Why Price Gouging is Immoral: Recovering from Disasters

IEPA Guest Speaker: Dr. Elizabeth Brake

5:30 PM
Wednesday, October 17, 2018
Batten Arts and Letters Building
RM 1012

Free & Open to the Public

philosophy@odu.edu
Natural Hazards and Disaster

Class 5: Disasters Triggered by Earthquakes and Tsunamis
- Magnitude and Locations
- Cases
- Extreme Events
- Managing Disaster Risk
- Tsunamis
2018 Sulawesi earthquake and tsunami

UTC time: 2018-09-28 10:02:44
ISC event: 612780996
USGS-ANSS: ComCat
Local date: 28 September 2018
Local time: 18:02:44 WITA (Indonesia Central Standard Time)
Magnitude: $M_w$ 7.4
Depth: 10.0 km
Epicentre: 0.178°S 119.840°E
Fault: Palu-Koro fault
Type: Strike-slip
Max. intensity: IX (Violent)
Tsunami: Yes (highest 7 m (23 ft) in Donggala Regency)
Landslides: Yes
Foreshocks: $M_w$ 6.1, M5.4, M5.0
Aftershocks: Five M≥5.5
Casualties:
- 1,347 dead
- 632 injured
- 100+ missing
- 48,025 evacuated

Casualties (Oct. 2, 2018):
• 1,347 dead (initial: 80)
• 632 injured
• 100+ missing
• 48,025 evacuated

In Indonesia, Aftershocks And Uncertainty Remain After Deadly Earthquake

October 2, 2018 - 4:27 AM ET

EMILY SULLIVAN

Rescuers assist 15-year old earthquake victim Nural Ilsharah from flood water in her damaged house following earthquakes and tsunami in Palu, Central Sulawesi, Indonesia on Sept. 30.
The tsunami caught geologists by surprise. Since the earthquake was a **strike-slip earthquake**, the tsunami was expected to be at a low height, with a maximum height of approximately 2 metres. During a strike-slip earthquake, the movements of the crusts were largely in horizontal motion while most tsunamis occurred in earthquakes with vertical motion. One explanation is that the earthquake triggered underwater landslides, causing the tsunami.


This photo layout of satellite images provided by DigitalGlobe shows the Petobo neighborhood of Palu, Indonesia, on Aug. 17, prior to the earthquake, left, and on Oct. 1, devastated by the subsequent tsunami, right.

*DigitalGlobe, a Maxar company via AP*
Natural Hazards and Disaster

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The total energy of all explosives used in World War II, including the Hiroshima and Nagasaki atom bombs: 3 megatons TNT

- Average seismic energy: ~0.000010 TerraWatt
- Human energy usage: ~20 TerraWatt,
- Solar energy to earth: ~89,000 TerraWatt

Century average ≈ 80 megatons/year:
40% from Mw>8.5 earthquakes
Magnitude and Location

7d

Number of Deaths

7b

Total Damage
80 Mt/year for 7 billion people is equivalent to ≈11 kg of TNT per person per year
Assuming that a stick of dynamite = 1 lb

Earthquake energy release is equivalent to 2 sticks of dynamite per person per month

FROM Mw > 8.5

FROM ALL OTHER EARTHQUAKES
Magnitude and Location

[Map showing various earthquakes around the world with different colors indicating deadliness, magnitude, and combination of both.]
Magnitude and Location

Most deaths from M<7.5 plate interior earthquakes.

Fewer deaths from much larger plate boundary earthquakes.
Magnitude and Location

1000 years of earthquake deaths

84% earthquake deaths in 12% of land area
City size exploded after 1800
When cities became no longer a place to die.
Magnitude and Location

earthquake deaths per country since 1500

number of 10,000/event earthquakes
The problem: Too many people in poorly constructed buildings

“Earthquake don’t kill people, buildings do!”
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1556 Shaanxi earthquake or Huaxian earthquake:
- deadliest earthquake on record,
- approximately 830,000 death,
- in some counties 60% of the population killed,
- built infrastructure: mostly yaodongs, artificial caves in loess cliffs,
- epicenter was in the Wei River Valley in Shaanxi Province, near the cities of Huaxian, Weinan and Huayin,
- in Huatian, every single building and home was demolished,
- in certain areas, crevices 20 m deep opened,
- landslides contributed to the death toll.
San Andreas Fault slipped along a segment about 430 km long,

Shaking was felt from Los Angeles in the south to Coos Bay, Oregon, in the north.

Damage was severe in San Francisco and in other towns situated near the fault, including San Jose, Salinas, and Santa Rosa.
Cases

Apr. 18, 1906 San Francisco, Mw=7.9, I=XI,
Depth 8 km, Deaths 700 - 3,000
Cases

Sep. 19, 1985 Mexico City, Mw=8.0, I=IX, Depth 20 km, Deaths 10,000 (up to 45,000)

- Central city is constructed on the dry bed of the drained Lake Texcoco.
- There, heaviest shaking because loose lacustrine sediments amplified the shock waves.
- Ground motion there measured five times that of surrounding areas.
- Buildings of 5 to 15 stories were most affected.
- Their eigenperiod resulted in harmonic resonance.
- More than 400 buildings collapsed, and thousands more were damaged.

