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

Annual Project Summary

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Won-Young Kim
Lamont-Doherty Earth Observatory of Columbia University
Palisades, NY 10964, USA
Tel: 845-365-8387, Fax: 845-365-8150
E-mail: wykim@ldeo.columbia.edu
URL: <http://www.ldeo.columbia.edu/LCSN>

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Investigations undertaken

The operation of the Lamont-Doherty Cooperative Seismographic Network (LCSN) to monitor earthquakes in the northeastern United States is supported under this award. The goal of the project is to compile a complete earthquake catalog for this region to assess the earthquake hazards, and to study the causes of the earthquakes in the region. The LCSN now operates 40 seismographic stations in seven states: Connecticut, Delaware, Maryland, New Jersey, New York, Pennsylvania and Vermont. During October 2002 through November 2003, scientists and staff 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 regional networks and the USNSN for development of an Advanced National Seismic System (ANSS) and expanded earthquake reporting capabilities, and 3) to promote effective dissemination of earthquake data and information.

A significant amount of associated research effort was related to deployment of portable seismographs in Milford, NJ – Upper Black Eddy, PA along the Delaware River following the 26 August, 2003 Mw 3.5 Milford, NJ earthquake. The seismic moment tensors for earthquakes with magnitude $M_L \geq 3.8$ that occurred in the northeastern U.S. and southeastern Canada have been determined by using three-component, broadband seismic waveform data. Results are reported by Du, Kim & Sykes (2003) and Kim (2003). Most significant results were distribution of deep and shallow earthquakes in the Central and northeastern US and their implications on the thickness of the seismogenic layer. This in turn, yields information on the seismic potential of a seismic zone in the region.

We implemented rapid generation of instrumental ground motion and intensity maps – ShakeMaps. A ShakeMap is a representation of ground shaking produced by an earthquake.

Results

Network Operation

In operating the Lamont-Doherty Cooperative Seismographic Network (LCSN) during Oct. 2002–Nov. 2003, we accomplished: 1) Deployed a new broadband, 3-component seismograph at Flat Rock, New York. Total of 16 broadband seismographic stations are now operated directly by LCSN or affiliated to LCSN (Figure 1); 2) deployed four ANSS strong-motion instruments in the metropolitan New York City area as part of the ANSS-NE (Northeast) urban monitoring network. These modern digital accelerometers record 3-component ground motion at 100 samples/sec and transfers continuous data to a data concentrator (PC and a hard disk drive) at the Department of Civil Engineering and Engineering Mechanics (CEEM), Columbia University; 3) Continuous waveform data from 12 stations (vertical-component) are now sent to NEIC/USNSN in Golden, CO in real time; 4) All waveform data from 39 seismographic stations of the LCSN are now sent to IRIS-DMC in real time and are made available to sesimological community in real time. Data are found in BUD (Buffer of Uniform Data) with network id "LD" at <http://www.iris.washington.edu/bud_stuff/dmc>; 5) Rapid earthquake information dissemination system under ANSS is implemented. It is called "recenteqs" and is accessible at <http://www.ldeo.columbia.edu/LCSN/recenteqs>; 6) Waveform data distribution system based on email request and automatic processing is implemented. Data are accessible at <http://tremor.ldgo.columbia.edu:8081/data.request.form.htm>; 7) Waveform data for earthquakes in the finger quake list are now provided as assembled SEED volumes for each event via WWW.

In addition, we around Lake Champlain, New York established a new LCSN Lake Champlain subnetwork node at the William H. Miner Agricultural Research Institute in West Chazy, NY. The new broadband seismographic station at the Flat Rock, NY (FRNY) is telemetered to the Minier Institute using spread-spectrum radios. The short-period stations, HBVT, FLET, and PNY are sending seismic data to the Minier Institute using analog FM radios in UHF/VHF band. For a second node at the Middlebury College, Vt, a 24-bit A/D datalogger is installed to digitize signals from MIV and MDV (see Figure 2). A possible additional seismographic station at Au Sable Forks, NY is indicated by dashed line between the field site and Minier Institute. Important earthquakes are marked by dates (Altona, 06/09/1975 M4.1; Au Sable Forks 04/20/2002, M_L = 5.3).

The primary emphasis was on implementing automatic, prompt data processing and distribution system. We will continue to work for improving accuracy of earthquake location and timely dissemination of earthquake message.

