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Salvus: A flexible high-performance and open-source package for waveform modelling and inversion from laboratory to global scales

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Recent years have been witness to the application of waveform inversion to new and exciting domains, ranging from non-destructive testing to global seismology. Often, each new application brings with it novel wave propagation physics, spatial and temporal discretizations, and models of variable complexity. Adapting existing software to these novel applications often requires a significant investment of time, and acts as a barrier to progress. To combat these problems we introduce Salvus, a software package designed to solve large-scale full-waveform inverse problems, with a focus on both flexibility and performance.

Currently based on an abstract implementation of high order finite (spectral) elements, we have built Salvus to work on unstructured quad/hex meshes in both 2 or 3 dimensions, with support for P1-P3 bases on triangles and tetrahedra. A diverse (and expanding) collection of wave propagation physics are supported (i.e. viscoelastic, coupled solid-fluid). With a focus on the inverse problem, functionality is provided to ease integration with internal and external optimization libraries. Additionally, a python-based meshing package is included to simplify the generation and manipulation of regional to global scale Earth models (quad/hex), with interfaces available to external mesh generators for complex engineering-scale applications (quad/hex/tri/tet). Finally, to ensure that the code remains accurate and maintainable, we build upon software libraries such as PETSc and Eigen, and follow modern software design and testing protocols.

Salvus bridges the gap between research and production codes with a design based on C++ template mix-ins and Python wrappers that separates the physical equations from the numerical core. This allows domain scientists to add new equations using a high-level interface, without having to worry about optimized implementation details. Our goal in this presentation is to introduce the code, show several examples across the scales, and discuss some of the extensible design points.