Application of BOINC-based volunteer computing for comparison of the geoacoustic inversion algorithms efficiency

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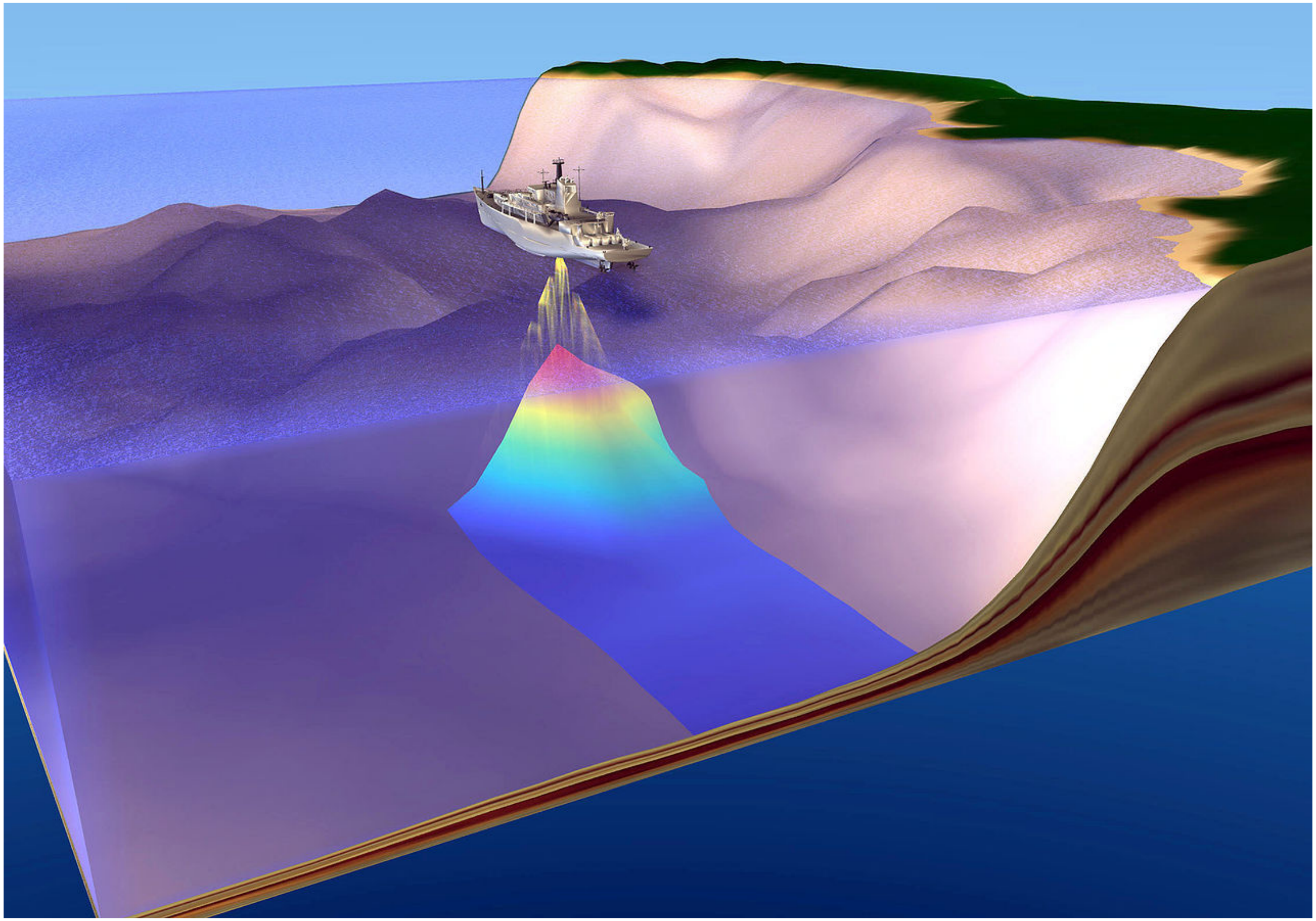
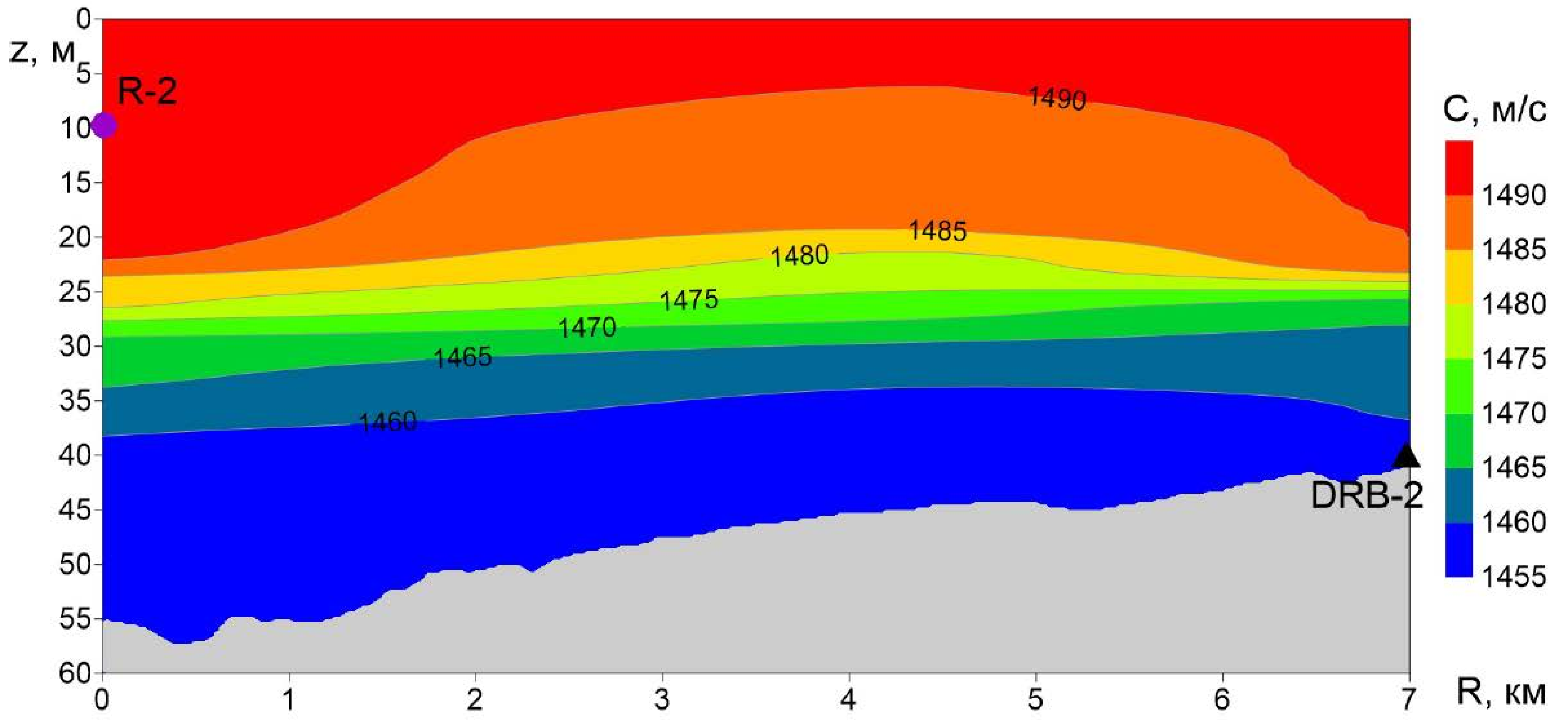
Seabed topography



