Lessons Learned from Fukushima Related to Seismic Hazards at U.S. Nuclear Power Plants and Future Seismic Hazard Studies

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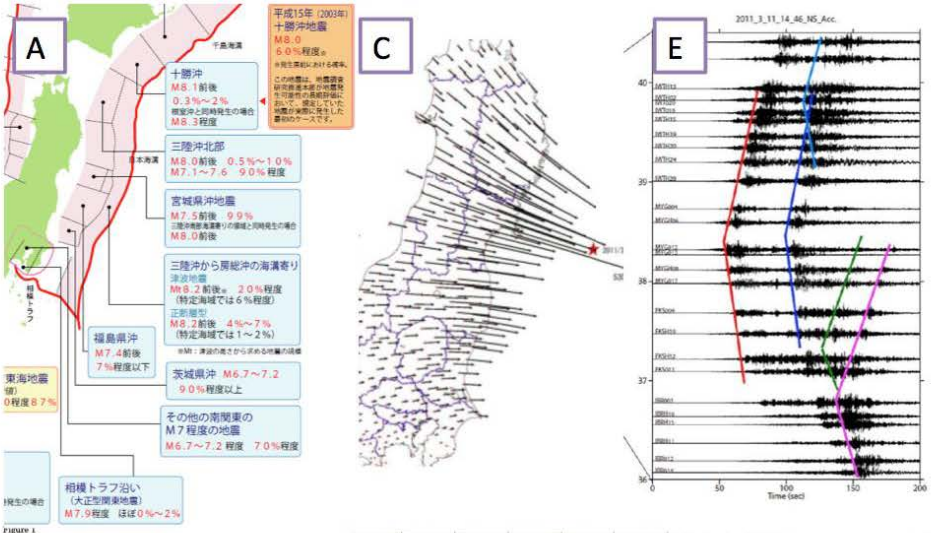
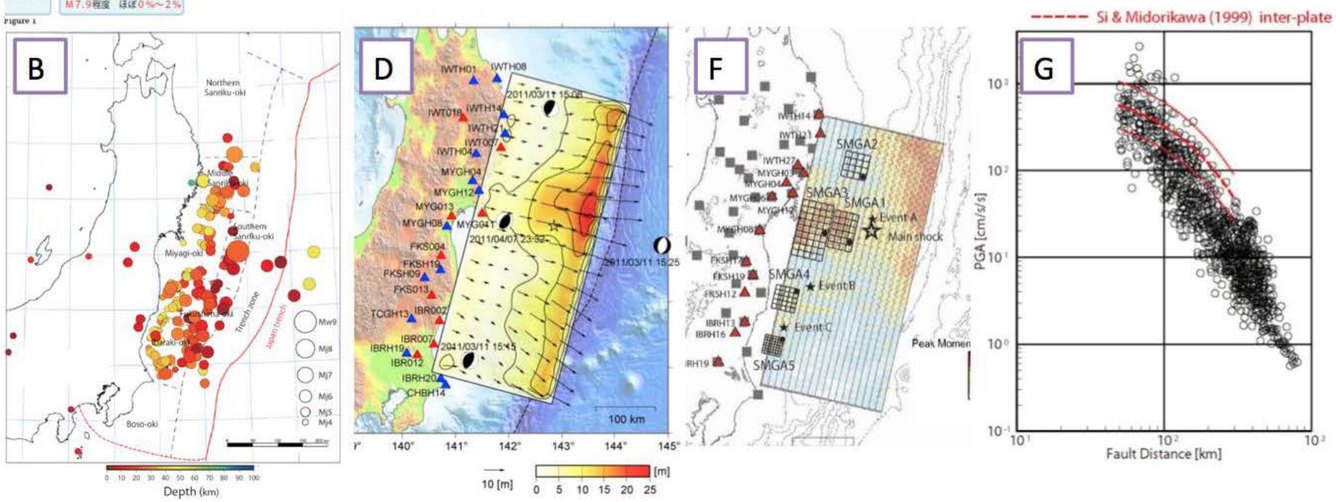
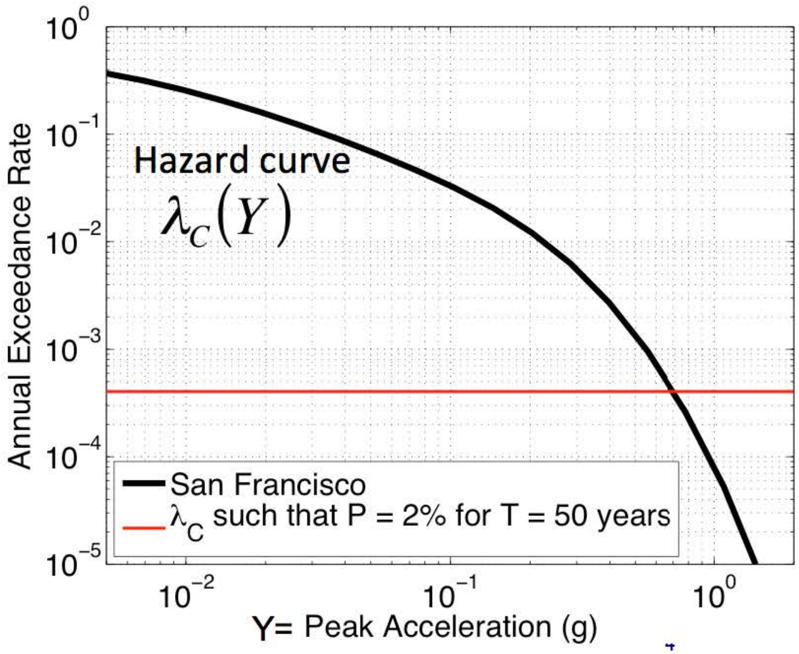


