THE LAMONT COOPERATIVE SEISMIC NETWORK AND THE NATIONAL SEISMIC SYSTEM: EARTHQUAKE HAZARD STUDIES IN THE NORTHEASTERN UNITED STATES.

Technical Report

July 01, 1998 - June 30, 2001

External Grant Award Number: 1434-98-AG-01946

Won-Young Kim
Lamont-Doherty Earth Observatory of Columbia University
Palisades, New York 10964

Program Element: Element II. Research on Earthquake Occurrence and Effects

"Research supported by the U.S. Geological Survey (USGS), Department of the Interior, under USGS award number (Recipient, insert award number). The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government."

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Won-Young Kim
Lamont-Doherty Earth Observatory of Columbia University
61 Route 9W, Palisades, New York 10964

Tel: 845-365-8387, Fax: 845-365-8150
E-mail: wykim@ldeo.columbia.edu

TECHNICAL ABSTRACT

During the period of July 1, 1998 through June 30, 2001, under the terms of a 3 year cooperative agreement under the NEHRP External Research Program, scientists and engineers at the Lamont-Doherty Earth Observatory of Columbia University (LDEO) satisfactorily carried out three main objectives of the project:

1) Continued seismic monitoring for improved delineation and evaluation of hazards associated with earthquakes in the northeastern United States;
2) Improved real-time data exchange between neighboring regional networks and the United States National Seismographic Network (USNSN) for development of an Advanced National Seismic System (ANSS) and expanded earthquake reporting capabilities;
3) Promotion of effective dissemination of earthquake data and information.

Specifically, in operating the Lamont-Doherty Cooperative Seismographic Network (LCSN), during the three year time period, we accomplished:

1) Installation of the Earthworm data acquisition and processing system at four sub-networks (24 short-period stations) and at seven new sites with broadband seismographs. These Earthworm systems have been operating since October 1999 and acquire data in real time;
2) Installation of four new broadband, three-component seismographs in FY1999/2000, as well as the addition of three more broadband, three-component seismographs in FY2000/2001. Each one of these stations is operating on the Earthworm system and sending data to the central site at LDEO via the Internet in real time;
3) Installation of a new USNSN station at Newcomb, New York (NCB) in the Adirondack Mts. In coordination with USNSN staff at USGS/Golden a new USNSN station NCB is installed in October 1999. The continuous waveform data from the station is sent to USNSN in Golden via satellite link and the data are received at LCSN using the Earthworm system via the Internet in real time.
4) Installation of the Antelope real-time system at the central LDEO site for real-time data collection, archiving, and dissemination. This system has been running on top of the Earthworm system since January, 2001.

The configuration of the LCSN has evolved continuously for the past 25 years and the network now consists of four sub-networks with a total of 24 short-period stations, seven three-component broadband stations, six strong ground motion accelerographs and five cooperating

USNSN stations, covering seven states: New York, New Jersey, Pennsylvania, Connecticut, Delaware, Maryland and Vermont.

About 120 local and regional earthquakes (magnitude 1.2 to 5.4) that have occurred in the northeastern United States and southern Canada were detected and located by the LCSN during July 1, 1998 through June 30, 2001. A general seismicity pattern during this period is similar to the previous years. A relatively higher level of seismicity is in the Adirondacks and in the Western Quebec seismic zone in southern Canada. Other regions with considerable seismicity are: Lancaster - Reading, PA; western New York around Buffalo; New England and the Charlevoix seismic zone in Canada.

NON-TECHNICAL ABSTRACT

The primary objective of the LCSN is to gather data about eastern US seismicity in order to understand the causes of earthquakes, the identification of areas of high seismicity, and the resulting effects of seismic activity. This is a difficult problem, while eastern seismicity is significantly less that that of the western US, potentially damaging earthquakes have occurred and it is important to assess the risk.

The LCSN currently operates with 31 stations in the Middle Atlantic States, ranging from the NY/Canadian border to south of Baltimore, Maryland. Twenty-four of these stations are organized in four subnetworks consisting of 5-6 short-period stations. The other seven stations are stand-alone broad band stations. The LCSN is a cooperative operation, participants include: SUNY Potsdam; the Delaware Geologic Survey; the Maryland Geologic Survey; Middlebury College, VT; Adirondack Community College; SUNY Cobleskill; Millersville and Lehigh Universities, PA. All data from these stations is transmitted to Lamont in real-time for automatic detection and location of seismic activity. During the time period included in this report, 120 events were recorded by the LCSN. This data, along with data from subsequent years, has helped to define areas of relative high seismicity, as well as determine ground motion and associated potential risk.

SEISMOGRAPHIC NETWORK DESCRIPTION AND OPERATION

Research into the causes and effects of intraplate earthquakes in the northeastern United States has been the primary reason for Lamont-Doherty's involvement in seismic monitoring in this region for over 25 years. Regional monitoring, complemented by deployment of portable instruments, has allowed us to define the sources of several significant earthquakes in this region with previously unavailable clarity. Since 1995, the Lamont Seismic Network evolved into a "cooperative" seismographic network called LCSN (Lamont-Doherty Cooperative Seismographic Network). The LCSN relies upon the support of cooperating institutions such as the State University of New York at Potsdam, the University of Vermont, Middlebury College, Westchester Community College, Adirondack Community College, the Delaware Geological Survey, the Maryland Geological Survey, Millersville University, Lehigh University, and the State University of New York at Cobleskill in monitoring the earthquakes and acquiring data for studies of earthquake hazards in the region. The LCSN promotes active participation of educational institutions and emergency management organizations in the northeastern U.S. and collaborates with these organizations in acquiring and disseminating the earthquake information for education, public earthquake preparedness and hazards studies.

The configuration of the LCSN has evolved continuously for the past 25 years and the network now consists of four sub-networks with a total of 24 short-period stations, seven three-component broadband stations, and five cooperating U.S. National Seismographic Network (USNSN) stations, covering New York, New Jersey, Pennsylvania, Connecticut, Delaware, Maryland and Vermont. Six strong ground motion accelerographs are also part of the LCSN. Locations of the seismographic stations of the LCSN and other organizations in the northeastern U.S. are shown in Figure 1 and are listed in Appendix 1.

In October 1999 , LCSN successfully implemented the Earthworm data acquisition and processing system at four sub-networks and at the data collection center at Lamont-Doherty Earth Observatory (LDEO). The Earthworm system at the sub-networks collects seismic data from short-period or 3-component broadband stations and sends the data in real time to the master Earthworm system at the central processing facility at LDEO via the Internet. This Earthworm based real time system has improved real-time data exchange between LCSN, neighboring New England Seismic Network and the USNSN for expanded and rapid earthquake reporting capabilities.

In January 20001, LCSN successfully implemented the Antelope real-time data acquisition and processing system at the central LDEO site. The Antelope system takes real-time data from the existing Earthworm system and archives it in database format.

Sub-networks with Short-period Seismometers

During October, 1999, Earthworm data acquisition systems were installed at four sub-networks of the LCSN. Each sub-network consists of five to seven short-period, high-gain seismic stations and the analog seismic signals are telemetered to a sub-network node via RF links. At each sub-network node, analog data are digitized by 16-channel, 12-bit A/D Earthworm data acquisition system. Broadband station data are digitized by external 24-bit A/D dataloggers and are fed into the sub-network Earthworm system. The sub-network Earthworms transmit the data to the master Earthworm system at the data collection center at LDEO in real time. The key is a semi-automated, real time Earthworm data acquisition system using the Internet as the communication backbone. These four sub-networks are:

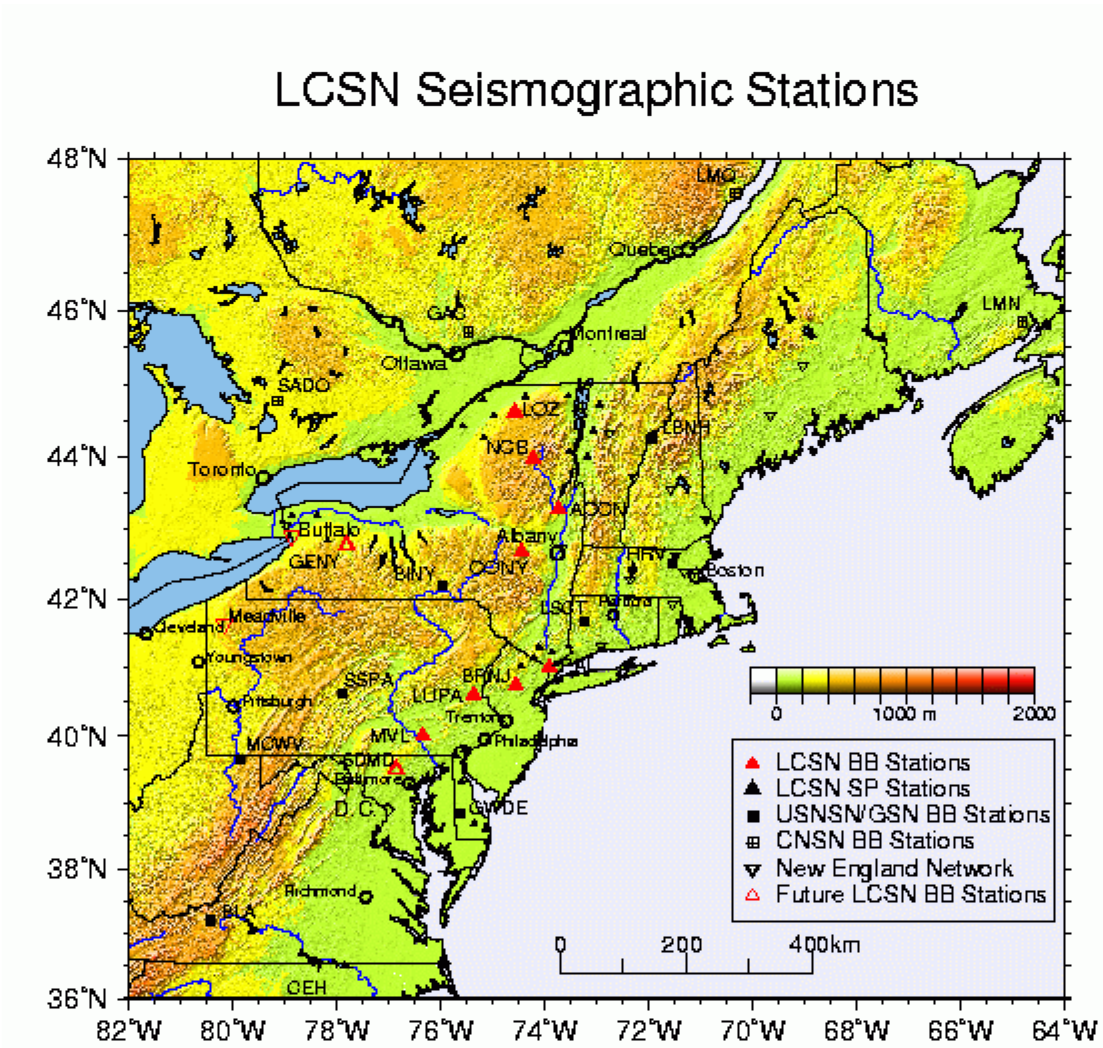

Figure 1. Locations of the seismographic stations in the northeastern United States and Canada. LCSN short-period sites (triangles), broadband sites (red triangles) as well as broadband stations of the MIT network (solid inverted triangles) and Weston Observatory network (inverted open triangles) are plotted. Broadband stations of the USNSN (squares) and the Canadian National Seismograph Network (CNSN) (open squares) are also plotted for reference. Four sites for new broadband station with Earthworm system are indicated by open red triangles.

1) Palisades sub-network: 5 short-period vertical-component and 2 short-period three-component stations in southern NY and northern NJ telemetered to the node at LDEO in Palisades, NY;
2) St. Lawrence sub-network: 7 short-period vertical-component stations telemetered to the node at the Potsdam College of Art and Science, State University of New York (SUNY) in Potsdam, NY;
3) Lake Champlain sub-network: 5 short-period vertical-component stations telemetered to the node at Middlebury College in Middlebury, VT;
4) Delaware sub-network: 5 short-period vertical-component stations operated by the Delaware Geological Survey (DGS) telemetered to the node at DGS in Newark, DE.

Broadband Seismographic Stations

In conjunction with the installation of the Earthworm data acquisition systems, the following eight broadband seismographic stations were deployed during October 1999 - June 2001.

1) ACCN (Adirondack Community College, SUNY, NY): The broadband seismometer (model CMG-3T), 24-bit digitizer module and GPS receiver are installed at a quiet site in a mountain near Glens Falls, NY. This remote site sends the digitized data to the Adirondack Community College campus (about 10 km) by using spread-spectrum wireless transceiver. The remote site is powered by two 50Watts solar panels and two 100 AMPH deep-cycle rechargeable batteries. At ACC, continuous, real time digital data are handled by SCREAM! software on a PC running under the Windows NT 4.0 system. The PC also runs Earthworm software and data are fed into Earthworm using scream2ew Earthworm module (=program). The ACC Earthworm sends the continuous, real time data to the central processing site at LDEO via the Internet. At LDEO, the LCSN master Earthworm system receives the data and performs event detection, arrival picking, and archiving. Then the archived waveform data are converted into a uniform data format (AH format), and the daily, 24 hour, seismogram traces are plotted as GIF (Graphics Interchange Format) images. The daily seismograms in GIF image (we call it "webseismogram") and the waveform data are made available via the WWW (World Wide Web) at URL http://www.ldeo.columbia.edu/LCSN. The users – (college and high-school students as well as the general public) have nearly unlimited access to the data, in classrooms, at offices, and at home, regardless of type of computers they use, as long as the user has a connection to the Internet and has an Internet browser or navigator. This is a partnership among three organizations: 1) NHEEEP (North Hudson Electronic Education Empowerment Project) and Hudson Falls Central School District, NY, who purchased a complete seismograph used for the station ACCN; 2) the Adirondack Community College (ACC), SUNY, led by Dr. Don Minkel; 3) LCSN and Columbia University. So far, this model has proven to be very useful in achieving several goals of the LCSN in terms of high-quality data acquisition for research, improved coverage of earthquake monitoring and promoting earthquake science through outreach and education program.

