Numerical Modeling of Dynamic 3D Processes

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- Numerical simulation in geology
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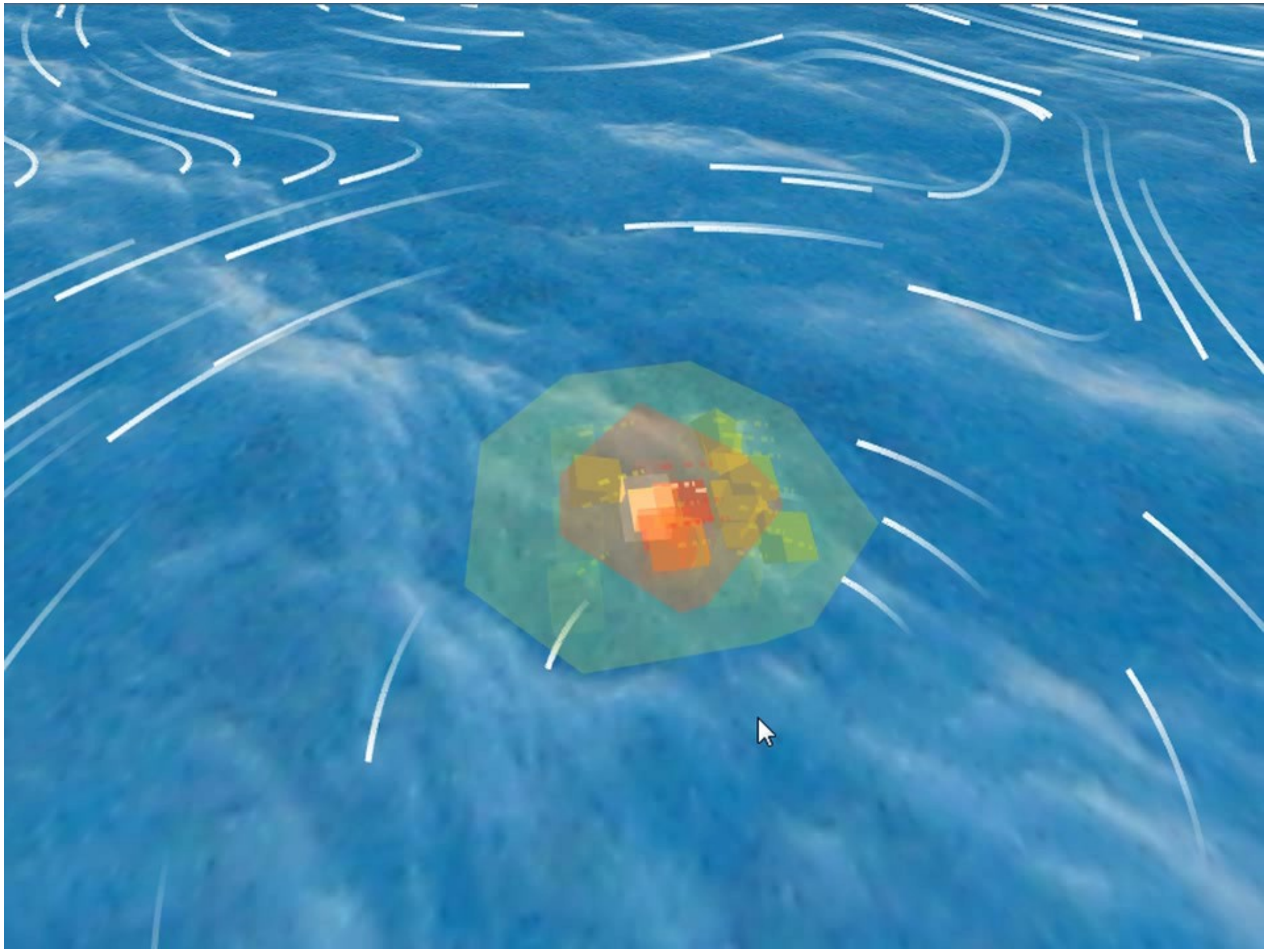
- Robot-technique
- Grid-characteristic method

Numerical modeling of Arctic problems

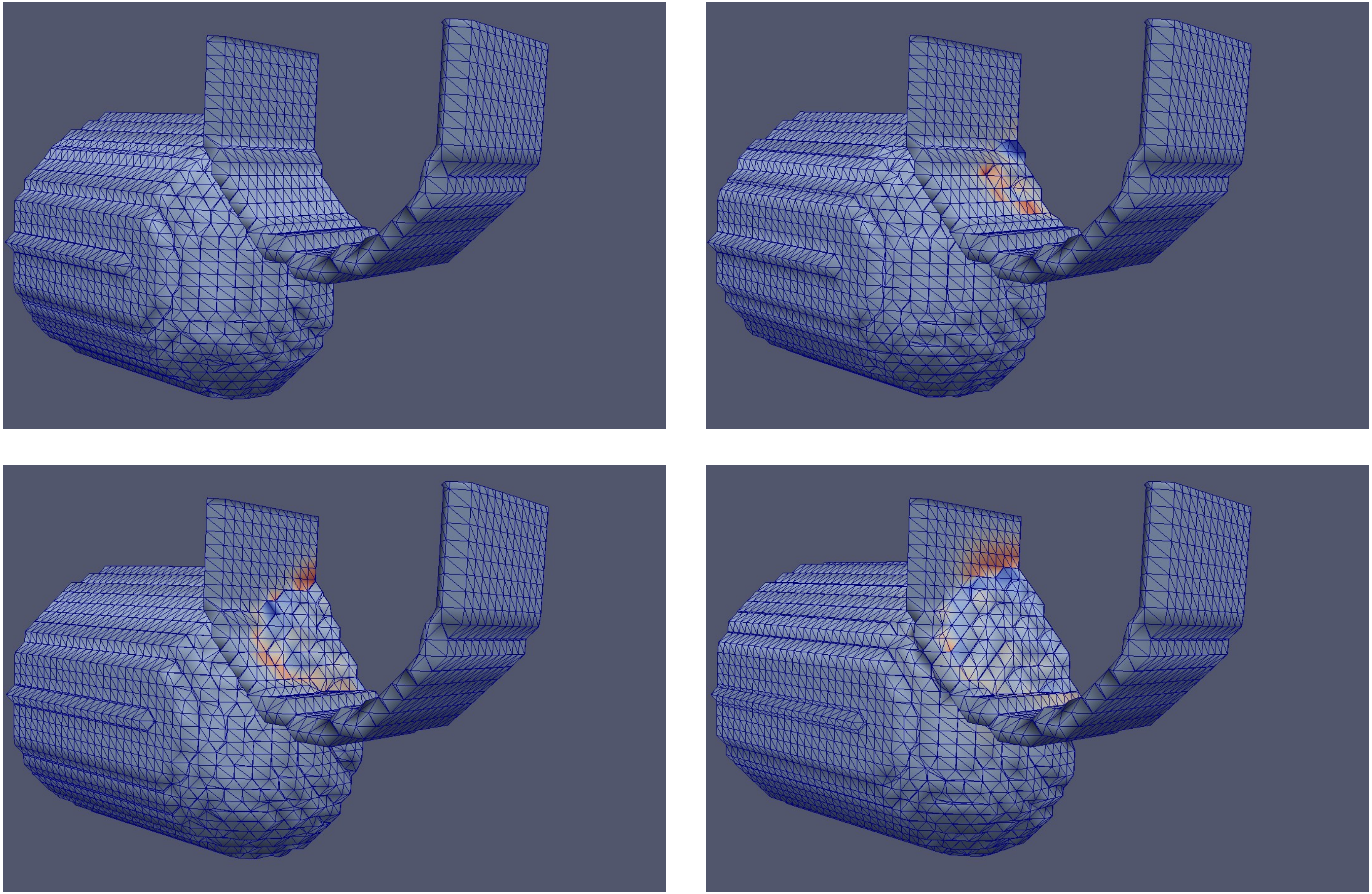
Migration of iceberg



Picture of Ship's Damage

R.E. Gagnon, J. Wang Numerical simulations of a tanker collision with a bergy bit incorporating hydrodynamics, a validated ice model and damage to the vessel // Cold regions. Science and Technology, 2012.

Collision between the ice-breaker and the ice-hummock

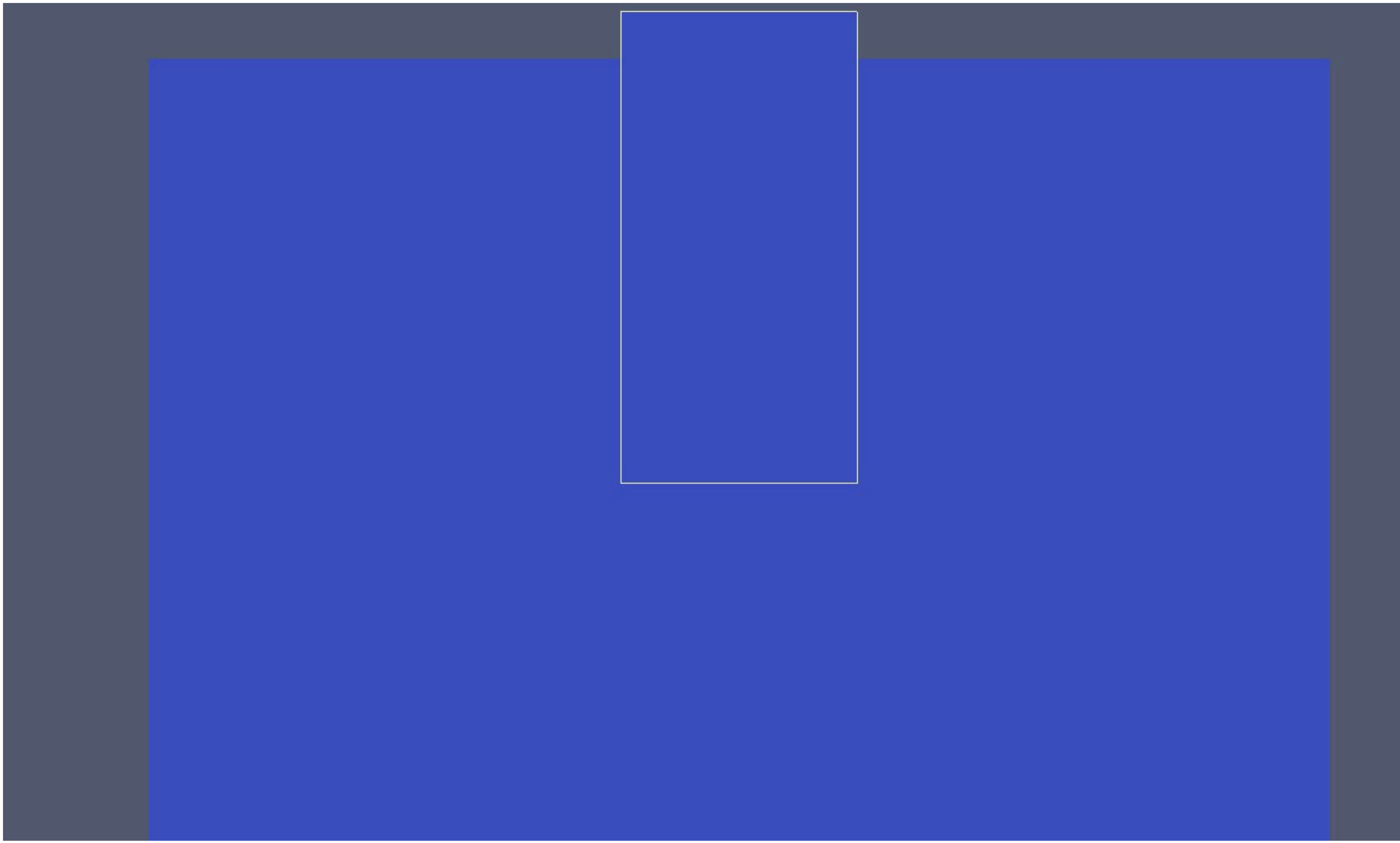


Impact of the ice hummock's keel on the seabed and on the underwater pipelines.

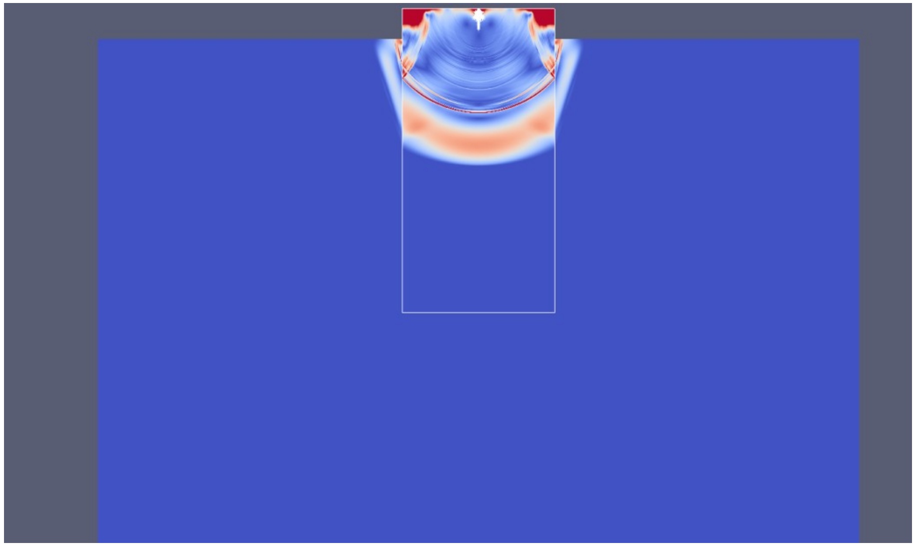
M.A. Naumov, D.A. Onishchenko, Presentaion

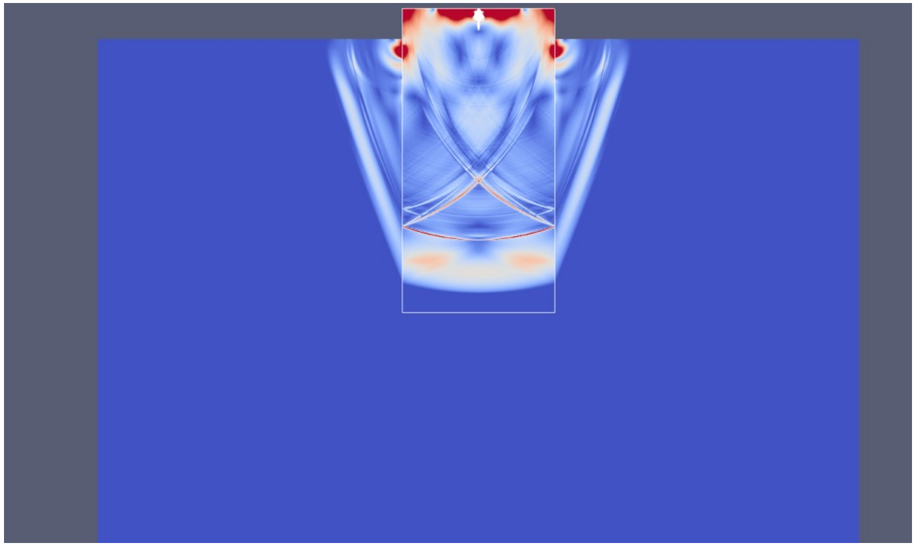
Gazprom VNIIGAZ LLC

Destruction of the iceberg under intense dynamic impacts

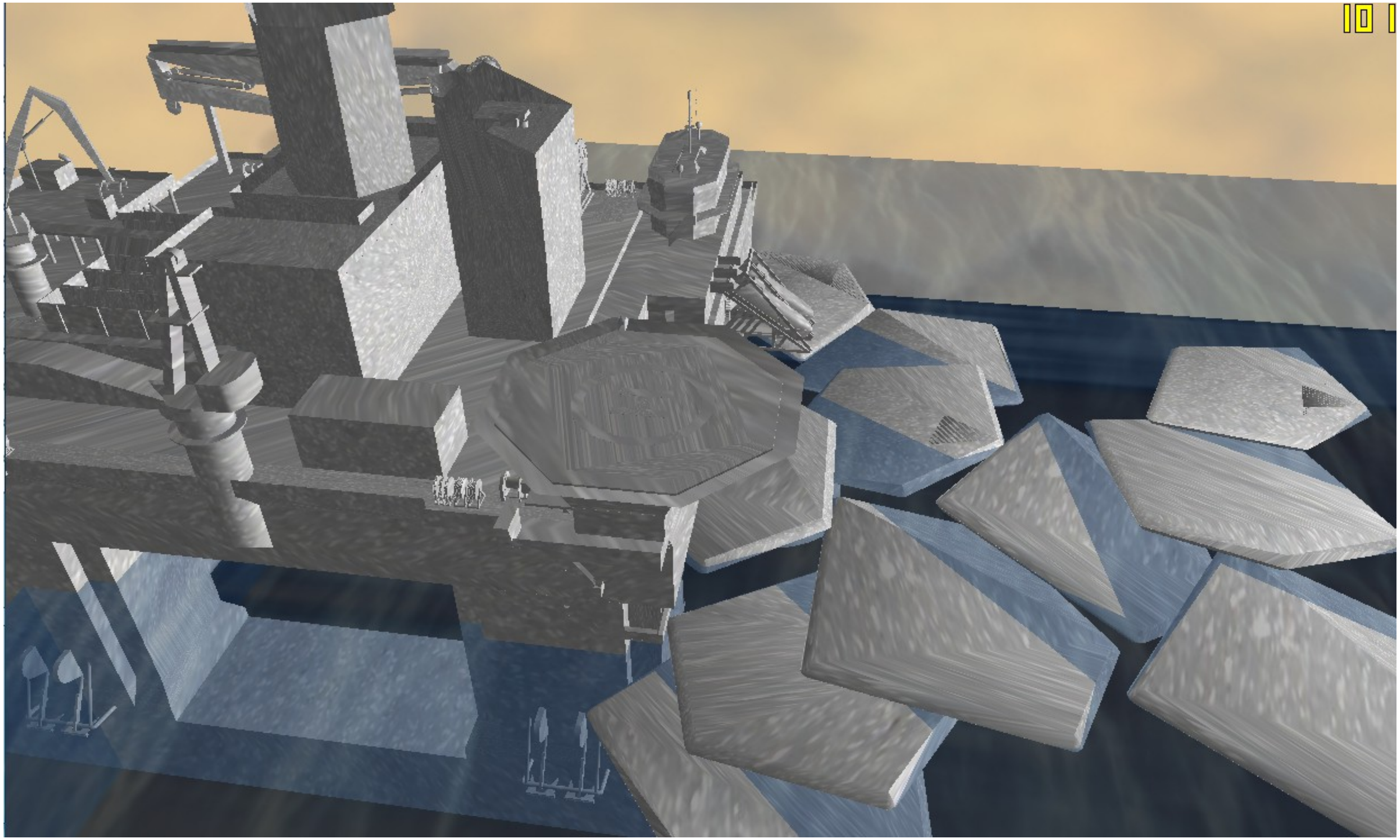


Destruction of the iceberg under intense dynamic impacts

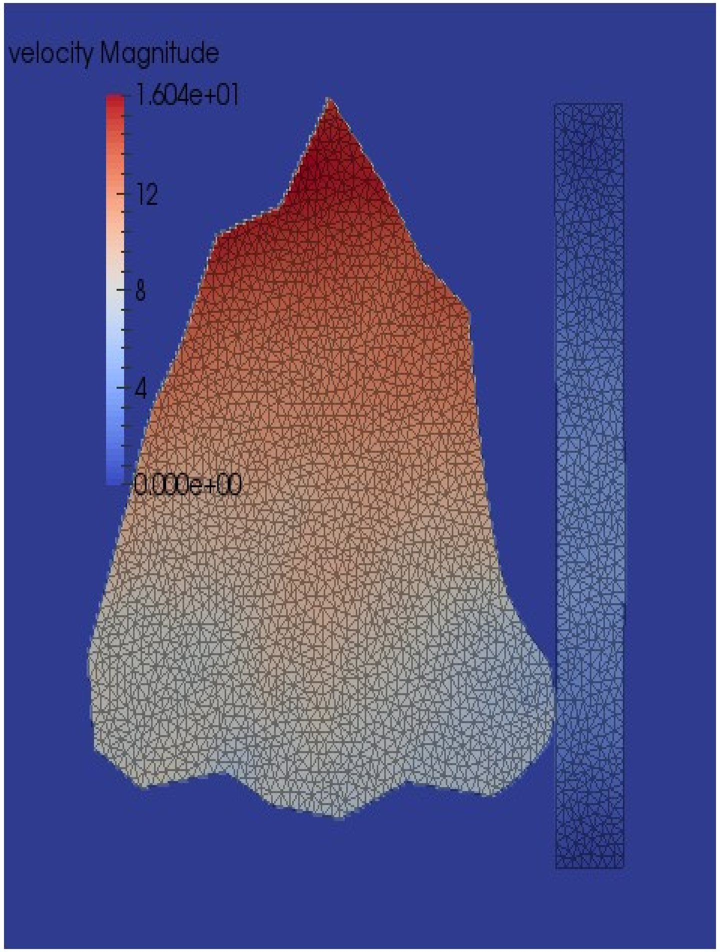


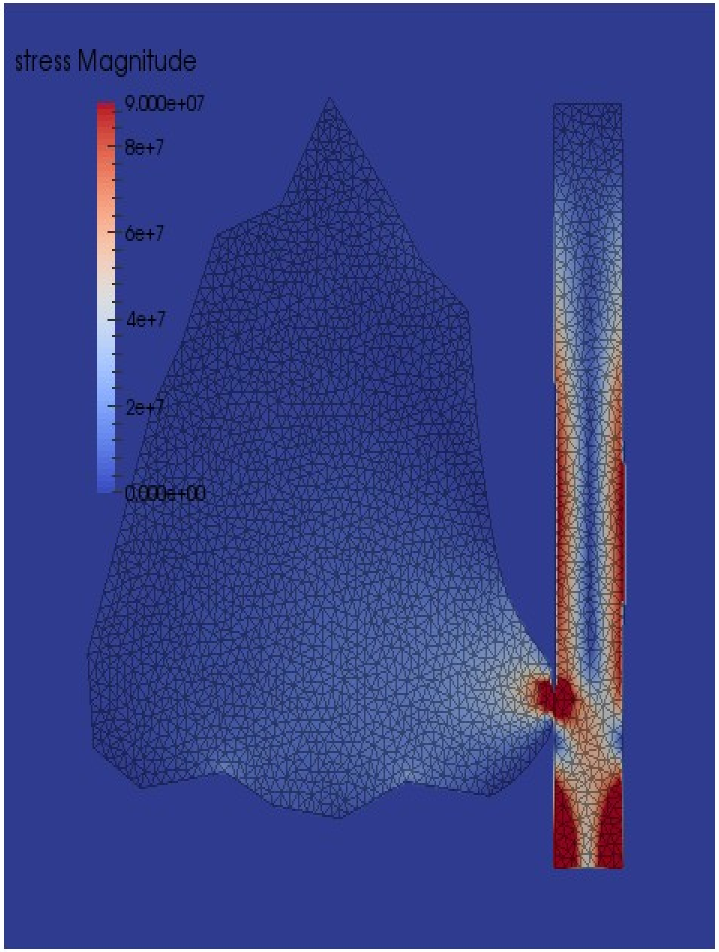


The flow of ice floes towards the rack of fixed oil-extracting platform



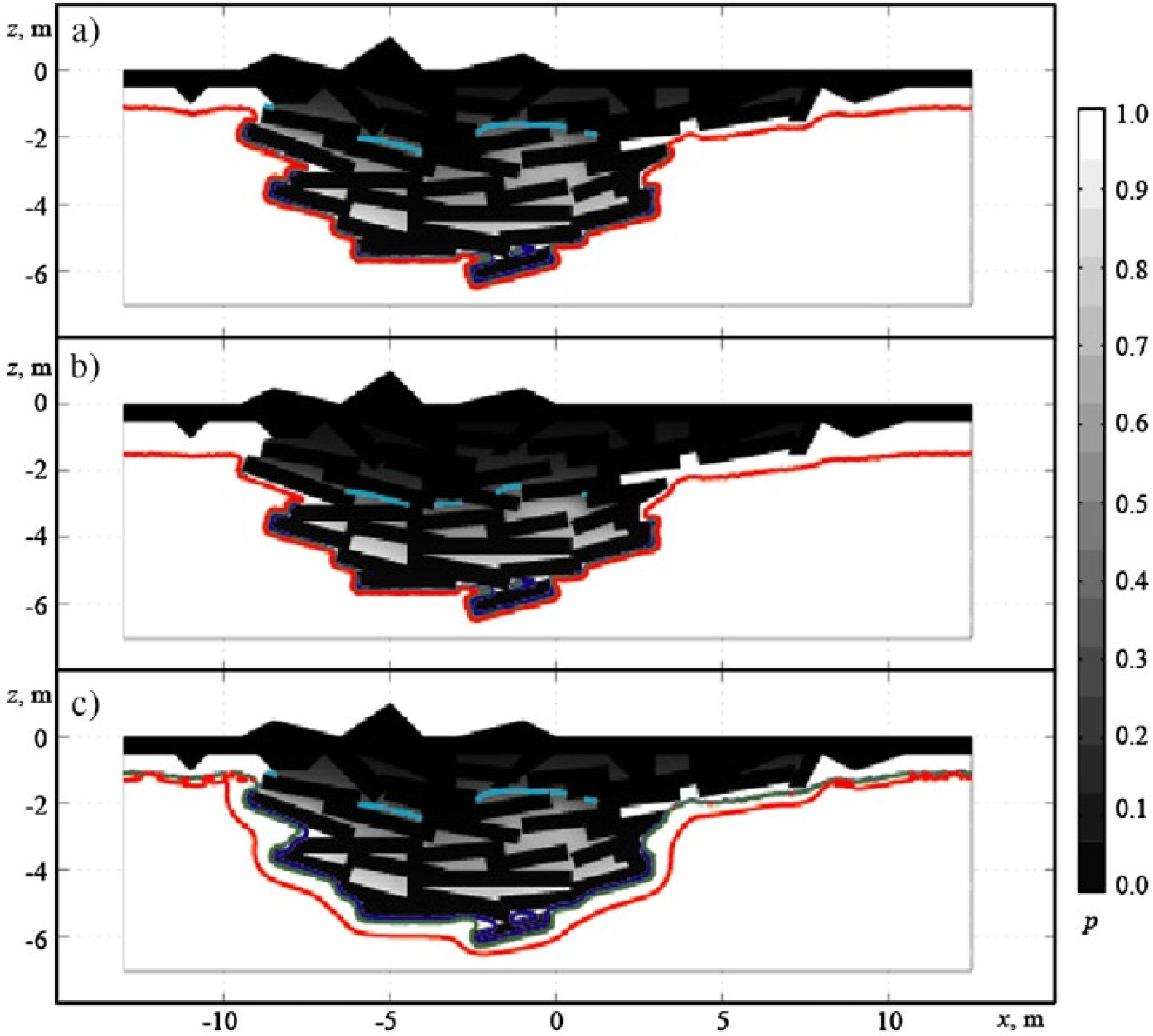
Collision between the iceberg and the fixed oil-extracting platform



