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

Annual Project Summary

October 01, 2004 - September 30, 2005
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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 2004 through September 2005, 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) promoted effective dissemination of earthquake data and information.

A significant amount of associated research effort was related to determining seismic moment tensor and focal depth of small to moderate-sized earthquakes in the eastern United States by using three-component, broadband seismic waveform data.

We studied the 4 August 2004, M_w 3.1 Lake Ontario, earthquake which occurred along the United States - Canada border, about 30 km south from Port Hope, Ontario, Canada. Dispite its small size, the shock was very well recorded by broadband seismographic stations deployed in recent years in Ontario, Canada and in New York State. Waveform data constrained the source at a shallow focal depth ($\approx$ 4 km), which places the shock in the shallow Precambrian basement beneath Paleozoic platform deposits. The source mechanism from the regional waveform inversion for the double-couple moment tensor is predominantly strike-slip faulting. A NS striking (8°) nodal plane dipping to east (dip= 59°) is the likely fault plane which represents right-lateral strike-slip motion. The subhorizontal *P* axis orientation (trend=234°and plunge=12°) is consistent with the maximum horizontal compressional stress (SHmax) direction in eastern North

America.

Although the 4 August 2004 event is a small shock and has a seismic moment of M_0= 4.45 ($\pm$2.30) $\times$ 10^{13} Nm, it is the largest instrumentally recorded earthquake that has occurred in Lake Ontario. This and other significant earthquakes in the region suggest a broad-scale strike-slip faulting stress regime with a shallow seismogenic layer in the Erie-Ontario Lowland region. The shallow focal depths of earthquakes in the region increase the risk of higher ground shaking compared to other seismic zones in northeastern North America with a deeper seismogenic layer.

The most significant results of these and other earlier studies were the 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. 2004–Sept. 2005, we accomplished: 1) Deployed three new broadband, 3-component seismographic stations: University of Connecticut, Storrs, Connecticut (UCCT); Franklin & Marshall College, PA (FMPA); Lake Ozonia, NY (LONY, ANSS Backbone station). A total of 18 broadband seismographic stations are now operated directly by LCSN or affiliated to LCSN (Figure 1); 2) ANSS strong-motion instruments in the metropolitan New York City area have been recording 3-component ground motion at 100 samples/sec and transfer continuous data to a data concentrator at the Department of Civil Engineering and Engineering Mechanics (CEEM), Columbia University; 3) Continuous waveform data from 15 stations are now sent to NEIC/USNSN in Golden, CO in real time; 4) All waveform data from 44 seismographic stations of the LCSN are now sent to IRIS-DMC in real time and are made available to the 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://almaty.ldgo.columbia.edu:8080/data.request.htm>; 7) Waveform data for earthquakes in the finger quake list are now provided as assembled SEED volumes for each event via WWW.

During the spring – fall, 2005, a new seismic vaults were built at several broadband stations. The new vaults were constructed at Flat Rock, NY (FRNY) and Newcomb, NY (NCB). The signals from the sensors in the new vaults was much better quality than before. Improvement is more obvious at long-period band. PSD (power spectral density) of noise signals at periods longer than 10 sec shows significant improvement after the new vault construction. PSD at 100s is -170 db (from -135 db) at NCB.

Since the spring of 2002, LCSN has been cooperating with POLARIS (Portable Observatories for Lithospheric Analysis and Research Investigating Seismicity) Consortium of Canada, for improved earthquake monitoring along the well developed and highly populated eastern US-Canada border region. In the spring of 2004, a new POLARIS station MEDO (Medina, NY) was