- Soil liquefaction contributed to the extensive damage in the southern part of the city.
- The liquefaction of the soft lake sediments amplified the effect of the surface waves, particularly at periods between 2 and 5 s.
Cases

Jan. 17, 1995, Kobe, Japan, Mw=6.9, I=XI
Depth 17.6 km, Deaths 5,502-6,400,
Damage $200 billion

- Structures damaged beyond repair included nearly 400,000 buildings, numerous elevated road and rail bridges, and 120 of the 150 quays in the port of Kobe.
- Triggered around 300 fires.
- Disruptions of water, electricity and gas supplies were extremely common.

USGS ShakeMap: Kobe, Japan

Map Version 1.1 Processed Sat Nov 8, 2008 06:19:38 PM MST


case history

Depth Scale

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<th>Depth</th>
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<tr>
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<td>USGS</td>
</tr>
<tr>
<td>TT</td>
<td>15.0</td>
<td>USGS</td>
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<tr>
<td>TTI</td>
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<td>USGS</td>
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density of population

<table>
<thead>
<tr>
<th>Density</th>
<th>Population</th>
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<tr>
<td>High</td>
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</tr>
<tr>
<td>Medium</td>
<td>5,000</td>
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<tr>
<td>Low</td>
<td>1,000</td>
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</tbody>
</table>


damage distribution

<table>
<thead>
<tr>
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<th>Scale</th>
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<td>Minor</td>
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<tr>
<td>Moderate</td>
<td>2</td>
</tr>
<tr>
<td>Severe</td>
<td>3</td>
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</table>


cost of damage

<table>
<thead>
<tr>
<th>Damage</th>
<th>Cost of Damage</th>
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<tr>
<td>Minor</td>
<td>$100 million</td>
</tr>
<tr>
<td>Moderate</td>
<td>$500 million</td>
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<tr>
<td>Severe</td>
<td>$1 billion</td>
</tr>
</tbody>
</table>


central region

- Kobe
- Osaka
- Kurume


case history

- January 17, 1995
- Mw=6.9
- Depth 17.6 km
- Deaths 5,502-6,400
- Damage $200 billion

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- Triggered around 300 fires.
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Cases

Oct. 8, 2005, Azad Kashmir, Mw=7.6, I=VIII, Depth 26 km
Deaths 86,000 to 87,000, Damage $5.2 billion

- The tremors were felt at a distance of up to 620 miles (1,000 km), as far away as Delhi and Punjab in northern India.
- The property loss caused by the quake left an estimated four million area residents homeless.
- The severity of the damage and the high number of fatalities were exacerbated by poor construction in the affected areas.
Cases

Oct. 8, 2005, Azad Kashmir, Mw=7.6, I=VIII, Depth 26 km
Death 86,000 to 87,000, Damage $5.2 billion

North-South profile of the present Indian-Eurasian plate boundary, with approximate focal depths of the 2005 Kashmir (blue star) and 2015 Nepal (red star) earthquakes.

The Indian Plate’s northward migration culminated in continent-continent collision at between 50 and 40 million years ago, causing the uplift of the Himalayas. Epicenters marked by stars on Google Earth image for the 2005 Kashmir (blue) and 2015 Nepal (red) earthquakes.
Oct. 8, 2005, Azad Kashmir, Mw=7.6, l=VIII, Depth 26 km
Death 86,000 to 87,000, Damage $5.2 billion

Example earthquake Mw=7.6 Kashmir 2005
official death toll after 2 months 82,000

30 minute death toll high attenuation
7,000-14,000 dead
30 minute death toll low attenuation
27,000-52,000 dead

24 hour death toll with focal mechanism
29,000-56,000 dead

Death causes for most earthquakes:
First 2 hours 20% of deaths: asphyxia from dust inhalation or chest compression, hypovolemic shock, or hypothermia.

Days 1-3 80% of deaths
Delayed death occurs within days due to dehydration, hypothermia, hyperthermia, crush syndrome, wound infections, or postoperative sepsis.
Cases

Oct. 8, 2005, Azad Kashmir, Mw=7.6, I=VIII, Depth 26 km
Death 86,000 to 87,000, Damage $5.2 billion

Apr. 25, 2015, Nepal, Mw=7.8, Depth 15 km
Death: 9,000, Damage: $10 billion (50% of Nepal’s GDP)
Cases

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Deaths: 9,000, Damage: $10 billion (50% of Nepal’s GDP)

May 12, 2015, Nepal, Mw=7.3, Depth 15 km
Deaths: 218
Cases

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Deaths: 218

Destruction in Punjab, Pakistan Kashmir, caused by 23 seconds of ground shaking during the October 2005, Mw7.6 earthquake.