2) BRNJ (Basking Ridge, NJ): This station is at the William-Annin Middle School in Basking Ridge, NJ. The science teacher, Mr. Breck Kent, requested us to help him develop a high-quality seismographic station at the school. The school offered to house a seismographic

station. Here we installed a broadband seismometer (model CMG-40T) on a bedrock outcrop at the school campus. The signal is digitized using RefTek DAS (Data Acquisition System) and the digitized data are fed into a PC running under the Windows NT 4.0 system. The PC also runs Earthworm software and data are fed into Earthworm using reftek2ew Earthworm module. The BRNJ Earthworm sends the continuous, real time data to the central processing site at LDEO via the Internet as in ACCN. At LDEO, the LCSN master Earthworm system receives the data and performs all procedure as in ACCN. Again the daily seismograms in GIF and the waveform data are made available via the WWW for student and teachers to view and utilize. The users can download the data from the web page.

3) LOZ (Lake Ozonia, NY): This remote site is located in the northwestern Adirondacks near a former USNSN site RSNY. It is about 56 km from the node at Potsdam, NY and until June of 2000, ran a three-component broadband seismometer (model STS-2), RefTek DAS and GPS receiver. Presently, the station is equipped with a Guralp CMG-3ESP seismometer with built-in digitizer and GPS receiver. Solar panels and deep-cycle rechargeable batteries power the remote site. The digital data are telemetered to the node at SUNY, Potsdam (Δ=56 km, AZ=38°) using spread-spectrum digital radios. There the data is handled by SCREAM! software on a PC running Windows NT. The PC also runs Earthworm software and data are fed into Earthworm using rscream2ew Earthworm module. As in other stations (ACCN), the Earthworm system at SUNY, Potsdam sends the data in real-time to the LCSN master Earthworm system at LDEO where it is processed and made available as daily seismograms via the WWW.

4) PAL (Palisades, NY): Various types of 3-component, broadband seismometers and dataloggers have been operated in a seismic vault on the Lamont-Doherty Earth Observatory campus in Palisades, NY since 1992. This is the same vault where Frank Press and Maurice Ewing had developed a modern long-period seismometer in the 1950's known as Press-Ewing LP seismometer. In September 1999, we installed STS-2 seismometer and Quanterra Q680 datalogger, making the station compatible with other GSN and USNSN stations. The digitized data are telemetered to the LCSN master Earthworm at the data collection center at LDEO. Hence, PAL begun to produce high-quality digital data in real time and send the continuous data stream to other Earthworm sites such as USNSN in Golden, CO and MIT in Cambridge, MA. At LDEO, digital data are filtered to simulate Press-Ewing LP and Benioff SP seismograms and are recorded on visible drum recorder as conventional WWSSN seismograms. These traditional forms of seismogram displays are still very useful for educational and record reading purposes.

5) NCB (Newcomb, NY): Various types of 3-component, broadband seismometers and dataloggers have been operated at the Ecological Center Campus, SUNY, Syracuse in Newcomb, NY since 1992. The station had been operated as stand-alone mode and accessible via telephone dial-up only, since there were no Internet node available near the site. Hence, LCSN worked with USNSN to make the station as a USNSN site sending the data via VSAT. In October, 1999, we installed the USNSN station NCB with broadband STS-2 sensor and USNSN datalogger (Quanterra Q730). LCSN receives continuous data in real time from NCB via Earthworm from USNSN. Staff of the LCSN services the station in coordination with USNSN staff.

6) MVL (Millersville, PA): This station is located on the campus of Millersville University in Millersville, PA. With help from LCSN staff, the University (represented by Dr. Charles Scharnberger) purchased its own three component broadband seismometer. The seismometer is a Guralp CMG-3ESP with built in digitizer and GPS receiver. LCSN staff installed the station and necessary software for real-time data transmission through Earthworm. The seimometer is temporarily housed in the basement of the Geology building. Plans to construct a permanent vault are underway. Software setup is the same as previous stations (ACCN, LOZ), with the same end result of real-time export to LDEO and seismograms available on the WWW.

7) LUPA (Lehigh University, PA): Lehigh University maintains its own station located on South Mountain within University property. The station operates with a Guralp CMG-3TD three component broadband seismometer with built in digitizer and GPS receiver. Working with Anne Meltzer of Lehigh University, LCSN staff incorporated the station into the network through installation of the appropriate software. Software setup is the same as previous stations (ACCN, LOZ), with the same end result of real-time export to LDEO and seismograms available on the WWW.

8) CONY (Cobleskill, NY): This remote site is located to the northwestern Catskills. The site itself is located within a Cellular One antennae station. It is about 1 km from SUNY Cobleskill, NY and runs a three-component broadband seismometer (model CMG-40T), RefTek DAS and GPS receiver. The digital data are telemetered to SUNY, Cobleskill using spread-spectrum digital radios. The remote site is gets power on-site from the Cellular One maintenance building. Back up power comes from deep-cycle rechargeable batteries. Data is received at the college by RTP software on a PC running Windows NT. The PC uses the reftek2ew Earthworm module to move data into Earthworm where it is exported to LDEO in real-time.

Real Time Monitoring and Integration of LCSN with Other Networks

Since October 1999, all earthquake monitoring activity at LCSN is handled by the Earthworm seismic data acquisition and processing system. We now have seven Earthworm systems operating as an automated real-time seismic data acquisition and earthquake monitoring system, which consists of various data processing software modules. The Earthworm system allows us to share waveform data, event trigger messages, arrival picks and hypocenter parameters among regional networks with Earthworm systems over the Internet in near-real time. Currently, LCSN sends continuous waveform data from stations PAL (3 component broadband, 3 component long period), ACCN (vertical broadband), BRNJ (vertical broadband), PTN (vertical short period), BRCN (vertical short period), MSNY (vertical short period), MIV (vertical short period), and MDV (vertical short period) to the USNSN and receives continuous waveform data from four stations of the USNSN (NCB, BINY, LSCT, LBNH, & SSPA) and from a site of the New England Seismic Network in Massachusetts (WFM).

In January, 2001, LCSN implemented the Antelope program developed by BRTT. Antelope works similar to the Earthworm system, but creates its own network database. At present Earthworm and Antelope have been integrated together to improve archiving and dissemination of real-time data. Earthworm is used at all stations and subnetworks to move the data to the central processing node at Lamont where it is then exported into Antelope using the eworm2orb Earthworm module. LCSN real time data flow is shown in Appendix 2.

EARTHQUAKES IN THE NORTHEASTERN U.S. IN JULY 1998 - JUNE 2001

About 120 local and regional earthquakes that have occurred in the northeastern United States and southern Canada were recorded by the LCSN during July 1, 1998 through June 30, 2001. These earthquakes range from magnitude $m_b(Lg)$ 1.2 to 5.4. These earthquakes are listed in Table 1 and Appendix 3 and are plotted in Figure 2. A general seismicity pattern during this period is similar to the previous years. A relatively higher level of seismicity is in the Adirondacks and in the Western Quebec seismic zone in southern Canada. Other regions with considerable seismicity are Lancaster - Reading, PA; western New York around Buffalo; New England and the Charlevoix seismic zone in Canada (see Figure 2). We will describe notable areas of seismicity and few selected earthquakes during this period.

Adirondack Mountains, New York

In the period of July 1, 1998 through June 30, 2001, 17 earthquakes of magnitude ML=0.7 to 3.8 were recorded by the LCSN in the Adirondack region of New York State. These events range in. Figure 3 shows the location and magnitude of these events. Those discussed below are labeled.

An earthquake of ML = 2.3 occurred on April 16, 2000 (18:59:12) just beneath the new USNSN station NCB (Newcomb, NY). The epicentral distance is about 1.8 km from NCB. This event is followed by a much bigger event on 04/20/2000 at 08:46 (ML=3.8, Δ = 3.3 km from NCB). The mainshock was felt through out the Adirondack Mts., upstate New York and western Vermont. There were 6 aftershocks whose size ranged from ML = -0.17 to 0.8 following the ML=3.8 mainshock. These earthquakes have occurred very close to the mb(P) =5.1 earthquake which occurred on Oct. 7, 1983 at 10:18 (it is known as the Goodnow, NY earthquake; see Nabelek & Suarez, 1989). Waveform data from the foreshock and mainshock recorded at NCB are shown in Figure 4. The data are filtered between 0.6 and 5 Hz. The three-component records show that the P and S waveforms from these two events are nearly identical indicating that the two events had similar depth and source mechanism. The S-P time is about 0.98 sec for both events, which indicates that the focal depths must be less than 6 km. Particle motions of the first arrival P waves on three component records suggest that the foreshock P wave had nearly vertical incidence angle suggesting a slightly deeper depth than the mainshock. This example illustrates the importance of high-quality digital data obtained by high-dynamic range broadband seismographs for studying earthquake sources.

On Feb. 10, 2000 (15:33:26), an earthquake of magnitude ML=2.0 occurred near Massena, NY. Although the event is a small event, seismic signals are well record at nearby broadband station LOZ (Δ = 42 km) and other broadband stations installed in the fall of 1999. The waveform data from this event are shown in Figure 5. High quality broadband waveform data from this event will allow us to determine an accurate focal depth of the event using waveform-modeling technique. These data will also provide much needed ground motion attenuation relation at short distances (usually less than 100 km) from the source in the northeastern U.S. (see e.g., Kim, 1998).

Table 1. Selected events for period July 1, 1998 through June 30, 2001

Origin time year/mo/dy	hh:mm:sec	Lat (°N)	Long (°W)	h (km)	Magnitude*	Location
			1. Adirondacks, New York			
1998/07/09	01:52:13.1	44.735	73.677	01	Mc 2.5	18 km W Plattsburgh, NY
1998/12/05	04:05:45.9	44.402	75.135	01	Mc 1.7	22 km S Canton, NY
1999/01/14	22:49:33.7	44.891	74.678	09	Mc 2.2	17 km E of Massena, NY
1999/03/09	12:07:05.5	44.764	73.802	10	Mc 2.9	29 km W of Plattsburgh, NY
1999/09/09	04:37:09.0	44.610	73.720	18	Mn 2.0	23 km SW of Plattsburgh, NY
(OTT)						
2000/01/02	06:46:03.0	44.760	73.700	18	Mn 2.3	20 km W Plattsburgh, NY
2000/01/17	13:30:47.0	44.770	73.690	18	Mn 2.3	20 km NW Plattsburgh, NY
2000/02/10	15:33:26.0	44.980	74.760	06	Ml 2.0	12 km NE Massena, NY
2000/02/27	12:50:32.0	44.610	73.520	18	Mn 1.7	11 km SW Plattsburgh, NY
2000/04/15	08:39:24.0	44.290	75.480	05	Mn 1.5	42 km SW Canton, NY
2000/04/16	18:59:13.0	43.960	74.240	06	Ml 2.3	2 km Newcomb, NY, Foreshock
2000/04/20	08:46:55.5	43.949	74.257	05	Ml 3.8	3 km Newcomb, NY, Mainshock
2000/04/20	13:13:38.8	43.949	74.257	05	Ml 0.8	3 km Newcomb, NY,Aftershock
2000/04/20	15:00:14.8	43.949	74.257	05	Ml 0.7	3 km Newcomb, NY,Aftershock
2000/07/01	07:31:25.0	43.530	75.280	18	Mn 2.3	48 km N of Utica, NY
2000/07/22	05:02:30.0	43.470	75.250	01	Mn 2.7	41 km N of Utica, NY
2000/11/06	12:16:36.0	42.760	74.070	08	Mc 2.4	12 km SW of Schenectady, NY
			2. Western New York			
1999/01/25	20:12:30.0	42.733	77.850	03	Mn 2.7	8 km S of Geneseo, NY
1999/04/18	03:03:25.0	42.733	77.850	03	Mc 2.4	8 km S of Geneseo, NY
1999/07/08	07:04:05.0	42.740	78.840	18	Mn 1.5	16 km S Buffalo, NY (OTT)
1999/08/28	23:01:32.0	42.560	77.970	05	Mn 2.6	29 km SW Geneseo, NY (OTT)
1999/10/10	04:51:12.0	42.840	77.970	18	Mn 2.3	13 km W Geneseo, NY
1999/11/01	10:12:28.0	42.780	78.930	18	Mn 2.7	12 km S of Buffalo, NY
1999/12/31	11:34:24.0	43.250	78.660	18	Mn 1.7	36 km NE Niagara Falls, NY
2000/01/23	21:46:13.0	43.210	78.870	18	Mn 2.2	15 km W Lockport, NY
2001/02/03	20:15:15.0	42.340	77.390	00	Mb 3.2	6 km W of Bath, NY
			3. Lancaster - Reading, Pennsylvania			
1999/04/18	09:44:55.7	40.317	75.966	02	Mc 1.9	1 km N of Shillington, PA
1999/10/22	14:37:33.3	40.380	75.927	10	Mc 1.9	5 km N Reading, PA
2000/02/24	14:47:19.0	41.120	75.750	06	Mc 2.3	17 km SE Wilkes-Barre, PA
2000/03/22	20:48:00.0	40.070	76.300	01	Mc 1.8	3 km N Lancaster, PA
2000/10/05	23:33:59.0	40.080	76.300	07	Mc 2.1	5 km N Lancaster, PA
			4. Metropolitan NY City			
1998/08/29	23:41:56.5	41.212	74.047	08	Mc1.4	5 km W of West Haverstraw, NY
1998/09/08	03:47:03.6	41.203	74.046	02	Mc 1.2	5 km W of West Haverstraw, NY
2000/08/22	05:45:14.0	41.420	73.630	07	Mc 2.6	28 km NE of Peekskill, NY
2001/01/17	12:34:22.6	40.777	73.954	07	Mc 2.4	Manhattan, NY
2001/01/19	15:04:42.9	40.777	73.960	05	Mc 1.2	Manhattan, NY
			5. New England			
1999/02/26	03:38:43.1	44.513	69.466	07	Mn 3.8	13 km E of Winslow, ME
1999/04/04	05:06:03.8	44.456	72.421	07	Mc1.5	25 km NE of Montpelier, VT
1999/06/22	09:44:20.4	44.221	73.382	08	Mc 1.3	28 km NW of Middlebury, VT
1999/10/13	10:09:00.0	42.550	71.440	02	Mc 2.3	14 km SW Lowell, MA
1999/12/25	00:21:41.0	44.940	69.370	05	Mn 3.0	34 km NE Skowhegan, ME

2000/01/03	21:05:49.6	44.335	70.234	05	Ml 3.3	26 km N Lewiston, ME
2000/01/17	08:16:19.5	44.632	70.473	05	Mb 3.4	11 km NE Rumford, ME
2000/01/21	05:59:50.7	43.007	71.237	05	Mb 2.4	16 km NE Derry, NH
2000/01/27	14:49:39.1	42.998	71.163	05	Mn 2.9	19 km NE Derry, NH
2000/06/16	04:02:53.0	42.100	72.800	05	Ml 2.8	4 km SW of Westfield, MA
2000/09/07	10:07:40.7	44.353	69.383	05	Mb 3.2	28 km SE of Winslow, ME

