Virtual Earthquakes

Jean-Pierre Bardet

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Acknowledgements

• Dedicated to the late Dr. Cliff Astill, NSF

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1. Past Reports on Earthquakes
2. Virtual Earthquakes
3. Conclusion
Each time earthquakes strike, researchers, engineers, and scientists discover something they had overlooked in the past and make another successful step toward better understanding these complex natural phenomena.

Earthquake engineering has evolved in concert with unexplained information collected from field surveys after major earthquakes.

- 1906 San Francisco, California
- 1964 Alaska, USA
- 1964 Niigata, Japan
- 1971 San Fernando, California
- 1989 Loma Prieta, California
- 1994 Northridge, California
- 1995 Hyogoken Nanbu, Japan

How did the reports of post-earthquake surveys have evolved with GPS and the Internet?
1. Reports on Earthquakes
2. Virtual Earthquakes
3. Conclusion
1980: Born at CERN
1993: Mosaic web browser developed by a team at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC).
April 1994: Mosaic Communications Corporation changed its name to Netscape, and the browser was developed further as Netscape Navigator.
May 1994: First International WWW Conference,
September 1994: the World Wide Web Consortium (W3C) is founded
November 1995: HTML 2.0 was published
January 1996: Google is a research project at Stanford.
September 1998: Google Inc.


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Evolution of Web Reports

- Prehistory: Hard copy reports
- Early Age: GPS, Mosaic and HTML
- Middle Age: GIS and IMS
- Renaissance: Google, Wikipedia & Photo Metadata
- Future: Virtual earthquakes

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Web reports on GEES website

GEES Geotechnical Earthquake Engineering Server

GEES home page
Google MAPper
Reports on line
Data on line
Software on line
Contact GEES
Acknowledgements
Other Natural Hazards
GEER website
ROSRINE project
Vedanta project
Useful links

Mw 7.9 earthquake in Sichuan, China on May 12, 2008
Post-earthquake reconnaissance of EER-GEER team (August 4-6, 2008)

Mw 5.6 earthquake in Japan on October 23, 2004

Mw 7.7 earthquake in India on January 26, 2001
The preliminary report of the National Science Foundation geotechnical reconnaissance team (March 1, 2001).
It includes videos and a GIS/IMG database of photos.

Mw 7.4 earthquake in Turkey on November 12, 1999
The preliminary report of the National Science Foundation geotechnical reconnaissance team (November 25, 1999)

Mw 7.6 earthquake in Taiwan on September 21, 1999
The preliminary report of the National Science Foundation geotechnical reconnaissance team (October 8, 1999).

Mw 7.8 earthquake in Turkey on August 17, 1999
The preliminary report of the National Science Foundation geotechnical reconnaissance team (September 3, 1999).

The Great Hanshin Earthquake Disaster
The January 17, 1995 South Hyogo Prefecture, Japan, Earthquake
One of the first reports over the Internet sponsored by the National Science Foundation, released on Mosaic on February 9, 1996.
Growth of information on GEES

Year

Volume of Information (Mb)

GIS-IMS
Google
Niigata
Bhuj
Chichi
Kocaeli, Ducze

Mosaic
HTML
HTML 5
AJAX

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The Great Hanshin Earthquake Disaster
The January 17, 1995
South Hyogo Prefecture Earthquake

Preliminary Investigation Report
February 5, 1995

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and

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DAMAGE TO INFRASTRUCTURES, AND RESIDENTIAL AND INDUSTRIAL BUILDINGS

A general location of all the observations (i.e., photographs) made during the earthquake investigation are indexed by using letter A through Z.

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   c. Earthquake intensity
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   b. Attenuation of maximum peak ground acceleration with distance
   c. Time history and response spectra of acceleration, velocity and displacement
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   b. Assessment of total damage
   c. Fire
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   b. Industrial buildings and factories
   c. Railways lines and bridges
   d. Highway bridges
6. DAMAGE TO GEOTECHNICAL STRUCTURES
   a. Embankments and slopes

Photograph A2 Hanshin Expressway Bridge in Nishinomiya City. The photograph, taken under the collapsed deck, shows that the reinforced concrete pier is leaning sideways.

Photograph B11 Girl in New Town Square, in the center of Kobe. The image illustrates the destruction caused by the earthquake.

Photograph B12 Girl in New Town Square, in the center of Kobe. The image illustrates the destruction caused by the earthquake.