Nepalese village near Gorkha destroyed by a landslide that occurred during the April 2015, Mw 7.8 earthquake.
Cases

Jan. 12, 2010, Haiti, Mw=7.0, I=VIII, Depth 13 km
Deaths 80,000 to 315,000

- Generated by contractional deformation along the Léogâne fault,
- A small hidden thrust fault discovered underneath the city of Léogâne. Descends northward at an oblique angle away from the Enriquillo–Plantain Garden (EPG) strike-slip fault system
- Earthquake resulted from the slippage of rock upward across its plane of fracture.
Jan. 12, 2010, Haiti, Mw=7.0, I=VIII, Depth 13 km
Deaths 80,000 to 315,000
Cases

Jan. 12, 2010, Haiti, Mw=7.0, I=VIII, Depth 13 km
Deaths 80,000 to 315,000

“… the Enriquillo fault in Haiti is currently capable of a Mw7.2 earthquake if the entire elastic strain accumulated since the last major earthquake was released in a single event today” (Manaker et al., 2008)

Ismail-Zadeh, 2011
Apr. 6, 2009, L’Aquila M 6.3, I=VIII, Depth 9.5 km
Deaths 309, Damage $16 billion

- Occurred in the region of Abruzzo, in central Italy.
- L’Aquila, the capital of Abruzzo, suffered most damage.
- There were several thousand foreshocks and aftershocks since December 2008. More than thirty of which had magnitude greater than 3.5.
- Deadliest earthquake to hit Italy since the 1980 Irpinia earthquake.
Cases

Apr. 6, 2009, L’Aquila M 6.3, I=VIII, Depth 9.5 km
Deaths 309, Damage $16 billion

• Poor building standards led to the failure of many modern buildings in a known earthquake zone:
• Official at Italy’s Civil Protection Agency, Franco Barberi, said that “in California, an earthquake like this one would not have killed a single person”.
Apr. 6, 2009, L’Aquila M 6.3, I=VIII, Depth 9.5 km
Deaths 309, Damage $16 billion

(Chiaraluce et al., 2011)
Cases

Apr. 6, 2009, L’Aquila M 6.3, I=VIII, Depth 9.5 km
Deaths 309, Damage $16 billion

Before the Earthquake:

- The rate of earthquake production increased on March 30th 2009 after a M_l 4.1 earthquake that struck the L’Aquila area
- Preoccupation and panic in population raised
- After a prediction broadcasted by Giuliani, vans mounted with loudspeakers blare warnings to Sulmona residents to flee. Many people do. No earthquake occurs in the prediction window.
- On March 31st the Italian Civil Protection organize in L’Aquila a meeting of the Commissione Grandi Rischi (Major Risks Committee), an expert group that advises the Civil Protection agency on the risks of natural disasters
- Immediately after that meeting, De Bernardinis and Barberi, acting president of the committee, held a press conference in L’Aquila, where De Bernardinis told reporters that “the scientific community tells us there is no danger, because there is an ongoing discharge of energy. The situation looks favorable”.

Subsequently, seven members of the Italian National Commission for the Forecast and Prevention of Major Risks were accused of giving "inexact, incomplete and contradictory" information about the danger of the tremors prior to the main quake.
- On 22 October 2012, six scientists and one ex-government official were convicted of multiple manslaughter for downplaying the likelihood of a major earthquake six days before it took place.
- They were each sentenced to six years' imprisonment.
- On 10 November 2014, the verdict was overturned.
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Extreme Events