Tohoku, 2011, M9 Results

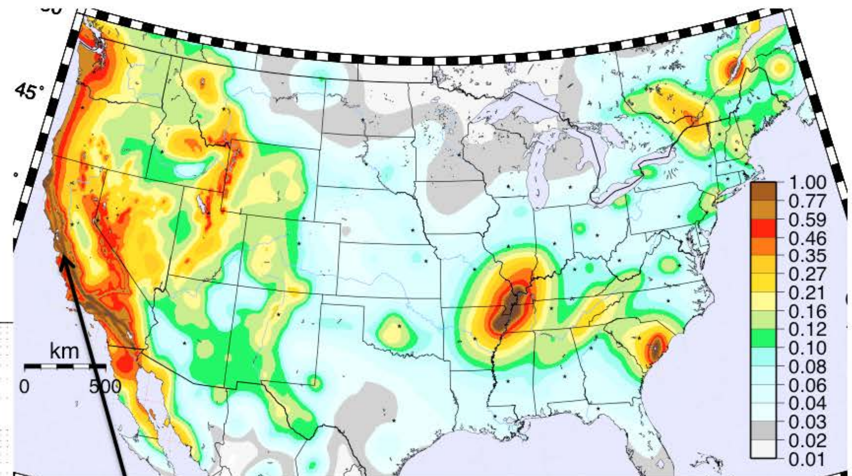


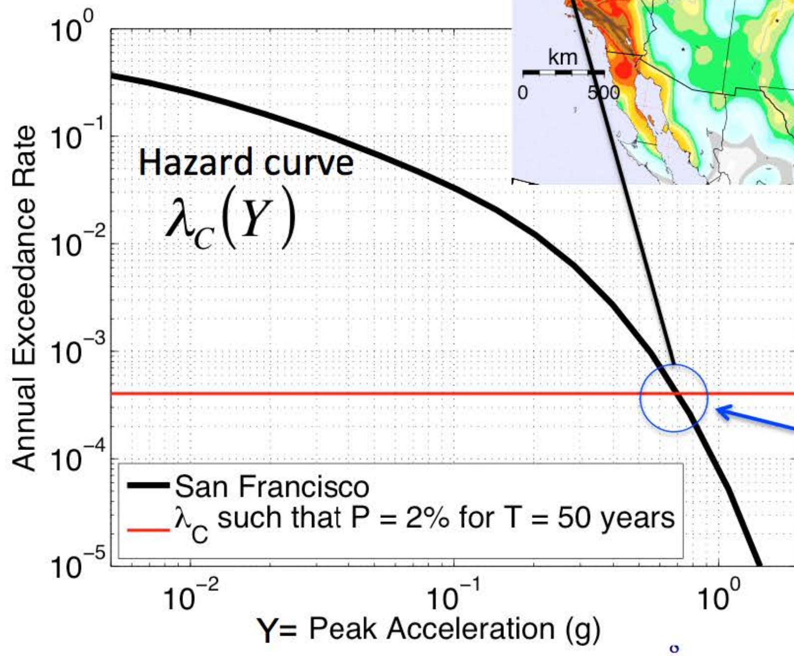
Probabilistic Seismic Hazard Maps



Hazard curve "conceptually observable"

