

# CONSORTIUM TO STUDY TRENDS IN SEISMICITY

Quarterly report:  
October 1, 2018 through December 31, 2018

by

Rex Buchanan  
Shelby Peterie  
Rick Miller

Kansas Geological Survey  
1930 Constant Avenue  
Lawrence, KS 66047-3726

ph (785) 864-3965 / fax (785) 864-7728

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## INTRODUCTION

The Kansas Geological Survey's Consortium to Study Trends in Seismicity (CSTS) is a public-private partnership aimed at studying trends in seismicity in sensitive areas of Kansas. In 2009, seismicity increased significantly (both in terms of earthquake numbers and magnitude) in the midcontinent and later in Kansas, leading to a need to better define and understand seismicity, particularly in proximity to subsurface fluid disposal. The CSTS operates a seismic network that records and allows accurate location and magnitude estimates of seismicity for both felt earthquakes and especially microseismic events that are hundreds of times smaller than can be routinely identified with previous regional seismic networks.

The CSTS is an alliance of the Kansas Geological Survey (KGS), a research and service division of the University of Kansas with a long history of studying the state's subsurface and seismic issues with members of the state's Class 1 disposal well community. Class 1 wells are used for disposal of municipal and industrial waste and are regulated by the Kansas Department of Health and Environment (KDHE). Membership in the CSTS is voluntary, with a common goal of locating and understanding seismicity, especially microseismicity, in proximity to member facilities. The CSTS works to establish the baseline or background seismicity near those facilities and provide a scientific basis for differentiating natural (or tectonic) from induced seismicity.

The following report describes CSTS activities for the fourth quarter of 2018 (which is also the second quarter of the second year of CSTS operation), including a discussion of membership status; network station installation and operation; earthquakes recorded and identified, and earthquake alerts provided to members; and other activities. Quarterly reports and an annual report have been provided to members since the Consortium's first meeting in July 2017, as per contractual agreement.

## STATUS OF MEMBERS

The CSTS was established with a two-tier membership system. The CSTS provides Tier 1 members with equipment, installation, and monitoring of a seismograph station; maintains a catalog of seismic events, updated weekly, with a goal of providing e-mail alerts within 24 hours or less of any earthquakes greater than magnitude 2 within 30 miles of a facility; provides an annual report and quarterly reports of monitoring findings; and hosts an annual meeting at which results are discussed and plans formulated for the coming year. Tier 2 members have access to general information about the seismicity being studied by the CSTS—but not the detailed studies or the quarterly reports. They also can attend the annual meeting but do not have the right to vote at that meeting. The CSTS currently has eleven Tier 1 members and one Tier 2 member.

## STATUS OF NETWORK

The CSTS seismic network consists of twelve stations in Kearny, Ellsworth, Rice, McPherson, Reno, Kiowa, Sedgwick, Butler, and Johnson counties, Kansas (Figure 1). Waveforms for these stations are available for Tier 1 members on the seismic network page of the CSTS website (<http://www.kgs.ku.edu/Geophysics/CSTS/index.html>). For each of those locations, ambient noise tests were undertaken, identifying noise from nearby highways, trains, pump jacks, and other facilities that might create problems with earthquake analysis. In places where noise and vibrations interfered with a station's response, the station was relocated, mindful to retain sensitivity while improving signal to noise. Many of the existing sites are in cemeteries, on government property, or in other locations where noise levels are likely to be low. In all cases, written agreements with landowners are in place.

Each station consists of a seismic sensor that includes a shallowly buried seismometer (sensing motion polarized in x, y, and z directions) on a concrete platform embedded in a gravel layer, and a digitizer housed in an instrument enclosure powered by a sustainable battery system. Ground motion detected by the seismometer is transmitted back to KGS offices in Lawrence real-time via a cellular modem. That communication system is also powered by the sustainable battery system that includes a solar panel charging two deep-cycle marine batteries controlled by a power regulating circuit. The footprint for each station is approximately 10 feet by 10 feet. The stations have operated with a better than 98% continuous data stream and within designated operational sensitivity and signal-to-noise ratio.

A station's vital statistics are telemetered back to Lawrence coincident with the seismometer responses. In the second half of 2018, two stations received a visit to adjust solar panels twisted by the wind or torn from the post by the wind. All issues with station operations were detected immediately and service calls issued to avoid or minimize down time (non-transmitting).

## EARTHQUAKE ALERTS, CATALOG

Earthquakes with magnitudes of 2 or larger (some of which may be below felt levels) represent a threshold above which the CSTS network, in conjunction with the KGS regional and subregional networks, can provide highly confident automatic analysis. It is therefore reasonable to provide accurate epicenter locations using automated picking routines for each event at these energy levels, with results available within minutes of the fault rupture. Beginning in September 2018, the CSTS used an automated notification process to inform members of events of M 2 or larger earthquake within 30 miles of Tier 1 member wells. Those notifications provide epicenter latitude and longitude, origin time, and distance from the member well(s). These automatic notifications must be approved by a senior analyst before they can be sent to members to insure the authenticity of computer-interpreted earthquakes.