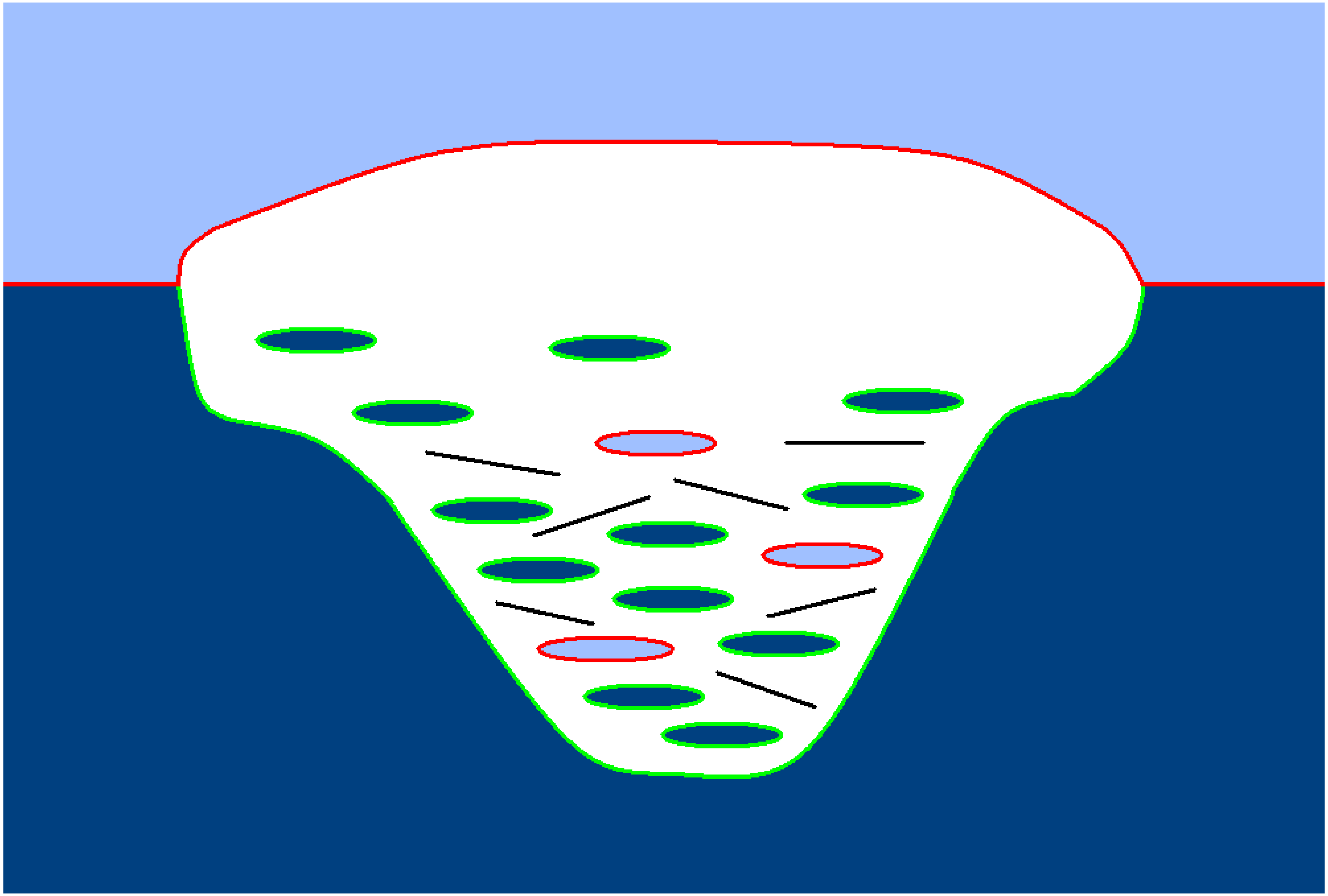


Structure of Ice-hummocks

A. Marchenko Thermodynamic consolidation and melting of sea ice ridges // Cold regions. Science and Technology, V. 52, N. 3, 2008.



Ice-hummock model

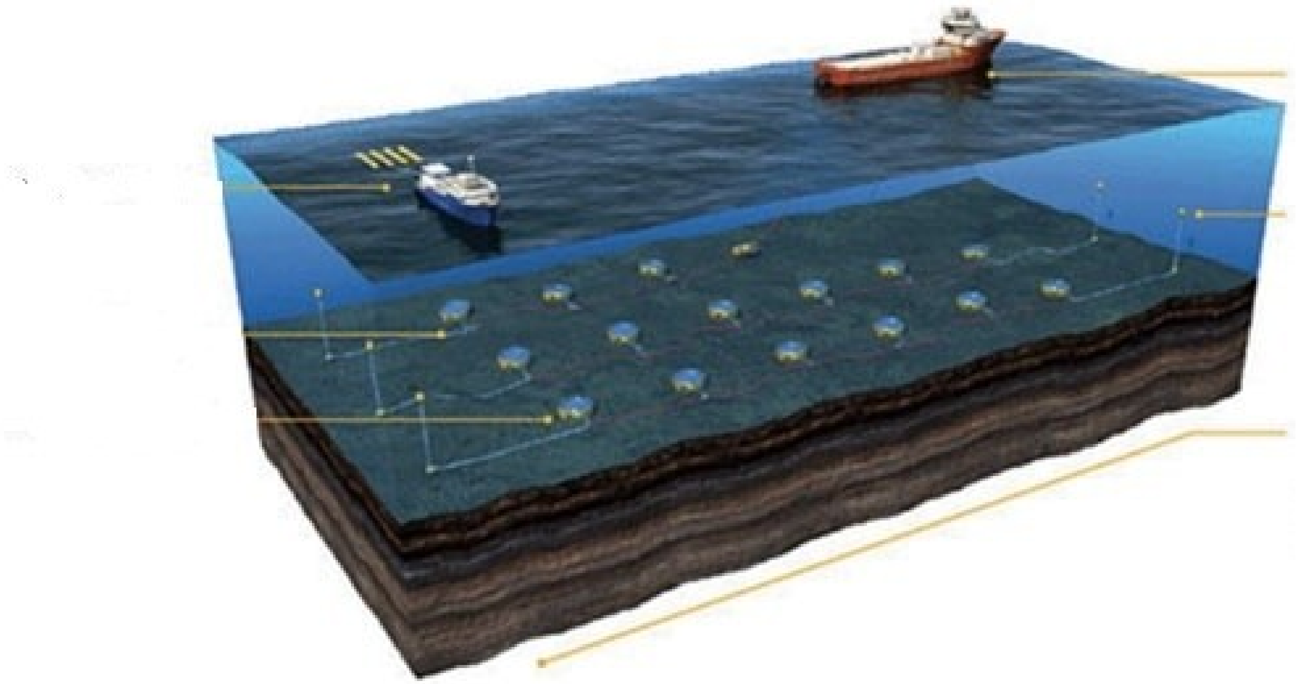


Seismic exploration in the conditions of the Arctic shelf

Strimmer

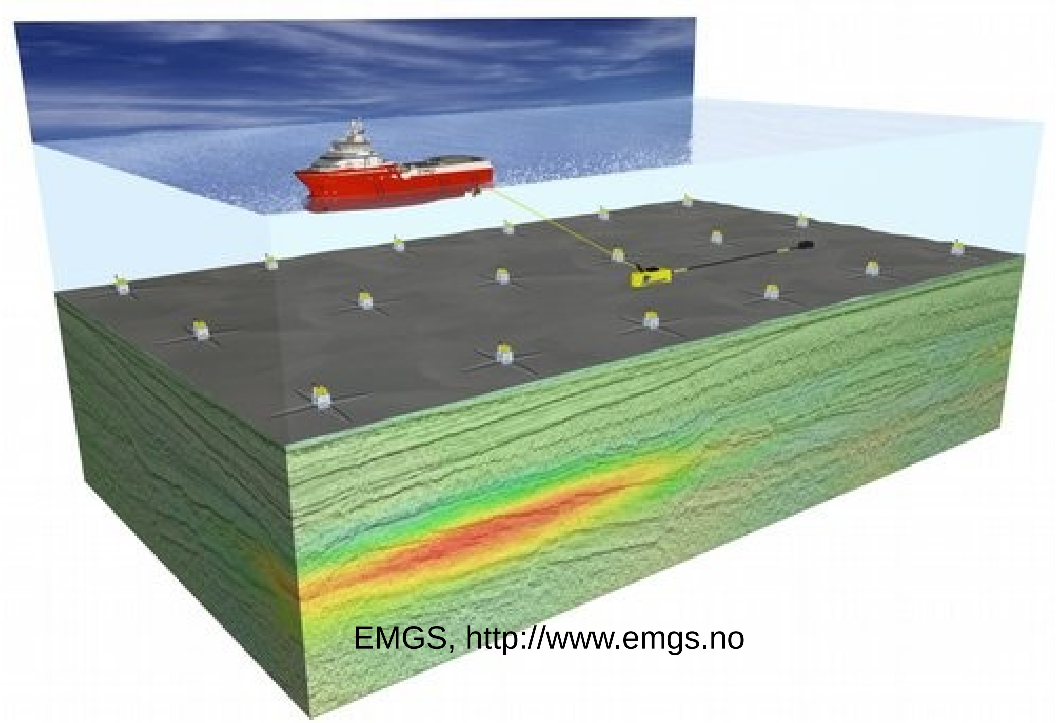
- 3D
- P-waves
- High performance

Seabed stations



- 3D/4C
- High price
- High comprehension of obtained data

Geophysical prospecting by electric means – seabed stations



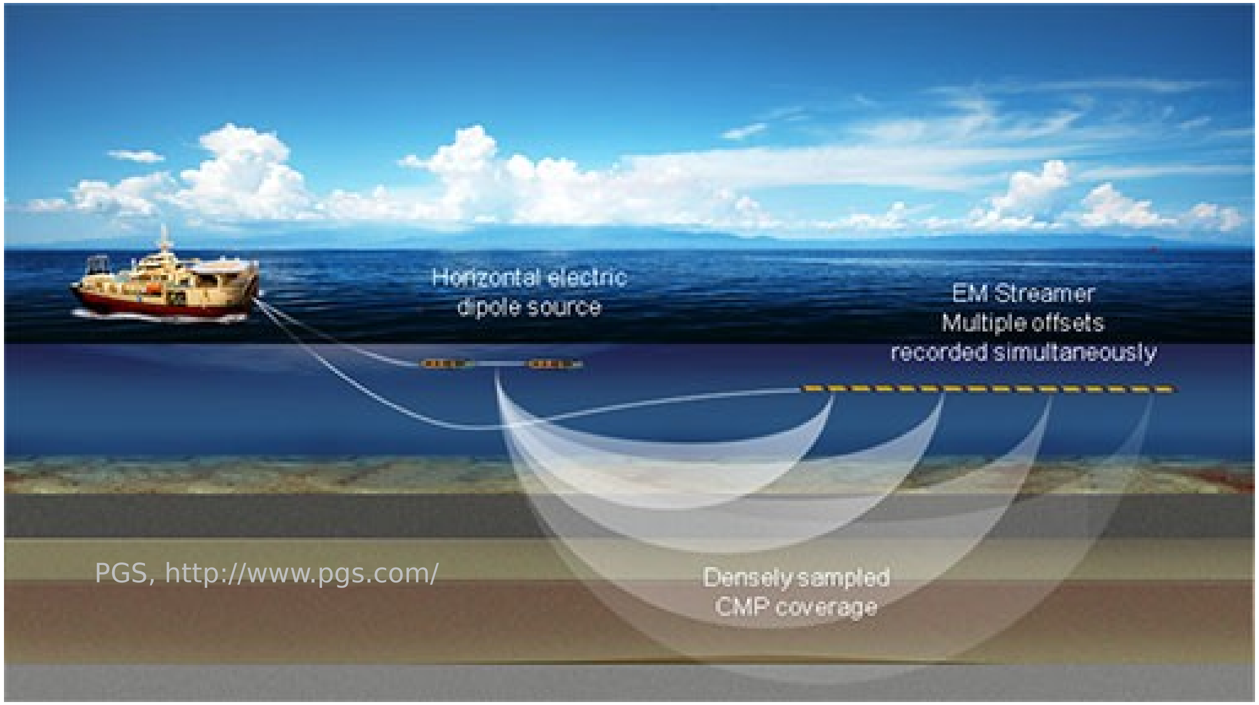
EMGS, http://www.emgs.no

The leader of volume of work

6 components of the EM field (important for 3D inversion)

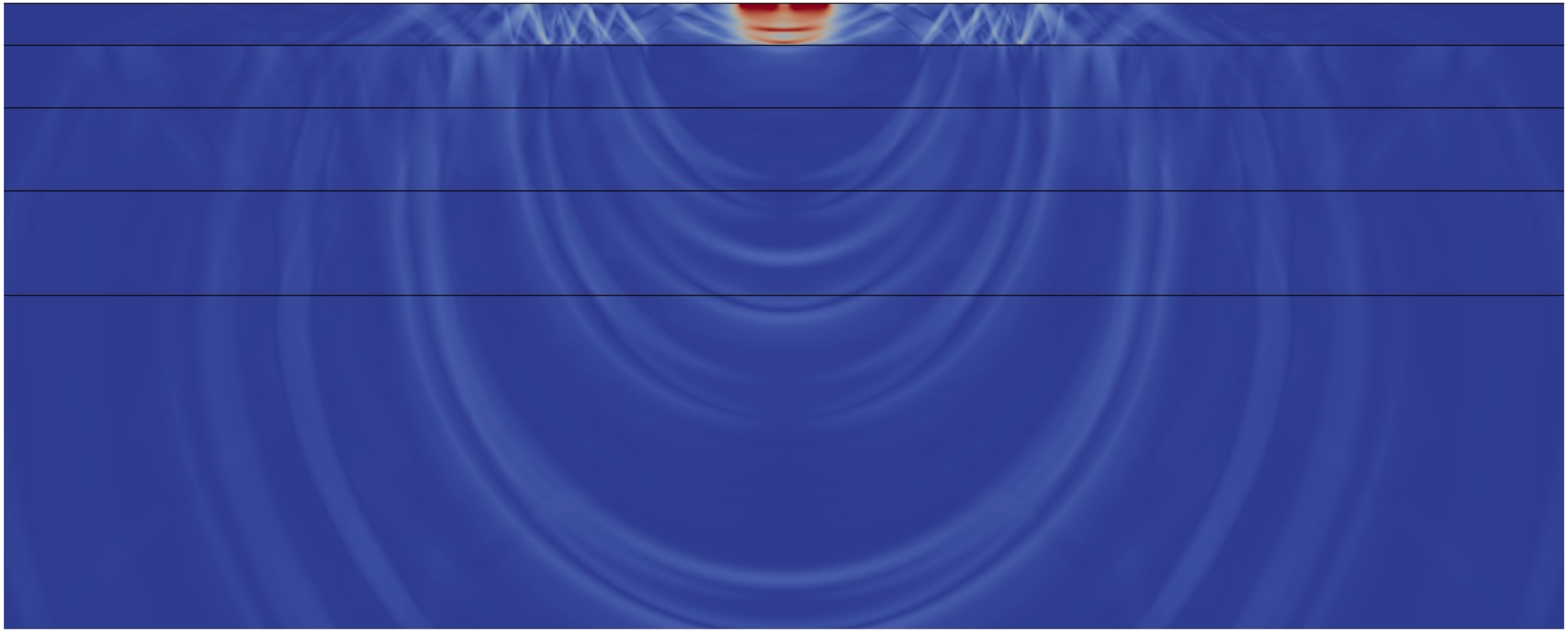
Not smaller than 50 m

Geophysical prospecting by electric means - strimmers

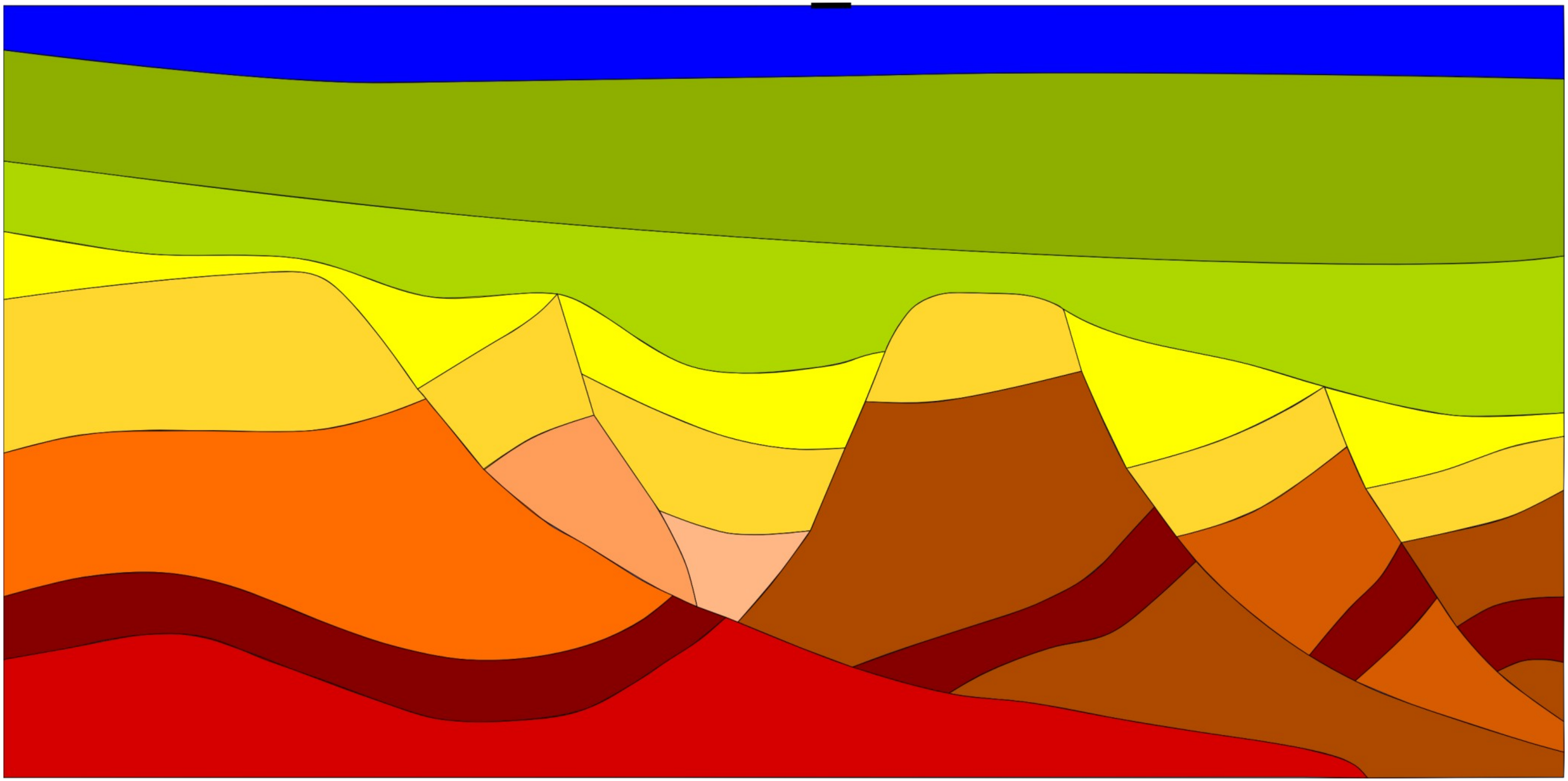


- High performance
- No deeper than 300 m
- One axial component of the field: Ex
- Frequency and time domain