6. Ashtabula, Ohio

1998/09/25	19:52:52.0	41.495	80.388	5	Mn 5.4	Ohio-Penn border,(PDE)
1999/10/30	08:02:48.0	42.060	80.400	18	Mn 2.5	37 km NE Ashtabula, OH
2000/06/07	06:19:18.0	42.010	80.780	18	Mn 2.0	14 km N Ashtabula, OH
2000/06/07	06:55:09.0	42.010	80.780	18	Mn 2.4	14 km N Ashtabula, OH
2000/08/07	02:02:30.4	40.958	81.151	05	Mb 2.9	26 km NE of Canton, OH
2001/01/26	03:03:21.4	41.909	80.722	05	Mn 4.2	6 km NE of Ashtabula, OH
2001/06/03	22:36:45.4	41.996	80.954	05	Mb 3.0	18 km NW of Ashtabula, OH

7. Western Quebec, Canada

1998/07/30	08:57:22.0	46.168	74.721	10	Mn 4.4	NE Ripon, QUE (OTT)
1999/10/31	20:14:10.0	45.850	74.320	18	Mb 3.7	22 km N Lachutte, QUE
2000/01/01	11:22:55.9	46.819	78.883	10	Ml 4.9	18 km NE Temiskaming, QUE
2000/02/12	08:31:28.0	45.190	73.780	18	Mn 2.3	27 km S Pointe-Claire, QUE
2000/03/02	20:48:29.0	46.120	75.700	18	Mn 3.0	25 km S Maniwaki, QUE
2000/05/24	05:41:52.0	45.480	75.400	18	Mn 2.2	10 km S Buckingham, QUE
2000/07/11	20:13:55.0	45.340	75.300	18	Mn 2.5	32 km E Ottawa, ONT
2000/08/06	08:52:24.0	46.190	74.970	18	Mb 4.0	47 km SE Mont-Laurier, QUE
2001/01/14	11:03:47.6	45.842	74.940	00		17 km NE of Ripon, QUE
2001/02/03	00:31:28.3	45.943	74.951	00	Ml 2.45	25 km NE of Ripon, QUE

8. Charlevoix Seismic Zone, Quebec, Canada

1999/07/27	12:23:05.0	46.570	69.000	05	Mn 2.7	76 km W Presque Isle, ME (OTT)
2000/06/08	11:59:49.0	46.850	71.410	18	Mn 2.8	14 km W Quebéc City, QUE
2000/06/15	09:25:54.0	47.670	69.810	10	Mn 3.7	3 km S Charlevoix, QUE
2000/06/29	08:15:17.0	46.910	70.770	18	Mn 3.2	37 km E of Quebec, QUE
2000/07/12	15:01:49.0	47.520	71.100	10	Mn 4.2	47 km W Baie-St-Paul, QUE
2000/07/12	15:06:35.0	47.550	71.080	18	Mn 3.5	47 km W Baie-St-Paul, QUE
2000/07/12	15:07:50.0	47.550	71.080	18	Mn 2.5	47 km W Baie-St-Paul, QUE
2000/07/12	16:05:05.0	47.560	71.080	18	Mn 2.4	47 km W Baie-St-Paul, QUE

9. Southern Ontario, Canada

1999/11/26	22:33:01.4	43.710	78.997	13	Mb 3.4	34 km E Toronto, ONT
2000/05/24	10:22:46.2	43.806	79.099	18	Mn 3.1	28 km NE of Toronto, ONT
2000/05/28	20:26:03.0	44.430	77.500	10	Mn 2.7	Madoc, ONT (OTT)
2000/05/31	05:36:19.0	44.440	77.510	10	Mn 2.5	Madoc, ONT (OTT)
2000/05/31	18:47:43.0	44.440	77.470	10	Mn 2.2	Madoc, ONT (OTT)

* Mb = mb(*Lg*) magnitude determined by NEIS and listed in PDE monthly list,
Mn = Nuttli's Mb(Lg) reported by Geological Survey of Canada, Ottawa or by the Weston Observatory, Boston College, MA;
ML = Local Richter magnitude determined by Lamont-Doherty Earth Observatory of Columbia University;
Mc = coda duration magnitude determined by LCSN.

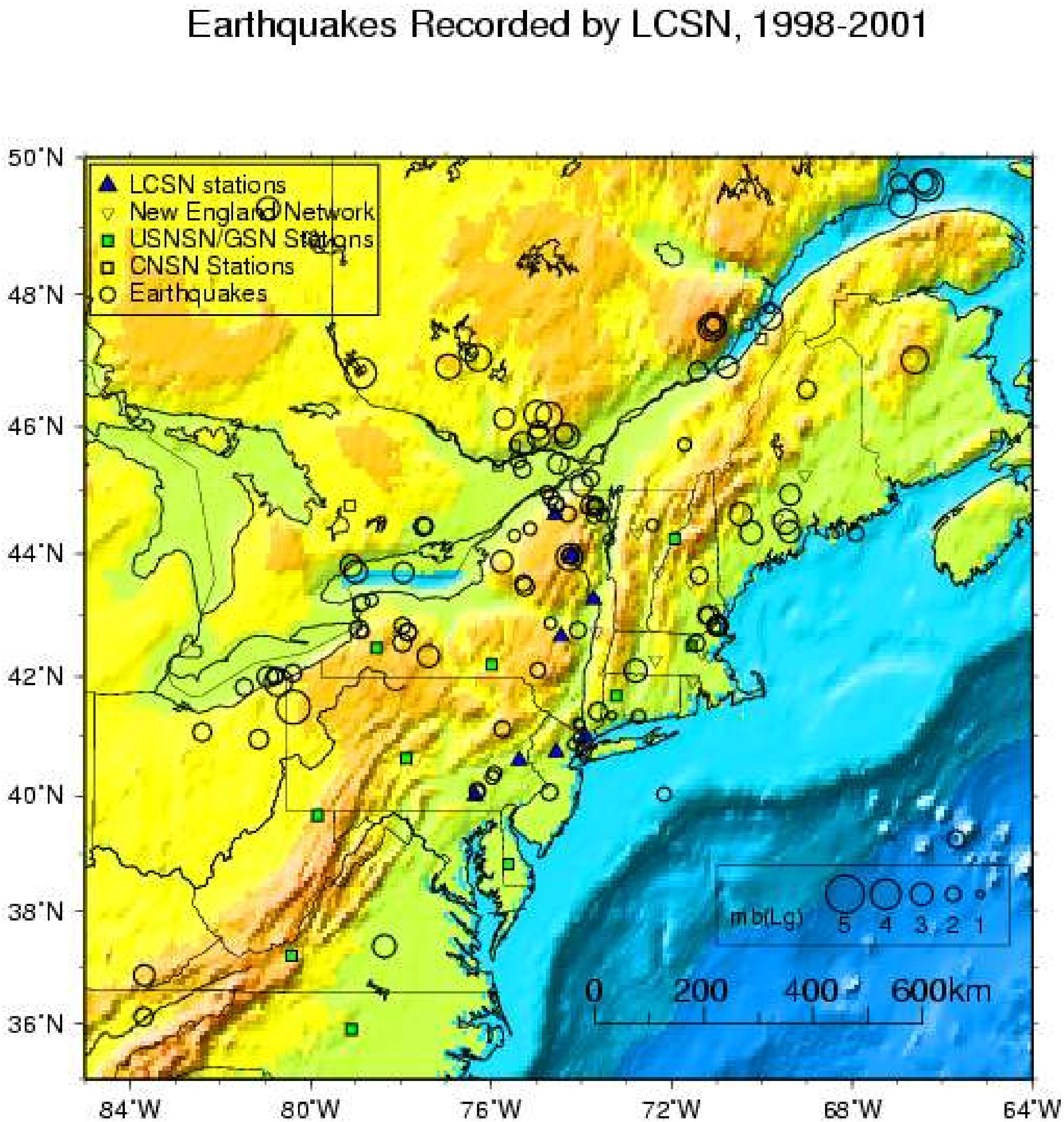

Figure 2. Epicenters of the earthquakes that have occurred during July 1, 1998 through June 30, 2001 in the northeastern U.S. and southeastern Canada recorded at LCSN stations (circles). The circle size is proportional to the size of the earthquakes. Seismographic stations in the region are plotted for reference: LCSN stations (solid triangles), New England Network (inverted triangles), the Canadian National Seismograph Network (CNSN) (open squares) and USNSN (solid squares).

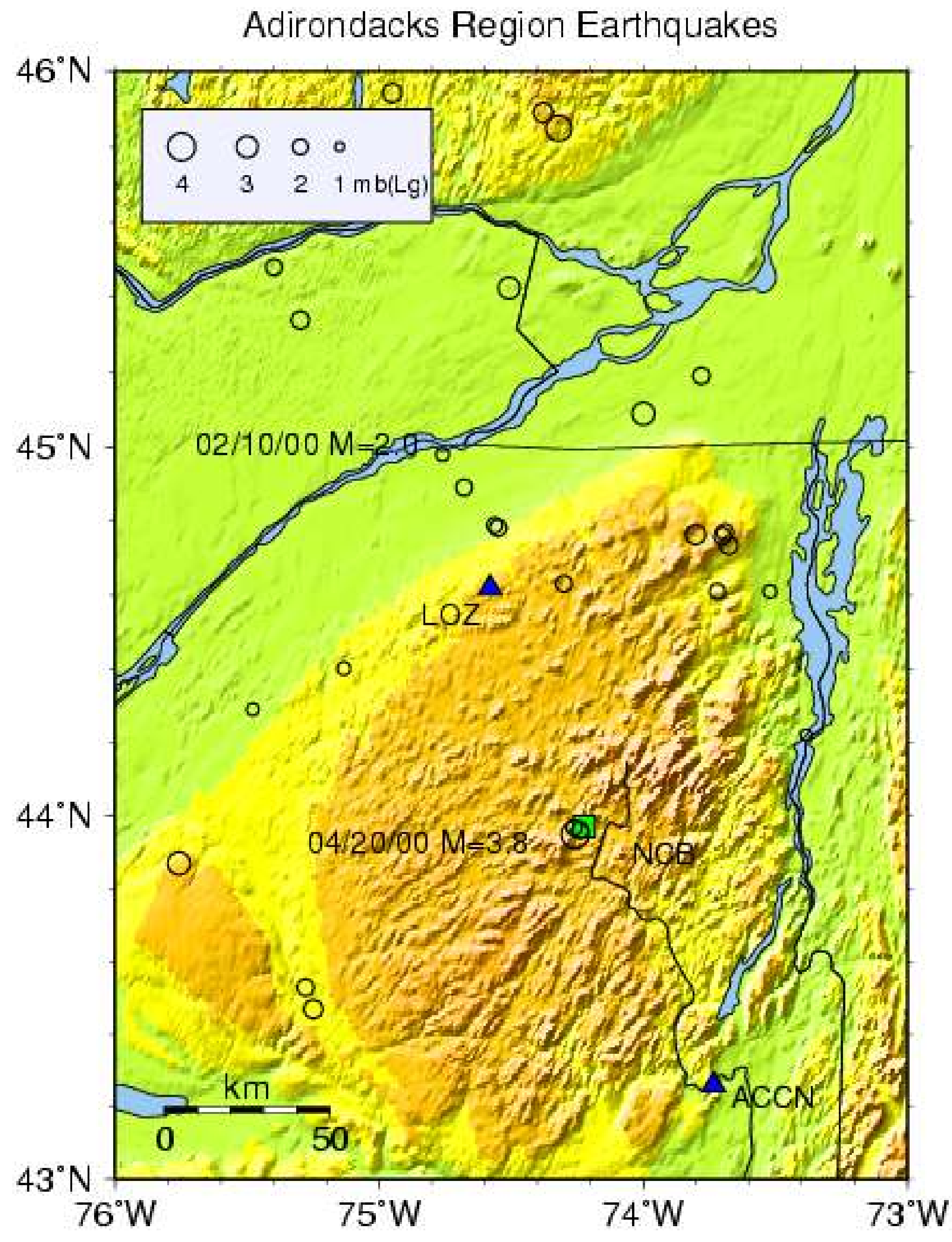

Figure 3. Earthquakes that occurred in the Adirondack Region of New York during July 1, 1998 - June. 30, 2001 recorded by LCSN. Symbol size is proportional to the magnitudes. LCSN and USNSN broadband sites are plotted for reference.

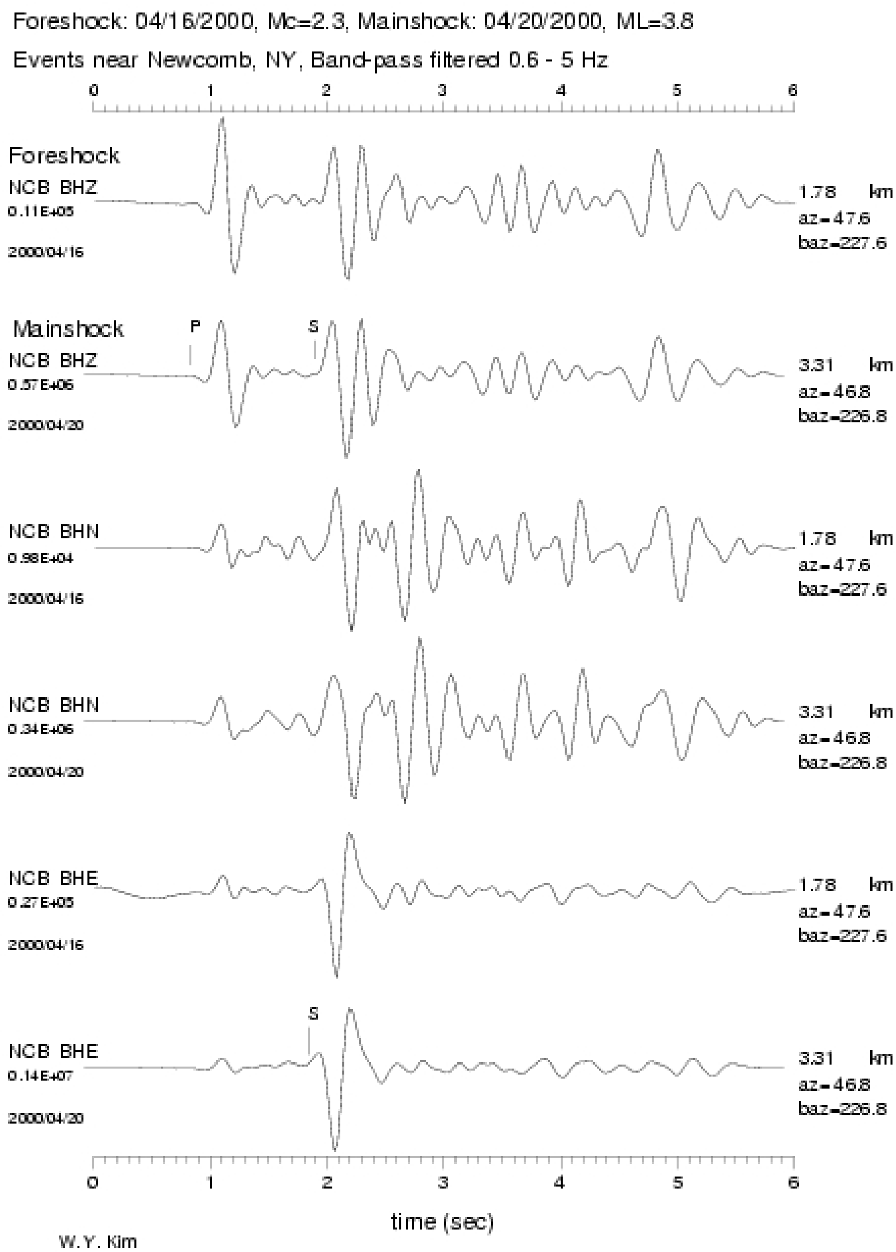

Figure4. Three-component broadband records from the foreshock (04/16/2000, 18:59) and the mainshock (04/20/2000, 08:46) recorded at the USNSN site NCB (Newcomb, NY) in the Adirondacks. The data are filtered between 0.6 and 5 Hz.

