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

Annual Project Summary

October 01, 2001 - September 30, 2002
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Key Words: Wave Propagation, Regional Seismic Hazards and Real-time earthquake information

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 39 seismographic stations in seven states: Connecticut, Delaware, Maryland, New Jersey, New York, Pennsylvania and Vermont. During October 2001 through September 2002, sicentists 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 the Adirondacks following the April 20, 2002 Mw 5.0 Au Sable Forks, New York earthquake. LCSN also supported two portable seismographs for aftershock studies following the June 18, 2002 Mw 4.6 Evansville, Indiana earthquake.

Results

Network Operation

In operating the Lamont-Doherty Cooperative Seismographic Network (LCSN) during Oct. 2001–Sept. 2002, we accomplished: 1) Deployed six new broadband, 3-component seismographs. Total of 15 broadband seismographic stations are now operated directly by LCSN or affiliated to LCSN (Figure 1); 2) Continuous waveform data from 12 stations (vertical-component) are now sent to NEIC/USNSN in Golden, CO in real time; 3) 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://bud.iris.washington.edu/bud_stuff/dmc/index.htm> 4) Rapid earthquake information dissemination system under ANSS is implemented. It is called "recenteqs" and is accessible at <http://www.ldeo.columbia.edu/LCSN/recenteqs>; 5) 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>.

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 30 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, 2001 through September 30, 2002. These earthquakes range from magnitude mb(Lg) 1.5 to 5.3 (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 Quebc seismic zone in southern Canada. Notable earthquakes during the period are: October 27, M_L 2.6 earthquake in Manhattan, New York City and April 20, 2002 M_L 5.3 Au Sable Forks, New York earthquake sequence (see Figure 2).

Manhattan, New York City earthquake on Oct. 27, 2001

A small earthquake of M_L =2.6 occurred on 10/27/2001 at 12:34 in Upper West Side of Manhattan, New York City. Residents in the Upper West Side of Manhattan felt the event, but the response from the public were less than M_L 2.3 event that occurred on Jan. 17 in the Upper East Side of Manhattan. Probably due to the fact that it occurred in early morning hour (local time 00:42) on Saturday. LCSN deployed four portable seismographs around the epicenter in New York City to capture aftershocks which can provide accurate locations of the earthquakes that occurred in 2001. So far, no clear aftershocks are detected.

Au Sable Forks, New York, Earthquake on April 20, 2002

On April 20, 2002 at 06h 50m 47.5s (EDT), a moderate earthquake of magnitude M_L 5.3 occurred about 29 km SW of Plattsburgh, New York (Figure 3). The epicenter of the mainshock is about 5 miles north of town of Au Sable Forks and the focal depth of the mainshock is about 11 km from the surface. The earthquake on April 20, 2002 is now formally called **Au Sable Forks** earthquake. The mainshock was felt widely by residents in New York and adjacent states. It was felt from Maine, Boston, Massachusetts, metropolitan New York City area, down to Baltimore, Maryland. It is also widely felt in Ottawa and Montreal, Canada. Residents in the two counties – Clinton and Essex Counties, around the epicenter felt intensity VI (MMI) and up to

