

Development of Automatic Processing Methods for Analysis of Local Network Datasets

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Investigations Undertaken

We continued our development of automatic methods for processing and stacking local network seismic data. Our focus during the last year has been on improving the accuracy of earthquake locations in southern California.

Our earthquake location project has involved two complementary approaches:

We have developed a robust, grid-search algorithm for locating earthquakes using existing P and S arrival-time picks that includes spatially varying station terms to account for three-dimensional velocity structure. We have relocated over 300,000 events from 1975 to 1996 using this approach.

We have continued using waveform cross-correlation methods to achieve high location accuracy for localized clusters of events. We have recently applied this technique to aftershock sequences of the Upland earthquakes, the Oceanside earthquake, and a number of other offshore events. In addition, we have analyzed a small swarm of very similar events beneath Oak Ridge in Ventura county.

Results

We are relocating earthquakes in southern California using a variety of approaches that provide increased accuracy compared to standard methods. These involve application of the L1-norm for robustness with respect to outliers in the data, use of customized station terms to account for three-dimensional structure, and use of waveform cross-correlation for precision relocation of similar events. Our efforts are proceeding on two fronts: (1) relocation of the entire southern California earthquake catalog (>300,000 events since 1980) using the archived SCSN picks, a grid-search L1-norm algorithm, and customized station terms, (2) relocation of selected seismicity clusters using waveform cross-correlation to provide precise differential times between events.

Improving catalog locations

The accuracy of the earthquake locations in the Southern California Seismic Network (SCSN) catalog is limited, particularly in depth. We have found that the relative location accuracy between nearby events can be greatly improved through the use of the L1-norm and station terms. Customized station terms have often been used to improve location accuracy for individual clusters of events, and provide results comparable to master event methods by accounting for three-dimensional velocity variations between the cluster and the stations recording the events. However, such methods are not as useful for larger distributions of seismicity since a single set of station terms is not optimal for the entire seismicity volume.

A practical way to relocate large areas of seismicity while achieving high relative location accuracy between nearby events is to permit spatial variations in the station terms. We implement this approach through an interactive procedure that first locates the events, then smooths the residuals at each station, relocates the events, etc. We apply a smoothing algorithm based on the seismicity density that naturally increases the station term resolution in areas with large number of events.