In the fourth quarter of the calendar year there were 35 earthquakes that met these criteria (Table 1), about a dozen more than the previous quarter. Microearthquake activity recorded by the KGS and CSTS networks was about the same as the previous quarter. A total of 54 earthquakes ranging from M 1.0 to 2.7 were recorded within 20

miles of member wells (Figure 2, Table 2). Most epicenters are within previously identified clusters or along known trends. Subnetwork activity (Table 3) was similar to the previous quarter, with the exception of events near station RN01. The trend of declining subnetwork events near RN01 continued with only 61 events this quarter, a decrease of more than 50% relative to last quarter (138 subnetwork events). Fluctuations are related to changes in the stress field along properly oriented faults, so the decrease is meaningful, but more data over a longer temporal sampling window will be necessary to begin postulating possible causes for this effect.

## OTHER ACTIVITIES

The KGS hosted a meeting to discuss Arbuckle disposal issues at the Kansas Corporation Commission offices in October 2018. Kyle Murray from the Oklahoma Geological Survey presented information on Arbuckle fluid levels and pressures in monitoring wells in Oklahoma, along with an update on Oklahoma seismicity. Shelby Peterie of the KGS discussed seismic monitoring in Kansas and pressure changes related to seismic activity in south-central Kansas. Dave Newell from the KGS analyzed and summarized available data for Arbuckle fluid levels in Kansas, the need for additional data, and the challenges of obtaining that data. KGS researcher Geoff Bohling presented results of a statistical analysis of available Arbuckle data. The meeting was attended by staff from the KGS, KCC, KDHE, and operators that utilize Class I and Class II disposal wells.

## PLANS

Planning and scheduling is now underway for the 2019 annual meeting. The location and date will be announced pending availability of Consortium members. The annual meeting agenda will include presentations from both researchers at the KGS and a topically significant speaker familiar to our industry members.

During the 1st and 2nd quarters of 2019, the KGS will complete annual inspections of all CSTS stations. Annual inspections include a complete fitness diagnostic of the seismometer, charging system, and telemetry. As with any outdoor installation, rodents can do minor damage that over time results in a system failure, so care is taken to carefully inspect wires and seals.

Over the coming months, results will be available from the KGS in-depth examination of microearthquakes too small to uniquely locate with the existing network, but in areas of strategic interest to CSTS members. A single seismograph station location can be determined to help triangulate on these microearthquakes and establish the culprit fault, or at least narrow the earthquake epicenter to two possible locations.

Over the next few months improved options for earthquake mapping and listing of event-specific information will be available to Tier 1 members on the CSTS web site. These improvements should provide significant value when comparing reported injection volumes with changes in seismicity in proximity to member facilities. All KGS injection data reported by Class I and II operators will be accessible.

Discussion are underway concerning the value/need of a CSTS member survey, with the intent to help us better understand areas in need of more engagement by the KGS

researchers. We would like to know how we can better meet the expectations of our members. After almost two years of operation the product line provided to our different tier members should be reasonably understood and reviewed occasionally to insure we are getting everyone the information that fits with their business. This will be an agenda item for our annual meeting in July.

## CONCLUSION

Operation of the network has been at or above anticipated levels with a focus on felt earthquakes below felt-level within 30 miles of member facilities. Reduced numbers of earthquakes below 1.5 is consistent with the trends observed with felt events reported by the KGS regional network. Earthquake activity levels reported by the USGS for the State are down significantly. This reduction is also observed in the KGS regional network, but not nearly as dramatically. The 50% reduction in subnetwork earthquakes is an important observation that, if consistent for the next several quarters, could be an indicator of stabilizing or possibly declining basement fluid pressures, and possibly an advanced indication of changes in upcoming bottomhole tests at Class I facilities.

Upcoming annual station maintenance runs and plans for release of enhanced earthquake mapping capabilities for tier 1 members are indicators of the high levels of activity ongoing in this program and the focus on network fitness and high-quality data. Faults along subnetwork earthquake trends are interesting, but more recorded events along these trends are necessary for their significance to be postulated that minimizes speculation.

Agreements for the 12 Tier 1 members and the one Tier 2 member are continuing in the second year of the Consortium's operation. The installed stations have operated successfully, and alerts are now being delivered to members automatically as prescribed under contract. CSTS staff continues to look at methods of providing information based on conversations at the 2018 annual meeting and continues to develop information related to the connection between seismic activity and Arbuckle fluid disposal. To enhance the quality and value of the product the CSTS is delivering to its members, feedback from members is essential and highly valued. Please spend time reviewing CSTS products and providing feedback about improvements to current or additional products.

