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A new approach to global seismic tomography based on regularization by sparsity in a novel 3D spherical wavelet basis

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Global seismic wavespeed models are routinely parameterized in terms of spherical harmonics, networks of tetrahedral nodes, rectangular voxels, or spherical splines. Up to now, Earth model parametrizations by wavelets on the three-dimensional ball remain uncommon. Here we propose such a procedure with the following three goals in mind: (1) The multiresolution character of a wavelet basis allows for the models to be represented with an effective spatial resolution that varies as a function of position within the Earth. (2) This property can be used to great advantage in the regularization of seismic inversion schemes by seeking the most sparse solution vector, in wavelet space, through iterative minimization of a combination of the ℓ_2 (to fit the data) and ℓ_1 norms (to promote sparsity in wavelet space). (3) With the continuing increase in high-quality seismic data, our focus is also on numerical efficiency and the ability to use parallel computing in reconstructing the model.

In this presentation we propose a new wavelet basis to take advantage of these three properties. To form the numerical grid we begin with a surface tesselation known as the “cubed sphere”, a construction popular in fluid dynamics and computational seismology, coupled with an semi-regular radial subdivison that honors the major seismic discontinuities between the core-mantle boundary and the surface. This mapping first divides the volume of the mantle into six portions. In each “chunk” two angular and one radial variable are used for parametrization. In the new variables standard ‘cartesian’ algorithms can more easily be used to perform the wavelet transform (or other common transforms). Edges between chunks are handled by special boundary filters. We highlight the benefits of this construction and use it to analyze the information present in several published seismic compressional-wavespeed models of the mantle, paying special attention to the statistics of wavelet and scaling coefficients across scales. We also focus on the likely gains of future inversions of finite-frequency seismic data using a sparsity promoting penalty in combination with our new wavelet approach.