A Practical Guide to Global Earthquake Forecasting

Market Street
San Francisco
April 14, 1906

YouTube Video

John B Rundle

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Chairman, Open Hazards Group (www.openhazards.com)

Major Contributors

Open Hazards Group:

James Holliday (and University of California)
William Graves
Steven Ward (and University of California)
Paul Rundle
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QuakeSim (NASA and Jet Propulsion Laboratory):

Andrea Donnellan

On Forecasting

- Why forecast? (A vocal minority of our community says we shouldn't or can't)
  - Insurance rates
  - Safety
  - Building codes
- Fact: Every country in the world has an earthquake forecast (it may be an assumption of zero events, but they all have one)
- Premise: Any forecast made by the seismology community is bound to be at least as good as, and probably better than, any forecast made by:
  - Politicians
  - Lawyers
  - Agency bureaucrats

Forecasting vs. Prediction

Context	Characteristic
Prediction	A statement that can be validated or falsified with 1 observation
Forecast	A statement for which multiple observations are required to determine a confidence level

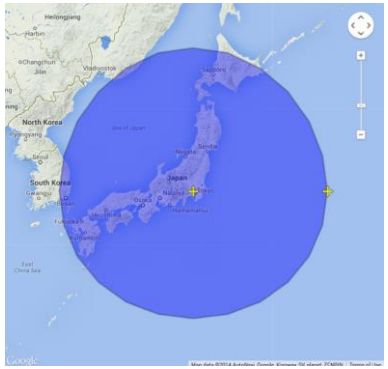
Challenges in Web-Based Forecasting

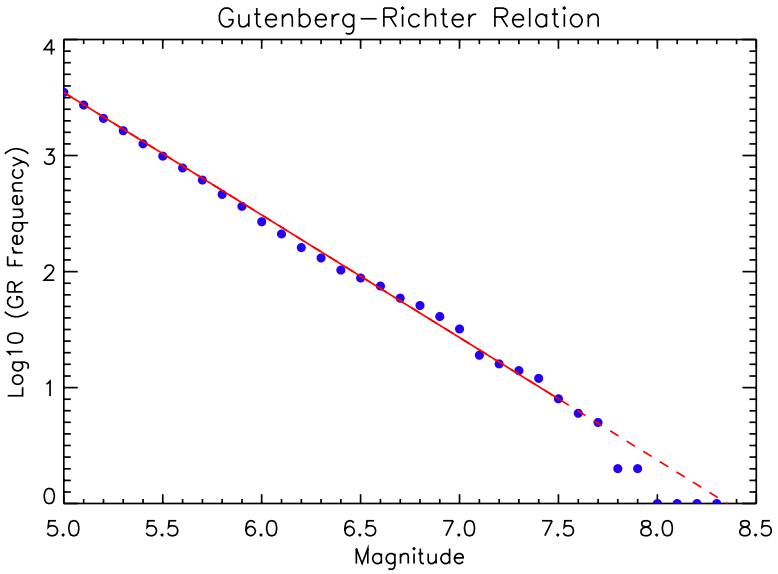
Data & Models	Information Delivery	Meaning
Acquiring & validating data	Automation	What is probability?
Model building	Web-based integration	Visual presentation
Efficient algorithms	UI	GIS
Validating/verifying models	Tools	Correlations
Error reporting, correction, model steering	Collaboration/social networks	Expert guidance/blogs

Filling in the Gutenberg-Richter Relation

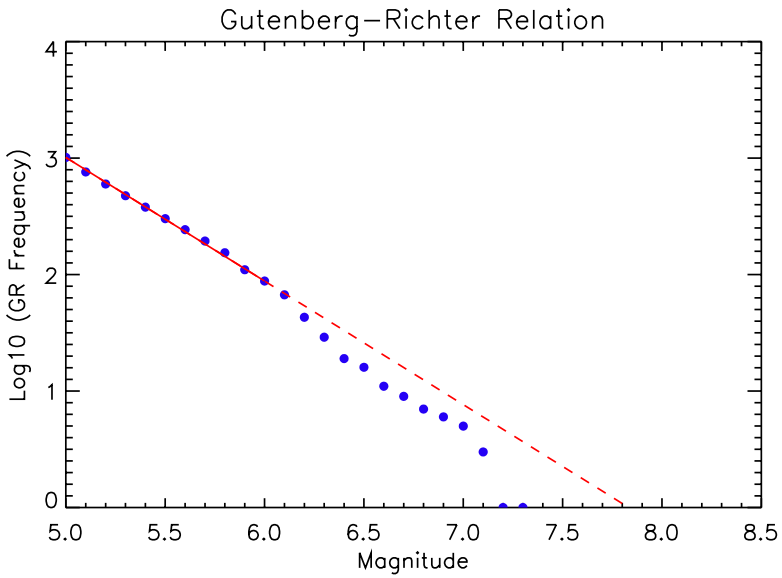
Statistics Before and After 3/11/2011
Radius of 1000 km Around Tokyo

b=1.01 +/- 0.01





All events prior to M9.1 on 3/11/2011
("Normal" statistics)



All events after M7.7 on 3/11/2011
(Deficit of large events)

A Different Kind of Forecast: Natural Time Weibull

Features

JBR et al., Physical Review E, 86, 021106 (2012)
J.R. Holliday et al., in review, PAGEOPH, (2014)

- A self-consistent global forecast
- Displays elastic rebound-type behavior
  - Gradual increase in probability prior to a large earthquake
  - Sudden decrease in probability just after a large earthquake
- Only about a half dozen parameters (assumptions) in the model whose values are determined from global data
- Based on global seismic catalogs
- Probabilities are highly time dependent and can change rapidly
- Probabilities represent perturbations on the time average probability
- Web site displays an ensemble forecast consisting of 20% BASS (ETAS) and 80% NTW forecasts

"If a model isn't simple, its probably wrong" – Hiroo Kanamori (ca. 1980)