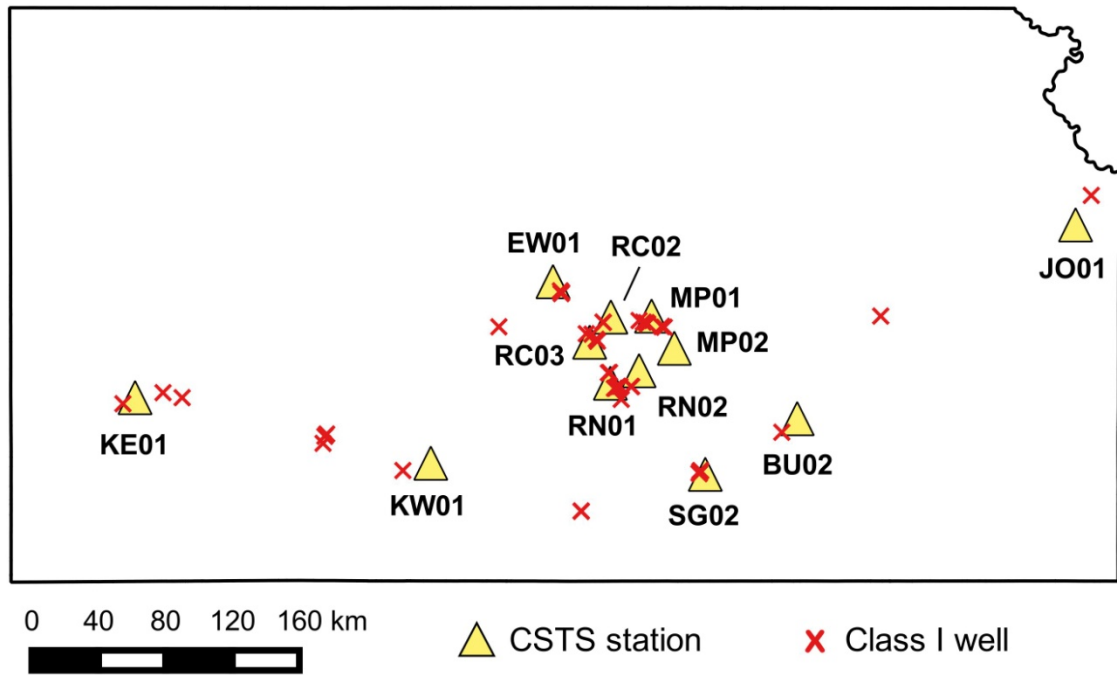


Figure 1. The 12 stations in the current CSTS seismic network.

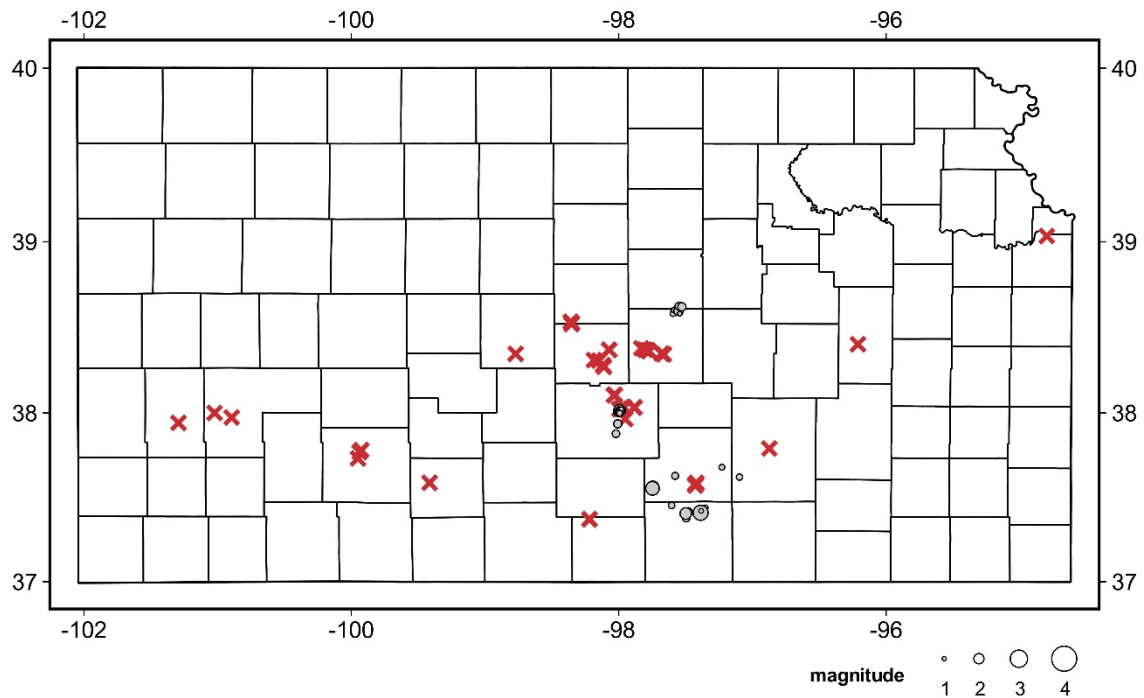


Figure 2. Earthquakes (gray circles) and Class I wells (red Xs) recorded by the KGS and CSTS seismic networks from October 1 to December 31, 2018, located within 20 miles of CSTS member wells.

