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AxiSEM: Exploiting structural complexity for efficient wave propagation across the scales

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Our open-source seismic modeling method AxiSEM (www.axisem.info) is presented a backbone for numerous further extensions, including accurate and efficient wave propagation in 3D Earth models, a database mode (www.instaseis.net), local domains, hybrid methods, and waveform sensitivity kernels for tomography. Our general mantra is to enable wave propagation across the observable frequency spectrum in a most efficient manner by adapting the methodology directly to the level of structural complexity, in the vein of Occam's razor.

The basic AxiSEM approach relies upon axisymmetric (including spherically symmetric) models, thereby satisfying a large fraction of observable data. The benefit of this method stems from the resultant dimensional collapse to two numerical dimensions, whereby the third azimuthal dimension is tackled analytically. For high-frequency wave propagation, this leads to 3-4 orders of magnitude speedup in computational cost compared to 3D domain discretizations. AxiSEM is highly scalable anywhere between laptops and supercomputers, and includes novel, optimized implementations of viscoelasticity and anisotropy. We present benchmarks, data comparisons, a range of unique applications from inner-core anisotropy to noise modeling and lowermost mantle structures.

1D structures are exploited by instaseis, a methodology to extract full, broadband and accurate waveforms instantaneously from wavefield databases computed with AxiSEM. A webservice built on instaseis ("syngine") has been launched at IRIS (see abstract EGU2016-8190) to generate on-demand synthetics up to 1Hz for prominent Earth models.

3D structures are tackled by our recent extension AxiSEM3D: We expand the wavefield in the azimuthal dimension in Fourier series, leading to a drastic computational cost speedup compared to classic 3D methods (up to a factor of 100), especially in the high-frequency regime. We will show benchmarks for typical global tomographic models and sketch our approach to determine the required extent of azimuthal spectral expansion.

Other ongoing efforts include a generalization to arbitrary domains (including local-scale) and a hybrid method linking any of the above to full 3D discretizations for localized, small sharp features. Finally, we sketch the application to the inverse problem by means of a sensitivity kernel methodology for large-scale waveform tomography (see also abstract EGU2016-7020).