Probabilistic Seismic Hazard Maps



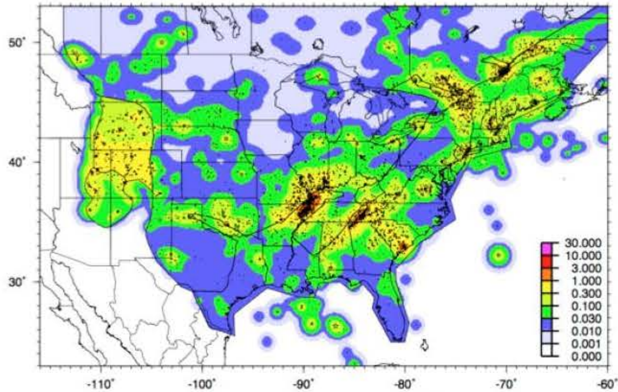


Hazard curve "conceptually observable"

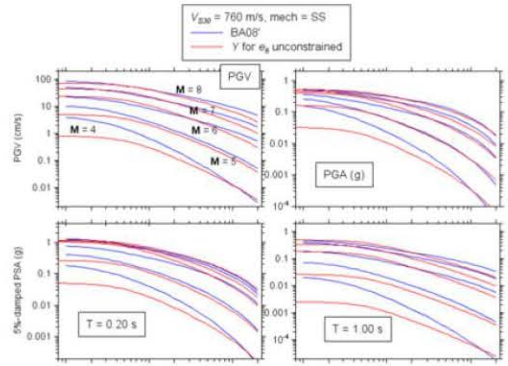
Contour these points. $\lambda_C(Y)$

Quality of hazard map depends on quality of the hazard curve.

Science Behind PSHA

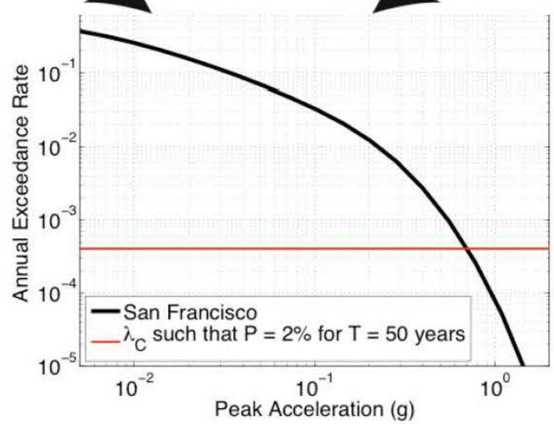


Seismicity model



Ground motion prediction equations

Hazard curve



Lesson from pre-2011 Hazard Map

- M9 earthquake off the north coast was not included in the model.
  - Smaller fault segments expected
  - Linkage not considered
- Lesson: need to include fault linkages.
  - US National Seismic Model for 2014 does this in California – overcomes this problem.
  - Needs to be extended to the rest of the west.

Lesson from lost credibility

- Main "evidence" criticizing PSHA
  - M9 in Tohoku, Haiti, Wenchuan, Christchurch
  - Criticism misplaced
- Lesson:
  - To assure quality PSHA, need an open process
  - Ongoing two-way communication with global seismology community
  - Goal: pathway for new relevant discoveries be promptly considered, without even waiting for formal updates of hazard maps.