Table 1. M 2 or larger earthquakes recorded from October 1 through December 31, 2018, with epicenters located within 30 mi of Tier 1 member wells.

<u>Origin Time (UTC)</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Magnitude</u>	<u>County</u>
2018-10-01 00:32:27	37.185	-97.448	2.3	Sumner
2018-10-01 00:33:23	37.169	-97.443	3.3	Sumner
2018-10-01 00:57:19	37.174	-97.452	2.2	Sumner
2018-10-03 16:49:03	37.357	-97.984	2.0	Harper
2018-10-19 12:21:56	38.584	-97.443	2.0	McPherson
2018-10-30 14:55:21	37.493	-99.762	3.4	Ford
2018-10-30 17:11:47	38.010	-98.005	2.1	Reno
2018-11-15 00:48:51	37.412	-97.394	2.4	Sumner
2018-11-16 08:58:27	38.739	-97.543	2.0	Saline
2018-11-17 03:47:08	38.726	-97.535	2.0	Saline
2018-11-17 04:20:54	38.722	-97.533	2.0	Saline
2018-11-17 08:09:20	38.716	-97.536	2.0	Saline
2018-11-17 13:24:39	38.727	-97.542	2.1	Saline
2018-11-17 21:34:26	38.747	-97.542	3.0	Saline
2018-11-17 22:02:32	38.695	-97.544	2.5	Saline
2018-11-18 09:59:24	38.741	-97.532	2.0	Saline
2018-11-19 07:44:12	38.744	-97.548	2.9	Saline
2018-11-19 09:01:03	38.732	-97.541	2.8	Saline
2018-11-19 09:31:24	38.755	-97.568	2.2	Saline
2018-11-19 12:37:06	38.741	-97.544	2.5	Saline
2018-11-19 13:12:47	38.730	-97.507	2.3	Saline
2018-11-21 11:30:51	37.319	-97.803	2.0	Sumner
2018-11-24 10:29:22	38.725	-97.535	2.0	Saline
2018-11-26 21:30:36	38.745	-97.543	2.4	Saline
2018-11-26 22:19:09	38.701	-97.559	2.0	Saline
2018-11-27 00:50:21	38.749	-97.534	2.7	Saline
2018-11-29 00:47:11	38.748	-97.605	2.5	Saline
2018-11-29 06:03:00	37.406	-97.498	2.2	Sumner
2018-12-16 20:13:38	37.562	-97.743	2.1	Sedgwick
2018-12-16 23:18:30	37.560	-97.748	2.2	Sedgwick
2018-12-16 23:52:45	37.562	-97.744	2.3	Sedgwick
2018-12-17 00:08:14	37.562	-97.737	2.0	Sedgwick
2018-12-17 04:31:11	37.561	-97.748	2.3	Sedgwick
2018-12-17 20:36:16	37.410	-97.387	2.7	Sumner
2018-12-20 20:56:54	37.555	-97.747	2.5	Sedgwick

Table 2. Earthquakes located within 20 miles of member wells.

Origin Time (UTC)	Latitude	Longitude	Magnitude	Origin Time (UTC)	Latitude	Longitude	Magnitude
2018-10-02 02:53:12	38.008	-97.999	2.0	2018-11-29 01:32:30	38.007	-97.992	1.3
2018-10-02 04:58:27	38.013	-97.991	1.4	2018-11-29 06:03:00	37.406	-97.498	2.2
2018-10-05 07:05:24	38.011	-98.000	1.8	2018-11-29 10:30:49	38.013	-97.995	1.1
2018-10-05 07:35:26	38.001	-97.994	1.2	2018-12-04 08:53:09	37.878	-98.020	1.6
2018-10-07 03:05:35	38.018	-97.981	1.6	2018-12-04 20:48:32	38.008	-97.995	1.1
2018-10-07 04:07:30	37.379	-97.495	1.6	2018-12-05 22:55:23	38.020	-97.981	1.2
2018-10-08 08:24:31	37.629	-97.577	1.5	2018-12-12 08:07:28	38.001	-97.997	1.0
2018-10-11 05:07:26	37.441	-97.351	1.2	2018-12-16 19:58:07	37.563	-97.743	1.8
2018-10-12 20:47:27	37.454	-97.604	1.4	2018-12-16 20:13:38	37.562	-97.743	2.1
2018-10-12 22:56:47	38.020	-98.000	1.7	2018-12-16 23:18:30	37.560	-97.748	2.2
2018-10-12 23:48:18	38.000	-97.994	1.4	2018-12-16 23:27:52	37.556	-97.749	1.7
2018-10-13 04:36:38	38.003	-97.989	1.6	2018-12-16 23:37:36	37.562	-97.745	1.7
2018-10-18 14:44:28	37.936	-98.007	1.7	2018-12-16 23:52:45	37.562	-97.744	2.3
2018-10-21 02:01:12	38.619	-97.543	1.3	2018-12-17 00:08:14	37.562	-97.737	2.0
2018-10-21 02:18:56	38.583	-97.593	1.3	2018-12-17 00:11:56	37.562	-97.743	1.9
2018-10-21 10:23:19	38.603	-97.584	1.3	2018-12-17 01:07:20	37.564	-97.742	1.9
2018-10-23 16:28:36	38.015	-97.980	1.8	2018-12-17 04:31:11	37.561	-97.748	2.3
2018-10-27 03:57:28	37.622	-97.096	1.4	2018-12-17 06:02:53	37.561	-97.747	1.7
2018-10-30 17:11:48	38.015	-97.994	2.2	2018-12-17 10:03:57	37.555	-97.734	1.6
2018-10-30 18:06:38	38.009	-97.996	1.7	2018-12-17 20:36:16	37.410	-97.387	2.7
2018-11-05 07:33:54	37.680	-97.228	1.3	2018-12-20 20:56:54	37.555	-97.747	2.5
2018-11-15 00:48:51	37.412	-97.394	2.4	2018-12-20 23:13:57	38.599	-97.552	1.9
2018-11-16 07:50:11	38.014	-97.997	1.6	2018-12-21 03:24:54	38.626	-97.550	1.6
2018-11-20 15:33:17	37.418	-97.388	1.9	2018-12-21 09:43:35	38.582	-97.543	1.1
2018-11-22 16:14:51	38.016	-97.995	1.2	2018-12-27 00:36:22	37.999	-97.992	1.3
2018-11-28 17:24:47	37.413	-97.482	1.8	2018-12-30 08:41:49	37.422	-97.383	1.1
2018-11-29 01:22:24	37.418	-97.480	1.6	2018-12-31 16:32:16	38.622	-97.527	1.7