Photograph D2 Umeda Sky Building. The photograph shows the building's structural damage following the earthquake.
The August 17, 1999, Kocaeli, Turkey, earthquake

Preliminary Reports of the Turkey-US Geotechnical Earthquake Engineering Reconnaissance Team
Sponsored by the National Science Foundation

Reconnaissance Report (View Download PDF version, 14 MB)

- Summary
- Aerial survey over Izmit, Adapazari, Lake Bagcilar, Golbuk, Yalova and Lake Izmit (August 22, 1999)
- Adapazari and its southern vicinity (August 25, 1999)
- Southern coast of Marmara Sea including Yalova, Karamursel and Haldere (August 26, 1999)
- Sapanca Lake and Adapazari (August 27, 1999)
- Golbuk and its vicinity (August 28, 1999)
- Avcali (August 28, 1999)

Map Server
Useful links
Maps
Directory

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The flight path initiated from the Istanbul airport to the west and went over the Izmit and Derince areas, Adapazari, Sapanca Lake, Golbuk, Karamursel, Yalova, and the Izmit lake.

Izmit and Derince areas

Overview of the TUPRAS refinery along the Izmit Bay after the fire that started right after the earthquake on August 17, 1999 (N40°46 830', E38°33.664', 8/24/99, 15:23:17).
Reconnaissance Investigations of 1999 Kocaeli earthquake

Photo From 1999 Earthquake Reconnaissance Efforts in Turkey: Sapanca Lake

Subsidence of hotel Sapanca on the shore of the Sapanca lake.

This photo was taken by J.P. Bardet
Reconnaissance Investigations of 1999
Duzce earthquake

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Serving Spatial Data with Google

Apache HTTP Web server

PHP

Red Hat Enterprise 4

PostgreSQL DBMS

Internet

Server

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Google: 1999 Kocaeli, Turkey, Earthquake

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1999 Chichi, Taiwan, Earthquake

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1999 Chichi, Taiwan, Earthquake

1. Waterfall created by reverse fault movement just north of the south abutment of heavily damaged multi-span bridge north of City of Fengyuan and to the west of the Shihkang Dam (N 24.2036 E 120.7592; 9/30/99).

2. View to south showing right lateral offset of about 3 to 4 m and uplift of about 4 to 5 m in this bridge (N 24.28 E 120.76; 9/30/99).

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11. Close-up view of landslide above collapsed bridge (N 24.2854 E 120.7589).

12. Collapsed bridge spans near Highway 129/136 intersection near Taiping (N 24.1306 E 120.7352). The longitudinal direction for the bridge has an azimuth of approximately 300 degrees. The fault is known to pass beneath the bridge based on exposures west and east of the spans, but its precise location is unknown due to grading near the bridge. View in photo is to the NE. Note the spans have been pushed to the SE (to the right in the photograph) off their supports, possibly from compression associated with the faulting.
2001 Bhuj, India, Earthquake

The Bhuj, India, Earthquake of January 26, 2001

This page was last updated on May 21, 2007

Preliminary Report of the India-US Geotechnical Earthquake Engineering Reconnaissance Team

Sponsored by the US National Science Foundation in collaboration with the Earthquake Engineering Research Institute (EERI) and the Mall Arvind Earthquake (MAEC) Center

- Introduction
- Reconnaissance report
- Damage to towns and villages
  - Ajmer
- Benaulum
- Bhuj
- Damage to dams
- Damage to port
  - Kandla
  - Navlak
  - Anjar
- Damage to bridges
  - Suratbridge
- Highway SA Bridge
- Ground failure, liquefaction, and cracking
  - South of Chang dam and north of epicenter (February 17, 2001)
  - East of Lodar
  - Farm of Kachh (February 16, 2001)
  - Farm of Kachh (February 20, 2001)
- USGS database server of photos from post-earthquake reconnaissance
- Video from earthquake reconnaissance
- PowerPoint presentations
  - Bardet's presentation
  - Bardet's presentation at EERI benefit on April 4, 2001
  - Singh's presentation in San Diego

Additional Information
2001 Bhuj, India, Earthquake

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October 23, 2004 Niigata-ken Chuetsu Earthquake, Japan

Report of the first reconnaissance team (October 30–November 2, 2004)

- Introduction
- Field reconnaissance of October 30, 2004
- Field reconnaissance of October 31, 2004 (Onaho Rockslide, Shinkansen derailment, and damage to Shinkansen bridge)
- Field reconnaissance of November 1, 2004 (Landslides to the North of earthquake area, East of Nagashiwa)
- Field reconnaissance of November 2, 2004 (Landslides to the South of earthquake area, North of Kawanishi)
- CSBE database of photos from post-earthquake reconnaissance
- Video from earthquake reconnaissance
- PowerPoint presentations


- Field Reconnaissance of November 16, 2004 (Damage Observations throughout Affected Area)
- Field Reconnaissance of November 17, 2004 (Landslides east of Yamakoshi Village)
- Field Reconnaissance of November 18, 2004 (YDAX System of Chitosan Flows)
- Field Reconnaissance of November 18, 2004 (Embarkment FR Failures in Takamachi Residential Area)
- Field Reconnaissance of November 19, 2004 (Landslides South Yamakoshi and East Oyama)
- Field Reconnaissance of November 20, 2004 (Reconnaissance of Possible Earth-related Surface Deformation)
- Field Reconnaissance of November 20, 2004 (Reconnaissance of Komasugawa Landslide Dam)
2003 Niigata-Chetsu Earthquake

