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Nonlinear to Linear Modeling Toward an End-to-End Capability

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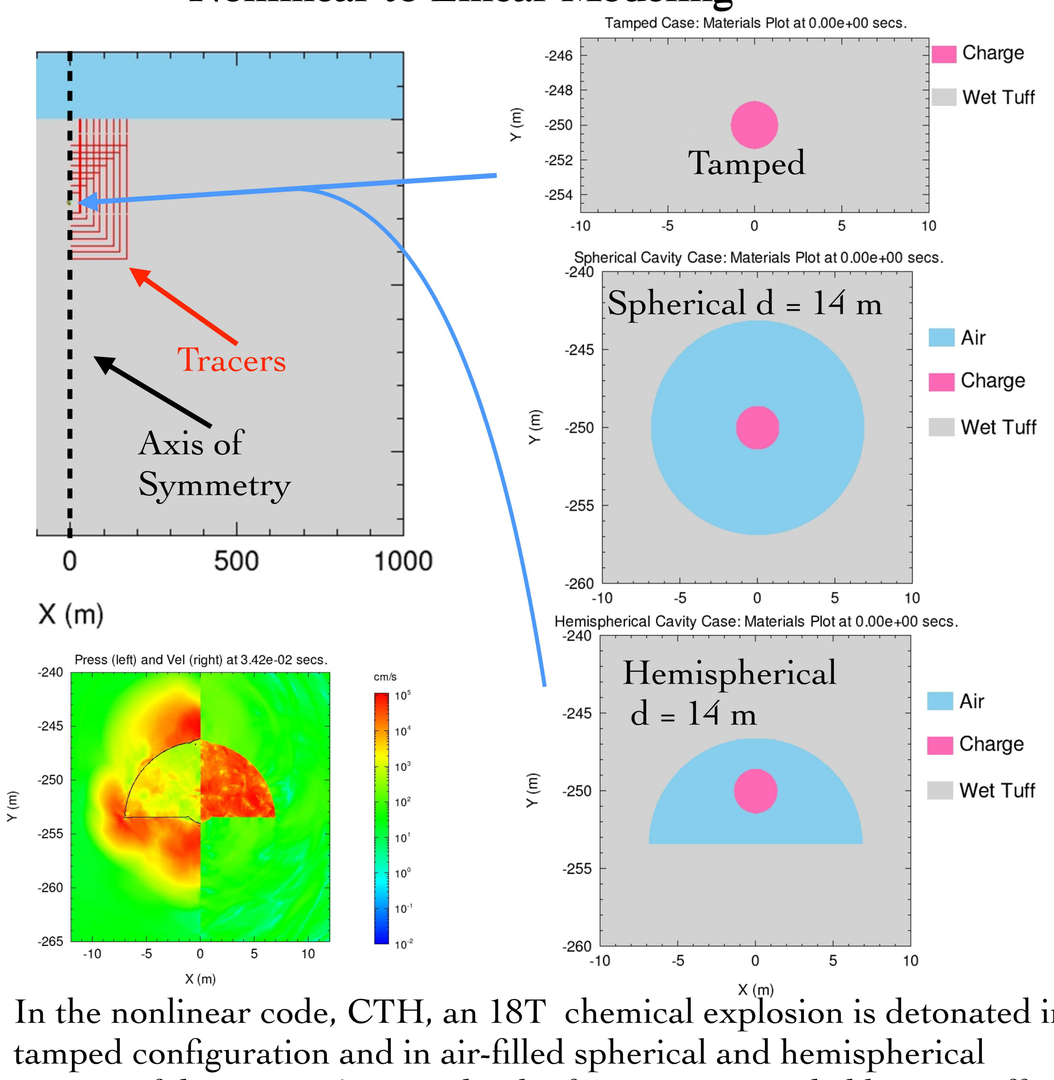
Goals

