pulsating localised fluid expulsions

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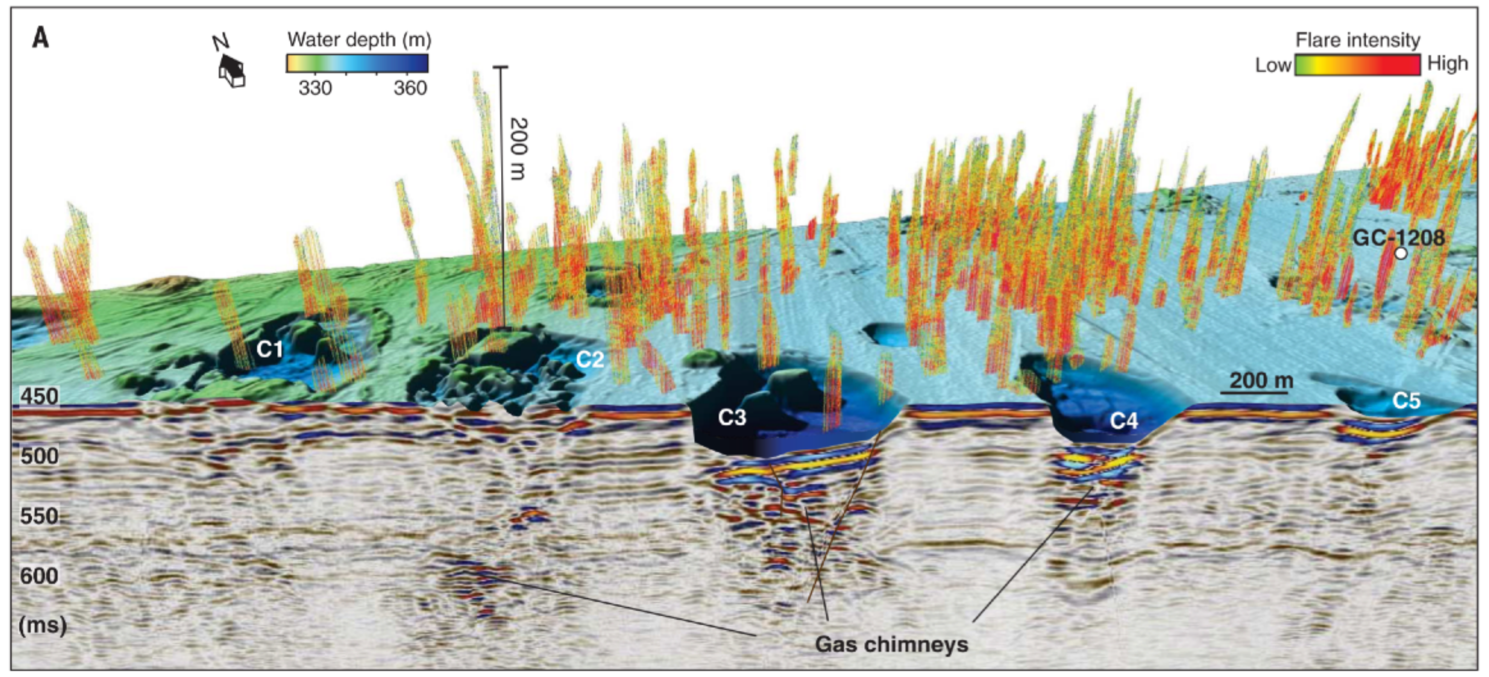
Within this work, we aim at investigating the role of coupled hydro-mechanical processes to trigger pulsating localised fluid expulsions in the subsurface.

Buoyant fluids trapped within the pore-space of rocks tend to migrate towards the surface along pre-existent or dynamically created escape paths.

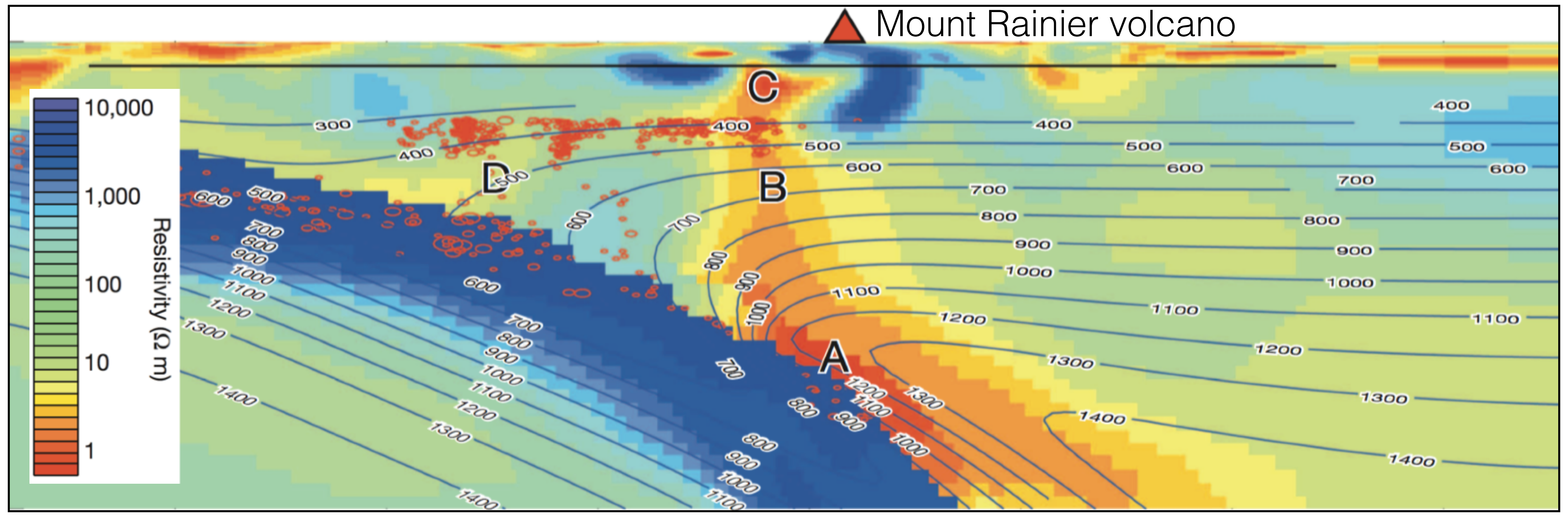
Geophysical monitoring of various two-phase systems exhibit pulsating signals, interpreted as the systems' response to ongoing localised fluid migration and expulsion.