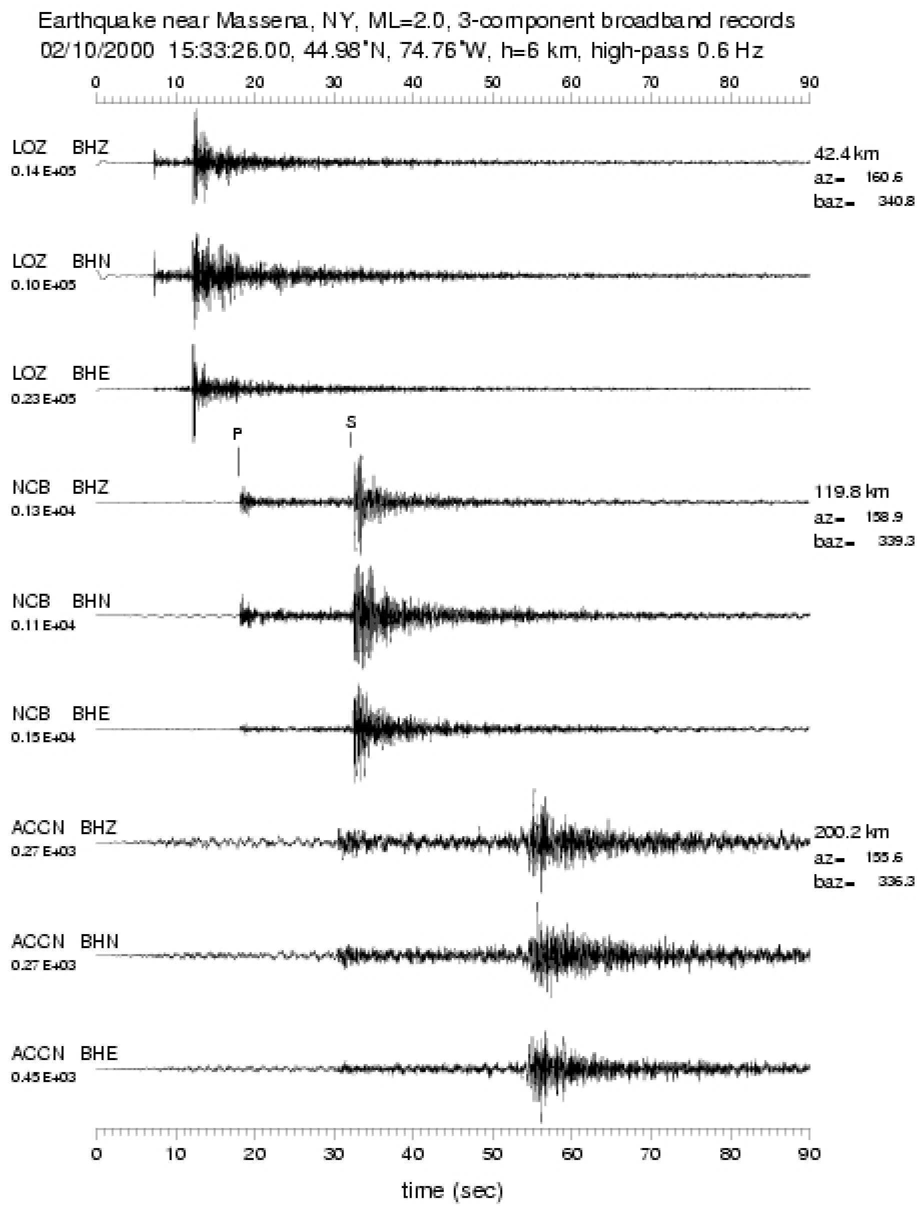

Figure 5. Three-component broadband records from ML = 2 event on February 10, 2000 (15:33:26) earthquake which have occurred near Massena, NY. Seismic signals are well recorded at nearby broadband station LOZ (Δ = 42 km; Lake Ozonia) and other two new broadband stations.

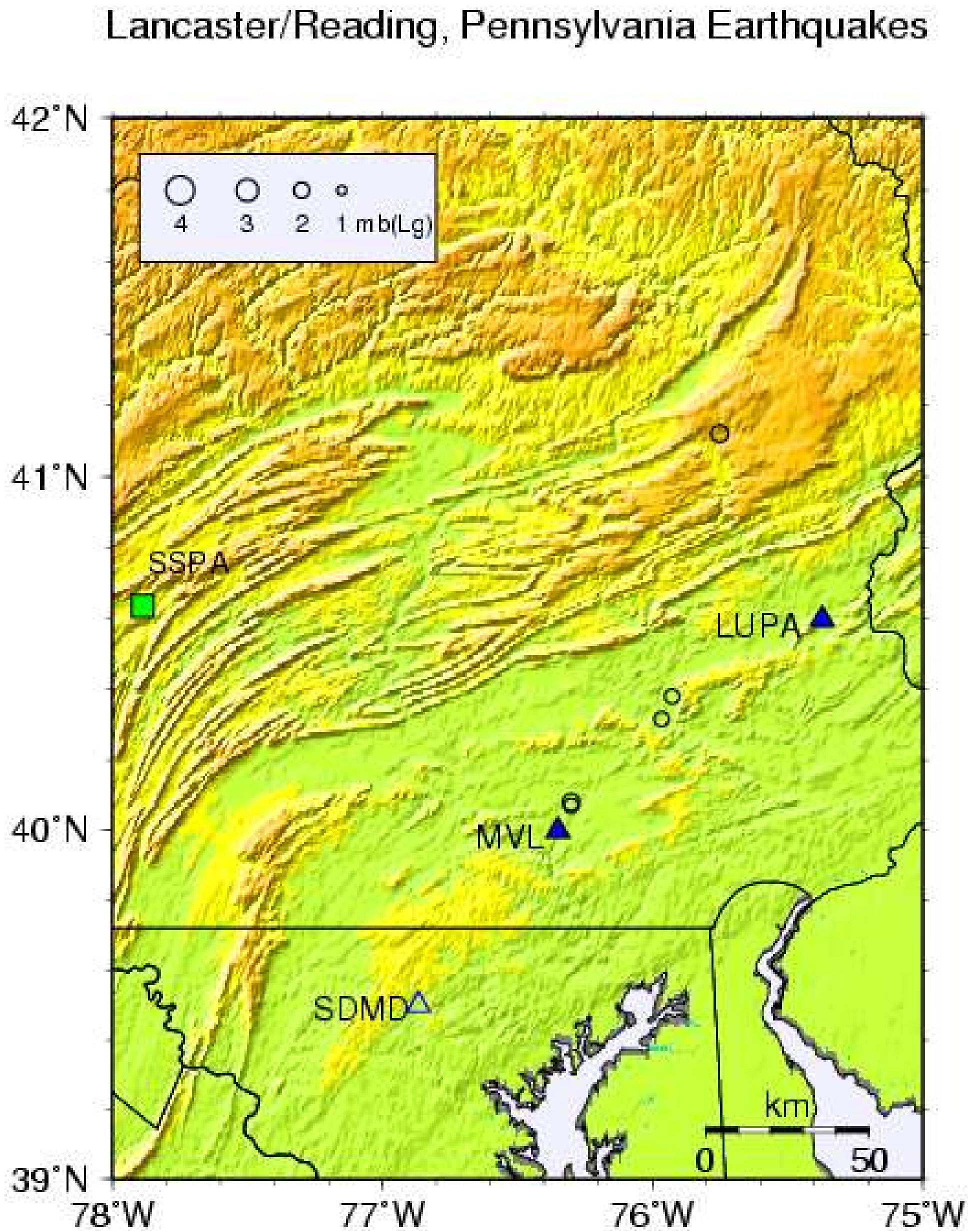

Figure 6. Earthquakes that occurred in the Lancaster/Reading Region of Pennsylvania during July 1, 1998 - June. 30, 2001 recorded by LCSN. Symbol size is proportional to the magnitudes. LCSN and USNSN broadband sites are plotted for reference.

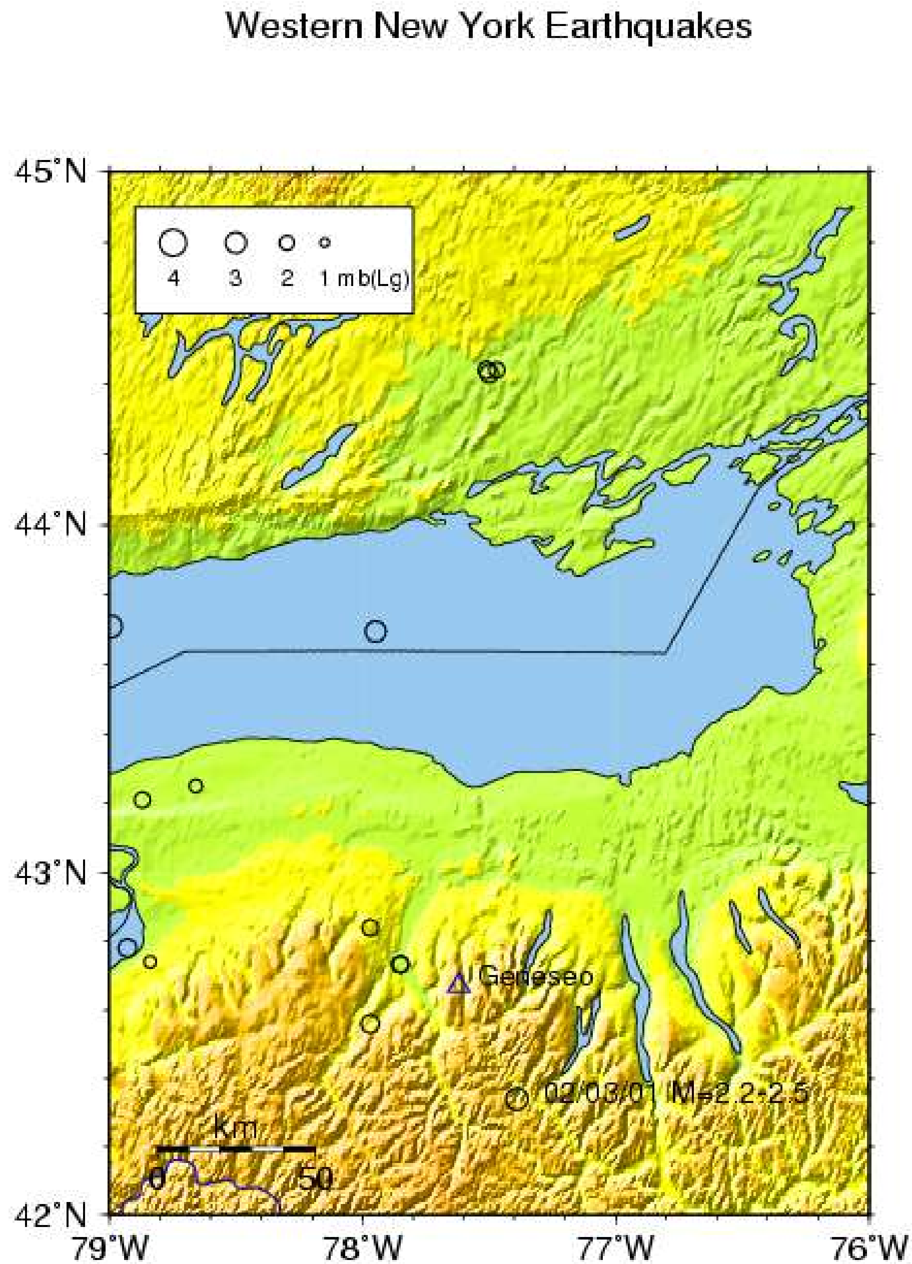

Figure 7. Earthquakes that occurred in Western New York during July 1, 1998 - June. 30, 2001 recorded by LCSN (circles). Symbol size is proportional to the magnitudes. LCSN broadband sites are plotted for reference.