Media example



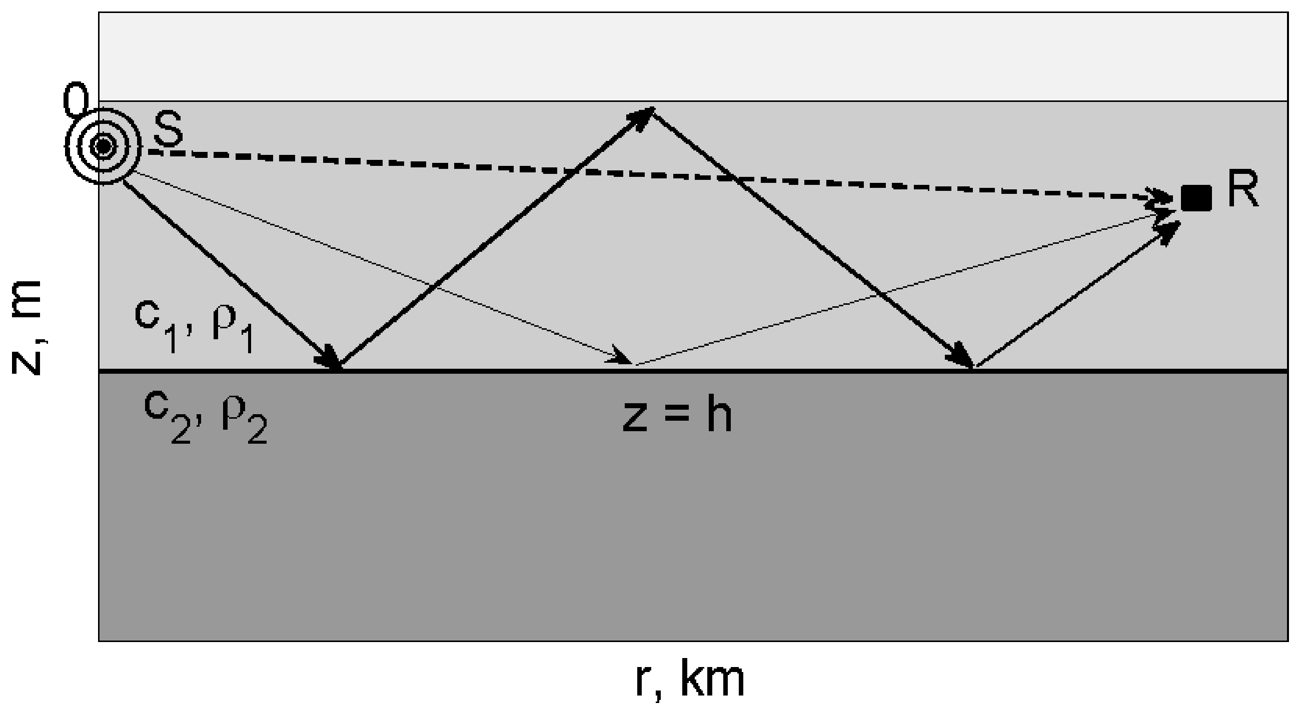
Geoacoustic inversion: what is it?

Consider a shallow-water geoacoustic waveguide ($z<0$ – air, $z>h$ – bottom)

Direct problem: for given source (**S**) and receiver (**R**) positions and known media parameters $\boldsymbol{c=c(z)}$ and $\boldsymbol{\rho= \rho(z)}$ compute the **signal** at the receiver → propagation problem.

Inverse problem: given the recorded **signal** at **R** determine the media parameters $\boldsymbol{c}$, $\boldsymbol{\rho}$ and/or relative source position → inversion problem.

