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Detection, location, and analysis of earthquakes using seismic surface waves (Beno Gutenberg Medal Lecture)

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For shallow sources, Love and Rayleigh waves are the largest seismic phases recorded at teleseismic distances. The utility of these waves for earthquake characterization was traditionally limited to magnitude estimation, since geographically variable dispersion makes it difficult to determine useful travel-time information from the waveforms. Path delays due to heterogeneity of several tens of seconds are typical for waves at 50 sec period, and these delays must be accounted for with precision and accuracy in order to extract propagation-phase and source-phase information. Advances in tomographic mapping of global surface-wave phase velocities, and continuous growth and improvements of seismographic networks around the world, now make possible new applications of surface waves for earthquake monitoring and analysis. Through continuous back propagation of the long-period seismic wave field recorded by globally distributed stations, nearly all shallow earthquakes greater than M=5 can be detected and located with a precision of 25 km. Some of the detected events do not appear in standard earthquake catalogs and correspond to non-tectonic earthquakes, including landslides, glacier calving, and volcanic events. With the improved ability to predict complex propagation effects of surface waves across a heterogeneous Earth, moment-tensor and force representations of seismic sources can be routinely determined for all earthquakes greater than M=5 by waveform fitting of surface waves. A current area of progress in the use of surface waves for earthquake studies is the determination of precise relative locations of remote seismicity by systematic cross correlation and analysis of surface waves generated by neighboring sources. Preliminary results indicate that a location precision of 5 km may be achievable in many areas of the world.