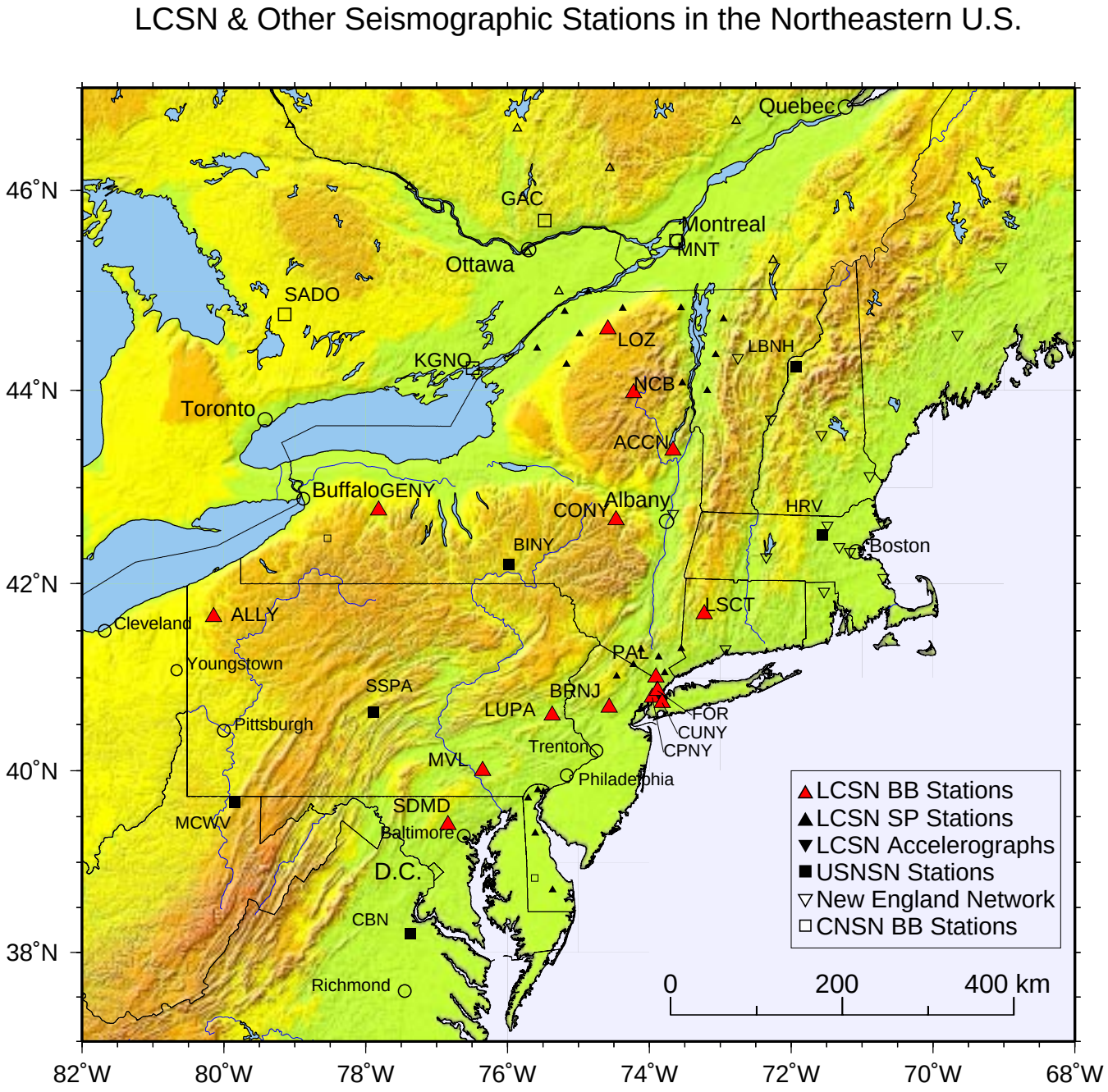

Figure 1: Seismographic stations in the Northeastern United States and Southeastern Canada. LCSN broadband sites (*red triangles*), short-period sites (*filled triangles*), New England Seismic Network sites (MIT & Weston Observatory; *inverted open triangles*) are plotted. Broadband stations of the USNSN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

