NOTE 1 : If you use this catalog, please reference and acknowledge the SCSN and SCEDC:

Hauksson, E., Shearer, P. M., & Yang, W. (2012). Waveform Relocated Earthquake Catalog for Southern California (1981 to June 2011). *Bull. Seismol. Soc. Am*, *102*(5), 2239–2244. https://doi.org/10.1785/0120120010

Data Source Statement:
We have used waveforms and parametric data from the Caltech/USGS Southern California Seismic Network (SCSN); doi: 10.7914/SN/CI; stored at the Southern California Earthquake Data Center. doi:10.7909/C3WD3xH1.

NOTE 2: The 1981-2019 catalog differs significantly from previous versions.

NOTE 3: There is some important information at the end of each line, like:
le h gc 78
le -- local event or re for regional event
h or l or w – type of magnitude
gc – a GrowClust solution; 1d hypinverse; and 3d Simulps
78 -- the relocation box. Also, see map below of the boxes.
We divided southern California into 12 boxes for the relocations:18,28,…a8, b8, c8, d8
++++++++++++++++++++++

The 1981- 2019 version of the Hauksson et al. (2012) is produced formatted differently from previous versions because we use GrowClust for the final locations.
The approach is a follows:

1) First, we relocated the complete catalog with phase picks and a 1d velocity model in Hypoinverse
These solutions are labeled '1d'

2) Second, we replace all 1d solutions with solutions determined with a 3d velocity model in SIMULPS.
These solutions are labeled '3d'.

3) Third, we replace 1d or 3d solutions with a GrowClust solution, labeled (gc).
These are the highest quality solutions that are based on differential travel times determined with cross-correlation. These solutions are labeled 'gc'.

4) If you prefer only to work only with the GrowClust solutions, you can apply "grep gc filename1 > filename2".

5) If you read in the file into your program, you can use an 'if' statement to key in on if you are reading: a)'1d' or '3d' solutions; or 'gc' solutions.

1d and 3d Formats:
1981 01 02 01 00 37.570 3301590 32.04917 -116.73633 11.220 1.77 7 310
70.200 2.300 5.100 0.220 le 1d
1981 year
01 month
02 day
01 hour
00 min
37.570 sec

3301590 id
32.04917 lat
-116.73633 lon
11.220 depth
1.77 mag
7 # of phases
310 Azimuthal Gap
70.200 distance (km) to nearest station
2.300 horizontal error (km)
5.100 vertical error (km)
0.220 root mean square residual (sec)
le local event (also have re-regional events' qb- quarry blasts or explosions)
1d—solution determined with 1d velocity model in Hypoinverse

GrowClust Format (Trugman and Shearer, 2017):

4.1 Relocated catalog file

The relocated catalog file provides an event list with the relocated event positions and origin time, along with other relevant event information. The catalog contains one line per event (nq total), and each line has the following 25 columns:

- **yr, mon, day, hr, min, sec**: relocated origin time (columns 1–6)
- **eID**: event ID (column 7)
- **latR, lonR, depR**: relocated latitude, longitude and depth (decimal degrees and km; columns 8–10)
- **mag** event magnitude (column 11)
- **qID, cID, nbranch**: event serial ID number, cluster serial ID number, total number of events in this cluster (columns 12–14)
- **qnpair, qndiffP, qndiffS**: number of event pairs, *P*-phase differential times, and *S*-phase differential times used to relocate this event (columns 15–17)
- **rmsP, rmsS**: RMS residual differential times for this event for *P*- and *S*-phases (s; columns 18–19)
- **eh, ez, et**: estimated location errors in horizontal (km), vertical (km), and origin time (s; columns 20–22)
- **latC, lonC, depC**: initial (catalog) latitude, longitude and depth (decimal degrees and km; columns 23–25)