Seismicity

About 25 local and regional earthquakes with magnitude greater than about 2 that have occurred in the northeastern United States and southern Canada were detected and located by the

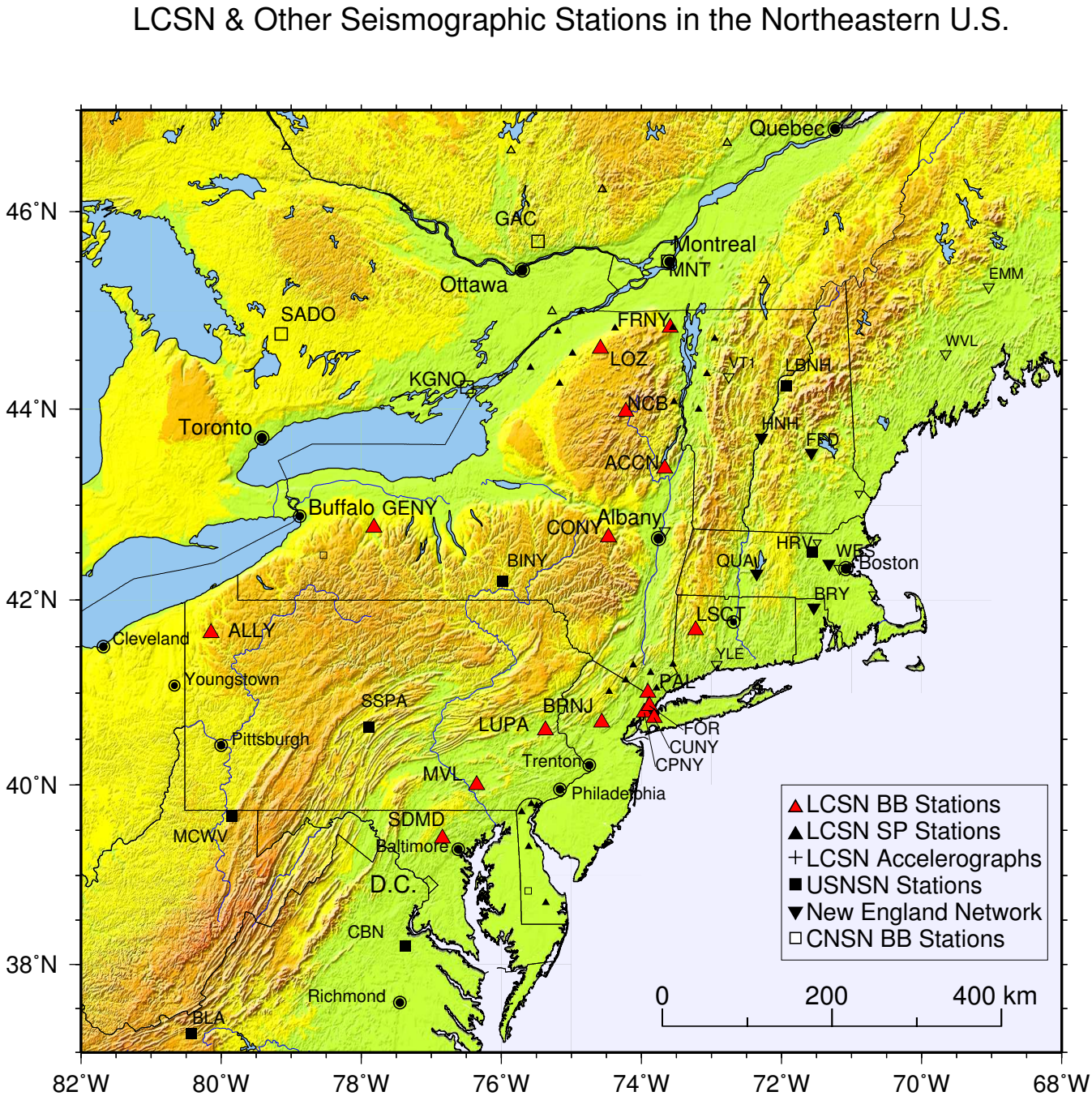

Figure 1: Seismographic stations in the Northeastern United States and Southeastern Canada. LCSN broadband sites (*red triangles*), short-period sites (*filled triangles*), New England Seismic Network sites (MIT & Weston Observatory; *inverted open triangles*) are plotted. Broadband stations of the USNSN (*squares*) and broadband stations of the Canadian National Seismograph Network (CNSN; *open squares*) are plotted for reference.