Table 3. Possible subnetwork earthquakes from October 1 to December 31, 2018, recorded within 12 miles of member wells (the largest published distance between an induced earthquake swarm and causal well). Epicentral distance is the estimated distance from the earthquake epicenter to the seismic station where it was recorded.

Station	Origin Time (UTC)	Distance (Miles)	Magnitude	Station	Origin Time (UTC)	Distance (Miles)	Magnitude
BU02	2018-10-21 00:49:30	3.0	0.4	RC03	2018-10-15 10:01:32	8.5	0.2
BU02	2018-11-23 20:23:02	11.8	0.9	RC03	2018-10-15 10:02:01	8.7	0.2
EW01	2018-12-02 20:29:34	2.7	-0.6	RC03	2018-10-15 10:02:37	7.6	0.3
EW01	2018-12-23 05:15:29	2.2	-0.9	RC03	2018-10-15 18:22:17	6.8	0.2
JO01	2018-12-04 20:54:24	7.1	0.4	RC03	2018-10-16 02:17:59	7.2	0.3
MP01	2018-10-21 01:32:29	3.7	-0.4	RC03	2018-10-16 02:18:13	7.4	0.2
MP01	2018-12-01 07:00:10	5.1	0.0	RC03	2018-10-17 18:15:51	7.5	0.4
MP02	2018-10-01 15:12:50	3.0	0.1	RC03	2018-10-18 10:18:40	7.1	0.3
MP02	2018-10-02 23:18:06	1.8	0.0	RC03	2018-10-18 18:20:53	7.4	0.4
MP02	2018-10-05 22:40:42	4.7	-0.2	RC03	2018-10-19 09:29:35	7.7	0.3
MP02	2018-10-08 15:30:56	4.3	-0.2	RC03	2018-10-19 09:30:06	7.3	0.0
MP02	2018-10-09 03:38:17	0.6	-0.6	RC03	2018-10-20 02:17:09	7.4	0.1
MP02	2018-10-21 18:42:36	2.0	-0.6	RC03	2018-10-20 02:17:58	7.4	0.2
MP02	2018-10-21 19:38:41	1.6	0.0	RC03	2018-10-20 18:19:14	8.0	0.4
MP02	2018-11-04 09:02:00	9.2	0.3	RC03	2018-10-22 10:22:43	7.8	0.0
MP02	2018-11-05 04:59:51	3.7	-0.4	RC03	2018-10-22 10:23:33	7.0	0.1
MP02	2018-11-09 17:44:05	10.1	0.4	RC03	2018-10-22 18:18:58	7.5	0.5
MP02	2018-11-10 19:31:31	2.9	-0.2	RC03	2018-10-23 10:13:57	7.0	0.2
MP02	2018-11-18 10:46:59	9.1	0.4	RC03	2018-10-23 18:30:51	7.2	0.4
MP02	2018-11-22 23:33:48	1.8	-0.6	RC03	2018-10-23 18:35:15	7.8	0.3
MP02	2018-11-23 05:17:35	1.6	-0.6	RC03	2018-10-24 10:04:37	7.4	0.4
MP02	2018-12-05 15:38:30	4.2	-0.4	RC03	2018-10-25 10:13:10	7.8	0.1
MP02	2018-12-05 20:53:07	1.6	-0.9	RC03	2018-10-26 18:18:57	6.8	0.1
MP02	2018-12-06 08:45:30	2.6	-0.9	RC03	2018-10-27 10:06:29	9.1	0.3
MP02	2018-12-12 18:22:13	3.9	-0.4	RC03	2018-10-27 15:54:51	7.0	0.3
MP02	2018-12-23 03:38:56	4.1	-0.4	RC03	2018-10-29 10:22:04	6.9	0.3
MP02	2018-12-24 15:46:15	1.7	-0.6	RC03	2018-10-31 10:13:27	7.3	0.3
MP02	2018-12-26 04:06:05	2.9	-0.4	RC03	2018-10-31 10:13:56	6.8	0.3
MP02	2018-12-26 15:15:35	1.6	-0.6	RC03	2018-11-01 02:16:47	7.4	0.6
MP02	2018-12-27 10:53:14	3.8	-0.2	RC03	2018-11-01 10:21:06	7.5	0.5
RC01	2018-10-03 01:08:16	4.6	0.5	RC03	2018-11-01 18:12:31	7.1	0.4
RC01	2018-10-18 01:37:28	4.9	1.1	RC03	2018-11-02 02:20:15	7.2	0.1
RC02	2018-10-06 05:14:37	6.9	0.3	RC03	2018-11-05 19:19:40	7.0	0.1
RC02	2018-12-23 23:30:52	5.0	-0.2	RC03	2018-11-06 03:21:53	7.5	0.3
RC03	2018-10-02 02:17:46	7.1	0.6	RC03	2018-11-06 03:22:39	7.6	0.3
RC03	2018-10-02 10:06:44	7.5	1.0	RC03	2018-11-06 11:14:02	8.2	0.4
RC03	2018-10-03 02:18:38	7.3	0.3	RC03	2018-11-06 11:15:09	8.0	0.1
RC03	2018-10-03 02:20:15	8.1	-0.2	RC03	2018-11-06 19:17:50	8.2	0.2
RC03	2018-10-03 18:22:14	7.2	0.4	RC03	2018-11-06 19:19:03	8.0	0.2
RC03	2018-10-04 18:17:25	8.6	0.1	RC03	2018-11-07 19:24:25	7.0	0.2
RC03	2018-10-04 18:17:58	7.1	0.2	RC03	2018-11-07 19:25:23	7.2	0.1
RC03	2018-10-05 02:16:57	7.4	0.2	RC03	2018-11-08 03:20:54	7.3	0.4
RC03	2018-10-05 17:29:05	2.0	-0.4	RC03	2018-11-08 11:26:51	7.5	0.0
RC03	2018-10-06 02:14:14	7.1	0.2	RC03	2018-11-08 11:27:18	8.1	0.1
RC03	2018-10-06 02:15:17	7.3	0.3	RC03	2018-11-08 19:23:04	6.6	-0.4
RC03	2018-10-07 07:42:51	5.2	0.2	RC03	2018-11-08 19:23:23	6.1	0.1
RC03	2018-10-09 10:03:30	7.4	0.2	RC03	2018-11-09 11:15:46	7.1	0.1
RC03	2018-10-10 10:23:05	6.5	0.2	RC03	2018-11-10 03:22:12	7.2	0.1
RC03	2018-10-11 02:20:32	7.9	0.2	RC03	2018-11-10 03:23:50	6.7	0.2
RC03	2018-10-11 02:22:49	7.7	0.4	RC03	2018-11-10 03:29:10	7.0	0.2
RC03	2018-10-11 10:14:35	8.6	1.0	RC03	2018-11-11 03:12:51	6.7	0.0
RC03	2018-10-12 02:18:33	7.5	0.5	RC03	2018-11-11 03:13:44	7.3	-0.2
RC03	2018-10-12 10:23:20	6.9	0.3	RC03	2018-11-11 03:13:58	7.0	0.0
RC03	2018-10-12 10:23:43	7.7	0.4	RC03	2018-11-13 19:00:54	7.4	1.1
RC03	2018-10-13 02:13:58	7.4	0.6	RC03	2018-11-14 19:15:18	7.2	0.0
RC03	2018-10-13 02:22:35	7.4	0.1	RC03	2018-11-14 19:15:56	7.2	0.0