NTW Method

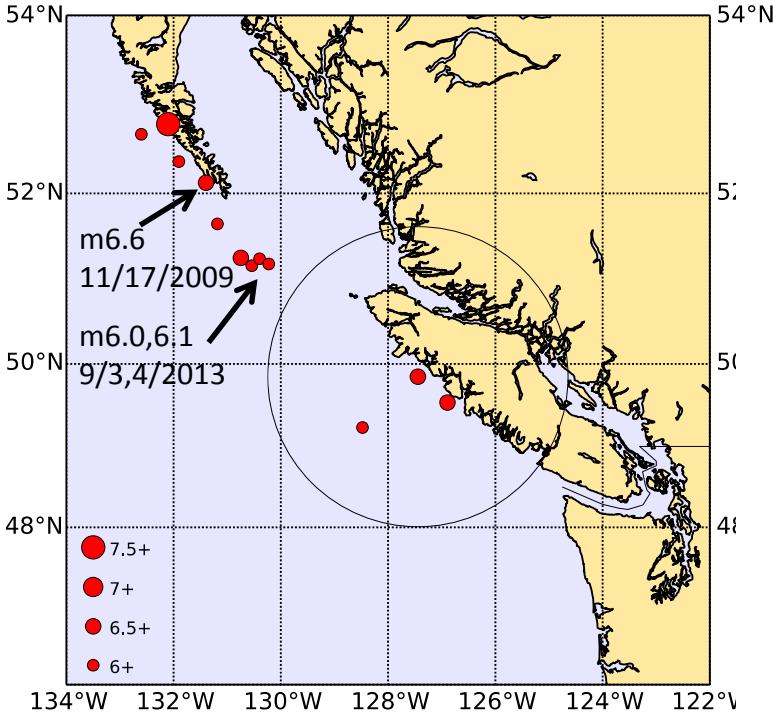
JBR et al., Physical Review E, 86, 021106 (2012)

- Data from ANSS catalog + other real time feeds
- Based on "filling in" the Gutenberg-Richter magnitude-frequency relation
- Example: for every ~1000 M>3 earthquakes there is 1 M>6 earthquake
- Weibull statistics are used to convert large-earthquake deficit to a probability
- Fully automated
- Backtested and self-consistent
- Updated in real time (at least nightly)
- Accounts for statistical correlations of earthquake interactions

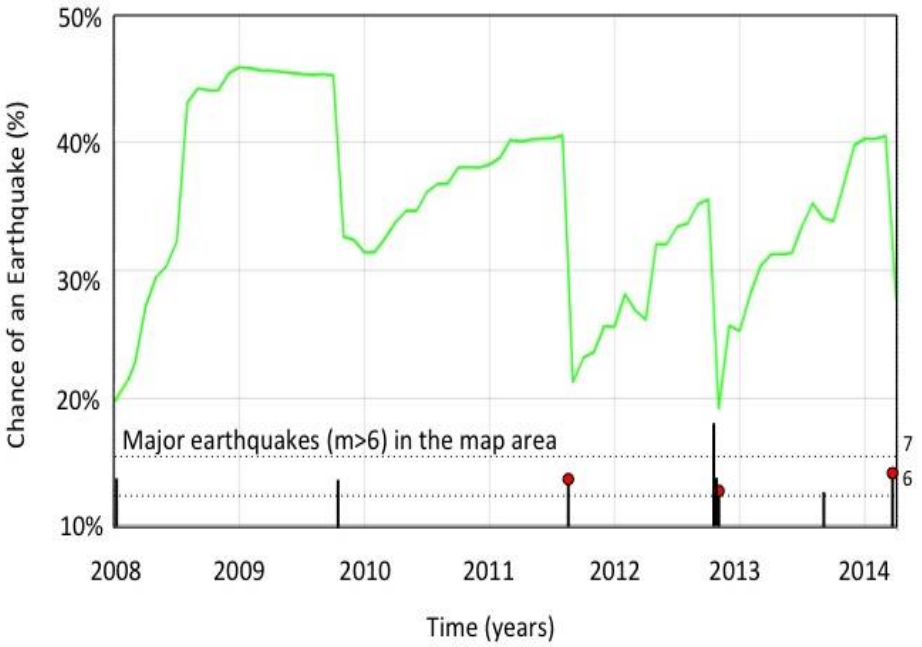
Example: Vancouver Island Earthquakes

Latest Significant Event was M6.6 on 4/24 /2014

JR Holliday et al, in review (2014)



Chance of M>6 earthquake in circular region of radius 200 km for next 1 year.
Data accessed 4/26/2014




