The second international conference "Quasilinear Equations, Inverse Problems and their Applications" in memory of G.M. Henkin

Simulation of 3-D seismic responses from curvilinear geological boundaries

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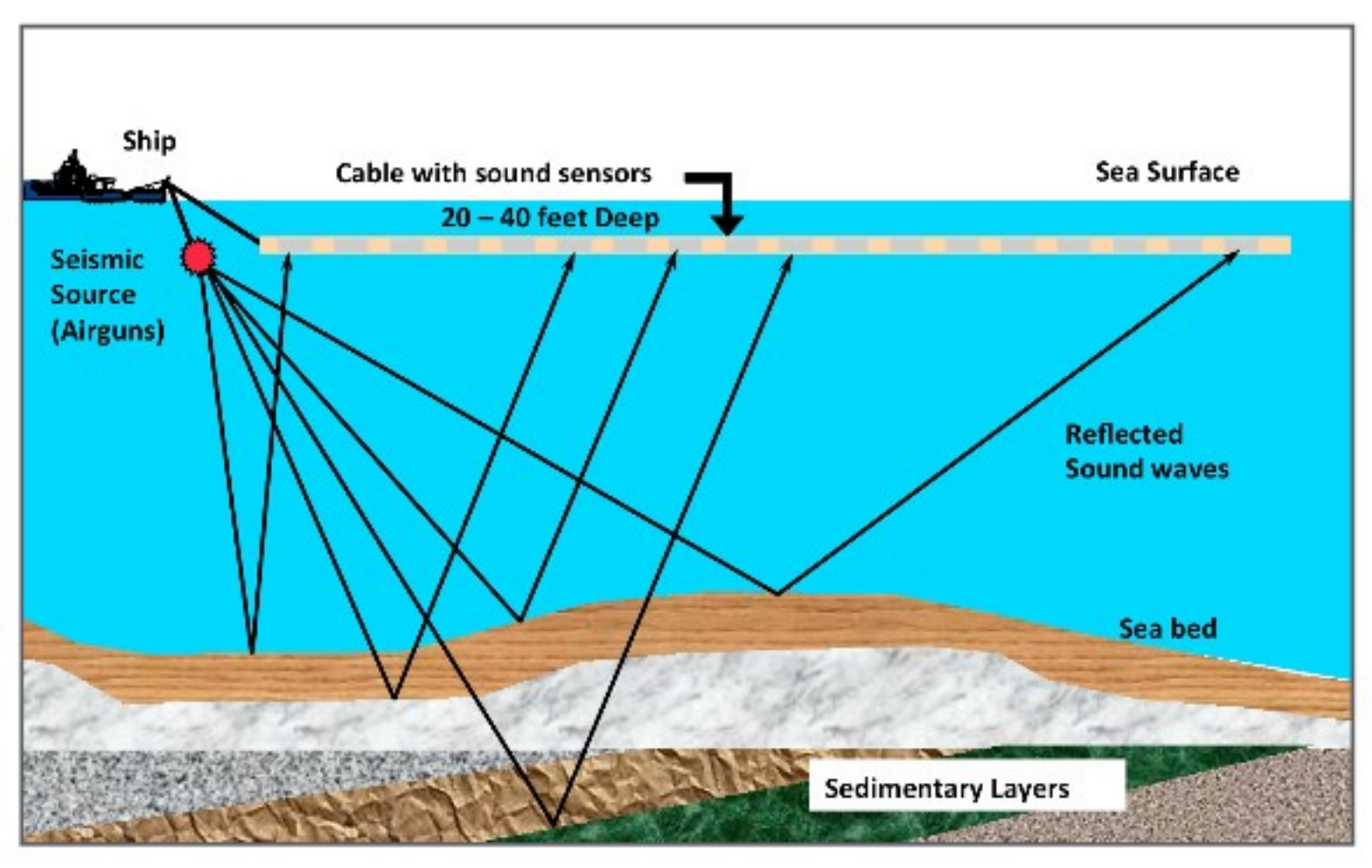
Dolgoprudny, Russia, September 12–15, 2016