How Big, How Bad, How Often?
## Extreme Events

### 20 largest earthquakes (hazards) recorded since 1900

<table>
<thead>
<tr>
<th>Mag</th>
<th>Location</th>
<th>Date (UTC)</th>
<th>Time (UTC)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Death</th>
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<tbody>
<tr>
<td>1.95</td>
<td>Chile Valdivia Earthquake</td>
<td>1960-05-22</td>
<td>19:11</td>
<td>38.14°S</td>
<td>73.41°W</td>
<td>5,700</td>
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<tr>
<td>2.92</td>
<td>Great Alaska Earthquake</td>
<td>1964-03-28</td>
<td>03:36</td>
<td>60.91°N</td>
<td>147.34°W</td>
<td>125</td>
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<tr>
<td>3.91</td>
<td>Sumatra-Andaman Islands Earthquake</td>
<td>2004-12-26</td>
<td>00:58</td>
<td>3.30°N</td>
<td>95.98°E</td>
<td>230,000–300,000</td>
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<tr>
<td>3.91</td>
<td>Tohoku Earthquake</td>
<td>2011-03-11</td>
<td>05:46</td>
<td>38.30°N</td>
<td>142.37°E</td>
<td>15,870</td>
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<tr>
<td>4.90</td>
<td>Kamchatka, Russia</td>
<td>1952-11-04</td>
<td>16:58</td>
<td>52.62°N</td>
<td>159.78°E</td>
<td>1,000</td>
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<tr>
<td>5.88</td>
<td>Chile Maule Earthquake</td>
<td>2010-02-27</td>
<td>06:34</td>
<td>36.12°S</td>
<td>72.90°W</td>
<td>523</td>
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<td>5.88</td>
<td>1906 Ecuador–Colombia Earthquake</td>
<td>1906-01-31</td>
<td>15:36</td>
<td>0.96°N</td>
<td>79.37°W</td>
<td>1000</td>
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<tr>
<td>5.87</td>
<td>Rat Islands Earthquake</td>
<td>1965-02-04</td>
<td>05:01</td>
<td>51.25°N</td>
<td>178.72°E</td>
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<tr>
<td>5.86</td>
<td>Assam, Tibet</td>
<td>1950-08-15</td>
<td>14:09</td>
<td>28.36°N</td>
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<td>6.86</td>
<td>off West Coast of Northern Sumatra</td>
<td>2012-04-11</td>
<td>08:39</td>
<td>2.33°N</td>
<td>93.06°E</td>
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<td>6.86</td>
<td>Indonesia Nias Earthquake</td>
<td>2005-03-28</td>
<td>16:10</td>
<td>2.09°N</td>
<td>97.11°E</td>
<td>1,303</td>
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<tr>
<td>6.86</td>
<td>Andreanof Islands, Alaska</td>
<td>1957-03-09</td>
<td>14:23</td>
<td>51.50°N</td>
<td>175.63°W</td>
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<td>6.86</td>
<td>Unimak Island Earthquake, Alaska</td>
<td>1946-04-01</td>
<td>12:29</td>
<td>53.49°N</td>
<td>162.83°W</td>
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<td>Banda Sea</td>
<td>1938-02-01</td>
<td>19:04</td>
<td>5.05°S</td>
<td>131.61°E</td>
<td>0</td>
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<td>7.85</td>
<td>Atacama, Chile</td>
<td>1922-11-11</td>
<td>04:33</td>
<td>28.29°S</td>
<td>69.85°W</td>
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<td>1963-10-13</td>
<td>05:18</td>
<td>44.87°N</td>
<td>149.48°E</td>
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<td>Kamchatka, Russia</td>
<td>1923-02-03</td>
<td>16:02</td>
<td>54.49°N</td>
<td>160.47°E</td>
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<td>Southern Sumatra, Indonesia</td>
<td>2007-09-12</td>
<td>11:10</td>
<td>4.44°S</td>
<td>101.37°E</td>
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<td>8.84</td>
<td>Peru Earthquake</td>
<td>2001-06-23</td>
<td>20:33</td>
<td>16.27°S</td>
<td>73.64°W</td>
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<td>Japan Sanriku Japan</td>
<td>1933-03-02</td>
<td>17:31</td>
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<td>XI</td>
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<td>XI</td>
<td>1000 c</td>
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<td>142,800</td>
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<td>1948</td>
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<tr>
<td>1970</td>
<td>Chimbote, Peru</td>
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<td></td>
<td>70,000 b</td>
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<tr>
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<td>X</td>
<td>240,000</td>
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</table>

a: tsunami caused many death  
b: landslides caused many death  
c: fires caused many death
<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Mag.</th>
<th>Int.</th>
<th>Deaths</th>
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<td>Spitak, Armenia</td>
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<td>X</td>
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<td>1990</td>
<td>Manjil, Iran</td>
<td>7.4</td>
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<td>1995</td>
<td>Kobe, Japan</td>
<td>6.9</td>
<td>XI</td>
<td>5,502 c</td>
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<tr>
<td>1999</td>
<td>Izmit, Turkey</td>
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<td>X</td>
<td>17,000</td>
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<td>2001</td>
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<td>X</td>
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<td>2004</td>
<td>Aceh, Sumatra</td>
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<td>VIII</td>
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<td>2008</td>
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<td>IX</td>
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<td>2010</td>
<td>Haiti</td>
<td>7.0</td>
<td>IX</td>
<td>&gt;80,000</td>
</tr>
<tr>
<td>2011</td>
<td>Japan</td>
<td>9.0</td>
<td>VIII</td>
<td>&gt;16,000 a</td>
</tr>
<tr>
<td>2015</td>
<td>Kathmandu, Nepal</td>
<td>7.8</td>
<td>IX</td>
<td>8,300</td>
</tr>
</tbody>
</table>

a: tsunami caused many death
b: landslides caused many death
c: fires caused many death
## Extreme Events