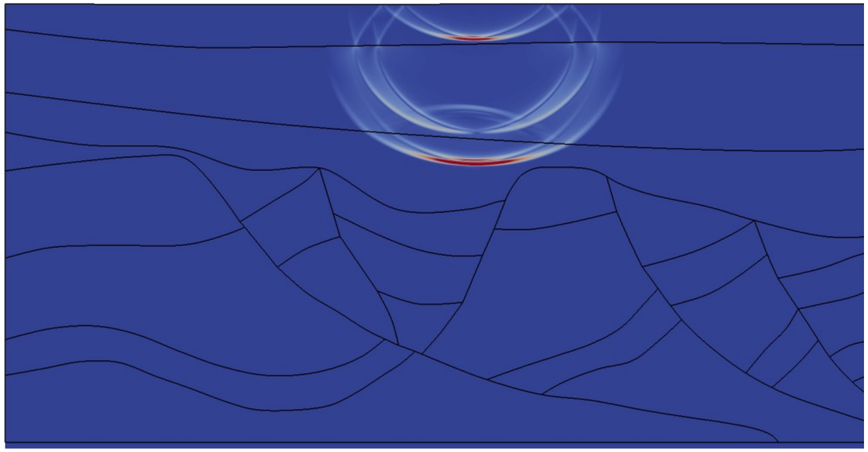
Multilayered geological medium

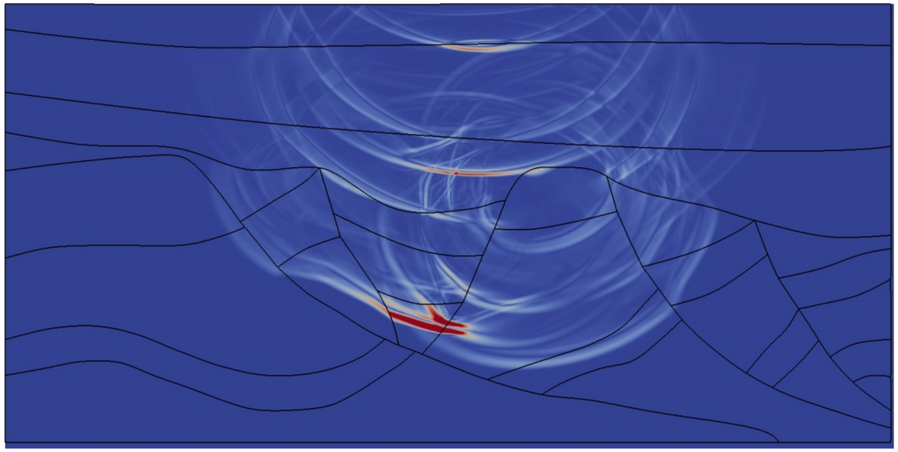


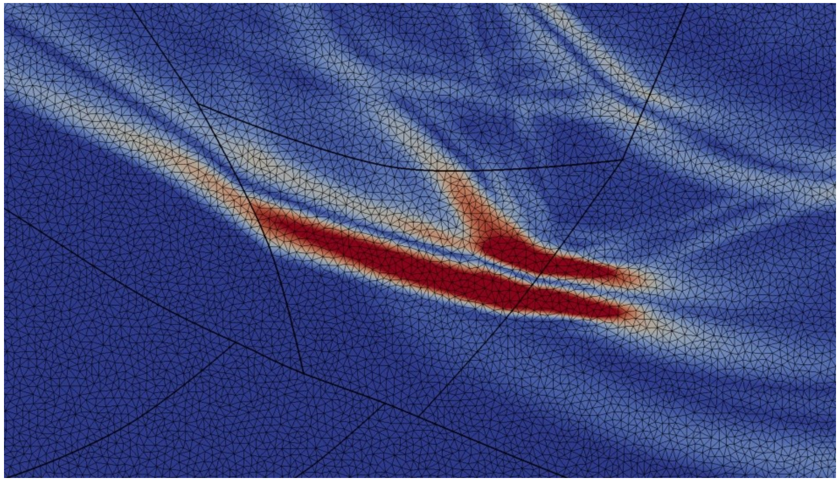
Complicated interfaces

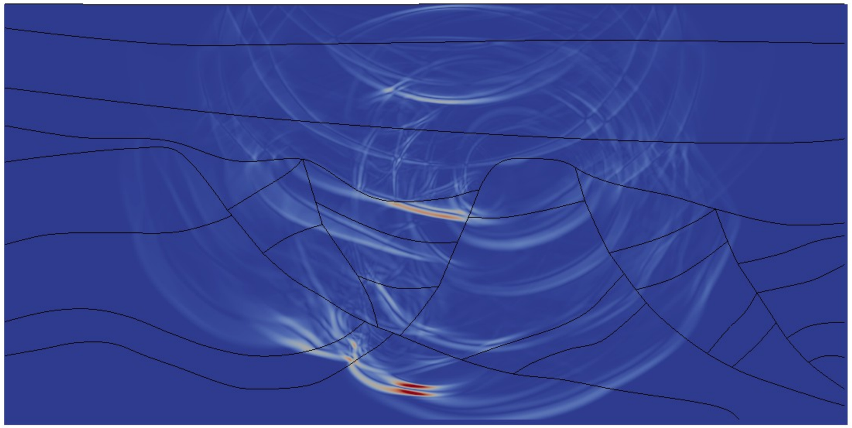


Complicated interfaces

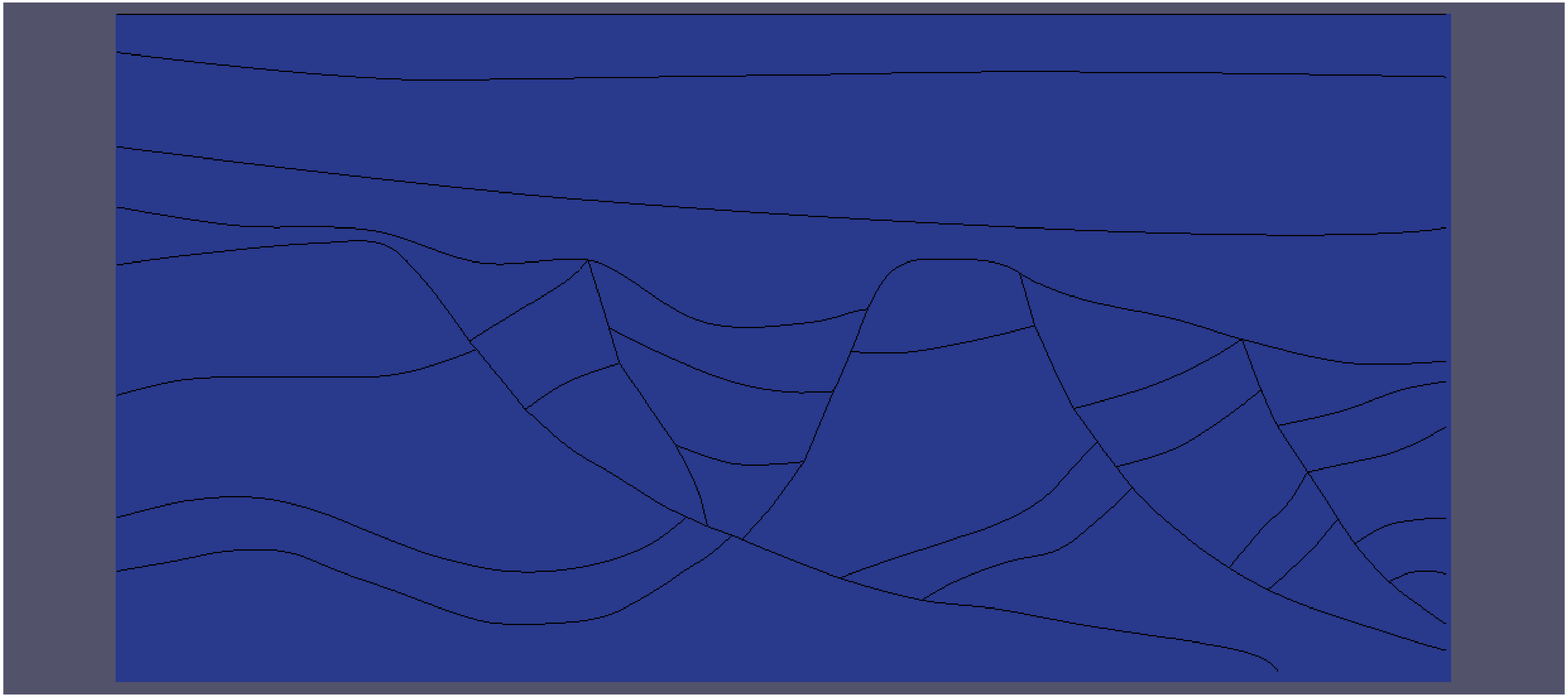




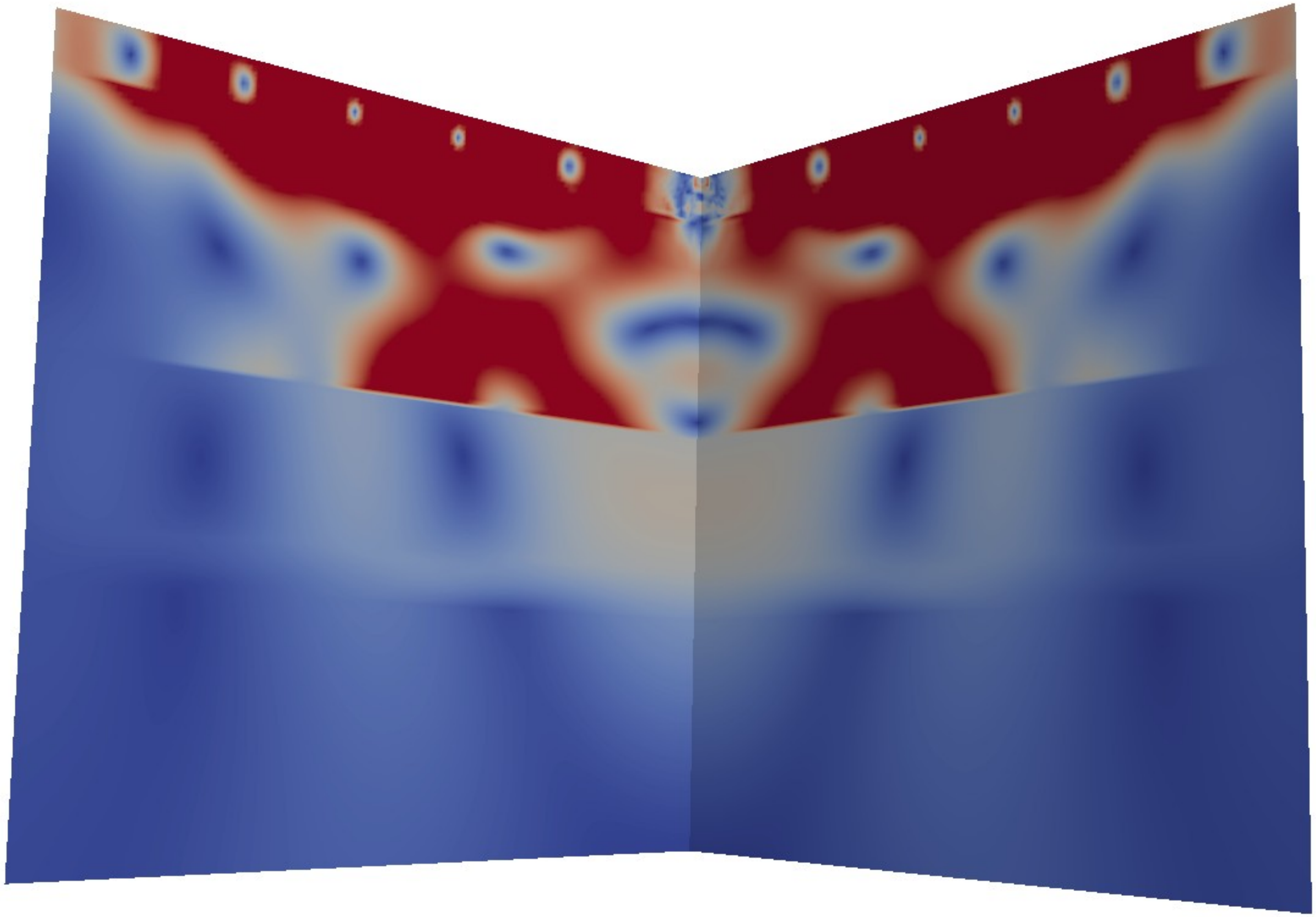




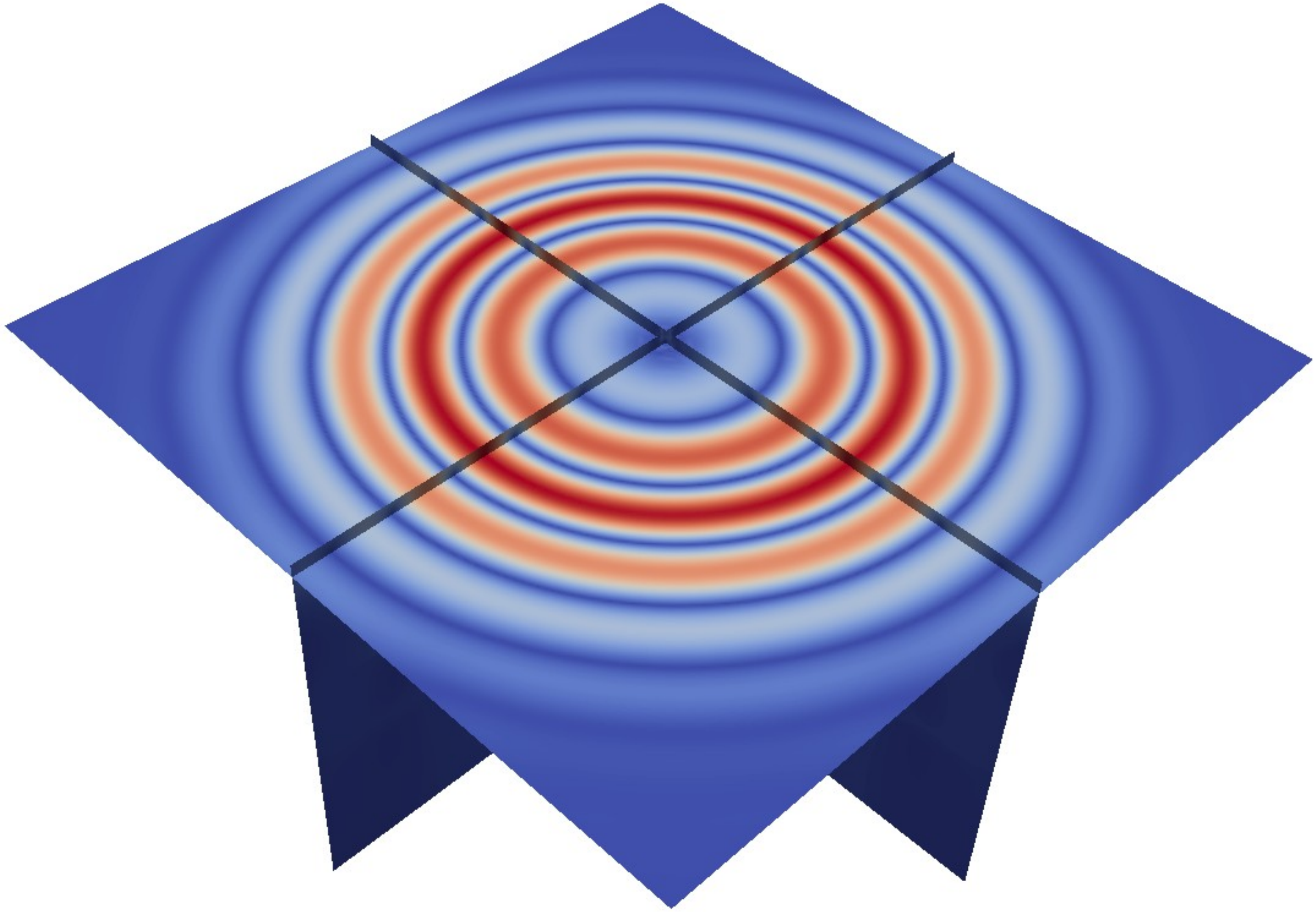
Complicated interfaces



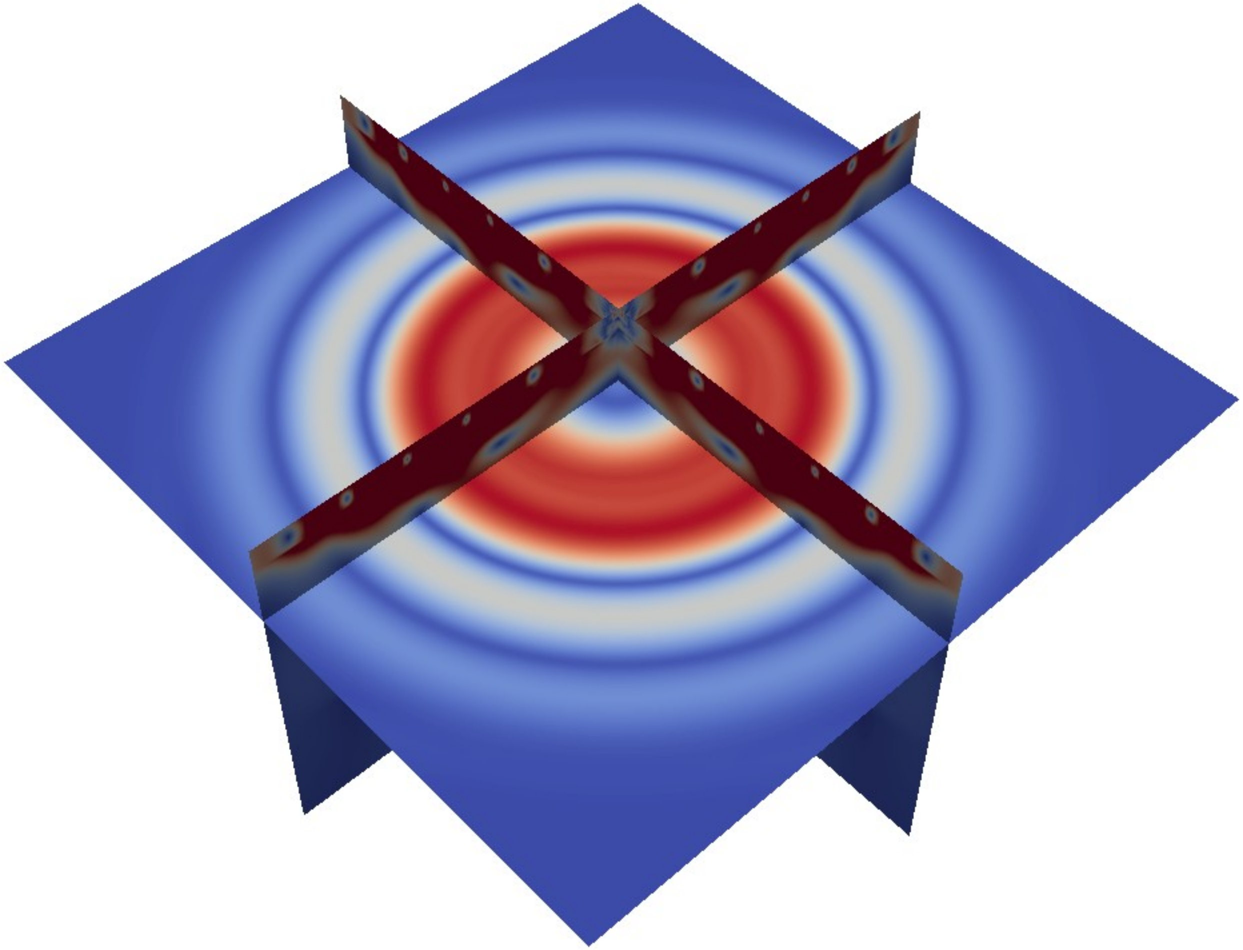
Seismic prospecting at the Arctic shelf



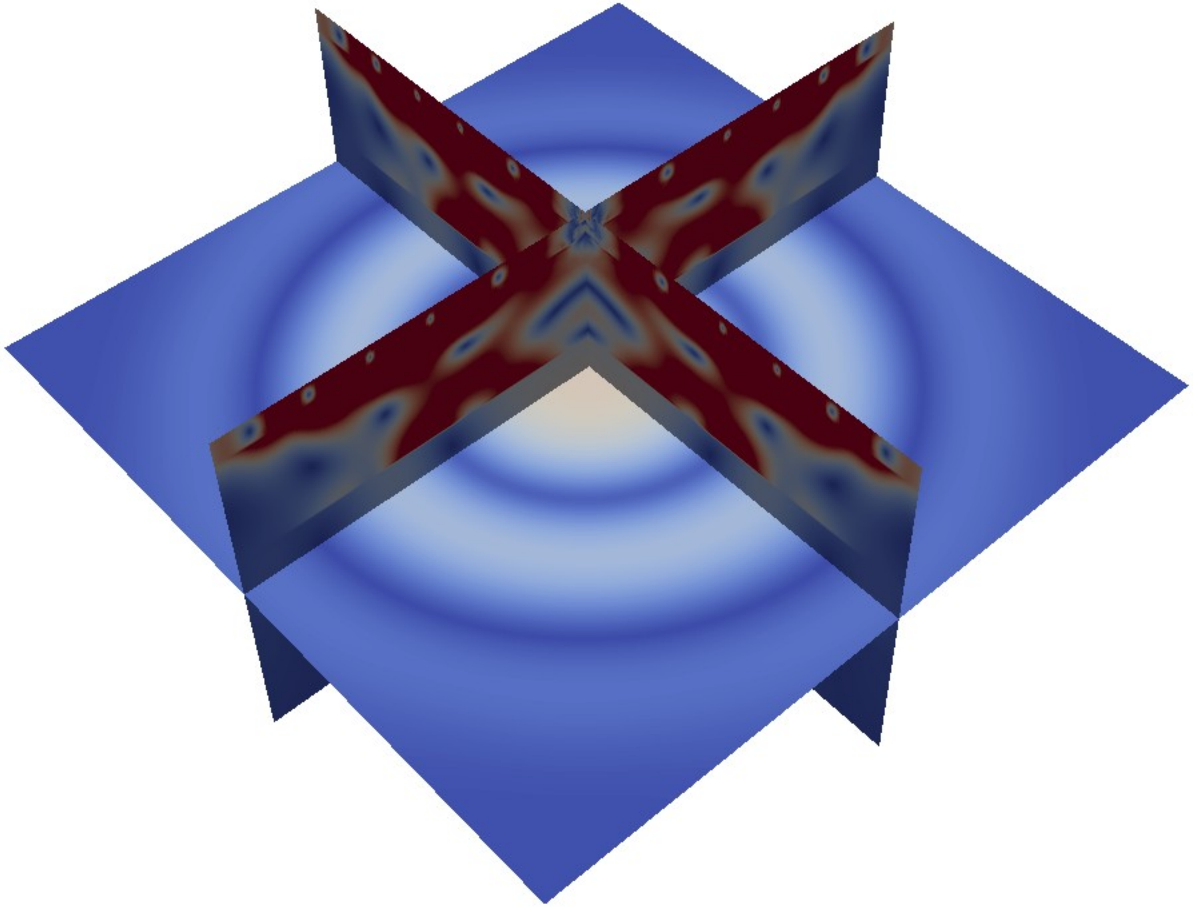
Wave pattern in the ice



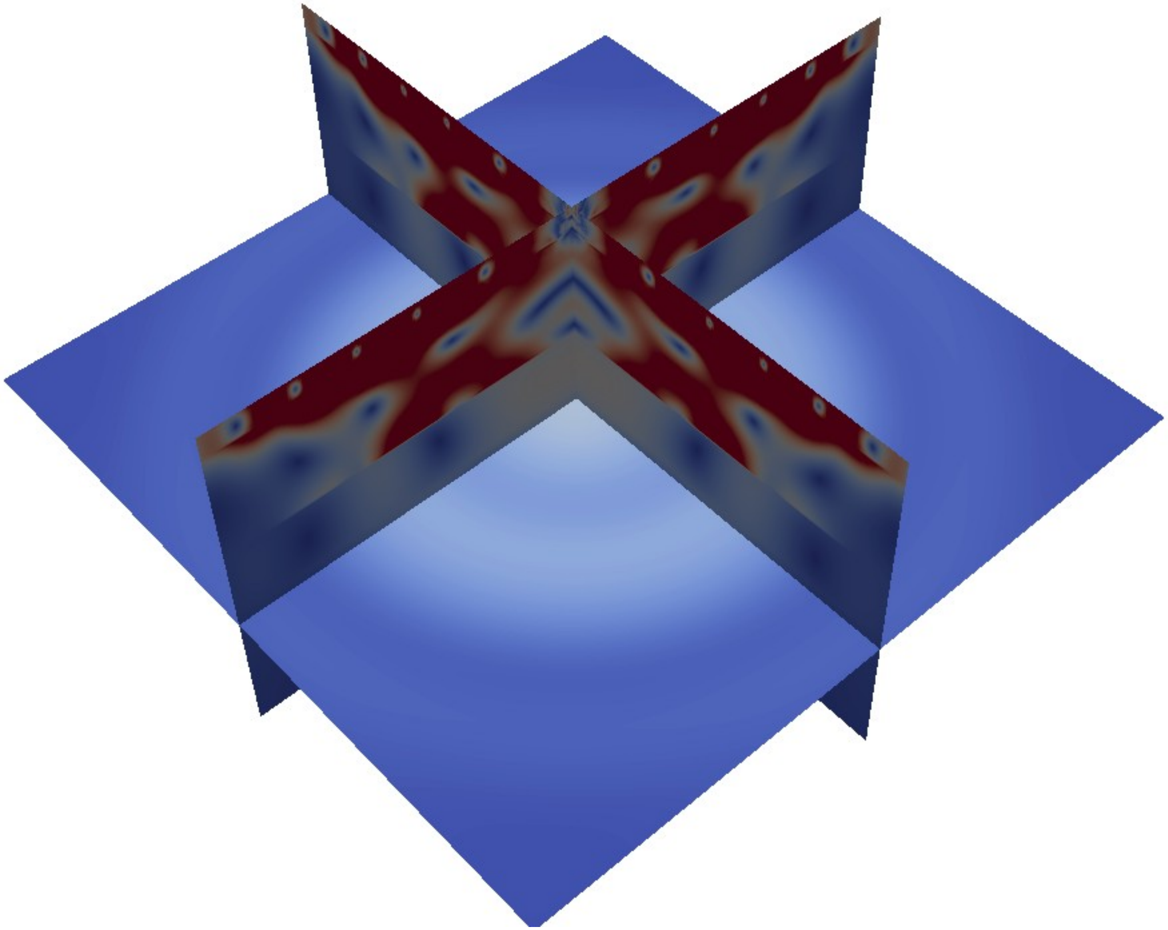
Wave pattern in the water



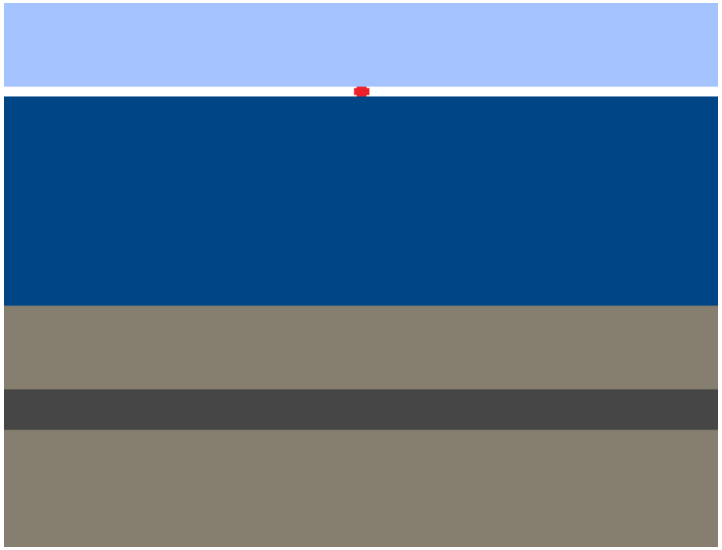
Wave pattern in the ground



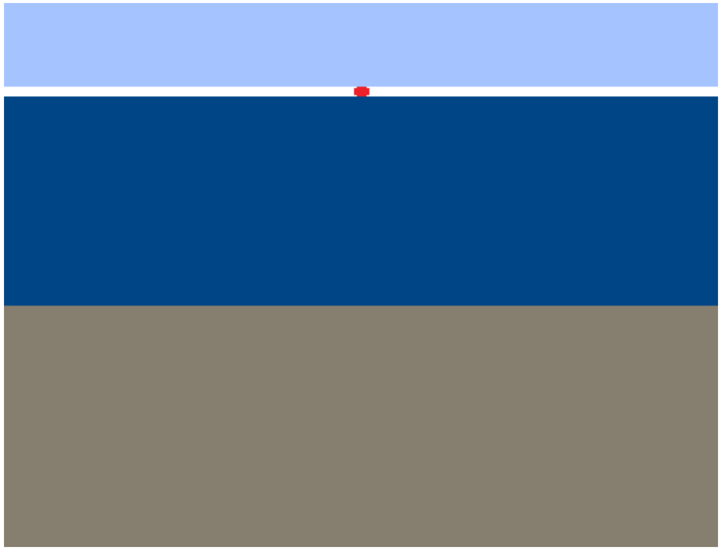
