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## Open-source hydrogeophysical modeling and inversion with pyGIMLi 1.1: Recent advances and examples in research and education

**Florian M. Wagner**<sup>1</sup>, Carsten Rücker<sup>2</sup>, Thomas Günther<sup>3</sup>, Friedrich Dinsel<sup>4</sup>, Nico Skibbe<sup>3</sup>, Maximilian Weigand<sup>5</sup>, and Joost Hase<sup>5</sup>

<sup>1</sup>RWTH Aachen University, Applied Geophysics and Geothermal Energy, Aachen, Germany (florian.wagner@eonerc.rwth-aachen.de)

<sup>2</sup>Berlin University of Technology, Department of Applied Geophysics, Berlin, Germany (now at: Federal Office for the Safety of Nuclear Waste Management, BASE)

<sup>3</sup>Leibniz Institute for Applied Geophysics (LIAG), S2 Geoelectrics & Electromagnetics, Hannover, Germany

<sup>4</sup>Berlin University of Technology, Department of Applied Geophysics, Berlin, Germany

<sup>5</sup>University of Bonn, Institute of Geosciences, Section Geophysics, Bonn Germany

Hydrogeophysics is interdisciplinary by definition. As researchers strive to gain quantitative information on process-relevant subsurface parameters while integrating non-geophysical measurements, multi-physical geoscientific models are often developed that simulate the dynamic process and its geophysical response. Such endeavors are associated with considerable technical challenges due to coupling of different numerical models, which represents an initial hurdle for students and many practitioners. Even technically versatile users often end up with individually tailored solutions at the cost of scientific reproducibility.

We argue that the reproducibility of studies in computational hydrogeophysics, and therefore the advancement of the field itself, needs versatile open-source software. One example is pyGIMLi - a flexible and computationally efficient framework for modeling and inversion in geophysics. The library provides management for structured and unstructured 2D and 3D meshes, finite-element and finite-volume solvers, various geophysical forward operators, as well as a generalized Gauss-Newton based inversion framework.

In this contribution, we highlight some of the recent advances and use cases in research and education since its 1.0 release in 2017 (Rücker et al., 2017) including:

- generalized modeling and inversion frameworks for conventional, joint, time-lapse and process-based inversion
- geostatistical regularization operators for unstructured meshes (Jordi et al., 2018)
- improved constraints in the presence of petrophysical parameter transformations demonstrated by an estimation of water, ice, and air in partially frozen systems (Wagner et al., 2019)

- 3D visualization leveraging upon PyVista (Sullivan and Kaszynski, 2019)
- simulation of electrical streaming potentials
- complex-valued forward modeling and inversion of induced polarization
- forward modeling with anisotropic parameters
- availability for Mac OS
- improved API and documentation

Since the library is freely available and platform-compatible, it is also well suited for teaching. We demonstrate examples from Master level university courses and public outreach, where learners can interactively change model and acquisition parameters to study their influence on a hydrogeophysical process simulation. Finally, we would like to use this opportunity to discuss future developments with the community.

## References

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