User login
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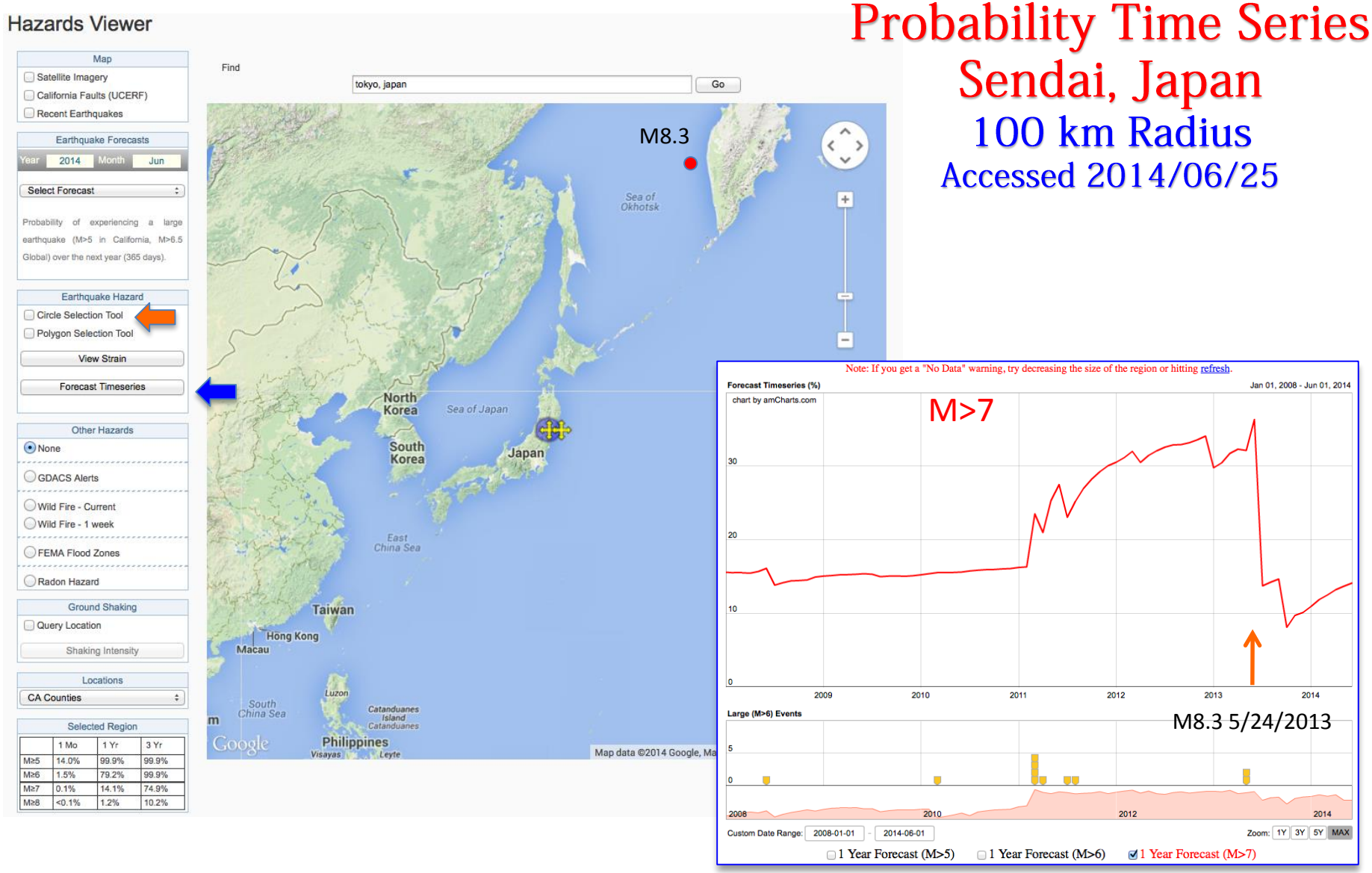
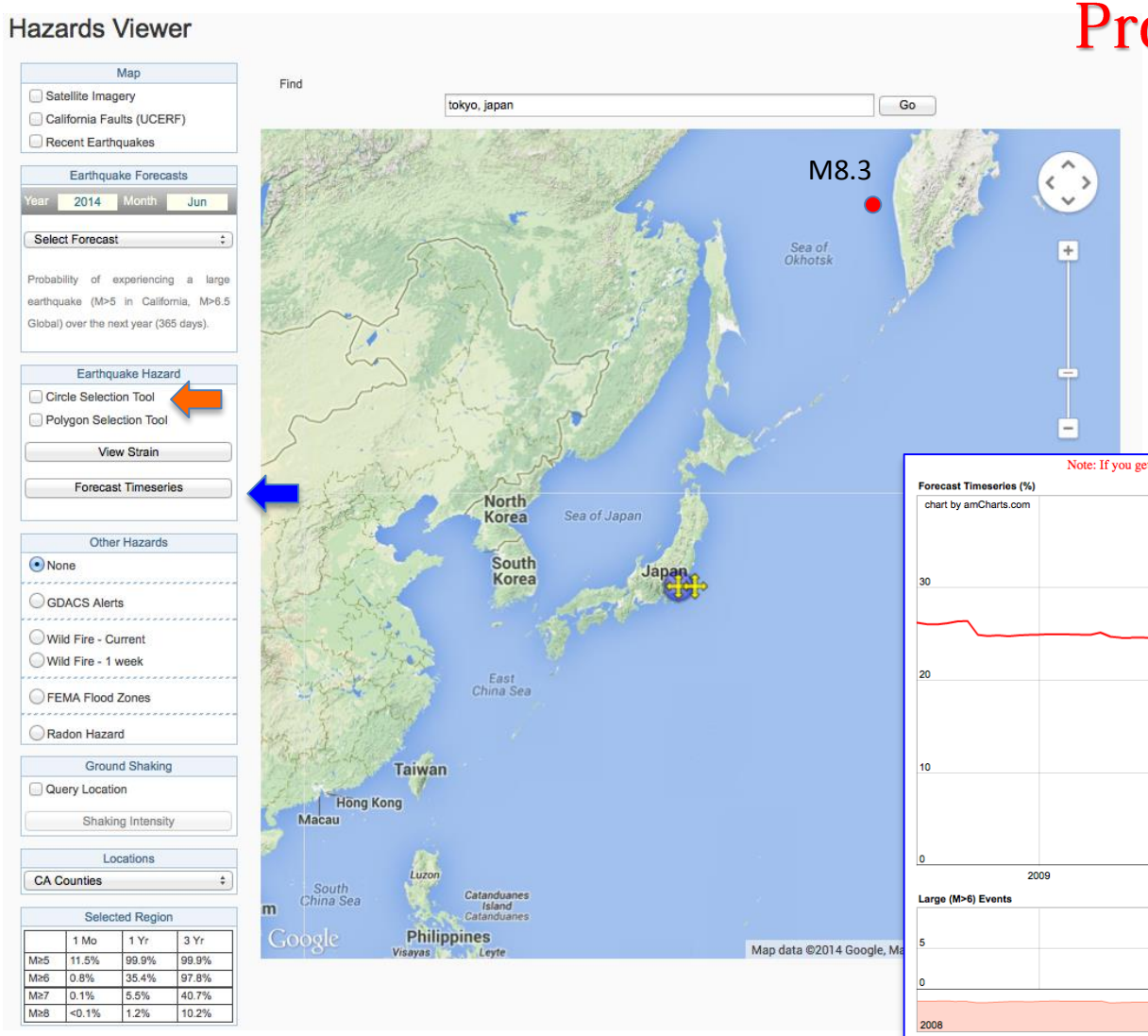
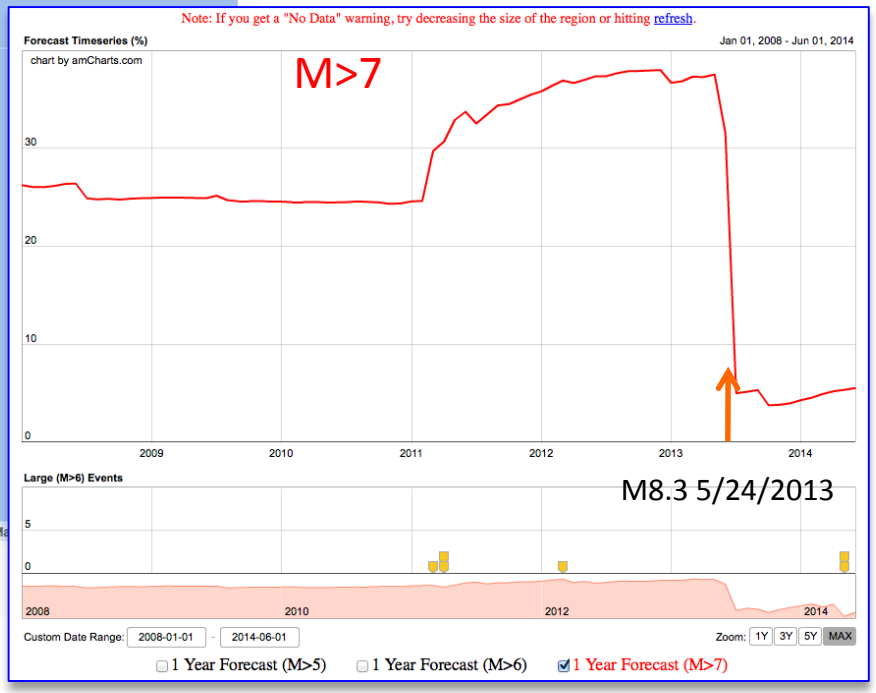
OH Community
Store
Tools
Data
About Us
Search
Personal Earthquake Forecast
Home Damage Estimator
Earthquake Viewer
Hazards Viewer
In the News:
Watch what we do
Steve's
VIDEO BLOG
WE ARE THE OPENHAZARDS GROUP.
WE ARE A TEAM OF SCIENTISTS AND ENGINEERS DEDICATED TO REDUCING THE IMPACT OF NATURAL DISASTERS.
WE PROVIDE PROFESSIONAL RISK ASSESSMENT AND WEB-BASED TOOLS, SERVING THE PREPARED HOMEOWNER AND THE SIMPLY CURIOUS.
WE ARE THE WORLD LEADERS IN EARTHQUAKE FORECASTING AND HAZARD ANALYSIS.
THE OPENHAZARDS GROUP:
KEEPING YOU ONE STEP AHEAD OF NATURE
Prepare
Custom Reports • Safety Guides
Protect your family and your home — knowledgably. You have options when it comes to preparing for an earthquake. What's right for you? We'll help you learn your risk and give you the tools to make informed decisions.
Explore
Natural Hazards • OH Forecasts
Learn more about natural hazards. Want to know where the next "big one" might strike? OpenHazards is the world leader in earthquake forecasts. Discover more about earthquakes and the other natural hazards of our planet.
Community
Blogs • Your Photos • Forums
Join the discussion. Read the latest news, watch videos, and get insights from our nationally recognized experts. Then, share your own comments, questions, and uploaded photos with the OpenHazards community.

