling



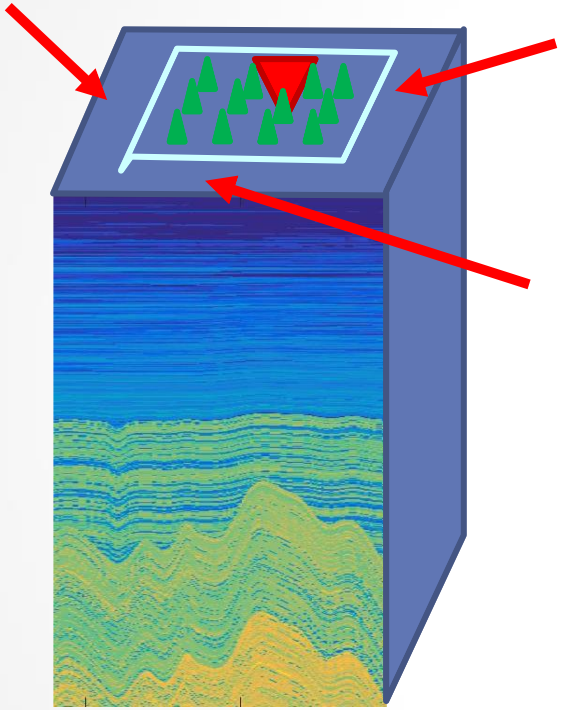
1. Multiple sources = multiple INDEPENDENT problems