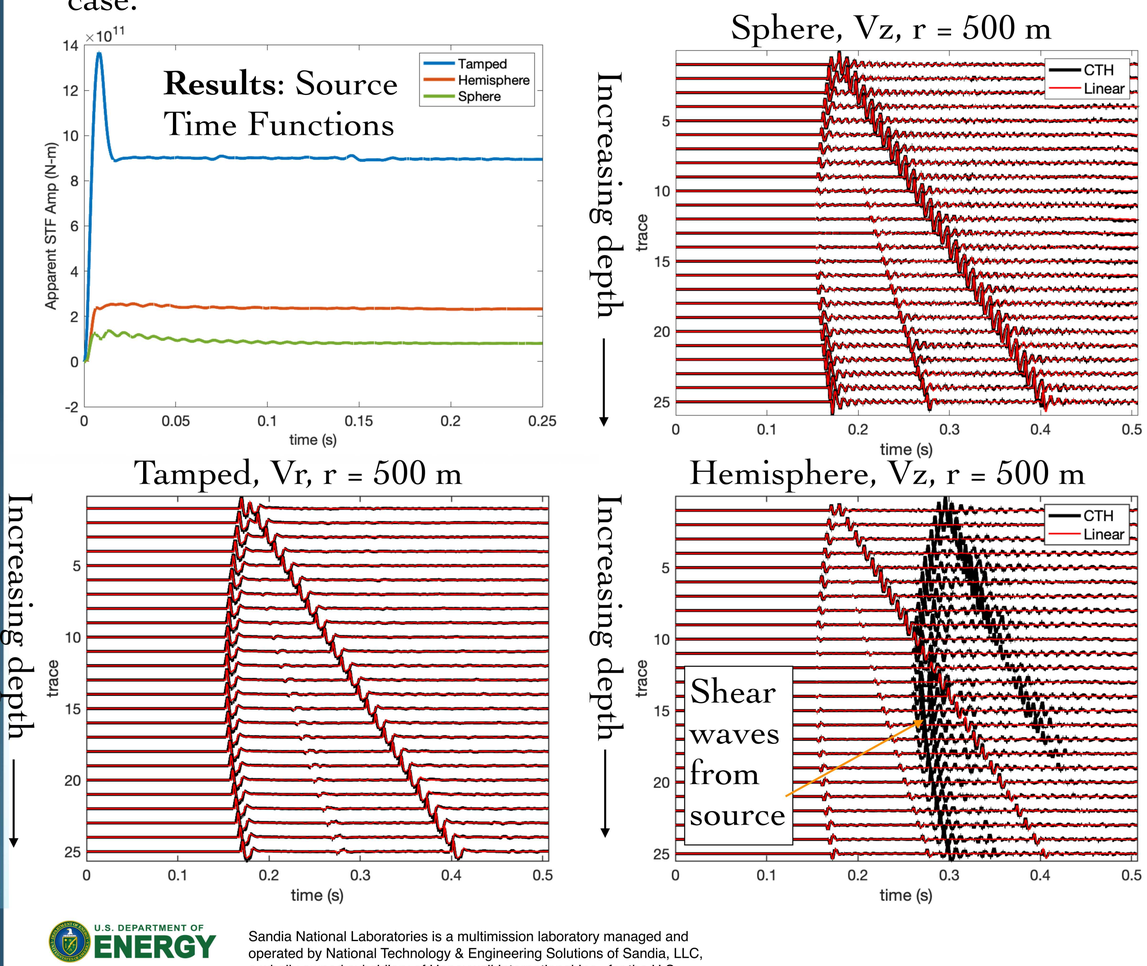
Using coupling of nonlinear to linear algorithms, we aim to understand:

- Under what circumstances and to what level of accuracy can purely linear (computationally efficient) algorithms match seismic waveforms from nonlinear sources in the far field
- How unknown earth structure in the near-source to local distances affect source models
- Uncertainty estimates for source characterization