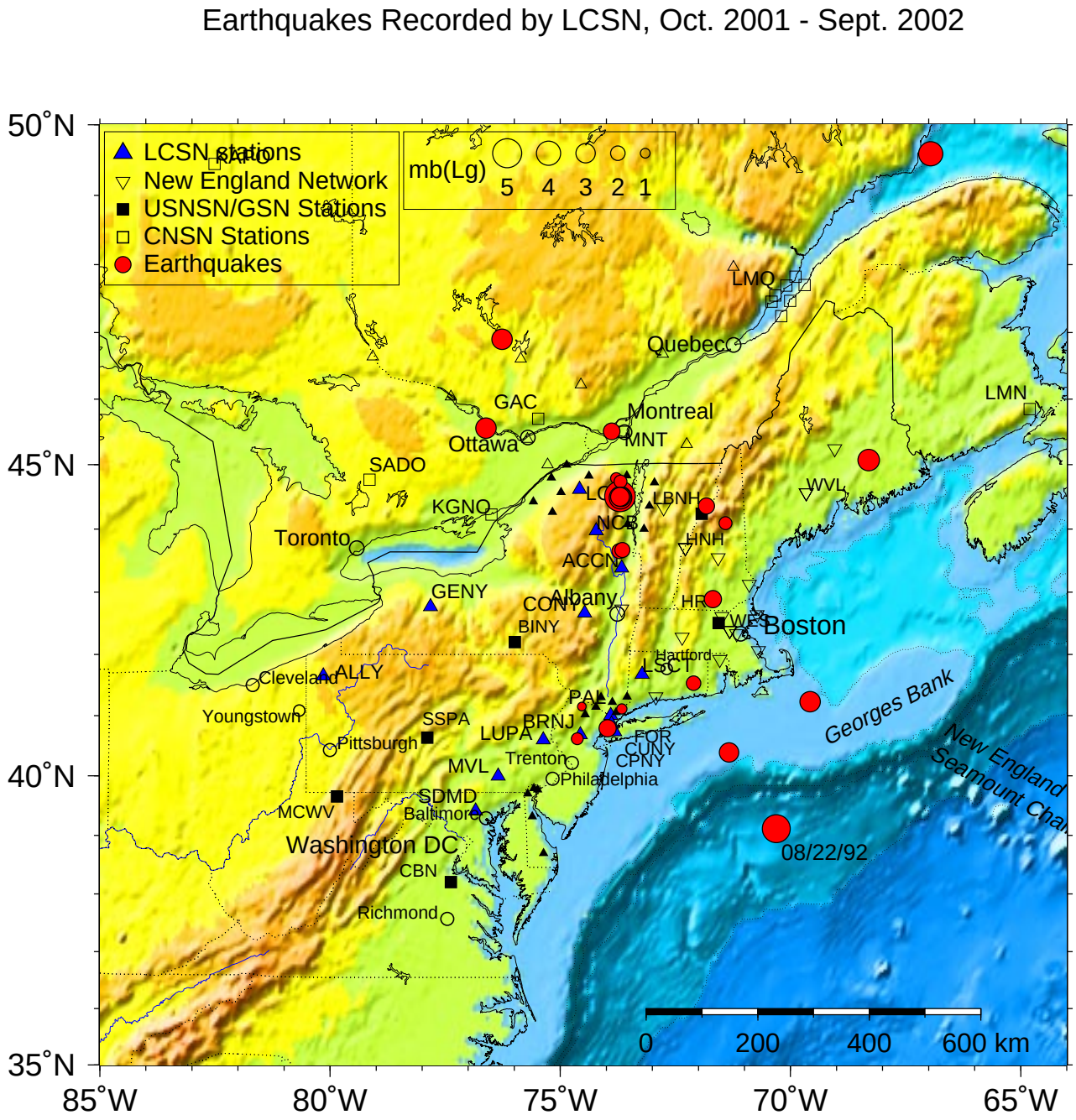

Figure 2: Earthquakes which have occurred in the northeastern United States and southeastern Canada in the time period of Oct. 1, 2001 through Sept. 30, 2002 recorded by the LCSN. Symbol size is proportional to magnitude. Broadband stations of the LCSN, USNSN, NESN, and CNSN are plotted for reference. The largest earthquake recorded by LCSN that occurred offshore New Jersey on 08/22/1992 (mb=4.8) is plotted for reference.

Table 1: Earthquakes recorded by LCSN for period Oct. 1, 2001 through Sept. 30, 2002