Slight deformation of railway track of the JR Joetsu line 800 m to the West of the Shinkansen.
2003 Niigata-Chetsu Earthquake

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2003 Niigata-Chetsu Earthquake

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Geo-referencing photos using time stamp and GPS track

GPS track consisting $n$ points that has coordinates $(t, X)$

Time-stamped picture

$$X^* = X_i + \frac{X_{i+1} - X_i}{t_{i+1} - t_i} (t^* - t_i)$$

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Embedded Metadata

- **Embedded metadata**
  - embed data about an image into the image file itself.

- **Embedded metadata can be written using**
  - EXIF (Exchangeable Image File Format)
  - IPTC (International Press Telecommunications Council)
  - XMP (Extensible Metadata Platform)

- **Embedded metadata**
  - can be extracted and gathered into databases.
  - are recognized by many applications, e.g., viewers, editors, and image archiving applications.

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1. Reports on Earthquakes
2. Virtual Earthquakes
3. Conclusion
Virtual Earthquakes

• Earthquakes are not virtual; they actually occur.

• “Virtual earthquakes” are models that comprehensively integrate a large volume of heterogeneous time-stamped geospatial data on earthquake effects to describe, preserve and display time-sensitive information of importance to science, engineering, and our society, so that everyone can navigate and observe the earthquake damage as if they had participated in the post-earthquake field surveys.

• Virtual earthquakes are to
  • Visualize earthquake damages in 3D, possibly 4D
  • Immerse into a virtual reality to explore observations on earthquake effects on population and built environment.
  • Educate students and instruct our society about the potential risks of damaging earthquakes.
  • Train rescue teams for emergency operations.

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Pilot Virtual Wenchuan Earthquake

- Sponsored by GEER and the US National Science Foundation
- Collaboration with the Chinese Earthquake Authority, Zifa Wa Tong Qiu, Clarkson University
- David Frost, Georgia Institute of Technology
- Team member of Geo-Engineering Earthquake Reconnaissance (GEER)
- Earthquake Engineering Research Institute (EERI).

Photos are embedded with metadata
Photos are displayed on GEES in two different ways:
  1. HTML Web photo albums
  2. KMZ files viewable using Google Maps and Google Earth.

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Workflow for sharing photos with embedded metadata

1. Synchronize times
2. Geo-code photo

3. Categorize photos
4. Theme albums
5. Add captions

Geo-coded photos

Categorized photos with metadata

Internet

Archive

Picture files
With time stamps

GPS tracks

Geo-reference Photos

Annotate Photos

Transform

1. HTML album
2. Google Earth files
...

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Wenchuan earthquake of 12 May 2008, Sichuan, China

An earthquake occurred 90 km (55 miles) NNW of Changdu, Sichuan, China and 1545 km (960 miles) SW of Beijing, China at 12:26 AM MDT, May 12, 2008 (2:26 PM local time in China). At least 89,165 people killed, 574,171 injured and 18,467 missing and presumed dead in the Changdu-Linxiu-Shuangqian area. More than 45.5 million people in 10 provinces and regions were affected. At least 15 million people were evacuated from their homes and more than 5 million were left homeless. An estimated 5.26 million buildings collapsed and more than 21 million buildings were damaged in Sichuan and in parts of Chongqing, Gansu, Hubei, Shaanxi and Yunnan. The total economic loss was estimated at 88 billion US dollars. 

Post-Earthquake Reconnaissance of EERI-GEER Team (August 4 - August 8, 2008)

- Reconnaissance Photos taken by J.P. Bardet (August 4, 2008) (HTML, View in Google Map, Download KML file)
- Reconnaissance Photos taken by J.P. Bardet (August 5, 2008) (HTML, View in Google Map, Download KML file)
- Reconnaissance Photos taken by J.P. Bardet (August 6, 2008) (HTML, View in Google Map, Download KML file)
- Reconnaissance Photos taken by J.P. Bardet (August 7, 2008) (HTML, View in Google Map, Download KML file)
- Reconnaissance Photos taken by T. Gu (August 7, 2008) (HTML, View in Google Map, Download KML file)
- Reconnaissance Photos taken by T. Gu (August 8, 2008) (HTML, View in Google Map, Download KML file)
- Click HERE to download a KMZ file showing seismic information (e.g., mainshock, aftershock, Longmenshan Fault, PGA map, etc.). You need to install Google Earth in order to view KMZ file. Google Earth can be downloaded from HERE.