Seismic modeling

1. Multiple sources = multiple INDEPENDENT problems
2. Domain size for a single problem can be restricted



Seismic modeling

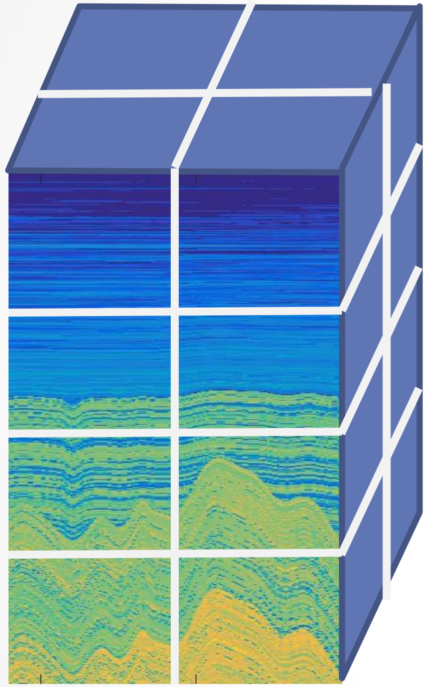


Perfectly matched layers

1. Multiple sources = multiple INDEPENDENT problems
2. Domain size for a single problem can be restricted

Size of the domain 1440x1280x1000 points =
= 130 Gb of RAM

Seismic modeling



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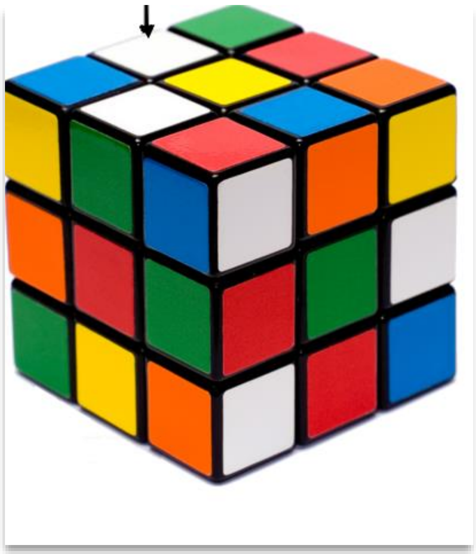
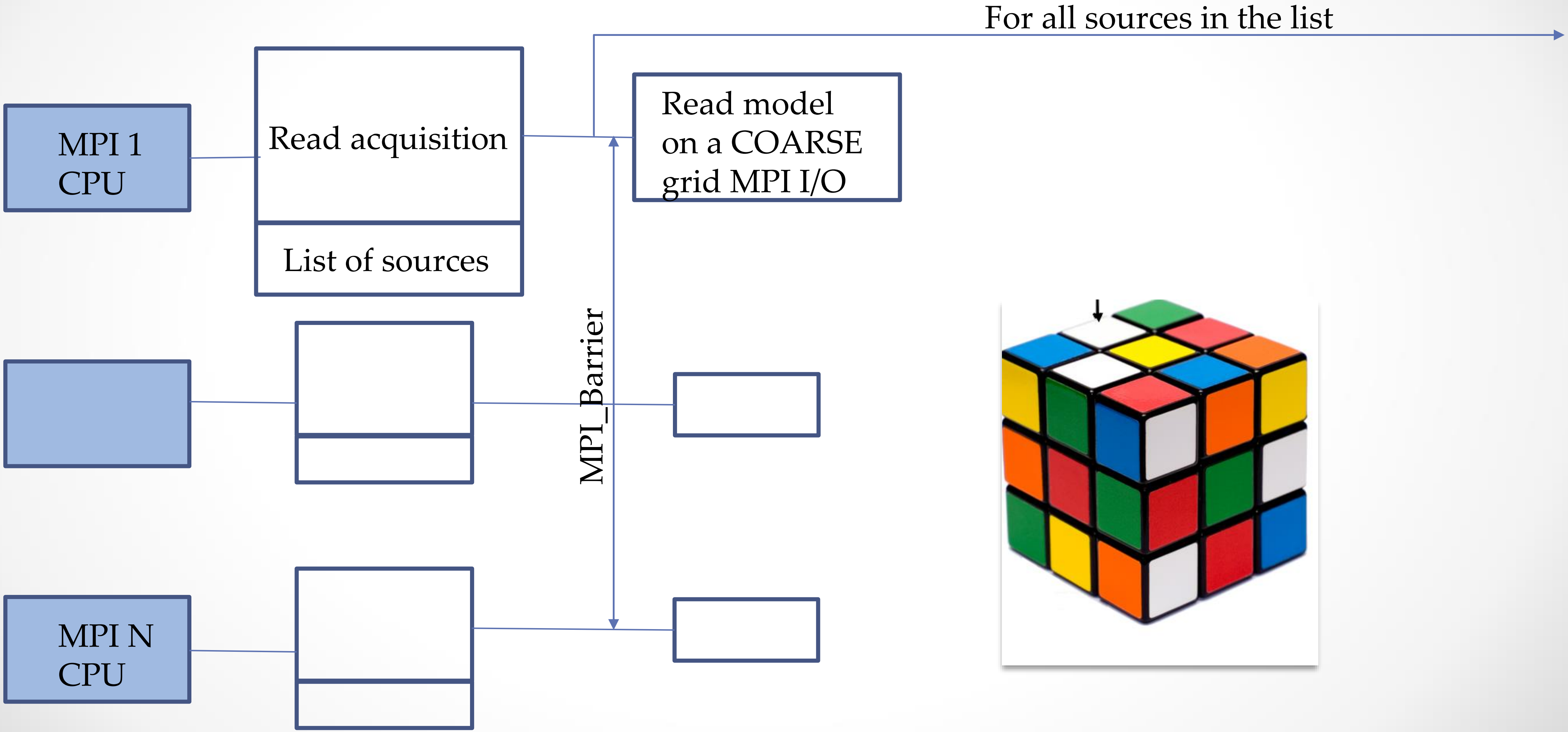
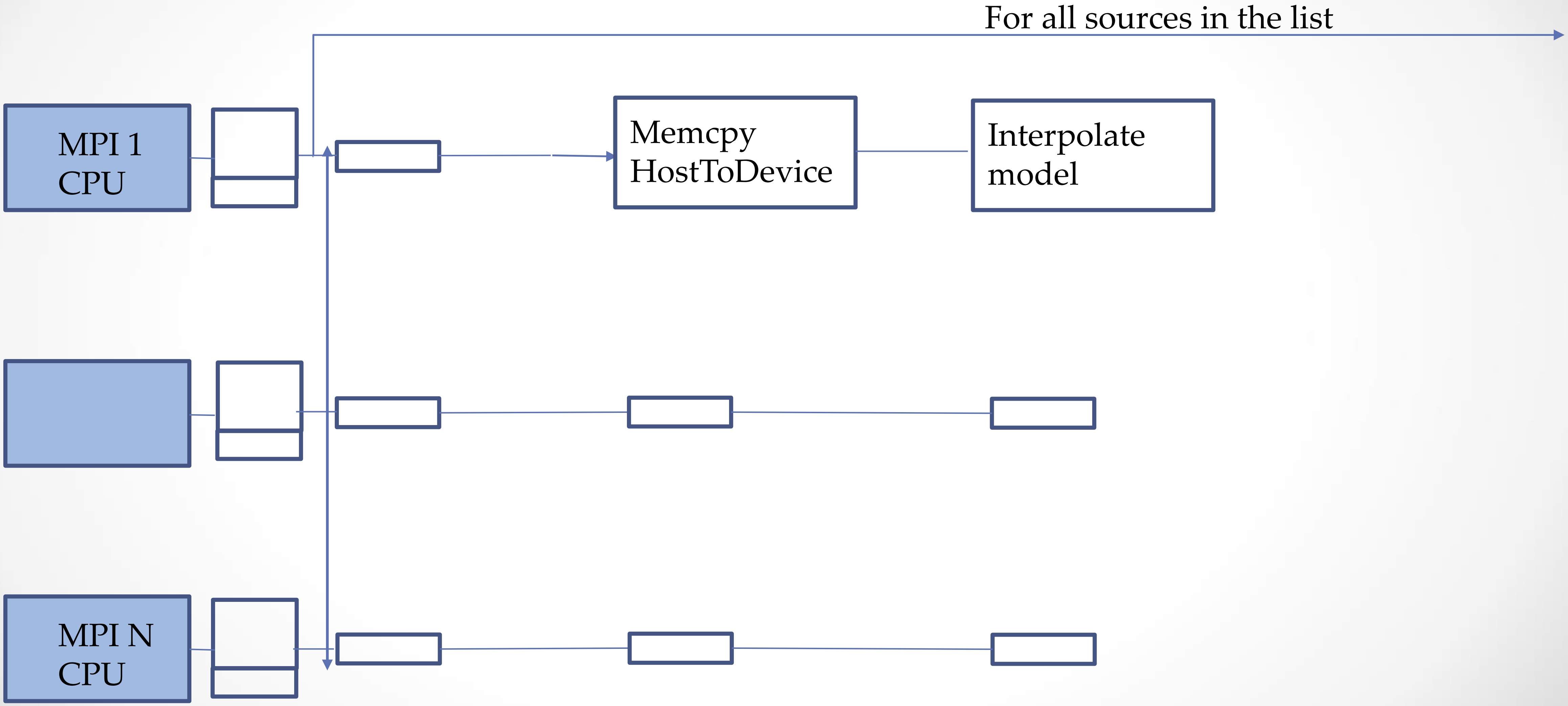