Process: U.S. National Seismic Model

- Collaborative, community model
  - USGS internal & external research programs
  - NRC, EPRI, NSF, PEER, SCEC, …
- Update every 6 years
  - Inclusive regional workshops

National Seismic Model: Issues

1. Better models for uncertainties
2. Selection of ground motion prediction equations
3. Validation and utilization of synthetic seismograms
4. Basins and long period ground motions
5. Test hazard curves – especially at low probability
6. Time dependence
7. Induced seismicity

National Seismic Model: Issue 1

- Better models for uncertainties
- Why?
  - At low probabilities, uncertainties dominate hazard estimates, and small changes in uncertainties have a strong effect on results.
- How?
  - Broadband seismic networks
  - Deal with the diversity in earthquake sources
  - Ground motion prediction (regionalized)
  - Seismic stations at the nuclear facility for local effects.

National Seismic Model: Issue 3

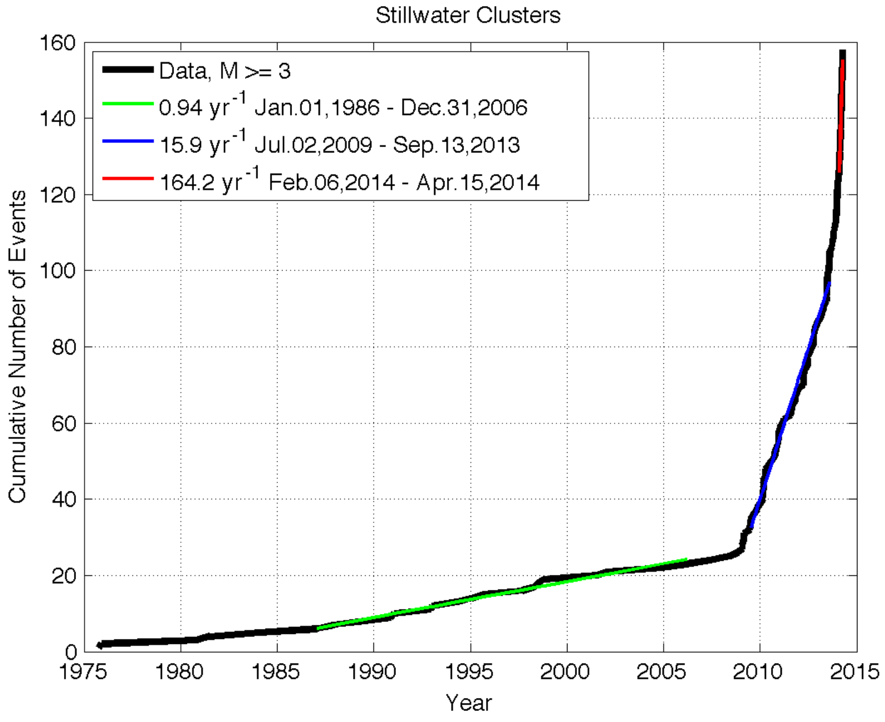
- Validation and utilization of synthetic seismograms
- Why?
  - Where data is sparse, simulations, if credible, can help reduce uncertainties.
  - Many uses in Japan
- How?
  - Seismic networks provide data to determine Earth structure and source domains and characteristics.
  - Validation exercises

National Seismic Model: Issue 6

- Time dependence
- Why?
  - Some nuclear facilities are near active faults likely to rupture within the facility lifetime.
  - Example: Palo Verdi hazard at long periods is dominated by southern San Andreas fault, highly likely to have a an M8 class earthquake in next 30 years
- How?
  - Paleoseismology research
  - Appropriately modify the hazard assessment

National Seismic Model: Issue 7

- Induced seismicity
- Why?
  - It is happening
  - Could happen in more places
- How?
  - Depends on human activity
  - Difficult issue