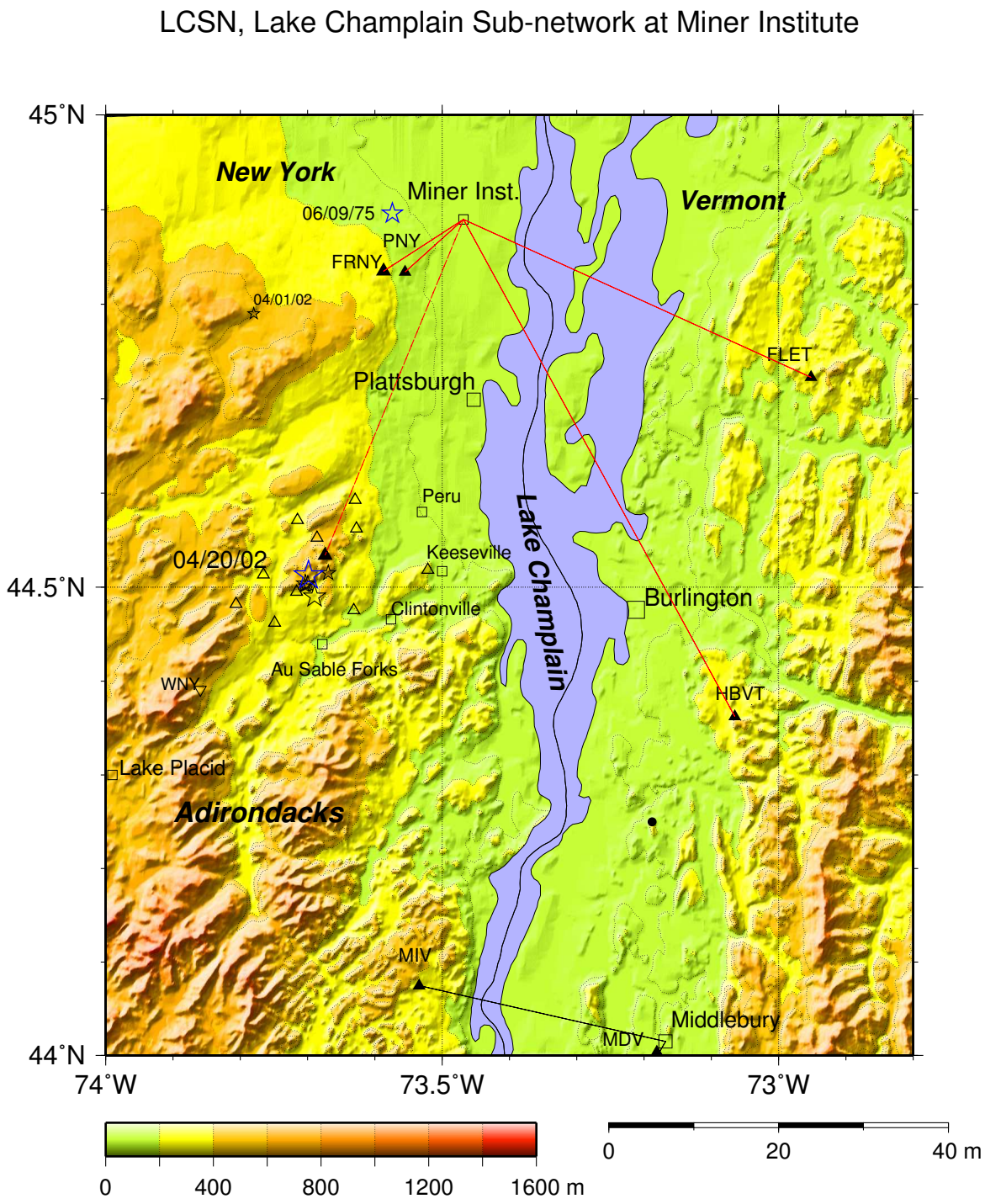

Figure 2: Topographic map around Lake Champlain, New York showing the newly established LCSN subnetwork node at the William H. Miner Agricultural Research Institute in West Chazy, NY. The new broadband seismographic station at the Flat Rock, NY (FRNY) is telemetered to the Minier Institute using spread-spectrum radios. Significant earthquakes are marked by dates (Altona, 06/09/1975 M4.1; Au Sable Forks 04/20/2002, M_L = 5.3).

LCSN during October 1, 2002 through November 30, 2003. These earthquakes range from magnitude mb(Lg) 1.2 to 4.6 (Table 1). A general seismicity pattern during this period is similar to the previous years. A relatively higher level of seismicity is in Adirondacks and in Western Quebec seismic zone in southern Canada. Notable earthquakes during the period are: May 5, m_b(Lg) 3.9 Central Virginia earthquake near Richmond, VA, July 22, M_L 3.6 Offshore Cape Ann, MA close to the 1755 M 6 Cape Ann earthquake and August 26, M_L 3.5 earthquake in Milford, NJ (see Figure 3).

