Annual Project Summary

USGS/NEHRP Grants Program

Seismic Investigation of Historical and Recent Earthquakes of the Mendocino Triple Junction Region

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Investigation Undertaken

The goal of our study is to better determine the locations, depths, source processes of historic and recent earthquakes, and develop preliminary attenuation models of the Mendocino Triple Junction (MTJ) region in order to 1) quantify the variability in moment release along important features in the MTJ region since 1906, 2) relate the events to specific tectonic features, 3) quantify differences in apparent stresses between intraplate and interplate events, and 4) analyze attenuation and its impact on strong ground motion in the region. The results and products of this study can be applied directly and indirectly to reduce losses from earthquakes in the U.S. The final outcome of our study will include attenuation models and refining our understanding of expected seismogenic zones, rupture processes and stress release, which may all be used to contribute to new seismic hazards maps for the region. The results will also assist in development of earthquake occurrence models by better quantifying changes in moment release since 1906 and the complex interactions of seismogenic features of the MTJ region, especially in relation to the Cascadia Subduction Zone (CSZ). The techniques developed in this study could also applied to studies of historic seismicity in other portions of the United States.

The study represents a collaborative effort between Dr. Aaron Velasco, with expertise in earthquake location algorithms, digital waveform analysis and studies of MTJ seismicity, Dr. Diane Doser, with expertise in historical seismogram acquisition and modeling, and Dr. Roberto Ortega (now at Centro de Investigación Científica y de Educación Superior Ensenada, Unidad La Paz: CICESE, La Paz), with expertise in attenuation model development.

Results

This project is multi-faceted and we report progress for data collection, relocations, source parameters, and an attenuation analysis. The project began on 05/01/2003, and thus we report on the progress for the fourth months up to 10/01/2003. The focus of our study is on the historical (1915-1976) and recent seismicity of the Mendocino Triple Junction region between 123° and 128° W and 39° and 42.5° N. We rely on teleseismic and regional phase arrival times and waveform data obtained from open data sources. The data will be used for earthquake relocation, source parameter, and attenuation studies.

Task 1: Data Collection

We have gathered both phase data and waveforms from a variety of sources. The bulk of data collection is the now complete for this project; however, we will continue this effort for approximately one year to recover data for events that we may have missed in our first attempt. We have based our selection of historic earthquakes on searches of the U.S. significant earthquake catalog available at the NEIC website, a summary of felt earthquakes for the MTJ region (to 1992) compiled by Dengler et al. (1992), and the isoseismal studies of Bakun (2000). Prior to 1915 it is difficult to obtain seismograms of sufficient quality for waveform modeling studies. As the station coverage, especially at regional distances, improved through time, we selected smaller magnitude events for study. We are collecting phase data for our relocation effort, and waveform data for source parameter and attenuation studies (see next sections). We outline below the historic data collection and the recent earthquake data collection.

Historical Event Data

We have collected phase data from International Seismological Survey (ISS) obtained at the Caltech archives for pre-1964 earthquakes. The data will be used our relocation effort (described below). The bulk of our collection thus far is after 1937, and we are in the process of transforming it all to digital form (Table 1), since much of it is in paper form. Upon careful examination of this catalog, we have discovered other events not included in our original proposal (Table 1). Thus, we will have more historical events to study than was originally proposed for our relocation effort.

For a number of seismograph stations (e.g. La Paz, DeBilt, Uccle, Weston), we have obtained copies of seismograms directly through written requests to the observatories. Sparks (1936) and Byerly (1938) published important photographic collections of seismograms for the June 1932 and July 1934 earthquakes, respectively. We also collected data from an important regional seismological archives located at Caltech (Figure 1). Table 1 summarized the events and stations for which we now have analog seismograms. We are in the process of scanning these seismograms and digitizing them using *SeisDig*, an interactive MatLab based digitizing tool, designed to digitize entire seismogram "tif" images with a minimum of user interaction. The Integrative Oceanography Division (IOD) of the Scripps Institution of Oceanography, University of California, San Diego developed the program. We expect to have all waveforms digitized by Feb. 2004.

Table 1: Collected waveform data for historic events.