Outline

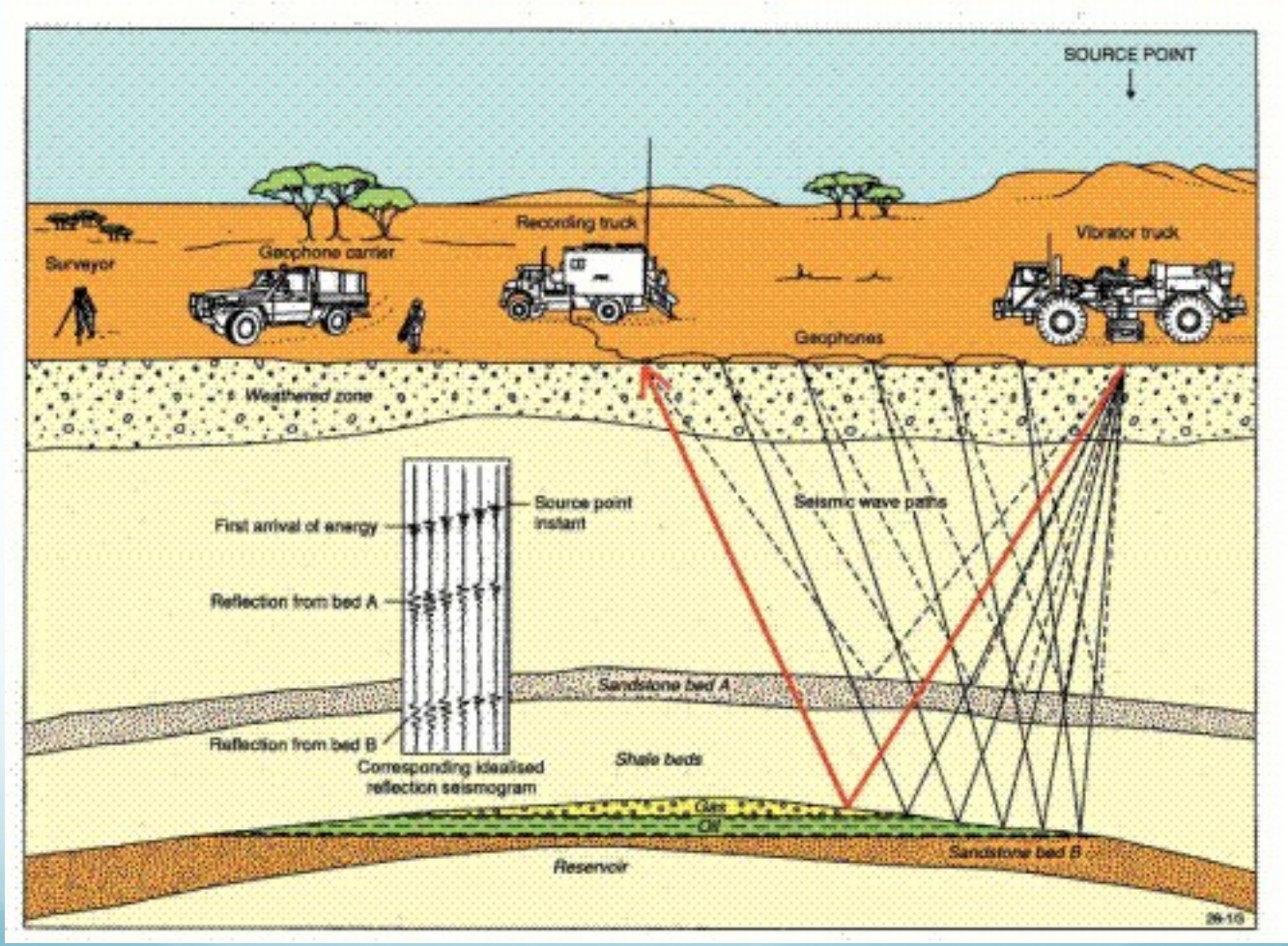
- Problem Formulation
- Mathematical Model and Numerical Method
- Explicit Layers Description
- Results of Simulation
- Conclusion