Wave pattern in the carbon reservoir



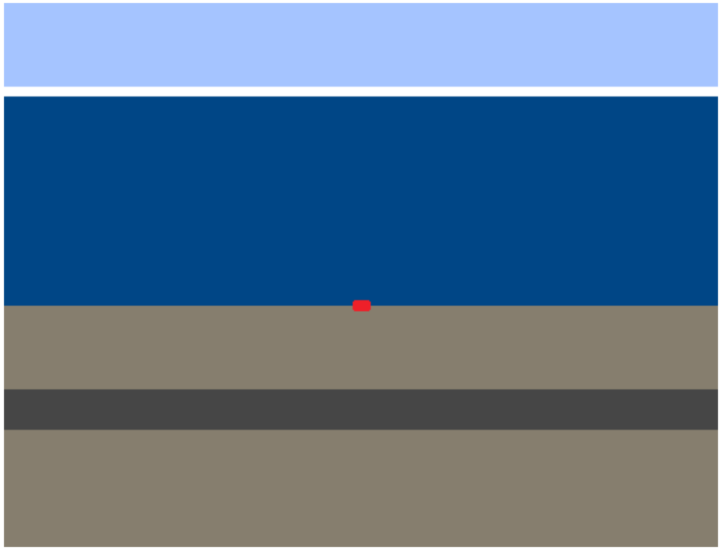
Problem defintions



Source in the ice



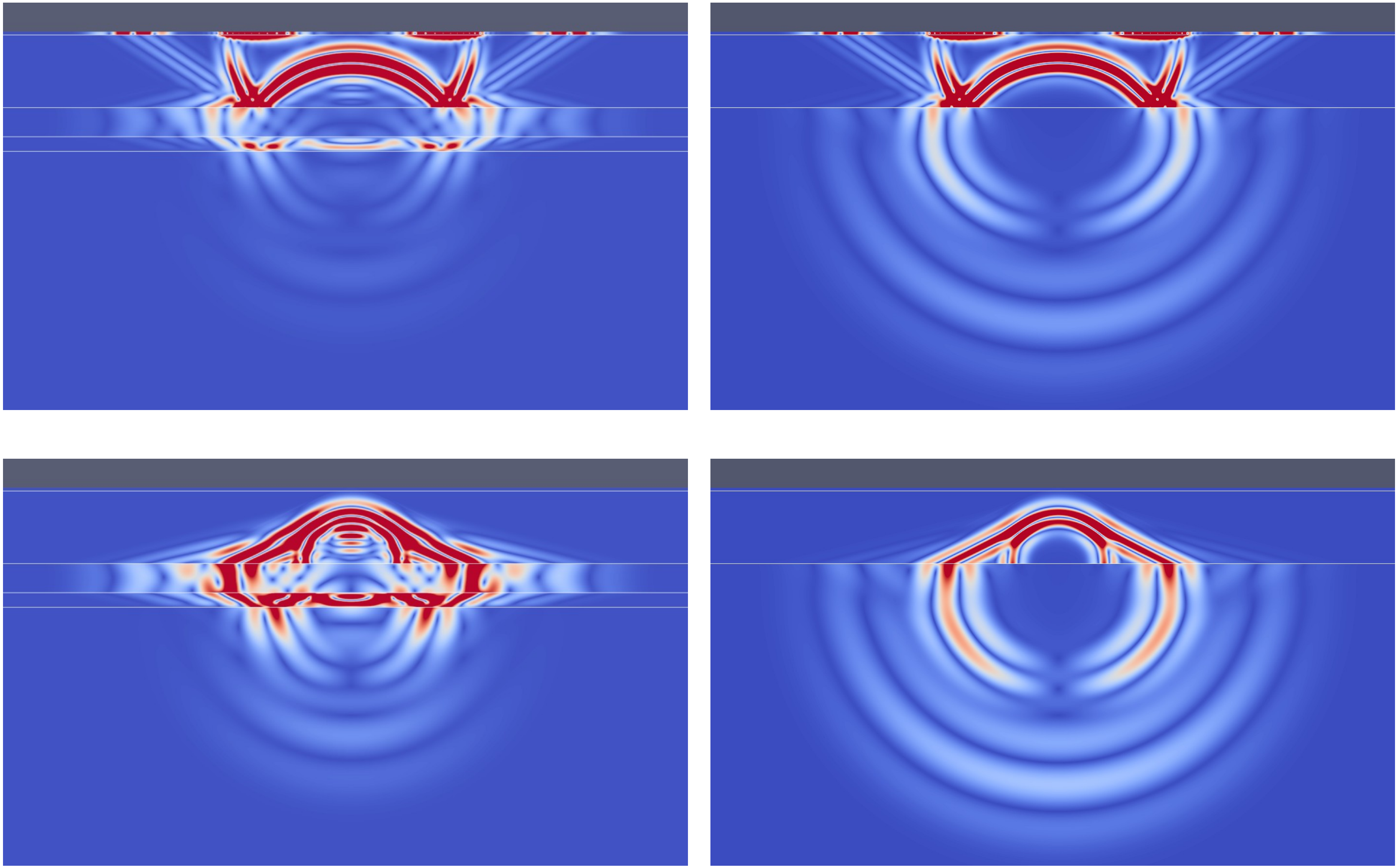
Source in the ice, without reservoir



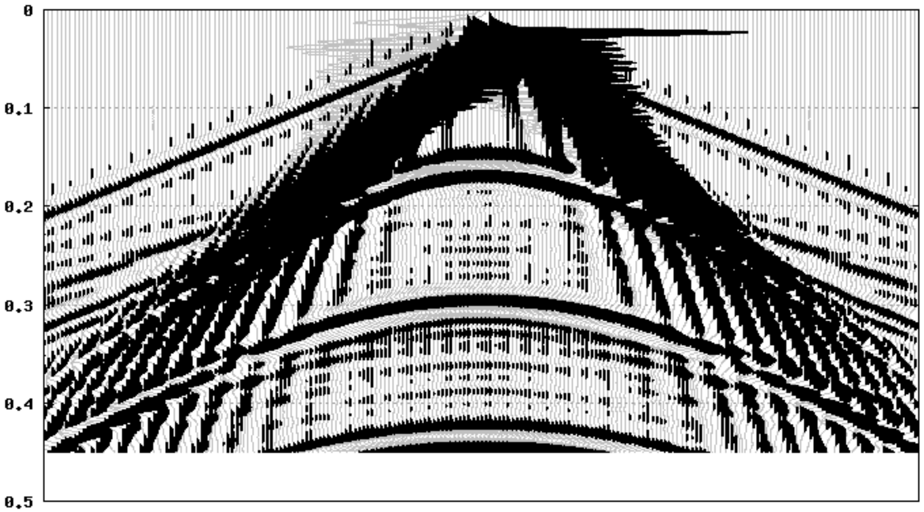
Source at the seabed

Source at the seabed, without reservoir

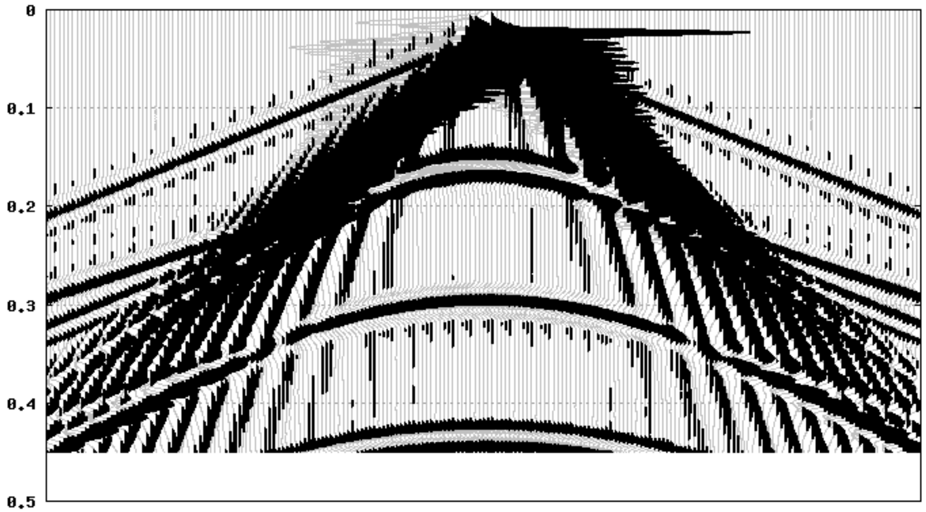
Wave patterns



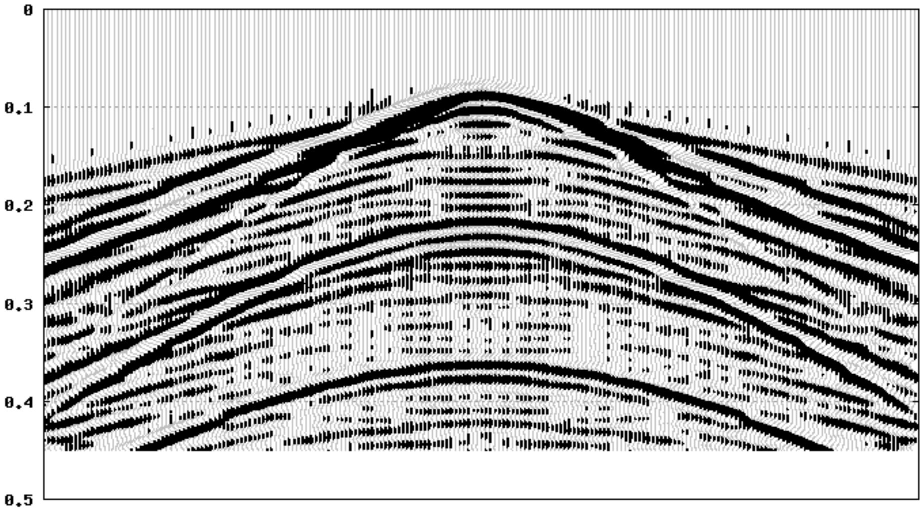
Seismograms from ice receivers, Vy



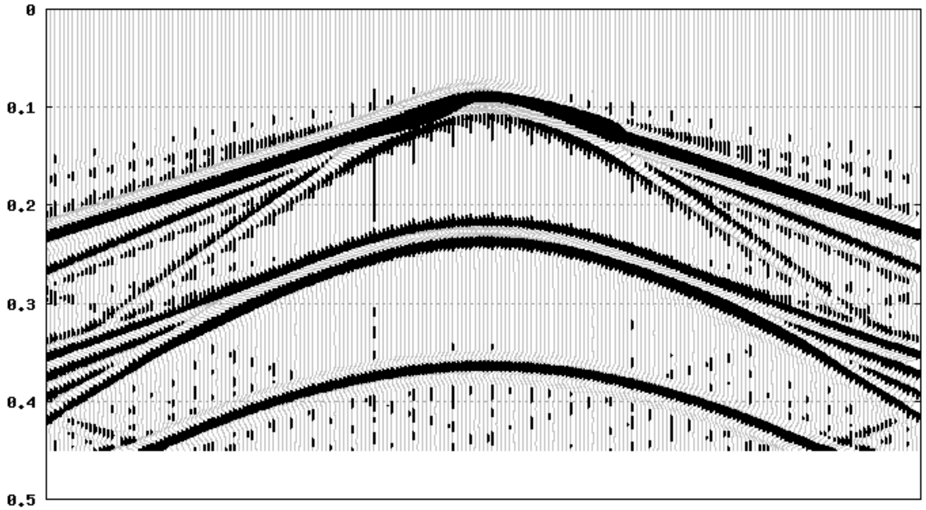
Source in the ice



Source in the ice, without reservoir

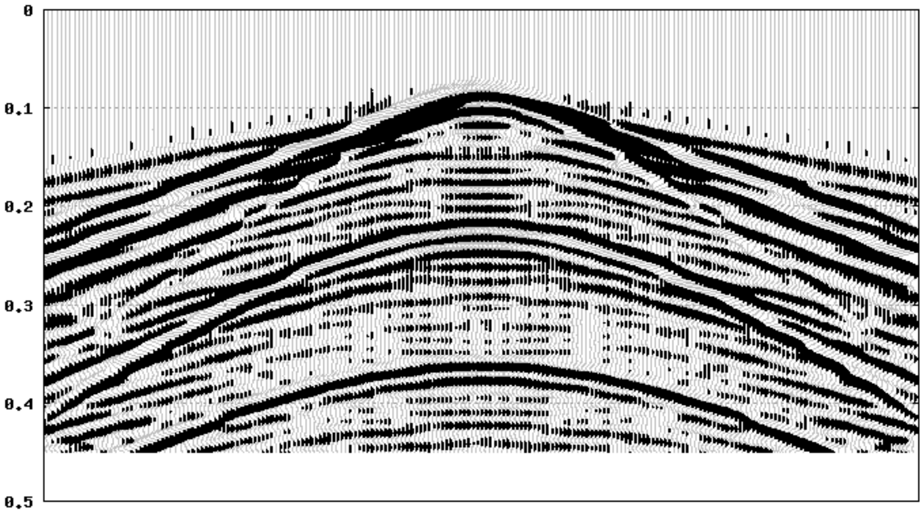


Source at the seabed

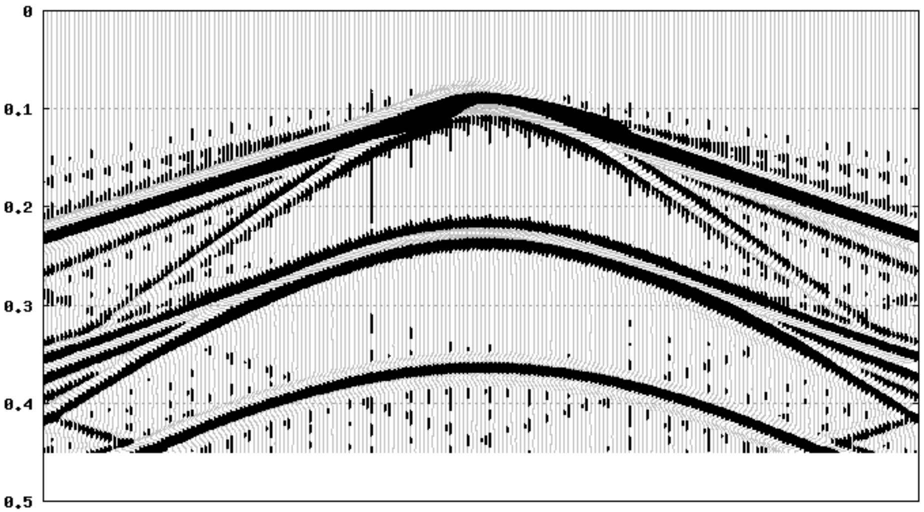


Source at the seabed, without reservoir

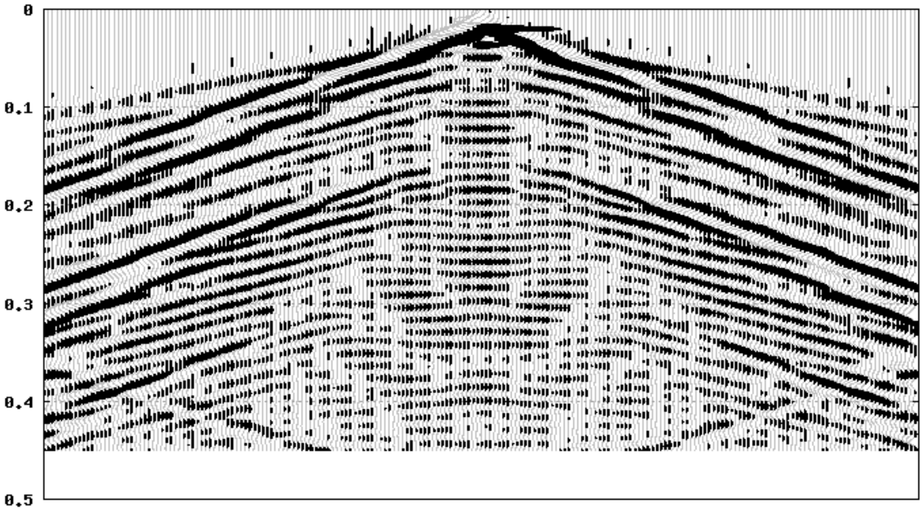