Probability Time Series
Sendai, Japan
100 km Radius
Accessed 2014/06/25

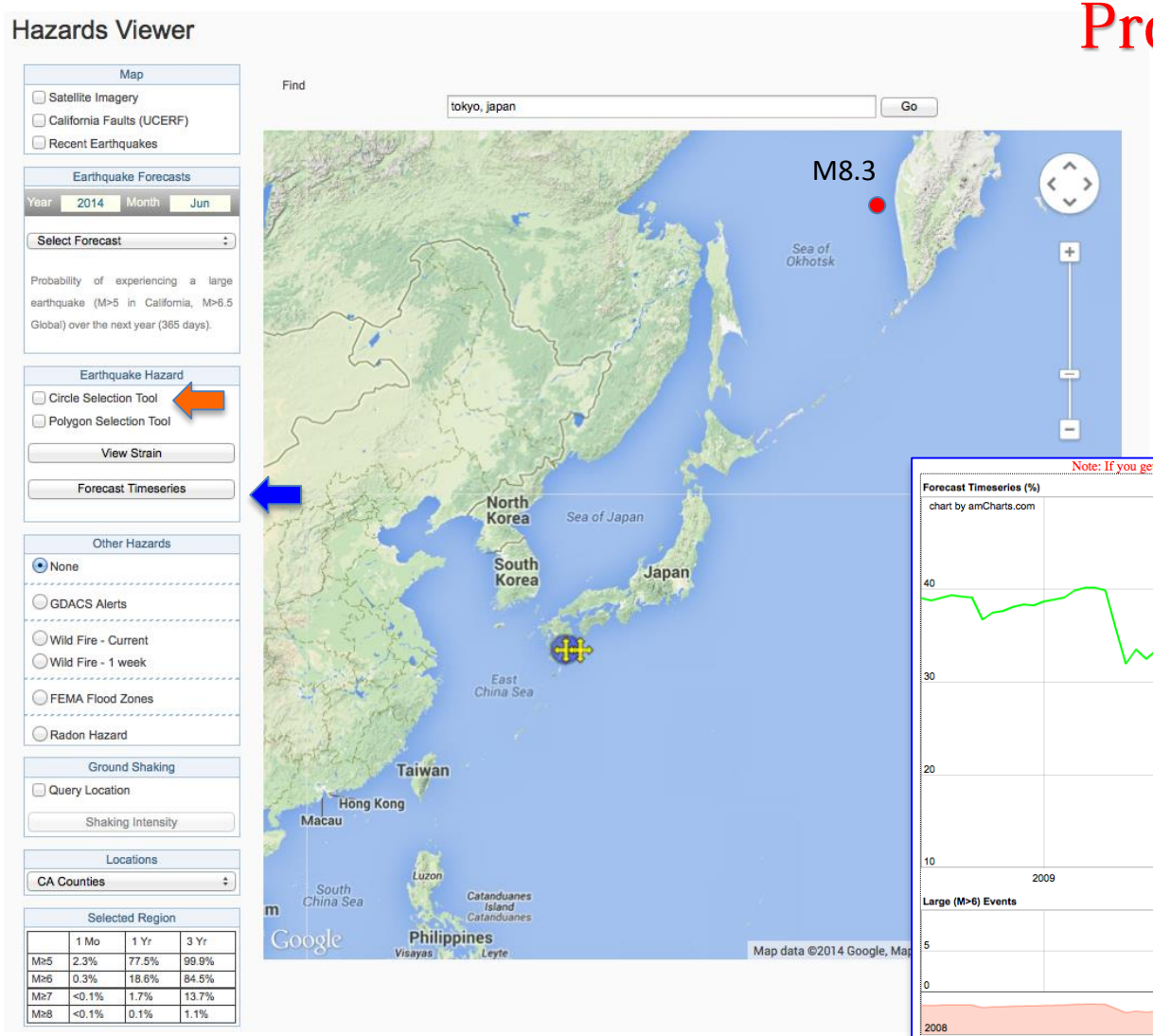


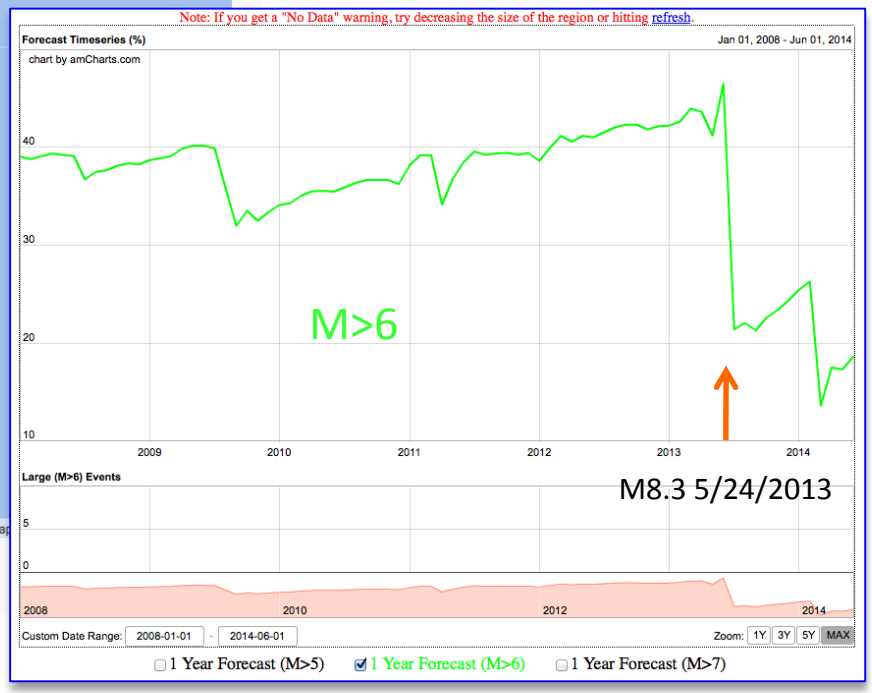
Probability Time Series
Tokyo, Japan
100 km Radius
Accessed 2014/06/25





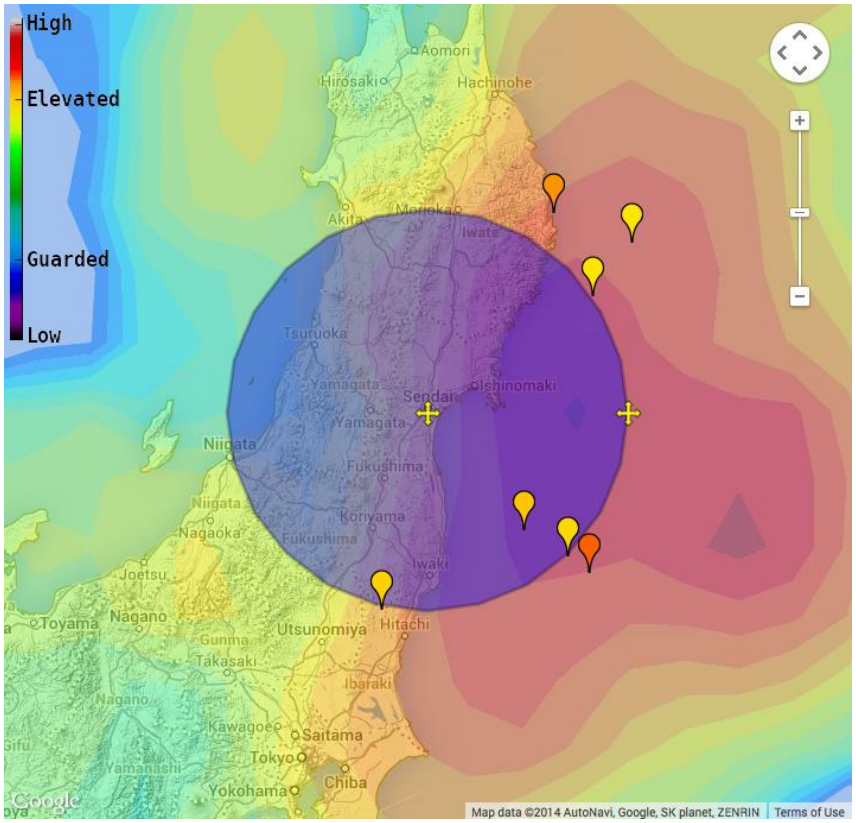
Probability Time Series
Miyazaki, Japan
100 km Radius
Accessed 2014/06/25