<table>
<thead>
<tr>
<th>Year</th>
<th>Date (UT)</th>
<th>Region</th>
<th>Deaths</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>856</td>
<td>December</td>
<td>Greece, Corinth</td>
<td>45,000</td>
<td>?</td>
</tr>
<tr>
<td>1290</td>
<td>September 27</td>
<td>China, Chihli</td>
<td>100,000</td>
<td>6.8</td>
</tr>
<tr>
<td>1556</td>
<td>January 23</td>
<td>China, Shensi</td>
<td>830,000</td>
<td>8.3</td>
</tr>
<tr>
<td>1755</td>
<td>June 7</td>
<td>Northern Persia</td>
<td>40,000</td>
<td>5.9</td>
</tr>
<tr>
<td>1755</td>
<td>November 1</td>
<td>Portugal, Lisbon</td>
<td>70,000</td>
<td>8.7</td>
</tr>
<tr>
<td>1908</td>
<td>December 28</td>
<td>Italy, Messina</td>
<td>120,000</td>
<td>7.5</td>
</tr>
<tr>
<td>1920</td>
<td>December 16</td>
<td>China, Kansu</td>
<td>180,000</td>
<td>8.5</td>
</tr>
<tr>
<td>1923</td>
<td>September 1</td>
<td>Japan, Tokyo</td>
<td>143,000</td>
<td>8.2</td>
</tr>
<tr>
<td>1960</td>
<td>February 29</td>
<td>Morocco, Agadir</td>
<td>14,000</td>
<td>5.9</td>
</tr>
<tr>
<td>1970</td>
<td>May 31</td>
<td>Peru</td>
<td>66,000</td>
<td>7.8</td>
</tr>
<tr>
<td>1976</td>
<td>July 27</td>
<td>China, Tangshan</td>
<td>~ 500,000</td>
<td>7.6</td>
</tr>
<tr>
<td>1985</td>
<td>September 19</td>
<td>Mexico, Michoacán</td>
<td>9,500</td>
<td>7.9</td>
</tr>
</tbody>
</table>

Wong, 2011
The problems:
- knowledge of rare events is limited
- know better the “why” and “how” but not the “when”
- probability is difficult to assess
- risk assessment is challenged

Assessing impacts: X-ness (Casti, 2012):

\[ X = \frac{\delta E}{E} \left(1 - \frac{U}{U + I}\right) \]

X: X-ness
\( \delta E \): Impacted ensemble (population, GDP, ...)
U: Unfolding time
I: Impact time

Poisson distribution; Chance that one or more “1 in \( N \) years” events occur in a century:

<table>
<thead>
<tr>
<th>( N )</th>
<th>C in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>99.99</td>
</tr>
<tr>
<td>100</td>
<td>63.21</td>
</tr>
<tr>
<td>500</td>
<td>18.13</td>
</tr>
<tr>
<td>1,000</td>
<td>9.516</td>
</tr>
<tr>
<td>10,000</td>
<td>0.995</td>
</tr>
<tr>
<td>100,000</td>
<td>0.100</td>
</tr>
</tbody>
</table>

In the 20th century we may have been lucky ...
Extreme Events

- Tsunami
- Earthquake
- Earthquake
- Cyclone
- Earthquake

![Bar chart showing extreme events]

- Total deaths
- Uncertainty in deaths
- Percentage of population killed
- Uncertainty in percentage

- Aceh, 2004 Tsunami
- Pakistan, 2005 Earthquake
- Sichuan, 2008 Earthquake
- Burma, 2008 Cyclone
- Haiti, 2010 Earthquake
Extreme Events

How Big, How Bad, How Often?

- The 2004 moment magnitude (M) 9.2 Sumatra and 2011 M 9.0 Tohoku, Japan earthquakes can be regarded as “extreme” events because in the past 200 years, less than 10 earthquakes have reached M 9.0 or greater.

- Both earthquakes can also be regarded as extreme events because of the devastating loss of life.

- However, the 2010 M 7.0 Haiti earthquake is also an extreme event because more than 80,000 deaths occurred even though it was of moderate size.
Extreme Events

How Big, How Bad, How Often?

Probabilistic Seismic Hazard Analysis (PSHA)

• The objective of PSHA is to answer the questions: How big, how bad, and how often?

• The latter can only be answered if the frequency of earthquake occurrence is an input into the analysis.

• This type of seismic hazard analysis is in contrast to a deterministic (scenario) analysis where the earthquake rates are not considered. Sometimes erroneously called a worse-case scenario analysis.

• Probabilistic hazard can be for ground shaking, tsunami inundation, fault displacement, slope failure, or liquefaction.
Extreme Events

How Big, How Bad, How Often?

Probabilistic Seismic Hazard Analysis (PSHA)

• The uncertainties in our knowledge of earthquake behavior need to be adequately included in PSHAs.

• However, even then there is no guarantee that all extreme events will be recognized; there are always unanticipated surprises.

• We must recognize that the results of even the best PSHAs have a limited “guarantee”.

• Although stability is sought in hazard predictions, the record suggests that hazard estimates may only be stable for a decade at best.

• Decisions should be and are based on risk rather than hazard because its the consequence of the hazards that we are concerned about.