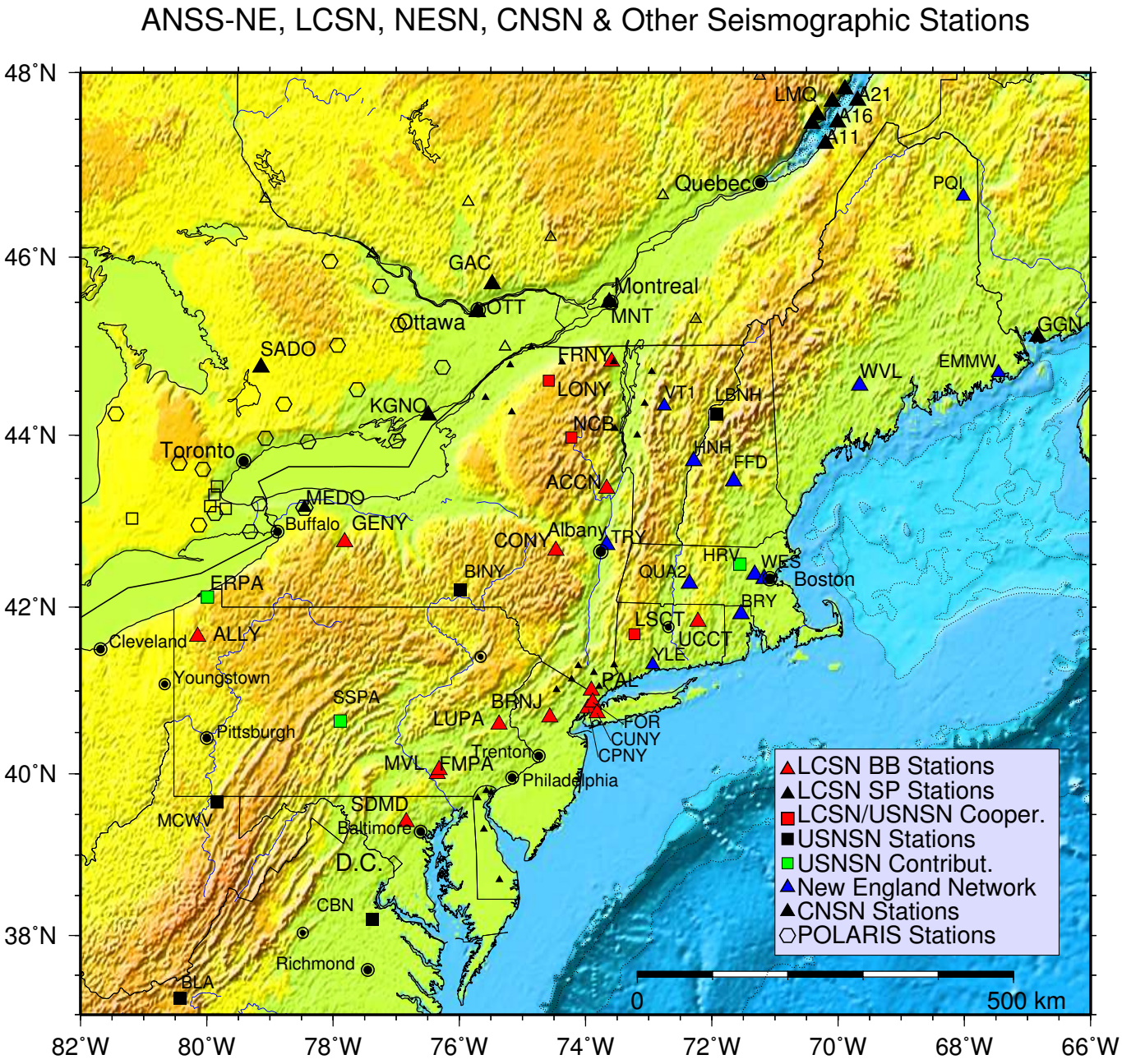

Figure 1: Seismographic stations in the Northeastern United States and Southeastern Canada. LCSN broadband sites (*red triangles*), short-period sites (*filled triangles*), New England Seismic Network sites (Weston Observatory; *inverted triangles*) are plotted. Broadband stations of the USNSN (*squares*)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

deployed in western NY. The new station improved significantly the earthquake monitoring along the Toronto-Niagara Falls-Buffalo region.

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

Over 60 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 LCSN during October 1, 2004 through September 30, 2005. These earthquakes range from magnitude 0.3 (Mc) to 4.7 (M_w) (Table 1).

Notable earthquakes during the period are: four very small earthquakes that occurred on Dec. 12-15, 2004 in Lower East Side of Mahattan, New York City just around the East River. These were small events magnitude ranging from Mc 0.3 to 0.8; many residents in Long Island City, Queens felt the events.

Five earthquakes with magnitude between 1.1 to 2.9 occurred near the town of Chateaugay about 20 km east of Malone, NY during March 3-June 12, 2005. Two events occurred around Au Sable Forks and Plattsburgh, NY on April 17 (Mc 2.5) and July 1, 2005 (Mc 2.2). The largest earthquake that occurred in the region was Mn 5.4 (M_w 4.7) Riviere-du-Loup, Quebec event in the Charlevoix seismic zone. (see Figure 2).