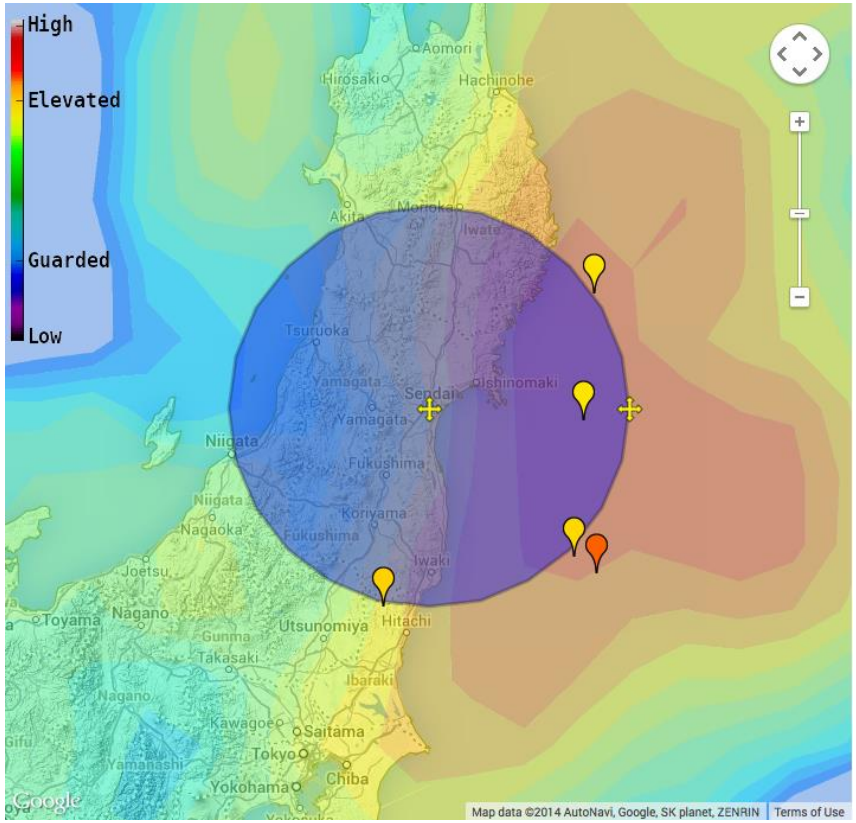


Namie, Japan: M6.5, 7-12-2014

Probability Contours, M≥6.5, 1 Year



7-12-2014
Pre-Earthquake



7-13-2014
Post-Earthquake

Namie, Japan: M6.5, 7-12-2014

Table of Probabilities

Selected Region			
	1 Mo	1 Yr	3 Yr
M≥5	34.6%	99.9%	99.9%
M≥6	4.7%	99.4%	99.9%
M≥7	0.5%	41.2%	99.2%
M≥8	<0.1%	4.2%	32.0%

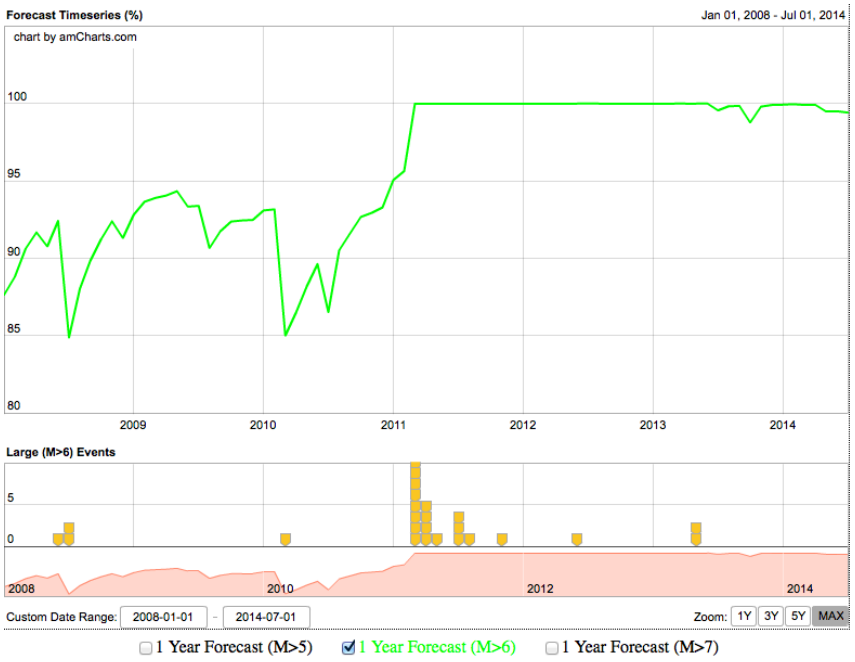
7-12-2014
Pre-Earthquake

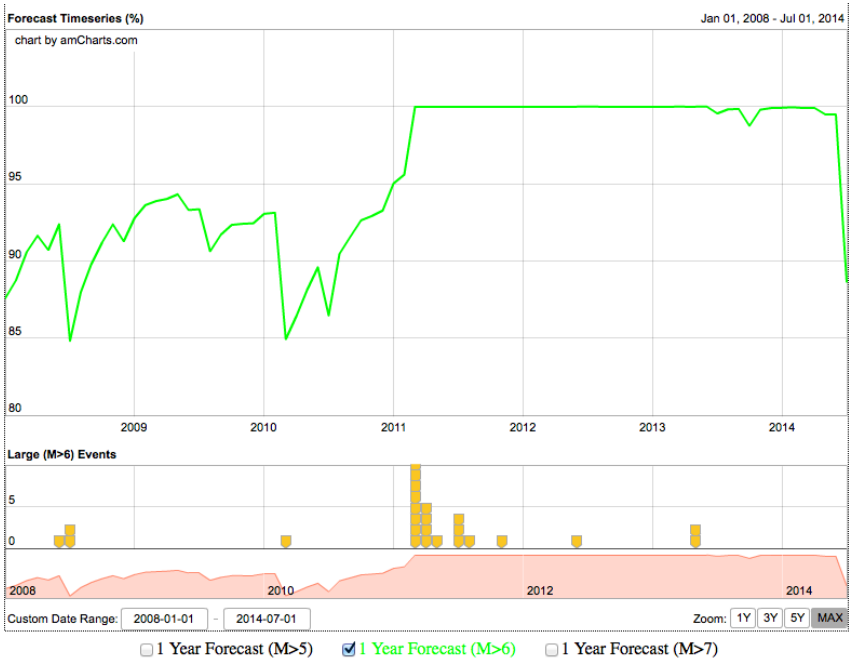
Selected Region			
	1 Mo	1 Yr	3 Yr
M≥5	32.0%	99.9%	99.9%
M≥6	2.6%	88.7%	99.9%
M≥7	0.5%	41.5%	99.3%
M≥8	<0.1%	4.2%	32.0%