• However, even when extreme events and their associated hazards are predicted, decisions to mitigate the impacts from such extreme events are likely put aside because of economic and societal limitations and competing demands.
Extreme Events

- Earthquakes do not kill people, but buildings (corruption, irresponsibility, ignorance …)
- Geohazards cannot be reduced, but vulnerability!
- Reducing predictive uncertainties in geohazard research and enhancing modeling capabilities
- Dealing with multiple and/or sequential events
- Developing a trans-disciplinary link and research
- Developing links to policy-makers, media & insurance
- Enhancing science education and improving awareness on extreme hazards and disaster risk

Ismail-Zadeh, 2011
Natural Hazards and Disaster

Class 5: Disasters Triggered by Earthquakes and Tsunamis

- Magnitude and Locations
- Cases
- Extreme Events
- Managing Disaster Risk
- Tsunamis
How large is the risk?
Managing Disaster Risk

Average cost earthquakes 1999-2011 = $35 billion/yr

$5/person per year
i.e. earthquakes are surprisingly affordable.

However cost is mostly born by the industrial world ($50/person/year)

LIFE IS WORTH HOW-MUCH?

From religion $\infty$ (Life is priceless etc)
9/11 WTC $1.6$ million/life
IPCC $6.1$ million/life
Of cheap things it is the cheapest”
The Sea-Wolf 1904

from cost/death regression
1 death = $10$ million

Reconstruction cost (US$ billion) vs. earthquake deaths

100 deaths per billion dollars

Haiti'10
Kashmir'05
Izmit'99
Indonesia'04
Armenia'88
Wenchuan'08
Bam'03
Bhuj'01
Mexico'85
Chile'10
Greece'99
NZ'11
Northridge'94
Nigata'95
Kobe'04
Tohuko 2011
Managing Disaster Risk

Deaths per decade since earthquake resistance implemented

Ten years 600k deaths $400 billion
Worst case? 1 million fatality event every 100 yr
Managing Disaster Risk

Potential Disasters
Americas

red=fatal earthquakes, green =cities
Managing Disaster Risk

southern margin of EuroAsian plate: 85% of all fatalities from earthquakes

Supercity growth EuroAsian convergence zone
Managing Disaster Risk

1000 million new dwelling units, mostly in the developing world

An educated world will be a more resilient world
A century of earthquake resistant construction

Deaths per earthquake

Magnitude, Mw
Managing Disaster Risk

Corruption and Disasters

90% of all deaths from earthquakes in low-income, excessively-corrupt nations
future earthquakes will target civilization's weaknesses

The fix........
for ignorance = education
for poverty = education
for corruption = education
Issues with Predictions:

FAILURES

False negative - unpredicted hazard

• Loss of life & property

False positive - overpredicted hazard

• Wasted resources, public loses confidence
  • Authorities typically ignore, deny, excuse, or minimize failure
  • More useful to analyze failures to improve future performance
Managing Disaster Risk

Perils of prediction: are scientists prepared to warn the public about geologic hazards?

The local economy collapsed, said Glenn Thompson, Mammoth Lakes’ town manager. Housing prices fell 40 percent overnight. In the next few years, dozens of businesses closed, new shopping centers stood empty and townspeople left to seek jobs elsewhere. (NYT 9/11/90)
Managing Disaster Risk

Issues with assessments

Mar. 11, 2011, Japan, Mw=9.0-9.1, I=IX, Depth 29 km
Death >15,900

Japan spent lots of effort on national hazard map, but

2011 M 9.1 Tohoku, 1995 Kobe M 7.3 & others in areas mapped as low hazard

In contrast: map assumed high hazard in Tokai “gap”

Geller 2011
Issues with assessments

Hazard maps fail because of

- bad physics (incorrect description of earthquake processes)
- bad assumptions (mapmakers’ choice of poorly known parameters)
- bad data (lacking, incomplete, or underappreciated)
- bad luck (low probability events)

and combinations of these (Tohoku!)
Natural Hazards and Disaster

Class 5: Disasters Triggered by Earthquakes and Tsunamis
- Magnitude and Locations
- Cases
- Extreme Events
- Managing Disaster Risk
- Tsunamis
Class 5: Disasters Triggered by Earthquakes and Tsunamis
- Waves
- Tsunamis
- Earthquake Tsunamis
- Landslide Tsunamis
- Tsunami Detection, Prediction and Awareness

“Harbor Wave”

Katsushika Hokusai (1760–1849)
Waves
### Waves

<table>
<thead>
<tr>
<th>Type</th>
<th>Wavelength</th>
<th>Period</th>
<th>Forcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>wind waves</td>
<td>up to a few 100 m</td>
<td>seconds to minutes</td>
<td>wind</td>
</tr>
<tr>
<td>tidal waves</td>
<td>$10^2$ to $10^4$ m</td>
<td>0.5 days, 1 day, 2 weeks, 1 months, 1 year</td>
<td>moon, sun, planets</td>
</tr>
<tr>
<td>tsunamis</td>
<td>in open ocean: several $10^2$ km</td>
<td>10 to 30 minutes</td>
<td>earthquakes, landslides, volcanic eruptions</td>
</tr>
</tbody>
</table>
Waves

Water waves only affect the uppermost part of the water …
Waves

Water waves only affect the uppermost part of the water …

… unlike ground surface waves that can affect a deeper section of rock
Waves

Water waves only affect the uppermost part of the water ...