localised fluid flow in two-phase systems

gas hydrate migration



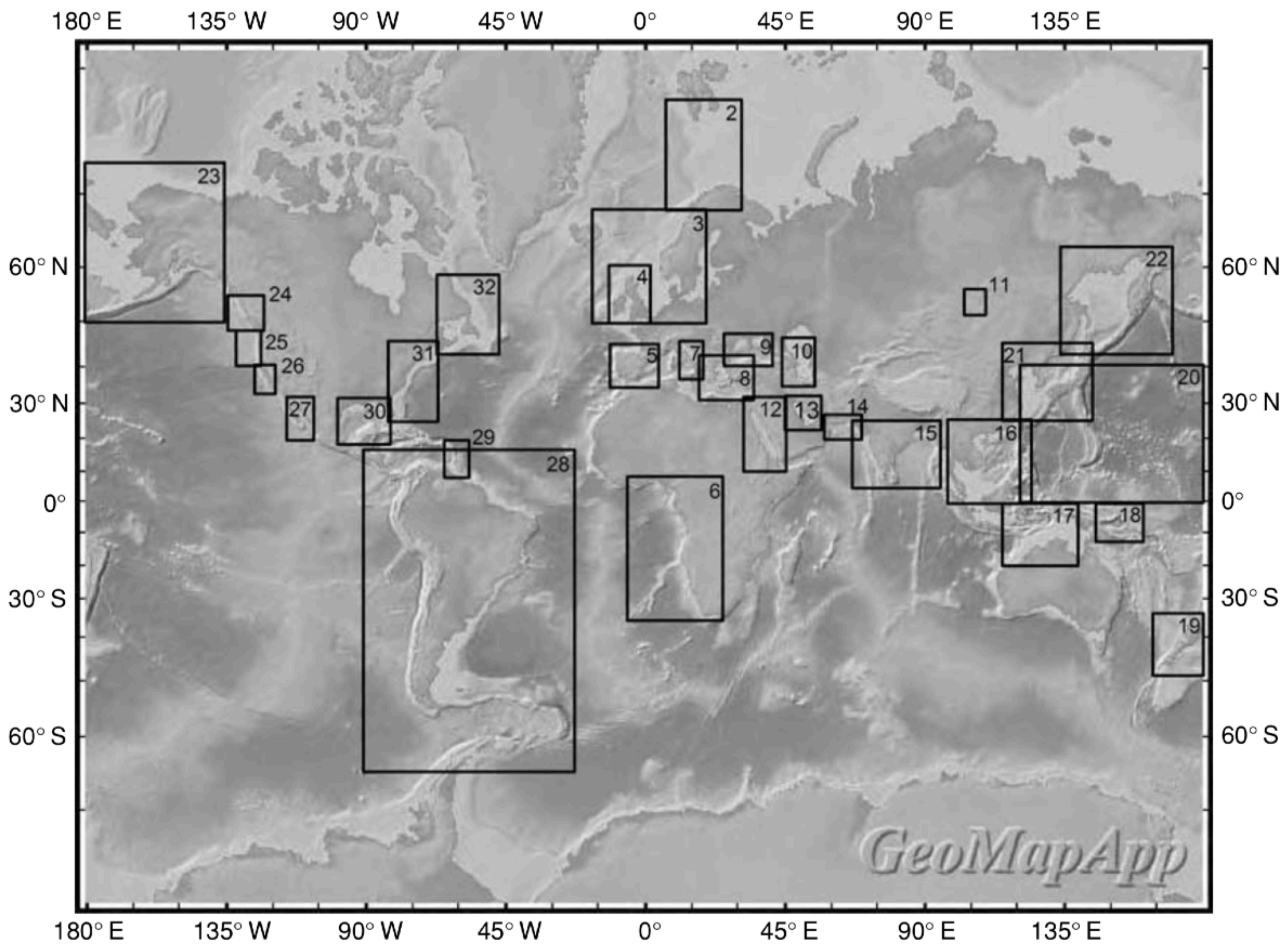
Andreassen et al., 2017



subduction zones

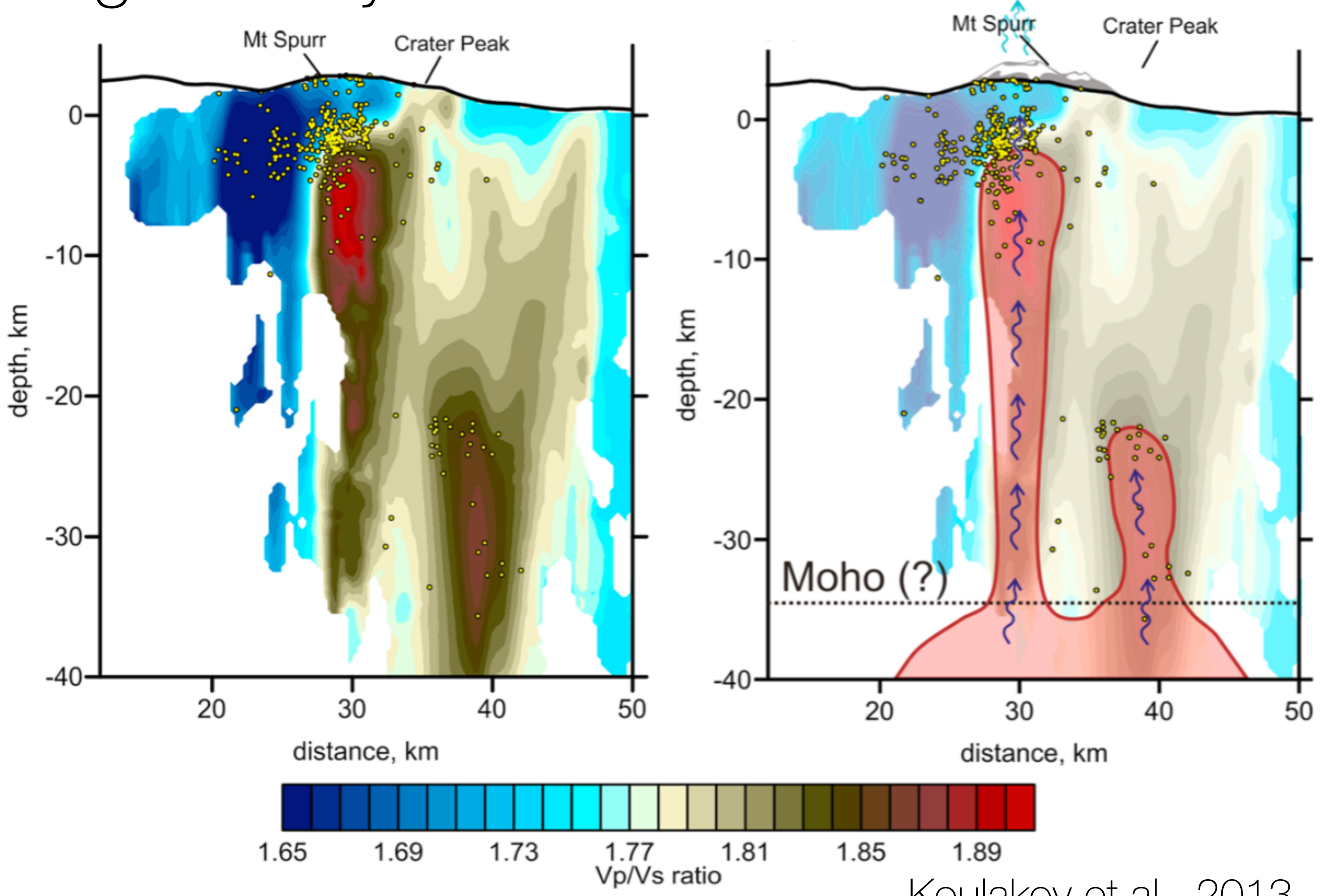
McGary et al., 2015

Sedimentary basins



Judd & Hovland, 2007. Seabed fluid flow

magmatic systems



Koulakov et al., 2013

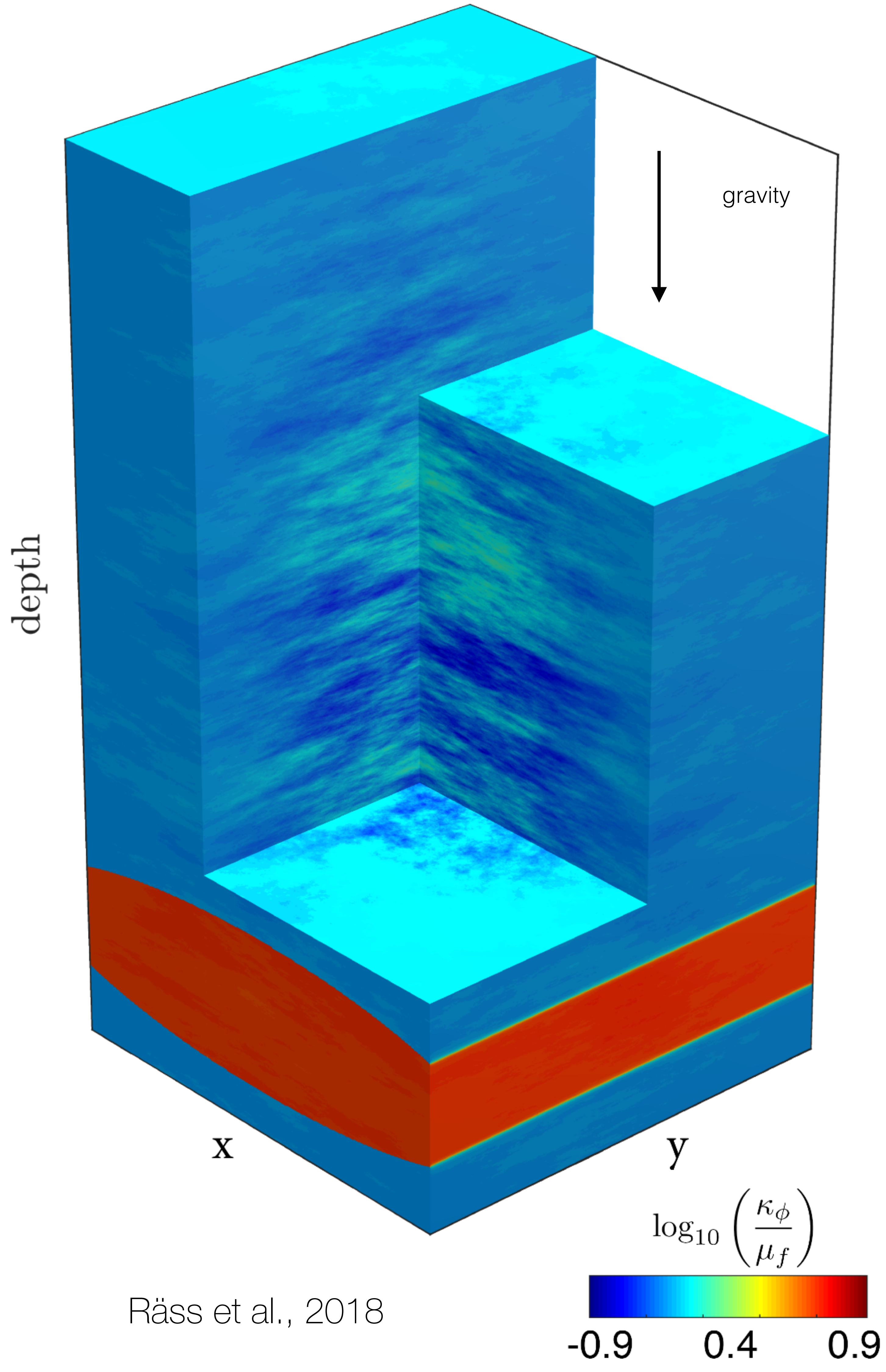