Date Year/Mo/Dy	Time (hr:mn:s)	Lat (°N)	Long (°W)	Depth (km)	Mag* (M_L)	Location
2001/10/02	23:40:19	44.36	71.82	00.0	2.3c	52 km W of Berlin, NH
2001/10/25	00:24:28	45.07	68.30	00.0	3.5c	31 km NE of Old Town, ME
2001/10/27	05:42:21	40.79	73.97	05.0	2.6	Upper West Side of Manhattan, NY
2002/03/05	01:33:52	41.11	73.66	06.0	1.1c	12 km NW of Stamford, CT
2002/03/12	07:13:23	41.23	69.57	04.5	3.2c	71 km SE of South Yarmouth, MA
2002/03/18	02:56:41	41.15	74.53	05.0	0.8c	21 km NE of Newton, NJ
2002/04/01	12:31:18	44.79	73.78	00.0	1.3c	28 km W of Plattsburgh, NY
2002/04/20	10:50:47	44.51	73.70	11.0	5.3	Au Sable Fork, NY
2002/04/20	11:04:42	44.49	73.69	05.0	3.7	Au Sable Fork, NY
2002/04/20	11:08:26	44.50	73.70	05.0	1.7c	Au Sable Fork, NY
2002/04/20	11:45:28	44.50	73.70	05.0	2.6	Au Sable Fork, NY
2002/04/21	11:47:09	44.51	73.67	10.0	2.2c	Au Sable Fork, NY
2002/04/21	12:39:10	44.50	73.70	05.0	2.3c	Au Sable Fork, NY
2002/04/25	13:39:56	44.50	73.67	11.0	2.2c	Au Sable Fork, NY
2002/05/16	07:06:18	44.74	73.69	03.0	1.7c	20 km W of Plattsburgh, NY
2002/05/24	23:46:00	44.50	73.68	10.0	3.1	Au Sable Fork, NY
2002/05/28	09:15:37	45.56	76.61	03.4	3.2n	73 km W of Ottawa, ONT
2002/06/01	11:35:29	45.51	73.88	15.0	2.4n	22 km W of Montreal, QUE
2002/06/25	13:40:28	44.50	73.70	09.0	3.0	Au Sable Fork, NY
2002/07/11	21:53:45	40.39	71.33	00.0	3.0c	114 km SE of Hampton Bays, NY
2002/07/23	02:08:59	49.59	66.95	18.0	4.0n	291 km N of Miramichi, N.B.
2002/08/09	14:59:56	40.62	74.63	03.8	1.5c	5 km N of Somerville, NJ
2002/08/11	03:06:00	43.65	73.71	05.0	2.1c	38 km N of Glens Falls, NY
2002/08/11	03:06:49	43.67	73.65	05.0	2.1c	40 km N of Glens Falls, NY
2002/08/22	18:58:37	41.53	72.10	12.3	2.0c	2 km W of Norwich, CT
2002/09/07	21:27:46	46.90	76.26	16.7	3.2n	64 km N of Maniwaki, QUE
2002/09/16	06:09:24	44.09	71.41	00.0	1.7c	45 km SW of Berlin, NH
2002/09/28	23:47:25	42.89	71.68	01.0	2.6c	6 km NW of Milford, NH

* 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.

VII at close to the epicenter. The earthquake caused substantial damage and on May 16, 2002, Presidential disaster declaration was issued for Clinton and Essex Counties, NY (Disaster No.: FEMA-1415-DR-NY).

There were damages to roads, bridges, chimneys and water mains in Clinton and Essex Counties, NY. Many people reported cracked walls and foundations, small items knocked from

shelves and some broken windows. The photo shows one of the road damage due to slumping on Route 9N near Clintonville Figure 4.

The main shock is followed by aftershock of magnitude M_L 3.7 at 11:04:42 and smaller aftershock with M_L 2.6 at 11:45:31 (see Table 2). Local magnitude (= Richter scale), M_L , of the mainshock is M_L = 5.3, measured from the three component seismograms at 12 stations in the distance ranges of 73 to 715 km from the source.

The mainshock and its largest aftershock (M_L =3.7) on 04/20/2002, 11:04 are well recorded by broadband, 3-component stations in the Eastern North America. For the mainshock, we obtained over 50 broadband, 3-component records from regional stations in the distance ranges from 70 to 2000 km. Waveform data are used to determine focal depth and source mechanism parameters using moment tensor inversion method. Source mechanism indicates predominantly thrust faulting along 45 degree dipping fault plane striking due South (aftershock distribution indicates that fault plane dips due West). The seismsic moment is M_0= $3.5 \cdot 10^{16}$ Nm (Mw = 5.0) and a rupture radius is about 1.3 km.

The waveform modeling technique also suggests that the synthetic seismograms calculated for a source depth of abut 11 km fit the observed records best. This focal depth is quite consistent with the early aftershock locations discussed in a later section.

Aftershocks: Following the mainshock, scientists and staff at the Lamont-Doherty Earth Observatory of Columbia University in Palisades, NY immediately went to the epicentral region with six digital portable seismographs to monitor aftershocks. The first station was installed about 1/2 day after the mainshock. Six more stations were installed the next day (see Figure 5).