Feature: multipath propagation → waveguide **dispersion!**



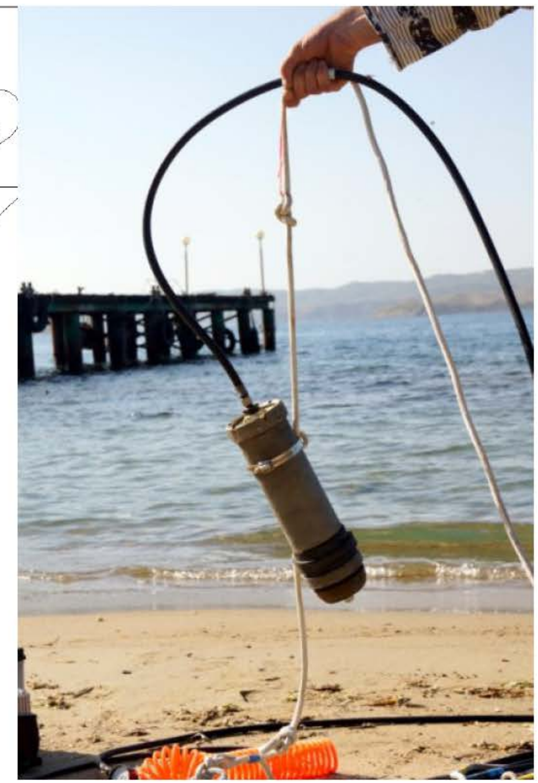
Applications

- Sea navigation (GPS doesn’t work under water)
- Search for oil and gas in sea bottom
- Cartography
- Monitoring of large sea animals (whales, dolphins, etc)

Experimental data

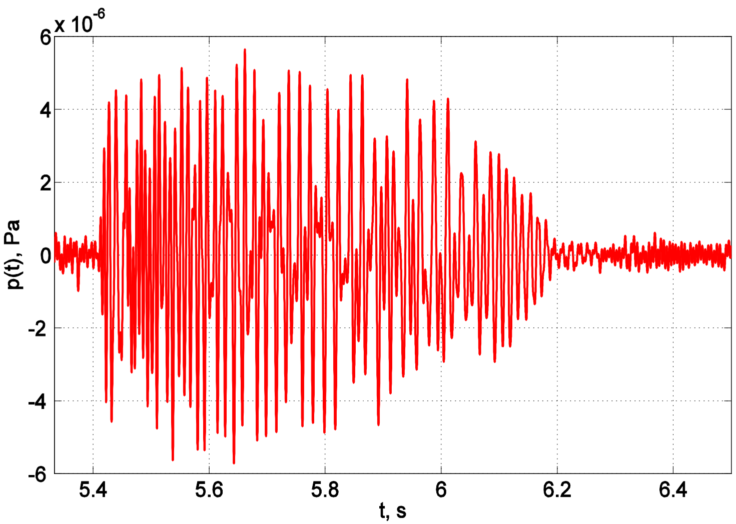
We work with experimental data obtained in Japan sea.

An example of hydrophone is depicted below.

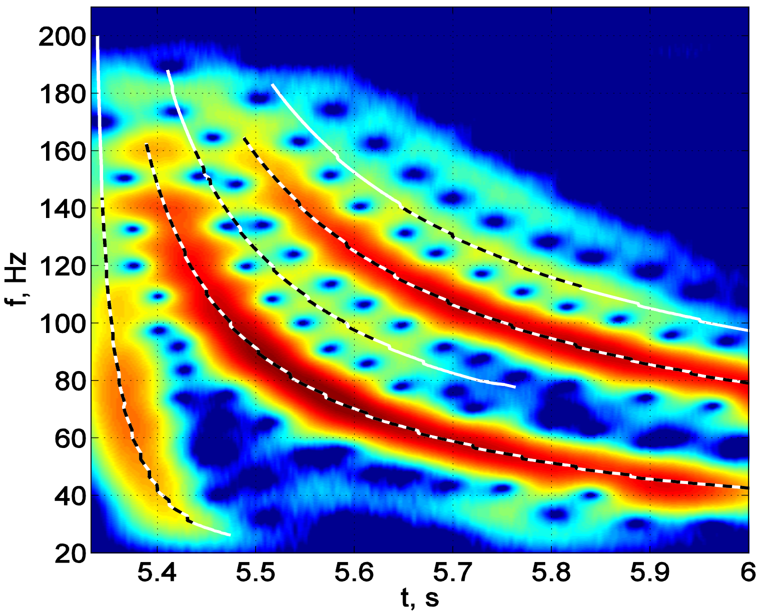


Extracting modal arrival times from the recorded acoustical signal

The modal arrival times $\tau^{\exp}(f,m)$ can be extracted from recorded signal time series. The idea of what the result look like is shown below.