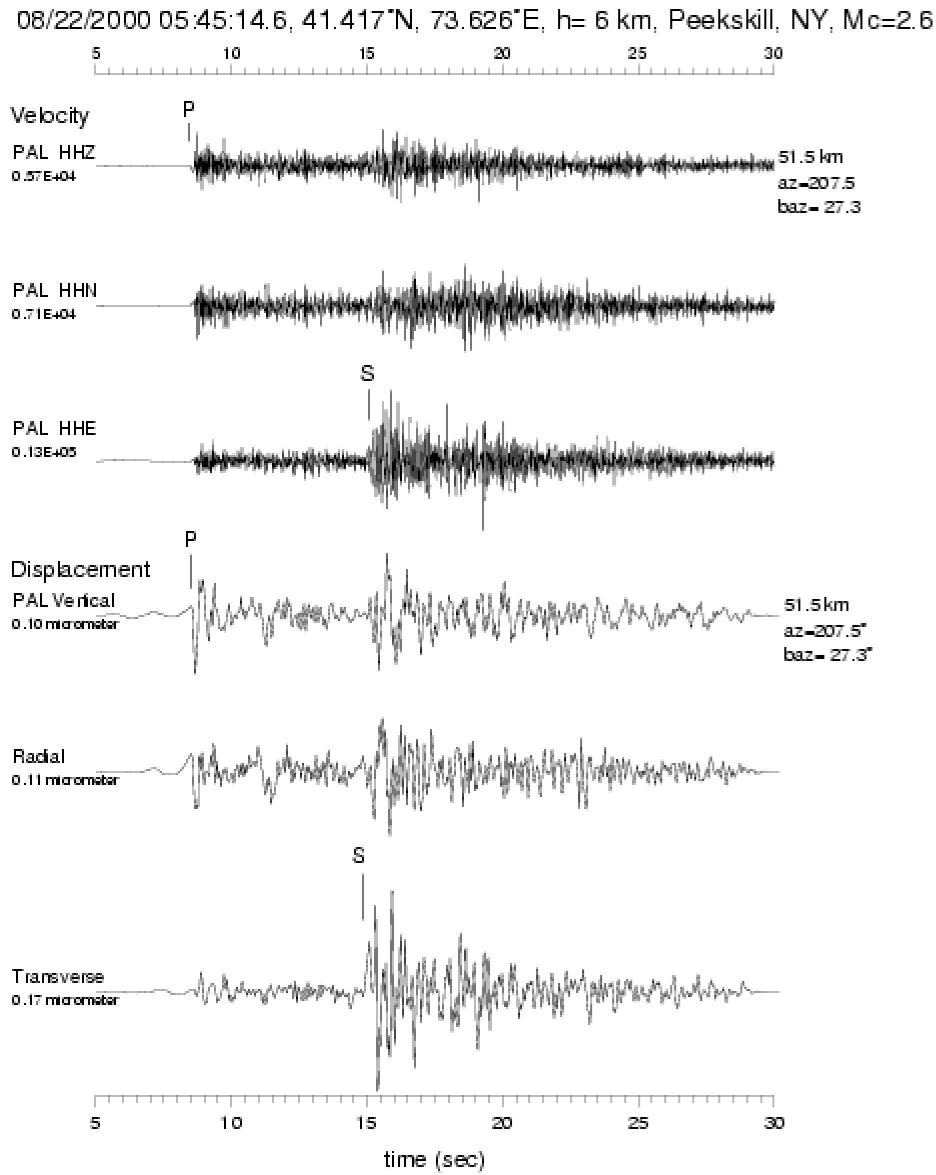

Figure 8. Three-component, broadband velocity (upper three traces) and displacement (lower three traces) records at station PAL (Palisades, Δ = 52 km) from the earthquake on Aug. 22, 2000, which have occurred in Putnam County, NY (Mc=2.6). The amplitude of the ground displacement ranges from 0.1 to 0.17 micrometer.

Lancaster - Reading, Pennsylvania

In the period of July 1, 1998 through June 30, 2001 five earthquakes of magnitude ML=1.8 to 2.3 were been recorded by the LCSN in the Lancaster-Reading area of Pennsylvania (Figure 6). These events occurred close to the Reading, PA earthquake that occurred on 16 January 1994 (mb(Lg)=4.6) which caused some moderate level of damage ($1.5 million). Whether or not these events are induced earthquakes related to old local mining operation is a key question (e.g., Armbruster & Seeber, 1987; Seeber et al., 1998). We have worked with Dr. Charles Scharnberger at Millersville University in Lancaster and Dr. Anne Meltzer at Lehigh University, Pa and the Maryland Geological Survey to improve the earthquake monitoring coverage in the epicentral area. The LCSN has incorporated broad band stations at Millersville as well as Lehigh and are, at the time of this report, working with the Maryland Geologic Survey to install another broadband station north of Baltimore Maryland.

Western New York

In the period of July 1, 1998 through June 30, 2001, nine earthquakes of magnitude ML=1.5 to 3.2 were recorded by the LCSN around the Attica Seismic Zone in western New York (Figure 7). These events occurred near the 12 March 1994 (mb(Lg)=3.6) induced earthquake near a salt mine around Cuylerville, NY. Note that these events were located by CNSN (Canadian National Seismographic Network) due to poor coverage of LCSN in western New York. It is necessary to improve the seismic station coverage in the western New York. To this end we are in the process of installing a permanent broadband station at SUNY, Geneseo and are working with Dr. Robert Jacobi at SUNY, Buffalo to install a permanent broadband station near Buffalo.

On Aug. 22, 2000 (05:02:30), a moderate sized earthquake of magnitude Mc = 2.6 occurred in Putnam County, about 28 km NE of Peekskill, NY. The event was felt around the epicentral area and was well recorded by Palisades Subnetwork stations and a broadband station at PAL (Palisades, NY; $\Delta = 52$ km). The waveform data in ground velocity and displacement are shown in Figure 8. The displacement records after removing the instrument response show clear P and S wave pulses from the source. Waveform data from such close-in station with on scale digital recordings allow us to study details about the earthquake source and excitation and propagation of ground motion in the northeastern U.S. (see e.g., Hough & Seeber, 1991; Shi et al., 1996; Shi et al., 1998).

On Feb. 3, 2001 (20:15:15), an earthquake of magnitude Mb = 3.2 occurred near Avoca, NY. The event was accompanied by many felt reports in the area. In January of 2001 the Canadian Geological Survey observed a series of at least five events near Avoca in western New York, near but to the southeast of the Retsof salt mine that generated collapse events starting in 1994. These other events reported to LCSN by the Canadian Geologic Survey were:

2001/01/22 12:05:40 42.48N 77.52W 5.0g 2.4MN
2001/01/25 14:19:23 42.50N 77.47W 5.0g 2.5MN
2001/01/25 19:00:26 42.49N 77.42W 1.0g 2.1MN
2001/01/30 07:52:02 42.62N 77.54W 5.0g 2.2MN

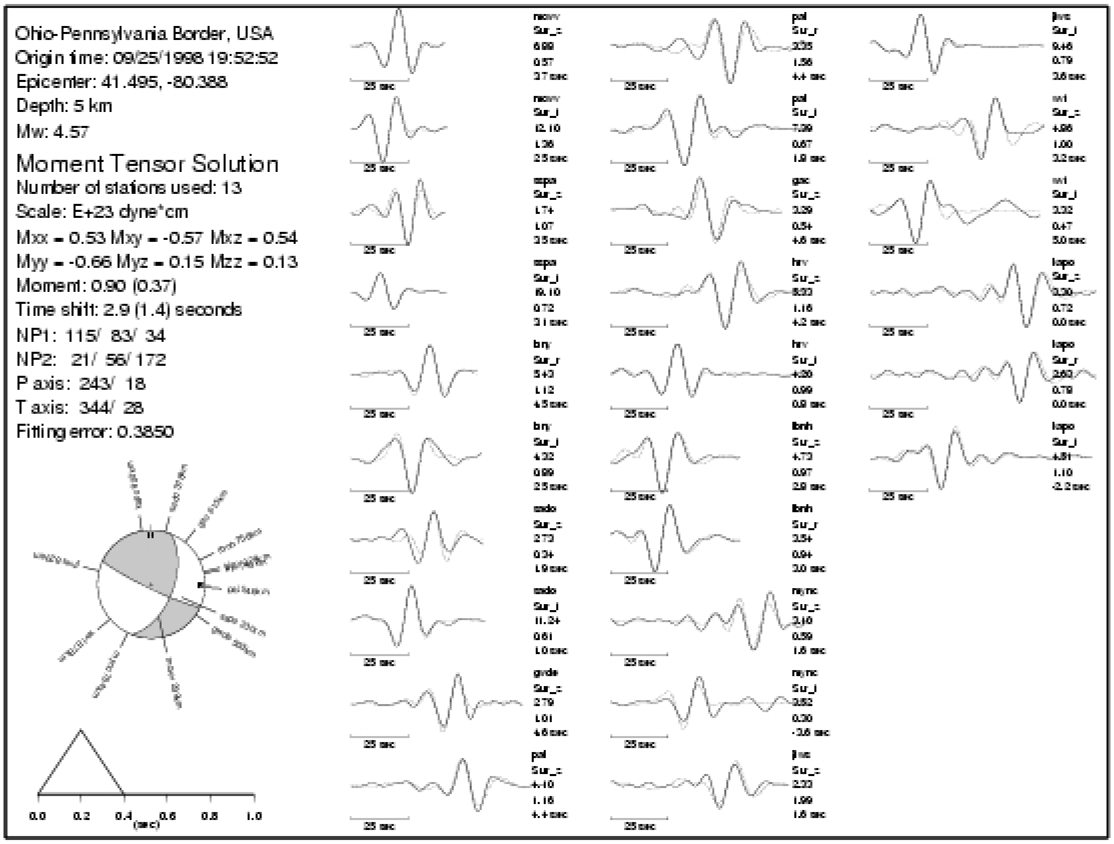

Figure 9. Source mechanism and focal depth determined by regional waveform inversion for the Pymatuning earthquake on September 25, 1998 (mb(Lg)=5.2). Surface waves observed at broadband stations in the distance ranges of 200 km (MCWV) to about 900 km (KAPO) are used for inversion. At each station, surface waves on vertical, radial and transverse components in the period range 10 to 50 sec are used for inversion depending upon the signal-to-noise ratios. For each trace, the best fit synthetic trace (*dotted line*) is superposed to the observed trace (*solid line*). Notice that Love waves on transverse components at stations over 500 km (e.g., PAL) start to show earlier arrivals than corresponding Rayleigh waves on vertical or radial components.

LCSN staff contacted Prof. W. Brennan at the State University of N. Y. at Geneseo and learned that tests were being conducted near Avoca to hydrofracture the Potsdam formation. The tests were related to a proposed natural gas storage facility near Avoca to be constructed by solution mining. LCSN staff contacted the local newspaper and found that the five events were felt in the vicinity of the hydrofracture tests. New York State DEC was asked for information on the history of fluid injection but they stated that they have agreements with the company to restrict this information. A formal request was made for that information to the NYS DEC. The news media reported that the seismic activity started a few days before the injection started and stopped soon after the injection stopped. The NYS DEC has ordered that "no further injection testing can take place without seismic monitoring in place". No further seismic activity has been seen since the injection stopped.

Source mechanisms and focal depths of moderate sized earthquakes (magnitude approximately greater than about 3.5) in the northeastern U.S. can be determined by regional waveform inversion method (e.g., Dreger & Helmberger, 1993). An example result for the Pymatuning earthquake on September 25, 1998 is shown in Figure 10. This is one of the largest events that have occurred in the northeastern U.S. since the deployment of broadband seismographic stations of the USNSN, CNSN and LCSN in the region. We are now able to use waveform data from about 12 stations in the distance ranges of 200 km out to about 1000 km for waveform modeling and inversion. For this event, we used surface waves on three component records in the frequency band 0.05 to 0.1 Hz. The best-fit synthetics constrained the focal depth at about 5 km with a scalar seismic moment M_0 = 9.3e+22 dyne-cm. The source mechanism is predominantly strike-slip with a significant amount of thrust component (see Figure 10).

The main causes of the clustered seismicity at around Reading, PA, and western New York are not well understood at present. These regions are relatively poorly covered by the LCSN, and hence it will be important to improve monitoring capability in this region. Until the early 90's, low data quality imposed primarily by the telemetry used in regional networks has limited the use of these data to a rudimentary level of earthquake cataloging (epicenter location, determination of fault plane solutions, etc.). While this has provided crucial data to delineate and define earthquake source regions, it has not allowed for detailed analysis of earthquake source characteristics and propagation effects. However, deployment of U. S.. National Seismic Network which begun in 1992 and other broadband stations in the eastern U.S. in the past five years or so, and recent advent of seismological theories have allowed us more quantitative analysis of the data for source and wave propagation path in the region (e.g., Shi et al, 2000; Levin et al. 1999). For earthquake hazard assessment in the northeastern U.S., it is essential that more be learned about the excitation and propagation of ground motions and how these factors differ from those found through more extensive studies in the western U.S. This must be accomplished by a coordinated effort to deploy more three component broadband seismographs in the northeastern U.S.

Metropolitan New York City

In the period of July 1, 1998 through June 30, 2001, five earthquakes of magnitude Mc=1.2 to 2.6 were recorded by the LCSN in the New York City area (Figure 11). While these events are small in magnitude, their proximity to a large, densely populated urban area like New

York City make them of considerable interest to members of the emergency management, media, engineering, and scientific communities.

On Jan. 17, 2001 (12:34:22), an earthquake of magnitude Mc=2.4 occurred in New York City. The event was located in Manhattan using arrival times from the LCSN. Waveforms of the event are shown in Figure 12. An aftershock of magnitude Mc=1.2 was felt on Jan. 19,2001 (15:04:42). The calculated location was similar to that of the mainshock. Felt reports for the mainshock indicate that the epicenter may be further east in Queens, NY. LCSN coverage in this area is predominantly to the west of the event, perhaps causing the calculated location to be "pulled" to the west. The discrepancy between the calculated epicenter and felt reports shows a lack in LCSN coverage to the east of Manhattan. LCSN is currently working with members of Fordham College in Bronx, NY and Queens College in Queens, NY to install broadband stations to fill in this gap.

Ashtabula, Ohio

In the period of July 1, 1998 through June 30, 2001, seven earthquakes of magnitude from Mn=2.0 to 5.4 were recorded by the LCSN near Ashtabula, OH (Figure 13). In July 1987, deployment of portable instruments by LDEO scientists in the vicinity of a magnitude 4.1 earthquake near Ashtabula recorded more than 50 aftershocks. Analysis of these data found that the source of the seismicity was a vertical east-west striking fault with left-lateral motion. It was also concluded that the seismicity was triggered by a class 1 waste disposal well less than 1 km from the fault that began operation within the previous year.

On January 26, 2001 (03:03:21) a magnitude Mn=4.2 earthquake occurred near the 1987 epicenter, the largest event known in the vicinity of Ashtabula. This event resulted in some property damage and two gas lines were broken.

