The Great East Japan Earthquake
March 11, 2011

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Synopsis of 2011 Tōhoku earthquake

• At 14:46 local time on March 11, 2011, a magnitude 9.0 earthquake occurred off the coast of northeast Japan. The epicenter coordinates are 38.322 N, 142.368 E, 129 km from Sendai, Honshu, Japan. The depth of the event was 24 km. The fault area is estimated in about 500x200 km.

• The earthquake unleashed a tsunami with waves up to 23.6 m (77 ft) and reaching shores as far as Chile.

• It also resulted in moving Japan 2.4 meters, and shifting the Earth's axis 15 centimeters.
Geographic position
Matsushima, Miyagi Prefecture
Cause of the Earthquake: Plate Tectonics
Cause of the Earthquake
Subduction zone in the Pacific Ocean
Japan Trench
Triangular Crack in Japan Trench
Cause of the Tsunami
Cause of the Tsunami

Slow distortion
Cause of the Tsunami

*Tsunami starts during earthquake*

Stuck area ruptures, releasing energy in an earthquake
Cause of the Tsunami

Tsunami waves spread
Tsunami
Fault Model

- Strike: 195 degrees
- Dip: 13 degrees
- Size: 510km × 210km

Results

- Largest slip: 23m
Tectonic Summary (USGS)
Ground Motions at Miyagi Prefecture
Magnitude of the Released Energy

- This earthquake released a surface energy ($M_e$) of $1.9 \times 10^{17}$ Joules, which is nearly double that of the 9.1-magnitude 2004 Indian Ocean earthquake and tsunami that killed 230,000 people. This energy would power a city the size of Los Angeles for an entire year.

- The total energy released, also known as the seismic moment ($M_0$), was more than 200,000 times the surface energy, slightly less than the 2004 Indian Ocean quake. This is equivalent to 9,320 gigatons of TNT, or approximately 600 million times the energy of the Hiroshima bomb.
Seismic Intensity
Large Earthquakes in the past 110 years

Source:
Educational Slides, Created & Compiled by Gavin Hayes & David Wald, U.S.G.S., National Earthquake Information Center

Data: USGS PAGERCAT 1900-2008, USGS-NEIC & gCMT 2008-present
Figure courtesy of Charles Ammon, after Ammon et al., SRL, 2010
Fukushima I Nuclear Power Plant, 1971
located 68 Km (40 miles) from the epicenter
Fukushima I Nuclear Power Plant, 2011
Seismic Design of the Unit 1

- Unit 1 is a 460 MW boiling water reactor (BWR-3) constructed in July 1967.

- Unit 1 was designed for a peak ground acceleration of 0.18 g (1.74 m/s²) and a response spectrum based on the 1952 Kern County earthquake, but rated for 0.498 g. The design basis for Units 3 and 6 were 0.45 g (4.41 m/s²) and 0.46 g (4.48 m/s²) respectively.

- The design basis for tsunamis was 5.7 meters.

- All units were inspected after the 1978 Miyagi earthquake when the ground acceleration was 0.125 g (1.22 m/s²) for 30 seconds, but no damage to the critical parts of the reactor was discovered.
Structural Aspects of Fukushima Nuclear Power Plants

Secondary containment: Area of explosion at Fukushima Daiichi 1

Primary containment: Remains intact and safe

Boiling Water Reactor Design
Mathematical model used for the original design of the plant structure

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<th>$\tau$ [sec]</th>
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Natural period and damping factors.

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<th>Frequency [sec⁻¹]</th>
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<td>$sf = 1/sT$</td>
<td>$sh$</td>
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Computed versus recoded after the May 26, 1970 Earthquake
Recorded Ground Motion during 2011 earthquake 75.1 Km from the epicenter
Human Cost

- 14,616 deaths, 5,278 injured, and 11,111 people missing across eighteen prefectures, as well as over 125,000 buildings damaged or destroyed.
- Around 4.4 million households in northeastern Japan were left without electricity and 1.5 million without water.
- Residents within a 20 km (12 mi) radius of the Fukushima I Nuclear Power Plant and a 10 km (6 mi) radius of the Fukushima II Nuclear Power Plant were evacuated.
Extent of the earthquake induced damage:
Soil liquefaction, 200 miles from the epicenter
Sendai Airport
The world was shaken on March 11