Thank you

Extra Slides

National Seismic Model: Issue 2

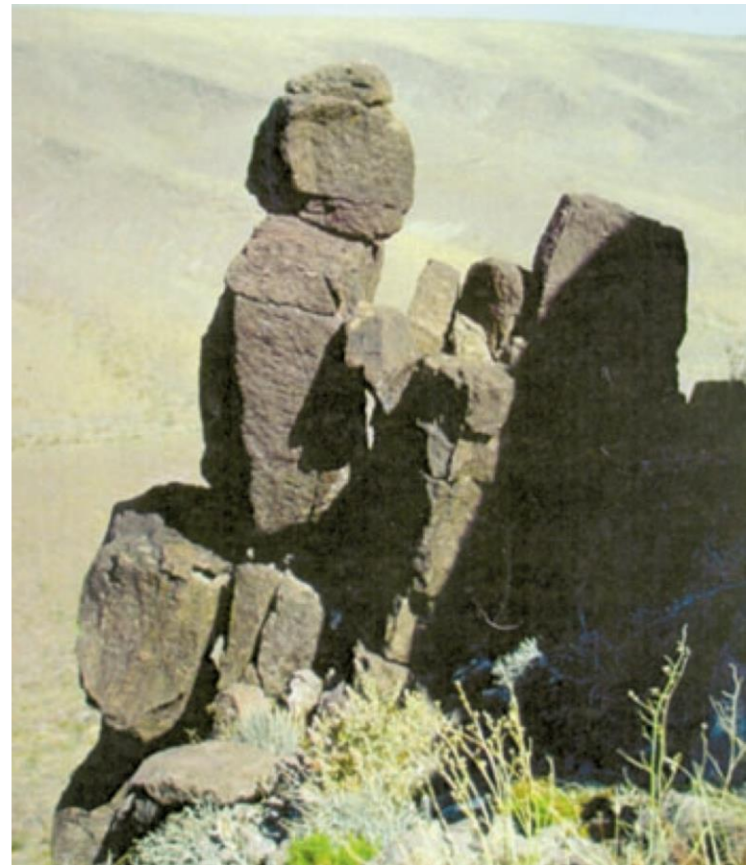
- Selection of ground motion prediction equations
- Why?
  - Current process too strongly influenced by judgment
- How?
  - Analytical methods to explore GMPE space
  - More explicit acceptance criteria

National Seismic Model: Issue 4

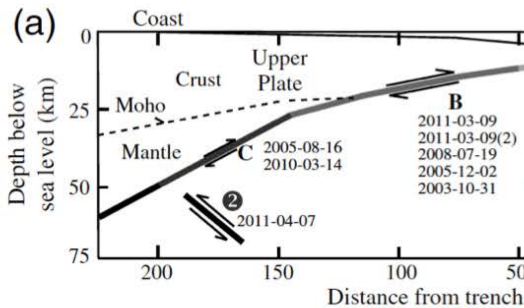
- Basins and long period ground motions
- Why?
  - Some geological structures can amplify ground motions enormously at long periods. (e.g. Mexico City, Hokkaido, Las Vegas, Los Angeles)
  - Engineers asking for this
- How?
  - Broadband instruments for validation data
  - Modeling is believed most reliable at long periods

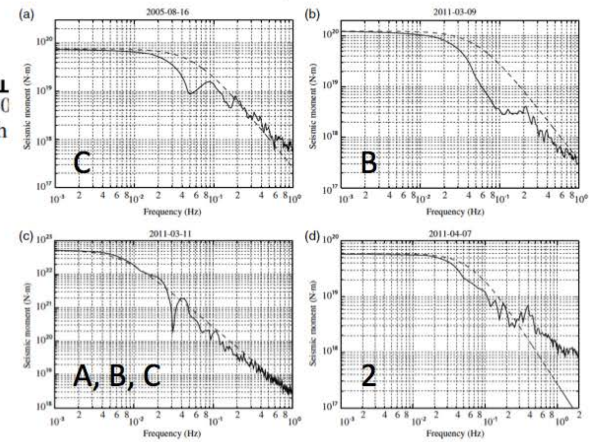
National Seismic Model: Issue 5

- Test hazard curves – especially at low probability
- Why?
  - At low probability, models are most sensitive to uncertainty
- How
  - Old fragile geological structures that have not been damaged by past earthquakes.
  - Example: precarious rocks near Yucca Mountain with ages >10,000 Inconsistent with the PSHA.



Lessons from Fukushima: Diversity in Earthquakes





Sources: Lay et al. (2012), Ye et al. (2013), Kanamori (2014)

Acronyms

- PSHA: Probabilistic Seismic Hazard Analysis
- GMPE: Ground Motion Prediction Equation
- M9: Magnitude = 9
- USGS: US Geological Survey
- NRC: Nuclear Regulatory Commission
- EPRI: Electric Power Research Institute
- NSF: National Science Foundation
- PEER: Pacific Earthquake Engineering Research Center
- SCEC: Southern California Earthquake Center