7-13-2014
Post-Earthquake

Namie, Japan: M6.5, 7-12-2014

Probability Timeseries, M>6, 1 Year



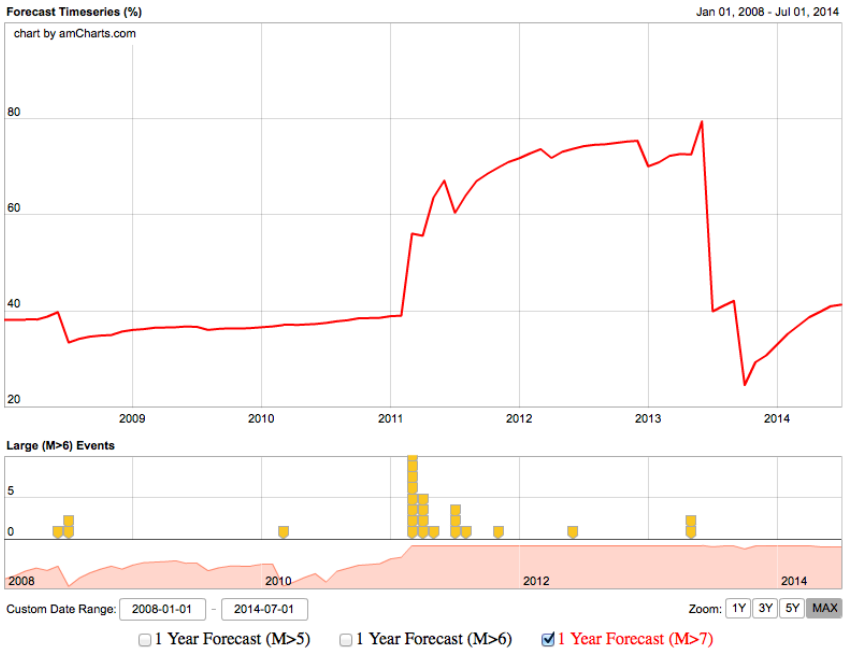


7-12-2014
Pre-Earthquake

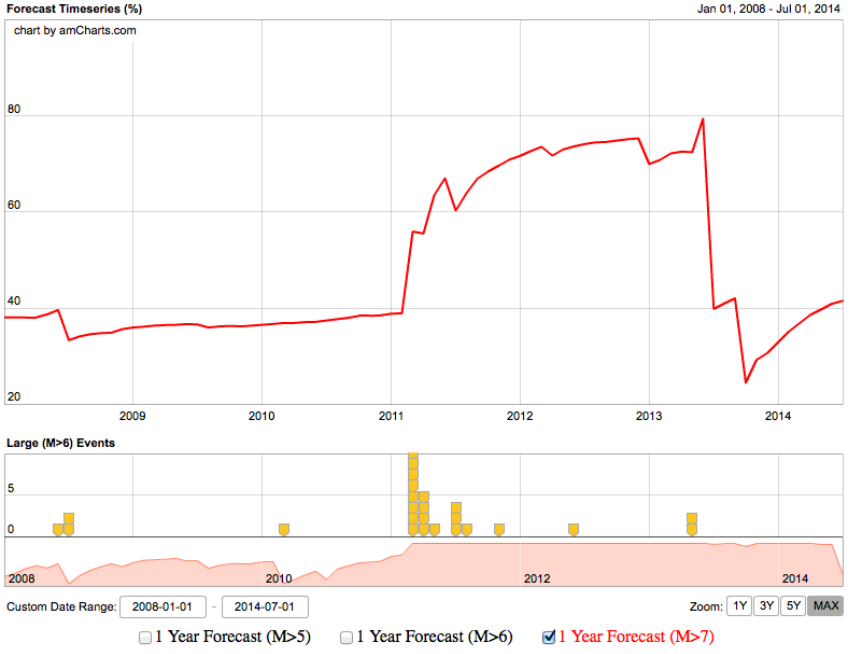
7-13-2014
Post-Earthquake

Namie, Japan: M6.5, 7-12-2014

Probability Timeseries, M>7, 1 Year



7-12-2014
Pre-Earthquake



7-13-2014
Post-Earthquake

Hazards Viewer

Map

- [ ] Satellite Imagery
- [x] California Faults (UCERF)
- [ ] Recent Earthquakes

Earthquake Forecasts

Year 2014 Month Jun

Select Forecast

Probability of experiencing a large earthquake (M>5 in California, M>6.5 Global) over the next year (365 days).