We recently proposed hydro-mechanical coupling and time-dependent creep to be responsible of spontaneous flow localisation within the subsurface [1,2].

We showed that a pocket of buoyant fluid located beneath saturated porous rocks could lead to the formation of fluid escape pipes as imaged using seismic methods.

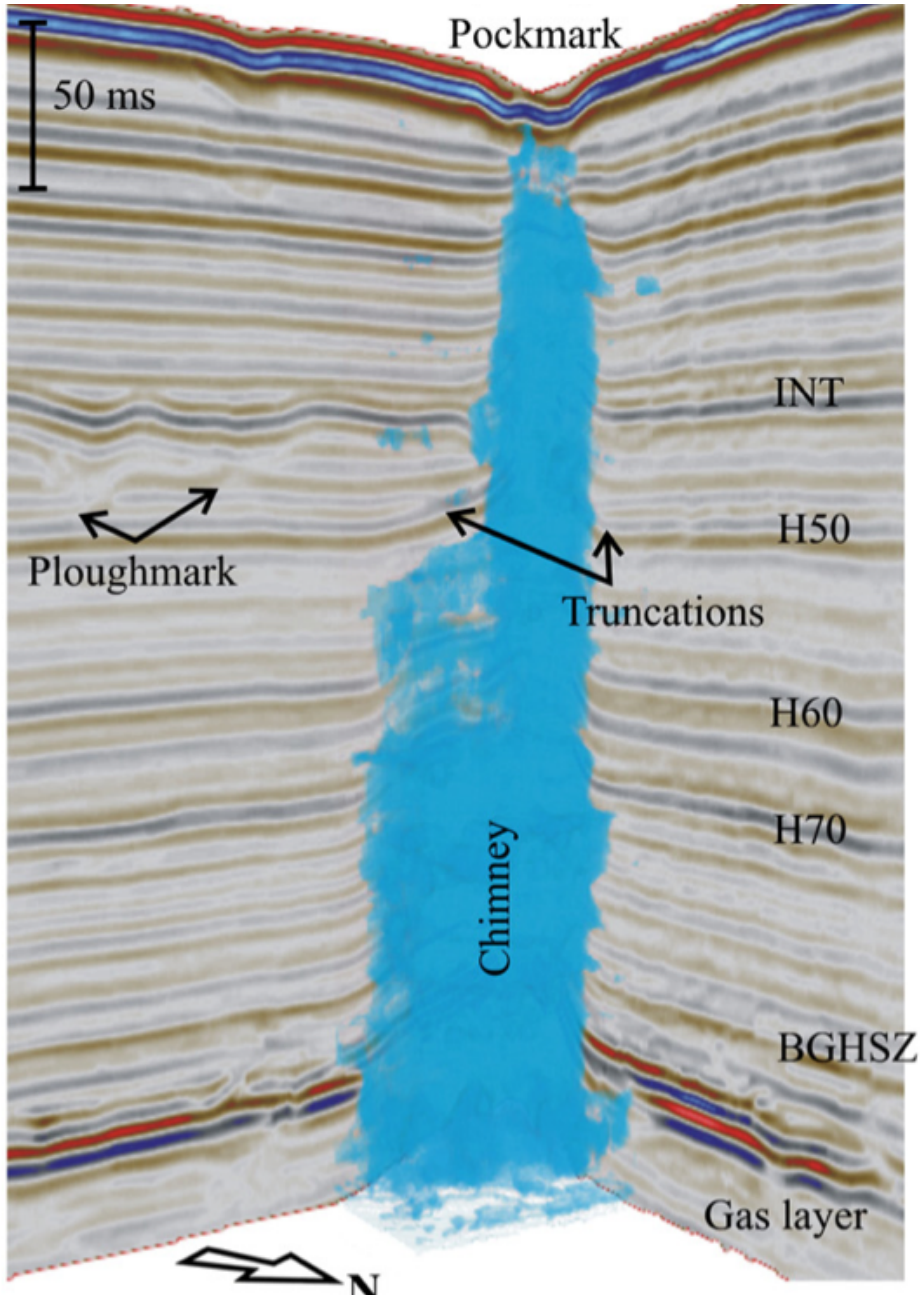
[1] http://www.nature.com/articles/s41598-018-29485-5