Nonlinear to Linear Modeling

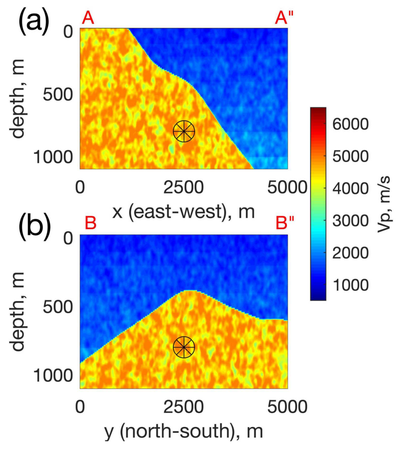


- In the nonlinear code, CTH, an 18T chemical explosion is detonated in a tamped configuration and in air-filled spherical and hemispherical cavities of diameter 14 m at a depth of 250 m surrounded by wet tuff. Note: These are similar to the PE1-A,-B, and -DL configurations, but do not exactly replicate them since we are testing the effects of changing various parameters (such as diameters, here).
- Particle velocities and stresses are captured at tracer points surrounding the charge at 130 m distance (red Tracers, above).
- These are used as time-varying boundary conditions in a linear seismic algorithm and propagated to 500 m distance.
- A purely linear Green's function, based solely on the tamped case, is used to compute linear-equivalent **isotropic** source time functions for each case.