Date	Time	Lat.	Lon.	M/I[1]	Location	Stations w/Waveforms
05/06/1915	12:09	39.50	-126.50	6.8/V^{+}	MFZ/PC	DBN, PAR
12/31/1915	12:29	41.00	-126.00	6.5/III^{+}	Gorda	API, DBN, PAR
07/15/1918	00:23	41.00	-125.00	6.5/VI^{+}	Gorda	API, DBN, LPZ, PAR
01/31/1922	13:17	41.00	-125.50	7.3/VI^{+}	Gorda	API, DMN, LPZ, PAR
01/22/1923	09:04	40.50	-124.50	7.2/VIII^{+}	Gorda	DBN, LPZ
06/06/1932	08:44	40.75	-124.50	6.4	NA	CSC, DBN, LPZ, PAR, PAS, SIT, TUC, UKI, WEL
07/06/1934	22:48	41.22	-125.27	6.5/I^{+}	Gorda	API, CSC, DBN, HON, LPZ, PAR, PAS, SIT, SJP, UKI, WEL
02/07/1937*	04:41	40.40	-125.10	V	Gorda	-
03/26/1937*	29:09	40.30	-126.60	-	MFZ	-
04/22/1937*	09:46	40.90	-125.50	-	Gorda	-
05/06/1937*	14:46	40.40	-125.10	-	Gorda	-
09/12/1938*	06:10	40.40	-125.10	VI	Gorda	-
02/13/1940*	23:52	40.50	-123.50	-	NA	-
12/20/1940*	23:40	39.50	-125.00	VI	MFZ/PC	-
02/09/1941	09:44	40.50	-125.25	6.6/VI^{+}	Gorda	API, DBN, LPZ, PAR, WEL
02/11/1941*	05:50	40.40	-125.10	-	Gorda	-
05/13/1941	16:01	40.30	-126.40	6.0/V^{+}	MFZ	DBN
06/09/1941*	06:17	42.50	-126.30	-	Gorda	-
06/09/1941*	08:43	42.50	-126.30	-	Gorda	-
10/03/1941	16:13	40.40	-124.80	6.4/VII^{+}	Gorda	API, DBN, LPZ
05/19/1945	15:07	40.25	-126.50	6.2/V^{+}	MFZ	-
03/24/1949	20:56	41.30	-126.00	5.9/III^{+}	MFZ	-
10/08/1951	04:10	40.28	-124.80	5.8/VII	MFZ	TUC, PAS, UKI
11/25/1954	11:16	40.27	-125.63	6.1/V	MFZ	-
12/21/1954	19:56	40.78	-124.17	6.5/VII	NA	CHR, COL, CSC, HON, LPZ, MAT, PAS, TUC, WEL
10/11/1956	16:48	40.67	-125.77	6.0/V	Gorda	-
07/24/1959	01:23	41.13	-125.30	5.8/IV	Gorda	MAT
06/06/1960	01:17	40.86	-124.60	5.7/VI	Gorda	-
08/09/1960	07:39	40.47	-126.62	6.2/V	MFZ	-
04/29/1961*	09:19	40.76	-127.42	-	Gorda	-

05/04/1961*	02:17	40.82	-127.46	-	Gorda	-
05/14/1961*	19:31	40.62	-127.44	-	Gorda	-
08/23/1962	19:29	41.84	-124.39	5.6/VI	Gorda	
121067	1206	40.50	-124.60	5.8/VI	Gorda	
062668	0142	40.29	-124.67	5.9/VII	MFZ	
030172	0928	40.50	-125.20	5.9/V	Gorda	
060775	0846	40.54	-124.29	5.7/VII	NA?	

[1]M/I: Magnitude or intensity; MFZ=Mendocino fault zone, NA=North American plate; PC=Pacific plate
*Events not previously identified and discovered with phase data.
Location from historical U.S. catalog of NEIC
+Maximum intensity from Dengler et al. (1992) or NEIC database

Recent Events

For recent events, we have collected phase data for all events in the region that have occurred since 1990 from the USGS Earthquake Data Reports (EDR). We are supplementing this information with phase data from the Northern California Seismic Network (NCSN). We will supplement this information with travel time picks obtained for digital data that we have collected (Table 2).