[2] https://doi.org/10.1093/gji/ggz239

predicting dynamic channel formation



Räss et al., 2018



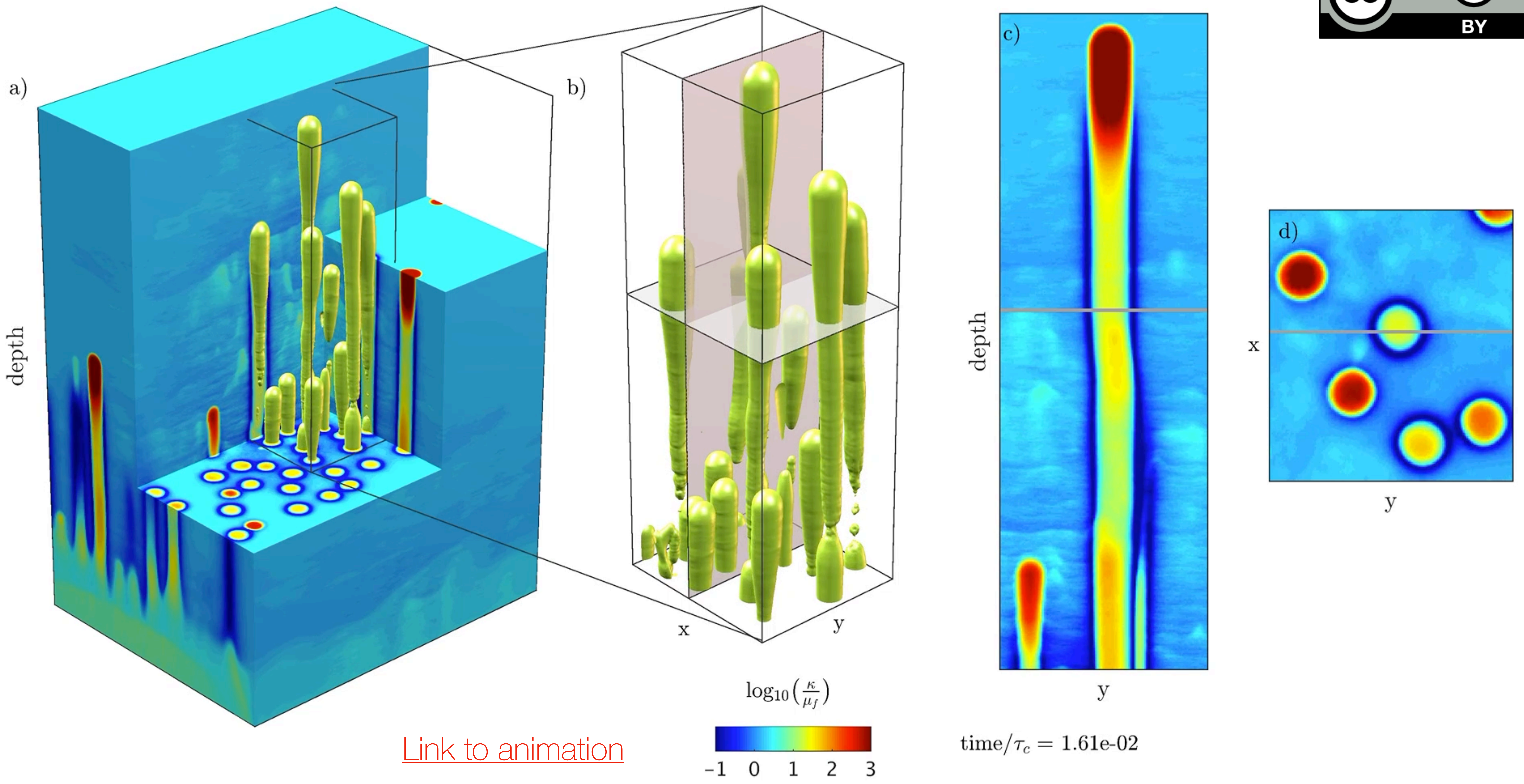
Plaza-Faverola et al., 2011

The initial condition depicted on the left-hand side picture permits to produce fluid escape pipes as widely observed in sedimentary basins.

The following animation illustrates the chimney formation in 3D using an ultra-high resolution model of two-phase flow in a viscously deforming porous matrix [1].

The colour scale represents the dynamic permeability which is function of the porosity. Thus, the red colour translate to high fluid content, while the blue colour stands for the background and low fluid content within the porous rocks.

[1] http://www.nature.com/articles/s41598-018-29485-5



Link to animation

Räss et al., 2018

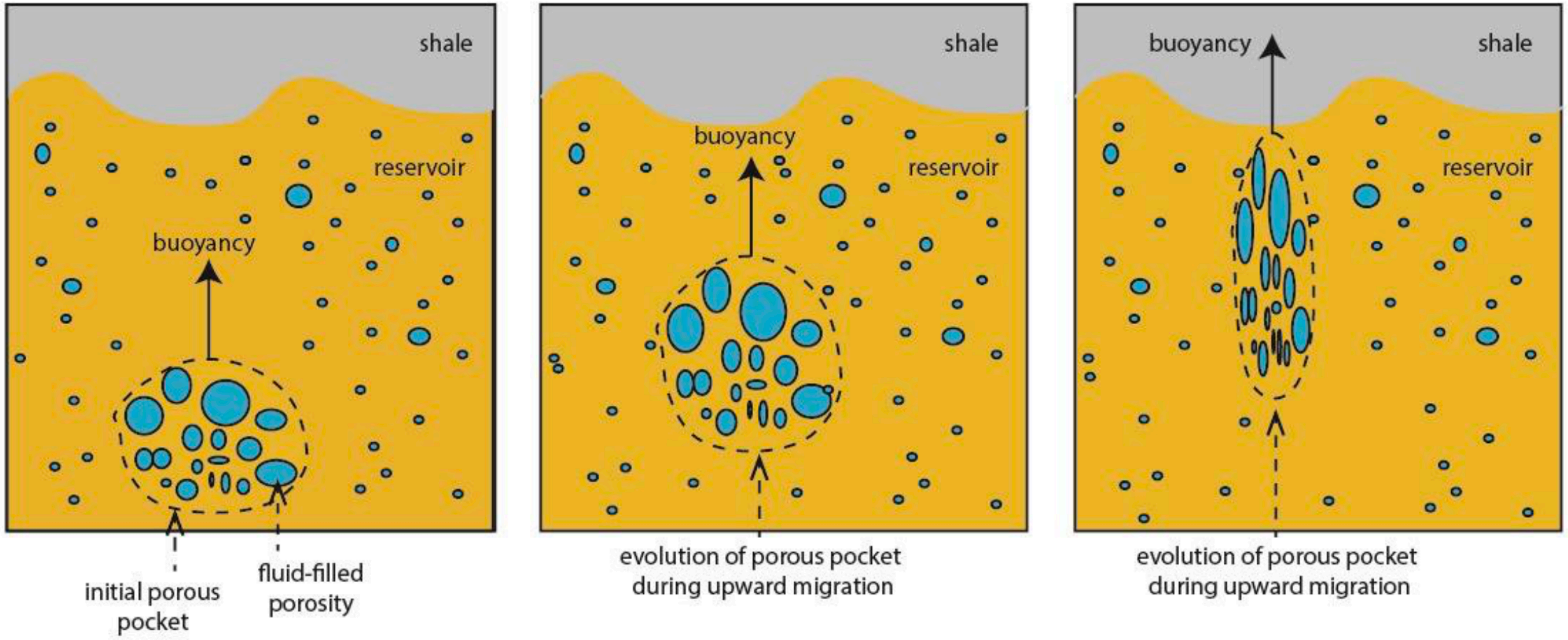
The fluid vertically escape by locally expanding the pores due to buoyancy. Once migrated one step upwards, pore would close again due to confining pressure being larger than pore pressure.