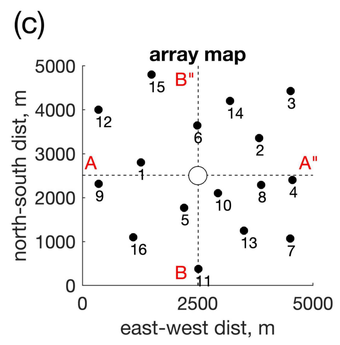


Stochastic Earth Model Effects on Moment Tensors

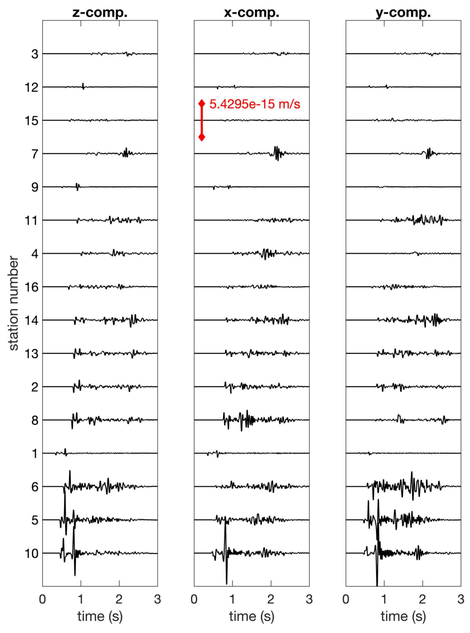
Earth Model with 7.5% perturbation



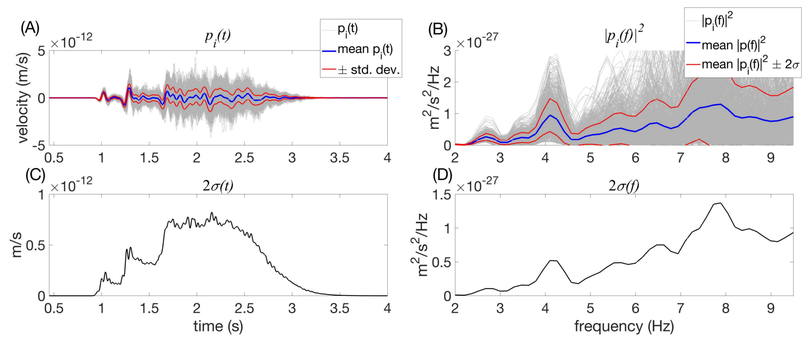
Seismic Array Geometry

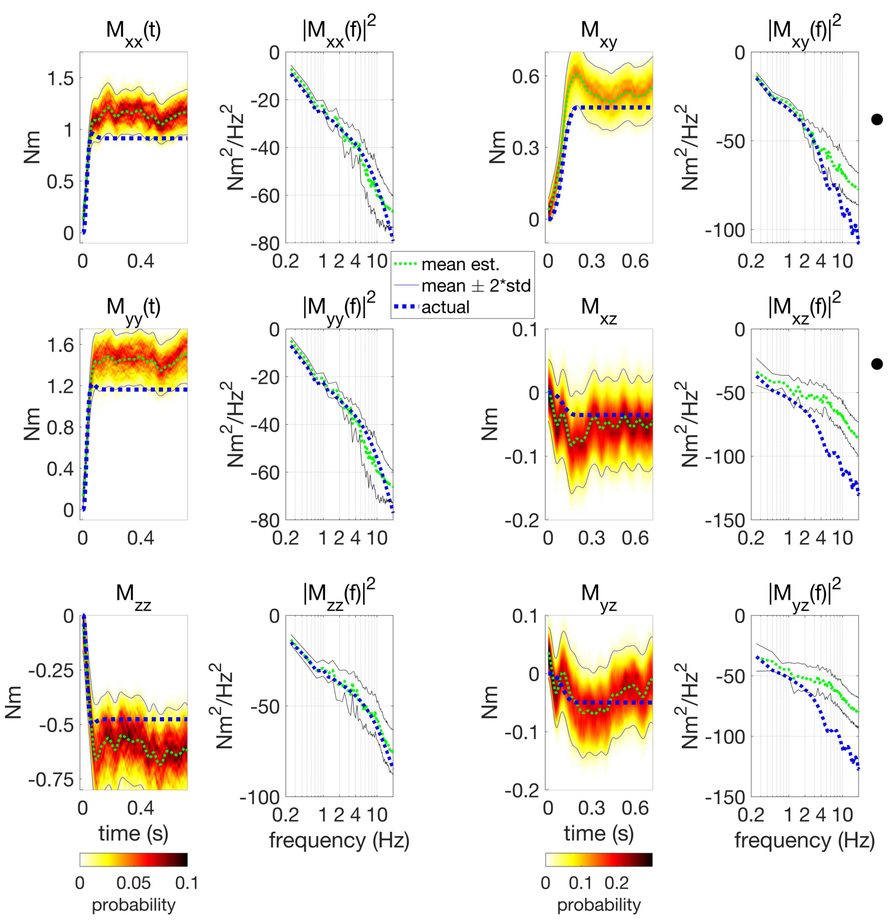


"Observed" data



Summary of the 1000 Green's functions: (A) time domain, (B) frequency domain, (C) standard deviation as a function of time and (D) frequency





- We formed over 1,000 3-D earth models with stochastic perturbations of 2.5%, 5%, and 7.5%
- Seismic Green's functions were computed on an array of 3-component receivers for each model
- "Observed" data were formed with known source time functions for all 6 components of the moment tensor with one of the stochastic models
- The "observed" data were inverted using the remaining Green's functions to provide an estimate of the effects of uncertain earth models on moment tensor solutions

Left: **Results** of 1000 inversions for each of the 6 components of the moment tensor in the time and frequency domains.

Impact

- Will identify when costly and time-consuming nonlinear simulations are necessary for source characterization
- Will quantify uncertainty caused by faster, linear source modeling and near-source properties on source characterization
- Will quantify the effects of earth heterogeneity on far-field moment tensors
- Thus, decision makers in DOE or elsewhere will be better informed as to the uncertainty and quality of source characteristics for events of interest

Future Plans

- Increase complexity of nonlinear models to include heterogeneity
- Model 3-D nonlinear to linear effects and the full moment tensor
- Comparison of modeling results with PE1 and other observed/laboratory data
- Explore generation and structural on infrasound signals

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