We have collected waveform data for 151 events (Figure 1; Table 2), significantly expanding the collection that we had originally proposed. Waveform data for stations of the Berkley Digital Seismic Network (BDSN) where also download from the NCSN. We also obtained data for global network stations from the Incorporated Research Institutions for Seismology (IRIS). Current systems make this effort fairly trivial, and we have all of the waveforms needed for this project. All data was recovered in Standard for the Exchange of Earthquake Data (SEED) format, and have been converted to Seismic Analysis Code (SAC) format. However, we will be building a Center for Seismic Studies (CSS) style database from the data collected for our relocation effort. The SAC files are now being utilized for our attenuation analysis (discussed below).

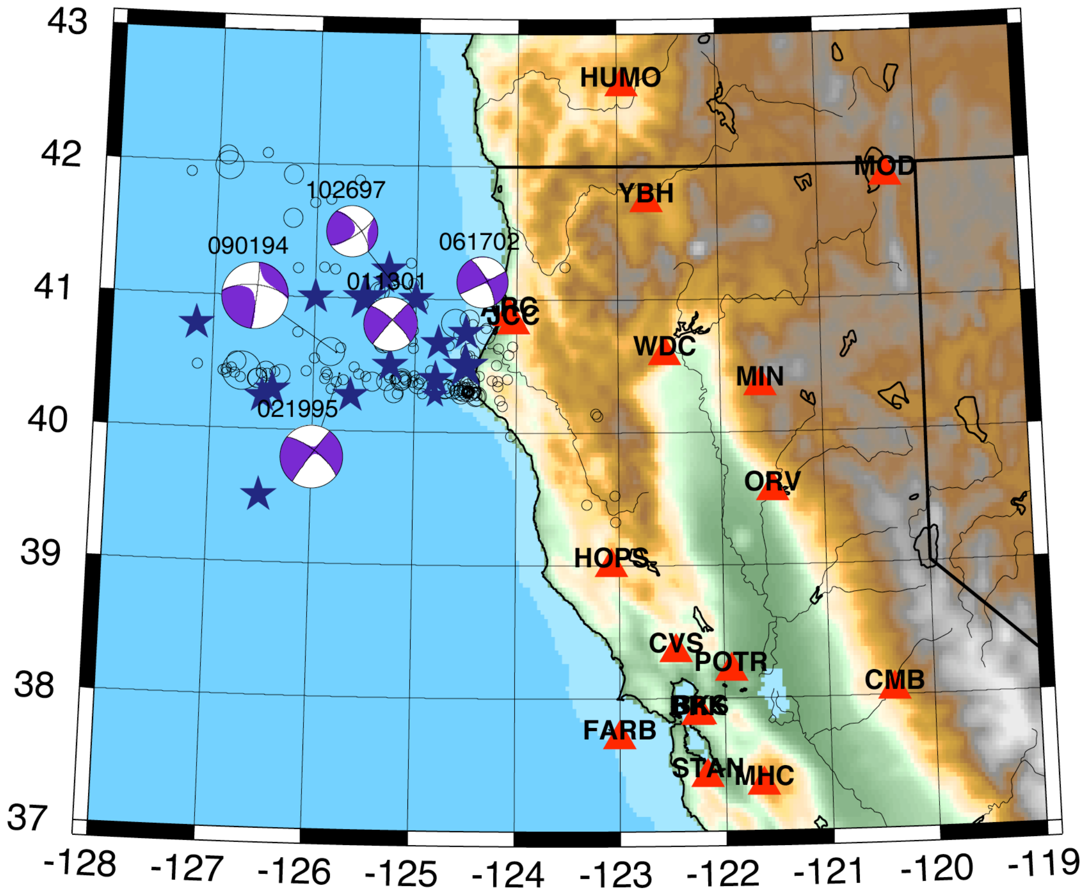

Figure 1: Map showing the locations of historic (blue stars) and recent (open circles) events for which we have collected data at NCSN and other stations (red diamonds). Calibration events for source inversions are given by the CMT solutions (purple focal mechanisms).

Table 2: Collected waveform data for recent events.