The rate of decompaction and compaction of the viscous and porous matrix is given by the bulk viscosity.

[3] https://doi.org/10.1002/2014JB011258

localised (de-)compaction

Nonlinear instability arising from hydro-mechanical coupling



Yarushina et al., 2020 (submitted)

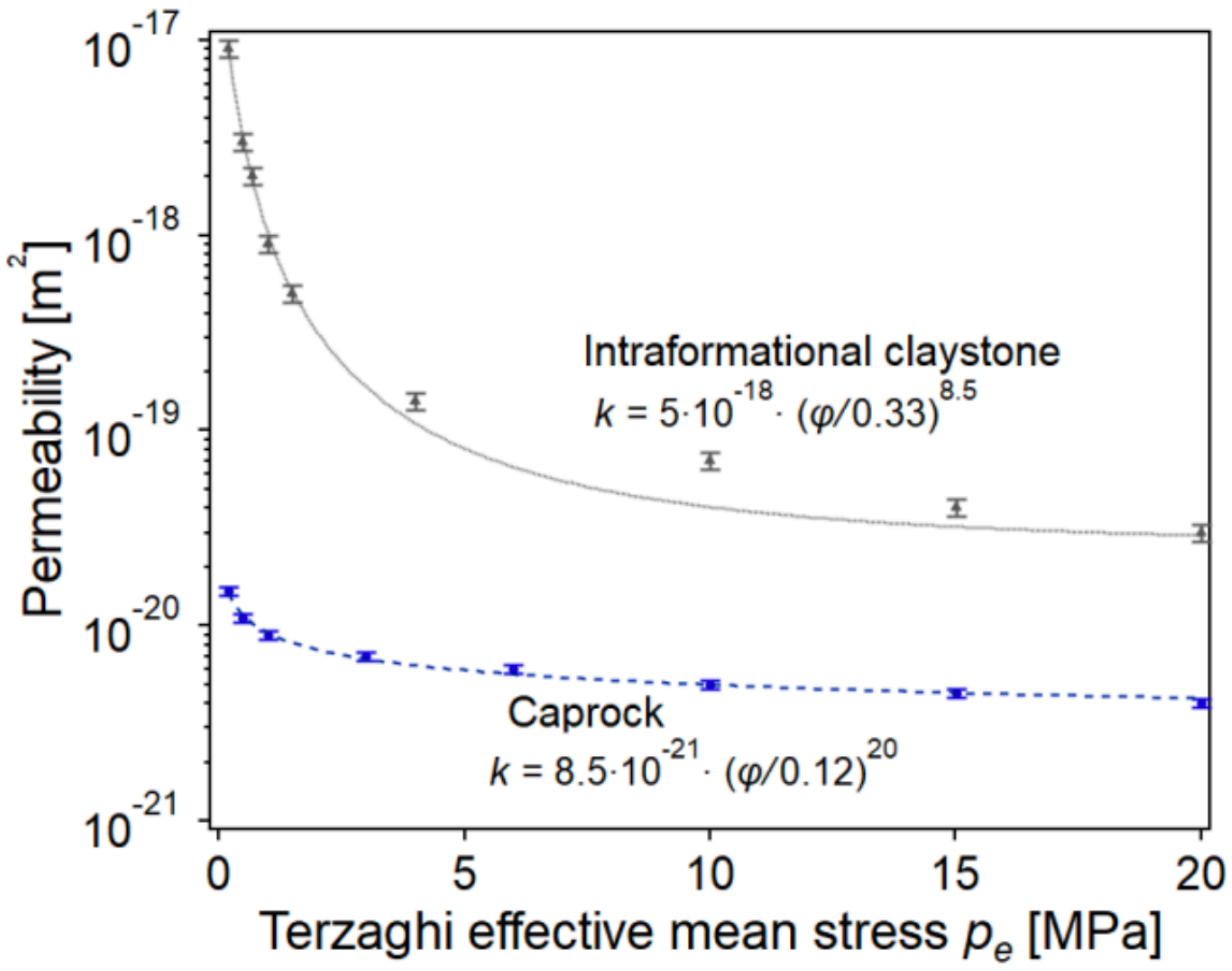
The fluid pocket would rise as a symmetric solitary wave (or blob) of elevated porosity if decompaction and compaction rates of the porous matrix where identical.

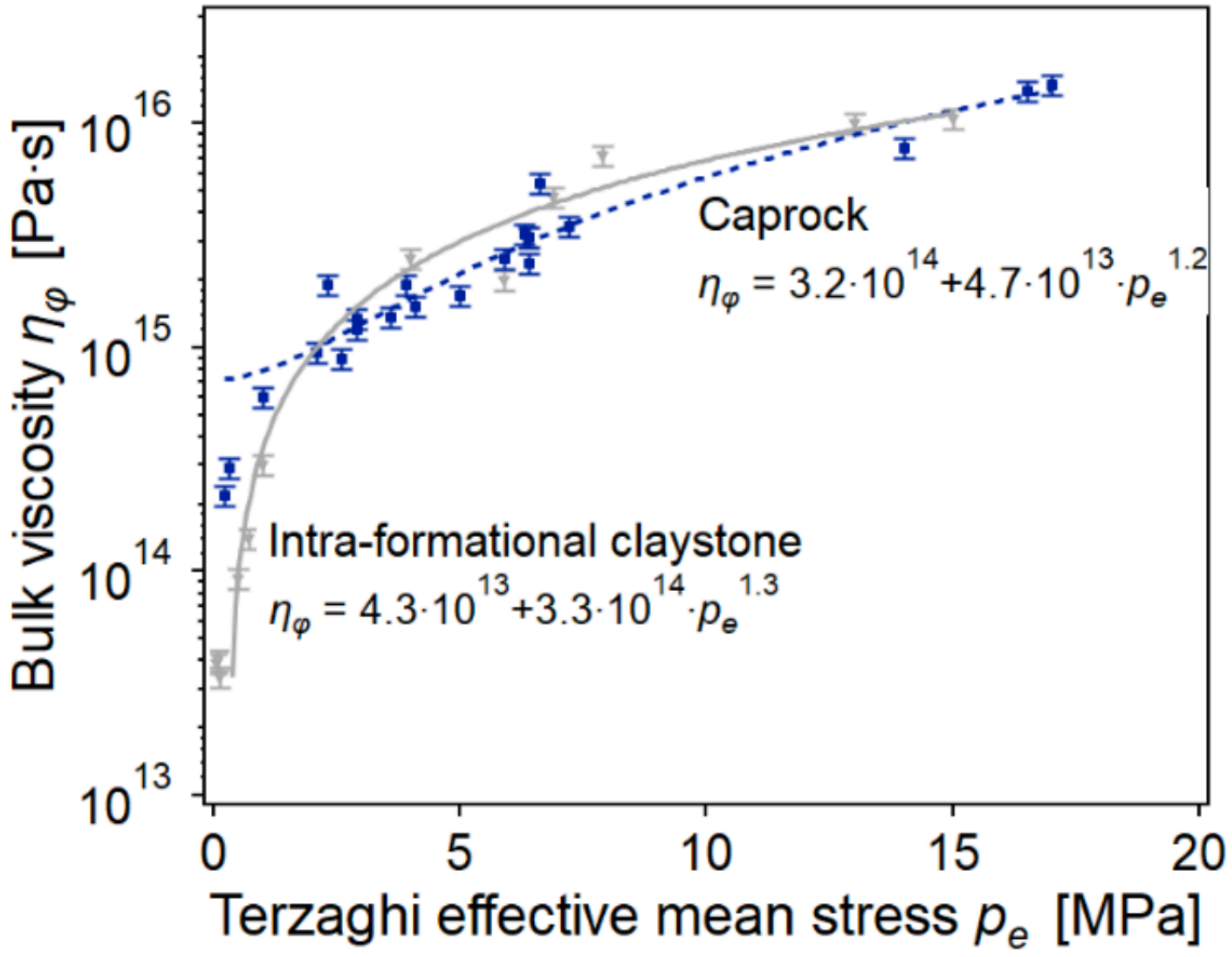
We recently showed that the bulk viscosity of saturated rocks (and their permeability) is sensitive to the effective pressure - the difference between the pore fluid pressure and the confining stress (total pressure) - as depicted in next [4,5].