Table 1: Earthquakes recorded by LCSN for period Oct. 1, 2002 through Nov. 30, 2003

Date Year/Mo/Dy	Time (hr:mn:s)	Lat (°N)	Long (°W)	h (km)	Mag* (M_L)	Location
2002/11/07	16:55:06	44.05	77.43	18	3.0c	93 km N of Webster, NY
2002/11/08	17:14:47	44.00	72.51	5	1.9c	22 km S of Barre, VT
2002/12/25	18:25:19	44.56	73.79	15	2.8	Au Sable Forks, NY
2003/01/11	02:24:09	41.00	73.88	3	1.2	Hastings-On-Hudson, NY
2003/01/15	00:58:18	40.99	73.87	4	1.4	Hastings-On-Hudson, NY
2003/02/09	16:18:03	46.51	75.20	18	3.3n	24 km E Mont-Laurier, Que (OTT)
2003/04/08	15:06:13	44.61	74.38	10	3.3	27 km S of Malone, NY
2003/04/20	12:24:43	41.36	74.37	7	2.3c	8 km SW of West Point, NY
2003/05/05	16:32:32	37.76	78.07	5	3.9	Central Virginia (PDE)
2003/06/13	11:34:40	47.70	70.09	11	4.1n	Charlevoix, Que (OTT)
2003/06/30	19:21:19	41.83	81.21	5	2.9	21 km NE of Painesville, OH
2003/07/17	00:44:10	41.86	80.76	2	2.5n	Ashtabula, Ohio (OGS)
2003/07/22	11:41:12	42.61	69.73	10	3.6	76 km E of Gloucester, MA
2003/08/20	01:58:17	46.01	74.95	18	3.5n	32 km NE of Ripon, QUE
2003/08/24	09:21:37	40.77	74.51	1	1.5c	18 km W of Millburn, NJ
2003/08/26	18:24:18	40.61	75.11	3	3.5	Milford, NJ-Upper Black Eddy, PA
2003/08/27	19:55:39	44.88	73.73	10	2.2c	30 km NW of Plattsburgh, NY
2003/09/19	17:22:34	45.79	74.85	18	3.3n	50 km NE of Buckingham, Que
2003/10/01	08:07:57	40.57	75.11	3	2.2	Milford, NJ-Upper Black Eddy, PA
2003/10/12	08:26:06	47.05	76.27	18	4.6n	76 km NW Maniwaki, Que (OTT)
2003/10/15	04:13:14	45.08	66.91	18	3.1n	21 km E St.Stephen,NB(OTT)
2003/10/18	16:25:07	46.94	67.19	18	3.5n	99 km SE Edmundston,NB(OTT)
2003/11/04	13:37:31	40.25	75.88	1	2.4c	10 km SE of Reading, PA

* c = Mc coda duration magnitude determined by LDEO, n = Nuttli's mb(Lg) reported by Geological Survey of Canada, Ottawa or by the Weston Observatory, Boston College, MA; default is the local Richter magnitude determined and reported by Lamont-Doherty Earth Observatory of Columbia University.

Milford, NJ–Upper Black Eddy, PA earthquake on August 26, 2003

A small earthquake of M_L =3.5 occurred on 08/26/2003 at 18:24 (14:24 EDT) close to the town