Velocity $V$ is wavelength dependent

$$V = \frac{\lambda}{P}$$

Period ($P$) = time for passage of 1 wavelength

amplitude = wave height/2

wave height

wavelength

crest

trough
Waves

Water waves only affect the uppermost part of the water ...

Velocity $V$ is wavelength dependent

$V = \frac{\lambda}{P}$

Period ($P$) = time for passage of 1 wavelength
Waves
Waves

as waves reach shallow water, wavelength decreases & wave height increases

constant, very long wavelength in deep water

http://www.tulane.edu/~sanelson/images/tsunami_wave.gif
as waves reach shallow water, wavelength decreases & wave height increases

constant, very long wavelength in deep water
as waves reach shallow water, wavelength decreases & wave height increases

constant, very long wavelength in deep water

almost undetectable by boats in deep ocean

http://www.tulane.edu/~sanelson/images/tsunami_wave.gif

http://isaac.exploratorium.edu/~pauld/summer_institute/cset/Tsunamishore.jpg
Waves

as waves reach shallow water, wavelength decreases & wave height increases
constant, very long wavelength in deep water

normal waves break

almost undetectable by boats in deep ocean
Waves

As waves reach shallow water, wavelength decreases & wave height increases.

Constant, very long wavelength in deep water.

Tsunamis surge.

Almost undetectable by boats in deep ocean.
Waves

as waves reach shallow water, wavelength decreases & wave height increases

constant, very long wavelength in deep water

normal waves break

tsunamis SURGE

almost undetectable by boats in deep ocean

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http://www.northcoastjournal.com/media/issues/032008/SCI-tsunami-wave-break-surge.jpg

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http://isaac.exploratorium.edu/~pauld/summer_institute/cset/Tsunamishore.jpg
Waves

As waves reach shallow water, wavelength decreases & wave height increases. Constant, very long wavelength in deep water.

Tsunamis surge are almost undetectable by boats in deep ocean.
Class 5: Disasters Triggered by Earthquakes and Tsunamis

- Waves
- Tsunamis
- Earthquake Tsunamis
- Landslide Tsunamis
- Tsunami Detection, Prediction and Awareness

“Harbor Wave”

Katsushika Hokusai (1760–1849)
wave height is greatly exaggerated in this image!
Tsunamis

wave height is greatly exaggerated in this image!

surge front

tsunami surge

http://www.erh.noaa.gov/okx/tsunamipic.jpg
Tsunamis
Tsunamis

first indication of approaching tsunami may be rapidly receding ocean

source: Pearson.com earthscience publications
Tsunamis

First indication of approaching tsunami may be rapidly receding ocean.

A tsunami will have more than one destructive surge until waves lose energy.
Tsunamis

In the open ocean a tsunami is less than a few tens of centimeters (1 ft) high at the surface, but its wave height increases rapidly in shallow water. Tsunami wave energy extends from the surface to the bottom in even the deepest waters. As the tsunami attacks the coastline, the wave energy is compressed into a much shorter distance and a much shallower depth, creating destructive, life-threatening waves. As shown in this figure, tsunamis are a series of waves that can be destructive for hours. Although not depicted, the 1st wave may not be the largest.

Calculated tsunami travel times for the December 26, 2004 earthquake off western Sumatra. Each concentric curve represents 30 minutes of tsunami travel time. Destructive tsunami hit Indonesia in 15 minutes, Sri Lanka in two hours, and Kenya nine hours after the earthquake (NOAA PMEL).

Maximum calculated global wave heights (cm) from the December 26, 2004 Indian Ocean tsunami. Waves were recorded on sea level gauges in Antarctica, and along the coasts of South and North America and Canada in both the Pacific and Atlantic Oceans (NOAA PMEL).

Natural Hazards and Disaster

Class 5: Disasters Triggered by Earthquakes and Tsunamis

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“Harbor Wave”

Katsushika Hokusai (1760–1849)
Earthquake Tsunamis

- Sumatra-Andaman Megathrust
- Sumatra plate thrusts over the subducting Indian Ocean plate.

Dec 26, 2004 hypocenter
Mw 9.2 earthquake

Site of numerous large magnitude earthquakes in historical times
Earthquake Tsunamis

December 26, 2004

Sudden thrust upward of Sumatra plate generated an initial upwards pressure wave 4m to 8m high in the ocean...

...resulting in a wave that spread out and across the Indian Ocean
Earthquake Tsunamis

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Earthquake Tsunamis

December 26, 2004

Sudden thrust upward of Sumatra plate generated an initial upwards pressure wave 4m to 8m high in the ocean...