Seismograms from seabed receivers, Vy



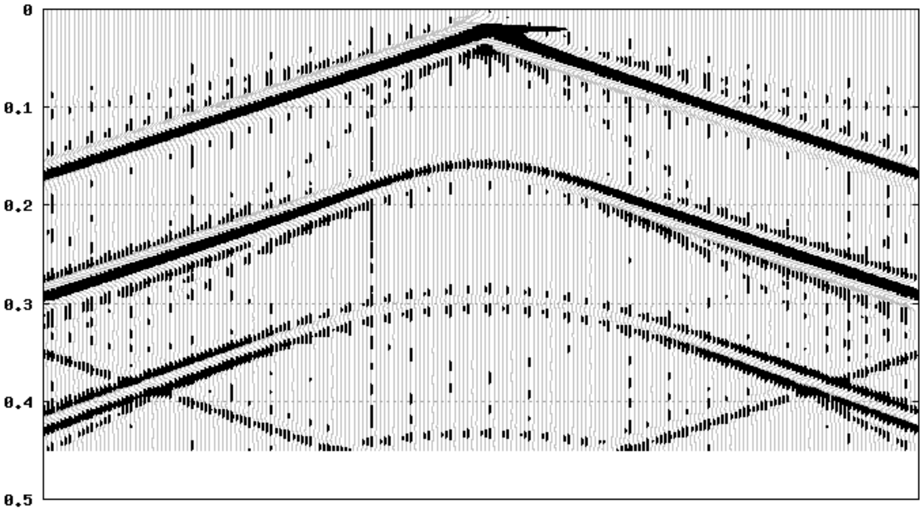
Source in the ice



Source in the ice, without reservoir



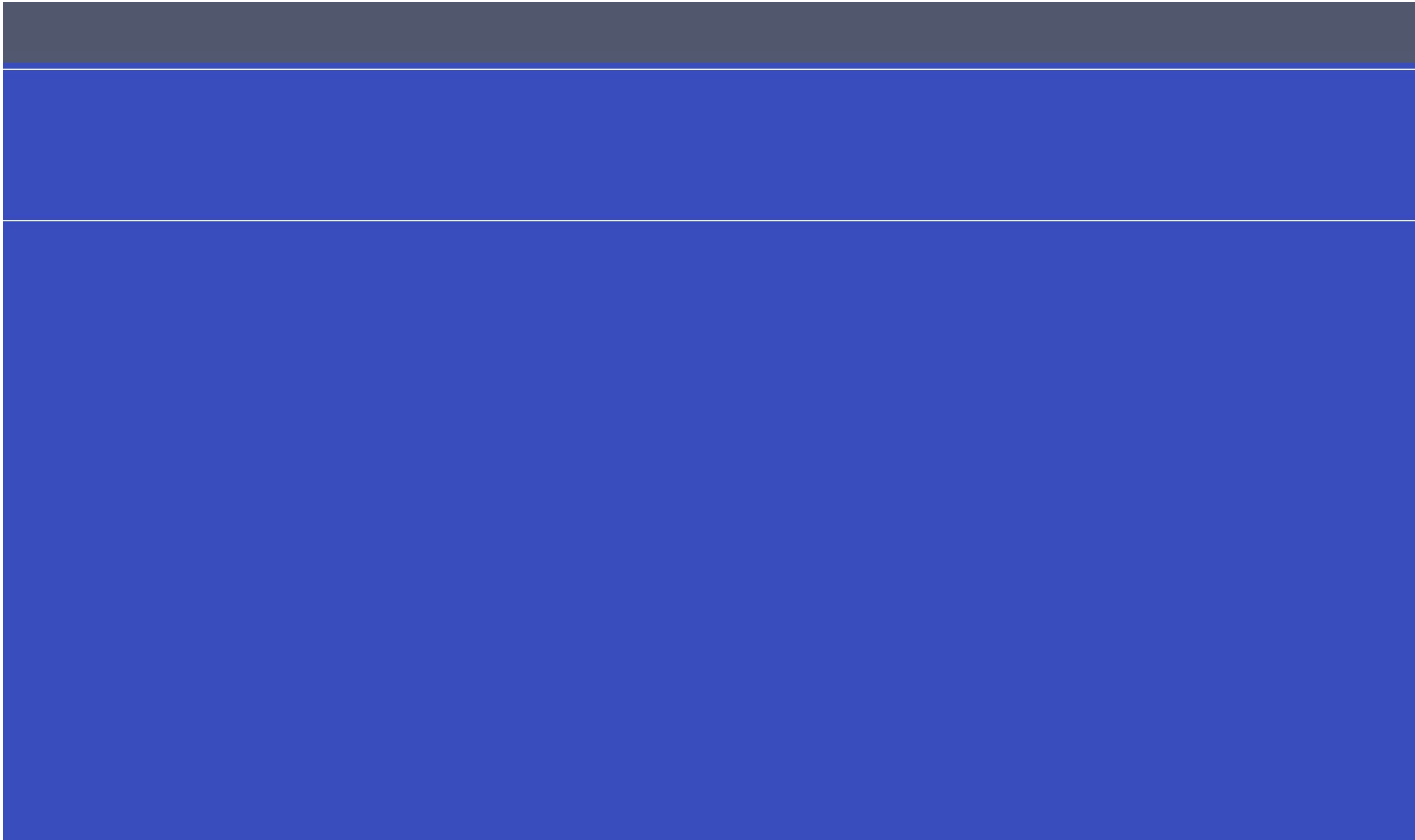
Source at the seabed



Source at the seabed, without reservoir

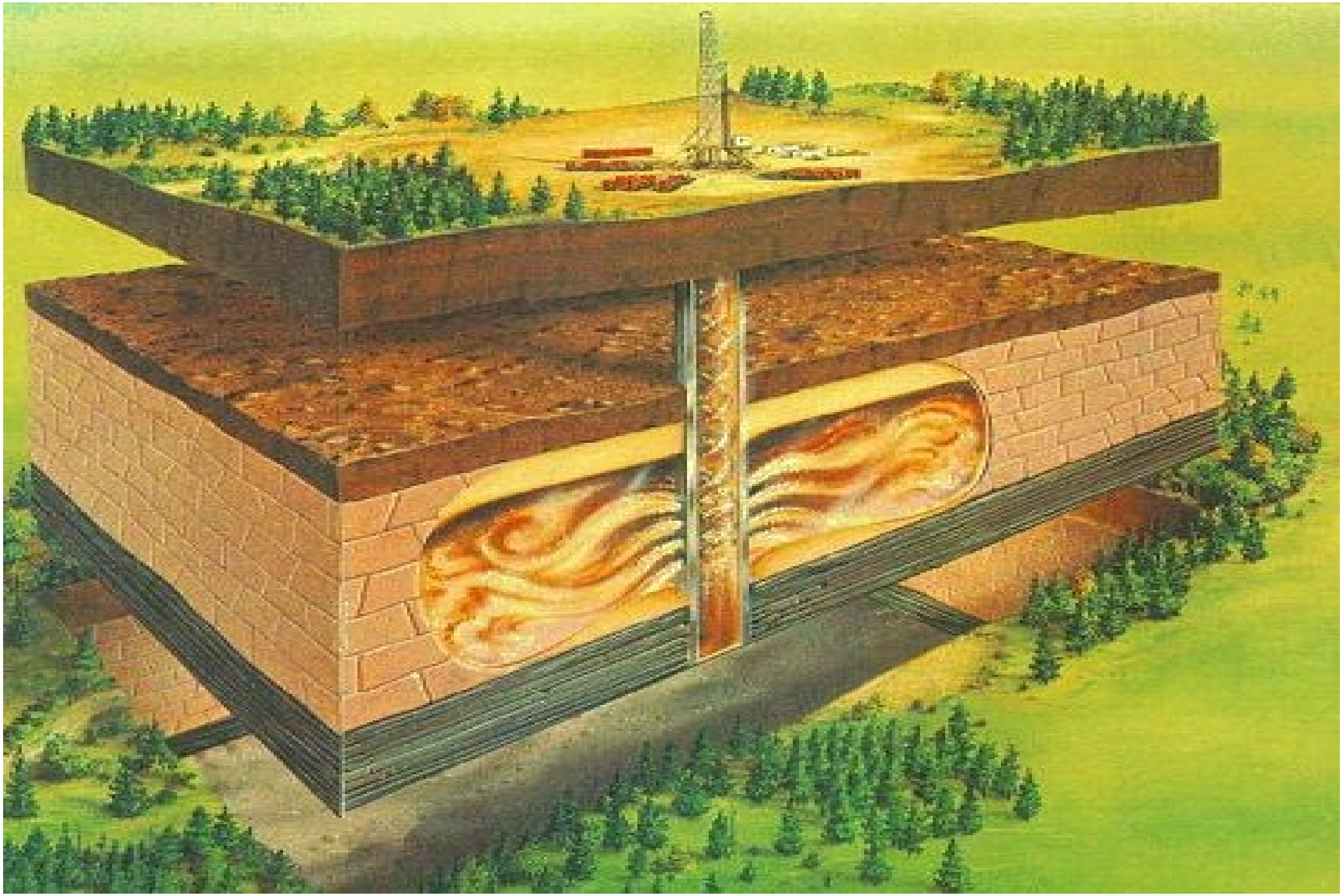
Source at the bottom

Source at the bottom, without the reservoir

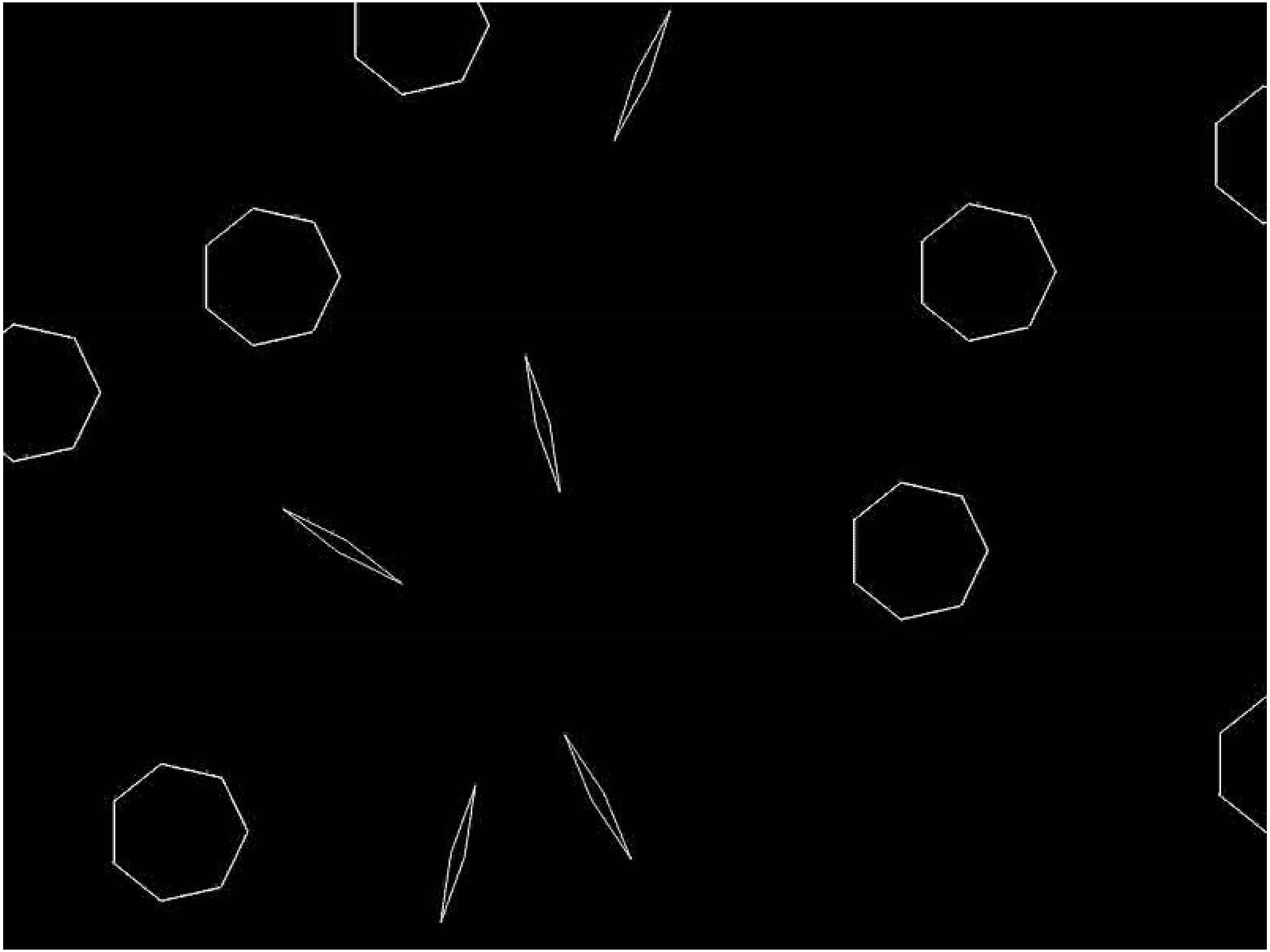


Numerical simulation in geology

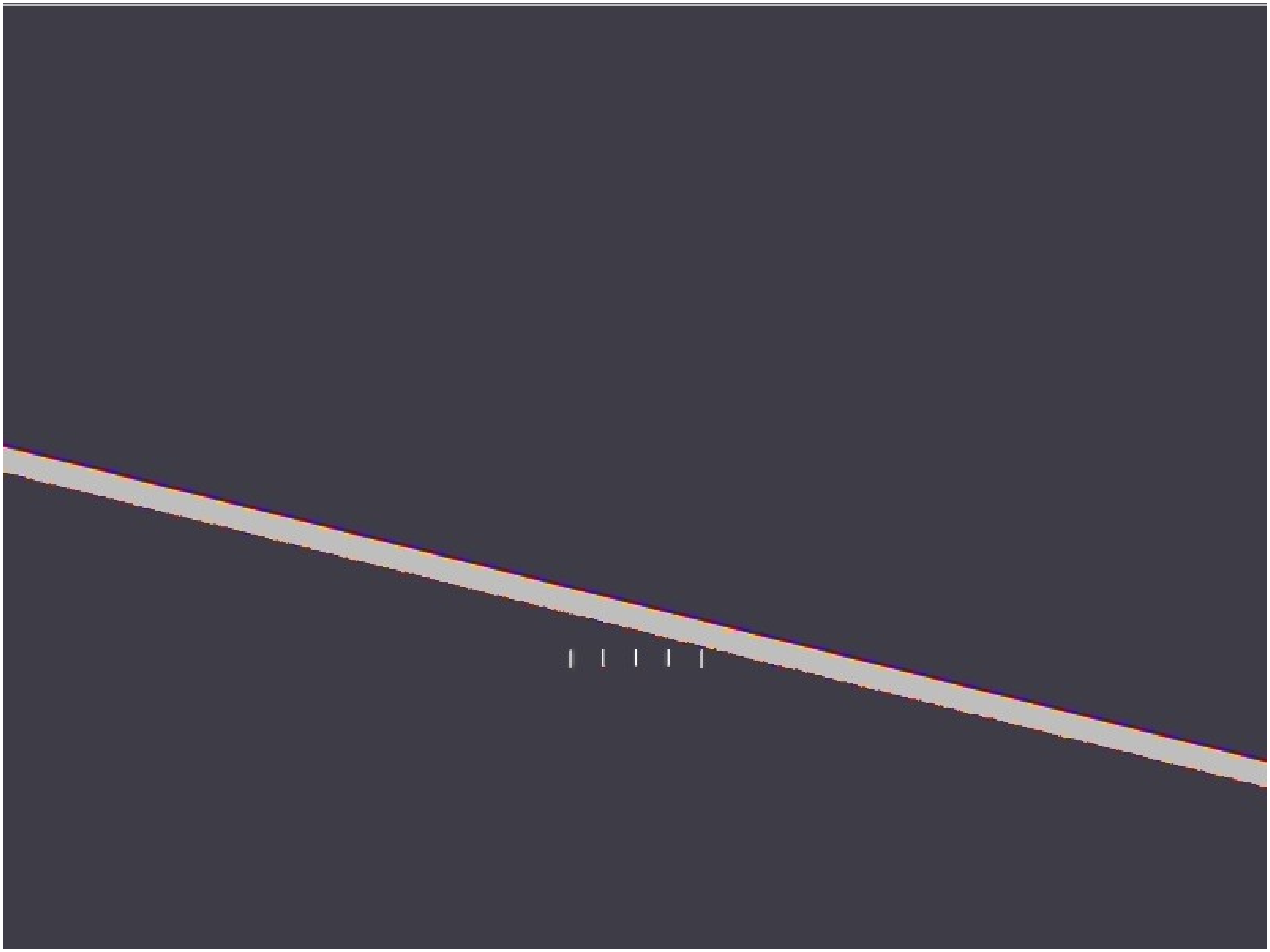
Numerical simulation in geology



Cavities of various shape



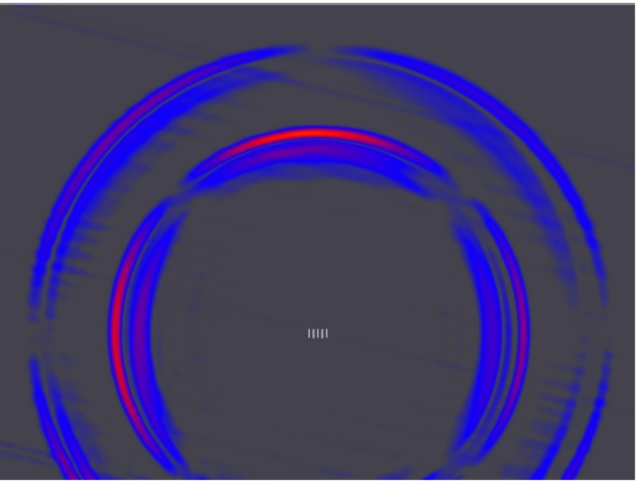
The array of subvertical fluid filled cracks



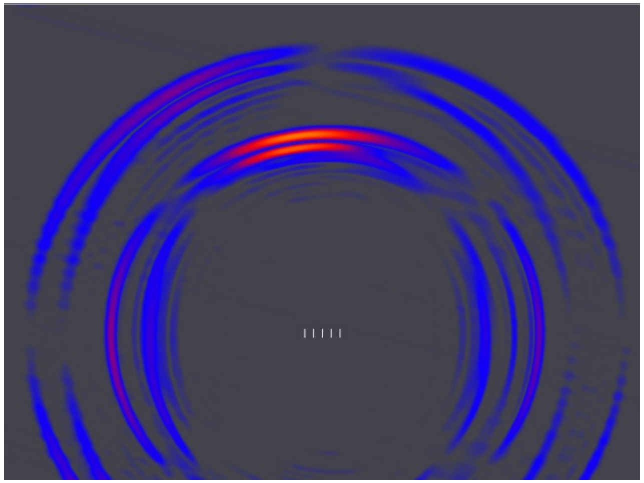
The array of subvertical fluid filled cracks