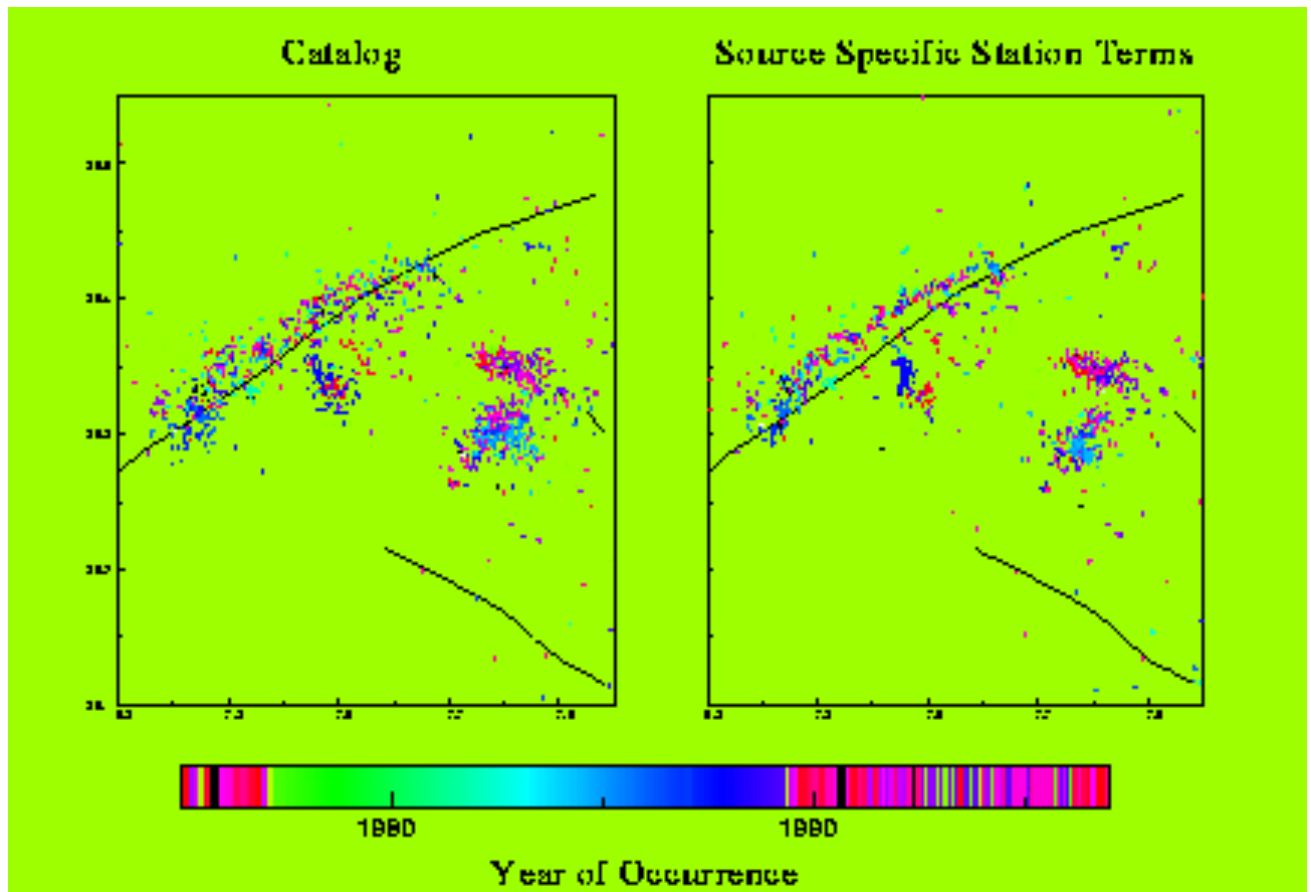


Figure 1. Earthquake on a small section of the Garlock fault, as located by the SCSN catalog and our source-specific station term method.

We have relocated the SCSN catalog of over 300,000 events (1975 to 1996) by applying this approach to the existing P and S picks. Scatter in the locations is reduced, particularly in depth, compared to the catalog locations. This is illustrated in Figure 1, for events along the Garlock fault. We are currently writing a paper describing our method and the results for southern California; we are also planning to provide easy access to our catalog by posting it on the web.

Offshore earthquakes

We have recently relocated offshore events in southern California, using waveform cross-correlation and our L1-norm approach (Astiz and Shearer, 1998). Events in this area are difficult to locate accurately due to the limited station coverage and uncertainties in the velocity structure. Accordingly we have carefully explored the sensitivity of our solutions to changes in the modeling assumptions for a number of offshore clusters (see Figure 2). These include the 1986 Oceanside sequence (OCS), Santa Barbara Island (SBI), Santa Catalina Island (SCA), Coronado Banks (CBK) and three regions near San Clemente Island (SCLN, SCL, SCLS). We interpret our results in terms of the inferred fault geometries in this area.