Marine seismic survey



http://www.keyword-suggestions.com

Land seismic survey



http://www.energyindustryphotos.com/

Relevance of research

- Optimization of sources and receivers positions to increase signal/noise ratio
- Estimation of seismic survey applicability in the case of known properties of geological massive
- Preparation of synthetic material for testing novel inversion/migration methods

Mathematical model and numerical method

$$\rho \partial_t \vec{v} = (\nabla \cdot \sigma)^T$$

$$\partial_t \sigma = \lambda (\nabla \cdot \vec{v})^T I + \mu (\nabla \otimes \vec{v} + (\nabla \otimes \vec{v})^T)$$

ρ– density,

$\vec{v}$– velocity,

σ– Cauchy stress tensor,

λ, μ– Lame parameters.

3D elastic system of equations, grid-characteristics numerical method on hexahedral meshes was used

Explicit layers description

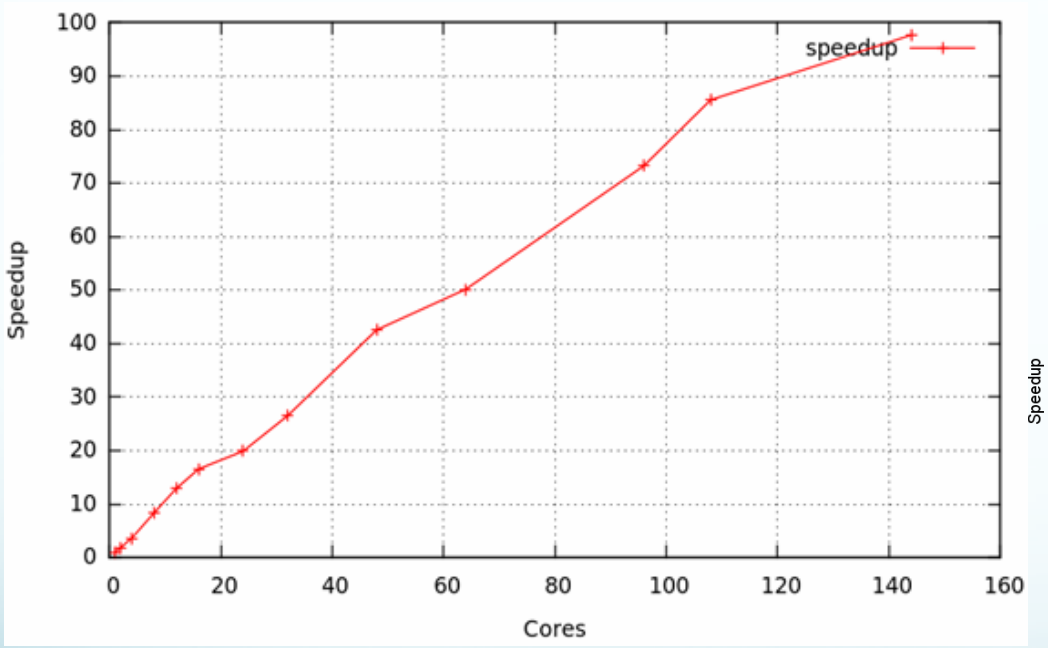
- Implicit contact borders (medium parameters – functions of coordinates) – “rough borders”
- Explicit contact borders – one mesh per layer
- Curvilinear mesh to describe complex geometry of layers – “smooth borders”
- Correct solution on each time step – glue conditions