Date	Time	Lat	Lon	Depth	Mag	Magt[1]	SRC[2]	CE
1992/06/05	21:46:40.83	40.2878	-124.5408	5.00	4.71	Md	NCSN	
1993/07/27	21:17:21.38	40.3077	-124.4662	8.50	4.03	Md	NCSN	
1993/10/23	18:45:51.05	40.5042	-126.7582	5.11	4.83	Md	NCSN	
1994/02/21	13:40:06.35	40.4022	-125.1843	0.16	3.94	Md	NCSN	
1994/03/02	10:21:44.00	40.6338	-125.2902	7.19	3.51	Md	NCSN	
1994/03/13	16:59:03.91	40.3610	-124.9663	12.53	4.37	Md	NCSN	
1994/05/09	14:14:41.00	42.0490	-126.9120	10.0	4.10	MB	NEIC	
1994/05/24	20:11:38.59	40.9597	-124.9300	4.37	3.16	Md	NCSN	
1994/06/19	10:39:32.85	40.3543	-124.4655	19.25	4.67	Md	NCSN	
1994/07/02	13:43:27.54	40.2997	-124.3995	8.67	3.66	Md	NCSN	
1994/09/01	15:15:44.09	40.4335	-126.7095	5.74	6.13	Mlg	NCSN	*
1994/10/14	00:57:25.43	40.3242	-124.6202	19.33	4.11	Md	NCSN	
1994/11/13	07:53:51.53	40.3983	-125.0922	0.04	3.54	Md	NCSN	
1994/12/26	14:10:29.17	40.7383	-124.3047	23.46	4.92	Mlg	NCSN	
1995/02/19	04:03:14.27	40.5903	-125.8338	5.34	5.75	Mlg	NCSN	*
1995/12/24	07:41:31.00	41.9698	-126.8985	10.0	5.30	MB	ISCCD	
1996/07/24	20:15:41.22	41.9172	-126.2530	2.52	4.90	Md	NCSN	
1996/09/04	10:18:21.79	41.9167	-127.2742	5.00	3.60	Md	NCSN	
1996/09/06	20:42:29.53	40.4142	-126.3200	3.14	4.44	Md	NCSN	
1996/09/27	13:44:44.85	40.4738	-127.1457	24.02	3.69	Md	NCSN	
1997/01/22	07:17:16.75	40.2728	-124.3880	23.64	4.85	Md	NCSN	
1997/06/07	19:39:59.02	40.4323	-126.4663	5.77	4.43	Md	NCSN	
1997/09/21	12:36:27.58	41.5885	-126.2430	3.17	4.31	Md	NCSN	
1997/10/04	10:57:34.34	41.0505	-125.3622	9.88	4.60	Md	NCSN	
1997/10/06	12:00:23.82	41.0713	-125.3665	5.00	3.82	Md	NCSN	
1997/10/26	10:44:08.16	41.0020	-125.1698	5.16	5.24	ML	NCSN	*
1997/12/15	22:42:42.11	40.3157	-124.5533	21.59	4.09	ML	NCSN	
1998-03-23	02:28:10.00	43.4471	-127.0971	10	4.90	MB	ISCCD	
1998/11/27	00:43:48.93	40.6628	-125.3168	5.28	4.86	Md	NCSN	
1999/07/24	00:38:41.21	40.3858	-125.1222	6.61	4.12	Md	NCSN	
1999/11/22	05:38:04.84	40.4005	-125.1262	6.81	4.22	Md	NCSN	
1999/12/26	19:41:53.10	40.2705	-124.4008	23.31	4.19	ML	NCSN	
2000/01/08	02:17:28.31	40.3777	-126.5475	4.99	4.81	Md	NCSN	
2000/02/02	23:14:32.55	40.5105	-124.4533	24.23	3.45	Md	NCSN	
2000/03/16	15:19:55.81	40.3803	-125.2807	5.00	4.76	Md	NCSN	
2000/05/08	09:12:34.47	40.3275	-124.6942	4.00	4.11	ML	NCSN	
2000/08/13	18:17:48.75	40.3657	-124.4728	18.23	3.91	ML	NCSN	
2000/08/21	04:45:13.51	39.3308	-123.0315	13.36	3.73	ML	NCSN	
2000/09/22	10:50:27.20	40.8527	-124.4627	13.24	4.38	ML	NCSN	
2000/10/25	16:48:19.27	40.4122	-125.4813	5.10	3.32	Md	NCSN	
2000/12/27	13:15:11.18	40.4647	-124.4653	28.74	3.96	ML	NCSN	
2001/01/05	15:46:52.50	40.3495	-124.6170	23.85	3.37	ML	NCSN	
2001/01/06	18:09:59.98	40.3818	-126.7205	18.53	3.17	Md	NCSN	
2001/01/11	18:10:40.84	40.6337	-124.1790	23.11	3.95	ML	NCSN	
2001/01/13	13:08:42.32	40.7398	-125.2847	5.60	5.19	ML	NCSN	*
2001/01/22	23:41:14.88	40.4263	-125.5515	23.39	3.05	Md	NCSN	
2001/02/01	06:19:38.93	40.4167	-124.4110	28.32	3.35	ML	NCSN	
2001/02/07	19:19:01.94	40.5760	-124.4627	22.80	3.22	ML	NCSN	
2001/02/07	21:08:43.43	40.5725	-124.4820	23.24	3.25	ML	NCSN	
2001/02/16	17:37:36.33	40.3653	-125.7735	6.41	3.10	Md	NCSN	
2001/02/20	18:51:20.19	40.2907	-124.9200	7.57	3.45	Md	NCSN	
2001/02/22	08:44:57.68	40.3833	-125.7058	2.62	3.69	Md	NCSN	
2001/03/22	12:31:54.10	40.1412	-123.2190	35.33	3.04	Md	NCSN	

