1D structure, 2D space, 3D wavefields: New windows to global tomography

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In most recent years, one of Tony Dahlen's many scientific interests lead to a generalized foundation for finite-frequency tomography without limitations as to which part of a seismogram may be utilized. Reformulating his previous ray-based banana-doughnut kernel developments which culminated in plume imaging, this necessitates the knowledge of 3D time-space wavefields for the Green functions that form the backbone of Fréchet sensitivity kernels. Although known for a while, this idea is still computationally intractable in 3D, facing major simulation and storage issues when global wavefields up to 1 Hz are considered.

This motivated Tony to dive into the underlying numerical theory of the spectral-element method, proposing a new "collapsed-dimension", 2D version thereof that solves the 3D equations based upon exploring symmetries of the seismic-wave radiation patterns. The mathematical framework was swiftly finalized, thus opening new doors to high-resolution inversions using e.g. diffracted phases around the core-mantle boundary. Before pursuing this endeavor, it was of utmost importance to him that such a numerical brainchild would be computationally advantageous for years to come in that full 3D wave propagation would not swallow its practicability in any nearer future. After thorough consultation in this regard, we set out to implement the method step-by-step adhering to Tony's infamous "scribbly notes", eventually passing its crucial 1.0 incarnation for (continental, non-gravitating) SNREI models. The advantage of such a once-and-for-all construction of reference-model waveform databases is its immediate, flexible applicability to arbitrary resolutions on moderate cluster infrastructures. This comes at the expense of being generally limited to 1D reference models, i.e. excluding iterative waveform fitting in contrast to adjoint tomography. However, we believe that it is timely for a complementary exploitation of all previously neglected time-frequency windows within a broadband seismogram for linearized inversions at the global scale.

I will present the ideas behind, development of, and proposed directions for this project which absorbed much of Tony's research planning into the next few years, drawing upon his minute diligence, infectious excitement and firm conviction of anticipating lowermost mantle images with unprecedented detail and sharpness in a collaborative effort within the seismology group at Princeton. His eager drive to mentor, support, and teach the entire group throughout these last few years made them a scientifically rewarding, thought-provoking, interesting, and always humorously painted journey – just one of many inspiring examples of his exceptional scientific rigor, strength of clearest thought, and ubiquitous modesty.