Data Availability

1) *LCSN Data Retrieval from Standard IRIS-DMC Archive*: Continuous 40 samples/sec waveform data from broadband, three-component seismographs recorded at PAL (Palisades, NY) and other stations of the LCSN 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 cover most of the data since the fall 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, the network code is “LD”. An example data request format is

PAL LD 2004 08 04 23 55 00.0 2004 08 05 00 05 00.0 3 BHZ BHN BHE
GENY LD 2004 08 04 23 55 00.0 2004 08 05 00 05 00.0 3 BHZ BHN BHE
ALLY LD 2004 08 04 23 55 00.0 2004 08 05 00 05 00.0 3 BHZ BHN BHE

We will continue to submit the continuous, broadband waveform data recorded at PAL and other stations of the LCSN 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

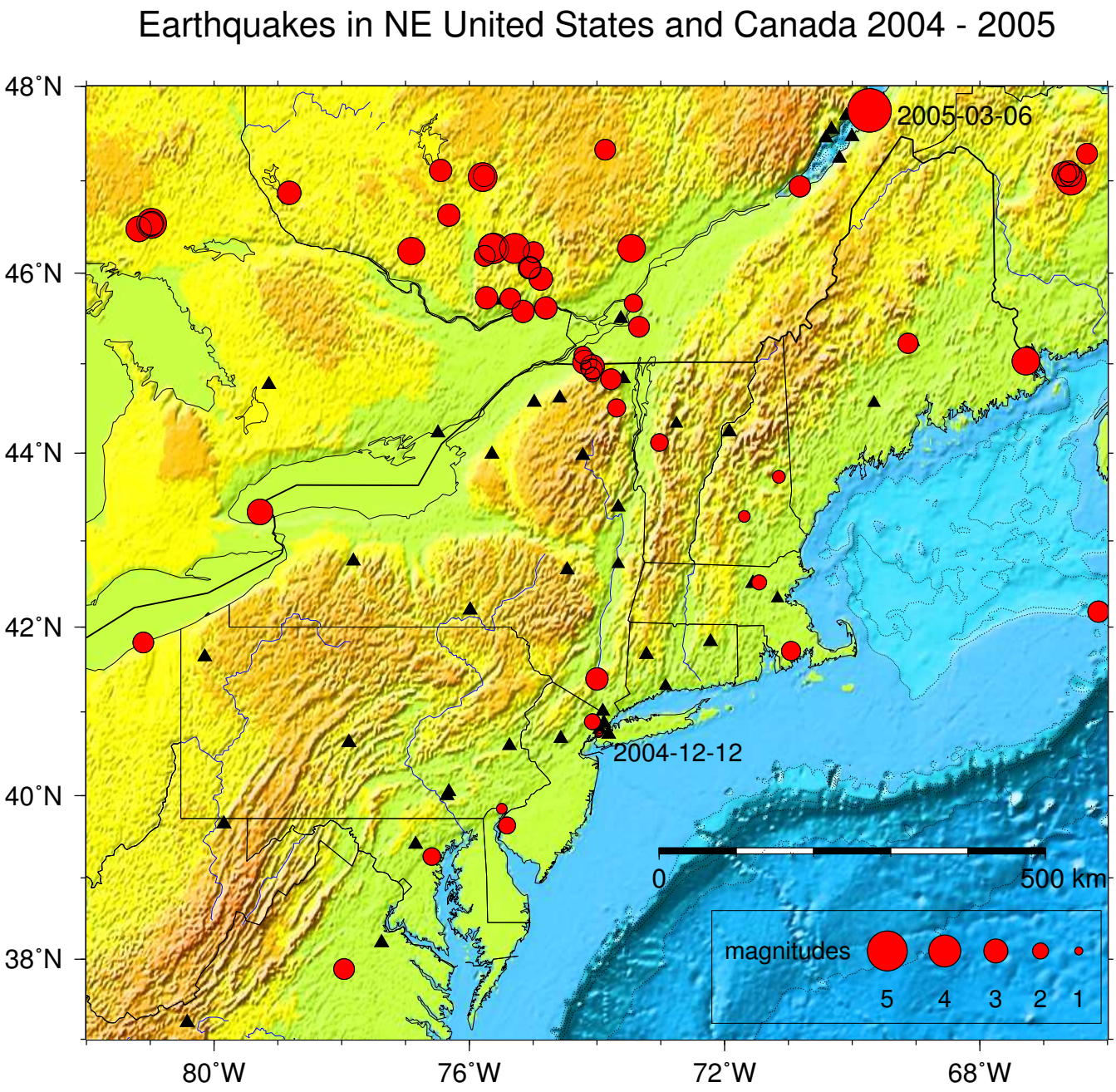

Figure 2: Earthquakes which have occurred in the northeastern United States and southeastern Canada in the time period of Oct. 1, 2004 through Sept. 30, 2005 recorded by the LCSN. Symbol size is proportional to magnitude. Broadband stations of the LCSN, USNSN, NESN, and CNSN are plotted for reference.