2001/03/22	12:55:52.82	40.1240	-123.1968	35.22	3.02	Md	NCSN
2001/03/22	21:22:30.11	40.3770	-126.5560	7.45	4.19	Md	NCSN
2001/03/23	15:02:07.58	40.2437	-124.1607	12.75	3.33	Md	NCSN
2001/03/27	12:21:49.84	40.4248	-124.3618	27.67	3.00	Md	NCSN
2001/03/28	20:33:28.99	40.6202	-125.7368	6.22	3.21	Md	NCSN
2001/04/20	05:19:51.86	40.6840	-125.3272	6.33	4.23	ML	NCSN
2001/04/23	18:05:42.74	40.4187	-125.8607	5.00	3.33	Md	NCSN
2001/04/28	03:54:22.86	39.5268	-123.0368	3.14	3.10	ML	NCSN
2001/05/02	04:55:53.73	40.3270	-124.7000	14.75	4.09	ML	NCSN
2001/05/03	10:49:19.88	40.4228	-125.0060	14.06	3.10	Md	NCSN
2001/05/05	02:18:04.61	41.2253	-125.9150	4.98	3.01	Md	NCSN
2001/05/22	00:40:39.39	40.4645	-124.8433	12.42	3.55	Md	NCSN
2001/05/27	09:27:04.03	40.3750	-125.0195	0.31	3.14	Md	NCSN
2001/06/07	23:38:14.00	40.6532	-124.6603	16.99	3.61	ML	NCSN
2001/06/16	04:26:53.32	40.3030	-124.5298	20.98	3.36	Md	NCSN
2001/07/12	06:10:33.91	41.2447	-123.5163	39.18	3.28	Md	NCSN
2001/07/12	07:18:35.98	42.0712	-126.5167	5.14	3.66	Md	NCSN
2001/07/15	06:56:53.44	40.4313	-126.8885	22.67	3.40	Md	NCSN
2001/07/15	11:02:52.83	40.4158	-126.7735	4.23	3.39	Md	NCSN
2001/07/31	20:21:36.11	40.3283	-124.6907	15.26	3.16	Md	NCSN
2001/08/07	14:59:43.31	40.3490	-124.1773	30.97	3.14	Md	NCSN
2001/08/26	20:41:24.92	40.3693	-124.9567	12.81	3.21	Md	NCSN
2001/09/12	01:36:08.78	40.4032	-124.0882	21.73	3.00	Md	NCSN
2001/09/12	01:39:10.89	40.3147	-124.6040	16.70	3.22	Md	NCSN
2001/09/20	08:02:24.16	40.3718	-125.4173	26.81	4.66	Md	NCSN
2001/10/10	23:49:37.88	40.3148	-125.8180	10.84	3.08	Md	NCSN
2001/10/20	22:05:50.55	41.2667	-125.0500	5.01	3.12	Md	NCSN
2001/10/22	08:23:51.71	40.9852	-124.2435	17.92	3.54	ML	NCSN
2001/11/10	18:55:49.79	40.6820	-125.0302	4.98	3.36	Md	NCSN
2001/11/18	02:17:00.01	41.2122	-125.8092	2.55	3.34	Md	NCSN
2001/11/20	16:58:17.43	41.5682	-125.5560	5.19	3.10	Md	NCSN
2001/11/21	02:01:28.99	41.7083	-126.0257	5.02	3.10	Md	NCSN
2001/12/08	11:43:05.61	40.3912	-124.2335	14.70	3.17	Md	NCSN
2001/12/10	09:09:27.17	40.5387	-125.9913	0.81	3.50	Md	NCSN
2002/01/10	00:44:51.03	40.4420	-126.0720	23.72	3.80	Md	NCSN
2002/01/12	21:52:50.92	41.2095	-124.2182	18.29	3.32	ML	NCSN
2002/02/04	12:03:47.24	40.7858	-124.2992	22.66	3.16	ML	NCSN
2002/02/08	18:38:46.20	40.7328	-126.1630	5.68	3.05	Md	NCSN
2002/02/13	21:41:55.51	40.4417	-126.8582	12.94	3.57	Md	NCSN
2002/03/18	20:37:11.53	40.4308	-126.3765	5.24	3.23	Md	NCSN
2002/03/18	20:37:23.68	40.2848	-125.1632	0.06	3.06	Md	NCSN
2002/03/27	03:53:04.92	40.2875	-125.2052	38.19	4.39	Md	NCSN
2002/04/01	08:49:58.99	40.4105	-125.1117	0.08	3.71	Md	NCSN
2002/04/10	16:38:12.61	40.6283	-125.0135	4.99	3.49	Md	NCSN
2002/04/29	00:43:29.72	40.6007	-124.4555	29.77	4.36	ML	NCSN
2002/05/04	04:58:52.13	40.2835	-124.4328	21.81	3.11	ML	NCSN
2002/05/04	09:39:52.38	40.3177	-124.5338	4.92	3.04	Md	NCSN
2002/05/04	10:20:23.60	40.3043	-124.4887	8.81	3.40	Md	NCSN
2002/05/04	12:17:01.24	40.3032	-124.4847	8.49	3.70	Md	NCSN
2002/05/04	12:54:24.91	40.3017	-124.4790	8.46	3.65	ML	NCSN
2002/05/04	13:05:36.20	40.2998	-124.4613	9.23	3.60	Md	NCSN
2002/05/04	13:28:08.61	40.3073	-124.4800	9.10	3.37	Md	NCSN
2002/05/04	13:56:33.31	40.3085	-124.5185	7.74	4.26	ML	NCSN
2002/05/04	14:24:48.42	40.3168	-124.4823	6.65	3.44	Md	NCSN
2002/05/04	17:45:48.22	40.3122	-124.4528	8.00	3.44	ML	NCSN
2002/05/04	19:33:00.34	40.3065	-124.4675	8.54	3.08	Md	NCSN

