Geophysical Research Abstracts
Vol. 17, EGU2015-8609, 2015
EGU General Assembly 2015

Developing Advanced Seismic Imaging Methods For Characterizing the Fault Zone Structure

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Here I present a series of recent developments on seismic imaging of fault zone structure. The goals of these advanced methods are to better determine the physical properties (including seismic velocity, attenuation, and anisotropy) around the fault zone and its boundaries. In order to accurately determine the seismic velocity structure of the fault zone, we have recently developed a wavelet-based double-difference seismic tomography method, in which the wavelet coefficients of the velocity model, rather than the model itself, are solved using both the absolute and differential arrival times. This method takes advantage of the multiscale nature of the velocity model and the multiscale wavelet representation property. Because of the velocity model is sparse in the wavelet domain, a sparsity constraint is applied to tomographic inversion. Compared to conventional tomography methods, the new method is both data- and model-adaptive, and thus can better resolve the fault zone structure.

In addition to seismic velocity property of the fault zone, seismic anisotropy and attenuation properties are also important to characterize the fault zone structure. For this reason, we developed the seismic anisotropy tomography method to image the three-dimensional anisotropy strength model of the fault zone using shear wave splitting delay times between fast and slow shear waves. The applications to the San Andreas fault around Parkfield, California and north Anatolian fault in Turkey will be shown. To better constrain the seismic attenuation structure, we developed a new seismic attenuation tomography method using measured t* values for first arrival body waves, in which the structures of attenuation and velocity models are similar through the cross-gradient constraint.

Seismic tomography can, however, only resolve the smooth variations in elastic properties in Earth's interior. To image structure at length scales smaller than what can be resolved tomographically, including elasticity contrasts across faults, one must use the scattered seismic wavefield (for instance, reflections and phase conversions). Here I present the results of using a generalized Radon transform (GRT) for the passive waveform imaging of near vertical faults in the shallow part of the crust around the SAFOD site, California. The application to the Longmenshan fault system using the aftershock data of the 2013 Mw6.6 Lushan earthquake, China will also be presented.