Table 1: Earthquakes recorded by LCSN for period Oct. 1, 2004 through Sept. 30, 2005

Date Year-Mo-Dy	Time (hr:mn:s)	Lat (°N)	Long (°W)	h (km)	Mag* (M_L)	Location
2004-10-08	02:25:46.0	42.52	71.46	1	1.8n	17 km SW of Lowell, MA (WES)
2004-10-14	09:36:02.4	41.394	73.986	8	2.5	6 km SE of Cornwall, NY (PAL)
2004-11-06	22:44:21.0	42.18	66.14	18	2.6n	Offshore Nova Scotia
2004-12-01	10:55:19.0	47.29	66.32	5	2.5n	65 km SW from Bathurst, NB
2004-12-03	00:06:29.0	45.94	74.88	18	2.8n	29 km NE Saint-Andre-Avellin, QC
2004-12-03	01:27:13.9	37.878	77.963	10	2.5	48 km E Charlottesville, VA (BLA)
2004-12-05	16:09:55.0	46.94	70.82	18	2.6n	14 km SE from Beaupre, QC
2004-12-12	01:25:38.0	40.746	73.973	5	0.8c	Lower East Side of Manhattan, NYC
2004-12-12	01:26:42.0	40.753	73.961	5	0.6c	Long Island City, Queens, NYC
2004-12-12	01:43:45.0	40.761	73.957	6	0.3c	Long Island City, Queens, NYC
2004-12-15	02:34:50.0	40.754	73.962	4	0.7c	Long Island City, Queens, NYC
2004-12-17	05:30:26.0	39.639	75.414	7	2.0c	17 km SE of Wilmington, DE
2004-12-24	19:30:23.0	46.87	78.82	9	2.8n	30 km NE from Temiscaming, QC
2005-01-02	15:05:15.0	45.73	75.73	18	2.7n	18 km NE from Wakefield, QC
2005-01-05	15:32:42.0	47.01	66.57	5	3.7n	Miramichi region, NB (OTT)
2005-01-08	20:30:00.0	43.28	71.69	0	1.4n	19 km NW of Concord, NH
2005-01-08	21:11:21.0	47.07	66.68	5	3.0n	Miramichi region, N.B. Aftershock
2005-01-09	13:22:33.0	47.06	66.58	5	2.7n	Miramichi region, N.B. Aftershock
2005-01-13	12:00:58.0	45.58	75.16	18	2.7n	19 km S of Ripon, QUE
2005-02-01	13:01:14.0	41.82	81.11	5	2.5n	Southern Lake Erie
2005-02-14	09:07:25.0	47.10	66.61	5	2.6n	Miramichi region, NB
2005-02-23	14:22:44.1	39.260	76.588	9	2.1c	7 km E of Baltimore, MD (PAL)
2005-02-26	11:12:14.0	46.53	80.99	1	2.9n	Sudbury, ON
2005-03-03	02:22:01.0	45.022	74.190	8	2.9c	21 km NE of Malone, NY
2005-03-06	06:17:49.0	47.75	69.73	15	4.7w	Riviere-du-Loup, QC
2005-03-13	17:08:14.0	46.54	80.98	18	3.6n	5 km N of Sudbury, ONT (GSC)
2005-03-28	16:39:38.0	43.33	79.28	5	3.1n	19 km N from St. Catharines, ON
2005-03-31	15:13:08.0	46.28	75.64	18	3.4n	27 km SE from Maniwaki, QC
2005-04-05	22:01:02.0	41.72	70.96	9	2.3n	19 km E of Fall River, MA (WES)
2005-04-08	04:32:38.0	46.27	73.46	18	3.4n	7 km SW Saint-Gabriel, QC
2005-04-10	00:27:06.0	39.84	75.49	5	1.2c	8 km N of Wilmington, DE
2005-04-10	03:06:50.0	43.73	71.15	10	1.5n	35 km NE of Laconia, NH (WES)
2005-04-10	17:37:17.0	49.49	66.59	18	2.9n	40 km N Sainte-Anne-des-Monts, QC
2005-04-15	23:58:42.0	47.33	73.87	18	2.5n	72 km N Saint-Michel-des-Saints,QC
2005-04-17	00:18:38.0	44.83	73.78	18	2.5n	30 km NW of Plattsburgh, NY
2005-04-23	14:24:51.0	40.885	74.069	6	1.9c	1 km E of Lodi, NJ
2005-05-11	02:34:10.4	45.230	69.124	1	2.4n	16 km NE of Dover, ME (WES)
2005-05-25	19:22:13.0	46.27	75.62	18	3.7n	29 km SE from Maniwaki, QC
2005-05-31	13:49:04.0	44.945	74.079	18	2.5c	20 km NE of Malone, NY

