Continuum Seismic Recording

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The principles of seismic recording have basically remained the same for nearly 150 years through the use of inertial seismographs that are primarily sensitive to ground velocity or acceleration. Progress in seismic recording has been made through dramatic improvements in sensor stability, bandwidth, sensitivity, and dynamic range with equally important technological breakthroughs in digital recording and accurate timing systems. However, the basic observation remains as a seismogram – a time record of a component of ground motion at a particular location on a planetary body. Seismology has progressed by interpreting these ground motions as seismic waves determining time and amplitude information to construct hypotheses about earth structure and seismic source processes. Through continuous testing and retesting of these hypotheses, errors in interpretations have been found and corrected to build the body of knowledge that we have today.

However, our fundamental measurement of the characteristics of a seismic wave, its vector ground motion, is a shadow of all of the attributes that we would like to know before using the wave to understand the earth. A seismic wave is not only a temporal disturbance but a spatial one as well. Imagine what it would be like to have a seismogram with additional information of wave velocity, wave type, wave propagation direction, and spatial amplitude changes at all points on the seismogram. Such data would offer an order-of-magnitude greater number of constraints to studies of velocity heterogeneity (e.g., tomography, wave scattering, anisotropy), source complexity (e.g., rupture propagation, finiteness), and studies of media non-linearity for strong ground motions. This kind of seismic recording is starting to be explored through the use dense seismic arrays (gradiometers) that have apertures of less than 10% of a wavelength and collocated seismometers, seismic rotation meters and strain meters. The latter configuration samples the local continuum at a scale of the seismic wavelength but measured at a single point – essentially a "point seismic array". The combined measurement of ground motion and its spatial gradients allows a direct look at a seismic wave by determining all of those wave attributes previously mentioned. The Figure shows an example of wave gradiometry using data recorded by the ANZA seismic network for the 4/01/07 M8.1 Solomon Islands earthquake.

Recording a seismic wave within its spatial continuum will be the next important step in seismology that will, no doubt, yield new source and structure paradigms and new processing methods. Although gradiometry experiments can be built using existing seismic instrumentation, the challenge will be developing economical strain and rotation meters with comparable fidelity to present high-quality broadband seismometers. Theoretical and practical advances will also be needed to numerically model the new data since wave gradiometry should give unprecedented detail on the heterogeneity of the earth. Reference to previous work in this emerging field can be found in Langston and Liang (2008) Gradiometry for polarized seismic waves, *J. Geophys. Res.*, 113, B08305, doi:10.1029/2007JB005486.

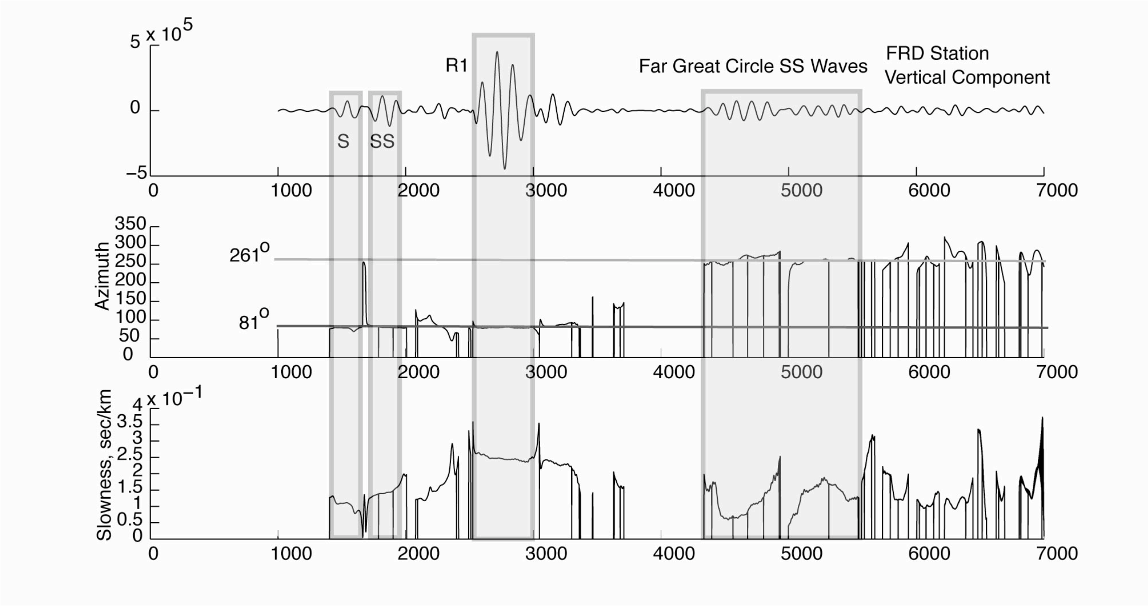

Figure showing two attributes of seismic waves contained in the vertical component wavetrain of data recorded by 10 stations of the ANZA seismic network in southern California for the 4/01/2007 M8.1 Solomon Islands earthquake. Stations of the network were used to compute seismic strains and rotations. The NS and EW spatial gradients of the vertical wavefield were processed using wave gradiometry to obtain wave propagation azimuth (middle panel) and wave slowness (lower panel). The upper panel shows filtered (0.01 – 0.4 Hz) ground displacements at station FRD near the center of the network. Seismic wavelengths are about 400km or larger compared to the ~50km aperture of the gradiometer. The theoretical great circle wave azimuth from the source to ANZA is 81^o and the far great circle path wave azimuth 261^o. Note how wave directions are resolved by the analysis. Further details can be found in the Langston and Liang reference above.