We achieved an important milestone in monitoring earthquakes and evaluating their hazards through rapid cross-border (Canada-US) and cross-regional (Central US-Northeastern US; Southwestern US-NE US) collaborative efforts. Hence, ISTI staff – Paul Friberg & Sid Hellman, who live in Upstate New York joined LDEO staff and deployed the first portable station in the epicentral area; CERI dispatched two of their technical staff to the epicentral area with four accelerometers and a broadband seismograph; the IRIS/PASSCAL facility shipped three digital seismographs and ancillary equipment within one day of the request; the POLARIS Consortium, Canada sent a field crew of three with a near real-time, satellite telemetry based earthquake monitoring system. This collaboration allowed us to maximize the scarce resources available for monitoring this damaging earthquake and its aftershocks in the Northeastern U.S.

At the moment (June 1, 2002), 12 seismographic stations are monitoring the aftershocks in the region. Following people have participated to the field work; CERI - field crew & support; Jim Bollwerk, Chris Watson, Arch Johnston, Mitch Withers; ISTI - Paul Friberg, Sid Hellman; POLARIS Consortium, Canada - field crew; Calvin Andrews, Mike Patten and Isa Asudeh; other personnel, John Adams, David Eaton and Gail Atkinson; PASSCAL/IRIS - Mark Alvarez, Noel Barstow, Jim Fowler; LDEO - John Grenville, Jian Zhang, John Contino, Golam Sarker, Jeremiah Armitage, John Armbruster, Nano Seeber and Won-Young Kim.

Data Availability

1) Continuous waveform data from broadband, three-component stations
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