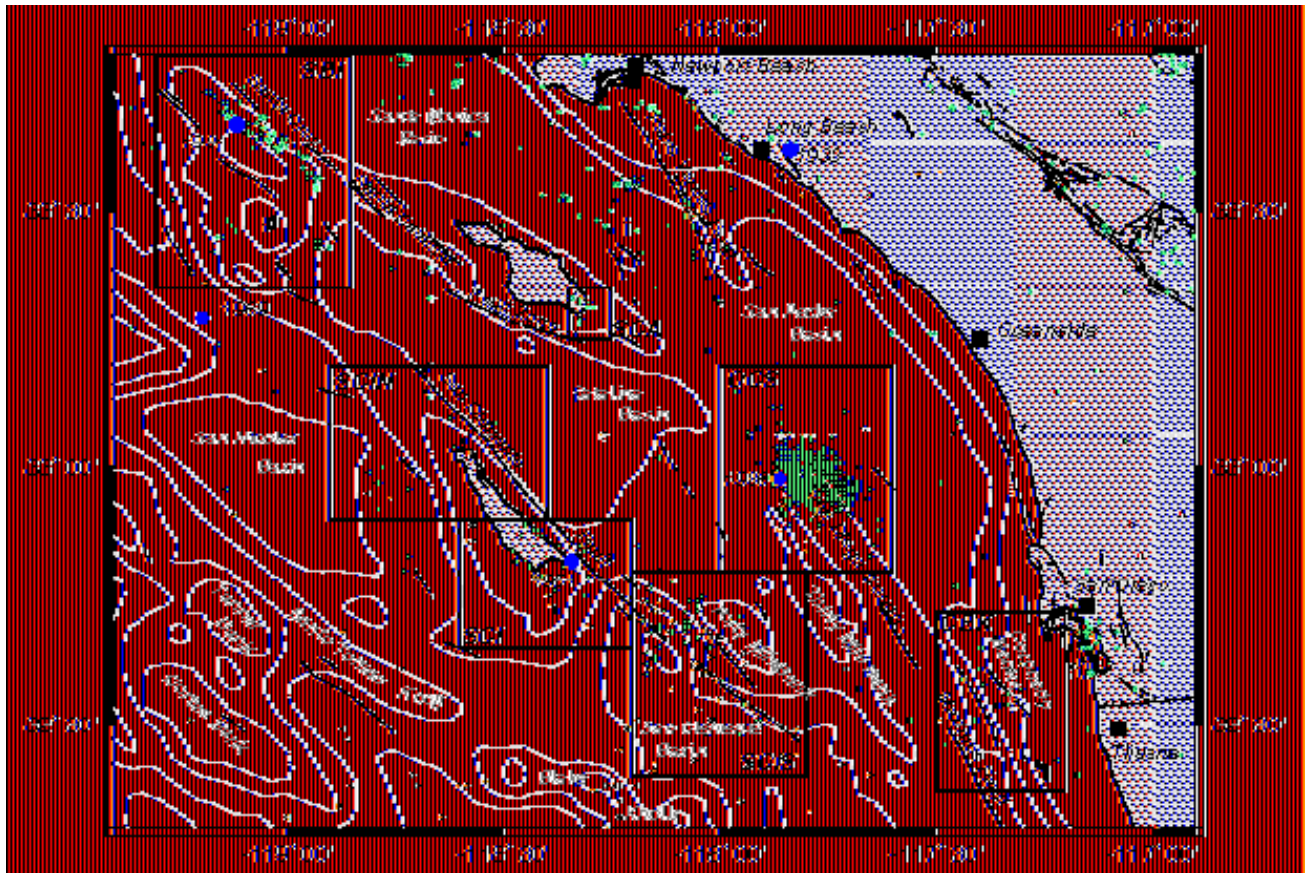


Figure 2. Locations of offshore earthquakes relocated in our study of the Borderland region.

The Oak Ridge Cluster

A swarm of about 50 small earthquakes ($M \sim 1.5$) occurred for a month during 1989 beneath Oak Ridge, southern California. We relocate these events using waveform cross-correlation and find that the relocated events form a small cluster about 1 km across at a depth of ~ 18 km, and are aligned along a plane that dips 35 degrees to the northwest. The time evolution of the sequence shows a gradual migration of activity away from its initiation point. Reliable fault plane solutions are difficult to obtain for these events, but our results suggest that the slip planes of probable focal mechanisms are not in agreement with the plane defined by the seismicity. The seismicity alignment may represent the extension of the Simi fault, in which case some shallowing of the fault dip would be required to match the observed 35 degree dip at 18 km.

Upland Aftershocks

Aftershocks of the 1988 ($M=4.6$) and 1990 ($M=5.2$) earthquakes at Upland, southern California, occur along a plane dipping steeply to the northwest. Relocations of ~ 1600 aftershocks based on waveform cross-correlation show that this seismicity plane shallows at depth to become more consistent with the focal mechanism of the earlier, deeper event. Comparisons between the aftershock positions with models of static stress changes caused by the mainshock slips indicate that the aftershock distribution is uncorrelated with the regions of expected favorable stress changes (Astiz, Shearer and Agnew, 1998).

Non-technical summary

We have developed new techniques for locating earthquakes in southern California and used them to relocate Offshore earthquakes

nearly 300,000 events during the last 20 years, including several major aftershock sequences following large earthquakes. Our locations are much more accurate than the standard catalog locations and permit better delineation of fault structures in southern California.

Reports Published

Shearer, P.M., Improving local earthquake locations using the L1-norm and waveform cross-correlation: application to the Whittier Narrows, California, aftershock sequence, *J. Geophys. Res.*, 102, 8269-8283, 1997.

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Data availability statement

We use arrival-time and waveform data that are readily available from the Southern California Seismic Network. Our earthquake locations will be published in the open literature; in addition, we will post our catalog of nearly 300,000 locations on the web.