Analysis of well located events finds that the source of these events is an east-west striking fault dipping steeply to the south with left-lateral motion. This fault is approximately 4 km to the south of the fault active in 1987 and current seismicity is probably triggered by the same waste disposal well associated with the 1987 activity. A proposal has been submitted to NEHRP for monitoring and detailed study of the Ashtabula seismic activity. A paper reporting the recent observations is in preparation:

An Active 14-Year Old Earthquake Sequence Triggered by Injection in Ashtabula, OH
by L. Seeber, J.G. Armbruster, W.-X. Du, and W.-Y. Kim

AFTERSHOCK AND SPECIAL STUDIES USING PORTABLE SEISMOGRAPH ARRAY

One of the major problems specific to the northeastern U.S. is a diffuse, relatively low level of seismicity and the sparse seismic network coverage. One result of this sparse coverage is that aftershock investigations using the temporary stations provide a particularly valuable set of data and allow us to understand better the local earthquake effects and to delineate seismogenic faults.

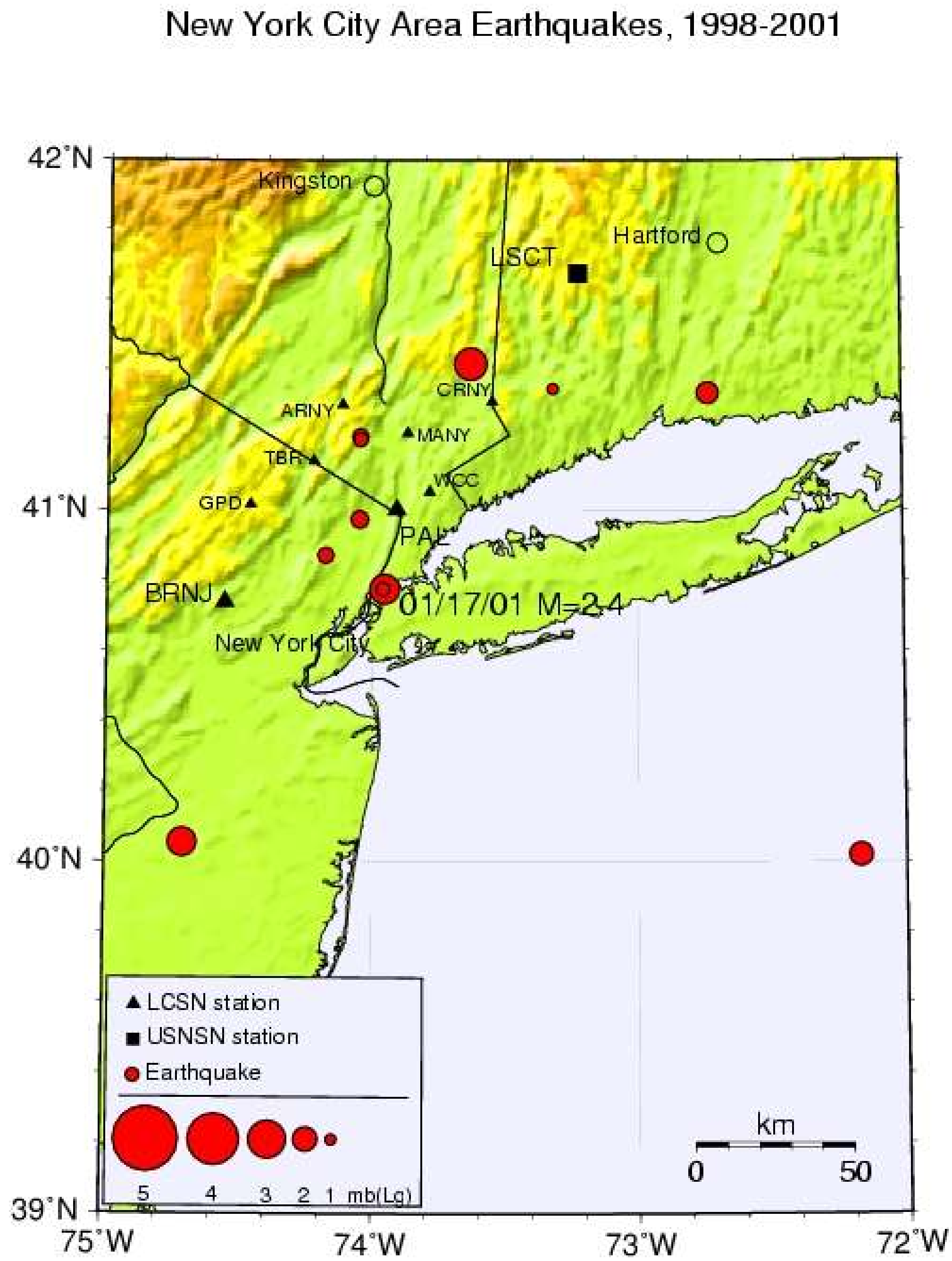

Figure 10. Earthquakes which occurred in the New York City area during July 1, 1998 through June 30, 2001 recorded by LCSN. Symbol size is proportional to magnitude. LCSN and USNSN stations are plotted for reference.

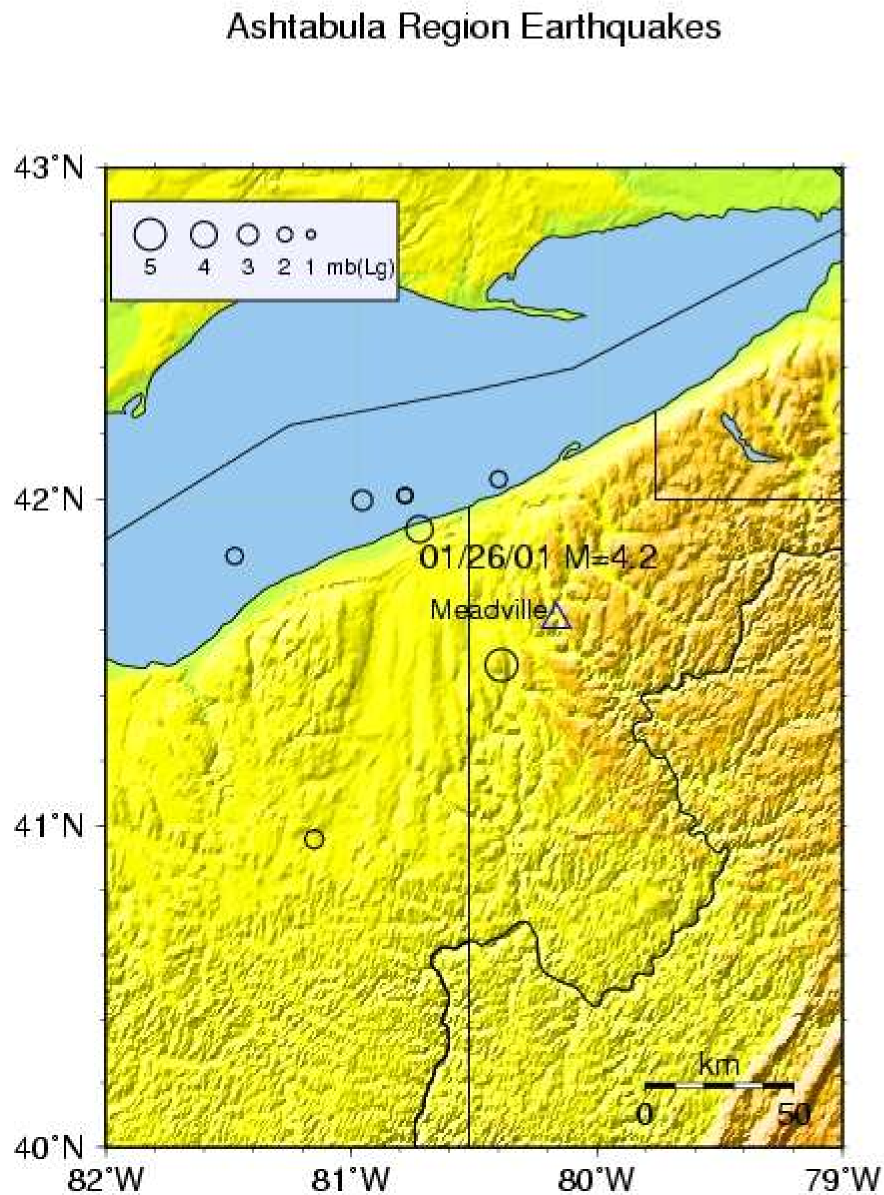

Figure 11. Earthquakes which occurred in the Ashtabula Region of Ohio during July 1, 1998 through June 30, 2001 recorded by LCSN. Symbol size is proportional to magnitude. LCSN and USNSN stations are plotted for reference

During FY98/00 (June 1998 – June 2000), LCSN acquired basic instrumentation for a four-element portable seismograph array for special studies and aftershock investigations in the northeastern U.S. The portable seismograph array consists of four broadband seismometers (model CMG-40T with 30 sec to 50 Hz flat response to velocity), low-power dataloggers (3-channel, 24 bit A/D, model RefTek RT72A-7), spread-spectrum digital radios, a network access server (router), and a portable PC.

The portable seismograph array may be deployed continuously for an extended period (a few weeks to more than a year) at various target areas primarily in the northeastern United States for aftershock monitoring, studies of local and regional seismicity and delineation of particular seismogenic faults. Such deployment can fill in the spatial gaps in permanent station networks in the northeastern U.S., and allow us to acquire high quality data to study ground motion attenuation and other issues relevant to address the regional earthquake monitoring and regional earthquake hazards in the northeastern U.S. (Kim, 1998).

During the FY00/01, three portable arrays were deployed in cooperation with and by the LCSN:

1) Lancaster Pennsylvania (Nov.11, 2000 – Feb. 13, 2001):

On 5 October 2000 an earthquake of magnitude 2.1 was felt in the southern part of Lancaster County, Pennsylvania. That is the most active part of the state and an analysis of felt reports by Prof. Charles Scharnberger of Millersville University concluded that the event was centered near the magnitude 4.1 Martic earthquake of 1984.

Three REF-TEK recorders with L-22 sensors were installed in a triangular array around the epicenter of the October 5 event. The instruments were checked weekly by Prof. Scharnberger and operated for 93 days. The instruments recorded no earthquakes, but several quarry blasts were recorded, indicating that the equipment was working properly.

2) New York City, New York (Jan. 19, 2001 – Feb. 7, 2001):

On January 17, 2001, an earthquake of magnitude 2.4 occurred beneath the Upper East Side of Manhattan, New York City. The shock was felt in Manhattan and Queens. On January 19, 2001 an aftershock of magnitude 1.2 was felt and recorded.

Two REF-TEK DAS with CMG-40T and L-22 sensors were deployed for further aftershocks. No further aftershocks were recorded.

3) Ashtabula, Ohio (June1, 2001 – present):

In response to the seismic activity discussed earlier in this report, four REF-TEK recorders with L-22 sensors were deployed in the vicinity of Ashtabula on June 1 and 2. On June 3 a magnitude 3.0 event was felt and recorded by the instruments. A request was made to the PASSCAL instrument center for an additional recorder and on June 10 the PASSCAL instrument was installed and one of the original instruments was moved.

DATA AVAILABILITY

Continuous waveform data from broadband, three-component stations:

Continuous 40 samples/sec waveform data from all broadband, three-component seismometers recorded by the LCSN are archived at IRIS/DMC in Seattle, WA for further dissemination to other scientists and public users. Waveform data in SEED format have been submitted and current PAL data holdings at IRIS/DMC cover most of 1994 and all of 1999. Waveform data from stations ACCN, BRNJ, and LOZ have been submitted from late 2000 to present. Newer stations, MVL, LUPA, CONY have been submitted since their inclusion into the LCSN. Interested users can request the waveform data to IRIS/DMC by using E-mail requests and other means. In case of E-mail request, station code is PAL and the network code is "LD". An example data request format is

PAL LD 1994 08 01 12 00 00.0 1994 01 12 01 00 00.0 3 BHZ BHN BHE

We will continue to submit the continuous, broadband waveform data recorded at LCSN stations to IRIS/DMC. We also submitted the continuous, broadband waveform data recorded at NCB (Newcomb, NY; CMG-40T seismometer with T_0=30 sec) to the IRIS/DMC for April - May 1999. We will continue to process and submit to DMC for data acquired at NCB for 1996 through 1998.

Waveform data from selected significant earthquakes in northeastern United States:

When felt earthquakes or significant events occurs in the northeastern United States, we put seismic phase arrival picks, short-period and broadband waveform data into LCSN web site which can be easily downloaded by users via the Internet using only a single click. Other event data requested by users, which include neighboring seismographic network operators, Geological Survey of Canada, Ottawa, high school teachers and students, these data are also processed and written into SEED format for download by users. Our experience indicates that it is the most efficient method to disseminate to multiple users without additional efforts. The URL for LCSN web site is: http://www.ldeo.columbia.edu/LCSN or users can navigate from the LDEO home page at: http://www.ldeo.columbia.edu, then click "Solid Earth", followed by "Lamont-Doherty Cooperative Seismographic Network". Waveform data of the selected events in SEED can be found in "Data Acquisition".

Real-time data export:

Since early 2001, the Master Earthworm system at LDEO has been configured to export real-time data for seven channels to the USGS. This was first implemented in response to satellite problems in Colorado which cutoff telemetry to the USNSN stations in the region.

More recently, at the time of this reports submission, IRIS DMC is configuring a real-time link with the LCSN using the Antelope real-time system.