2002/05/05	05:34:09.21	40.3152	-124.5588	6.80	3.30	Md	NCSN	
2002/05/06	07:43:24.00	40.3162	-124.4640	7.00	3.14	Md	NCSN	
2002/05/06	08:45:48.67	40.3080	-124.4735	7.64	3.27	ML	NCSN	
2002/05/08	14:28:42.35	40.4053	-125.2445	4.87	3.33	Md	NCSN	
2002/05/08	21:32:11.97	40.3310	-124.5275	0.67	3.19	ML	NCSN	
2002/05/09	05:56:35.76	40.3145	-124.4680	7.26	3.25	Md	NCSN	
2002/05/22	01:33:14.13	40.8152	-124.4293	23.33	3.69	ML	NCSN	
2002/05/29	19:30:09.39	40.1988	-124.1328	13.96	3.15	ML	NCSN	
2002/06/01	00:15:59.46	41.8845	-125.5813	2.51	3.65	Md	NCSN	
2002/06/11	04:30:55.41	40.3878	-125.0850	4.51	3.65	Md	NCSN	
2002/06/17	16:55:07.52	40.8228	-124.6020	22.34	5.09	ML	NCSN	*
2002/06/21	00:41:28.23	40.4520	-126.8093	11.58	3.23	Md	NCSN	
2002/06/30	02:51:41.54	40.4122	-126.8598	5.00	3.45	Md	NCSN	
2002/07/03	00:48:23.27	40.2790	-124.3835	15.06	3.32	ML	NCSN	
2002/07/03	12:58:57.40	39.4598	-123.3052	1.93	3.28	ML	NCSN	
2002/07/13	04:45:09.55	40.3982	-124.9340	16.42	3.09	Md	NCSN	
2002/07/14	03:52:34.33	41.2143	-126.1788	22.32	3.25	Md	NCSN	
2002/07/21	02:44:13.73	40.2998	-124.4803	13.23	3.29	Md	NCSN	
2002/07/30	19:03:22.13	41.7388	-125.8648	26.13	3.25	Md	NCSN	
2002/09/17	11:30:27.00	40.3623	-124.9647	1.92	3.02	Md	NCSN	
2002/10/17	08:12:01.64	40.4143	-126.4543	14.63	3.89	Md	NCSN	
2002/11/21	13:17:39.28	40.2973	-124.4148	8.92	3.59	Md	NCSN	
2002/11/24	22:46:56.63	39.9733	-124.0527	3.69	3.40	Md	NCSN	
2002/11/26	06:23:57.94	40.4265	-125.2625	7.25	3.00	Md	NCSN	
2002/12/23	04:16:03.72	40.3890	-124.1827	12.70	3.07	Md	NCSN	
2003/01/08	05:43:43.51	40.3822	-125.1383	2.61	4.07	Md	NCSN	
2003/01/14	15:51:33.24	40.7360	-124.5723	29.23	3.49	ML	NCSN	
2003/02/18	14:44:26.03	41.1172	-125.0235	2.54	3.63	Md	NCSN	
2003/02/25	16:37:15.01	40.3963	-125.1960	0.31	3.51	Md	NCSN	
2003/02/28	02:21:24.64	40.3985	-124.4232	30.99	3.24	Md	NCSN	
2003/03/23	00:55:28.07	40.4800	-125.5993	4.95	3.06	Md	NCSN	
2003/03/26	05:47:03.18	40.3907	-125.8873	5.08	3.00	Md	NCSN	
2003/04/03	03:38:14.30	40.3183	-124.7767	14.89	3.36	Md	NCSN	
2003/04/10	08:55:11.51	40.4388	-125.8768	11.40	3.13	Md	NCSN	
2003/04/22	10:46:09.52	40.5848	-124.0762	28.55	3.91	ML	NCSN	
2003/05/02	15:01:55.40	40.6467	-124.0367	26.10	3.12	Md	NCSN	
2003/05/04	14:17:44.89	40.5460	-124.4225	33.68	3.17	Md	NCSN	
2003/05/20	07:09:39.65	40.7645	-125.0220	13.53	3.09	Md	NCSN	
2003/05/24	11:20:32.50	40.5080	-124.1913	19.46	3.15	ML	NCSN	
2003/05/31	08:00:32.42	40.4815	-124.4387	26.54	3.05	ML	NCSN	
2003/06/26	03:39:35.53	40.4193	-126.5083	3.42	3.75	Md	NCSN	