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2005-05-31	13:49:05.0	44.945	74.079	10	2.5c	20 km NE of Malone, NY
2005-06-05	01:00:29.0	44.880	74.070	8	1.8c	18 km E of Malone, NY
2005-06-06	03:13:46.0	44.118	73.021	13	2.1c	16 km NE of Middlebury, VT
2005-06-12	04:54:10.0	44.991	74.175	12	1.1c	19 km NE of Malone, NY
2005-06-12	22:24:01.0	45.67	73.43	18	2.2n	14 km SW from Vercheres, QC
2005-06-14	04:43:37.0	47.11	76.45	18	2.7n	89 km NW from Ferme-Neuve, QC
2005-06-23	18:16:21.0	46.06	75.05	18	2.5n	35 km SW from Labelle, QC
2005-06-23	18:32:08.0	46.06	75.05	18	2.7n	35 km SW from Labelle, QC
2005-07-01	11:06:26.0	44.509	73.694	7	2.2c	29 km SW of Plattsburgh, NY
2005-07-01	13:05:08.0	46.06	75.06	18	2.7n	35 km SW from Labelle, QC
2005-07-04	11:47:13.0	46.24	76.91	18	3.3n	46 km N from Fort-Coulonge, QC
2005-07-10	04:51:07.0	46.48	81.18	1	3.1n	Sudbury, ON
2005-07-11	22:20:12.0	46.23	74.99	18	2.5n	21 km W from Labelle, QC
2005-07-21	20:10:54.0	47.05	75.77	18	2.6n	46 km NW from Ferme-Neuve, QC
2005-07-23	02:48:16.0	47.04	75.79	18	3.5n	46 km NW from Ferme-Neuve, QC
2005-07-27	11:24:32.0	45.41	73.34	18	2.5n	7 km SW from Chambly, QC
2005-08-02	09:36:56.0	46.63	76.32	18	2.7n	39 km NW from Maniwaki, QC
2005-08-04	23:19:46.0	46.19	75.76	18	2.5n	26 km SE from Maniwaki, QC
2005-08-30	16:03:47.0	45.62	74.80	18	2.7n	9 km W from L'Orignal, ON
2005-09-06	02:58:45.0	45.72	75.36	18	2.5n	16 km N from Buckingham, QC
2005-09-06	14:10:51.0	46.27	75.29	18	3.6n	35 km SE Mont-Laurier, QC
2005-09-19	16:12:12.0	45.10	74.22	18	2.1n	4 km NW from Huntingdon, QC
2005-09-21	03:36:31.0	46.54	80.98	0	2.9n	Felt by many people in Sudbury
2005-09-25	03:08:57.9	45.03	67.28	6	3.4n	11 km S St. Stephen, NB

* 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; w = M_w moment magnitude from waveform moment tensor inversion; default is the local Richter magnitude determined and reported by Lamont-Doherty Earth Observatory of Columbia University.

available to seismological 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 occur in the northeastern United States, we put seismic phase arrival picks, short-period and broadband waveform data into the LCSN web site which can be easily downloaded by users via the Internet. Other event data requested by users, which includes neighboring seismographic network operators, Geological Survey of Canada, Ottawa, high school

teachers and students, 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 effort. The URL for the 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 select "Research", "Databases and Repositories" and "Lamont-Doherty Cooperative Seismographic Network". Waveform data of the selected events in SEED format can be found in "Data Access & Archive" or from the 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://almaty.ldeo.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:
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Data format: SEED, AH, ASCII

Reports Published

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

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Non-Technical Summary

The primary objective of the Lamont-Doherty Cooperative Seismographic Network (LCSN) is to monitor earthquakes in the northeastern United States and to gather data about eastern U.S. seismicity in order to identify areas of high seismicity, to understand the causes of earthquakes, and to evaluate earthquake hazards in the region. 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 44 seismographic stations in the northeast covering seven states: Connecticut, Delaware, Maryland, New Jersey, New York, Pennsylvania and Vermont.