EARTHQUAKE RESPONSE

E-mail Notification

In the event of a regional earthquake, the LCSN sends out two separate email alerts. The first is a bulletin intended mainly for LCSN subnetworks, LCSN participating institutions, and others in the seismological community. The bulletin includes location and phase arrival information as shown below:

```
LCSN Reviewed Event
-------------------------------------------------------------
evid=1000717 orid=1000146 OHIO LDEO:antelope
1/26/2001 3:03:21.364 41.9087 -80.7216 h=5 ml=4.2 mb=-999
rms=0.585961

1000176     FINE P 1/26/2001 3:04:31.462 -1.312
1000173     ACCN P 1/26/2001 3:04:32.910 0.085
3966        GPD  P 1/26/2001 3:04:34.429 0.435
3982        TBR  P 1/26/2001 3:04:36.105 0.061
3970        ARNY P 1/26/2001 3:04:36.976 0.201
3979        PAL  P 1/26/2001 3:04:39.559 -0.021
3977        MANY P 1/26/2001 3:04:39.587 0.168
1000155     CRNY P 1/26/2001 3:04:43.286 0.776
1000157     BRCN S 1/26/2001 3:05:23.310 -0.988
1000156     FINE S 1/26/2001 3:05:29.158 0.546
1000158     GPD  S 1/26/2001 3:05:30.073 -0.732
1000177     BRNJ S 1/26/2001 3:05:30.907 -0.030
1000161     TBR  S 1/26/2001 3:05:34.090 -0.400
1000165     ARNY S 1/26/2001 3:05:36.399 0.595
1000164     MANY S 1/26/2001 3:05:39.629 -0.928
1000172     PAL  S 1/26/2001 3:05:41.379 0.531
1000162     LOZ  S 1/26/2001 3:05:42.372 0.394
3965        CRNY S 1/26/2001 3:05:45.317 -0.794
-------------------------------------------------------------
Reviewed by: J.Armitage
```