[1]Magt: Magnitude type; Md: duration; ML: local; MB: body wave; Mlg: Lg

[2]SRC: Catalog Source; NCSN: Northern California Seismic Network; ISCCD: International Seismic Center CD; NEIC: National Earthquake Information Center.

CE: Calibration event

Task 2: Relocations

Since we are still formatting and gathering phase data, we have not yet performed relocations. We plan to begin this effort by May 2004. Our approach will be to perform two distinct location algorithms. We will use an empirical calibration technique to obtain accurate locations for the MTJ region. This approach has been used to calibrate nuclear test sites in various countries around the world (e.g., Steck et al., 2001a). We will use travel time residuals of well-located events to construct correction surfaces, which will account for inadequate Earth models. The technique has proven to be useful for sparse networks, and may be effective to obtain accurate offshore event locations where station geometry is not optimal (Steck et al., 2001b). The correction surfaces will be constructed using the modified Bayesian kriging (MBK) method of Schultz et al (1998), which creates an interpolated surface from residuals using user-supplied correlation lengths of the background model and the data. MBK also produces an error variance surface associated with the correction surface, which allows for more realistic error ellipse estimation. Another location method that will be explored is the double-difference technique (Waldhauser and Ellsworth, 2000), which incorporates absolute travel-time measurements and/or cross-correlation *P*- and *S*- wave differential travel-time measurements. Observed and theoretical travel-time difference residuals are minimized using an iterative least squares solution. The technique has the advantage of minimizing velocity model errors without station corrections, similar to the MBK technique. Finally, a Joint Hypocenter Determination (JHD) approach may be applied which results in locations relative to a master event (Dewey, 1971, 1983). This technique has the ability to accurately locate events relative to one another, but may be off in an absolute sense if the master event is not accurately located. .