The received signal



Signal spectrogram with dispersion curves $\tau(f,m)$

Geoacoustic inversion scheme

Assume that we have the arrival times of the modes obtained from the signal recorded by a single hydrophone in an **experiment** $\tau^{\exp}(f,m)$

$$\downarrow$$

For every vector of waveguide parameters $\mathrm{A} = \{R, c_1, \rho_1, c_2, \rho_2, \dots\}$ (where $c_i = c(z_i), \rho_i = \rho(z_i)$, and z_i - some discrete set of values of depth) we can solve spectral problem to obtain **theoretical** arrival times

$$\tau^{\text{theor}}(f,m) =$$

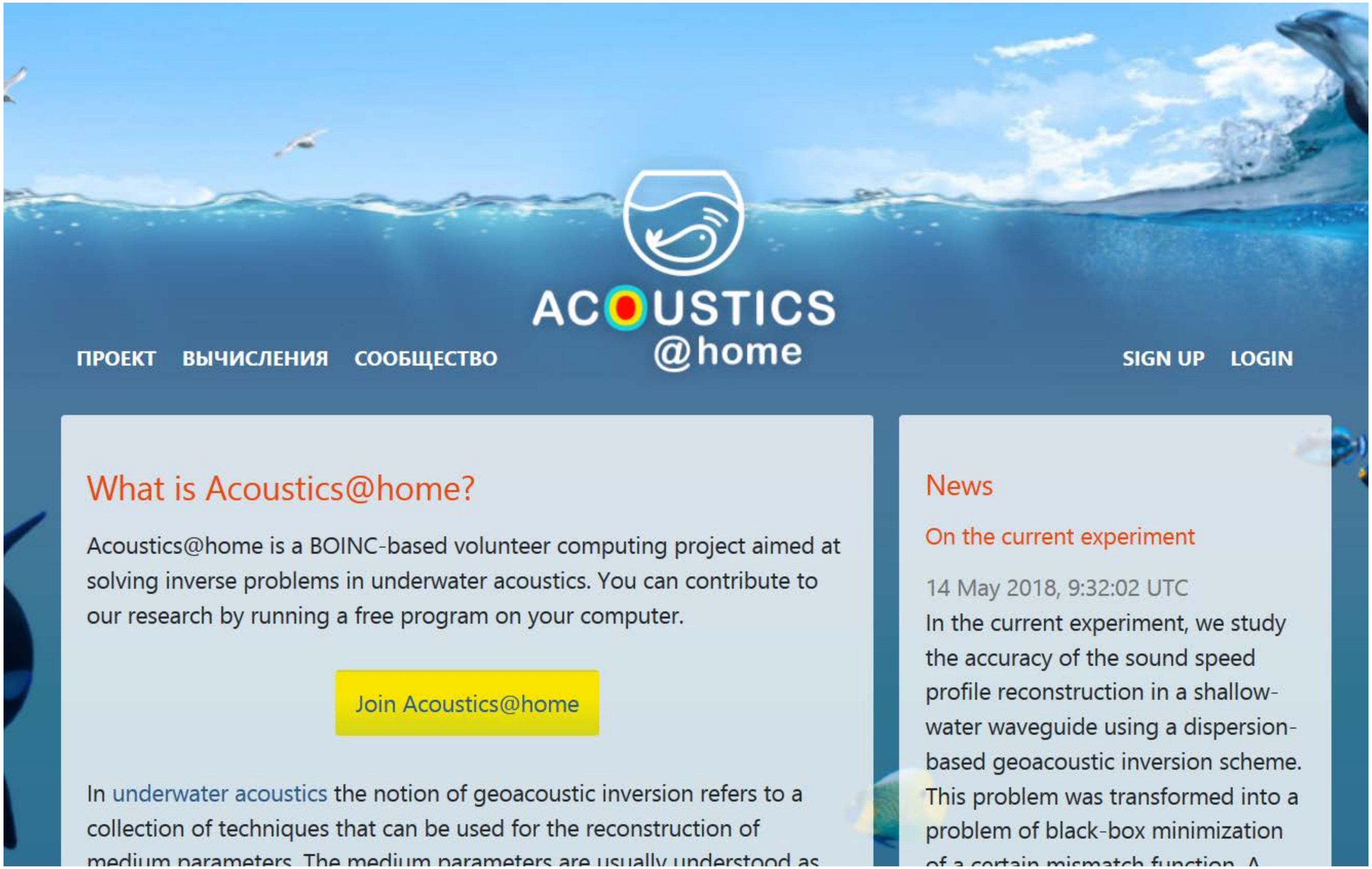
$$\downarrow$$

We then can estimate the mismatch of our **model** and the **data**:

$$E(A) = \sqrt{\sum_{i=1}^{N}\sum_{m=1}^{M}\frac{|\tau^{\text{theor}}(f_i,m) - \tau^{\exp}(f_i,m)|^2}{NM}}$$

…and minimize it over the space of the vectors A. Geoacoustic inversion= **nonlinear continuous minimization problem**.

Acoustics@home
www.acousticsathome.ru/boinc/



Acoustics@home

In order to solve computationally hard inversion problems in underwater acoustics, we launched the volunteer computing project Acoustics@home on 28 March 2017.

Acoustics@home is based on BOINC. All server daemons and computing application are based on the CAMBALA MPI-program, developed by us.

Work generator decomposes an original problem into independent subproblems by varying several parameters of a search space.

The rest parameters are varied in the computing application of the project. For each obtained set of parameters ***A*** the value of the object function $E(\mathbf{A})$ is calculated.

Acoustics@home: considered problem

The following constants were used:

$$R = 7000\ \text{м}, \rho_b = 1.7\ \text{g/cm}^3, c_b = 1700\ \text{м}/c$$