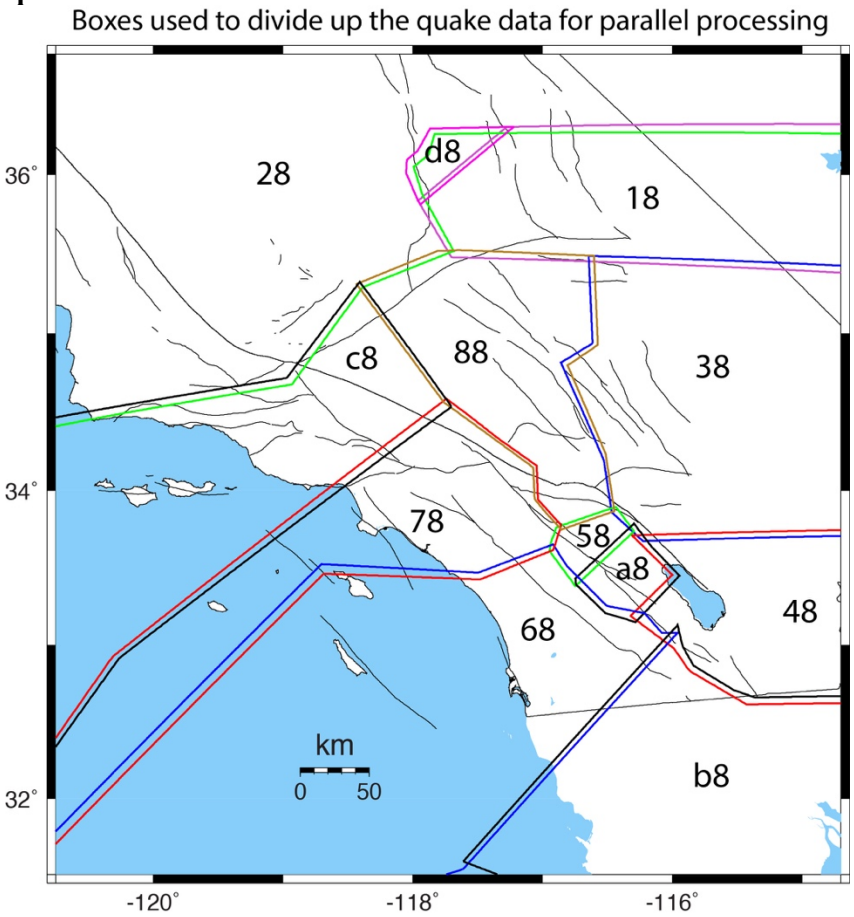
Lines are written in fixed format:
(i4, 4i3, f7.3, i10, f10.5, f11.5, f8.3, f6.2, 3i8, 3i6, 2f6.2, 3f8.3, 2x, f10.5, f11.5, f8.3).

All events that appear within the input event list are also listed in the relocated catalog (in the same order), even those that are not relocated by the GrowClust algorithm (e.g., due to insufficient waveform similarity). These events can be easily spotted within the relocated catalog, as they have have values nbranch = 1 and eh= ez = et = -1.000 (the default flag for unrelocated event errors).

References:

Trugman, D. T., and P. M. Shearer (2017). GrowClust: A Hierarchical Clustering Algorithm for Relative Earthquake Relocation, with Application to the Spanish Springs and Sheldon, Nevada, Earthquake Sequences, *Seismol. Res. Lett.* , 88 (2A), 379–391, doi:10.1785/0220160188 .

The cross-correlations and the catalog are determined by splitting the dataset into 12 different spatial boxes:



Known problems I:

There are several event pairs that have origin times within 1 or 2 seconds. These events have been verified by a human. However, the cross-correlation cannot distinguish such events because both events fall inside the same cross-correlation window. Thus they have the same location and origin time.

Mare details on known problems (from Ilia Zaliapin <zal@unr.edu> ; August 2019):

Hello Egill,

I preliminary checked the catalog, and see nothing alarming.
There are a couple of things though that I'd like to run by you.

1) I notice pairs of events at the exact same time/location with different

magnitudes. Two pairs are shown below; the catalog includes
143 pairs like these. Not sure if this is a real thing or not.

a)

1981	2	6	0	25	27.8	12254315	33.509	-116.76617	6	1.7
1981	2	6	0	25	27.8	12254319	33.509	-116.76617	6	0.9

b) (This one has the largest magnitude among the duplicate pairs)

2005	8	31	22	47	45.245	12217219	33.16531	-115.60582	13.642	3.5
2005	8	31	22	47	45.245	14178184	33.16531	-115.60582	13.642	4.59

2) Several days have abnormally low numbers of reported events:
January 14, 1981 5 events
March 31, 1981 5 events
April 26, 1983 4 events
April 27, 1983 2 events
April 29, 1983 4 events
April 13, 2002 3 events
April 14, 2002 3 events
April 15, 2002 1 event

With the average no. events per day is 46, the days above look like outliers.
Again, I'm not sure if this is real or not.

Next, I'll do declustering and some related analyzes, which may take a day or two.
Will let you know if see anything worth noting.

Thanks again for sharing the catalog.

Best,
Ilya

+++++++ from Jen Andrews:
Hi Egill, Ellen,

I've checked the 5 pairs listed for 2019 and in our catalogue these are true 'doublets'. The origin times are between 0.5 and 1.0s different, mag differences vary. The picks look fine to me, in the sense that it doesn't look like an identical phase pick is used in both events, but I didn't check exhaustively.

I'll continue my way back in time as I get the chance.

Thanks,
Jen

Hi Illia,

This estimate of 1 sec is probably optimistic because the cross correlation window is 1.5 sec. I need to find some time to look into this in more detail.
Regarding spatial duplicates. There are some bootstrapping location error estimates in the catalog. I have not had time to analyze these to see how the errors and locations compare, but it would be an interesting study.

Regards
Egill