The distance between cracks/ the length of craks

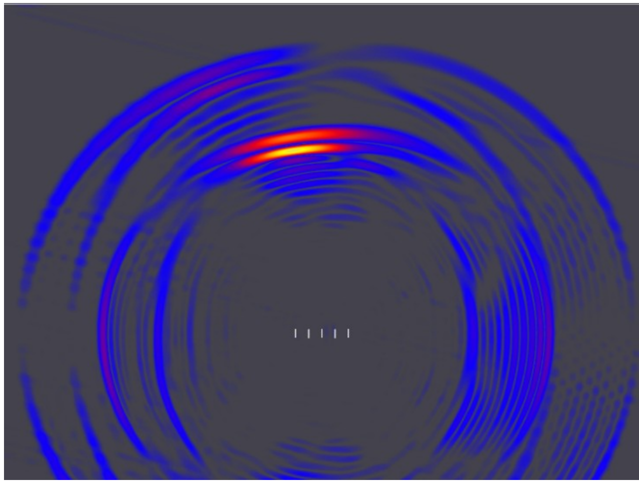
0,5



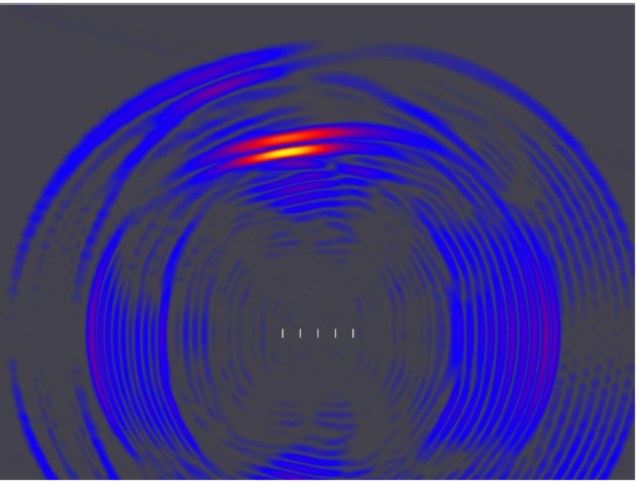
1,0



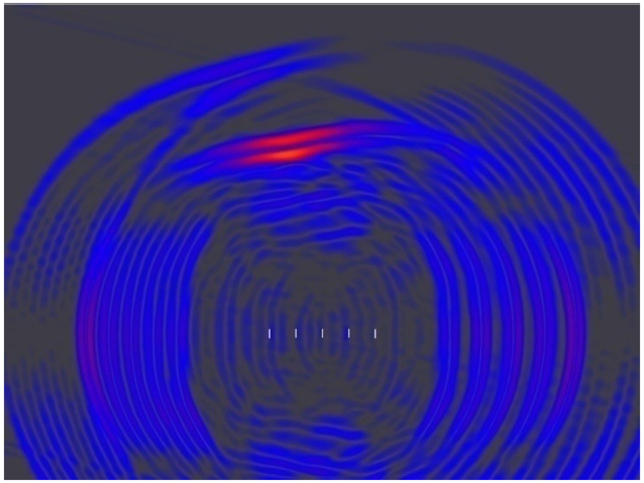
1,5



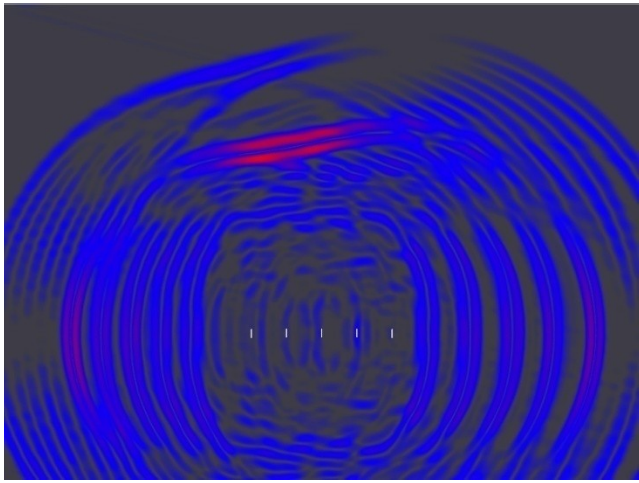
2,0



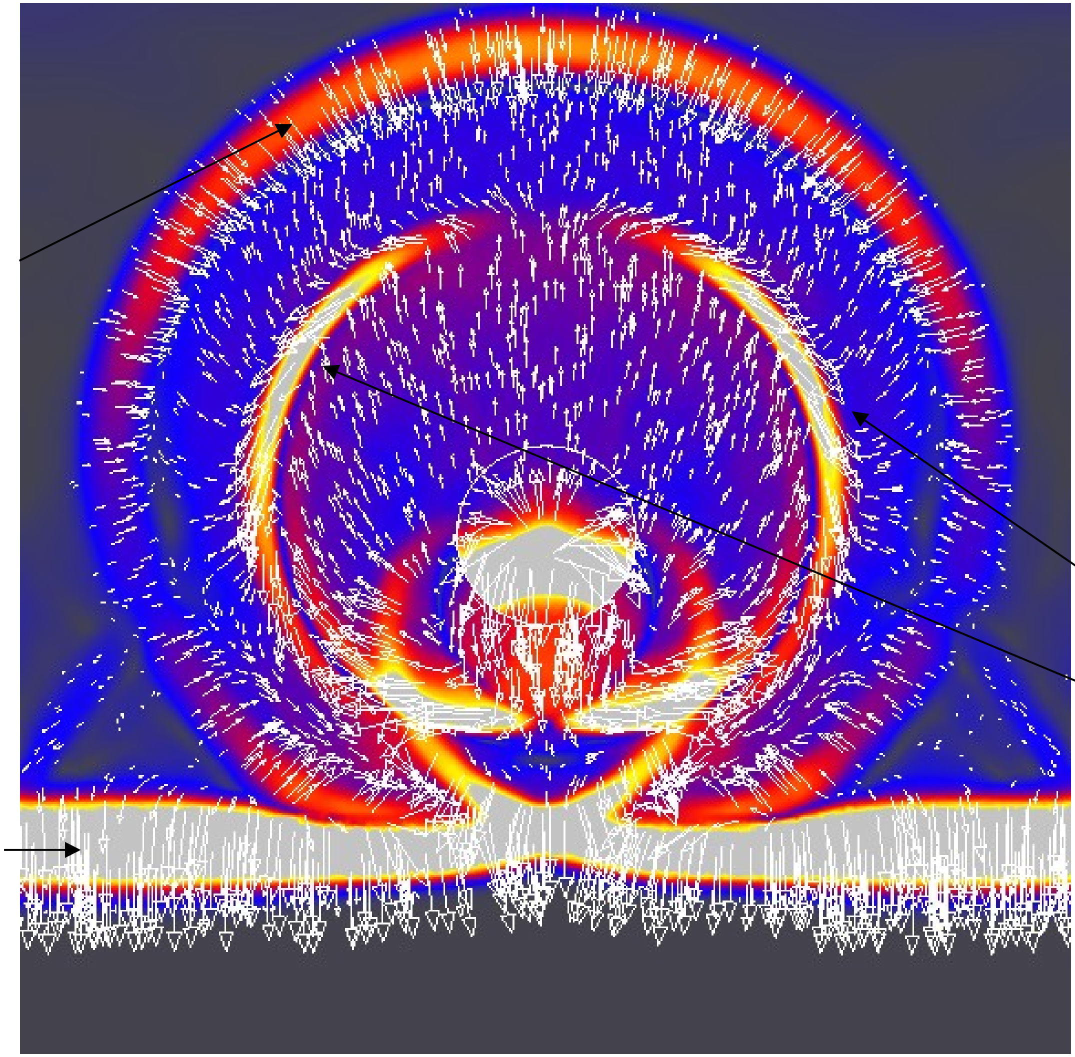
3,0



4,0



Simple fluid filled cavity



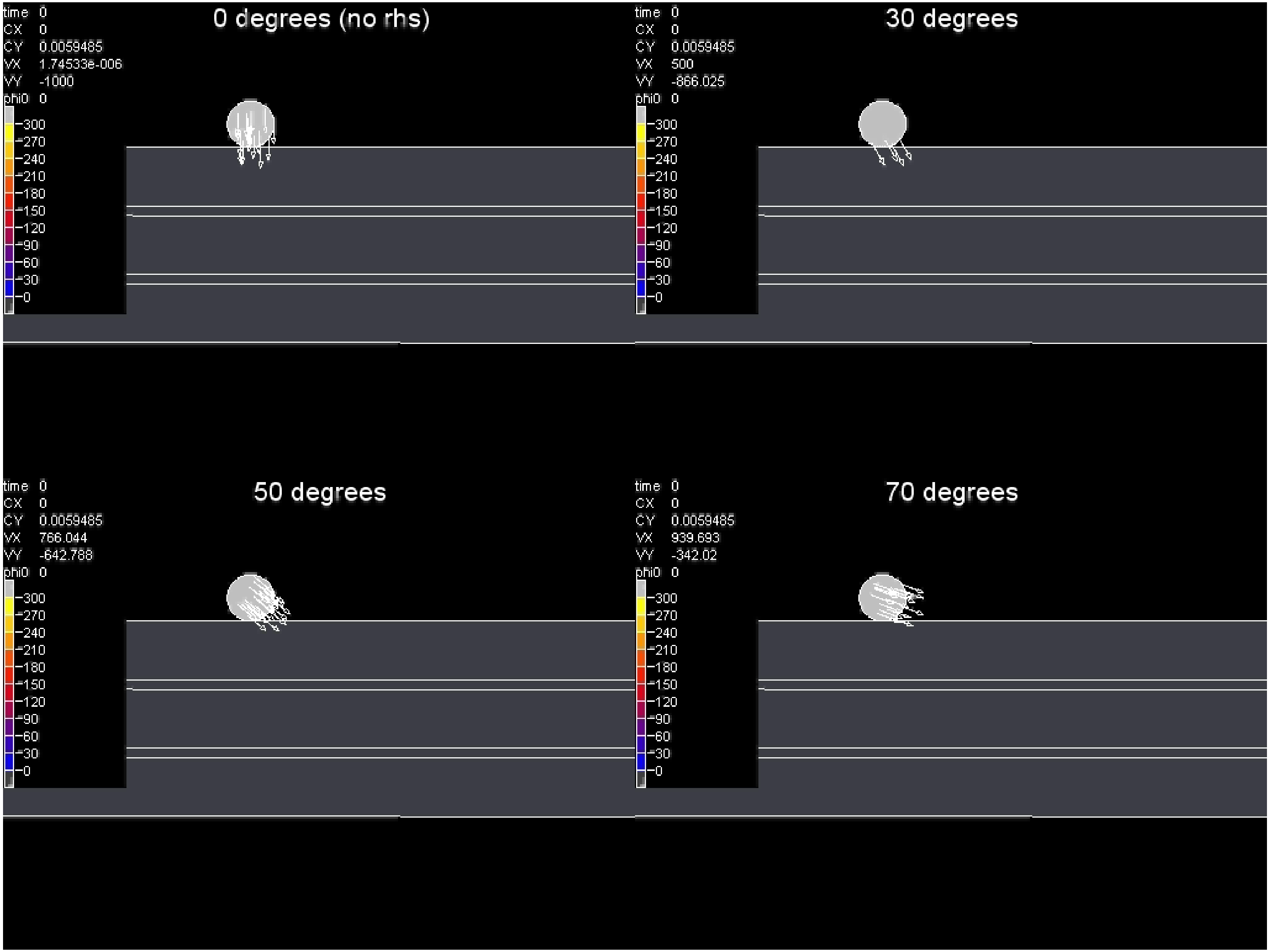
Reflected
P-wave

Wave from
the source

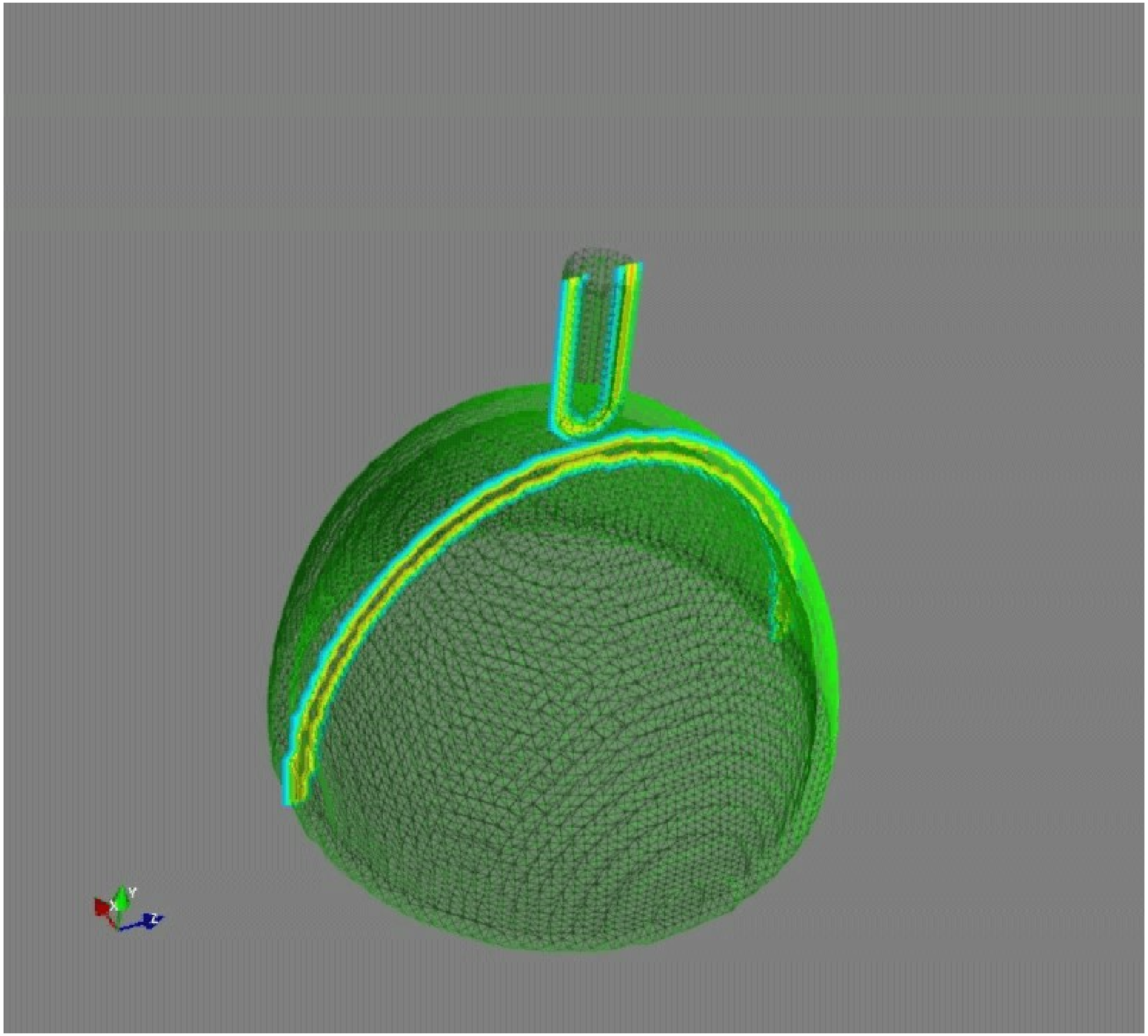
Reflected
wave

The numerical solution of collision problems

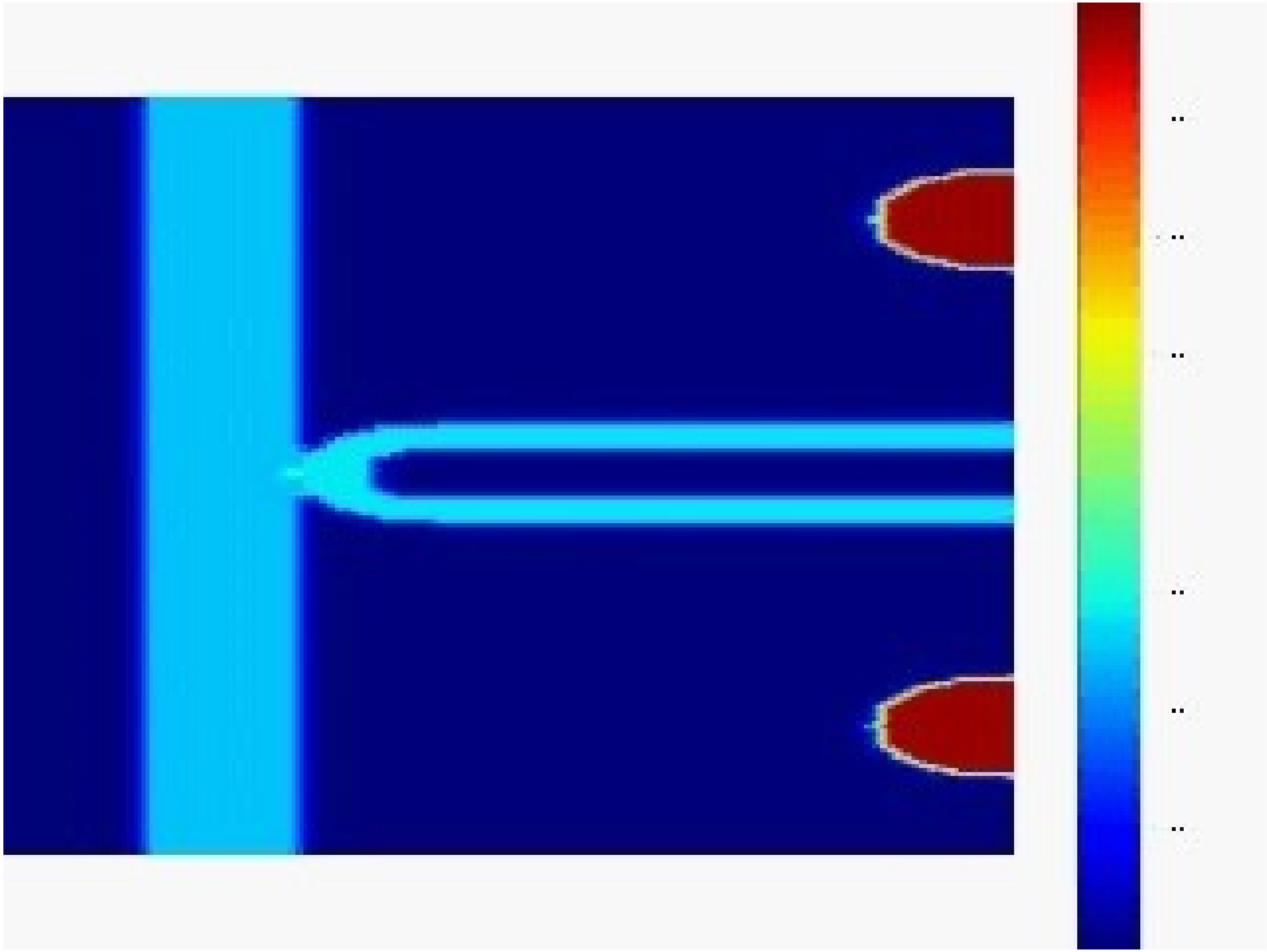
Collision with multilayered barrier



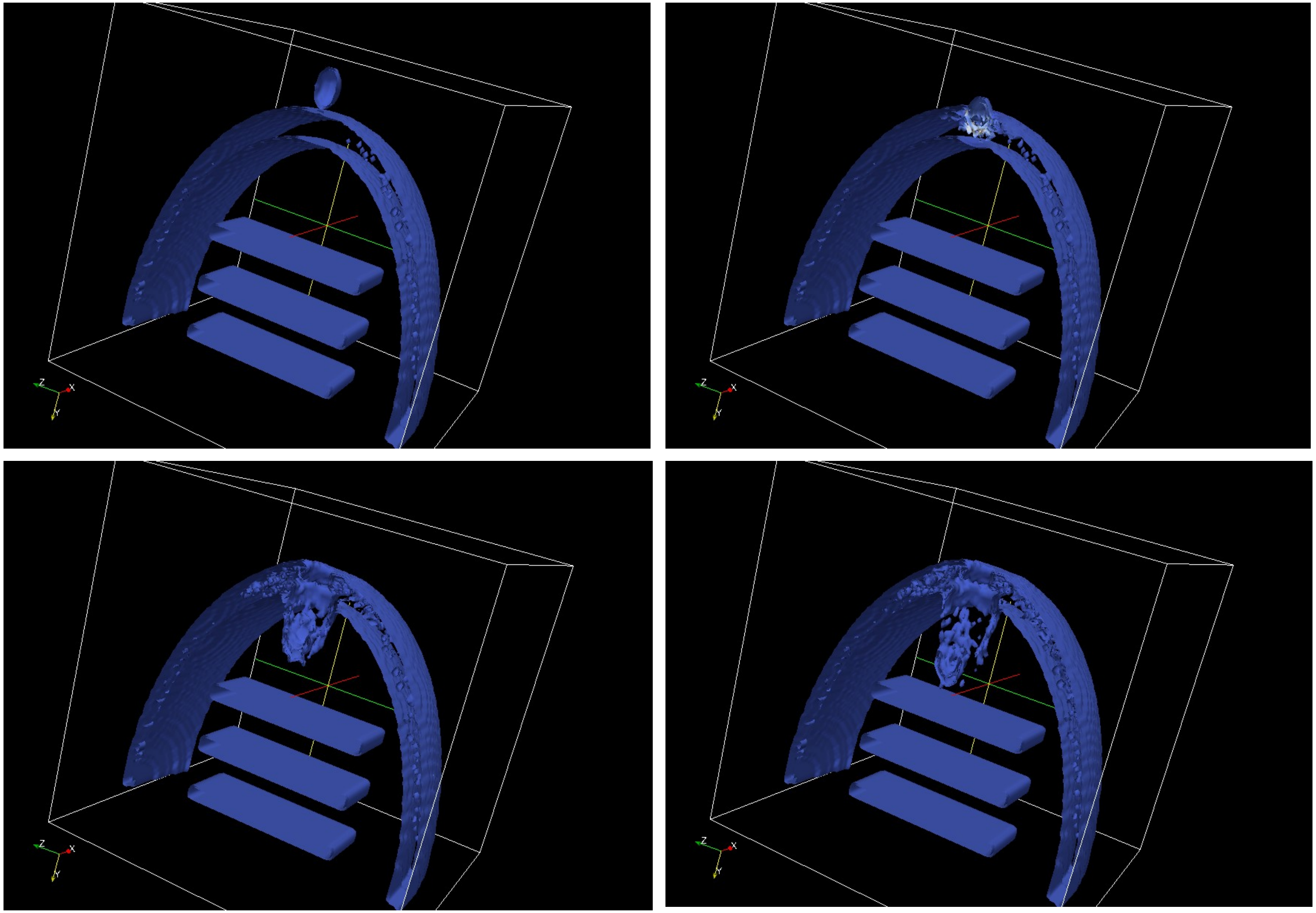
Penetration of striker into curved barrier



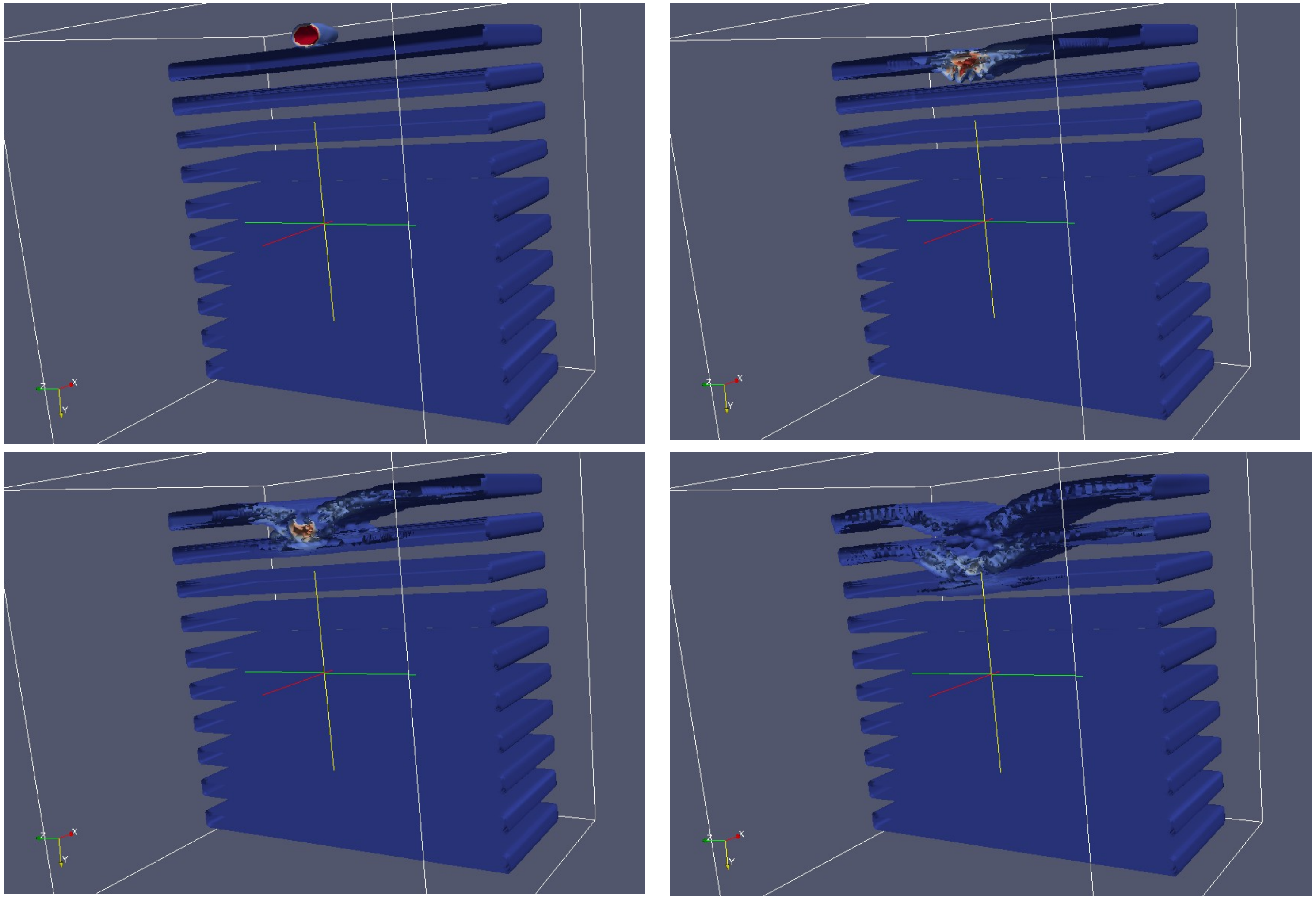
Aircraft collision with the pillar



Multilayer barrier



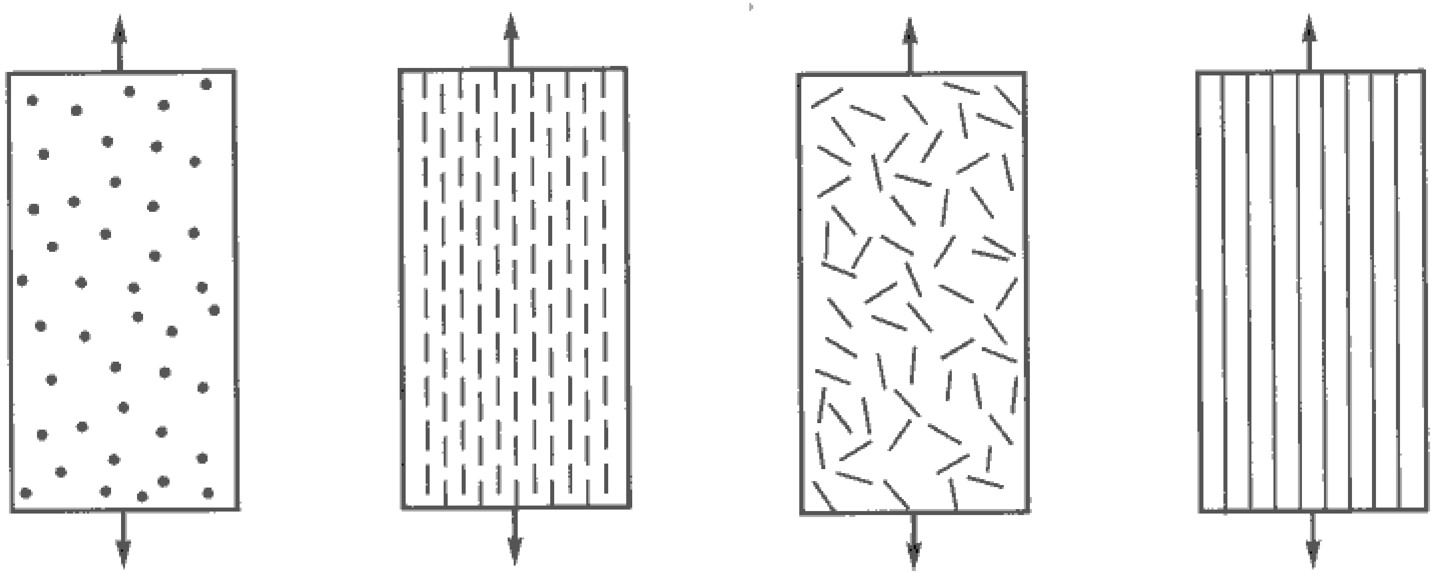
Multilayer barrier



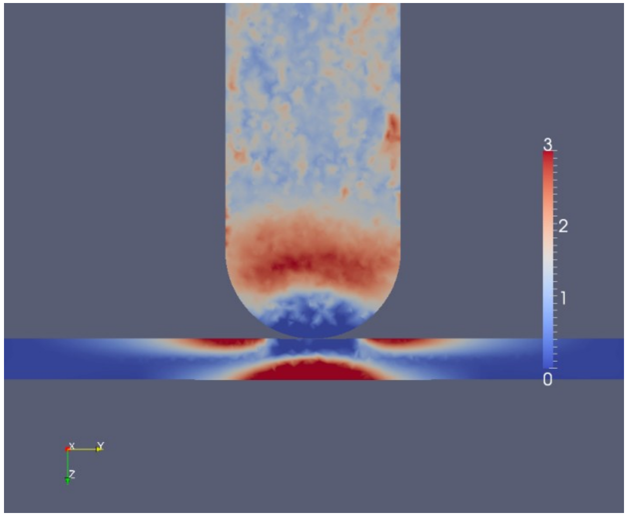
Numerical modeling of composite materials

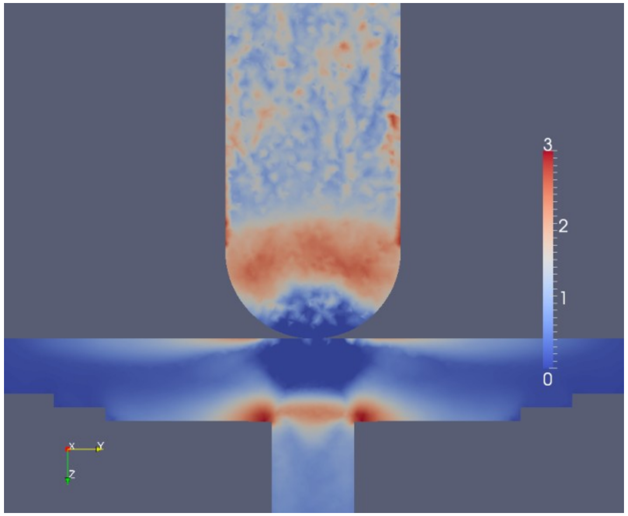
Composite materials

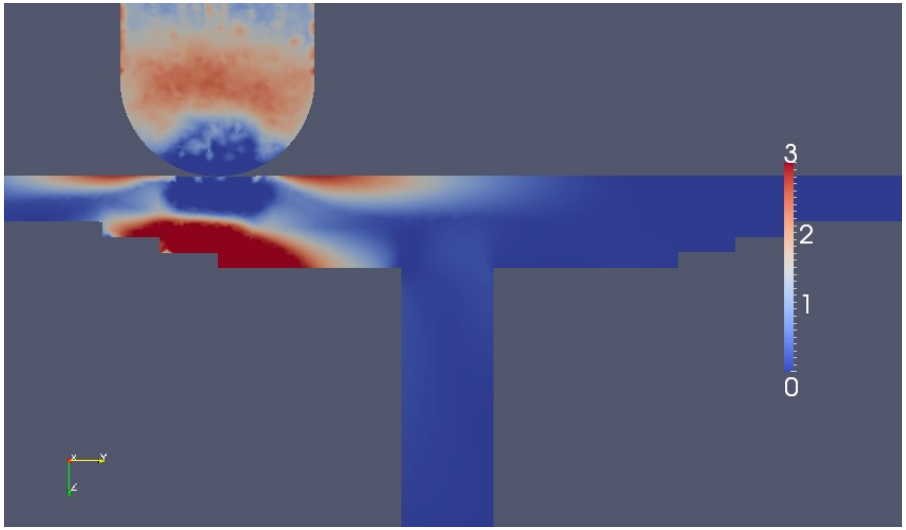
- Microstructure
  - Matrix and filler
  - Types of fibers and their orientations
  - 3D structure of fibers