Table 3. Continued

Station	Origin Time (UTC)	Distance (Miles)	Magnitude	Station	Origin Time (UTC)	Distance (Miles)	Magnitude
RC03	2018-11-14 19:16:52	7.2	0.1	RC03	2018-12-17 10:23:49	7.6	0.2
RC03	2018-11-15 03:20:07	7.0	0.1	RC03	2018-12-18 03:16:18	7.6	0.0
RC03	2018-11-15 03:21:05	7.3	0.1	RC03	2018-12-18 03:17:07	6.7	0.3
RC03	2018-11-15 19:08:34	7.1	0.1	RC03	2018-12-18 03:17:51	6.9	0.4
RC03	2018-11-15 19:09:37	6.6	0.4	RC03	2018-12-18 09:49:34	6.9	0.0
RC03	2018-11-15 19:10:44	7.0	0.3	RC03	2018-12-18 09:49:34	6.5	0.2
RC03	2018-11-16 11:14:17	7.6	-0.2	RC03	2018-12-19 03:13:11	6.8	0.2
RC03	2018-11-16 11:14:44	7.6	0.0	RC03	2018-12-19 03:14:13	6.6	0.0
RC03	2018-11-17 03:21:48	7.1	0.2	RC03	2018-12-19 23:34:06	6.9	0.0
RC03	2018-11-18 21:47:58	7.2	0.1	RC03	2018-12-20 03:18:29	7.1	-0.2
RC03	2018-11-18 21:48:52	7.6	0.4	RC03	2018-12-20 23:35:35	7.6	0.0
RC03	2018-11-20 03:15:30	7.5	0.4	RC03	2018-12-20 23:38:14	6.5	0.1
RC03	2018-11-20 03:16:14	7.0	0.3	RC03	2018-12-21 07:43:27	7.1	0.4
RC03	2018-11-20 19:28:50	7.3	0.0	RC03	2018-12-21 07:44:28	7.4	0.4
RC03	2018-11-20 19:29:27	7.1	-0.2	RC03	2018-12-21 19:17:13	7.0	0.2
RC03	2018-11-21 03:06:00	7.1	0.0	RC03	2018-12-22 11:17:11	7.0	0.1
RC03	2018-11-21 03:07:34	7.2	0.4	RC03	2018-12-22 11:17:48	7.2	0.3
RC03	2018-11-21 19:12:36	7.2	0.1	RC03	2018-12-27 09:12:11	6.8	-0.2
RC03	2018-11-21 19:13:18	6.9	0.1	RC03	2018-12-29 11:19:35	7.7	0.0
RC03	2018-11-26 23:25:19	7.1	0.3	RC03	2018-12-29 19:16:50	7.1	0.4
RC03	2018-11-26 23:26:32	6.7	0.0	RN01	2018-10-02 03:51:05	5.3	0.2
RC03	2018-11-26 23:27:09	6.8	0.0	RN01	2018-10-02 10:59:40	4.9	-0.6
RC03	2018-11-27 19:21:20	6.5	-0.2	RN01	2018-10-03 11:51:11	5.0	0.0
RC03	2018-11-28 03:19:34	7.3	-0.2	RN01	2018-10-04 02:26:30	2.6	-0.2
RC03	2018-11-28 03:21:35	7.0	0.2	RN01	2018-10-04 22:40:56	5.1	0.3
RC03	2018-11-28 23:50:25	7.5	0.4	RN01	2018-10-05 13:22:43	4.9	0.1
RC03	2018-11-30 03:25:19	7.4	0.2	RN01	2018-10-05 13:22:43	4.8	0.2
RC03	2018-11-30 23:00:57	7.4	0.3	RN01	2018-10-05 13:24:50	4.8	0.2
RC03	2018-11-30 23:01:19	7.3	0.4	RN01	2018-10-05 18:30:18	4.9	-0.2