1. Multiple sources = multiple INDEPENDENT problems
2. Domain size for a single problem can be restricted
3. Each problem requires domain decomposition

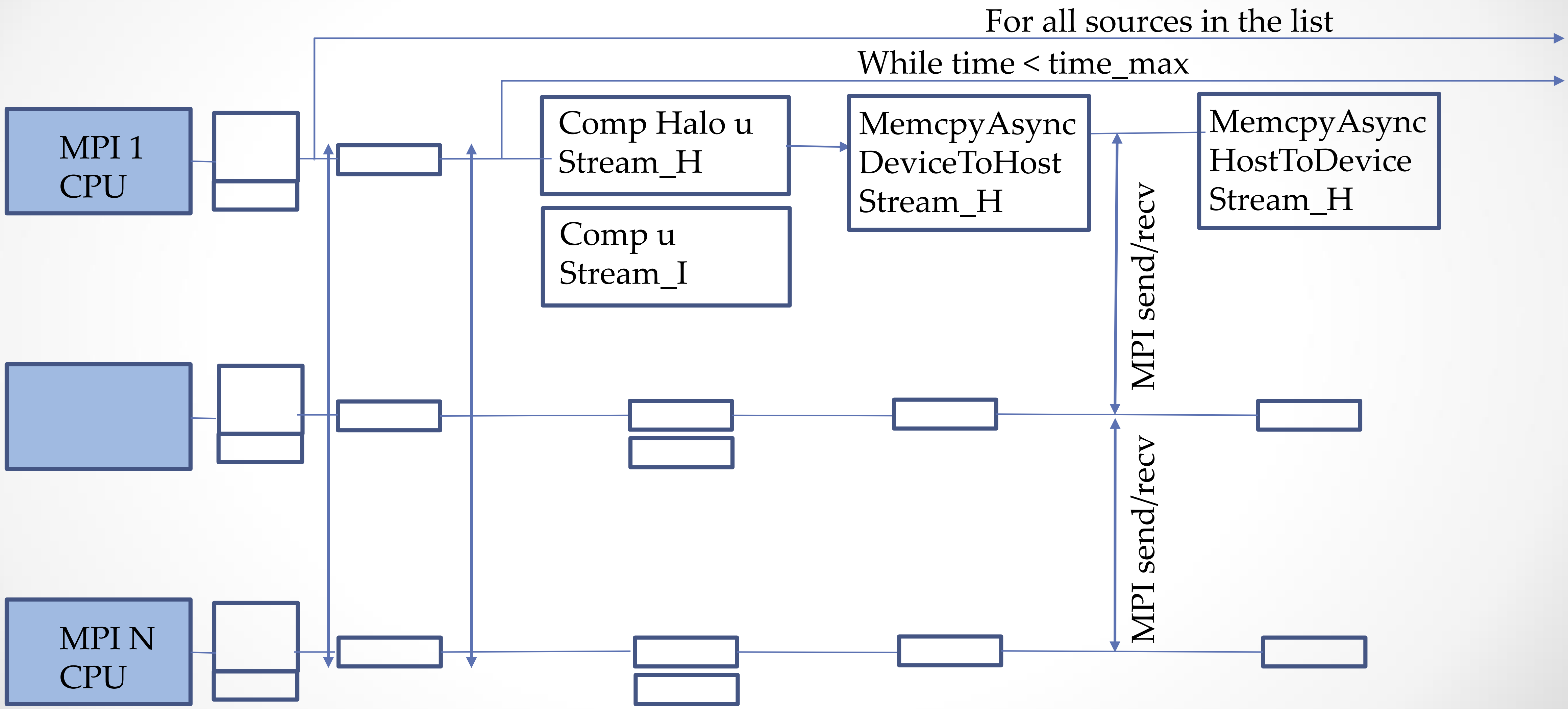
Seismic modeling - input



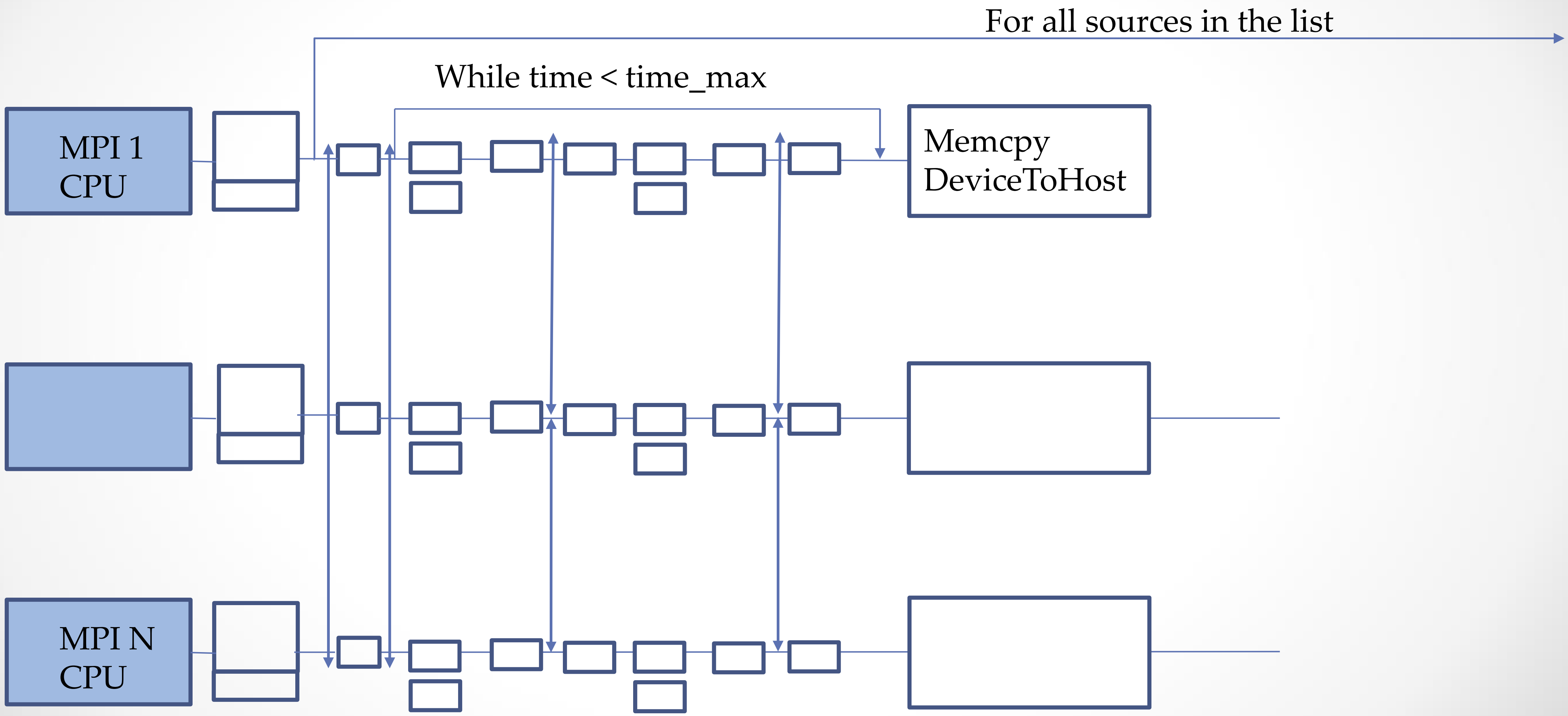
Seismic modeling - input



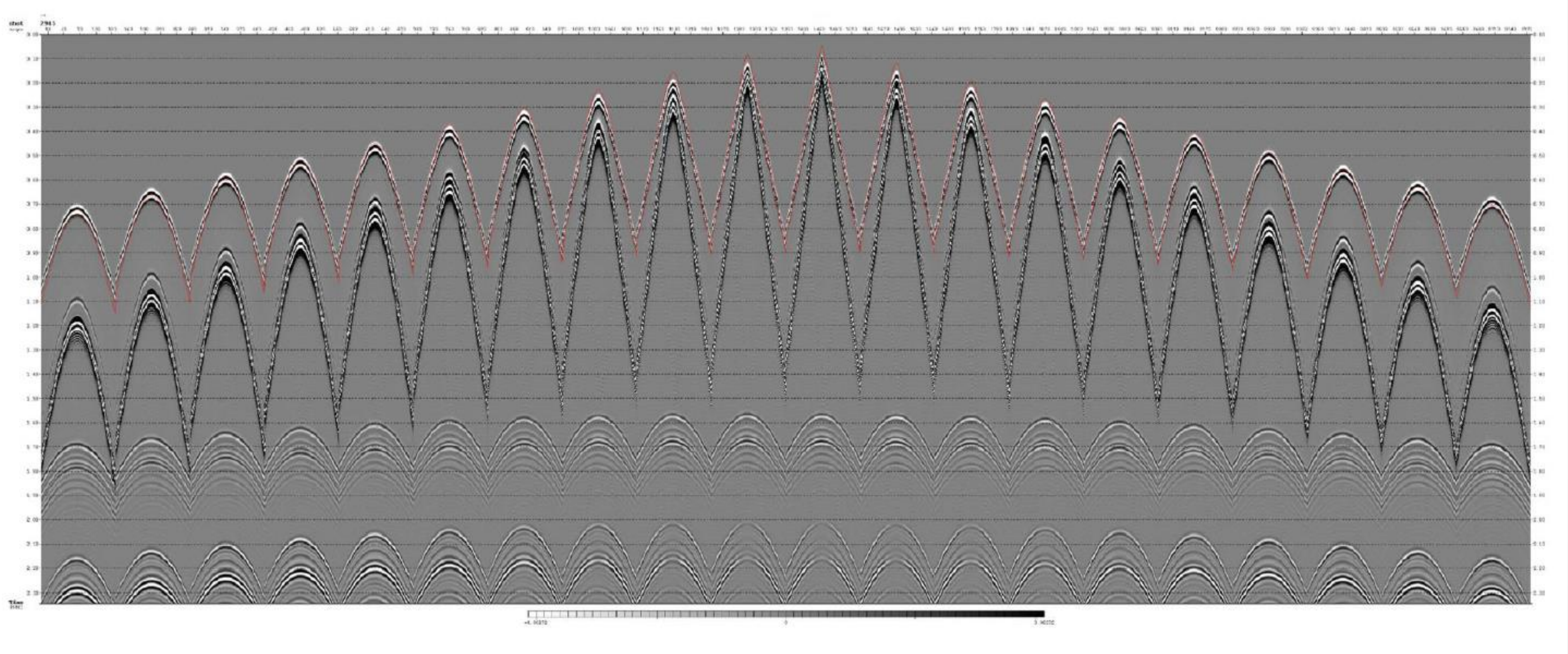