...resulting in a wave that spread out and across the Indian Ocean

note: time is in minutes!
Earthquake Tsunamis

December 26, 2004

Sudden thrust upward of Sumatra plate generated an initial upwards pressure wave 4m to 8m high in the ocean...

...resulting in a wave that spread out and across the Indian Ocean

In the open ocean, tsunamis travel at a speed of >200 m/s (>720 km/h)
Earthquake Tsunamis

Damage from December 2004 tsunami

Banda Aceh

almost total destruction in some areas
Earthquake Tsunamis

280,000 killed, millions made homeless
Natural Hazards and Disaster

Class 5: Disasters Triggered by Earthquakes and Tsunamis

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- Tsunamis
- Earthquake Tsunamis
- Landslide Tsunamis
- Tsunami Detection, Prediction and Awareness

“Harbor Wave”

Katsushika Hokusai (1760–1849)
Landslide Tsunamis

Why are submarine landslide tsunamis extreme?

- The landslides
  - May occur "anywhere" on the continental margins, also on very gentle slopes
  - Have extreme volumes, velocities, and travel distances
  - "Unpredictable" ⇒ Unprepared ⇒ Extreme consequences

The 8200 BP Storegga slide
Volume: 2400 km³
Max speed: 35 m/s
Run-out distance: 150 (800) km

http://www.geohazcop.org/workshops/Sant_Feliu_2011/
Landslide Tsunamis

Source location for all recorded tsunamis in the Caribbean – first data from year 1498

SE Asia

- 20% non-seismic
- ca. 2/3 are volcanic
- and 1/3 landslides, also combined with earthquakes

http://www.geohazcop.org/workshops/Sant_Feliu_2011/
Landslide Tsunamis

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- 20% non-seismic
- ca. 2/3 are volcanic
- and 1/3 landslides, also combined with earthquakes

http://www.geohazcop.org/workshops/Sant_Feliu_2011/
What about La Cumbre Vieja volcano, La Palma?

Ward & Day 2001: Great danger to US East Coast

Wynn & Masson 2003: Danger greatly overestimated - slide volume likely much smaller

Gisler, Weaver & Gittings 2006: Even with maximal slide, danger to US minimal

Løvholt, Pedersen & Gisler 2008: Maximal slide constitutes some danger to US East coast, severe danger to shores of Europe and Africa

- Need to look closer at realistic slide scenarios for La Palma

Landslide Tsunamis

Anatomy of a catastrophe: the 1936 mass wasting and tsunami event in the Nordfjord region, western Norway

http://www.academia.edu/446006/Anatomy_of_a_catastrophe_the_1936_mass_wasting_and_tsunami_event_in_the_Nordfjord_region_western_Norway

http://theforeigner.no/pages/columns/just-when-you-thought-it-was-safe-to-go-back-into-the-fjord/

20th century rock fall records in Lovatnet

<table>
<thead>
<tr>
<th>Date</th>
<th>Volume rock (m³)</th>
<th>Fallout (m asl)</th>
<th>Maximum run-up (m)</th>
<th>No. of casualties</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.01.1905</td>
<td>50,000</td>
<td>500</td>
<td>40.5</td>
<td>61</td>
</tr>
<tr>
<td>20.06.1960</td>
<td>ca. 15,000</td>
<td>400</td>
<td>&gt;40</td>
<td>0</td>
</tr>
<tr>
<td>13.12.1938</td>
<td>1 million</td>
<td>800</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>21.06.1938</td>
<td>ca. 100,000</td>
<td>500</td>
<td>ca. 45</td>
<td>5</td>
</tr>
<tr>
<td>06.10.1936</td>
<td>7</td>
<td>800</td>
<td>?</td>
<td>0</td>
</tr>
<tr>
<td>11.11.1938</td>
<td>1 million</td>
<td>800</td>
<td>&gt;74</td>
<td>0</td>
</tr>
<tr>
<td>22.06.1980</td>
<td>ca. 1 million</td>
<td>800</td>
<td>ca. 15</td>
<td>0</td>
</tr>
</tbody>
</table>

Based on Grimstad and Neodal (1991)

The 1936 tsunami

Numerical model

Wave height map

http://www.academia.edu/446006/Anatomy_of_a_catastrophe_the_1936_mass_wasting_and_tsunami_event_in_the_Nordfjord_region_western_Norway
The tsunami hit the village of Nuugaatsiaq just after 23:00 local time on June 17 (01:00 UTC on June 18), sweeping away 11 houses and leaving 4 people dead and 9 injured, 2 of them seriously.
Natural Hazards and Disaster

Class 5: Disasters Triggered by Earthquakes and Tsunamis
- Waves
- Tsunamis
- Earthquake Tsunamis
- Landslide Tsunamis
- (Tsunami Detection, Prediction and Awareness)

“Harbor Wave” by Katsushika Hokusai (1760–1849)
See Class 6