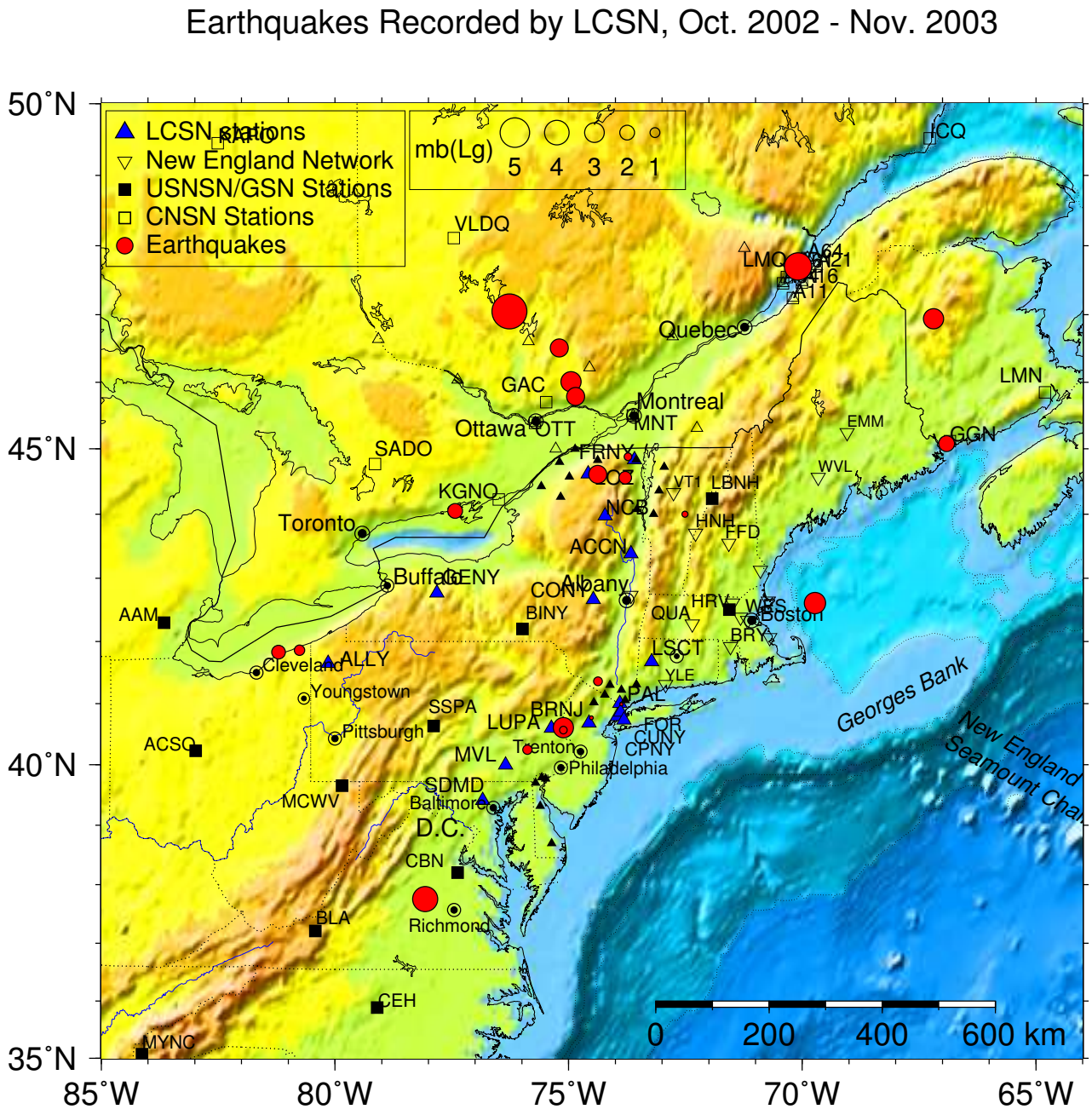

Figure 3: Earthquakes which have occurred in the northeastern United States and southeastern Canada in the time period of Oct. 1, 2002 through Nov. 30, 2003 recorded by the LCSN. Symbol size is proportional to magnitude. Broadband stations of the LCSN, USNSN, NESN, and CNSN are plotted for reference.

of Milford, NJ along the Delaware River. The shock was felt by residents with high intensity and residents around the Milford reported hearing explosion like sound associated with the shock. However, the isoseismic maps and felt areas during the shock is much smaller than other earthquakes of similar size in the eastern US. Aftershocks recorded by local network deployed in October 2003 indicated that main- and after-shocks must have be very shallow depths. Focal depth of about 40 aftershocks are clustered at around 1.5 to 2 km depth. The earthquake occurred close to the boundary fault between Precambrian Reading prong and Mesozoic Newark basin, but the lineation of the aftershocks seems nearly perpendicular to the orientation of the boundary fault. It is a significant event, for its implication on seismic hazards in the region and on seismo tectonic setting.

Data Availability

1) *LCSN Data Retrieval from Standard IRIS-DMC Archive*: Continuous 40 samples/sec waveform data from broadband, three-component seismometer (STS-2, T0=120 sec) recorded at PAL (Palisades, NY) are archived at IRIS/DMC in Seattle, WA for further dissemination to other scientists and to public users. Waveform data in SEED formats have been submitted and current PAL data holdings at IRIS/DMC covers most of 1994 and all of 1999. 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 PAL and three new sites (LOZ, ACCN, BRNJ) to IRIS/DMC.