Seismic modeling – main stage



Seismic modeling – main stage



Sample seismogramm



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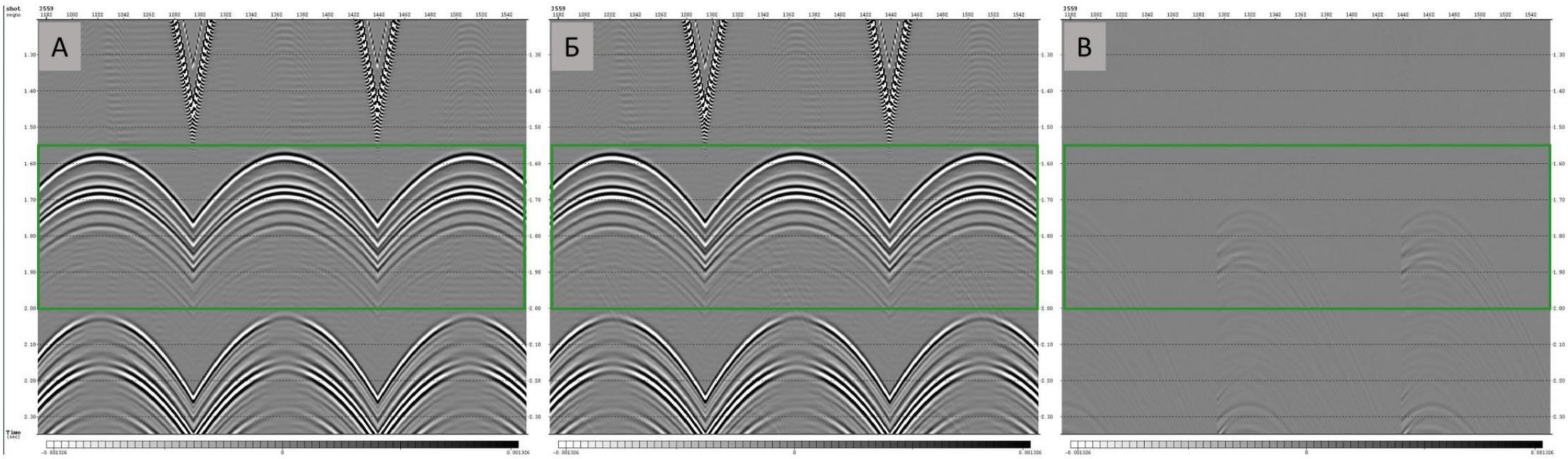


No fracture corridors

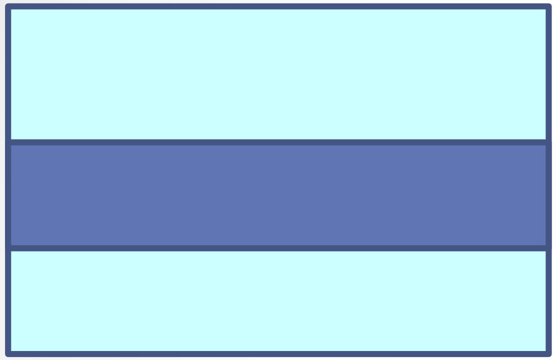
Fracture corridors

Difference

Performance

SpB Polytechnic Tornado	
CPU: 2x Intel Xeon	CPU: Intel(R) Xeon(R) Gold 6258R
GPU: 2x NVIDIA Tesla K40M	GPU: 8x NVIDIA A100
GPUs/shot - 16	GPUs/shot - 6
Wall-clock time – 30 minutes	Wall-clock time – 10 minutes
GPU-hours – 8	GPU-hours – 1
Number of shots - 6250	Number of shots - 6250
GPU-hours total - 50000	GPU-hours total - 6250
	1 month of full load