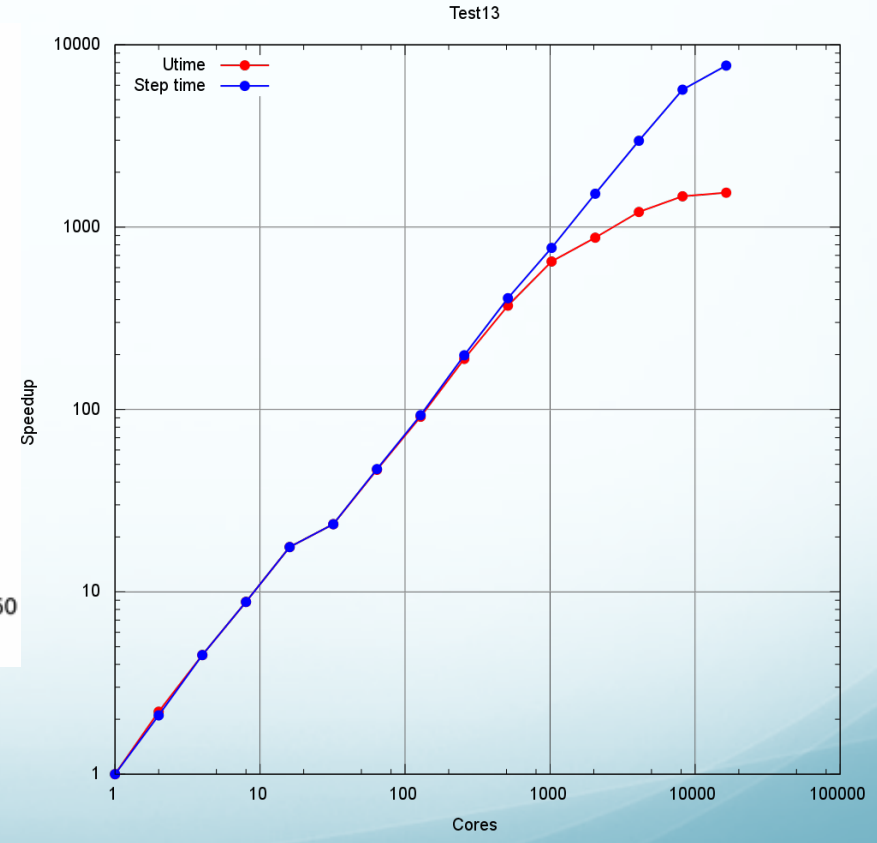
RECT Software

- Numerical simulation of waves propagation in 3D elastic (geological medium) and 3D acoustic (water) models
- Implicit/Explicit heterogeneities (multilayer, cracks, inclusions)
- C++, micro optimization (SIMD, SSE)
- OpenMP and MPI parallelization

Main developer: Khokhlov N.I.