Here is a collection of resources and links.
2008 Wenchuan Earthquake

August 4, 2008 Post-Earthquake Reconnaissance of Wenchuan Earthquake, May 12, 2008 (154 images)
Photos taken by J. P. Bardet, University of Southern California on August 4, 2008. The photos were taken during the post-earthquake reconnaissance that took place August 4-8, 2008, and was sponsored by Geo-Engineering Earthquake Reconnaissance (GEER) through a funding of the National Science Foundation. The GEER team, which was lead by David Frost, Georgia Institute of Technology, collaborated with the Earthquake Engineering Research Institute (EERI). Both GEER and EERI teams were hosted by the Chinese Earthquake Authority lead by Zifa Wang.

Click a picture to see a larger view.

August 4, 2008 Post-Earthquake Reconnaissance of Wenchuan Earthquake, May 12, 2008 -- Landslide on rock ridge with debris flow

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2008 Wenchuan Earthquake

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2008 Wenchuan Earthquake

- Failure of a masonry building along the fault. The brick building was also destroyed.
- Failure of a bridge due to compression from surface faulting.
- Failure of retaining wall. The area behind the building collapsed.
- One bridge section fell down as the bridge deck was pushed by surface faulting. The visible side of the bridge abutment was undamaged.
- One house was damaged while the other one was not. The cracks in the house are more characteristic of surface faulting than ground shaking.
- One of the bridge abutments was uplifted due to compression from surface faulting.
- One of the bridge sections fell down due to surface faulting.
- One side of the wooden deck had been uplifted by surface faulting, causing the flexible deck to become inclined.
- Part of road surface hang vertically after bridge deck fell down.
- Part of the bridge abutment collapsed, which resulted in the secondary fall of the concrete roadway.
- Part of the concrete slab of the road was uplifted by surface faulting. The buckled concrete slab implies that surface faulting had a thrust component in addition to vertical lift.
- Rocks fell from mountains. Some of these rocks were much larger than our vehicles.
- Section of building collapsed during quake.
- Shallow landslide.
2008 Wenchuan Earthquake

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Building a virtual earthquake requires a large volume of time-stamped and geo-referenced data and metadata

- before and
- after the earthquake.

Post-earthquake data could be generated using a team approach, in which many investigators share the geo-referenced photos with embedded metadata they collected during field surveys.
Building Virtual Earthquakes Together

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Google Street View

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Wikipedia Growth

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The 2008 Sichuan earthquake in southern Sichuan, China, struck on May 12, 2008. The quake measured 8.0 on the Richter scale and caused at least 69,000 fatalities and 11,000 injuries. The epicenter was in Wenchuan County, Sichuan Province, 80 kilometers northwest of Chengdu, the capital of Sichuan, with a depth of 19 kilometers. The earthquake was felt in nearly all of China and as far away as Taiwan and Singapore. The official death toll of 69,000 people exceeded any previous earthquake in China.

The quake affected a large area, especially in the cities of Beichuan, Dujiangyan, and Ya'an. The earthquake triggered landslides that blocked rivers and created new lakes, which in turn caused more fatalities and injuries. The epicenter was located in the Wenchuan County area, which is home to a large number of the local population.

The government and emergency services responded quickly to the disaster, with rescue operations underway within hours of the earthquake. However, the lack of infrastructure and the remote location of the affected areas made it difficult to provide aid. The government mobilized 25,000 military personnel and 3,000 vehicles to help with the rescue efforts. International aid also poured in, with countries from around the world offering assistance.

The impact of the earthquake was severe, with thousands of buildings collapsed or severely damaged. The official death toll initially stated 69,000 fatalities and 11,000 injuries, but the number was expected to rise as rescue and recovery efforts continued. The earthquake also triggered landslides, which added to the damage in the area.

The earthquake resulted in widespread destruction, with many buildings and infrastructure collapsing. The government and international aid organizations worked tirelessly to provide relief to the affected population. The aftermath of the earthquake highlighted the need for better earthquake preparedness and response strategies.

The earthquake highlighted the need for better earthquake preparedness and response strategies. The government and international aid organizations worked tirelessly to provide relief to the affected population. The aftermath of the earthquake highlighted the need for better earthquake preparedness and response strategies.
Conclusion

• Web reports about earthquakes have evolved since 1995 due to GPS, digital cameras, and web technologies.
  • Contain quantitative information on positions, times and characteristics of observations.
• Virtual earthquakes
  • Harvest data from photo repositories and other sources.
  • Metamorphose web/map reports using geo-coding and photo metadata.
  • Reproduce and share field experiences
  • Involve the public
• Virtual earthquakes may have profound impacts for
  • Research and education
  • Teaching everyone about earthquakes
  • Training rescue teams
  • Making a safer world.
Thank You

http://gees.usc.edu/GEES