[4] https://doi.org/10.1016/j.egypro.2017.03.1455

[5] Yarushina, V. M., Makhnenko, R. Y., Räss, L., and Podladchikov, Y. Y. Viscous behavior of clay-rich caprock affects its sealing integrity. *Submitted to International Journal of Greenhouse Gas Control.*

pressure-dependent creep





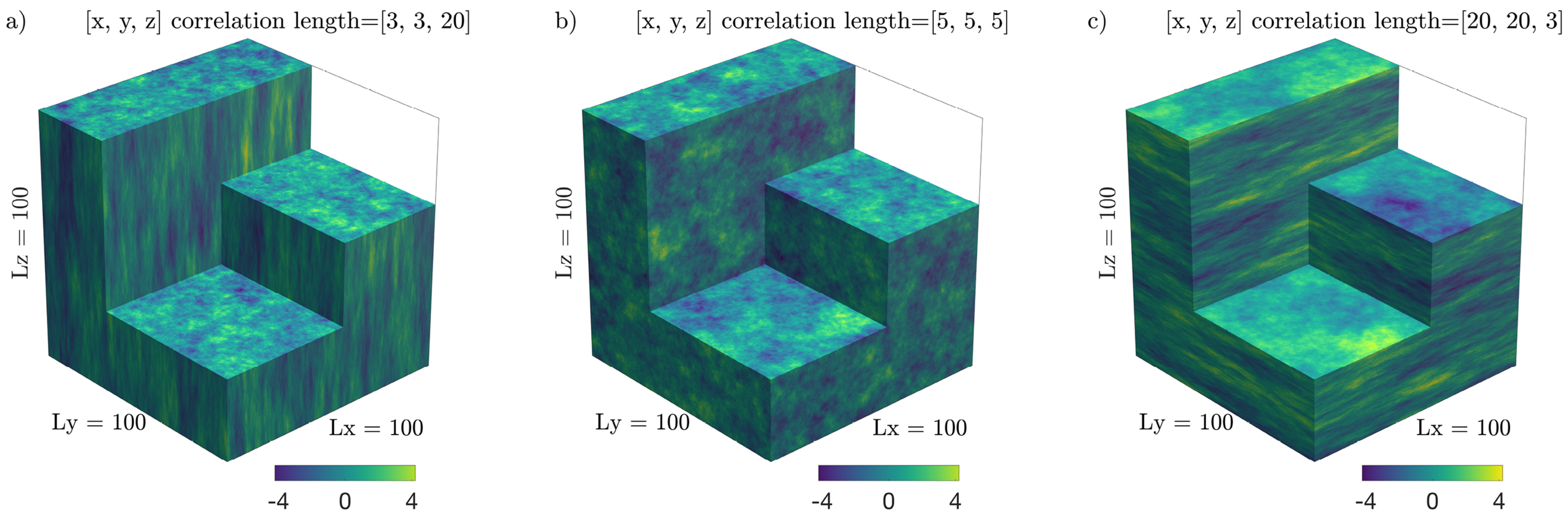
Yarushina et al., 2020 (submitted)

Can the random porosity distribution influence the fluid flow response in a two-phase system ?

What does the flow response tells about the internal structure of the porous media ?

The next picture shows 3 different porosity fields with distinct correlation lengths.