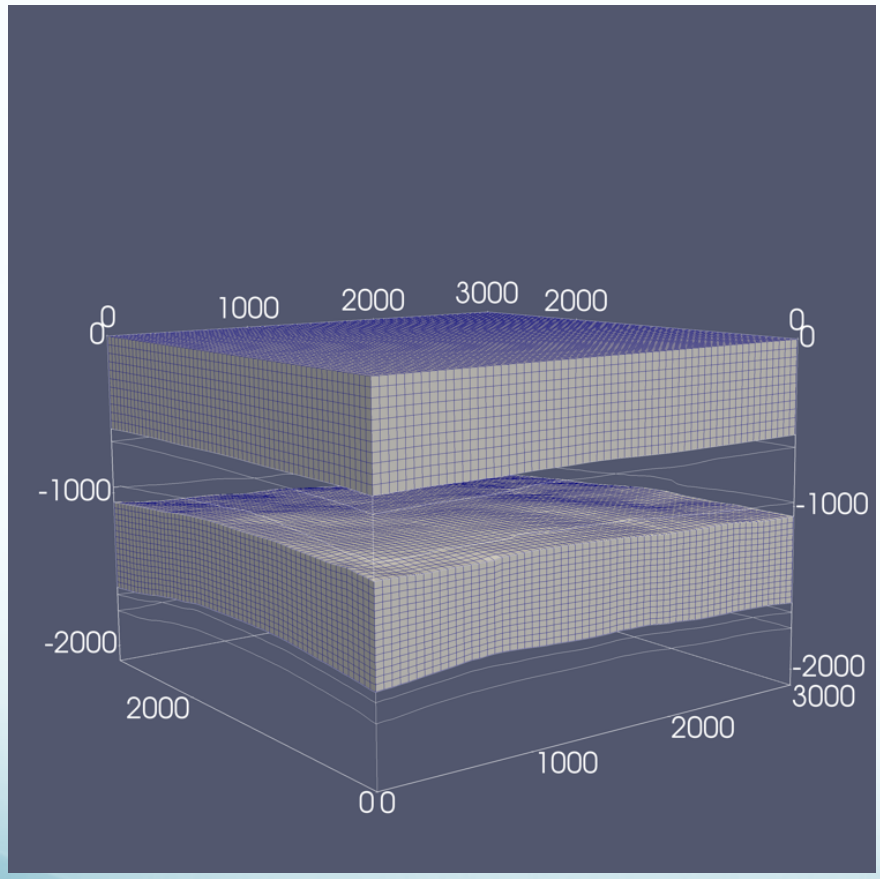
HPC systems usage





- **Clusters: MIPT-60, HECToR**
- **Scalability ~16 000 cores**
- **Efficiency ~ 80 %**