A second,less technical email is sent which is meant more for emergency management and others outside the seismological community:

```
Earthquake Information from Lamont-Doherty Cooperative Seismographic
Network (LCSN)

      On Saturday August 5, 2001, at 08h 12m 10s (EST), a small
earthquake of magnitude 1.5 occurred near Newcomb, New York

Origin Time: 08/05/01 at 08h 12m 10.23s (EST) 04:12:10.23 (UTC)
Location: 43.82N  74.13W, Depth = 9.48 km, shallow
Magnitude: Mc=1.5

Jeremiah Armitage
LCSN Network Manager
Won-Young Kim, Ph.D.
Research Scientist
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Media Relations

Often, events in the northeast bring some media attention if they are felt. In most cases, media attention is fairly limited and may consist of a single newspaper or radio station. The magnitude 2.4 earthquake in Manhattan in January of 2001 brought many inquiries from radio, television, and printed media. LCSN staff as well as LDEO staff armed with LCSN data, work with the media providing radio and television interviews, graphics for printed media and television, and general information about the event and seismic history of the area. Some media groups which have benefited from interaction with the LCSN and LDEO are the New York Times, CNN, ABC, NBC, various radio stations, and smaller newspapers.

EDUCATION AND OUTREACH PROGRAM AND LCSN WORLD WIDE WEB

In the spring of 1999, we developed a moderate level of education and outreach program for LCSN to meet growing demands in earthquake related inquiries from K–12 grades students and science teachers as well as the public in general. Much of this development is based on the LCSN World Wide Web site via the Internet. Junior scientists, graduate student and other researchers at LDEO on a voluntary basis have developed this web page and outreach program. We now have **webseism**(ogram) which is a near real-time, user interactive seismogram display on the LCSN web page, enhancing rapid information dissemination capability of the LCSN. The webseismogram provide live seismogram displays from twelve broadband stations (PAL, NCB etc.) where the continuous data had been transferred to central site at LDEO via Earthworm. User can display daily 24 hour webseismograms for single component from all stations or three-component from selected station, and choose among broadband, WWSSN short-period or WWSSN long-period type displays. For any time window or interested event window, user can "zoom" the display and extract the waveform data, filter the signals, review the PDE or QED catalog, select the event, and calculate travel times of various seismic phases for selected event, plot the signals in PostScript, print the display, and finally, download the data into their computer. This webseismogram proved to be very useful for students, teachers, college & graduate level students, as well as for professional researchers as a simple and handy tool to monitor earthquakes worldwide.

The results of various scientific studies such as, detailed distribution of micro-earthquakes, possible seismogenic faults revealed by the aftershock studies are all available on the LCSN web page and are disseminated to various customers using web page. The earthquake catalog, epicentral maps and associated waveform data are easily traceable on the web page and customers can "ftp" the waveform data in a single SEED volume by clicking interested event. The waveform is transferred to the users in the background and users do not have to struggle to send a complex query or to select appropriate time window.

Currently, the LCSN web site provides the information to the general public regarding station table and location map, regional earthquakes catalog for 1990-2001 and corresponding map, recent earthquakes and detailed information on selected events that were studied by the team of LCSN operators and scientists. The URL is **http://www.ldeo.columbia.edu/LCSN**

We also conducted a successful two-day workshop for Earth Science teachers at the Hudson Falls Central School District, NY in May 2000 with about 25 attendees. The school district purchased a new broadband instrument (ACCN, with CMG-3T & Guralp 24 bit datalogger), and is a participant of the LCSN. We will continue to update and explore ways to improve our education and outreach program. Notable improvements will be to integrate our webseismograms with other Earth and Environmental Science facilities at LDEO – Biosphere 2, Climate Forecasting Lab, Ocean circulation modeling and CIESIN (Center for International Earth Science Information Network).

Bibliography

Armbruster, J. and L. Seeber (1987), The 23 April 1984 Martic Earthquake and the Lancaster Seismic Zone in Eastern Pennsylvania, *Bull. Seis. Soc. Am.*, **77**, 877-890.

Dreger, D. and D. Helmberger (1993), Determination of source parameters at regional distances with single station or sparse network data, *Jour. Geophys. Res*., **98**, 8107-8125.

Hough, S.E. and L. Seeber (1991), Seismologic Constraints on Source Properties of the Mb = 4.0 1985 Ardsley, New York Earthquake: A Characteristic Rupture?, *Jour. Geophys. Res*., **96**, 18,183-18,195.

Kim, W. Y. (1998), The M_L scale in Eastern North America, *Bulletin of the Seismological Society of America*, **88**, 935–951.

Levin, V., W. Menke and J. Park (1999), Shear-wave splitting in Appalachians and Urals: a case for multilayered anisotropy, *Journal of Geophysical Research*, **104**, 17975-17994.

Nabelek, J. and G. Suarez (1989), The 1983 Goodnow earthquake in the Central Adirondacks, New York: Rupture of a simple, circular crack, *Bulletin of the Seismological Society of America*, **79**, 1762-1777.

Seeber, L., J.G. Armbruster, W.-Y. Kim, N. Barstow and C. Scharnberger (1998), The 1994 Cacoosing Valley earthquakes near Reading, Pennsylvania: A shallow rupture triggered by quarry unloading, *Journal of Geophysical Research*, **103**, 24505–24521.

Shi, Jinghua, W. Y. Kim and Paul G. Richards (1996), Variability of crustal attenuation in the northeastern United States from *Lg* waves, *Journal of Geophysical Research*, **101**, 25231–25242. Correction to "Variability of crustal attenuation in the northeastern United States from *Lg* waves", *Journal of Geophysical Research*, **102**, 11899, 1997.

Shi, Jinghua, W. Y. Kim and Paul G. Richards (1998), The corner frequencies and stress drops of intraplate earthquakes in the northeastern United States, *Bulletin of the Seismological Society of America*, **88**, 531–542.

Shi, Jinghua, Paul G. Richards and W. Y. Kim (2000), Determination of seismic energy from *Lg* waves, submitted to the *Bulletin of the Seismological Society of America*, **90**, 483-493.

Acknowledgements

Staff at LDEO: Jeremiah Armitage, John Armbruster, Doug Johnson and Ted Koczynski installed and serviced the seismographic stations of the LCSN. Technical staff at LDEO – John Contino, Robert Kakascik and Timour Rizvanov provided technical support in operating the LCSN. Dr. Michael Hagerty designed and implemented initial version of webseismogram for LCSN web page and the graduate student, Mr. Wayne Du completed the implementation of the webseismogram on the web page. Research staff at LDEO – Drs. Klaus Jacob, Art Lerner-Lam, Vadim Levin, Bill Menke and Leonardo Seeber participated at various discussions and site surveys for LCSN operation and provided valuable assistance and guidance. Graduate student at LDEO, Mr. Michael West lead two earthquake workshops for Earth Science teachers in New York and New Jersey, while graduate students – Chang Duan, John Granville, Anyi Li and Kristina Rodriguez helped paper record change.

Harley Benz, Alex Bittenbinder, Jim Cullen and Barbara Bogaert at USGS, Golden, CO provided invaluable help in installation of the Earthworm systems at LCSN. Ray Bulland, David Ketchum, Mark Meremonte and Kay Shedlock at USNSN, Golden, CO helped us to install the new USNSN station NCB (Newcomb, NY) and provided guidance in maintaining the

USNSN stations in the northeastern U.S.

Dr. Mitchell Whithers at CERI, University of Memphis provided invaluable assistance to configure Earthworm system. Mr. Paul Friberg at ISTI helped to install Quanterra system for the station PAL at Lamont.

We appreciate effort of PI's and staff at the cooperating organizations in operation of the LCSN: Potsdam College of Art and Science, State University of New York (PI: Dr. Frank Revetta and Mr. Jack Morgan); Delaware Geological Survey (PI: Dr. John Talley and Steffanie Baxter, Tom McKenna, Charles Smith); University of Vermont, Burlington, VT (PI: Christine A. Massey); Middlebury College, Middlebury, VT (PI: Dr. Raymond Coish & Mr. Goodrich); Adirondack Community College, SUNY (PI: Dr. Don Minkel); Hudson Falls Central School District & North Hudson Electronic Education Empowerment Project, NY (PI: Karen Woodard); William-Annin Middle School, Basking Ridge, NJ (Mr. Brect Kent); Westchester Community College, SUNY (Dr. Richard van Inwegen); Millersville University, Millersville, Pa (Dr. Charles Schanbeger); Lehigh University, Bethlehem, Pa (Dr. Anne Meltzer and Dr. Golam Sarker); College of Agriculture & Technology at Cobleskill, SUNY (PI: Dr. Edward Stander).

We also appreciate effort of PI's and staff at other cooperating organizations in planning and site surveys for the LCSN: State University of New York, Buffalo (PI: Dr. Robert Jacobi); ; Maryland Geological Survey (Dr. Gerald Baum and Mr. Richard Orts); Maryland Emergency Management Agency (Mr. Fleming A. El-Amin II); University of Connecticut, Storrs, CT (Dr. Vernon Cormier); Adirondack Ecological Center at Newcomb, SUNY College of Environmental Science and Forestry in Syracuse, NY; State University of New York, Geneseo, (Dr. William Brennan); Allegheny College, Meadville, PA (Mr. Sam Reese); Thiel College, Greenville, PA (Miss Katherine Stanley).

Appendix 1. LCSN Seismographic Stations

Broadband seismographic stations

STATION CODE	LAT (°N)	LONG (°W)	ELEV (m)	OPERATION (year/mo/da)	STATION NAME	INSTRUMENT
PAL	41.0042	73.9092	91	92/01/01-99/10/01	Palisades, NY,	CMG-3, STS-2
	41.0056	73.9079	66	99/10/01-		STS-2 Q380
NCB	43.9734	74.2229	474	92/01/01-10/01/99	Newcomb, NY	CMG-40T
	43.9734	74.2228	575	10/20/99-	USNSN, Newcomb, NY	STS-2
ACCN	43.3360	73.7379	340	11/09/99-06/19/00	Adirondack Comm. College, NY	
	43.3843	73.6678	340	06/20/00-		CMG-3T
LOZ	44.6197	74.5829	440	11/19/99-06/07/01	Lake Ozonia, NY,	STS-2
				06/08/01-		CMG-3ESP
BRNJ	40.6828	74.5660	50	11/21/99-	Basking Ridge, NJ	CMG-40T
MVL	39.9992	76.3506	91	02/13/01-	Millersville, PA	CMG-3ESP
LUPA	40.5985	75.3714	236	01/26/01	Lehigh, PA	CMG-3TD
CONY*	42.6658	74.4468	468	07/13/01-	Cobleskill, NY	CMG-40T

Short-period seismographic stations

STATION CODE	LAT (°N)	LONG (°W)	ELEV (m)	OPERATION (year/mo/da)	STATION NAME	COORPORATING INSTITUTION
Palisades Subnetwork						
ARNY	41.3032	74.1145	430	1993/12/16	Arden House, NY	LDEO
CRNY	41.3118	73.5482	293	1981/12/01	Cross River, NY	LDEO
GPD*	41.0177	74.4608	360	1976/08/01	Green Pond, NJ	LDEO
MANY	41.2220	73.8686	133	1993/12/08	Mount Airy, NY	LDEO
PAL*	41.0042	73.9092	91	1949/01/01	Palisades, NY	LDEO
TBR	41.1417	74.2222	261	1975/08/01	Table Rock, NY	LDEO
WCC	41.0585	73.7918	100	1987/06/01	Westchester Comm. College, NY	LDEO
Lake Champlain Subnetwork (Middlebury College, Vt)						
FLET	44.7227	72.9517	366	1977/08/01	Fletcher, VT	Middlebury/LDEO
HBVT	44.3623	73.0650	342	1980/09/01	Hinesburg, VT	UVT
MDV	43.9992	73.1812	134	1970/03/01	Middlebury, VT	Middlebury
MIV	44.0747	73.5340	317	1984/10/01	Mineville, NY	Middlebury/LDEO
PNY	44.8342	73.5550	177	1971/08/01	Plattsburg, NY	Middlebury/LDEO
St. Lawrence Valley Subnetwork (SUNY, Potsdam, NY)						
BGR	44.8288	74.3742	297	1976/11/01	Bangor, NY	Potsdam/LDEO
BRC	44.4275	75.5830	83	1976/11/01	Bracie Corner, NY	Potsdam
CHIP	44.7980	75.1950	97	1994/07/01	near Potsdam, NY	Potsdam
LOZ	44.6200	74.5800	482	1984/11/01	Lake Ozonia, NY	Potsdam
MSNY	44.9983	74.8620	55	1976/11/01	Massena, NY	Potsdam/LDEO
FINE	44.2650	73.5772	354	1997/10/01	Fine, NY	Potsdam
PTN	44.5700	74.9819	197	1971/10/01	Potsdam, NY	Potsdam/LDEO
Delaware Subnetwork (DGS)						
BVD	39.7748	75.4993	58	1985/02	Bellevue State Park, DE	DGS
BWD	39.7995	75.5767	63	1985/02	Brandywine State Park, DE	DGS
NED	39.7042	75.7048	47	1972/11	Newark, DE	DGS
DEMA	38.6957	75.3627		1999/10/01		DGS
SCOM	39.3187	75.6098		1999/10/01		DGS

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* three-component stations

Strong-Motion Accelerographs

STATION CODE	LAT (°N)	LONG (°W)	ELEV (m)	OPERATION (year/mo/da)	STATION NAME	INSTRUMENT
MSNA	44.9983	74.8472	67	1992/01/01	Massena, NY	SSA-1
JORD	44.3778	74.6050	468	1992/01/01	Jordan Lake, NY	SSA-1
NEWC	43.9708	74.2236	530	1992/01/01	Newcomb, NY	SSA-1
PAL	41.0042	73.9092	91	1992/01/01	Palisades, NY	SSA-1
CMPA	40.3455	76.0145		1992/01/01	Cacoosing Meadows, Pa	SSA-1
APL	39.1700	76.8900		1992/01/01	Applied Physics Lab, Johns Hopkins, Laurel, Md	K2

Cooperating Institutions

Potsdam: State University College of Art and Science, Potsdam, NY
DGS: Delaware Geological Survey, Newark, DE
Middlebury: Middlebury College, Middlebury, VT
RPI: Rensselaer Polytechnic Institute, Troy, NY
WCC: Westchester Community College, Valhalla, NY
UVT: University of Vermont, Burlington, Vt
APL: Applied Physics Lab, Johns Hopkins & Maryland Geological Survey
Lehigh: Lehigh University, Lehigh, PA
Millersville: Millersville University, Millersville, PA
MGS: Maryland Geologic Survey, Baltimore, MA
Cobleskill: State University College of Agriculture and Technology, Cobleskill, NY

Appendix 3. Earthquakes in July 1998 - June 2001

Date	Origin time	Lat(N)	Lon(W)	h(km)	Mc	mb	Mn	Location
1998/07/09	01:52:13.1	44.735	73.677	1	2.5	2.2		18 km W Plattsburgh, NY
1998/07/15	07:08:04.0	47.020	66.610	5			4.0	Miramichi, N.B. (OTT)
1998/07/24	09 49:52.5	44.632	74.301	4	2.2			24 km S Malone, NY
1998/07/30	08:57:22.0	46.168	74.721	10		4.0	4.4	NE Ripon, Que (OTT)
1998/08/24	19:27:33.0	43.870	75.760	18			3.1	17 km SE Watertown, NY
1998/08/29	23:41:56.5	41.212	74.047	8	1.4			5 km W West Haverstraw, NY
1998/09/08	03:47:03.6	41.203	74.046	2	1.2			5 km W West Haverstraw, NY
1998/09/25	19:52:52.0	41.495	80.388	5		5.2	5.4	Ohio-Penn border,(PDE)
1998/10/11	00 48:43.4	41.348	73.319	6	1.0			8 km E Bethel, CT
1998/10/21	05:56:47.2	37.381	78.367	13		3.3	3.8	Charlottesville, VA (BLA)
1998/10/22	09:43:35.0	49.340	66.880	18			4.1	Miramichi, N.B. (OTT)
1998/10/31	01:12:24.3	36.120	83.700	9	2.6			Cumberland, KY (TVA, PDE)
1998/11/25	02:55:06.0	41.071	82.405	5		2.7		75 km W Akron, OH (PDE)
1998/12/05	04:05:45.9	44.402	75.135	1	1.7			22 km S Canton, NY
1998/12/05	06:02:57.9	43.968	74.262	5	2.0			42 km S Saranac Lake, NY
1998/12/25	13:30:25.6	43.695	77.949	9	3.0	3.0	3.6	54 km N Brockport, NY
1999/01/05	16:08:44.0	44.782	74.549	5	2.3			21 km W of Malone, NY
1999/01/05	17:40:26.9	44.789	74.563	7	2.0			22 km W of Malone, NY
1999/01/10	10:52:16.0	42.840	70.980	2	3.0		3.1	5 km SW of Amesbury, MA(WES)
1999/01/10	15:20:44.3	42.840	70.980	2	2.9		3.0	5 km SW of Amesbury, MA(WES)
1999/01/10	15:22:18.0	42.820	71.060	5			1.9	5 km N of Haverhill, MA(WES)
1999/01/12	05:45:14.7	40.872	74.176	7	1.4			2 km NW of Clifton, NJ
1999/01/14	06:11:25.0	42.840	70.970	4			2.3	4 km SW of Amesbury, MA(WES)
1999/01/14	22:49:33.7	44.891	74.678	9	2.2			17 km E of Massena, NY
1999/01/17	18:38:04.0	36.87	83.69	5		3.0		61 km SW of Hazard, KY
1999/01/19	06:23:21.1	45.425	74.509	16	3.0			21 km SE of Hawkesbury, ONT
1999/01/25	20:12:30.0	42.733	77.850	3	2.5		2.7	8 km S of Geneseo, NY
1999/01/31	10:39:13.5	40.975	74.050	3	1.5			2 km W of Emerson, NJ
1999/02/01	22:22:05.6	49.267	80.939	18			3.4	265 km NW of Val-d'Or, Que
1999/02/26	03:38:43.1	44.513	69.466	7	3.6	3.8	3.8	13 km E of Winslow, ME
1999/03/09	12:07:05.5	44.764	73.802	10	2.9			29 km W of Plattsburgh, NY
1999/03/12	09:58:09.0	40.020	72.170	5			1.9	99 km S of Hampton Bays, NY
1999/03/15	14:32:35.5	45.890	74.380	18			2.8	S of STE-AGATHE-DESMONTS,Que
1999/03/16	12:50:48.0	49.610	66.320	18		4.8	5.1	64 km S of SEPT-ILES, Que
1999/03/16	13:01:20.0	49.650	66.420	18			3.0	65 km S of SEPT-ILES, Que
1999/03/16	20:13:10.0	49.630	66.350	18			3.5	64 km S of SEPT-ILES, Que
1999/04/01	20:39:10.7	45.721	71.708	1	1.7			39 km NE of Sherbrooke, Que
1999/04/04	05:06:03.8	44.456	72.421	7	1.5			25 km NE of Montpelier, VT
1999/04/05	19:20:19.0	42.874	74.688	10	1.5			24 km SE of Little Falls, NY
1999/04/18	03:03:25.0	42.733	77.850	3	2.4			8 km S of Geneseo, NY
1999/04/18	09:44:55.7	40.317	75.966	2	1.9			1 km N of Shillington, PA
1999/04/25	08:37:07.8	33.659	69.528	9	3.0			near Bermuda
1999/05/31	01:16:31.5	40.055	74.709	10	2.3			8 km W of Fort Dix, NJ
1999/06/09	06:03:01.0	44.330	67.920	18			2.2	46 km SE of Ellsworth, ME(OTT)
1999/06/22	09:44:20.4	44.221	73.382	08	1.3			28 km NW of Middlebury, VT
1999/07/08	07:04:05.0	42.740	78.840	18			1.5	16 km S of Buffalo, NY (OTT)
1999/07/27	12:23:05.0	46.570	69.000	05			2.7	76 km W of Presque Isle, ME (OTT)
1999/08/28	23:01:32.0	42.560	77.970	05			2.6	29 km SW of Geneseo, NY (OTT)
1999/09/02	16:17:28.0	41.700	89.400	05			3.5	Illinois (OTT)
1999/09/09	04:37:09.0	44.610	73.720	18			2.0	23 km SW of Plattsburgh, NY (OTT)
1999/09/22	10:02:22.2	41.826	81.476	18		2.5	2.8	22 km NW of Painesville, OH, (OTT)
1999/10/10	04:51:12.0	42.840	77.970	18			2.3	13 km W Geneseo, NY (OTT)
1999/10/13	10:09:00.0	42.550	71.440	02	2.3		2.7	14 km SW Lowell, MA, (WES)
1999/10/22	14:37:33.3	40.380	75.927	10	1.9			5 km N Reading, PA
1999/10/30	08:02:48.0	42.060	80.400	18			2.5	37 km NE Ashtabula, OH (OTT)
1999/10/31	20:14:10.0	45.850	74.320	18		3.7	4.2	22 km N Lachutte, QUE, (OTT)
1999/11/01	10:12:28.0	42.780	78.930	18			2.7	14 km S Fort Erie, ONT (OTT)
1999/11/26	22:33:01.4	43.710	78.997	13		3.4	3.8	34 km E Toronto, ONT, (PDE)
1999/12/25	00:21:41.0	44.940	69.370	05		3.0	3.0	34 km NE Skowhegan, ME (WES)
1999/12/31	11:34:24.0	43.250	78.660	18			1.7	36 km NE Niagara Falls, NY
2000/01/01	11:22:55.9	46.819	78.883	10		4.7	5.2	18 km NE Temiskaming, QUE

2000/01/02	06:46:03.0	44.760	73.700	18		2.3		20 km W Plattsburgh, NY
2000/01/03	21:05:49.6	44.335	70.234	05		3.4	3.5	26 km N Lewiston, ME
2000/01/17	08:16:19.5	44.632	70.473	05		3.4	3.6	11 km NE Rumford, ME
2000/01/17	13:30:47.0	44.770	73.690	18			2.3	20 km NW Plattsburgh, NY
2000/01/21	05:59:50.7	43.007	71.237	05		2.4	2.6	16 km NE Derry, NH
2000/01/23	21:46:13.0	43.210	78.870	18			2.2	15 km W Lockport, NY (OTT)
2000/01/27	14:49:39.1	42.998	71.163	05		2.9	3.0	19 km NE Derry, NH
2000/02/10	15:33:26.0	44.980	74.760	06	1.7		2.4	12 km NE Massena, NY
2000/02/12	08:31:28.0	45.190	73.780	18			2.3	27 km S Pointe-Claire, QUE
2000/02/24	14:47:19.0	41.120	75.750	06	2.3			17 km SE Wilkes-Barre, PA
2000/02/27	12:50:32.0	44.610	73.520	18			1.7	11 km SW Plattsburgh, NY
2000/03/02	20:48:29.0	46.120	75.700	18			3.0	25 km S Maniwaki, QUE (OTT)
2000/03/22	20:48:00.0	40.070	76.300	01	1.8			3 km N Lancaster, PA
2000/04/15	08:39:24.0	44.290	75.480	05			1.5	42 km SW Canton, NY (OTT)
2000/04/16	18:59:12.0	43.960	74.240	06	2.3		2.7	2 km Newcomb, NY
2000/04/20	08:46:55.0	43.949	74.257	05			4.0	3 km Newcomb, NY
2000/05/24	05:41:52.0	45.480	75.400	18			2.2	10 km S Buckingham, QUE
2000/05/24	10:22:46.2	43.806	79.099	18		3.1	3.1	28 km NE of Toronto, ONT
2000/05/28	20:26:03.0	44.430	77.500	10			2.7	Madoc, ONT (OTT)
2000/05/31	05:36:19.0	44.440	77.510	10			2.5	Madoc, ONT (OTT)
2000/05/31	18:47:43.0	44.440	77.470	10			2.2	Madoc, ONT (OTT)
2000/06/07	06:19:18.0	42.010	80.780	18			2.0	14 km N Ashtabula, OH (OTT)
2000/06/07	06:55:09.0	42.010	80.780	18			2.4	14 km N Ashtabula, OH (OTT)
2000/06/08	11:59:49.0	46.850	71.410	18			2.8	14 km W Quebec, QUE (OTT)
2000/06/15	09:25:54.0	47.670	69.810	10			3.7	3 km S Charlevoix, QUE
2000/06/16	04:02:53.0	42.100	72.800	05	2.8	3.3	3.3	4 km SW of Westfield, MA
2000/06/29	08:15:17.0	46.910	70.770	18			3.2	37 km E of Quebec, QUE (OTT)
2000/07/01	07:31:25.0	43.530	75.280	18			2.3	48 km N of Utica, NY (OTT)
2000/07/11	20:13:55.0	45.340	75.300	18			2.5	32 km E of Ottawa, ONT (OTT)
2000/07/12	15:01:49.0	47.520	71.100	10			4.2	47 km W Baie-St-Paul, QUE
2000/07/12	15:06:35.0	47.550	71.080	18			3.5	47 km W Baie-St-Paul, QUE
2000/07/12	15:07:50.0	47.550	71.080	18			2.5	47 km W Baie-St-Paul, QUE
2000/07/12	16:05:05.0	47.560	71.080	18			2.4	47 km W Baie-St-Paul, QUE
2000/07/22	05:02:30.0	43.470	75.250	01			2.7	41 km N of Utica, NY
2000/08/06	08:52:24.0	46.190	74.970	18		4.0	4.2	47 km SE Mont-Laurier, QUE
2000/08/07	02:02:30.4	40.958	81.151	05		2.9		26 km NE of Canton, OH (PDE)
2000/08/22	05:45:14.0	41.420	73.630	07	2.6			6 km SE of Lake Carmel, NY
2000/09/07	10:07:40.7	44.353	69.383	05		3.2		28 km SE of Winslow, ME
2000/10/05	23:33:59.0	40.080	76.300	07	2.1	2.0		5 km N Lancaster, PA
2000/10/06	13:59:05.0	45.090	74.000	08	3.2		3.8	20 km SE Valleyfield, QUE
2000/10/15	23:49:33.0	43.650	71.390	01			2.5	15 km NE Laconia, NH (WES)
2000/11/01	15:30:40.0	47.130	76.500	18			2.7	93 km NW of Maniwaki, QUE (OTT)
2000/11/06	12:16:36.0	42.760	74.070	08			2.4	12 km SW of Schenectady, NY
2000/11/10	07:40:53.0	45.740	75.300	18			3.3	20 km NE of Buckingham, Que. Felt (OTT)
2000/12/01	04:48:32.0	49.630	66.94W	18			2.8	75 km SW of SEPT-ILES, QUE. (OTT)
2001/01/05	05:02:46.0	39.249	65.689	15				near Bermuda
2001/01/14	11:03:47.6	45.842	74.940	00			3.3	17 km NE of Ripon, QUE
2001/01/15	00:28:47.0	42.110	74.960	00			2.0	38.1 km S of Oneonta, NY
2001/01/15	05:15:19.0	47.810	69.820	25			1.4	Charlevoix Seismic Zone (OTT)
2001/01/17	12:34:22.6	40.777	73.954	07	2.4			Manhattan, NY
2001/01/19	15:04:42.9	40.777	73.960	05	1.2			Manhattan, NY
2001/01/26	03:03:21.4	41.909	80.722	05		4.2		6 km NE of Ashtabula, OH
2001/02/03	00:31:28.3	45.943	74.951	00			2.6	25 km NE of Ripon, QUE
2001/02/03	17:50:41.7	41.336	72.734	05		1.8		9 km NE of Branford, CT
2001/02/03	20:15:15.0	42.340	77.390	00		3.2		6 km W of Bath, NY
2001/03/19	10:40:17.0	47.050	76.280	18			3.9	80 km NW of Maniwaki, QUE(OTT)
2001/04/11	21:30:53.3	46.920	76.950	05			3.6	97 km NW of Maniwaki, QUE
2001/06/03	22:36:45.4	41.996	80.954	05		3.0		18 km NW of Ashtabula, OH
2001/06/13	09:15:48.6	38.241	60.611	00		4.0		near Bermuda

PDE = source parameters are listed in PDE monthly list by USGS/NEIC; OTT = event is located and reported by Geological Survey of Canada, Ottawa; WES = event is located and reported by Weston Observatory, Boston College, MA.