impact of initial porosity distribution



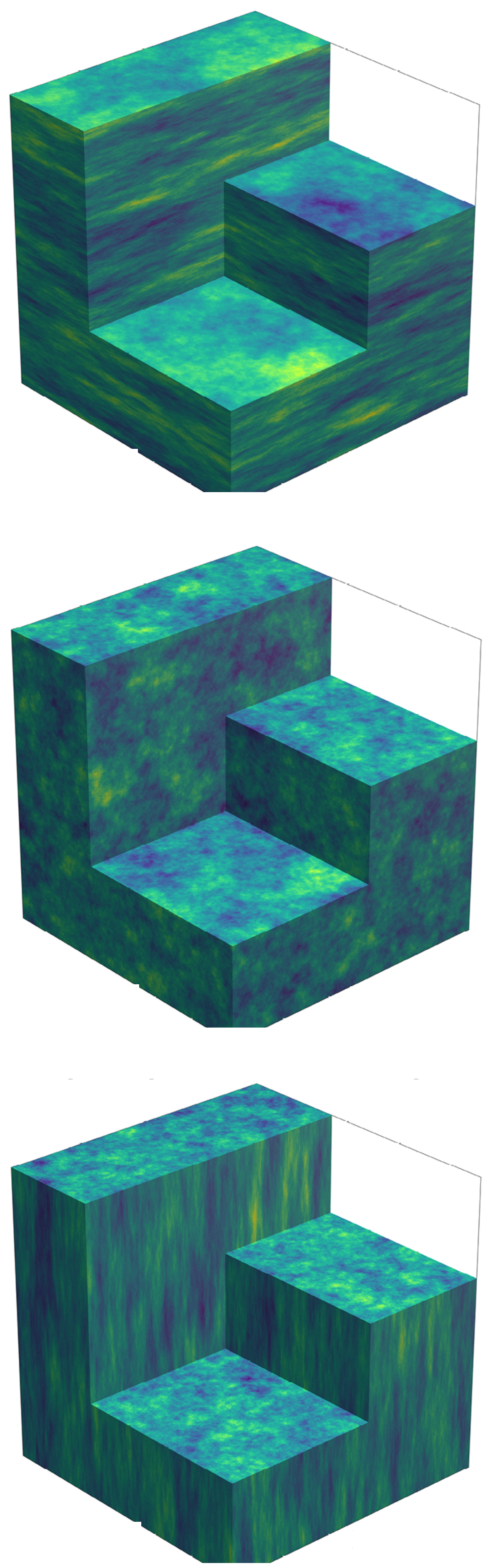
Räss et al., 2019

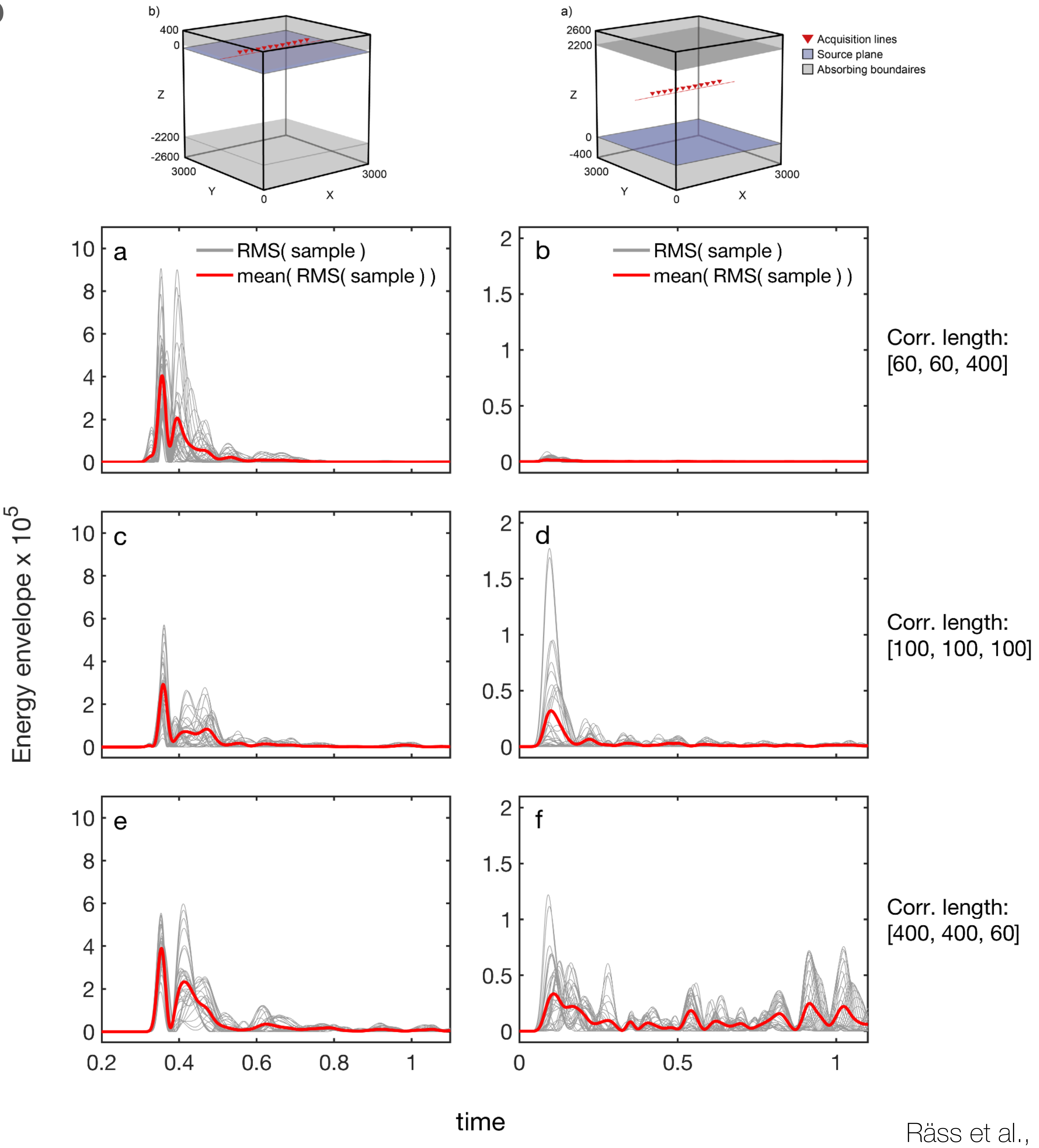
We know that seismic (p-) waves are sensitive to the porosity (here slowness) distribution [6].

The coda response suggest the porosity distribution with the smallest correlation length in the direction of the propagation wave to produce most scattering.

[6] https://doi.org/10.1016/j.cageo.2019.06.007

impact on seismic p-waves



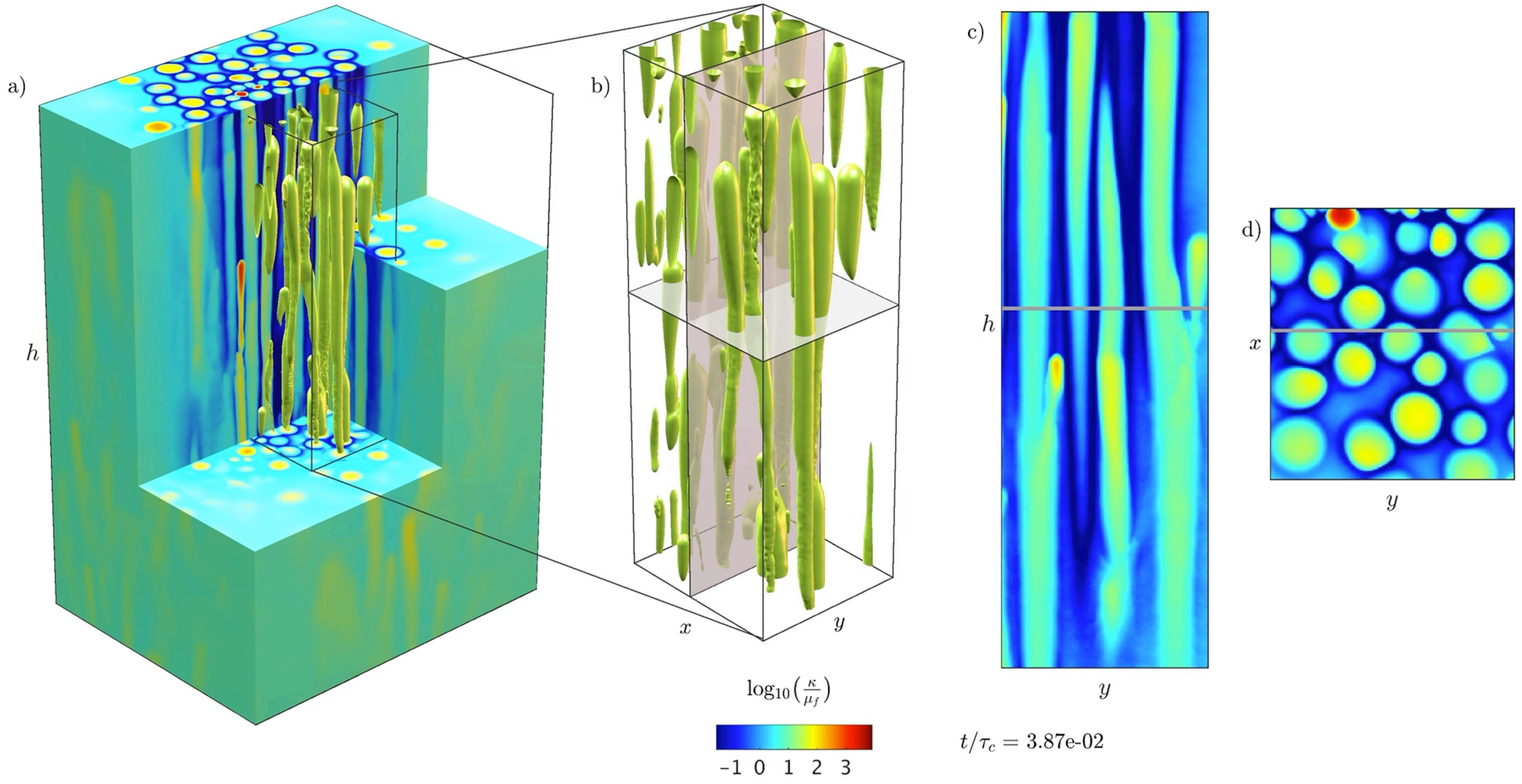


Räss et al., 2019

Letting the same three different samples with various initial porosity distribution compact under gravity may as well produce different signal when recording the integrated fluid fluxes.