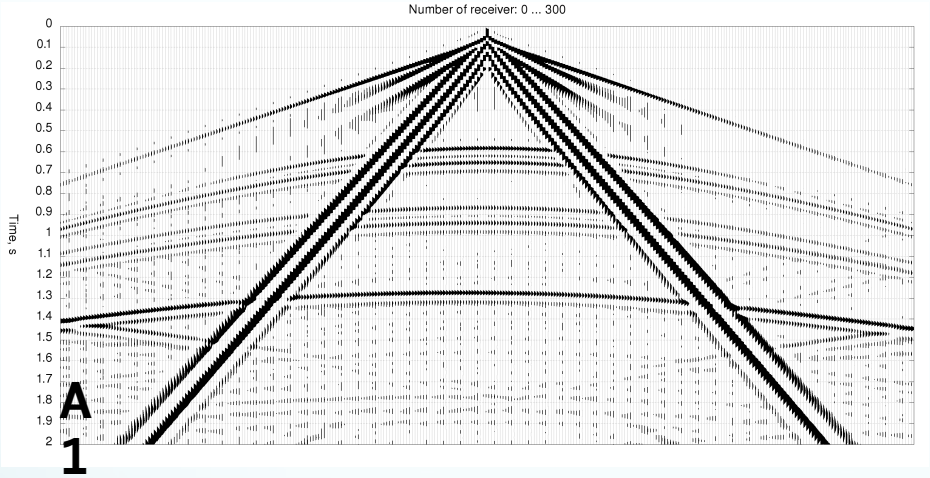
Numerical results – model description

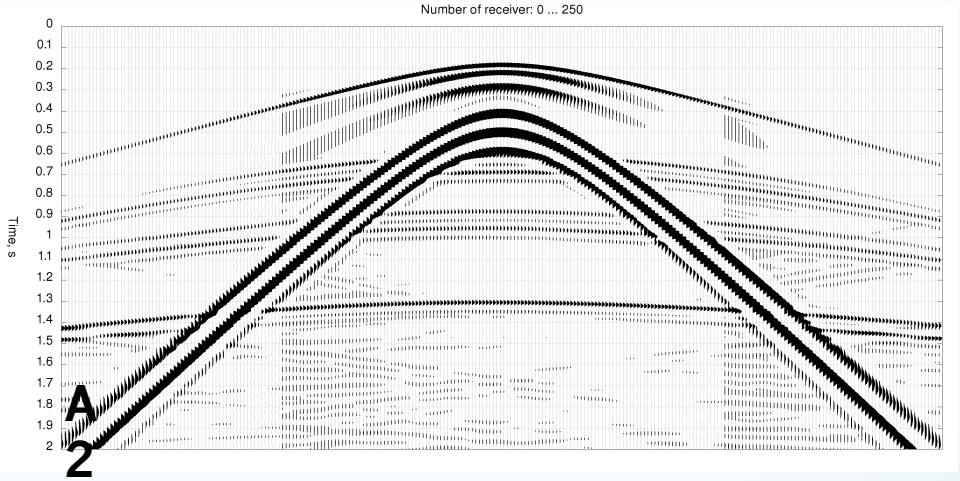


No	V_p, m/s	V_s, m/s	ρ, kg/m³
1	2170	674	2000
2	2130	795	2300
3	2500	1090	2200
4	2680	1220	2300
5	3000	1385	2400
6	5550	3144	2700
7	6000	1250	2800
8	6000	1550	2850

North-east of the European part of the Russian Federation on the territory of the Arkhangelsk Region within the Nenets Autonomous District, north of the Arctic Circle almost to the shores of the Barents Sea

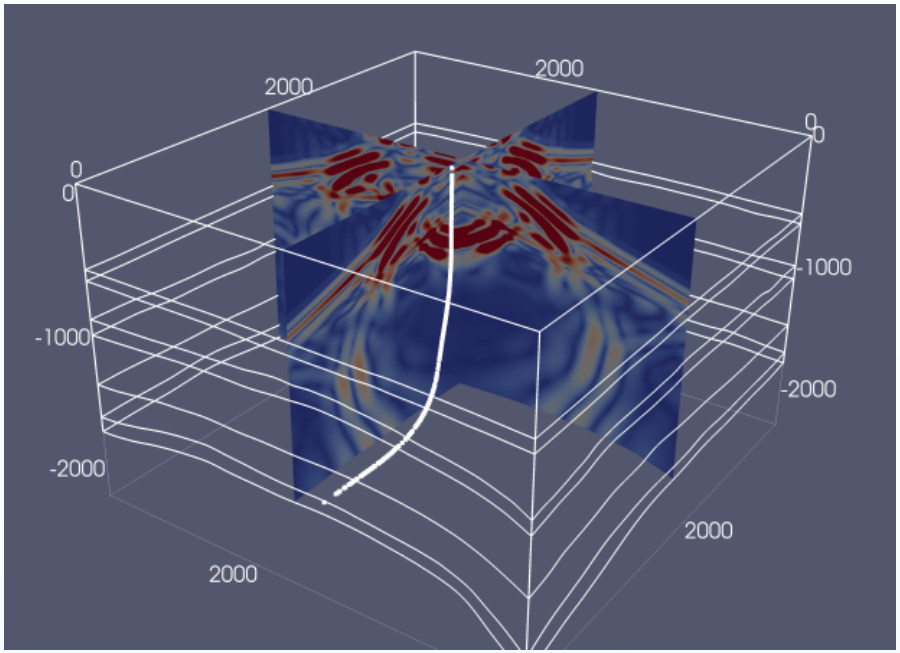
Numerical results - seismograms





	A1, implicit	A1, explicit	A2, implicit	A2, explicit
Time, s	815	7415	210	1908
Memory, Gb	21,7	47,5	31,3	68,5
Δ_1	22 %		39 %	
Δ_2	26 %		36 %	
Δ_3	30 %		34 %	

Numerical results – wavefield



	A1, implicit	**A1, explicit**	**A2, implicit**	**A2, explicit**
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Δ_1	22 %		39 %	
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Conclusion

- Explicit layers description changes amplitudes, but remain arrival times
- RECT, in the case of modern HPC systems usage, can be used to simulate seismic survey with high precision in complex media

Thank you for your attention!

Key feature of RECT

- Explicit description of any inclusions (cracks)
- Crack-crack interaction