RC03	2018-12-01 03:13:26	7.0	0.1	RN01	2018-10-08 21:21:57	4.9	0.5
RC03	2018-12-03 23:07:08	7.6	0.4	RN01	2018-10-09 16:04:00	4.9	0.2
RC03	2018-12-04 03:20:07	6.2	0.9	RN01	2018-10-11 11:04:44	4.8	0.4
RC03	2018-12-04 03:21:19	7.3	1.0	RN01	2018-10-11 15:02:30	5.7	0.1
RC03	2018-12-05 03:21:27	6.5	1.0	RN01	2018-10-13 00:42:46	4.9	0.3
RC03	2018-12-05 23:26:16	7.7	0.2	RN01	2018-10-13 04:00:15	5.1	0.9
RC03	2018-12-05 23:27:07	7.8	0.2	RN01	2018-10-13 04:01:04	4.9	0.5
RC03	2018-12-05 23:28:09	7.1	-0.2	RN01	2018-10-16 21:40:01	4.8	0.2
RC03	2018-12-06 03:20:08	6.9	0.1	RN01	2018-10-22 06:39:37	4.7	0.0
RC03	2018-12-07 03:11:26	7.0	0.4	RN01	2018-10-24 03:25:13	5.0	0.3
RC03	2018-12-07 03:12:25	7.1	0.4	RN01	2018-10-25 00:15:07	4.8	0.0
RC03	2018-12-07 11:21:41	6.9	0.7	RN01	2018-10-29 12:03:53	5.2	0.3
RC03	2018-12-08 11:17:21	7.1	0.0	RN01	2018-10-30 16:11:57	4.8	0.0
RC03	2018-12-08 14:11:13	2.1	-0.9	RN01	2018-10-31 09:05:40	5.0	0.3
RC03	2018-12-09 03:12:40	7.0	0.9	RN01	2018-10-31 20:08:28	5.1	-0.2
RC03	2018-12-10 11:23:12	6.8	-0.2	RN01	2018-11-03 04:27:06	4.6	0.1
RC03	2018-12-10 11:23:34	6.4	-0.2	RN01	2018-11-04 03:12:17	5.1	-0.2
RC03	2018-12-10 11:24:14	6.9	0.9	RN01	2018-11-04 23:31:54	4.7	-0.2
RC03	2018-12-11 03:25:14	7.2	0.7	RN01	2018-11-06 02:32:57	4.8	-0.4
RC03	2018-12-11 03:27:07	6.9	0.9	RN01	2018-11-13 07:12:04	4.9	0.0
RC03	2018-12-11 23:30:24	7.7	0.3	RN01	2018-11-18 06:03:56	4.4	-0.2
RC03	2018-12-11 23:31:19	7.5	0.1	RN01	2018-11-19 13:43:25	5.0	0.1
RC03	2018-12-12 03:11:11	6.9	0.4	RN01	2018-11-20 07:38:29	4.8	-0.2
RC03	2018-12-12 03:12:10	7.1	0.0	RN01	2018-11-23 10:32:18	4.9	-0.2
RC03	2018-12-13 03:09:58	7.2	0.2	RN01	2018-11-24 09:20:23	4.9	0.0
RC03	2018-12-13 03:11:15	7.1	0.2	RN01	2018-11-24 15:43:31	4.5	0.1
RC03	2018-12-13 11:13:44	7.2	0.0	RN01	2018-11-28 00:19:01	5.0	-0.2
RC03	2018-12-13 23:26:50	7.2	-0.4	RN01	2018-11-29 07:30:23	5.6	-0.2
RC03	2018-12-15 00:01:07	7.4	0.3	RN01	2018-12-02 10:50:43	4.9	-0.2
RC03	2018-12-15 00:02:43	7.2	0.0	RN01	2018-12-03 09:40:27	1.9	-0.4
RC03	2018-12-17 10:23:03	7.3	0.0	RN01	2018-12-05 02:39:13	4.9	0.1