Acoustics@home: experiment № 1

In the first experiments 5 water layers were considered.

parameter	min val	max val	step
$cw_j, j = 0, .., 4$	1450 m/s	1510 m/s	2 m/s

$31^5 = 28\,629\,151$ points in the search space

The experiment was launched in August 2017, it took 10 days.

Acoustics@home: experiment № 2

In the first experiments 6 water layers were considered.

parameter	min val	max val	step
$cw_j, j = 0,..,5$	1450 m/s	1510 m/s	2 m/s

$31^6 = 887\,503\,681$ points.

It took 58 days to complete it.

Acoustics@home: results of the first 2 experiments

For 1-4 layers experiments were held on a computing cluster.

Table 1: Results of geoacoustic inversion for different values of N_c.

N_c	Residue	Points	Time	Platform
1	0.0127314	31	10 seconds	cluster
2	0.00924369	961	2 minutes	cluster
3	0.00500185	29 791	45 minutes	cluster
4	0.00416296	923 521	23 hours	cluster
5	0.00428371	28 629 151	10 days	BOINC
6	0.00384831	887 503 681	58 days	BOINC

Acoustics@home: experiment № 3

In the third experiments 4 water layers were considered, but their depths were varied.

parameter	min value	max value	step
$cw_j, j = 0,..,3$	1440 m/s	1510 m/s	2 m/s
$d_j, j = 1,..,3$	2 m	40 m	1 m

7 140 possible combinations of depths values. For each of them 3 sound speeds were varied.
$7140 * 36^4 = 11\,992\,458\,240$ points in the search space.

Acoustics@home: experiment № 3

The experiment was launched in April 2018.

The current record is 0.003784

About 38 % of the search space have been processed.

0.003784 is better than 0.3848 (6 statis layers)

Conclusion: varying of few layers is better than many static layers. However, it takes more computational resources.

Thank you for your attention!