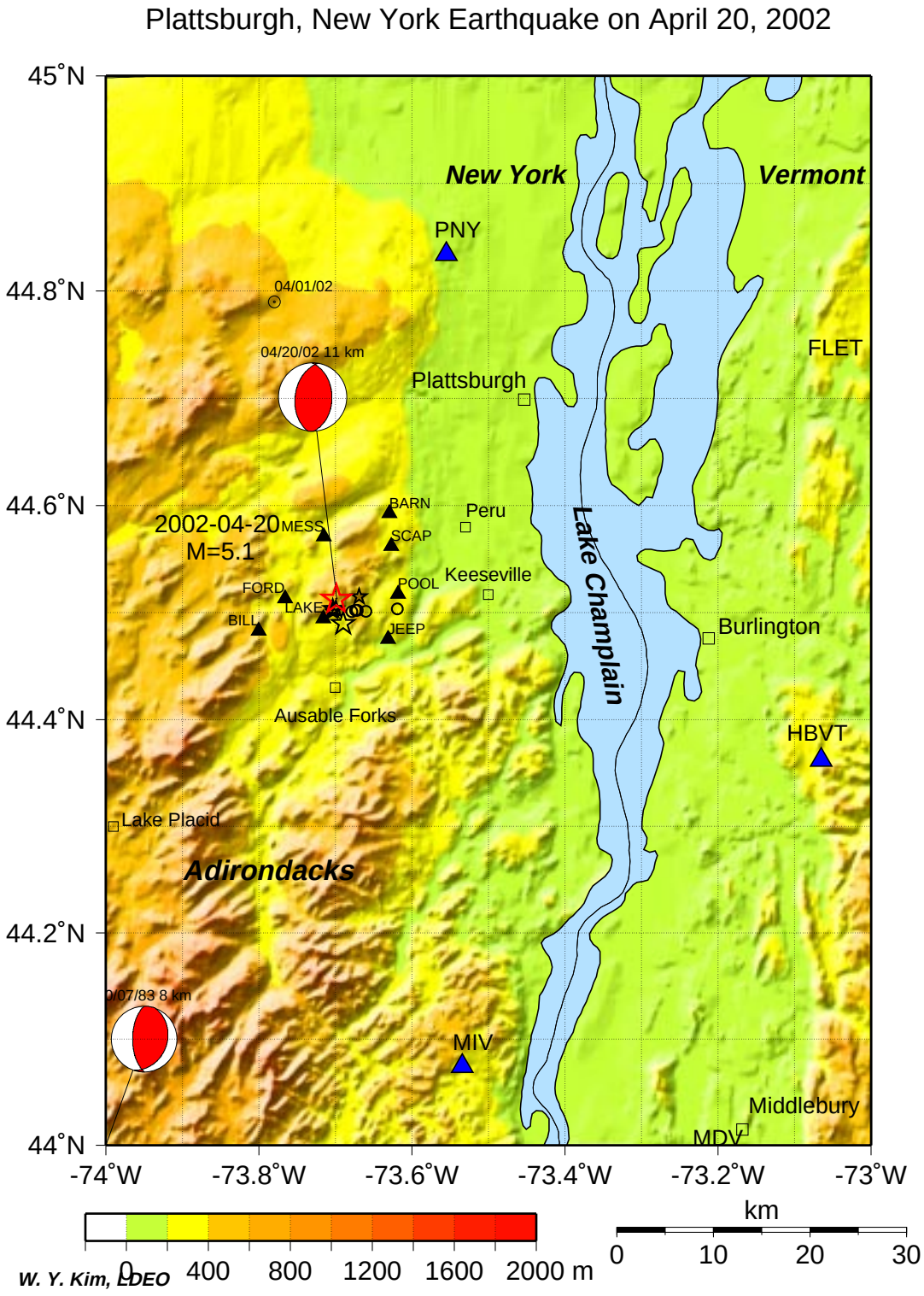

Figure 3: Topographic map of New York and adjacent states with the epicenters of earthquakes that occurred during 1970-2001. The 2002 Au Sable Forks epicenter is marked by a *red star*. Other important earthquakes are marked by dates (Altona, 06/09/1975 M4.1; Goodnow 10/07/1983 mb(Lg) 5.1; Massena 09/05/1944 mb=5.8). Broadband stations in the region are also plotted with triangles (Lamont Cooperative Seismic Network, New England Seismic Network and US National Seismic Network).

Figure 4: Road damage due to slumping on Route 9N near Clintonville, Clinton County, NY.

