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Constructing new seismograms from old earthquakes: Retrospective seismology at multiple length scales

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If energy emitted by a seismic source such as an earthquake is recorded on a suitable backbone array of seismometers, source-receiver interferometry (SRI) is a method that allows those recordings to be projected to the location of another target seismometer, providing an estimate of the seismogram that would have been recorded at that location. Since the other seismometer may not have been deployed at the time the source occurred, this renders possible the concept of "retrospective seismology" whereby the installation of a sensor at one period of time allows the construction of virtual seismograms as though that sensor had been active before or after its period of installation. Using the benefit of hindsight of earthquake location or magnitude estimates, SRI can establish new measurement capabilities closer to earthquake epicenters, thus potentially improving earthquake location estimates.

Recently we showed that virtual SRI seismograms can be constructed on target sensors in both industrial seismic and earthquake seismology settings, using both active seismic sources and ambient seismic noise to construct SRI propagators, and on length scales ranging over 5 orders of magnitude from $\sim$40 m to $\sim$2500 km[1]. Here we present the results from earthquake seismology by comparing virtual earthquake seismograms constructed at target sensors by SRI to those actually recorded on the same sensors. We show that spatial integrations required by interferometric theory can be calculated over irregular receiver arrays by embedding these arrays within 2D spatial Voronoi cells, thus improving spatial interpolation and interferometric results. The results of SRI are significantly improved by restricting the backbone receiver array to include approximately those receivers that provide a stationary phase contribution to the interferometric integrals. We apply both correlation-correlation and correlation-convolution SRI, and show that the latter constructs virtual seismograms with fewer non-physical arrivals. Finally we reconstruct earthquake seismograms at sensors that were previously active but were subsequently removed before the earthquakes occurred; thus we create virtual earthquake seismograms at those sensors, truly retrospectively. Such SRI seismograms can be used to create a catalogue of new, virtual earthquake seismograms that are available to complement real earthquake data in future earthquake seismology studies.

[1]E. Entwistle, Curtis, A., Galetti, E., Baptie, B., Meles, G., Constructing new seismograms from old earthquakes: Retrospective seismology at multiple length scales, JGR, *in press.*