Since January 2001, all broadband data are available from this method. and since January 2003, all short-period waveform data (100 samples/sec) are also available from here. The URL is:
<http://www.iris.edu/SeismiQuery>

2) *Real-time Retrieval of Waveform Data from BUD System at IRIS-DMC*: All waveform data from 40 seismographic stations of the LCSN are now sent to IRIS-DMC in real time and are available to sesimological community in real time. Data are found in BUD (Buffer of Uniform Data) with network id ”LD” at:
<http://www.iris.washington.edu/bud_stuff/dmc>

3) *Recent Earthquake Data from LCSN Local Archive*: Waveform data from selected significant earthquakes in northeastern United States can be retrieved from local archive. 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 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 Co-operative Seismographic Network". Waveform data of the selected events in SEED format can be found in "Data Access & Archive" or from webseismogram window.

3.1) *AutoDRM*: Waveform data can be obtained using AutoDRM E-mail response system by entering queries on the web page at: <http://tremor.ldgo.columbia.edu:8080/data.request.htm>

3.2) *Download LCSN Event SEED Volume*: Phase picks and waveform data from recent earthquakes in the northeastern US are easily downloadable via WWW. From the LCSN home page, clicking "Finger Quake for Recent Seismic Events in the Northeastern U.S." then clicking LAT or LON column allows user to choose an event and download data.

Contact person for additional inquiries and assistance:
Name: Dr. Golam Sarker
Phone: 845-365-8365
E-mail: sarkerldeo.columbia.edu
Data format: SEED, AH, ASCII

Reports Published

Du, Wen-xuan, Won-Young Kim, and Lynn R. Sykes (2003). Earthquake source parameters and state of stress for northeastern United States and southeastern Canada from analysis of regional seismograms, *Bull. Seism. Soc. Am.*, **93**, 1699-1699.

Won-Young Kim (2003). The 18 June 2002 Caborn, Indiana Earthquake: Reactivation of Ancient Rift in the Wabash Valley Fault Zone ?, *Bull. Seism. Soc. Am.*, **93**, 2200-2233.

Non-Technical Summary

The primary objective of the Lamont-Doherty Cooperative Seismographic Network (LCSN) to monitor earthquakes in the northeastern United States and to gather data about eastern U.S. seismicity in order to understand the causes of earthquakes in the region, 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 than that of the western U.S., potentially damaging earthquakes have occurred, and it is important to assess the risk accurately.

The LCSN currently operates 40 seismographic stations in the Middle Atlantic States, ranging from the New York – Canada Border to south of Baltimore Maryland. 24 of these stations are organized in four subnetworks consisting of 5 to 7 short-period stations. The other 16 stations are stand-alone broadband seismographic stations. The LCSN is a cooperative operation, participants include SUNY Potsdam and the Delaware Geological Survey; the Maryland Geological Survey; Middlebury College, VT; Adirondack Community College; SUNY Cobleskill; Millersville and Lehigh Universities, PA and Allegheny College, PA; Fordham University, in the Bronx; Queens College, CUNY in Queens and Central Park Conservancy, New York City. In 2003, Environmental Science Center at SUNY Plattsburgh joined LCSN as a new partner by hosting a broadband station at the Flat Rock, Altona, New York. The William H. Miner Agricultural Research Institute in West Chazy, NY became participating institute in 2003 by hosting three-station Lake Champlain subnetwork. All data from these stations is transmitted to Lamont-Doherty Earth Observatory (LDEO) in real time for automatic event detection and location of seismic activity. During the time period included in this report, over 20 regional earthquakes with magnitude greater than 1.5 were recorded by the LCSN in the northeastern United States. This data, along with data gathered in earlier years, has helps us to define areas of relatively high seismicity, as well as determine the ground motion and the associated potential risk.

A damaging earthquake occurred on 26 August 2003 within couple of kilometers from Milford, New Jersey. The mainshock was felt intensely by residents in New Jersey and Pennsylvania along the Delaware River. People at around the epicenter felt intensity VI (MMI) at close to the epicenter. The earthquake caused minor damage.

In the summer of 2003, we deployed four Advanced National Seismic System (ANSS) strong-motion instruments in the metropolitan New York City area as part of the ANSS-NE (Northeast) urban ground motion monitoring network. These modern digital accelerometers record 3-component ground motion at 100 samples/sec and transfers continuous data to a data concentrator (a PC with hard disk drive, and internet connection) at the Department of Civil Engineering and Engineering Mechanics (CEEM), Columbia University;