We realised 3 different high-resolution forward simulation taking the previously depicted 3 different porosity distributions as initial conditions. The next movie provides insight into a forward simulation.

impact on fluid escape pipes



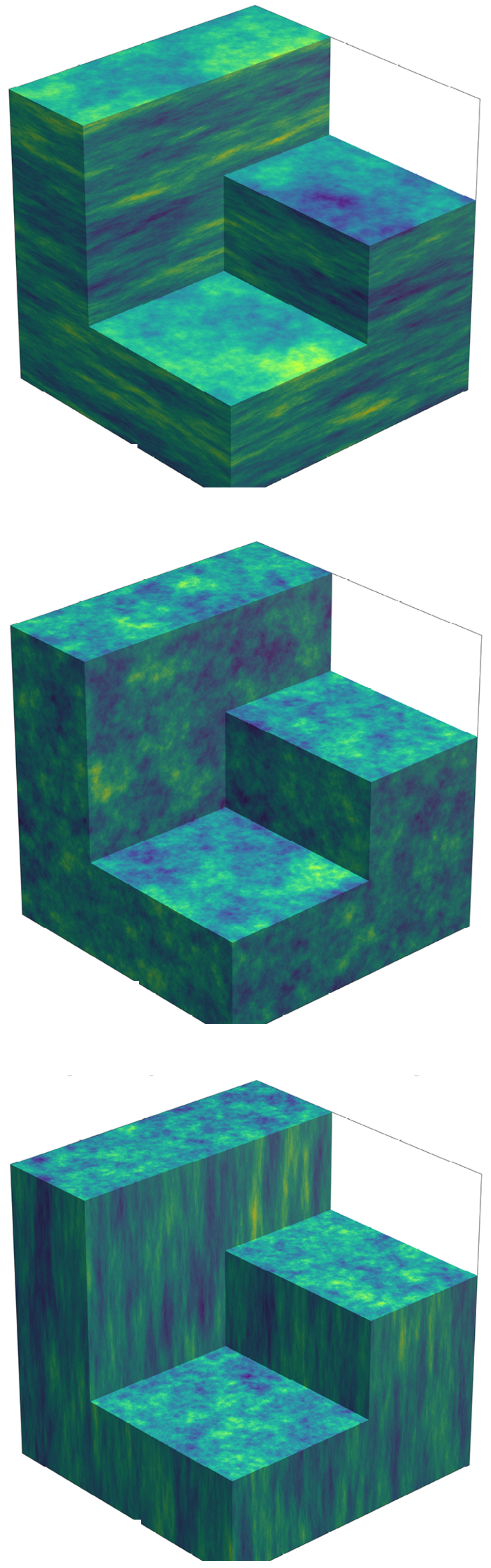
Our preliminary results suggest a different response of the recorder integrated vertical fluid flux as function of the initial porosity distribution.

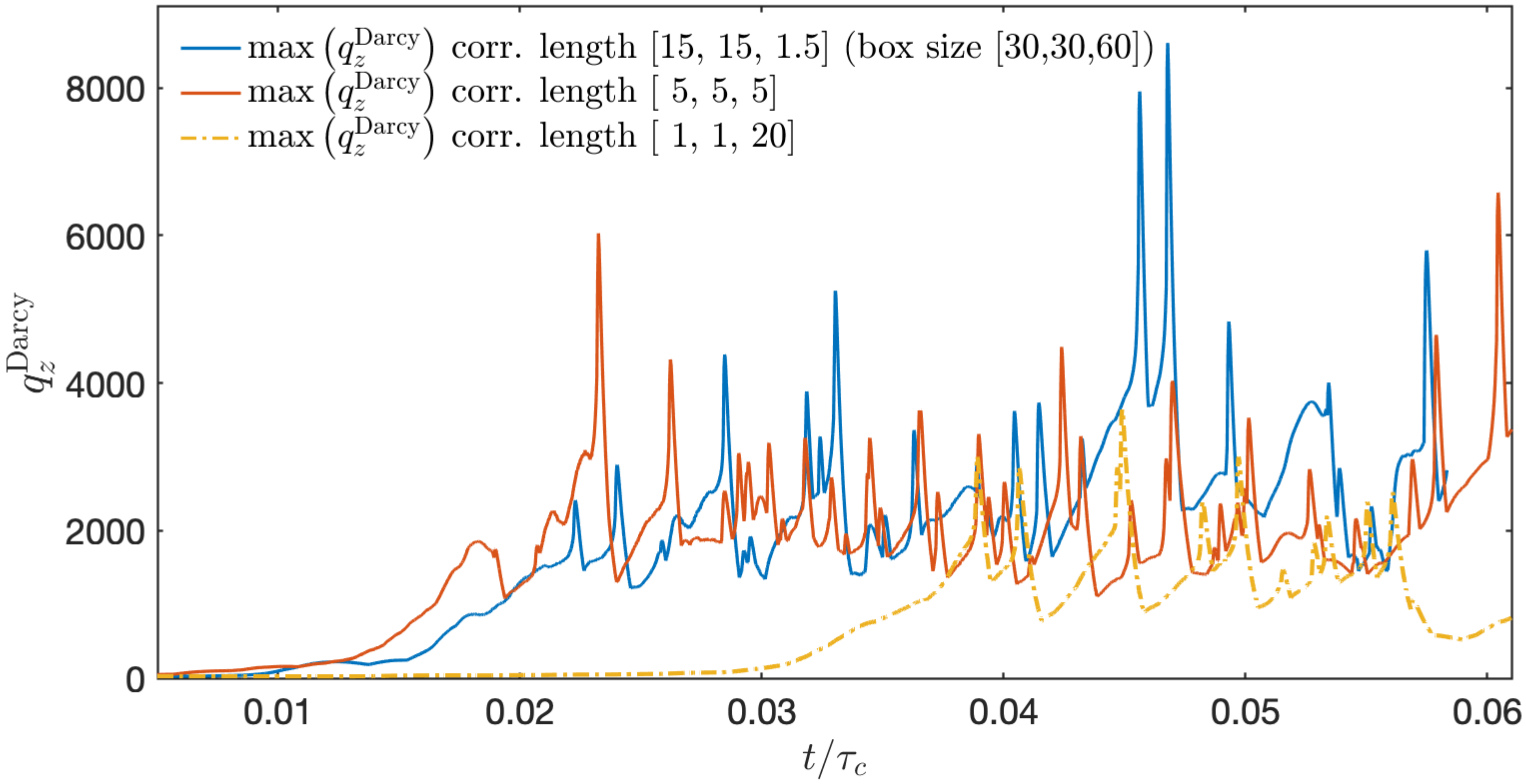
Sample generating most scattering of seismic waves also trigger largest peak values of fluid fluxes occurring at lowest “frequency”.

Sample generating less scattering of seismic waves also trigger slowest peak values of fluid fluxes but occuring at higher “frequency”.

The “first arrival” time-span is also function of the initial porosity distribution.

integrated fluid flux time-series





Our preliminary results suggest a specific response of the two-phase system as function of the porosity distribution within a given system.

The frequency analysis unveiled that the frequency distribution for all samples follows a log-normal trend. This would be consistent with previous observations of hydrological systems.

We need to further investigate the impact of initial fluid content and finalise the frequency analysis.

acknowledgment

Thank you !

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http://wp.unil.ch/geocomputing

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