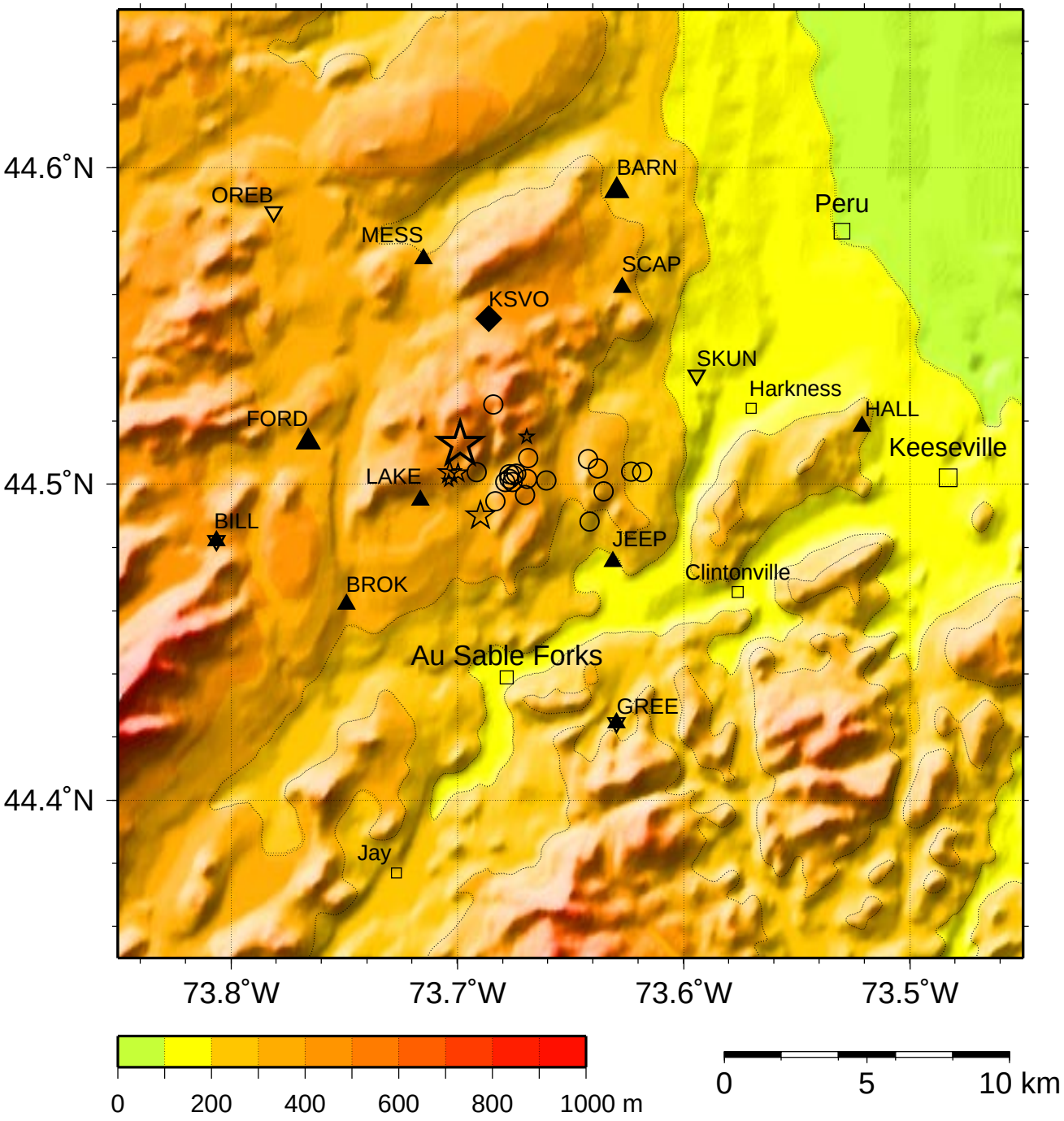

Figure 5: Topographic map of the Au Sable Forks source area in the northeastern Adirondacks showing the temporary monitoring stations and preliminary aftershock epicenters. Key to symbols: small and large triangles indicate short period and broadband sensors (GREE and HALL are contributed by IRIS-PASSCAL); inverted triangles are strong motion sensors (contributed by CERI, University of Memphis; some are co-located with velocity sensors); Diamond is a broadband sensor relayed near-real-time via satellite telemetry (contributed by the POLARIS project, Canada); stars are epicenters from the regional stations; circles are aftershocks located by the local stations.

Table 2: April 20, 2002, Au Sable Forks, New York Earthquake Sequence

Date Year/Mo/Dy	Time (hr:mn:sec)	Latitude (°N)	Longitude (°W)	Depth (km)	Magnitude M_L
2002/04/20	10:50:47.5	44.513	73.699	11	5.3
2002/04/20	11:04:42.4	44.490	73.690	10	3.7
2002/04/20	11:08:26.0	44.501	73.704	10	1.7
2002/04/20	11:45:28.7	44.504	73.703	10	2.6
2002/04/21	11:47:09.9	44.515	73.669	10	2.2
2002/04/21	12:39:10.7	44.504	73.700	10	2.3
2002/04/25	13:39:56.0	44.503	73.674	11	2.2
2002/05/24	23:46:00.1	44.505	73.675	12	3.1
2002/06/25	13:40:28.0	44.503	73.675	11	3.0

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.

2) 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 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 format can be found in “Data Access & Archive” or from webseismogram window.

3) All waveform data from 39 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://bud.iris.washington.edu/bud_stuff/dmc/index.htm>

Contact person for additional inquiries and assistance:
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Data format: SEED, AH, ASCII

Reports Published

Seeber, L., W.-Y. Kim, J. G. Armbruster, W.-X. Du, A. Lerner-Lam, and P. Friberg, The 20 April 2002 Mw 5.0 earthquake near Au Sable Forks, Adirondacks, New York: A first glance at a new sequence, *Seism. Res. Lett.*, **73**, 480–489, 2002.

Won-Young Kim, June 18, 2002, Evansville, Indiana Earthquake: Reactivation of Ancient Rift in the Wabash Valley Fault Zone ?, submitted to the *Bulletin of the Seismological Society of America*, October 2002.

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 39 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 15 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. 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 30 regional earthquakes with magnitude greater than 2 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 April 20, 2002 about 29 km SW of Plattsburgh, New York about 5 miles north of town of Au Sable Forks, Adirondacks. The mainshock was felt widely by residents in New York and adjacent states. Residents in two counties – Clinton and Essex Counties, around the epicenter felt intensity VI (MMI) and up to VII at close to the epicenter. The earthquake caused substantial damage and on May 16, 2002, Presidential disaster declaration was issued for Clinton and Essex Counties, NY (Disaster No.: FEMA-1415-DR-NY).