Task 3: Source parameter calibration and determination

We have just begun work for source parameter determination for the smaller events in the region. We have chosen calibrations events (Table 2) that can be used for our approach, the Earth simplification transform (EST) method developed by Zhang et al. (1997). The approach uses a large event with a known focal mechanism to remove propagation effects, effects that make it difficult to model small events. The method requires the calculation of synthetic waveforms, and events with well-constrained mechanisms. We will use events listed in Table 2 as our calibration events, and full reflectivity synthetics (e.g., Kennett, 1983). Over 1400 events have occurred in the region since 1990; some have moment tensor solutions from the Harvard CMT catalog and from the Berkeley REDI project. However, we are prioritizing our modeling efforts on the larger magnitude events that have not been modeled, and proceed to smaller magnitude events. We wish to extend this method to use for the historic events. Because many recent earthquakes have occurred in the vicinity of historical events we wish to study, we hope to use these events for calibration events to study source parameters of these historic events plus those of smaller events in the region.

We will also employ an empirical Greens function (EGF) technique (e.g. Velasco et al., 1994) to calculate stress-drop and rupture directivity (which can effect attenuation studies, described below), which also allows for the identification of fault planes. Waveform inversion techniques specifically designed for analysis of historic events (e.g. Baker and Doser, 1989) could also be used in cases where we do not have sufficient modern digital instruments co-located with historic seismographs.

Task 4: Preliminary attenuation analysis

We have made significant progress on the attenuation analysis. During the first two weeks of September 2003, Dr. Roberto Ortega visited UTEP to assist in the process of the attenuation relations for the events listed in Table 2. Dr. Ortega, along with a graduate student, initiated the preprocessing of the ground motion scaling.

Each seismogram was carefully reviewed, and we selected only well-located and high signal-to-noise ratio events for this analysis. In addition, the instrument response curves were carefully reviewed for accuracy. Each recording was organized in a hierarchical database, and we picked the *P* and *S* travel times of the vertical components and the entire earthquake record was corrected for the instrument response. The waveforms were filtered into 10 frequency bands using an 8-pole Butterworth filter with f_c frequencies equal to 0.2 0.4 0.7 1.0 2.0 3.0 4.0 5.0 6.0 and 7.0 Hz. The corner frequencies were given by 0.707 f_c and 1.41 f_c.. In addition, we computed the peak filter velocity and time duration between 5% and 75% of the integrated energy. This time duration is estimated starting from the *S* arrival and the integrated energy is normalized to a unit maximum value.

A spectral analysis was performed to obtain equivalent results such as those estimated for the time domain. The Fourier amplitude spectrum was computed and the root mean square (*RMS*) value between 0.707 f_c and 1.41 f_c was estimated. The time window used to estimate the Fourier transform is the same 5-75 % starting from the *S* arrival. The two values (maximum filtered velocity time series amplitude and the Fourier amplitude spectra *RMS* average over the frequency band between the cut-off frequencies) were stored in a table in addition to all statistical information. The waveform preprocessing is complete, and we are ready to estimate the attenuation relation, excitation and site terms using different techniques in the upcoming months.

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Non-technical Summary

The goal of our study is to better determine the locations, depths, source processes of historic and recent earthquakes, and develop preliminary attenuation models of the MTJ region. We wish to quantify the variability in energy release along important features in the MTJ region since 1906, relate the events to specific tectonic features, quantify differences in apparent stresses between intraplate and interplate events, and analyze attenuation and its impact on strong ground motion in the region. The bulk of our progress has been in data collection and we are moving toward analysis of the large amount of data that we have collected.

Reports Published

None at this time.

Data Availability Statement

We have gathered data from a variety of open sources, including the Northern California Seismic Center (NCSC), the United States Geologic Survey, the Incorporated Research Institutions for Seismology (IRIS), and various regional sources of information. We will be formatting this data into databases that may be useful to the community. Contact the lead PI for more information:

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