Table 3. Continued

Station	Origin Time (UTC)	Distance (Miles)	Magnitude	Station	Origin Time (UTC)	Distance (Miles)	Magnitude
RN01	2018-12-06 10:21:40	4.3	-0.4	RN02	2018-10-19 06:24:33	8.2	0.3
RN01	2018-12-06 22:03:45	4.8	0.2	RN02	2018-10-20 06:08:23	9.5	0.0
RN01	2018-12-08 07:44:28	5.0	-0.4	RN02	2018-10-20 06:08:23	2.3	-0.4
RN01	2018-12-08 09:22:48	5.2	0.0	RN02	2018-10-23 06:11:55	8.9	0.0
RN01	2018-12-10 01:31:55	4.6	0.0	RN02	2018-10-25 06:50:28	8.2	0.1
RN01	2018-12-10 16:10:01	5.2	-0.2	RN02	2018-10-26 06:47:27	8.8	0.2
RN01	2018-12-12 00:18:27	4.9	-0.2	RN02	2018-10-31 11:06:30	1.9	-0.9
RN01	2018-12-12 01:17:32	5.5	-0.2	RN02	2018-11-02 07:23:02	8.3	0.1
RN01	2018-12-12 06:55:01	4.8	-0.4	RN02	2018-11-03 07:20:05	9.2	0.1
RN01	2018-12-12 20:42:12	5.2	0.1	RN02	2018-11-13 13:04:43	3.5	-0.6
RN01	2018-12-12 23:07:10	4.7	0.0	RN02	2018-12-01 05:43:09	3.6	-0.4
RN01	2018-12-13 20:35:50	4.8	-0.4	RN02	2018-12-01 08:47:07	9.0	0.0
RN01	2018-12-14 04:21:07	5.0	-0.4	RN02	2018-12-05 19:20:05	5.5	0.0
RN01	2018-12-16 08:15:21	4.7	0.0	RN02	2018-12-05 21:16:38	1.7	-0.9
RN01	2018-12-20 23:50:56	4.6	0.0	RN02	2018-12-10 06:42:12	8.2	-0.2
RN01	2018-12-21 01:28:54	4.8	-0.4	RN02	2018-12-10 06:43:18	9.3	0.0
RN01	2018-12-21 08:40:19	2.7	-0.9	RN02	2018-12-15 07:08:56	9.0	0.0
RN01	2018-12-22 22:37:30	4.8	-0.4	RN02	2018-12-15 07:10:11	7.9	0.0
RN01	2018-12-23 03:05:44	4.7	0.0	RN02	2018-12-15 07:11:28	8.0	0.1
RN01	2018-12-25 01:21:13	3.4	-0.4	RN02	2018-12-15 07:12:24	7.5	0.0
RN01	2018-12-26 10:17:21	4.5	-0.4	RN02	2018-12-15 07:13:32	9.4	0.0
RN02	2018-10-02 06:58:16	8.2	0.1	RN02	2018-12-18 00:49:07	10.1	0.4
RN02	2018-10-09 03:37:21	7.5	1.0	RN02	2018-12-26 01:39:15	4.0	-0.4
RN02	2018-10-16 06:55:51	8.9	0.0	SG02	2018-12-28 03:40:30	4.2	-0.6
RN02	2018-10-18 06:40:49	8.8	0.4				