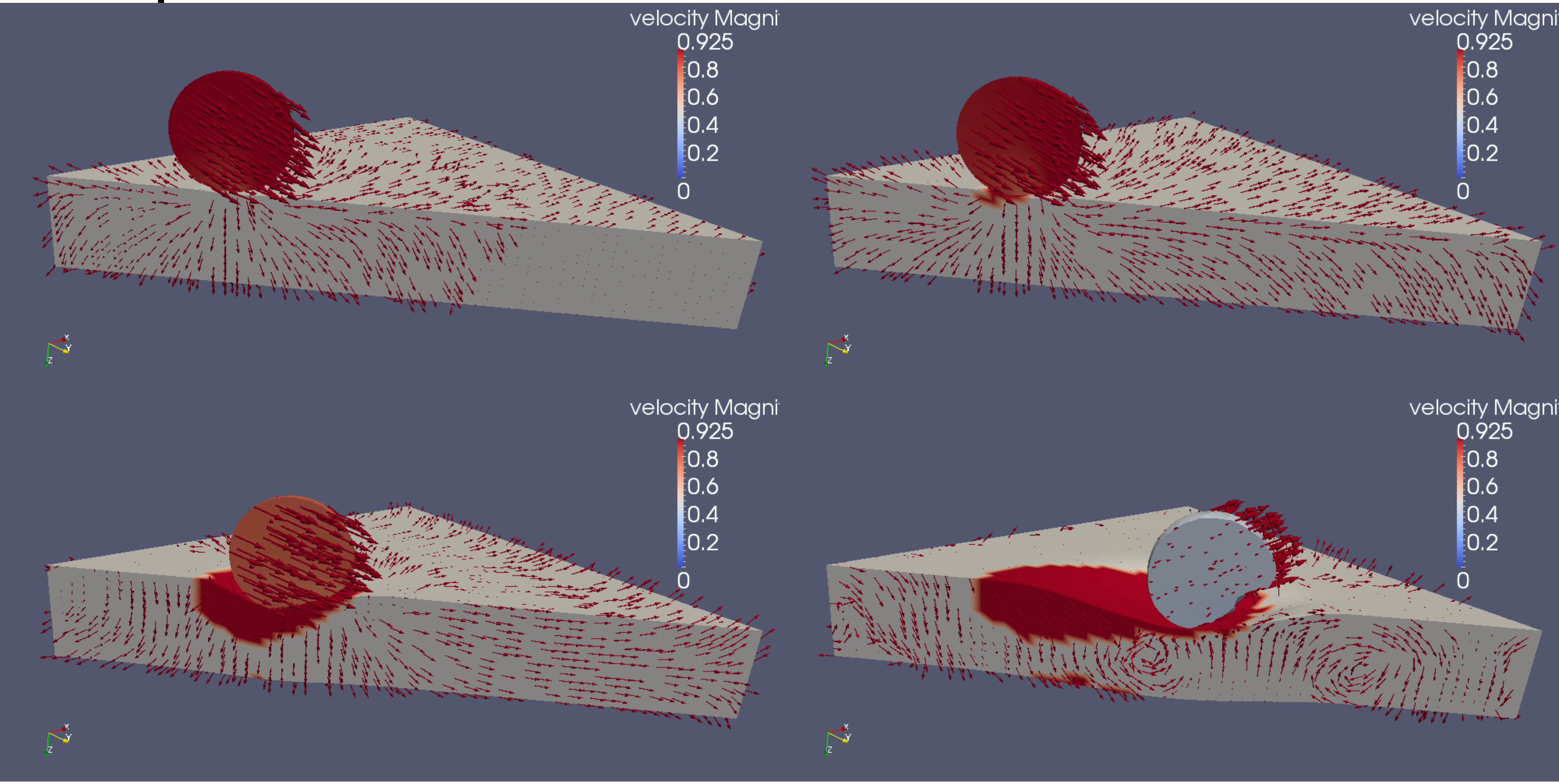
The impact on the stringer







The destruction of steel body during ricochet impact

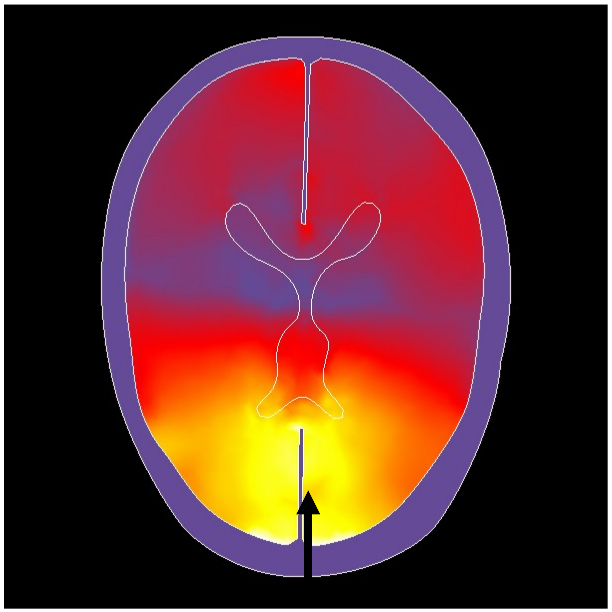


Numerical modeling in Medicine

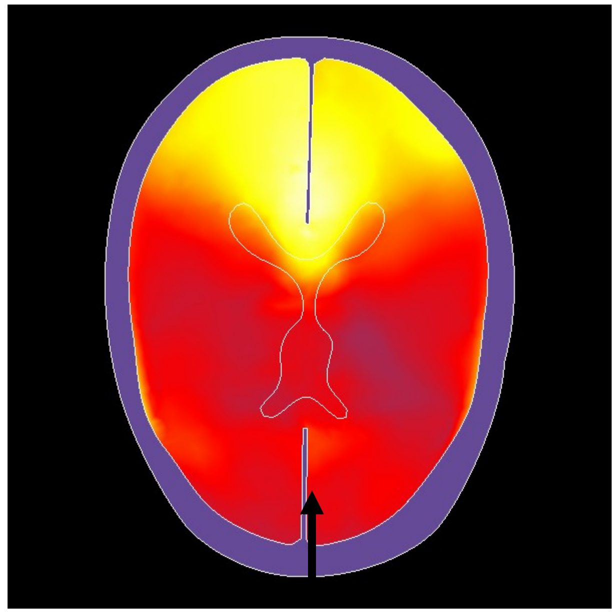
Head damage

Dependence from the angle

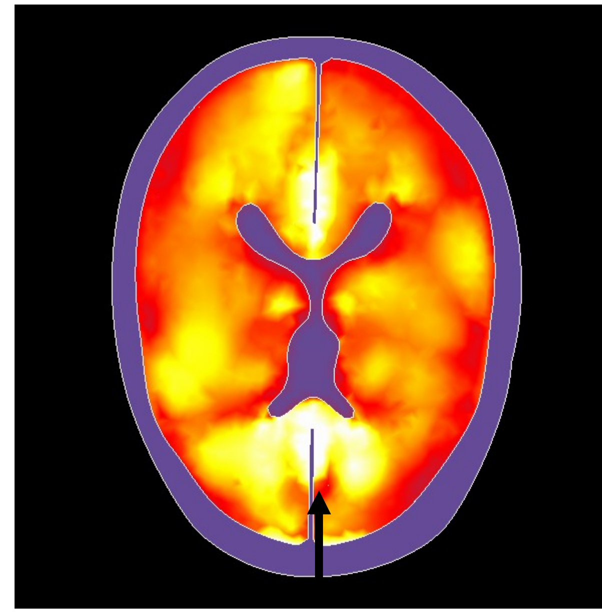
$\alpha = -90°$



Maximum compression, $3 \cdot 10^4$ Па

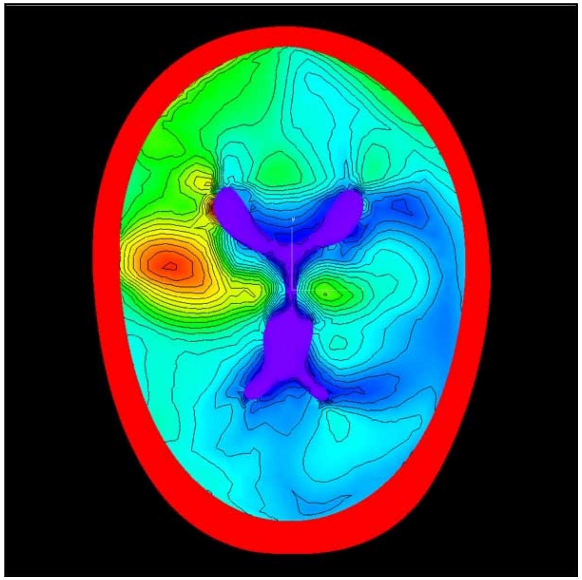


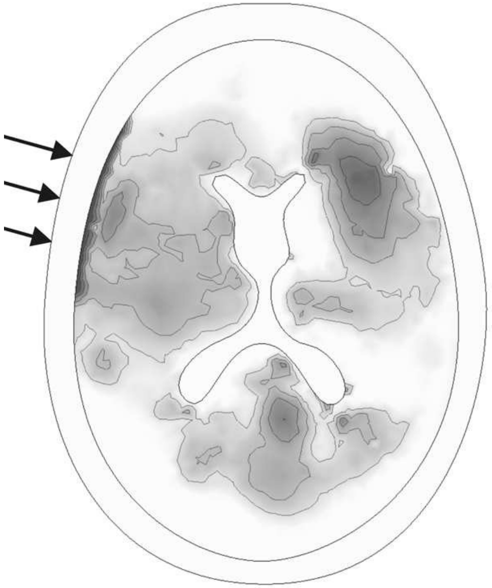
Maximum stretching, $3 \cdot 10^4$ Па

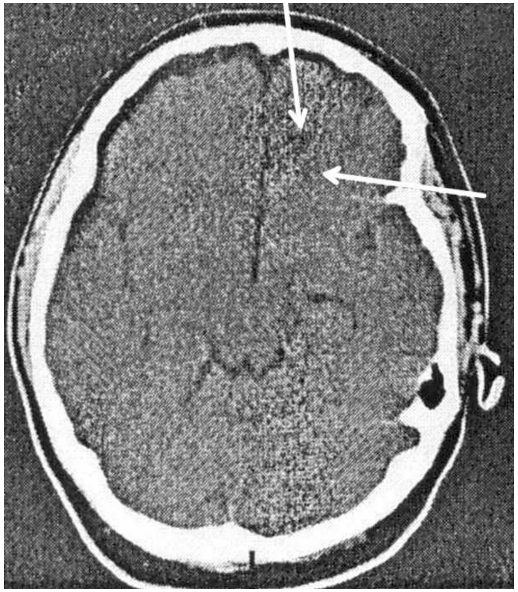


Maximum shear stress, $5 \cdot 10^3$ Па

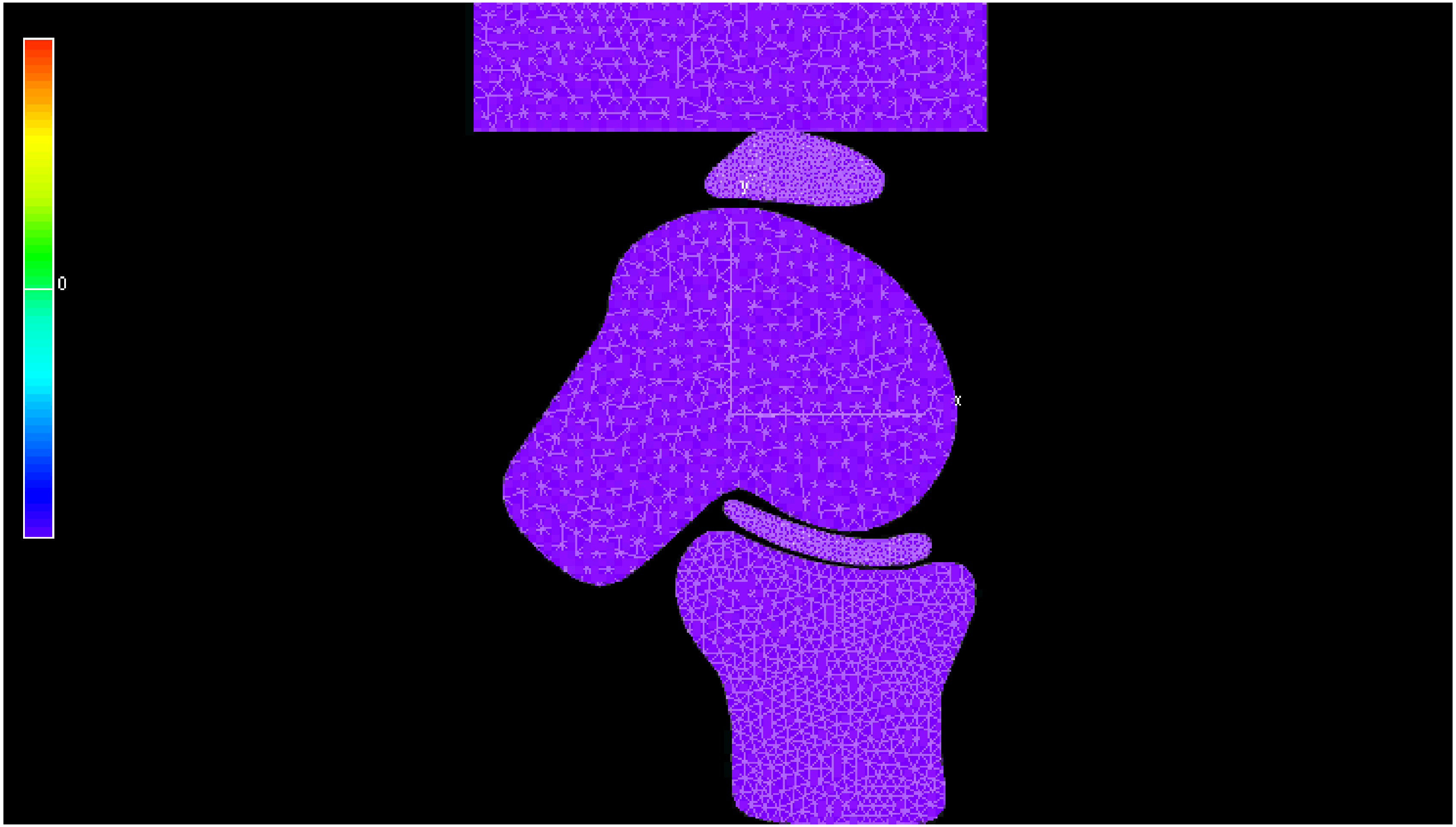
Comparison with clinical results



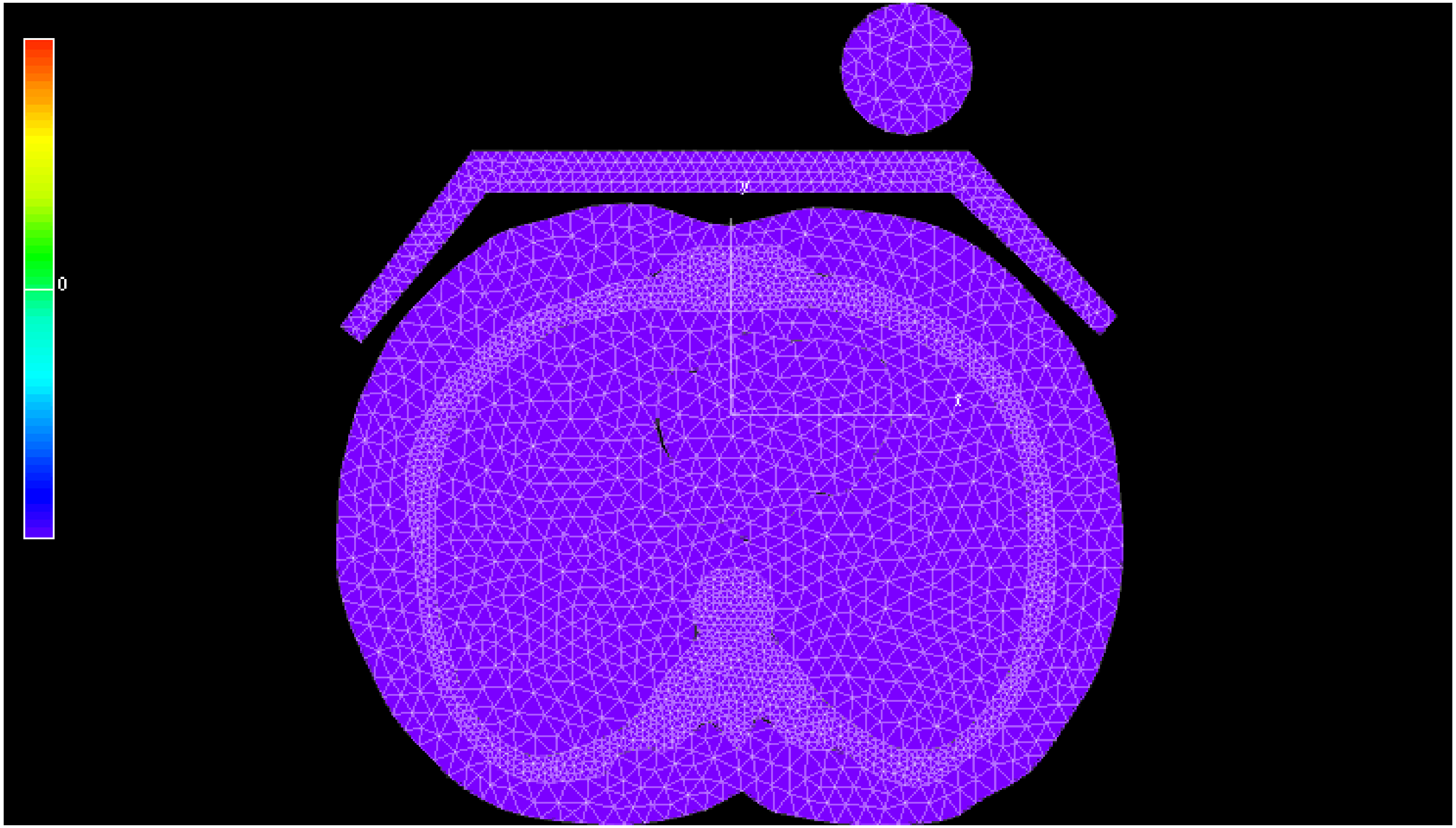




Knee injury

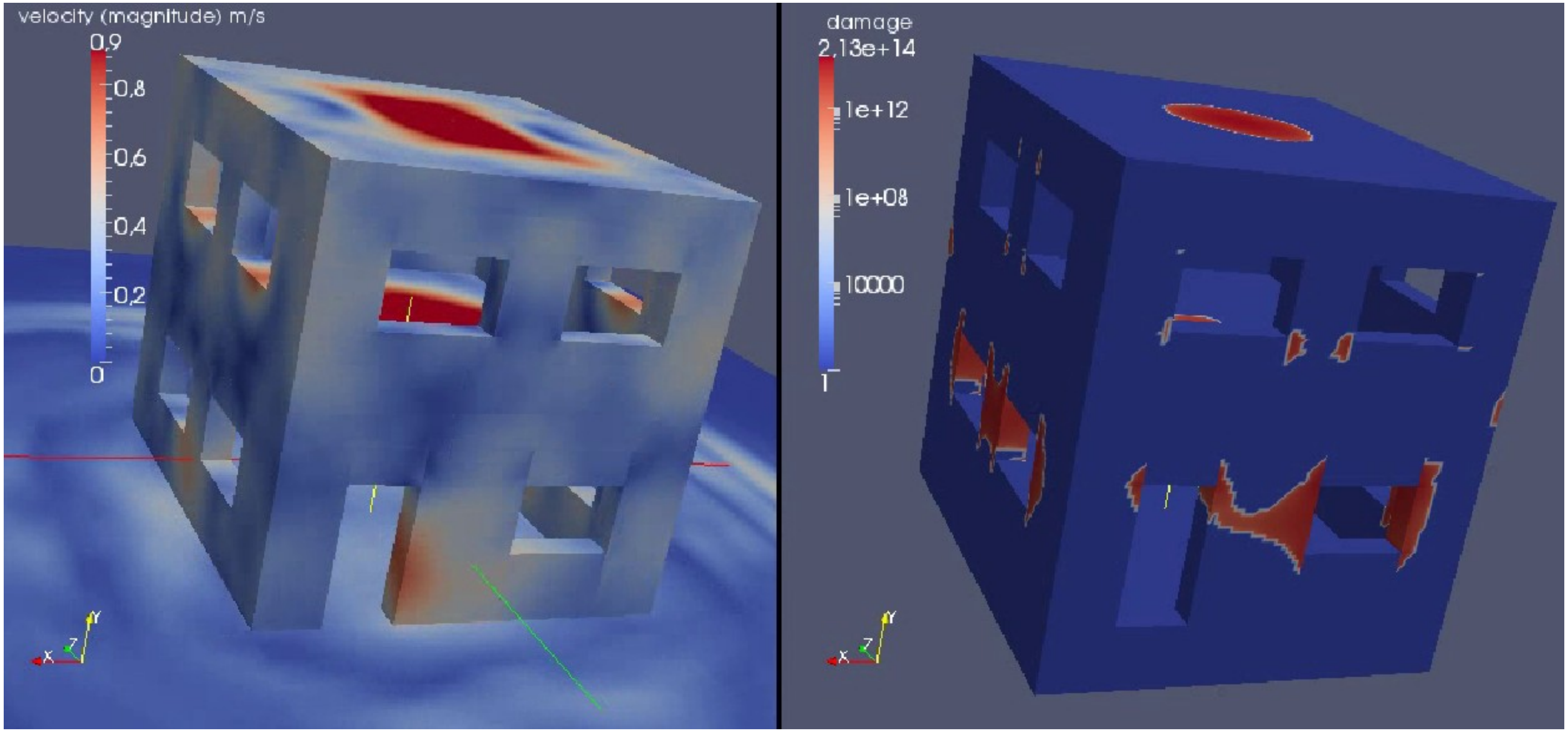


Body armour and human chest



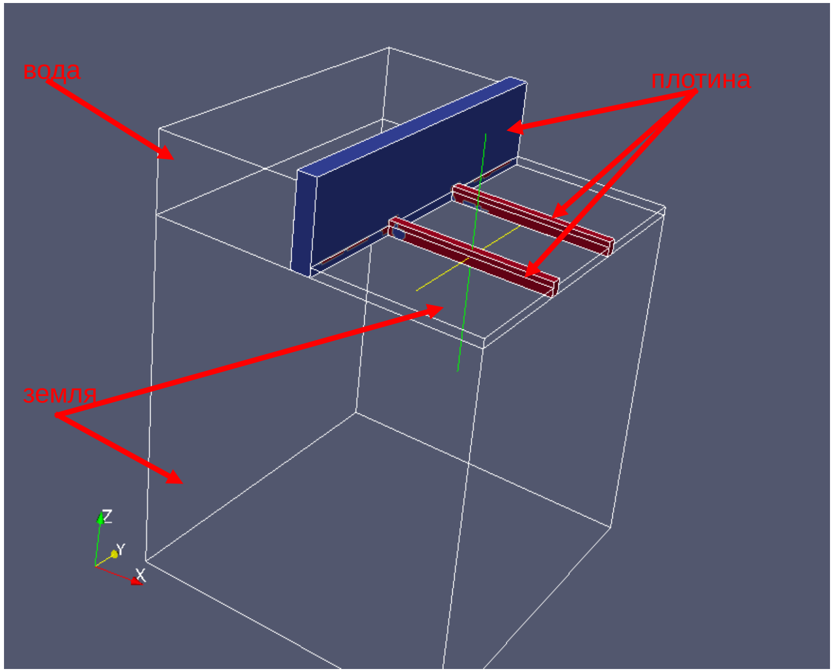
Numerical modeling of seismic stability

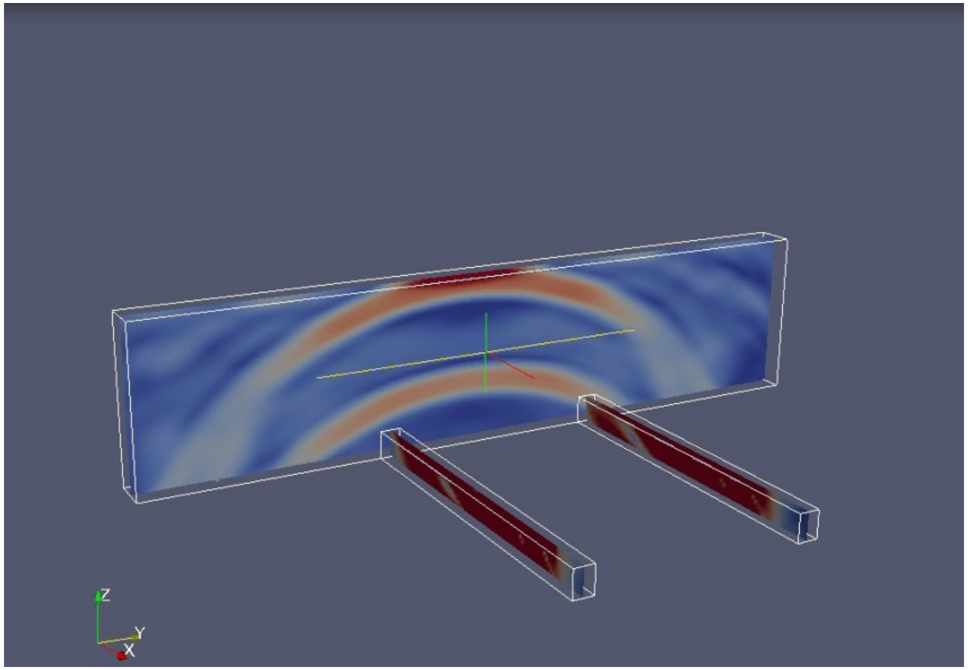
Seismic stability of the building



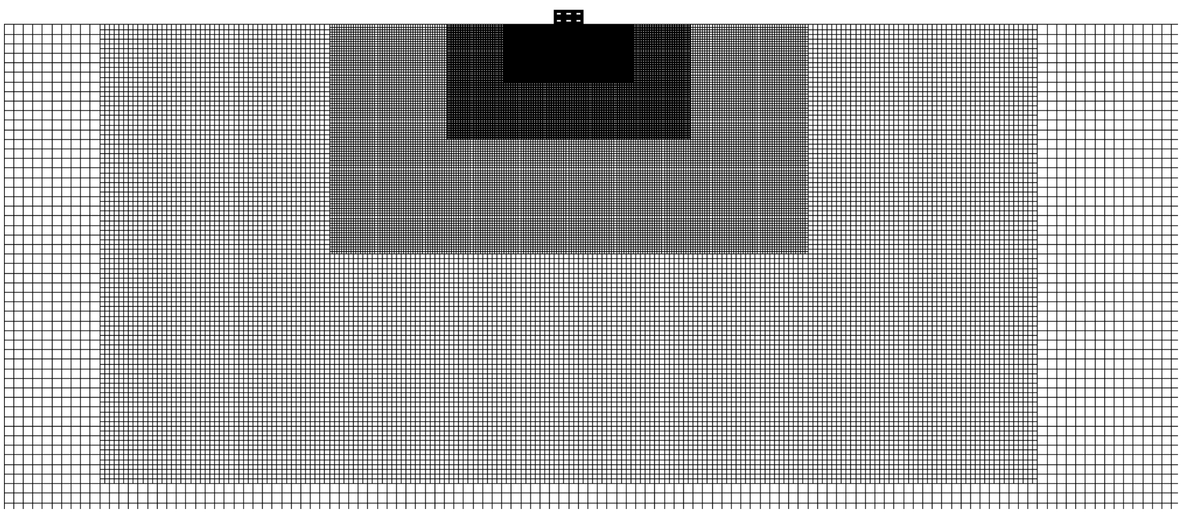
Absolute velocity (left) and destruction zones (right) in red

