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Evaluation of Model Resolution with Various Forward Theory and Parameterization: A Synthetic Study

Y.-H. Chang (1), S.-H. Hung (1), H.-Y. Yang (1), and L.-Y. Chiao (2)

(1) National Taiwan University, Department of Geoscience, Taipei, 10617, Taiwan (r96224210@ntu.edu.tw), (2) National Taiwan University, Institute of Oceanography, Taipei, 10617, Taiwan

Whether different forward theory and parameterization methods lead to the improvement of the resulting 3-D earth structure tomographic images has been a focus of attention in the tomography community. Recent advance in seismic tomography has gone beyond classical ray theory and incorporated the 3-D sensitivity kernels of frequency-dependent travel-time data into imaging the earth's internal structure with unprecedented resolution. On the other hand, the idea of multi-scale parameterization has been introduced to deal with naturally uneven data distribution and varying model resolution in tomographic inverse problems. The multi-resolution model automatically built through the wavelet decomposition and synthesis results in the non-stationary spatial resolution with data-adaptive resolvable scales. Because the Gram matrix of Frechet derivatives that relates observed data to seismic velocity variations is usually too large to be practically inverted by singular value decomposition (SVD), the iterative LSQR algorithm is instead employed in the inversion which inhibits the direct calculation of resolution matrix to assess the model performance. With the increasing computing power, we can now calculate the SVD of the Gram matrix more efficiently using the parallel PROPACK solver. In this study, we compute the ground-truth psudospectral seismograms in random media with various heterongeity strengths and scale lengths. The finite-frequency travel-time shifts measured from waveform cross correlation are then used to invert for the implanted random structure based on different forward theory and model parameterization. The tradeoffs between data fit and model resolution associated with different forward theory and parameterization will be systematically explored to subjectively compare the actual resolving power of a given dataset.