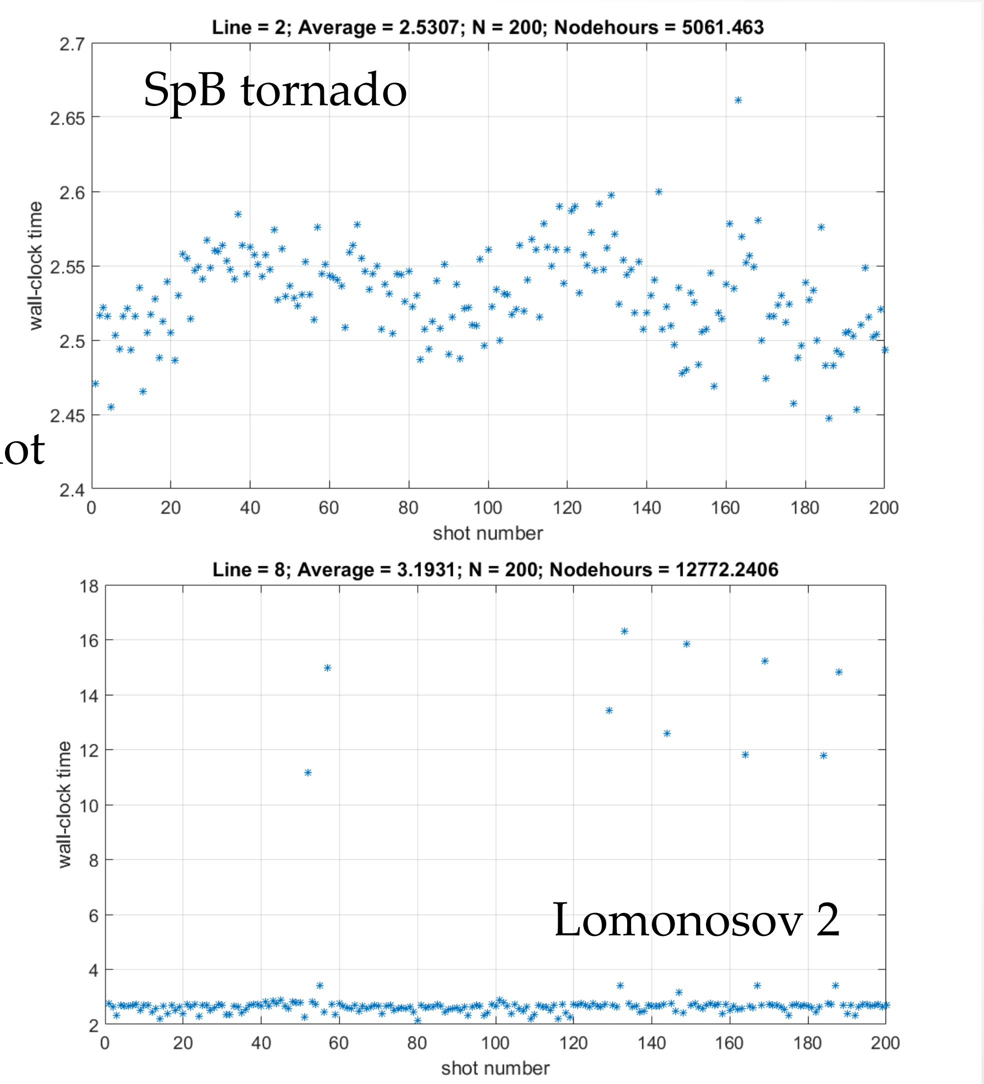
Использованные ресурсы



25 node-hours per shot

50 node-hours per shot

4 node-hours per shot – GPU



Conclusions

- We presented a numerical algorithm to simulate seismic data for real-life acquisitions
- The algorithm is based on the finite differences in combination with domain decomposition which makes is easy to implement using CUDA technology with asynchronous memcopy
- High computational performance of GPUs makes I/O a bottleneck again!
- Realistic wide-azimuth seismic data can be generated using a single server (8GPUs) in several weeks.