Seismic stability of river plant

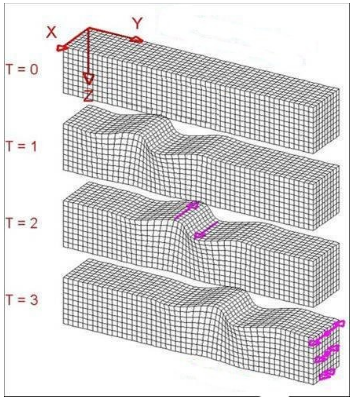




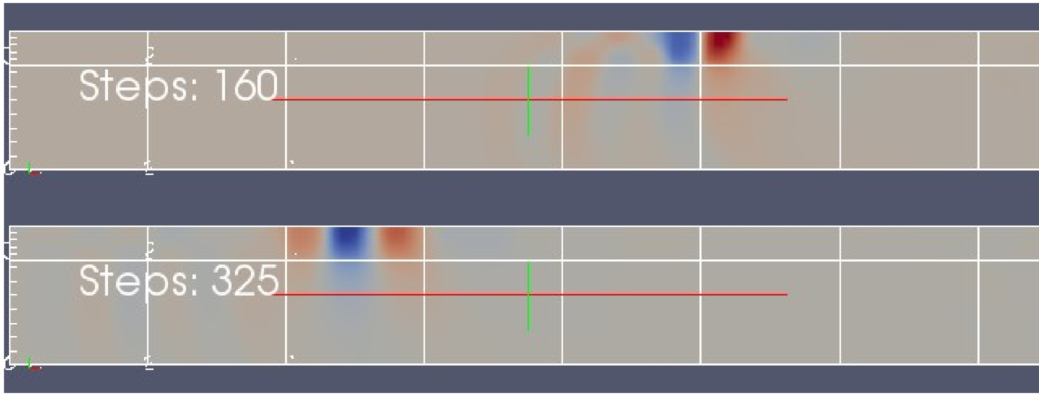
Seismic stability of the building

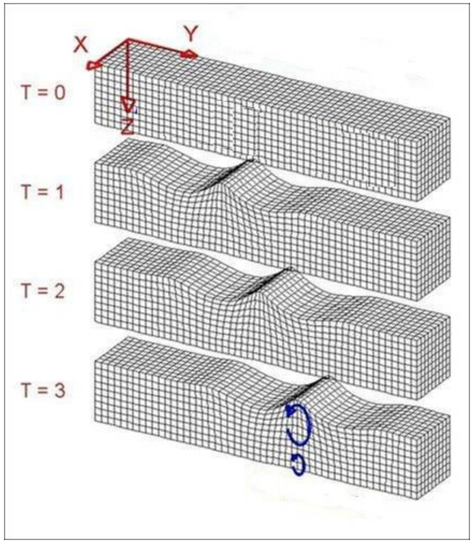


Love and Rayleigh waves

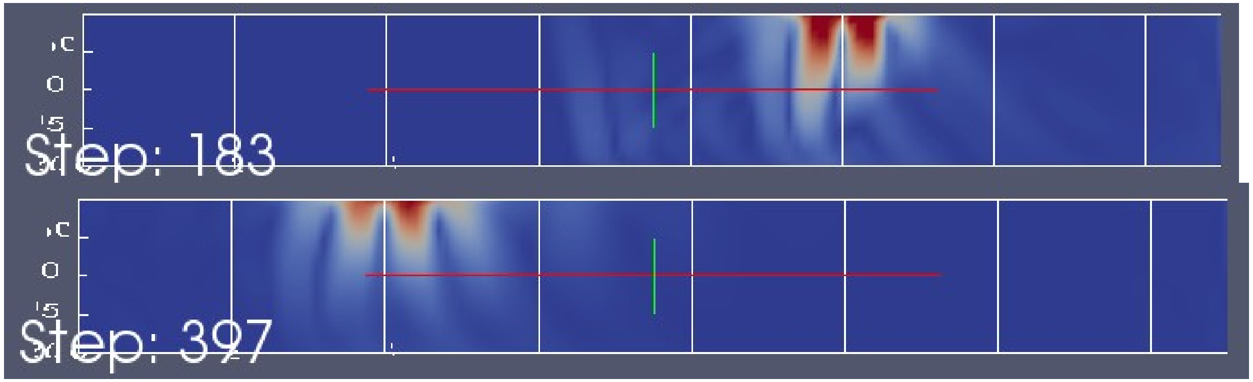


Love waves



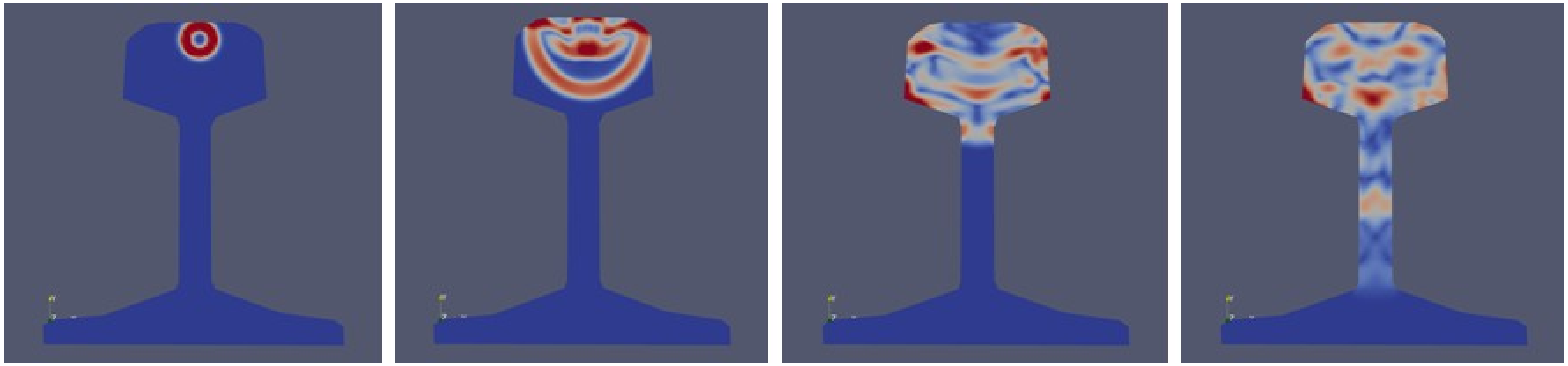


Rayleigh waves

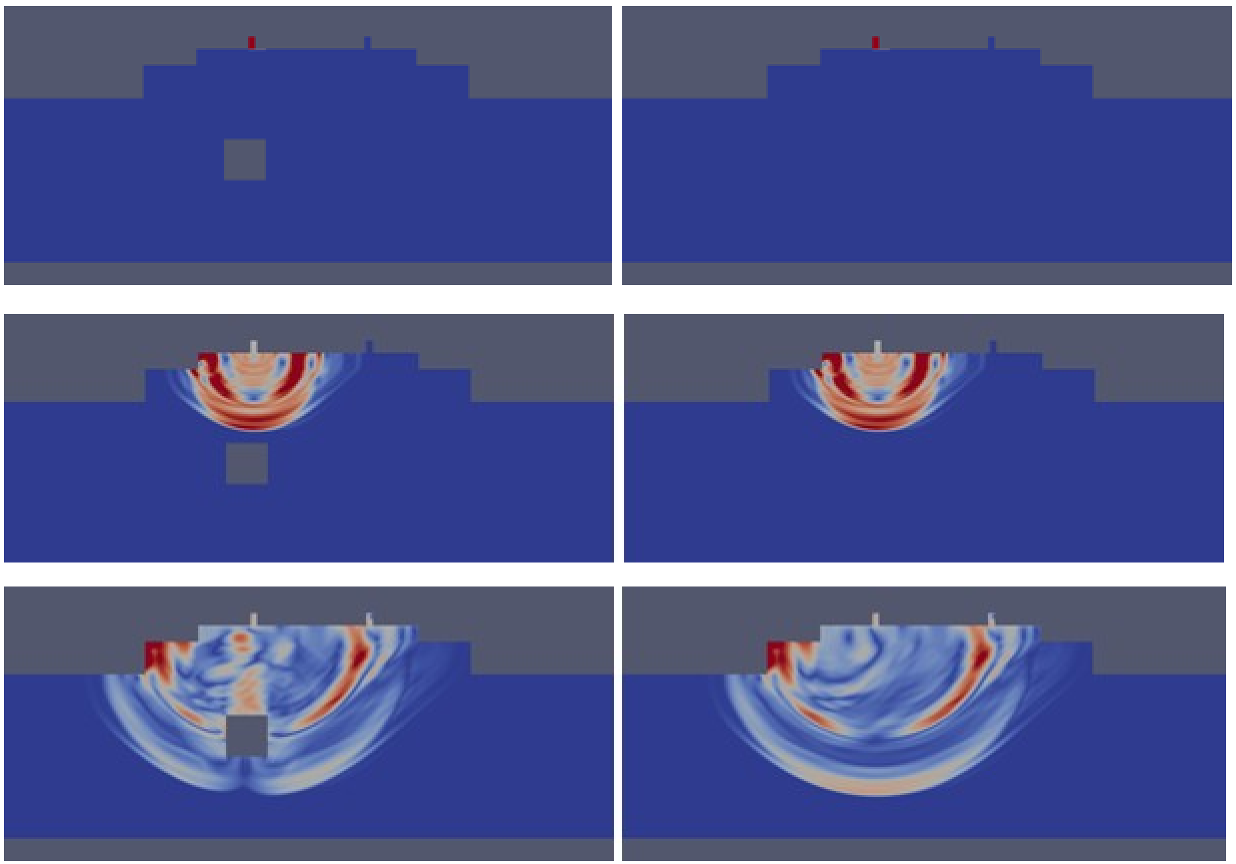


Numerical modeling of non-destructive railway control

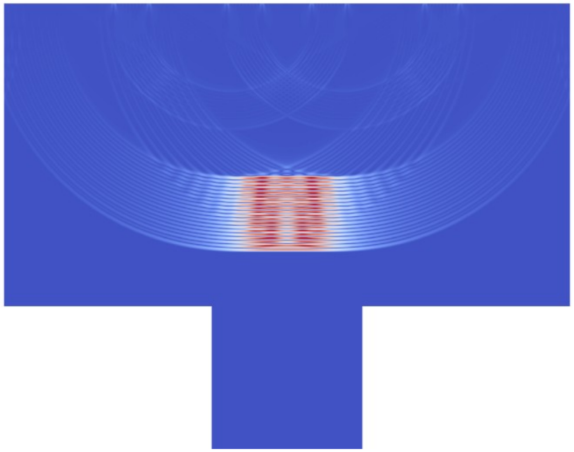
Dynamic impact on the rail



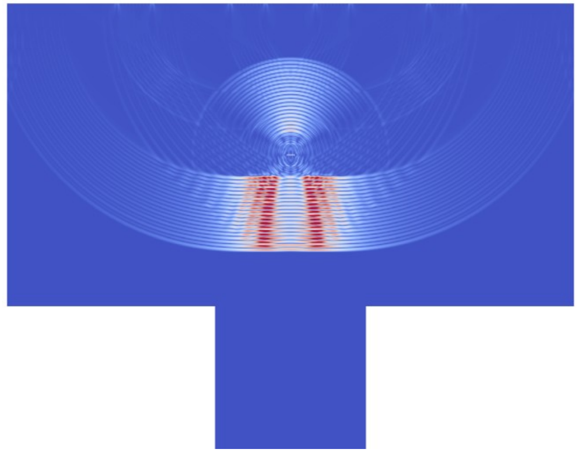
The influence of karst inclusions in the ground above the railway



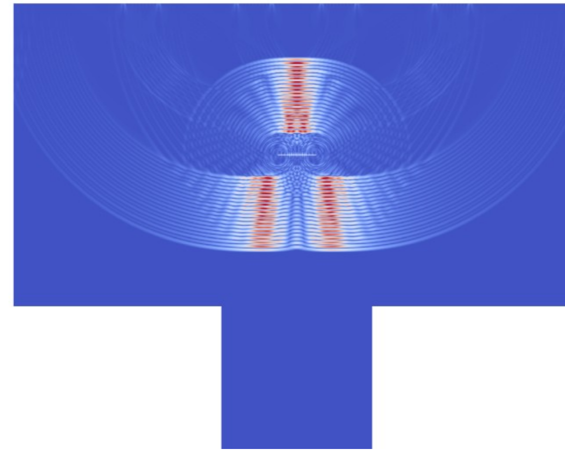
Non-destructive railway control



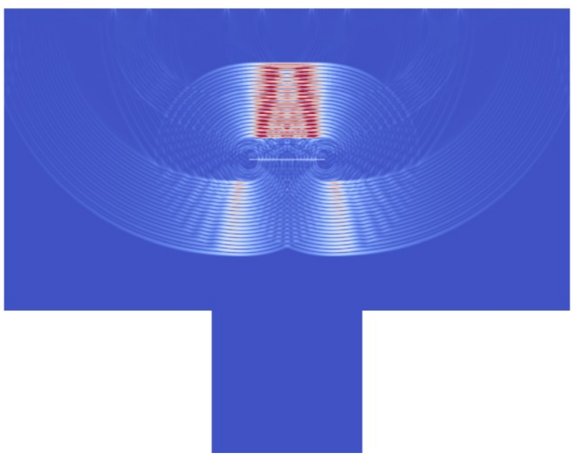
Without crack



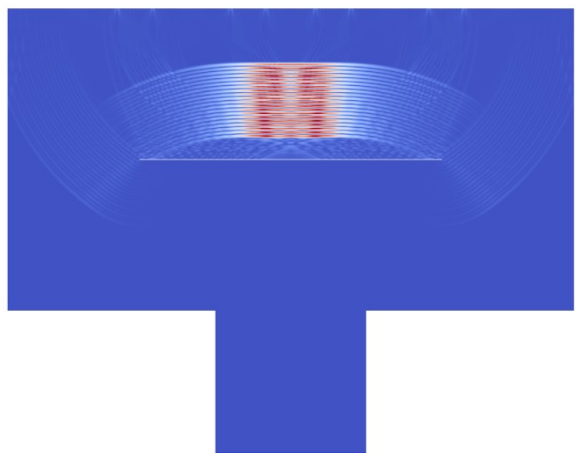
1 mm



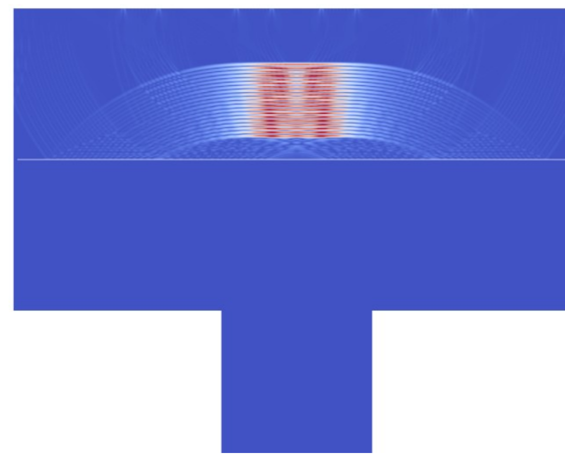
5 mm



10 mm



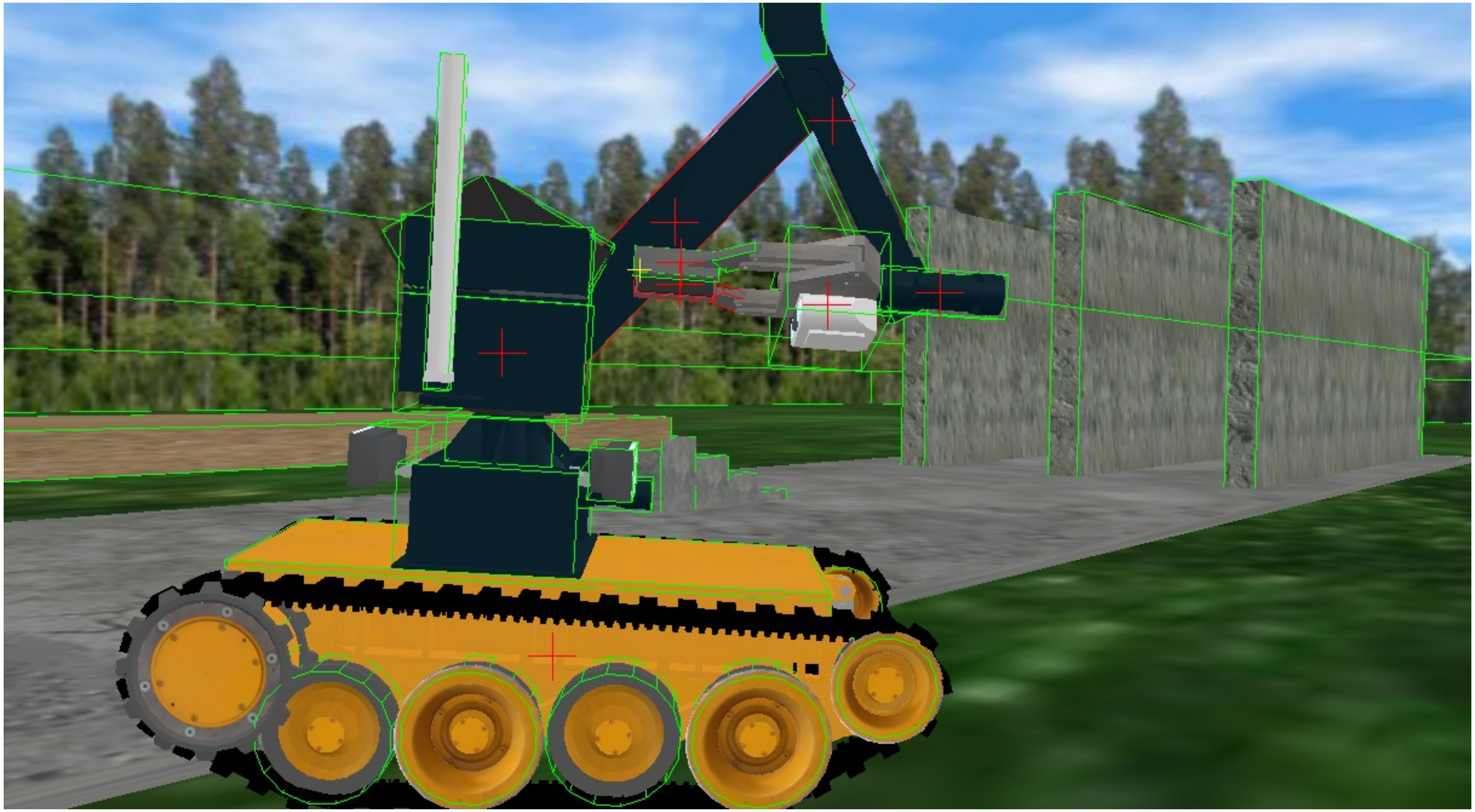
40 mm



74 mm

Robot-technique

Robot-technique



Robot-technique

Robot-technique

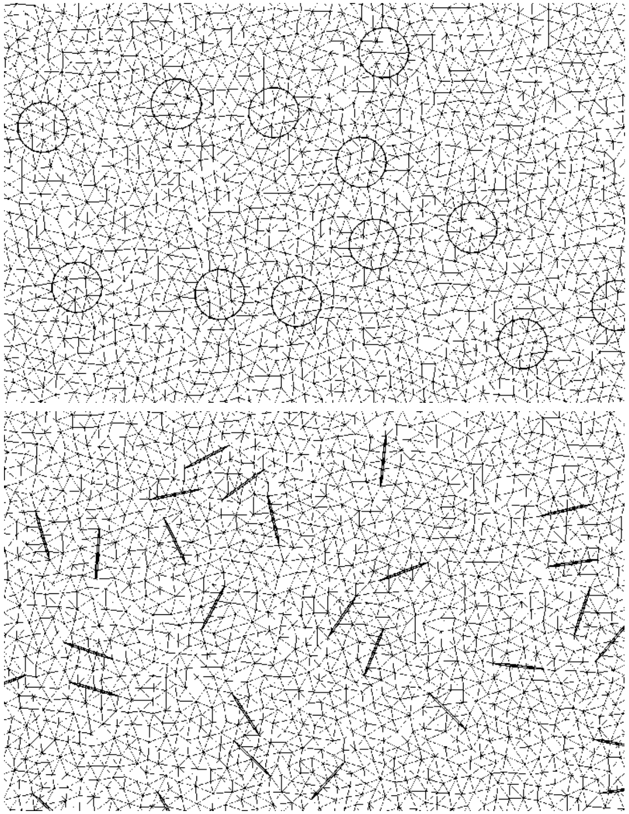
Robot-technique

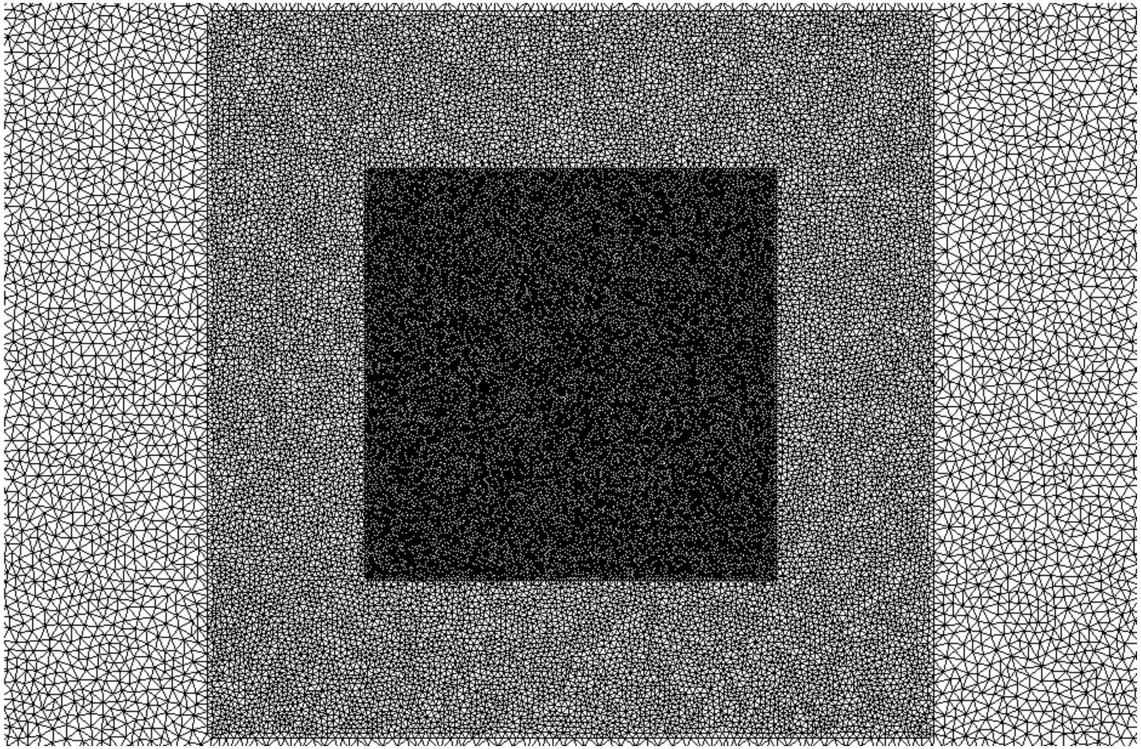
Robot-technique

Grid-characteristic method

Grids

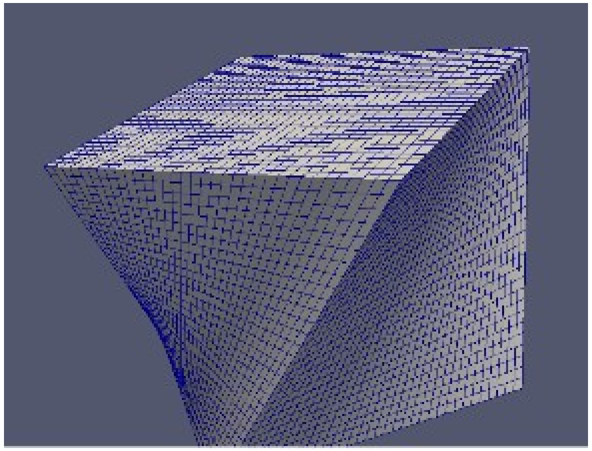
- Triangular unstructured grid
- Grids with various average step

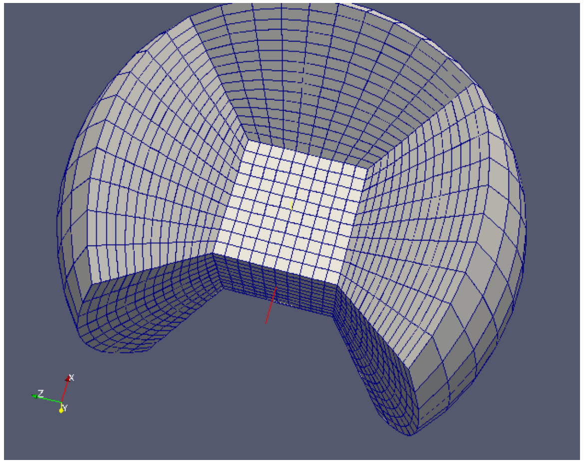


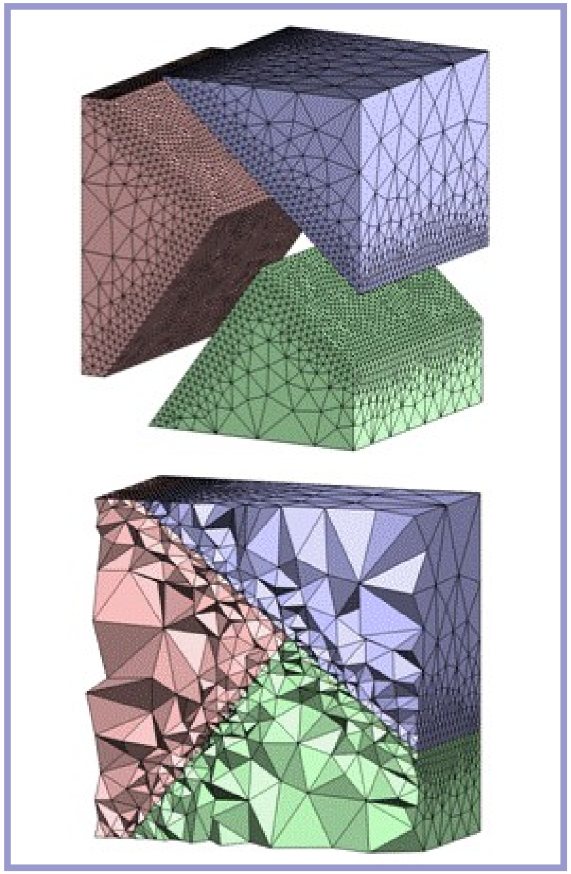


Grids

- Curvilinear grids
- Tetrahedral grids







System of equations describing elastic and acoustic waves

- Elastic waves:

$$\rho \partial_t \vec{v} = \left(\nabla \times \boldsymbol{\sigma} \right)^{T}$$

$$\partial_t \boldsymbol{\sigma} = \lambda \left(\nabla \times \vec{v} \right) \mathbf{I} + \mu \left(\nabla \otimes \vec{v} + \left(\nabla \otimes \vec{v} \right)^{T} \right)$$

ρ density, $\vec{v}$ velocity in the elastic media, $\boldsymbol{\sigma}$ stress tension,

λ, μ Lame's parameters,

$c_p = \left(\left(\lambda + 2\mu \right) / \rho \right)^{1/2}$ speed of P-waves,

$c_s = \left(\mu / \rho \right)^{1/2}$ speed of S-waves.

- Acoustic waves:

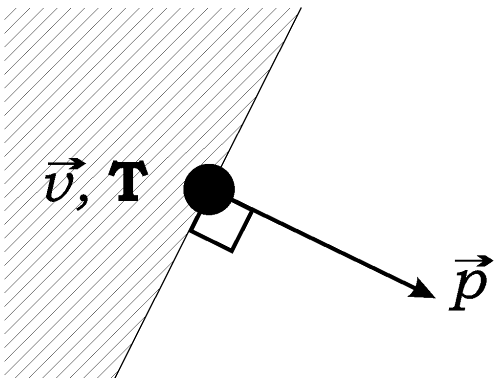
$$\rho \partial_t \vec{v} = \nabla p$$

$$\partial_t p = c^2 \rho \left(\nabla \times \vec{v} \right)$$

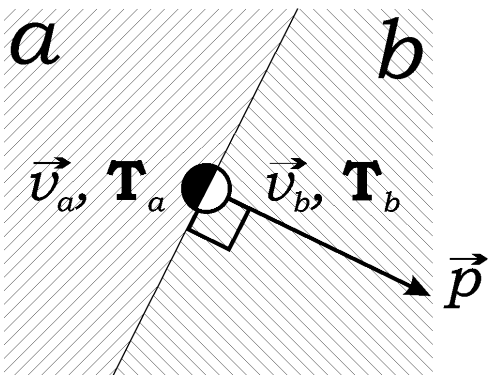
ρ density, $\vec{v}$ velocity in the acoustic media, p pressure, c speed of sound.

Boundary and interface conditions

Boundary



Interface



- Given traction

$$\boldsymbol{\sigma}\vec{p} = \vec{f}$$

- Given velocity of boundary

$$\vec{v} = \vec{V}$$

- Mixed boundary conditions
- Absorbing boundary contions

Continuity of the velocity and traction

$$\vec{v}_a = \vec{v}_b = \vec{V}, \vec{\sigma}_a = -\vec{\sigma}_b$$

Free sliding conditions

$$\vec{v}_a \cdot \vec{p} = \vec{v}_b \cdot \vec{p}, \sigma_p^a = \sigma_p^b, \sigma_\tau^a = \sigma_\tau^b = 0$$

The interface condition between acoustic and elastic bodies

Thank you for your attention!