Earthquake Hazard

- [ ] Circle Selection Tool
- [ ] Polygon Selection Tool

View Strain

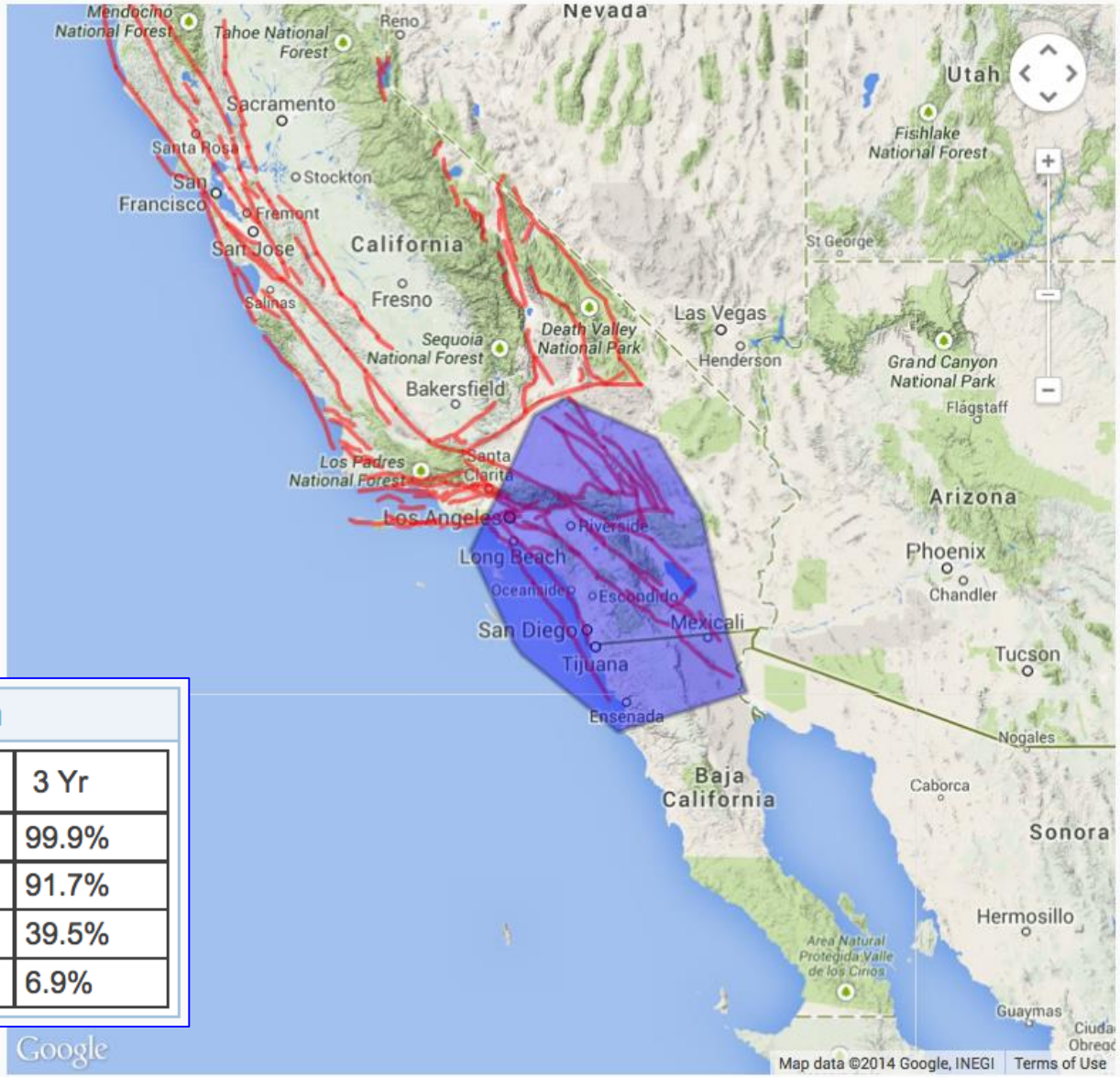
Forecast Timeseries

Other Hazards

- (•) None
- ( ) GDACS Alerts
- ( ) Wild Fire - Current

Find

Go



Selected Region

	1 Mo	1 Yr	3 Yr
M≥5	5.9%	97.9%	99.9%
M≥6	0.6%	24.5%	91.7%
M≥7	0.1%	5.3%	39.5%
M≥8	<0.1%	0.8%	6.9%

Personal Earthquake Forecast

Palo Alto, CA Go

Probability of Earthquake Within 50 Miles of Palo Alto, CA, USA

	1 Month	1 Year	3 Years
M≥5	1.05%	36.81%	98.34%
M≥6	0.14%	5.07%	34.12%
M≥7	<0.05%	1.59%	13.00%
M≥8	<0.05%	0.18%	1.42%

Fri Jul 05 2013 14:19:48 GMT-0700 (PDT)

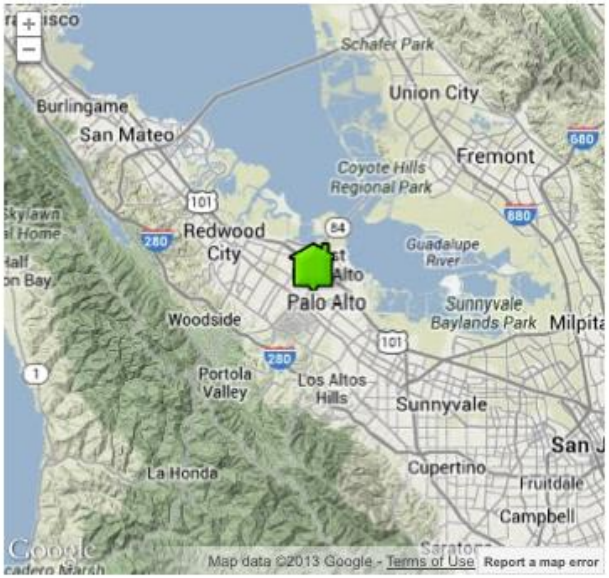
Home Damage Estimator

Calculate estimated damage to your home due to strong earthquakes in three easy steps.

Damage Factor: 0.0000

Step 1: Locate House

Drag the green house marker to your home's location or enter your street address in the search box below.



Address: 498 Fulton Street, Palo Alto, CA 94301

Search

Step 2: Describe House

Step 3: Place Sample Earthquake

Create Report

1. First, locate your house. You can do this by holding down on the green house marker in "Step 1" and dragging it to your home's location. You can also enter your street address in the search box.
2. Next, describe your house. You can do this by filling out the table in "Step 2". Initial guesses at appropriate values are supplied by Zillow.com.
3. Finally, place a sample earthquake to check for possible damage. You can do this by holding down on the red earthquake marker in "Step 3" and dragging it close to your home's location. The closer you place the earthquake, the more damage you'll see. You can also select a magnitude for the sample earthquake.

Home Damage Estimator

Calculate estimated damage to your home due to strong earthquakes in three easy steps.

Damage Factor: 0.0000

Create Report

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Home Damage Estimator

Calculate estimated damage to your home due to strong earthquakes in three easy steps.

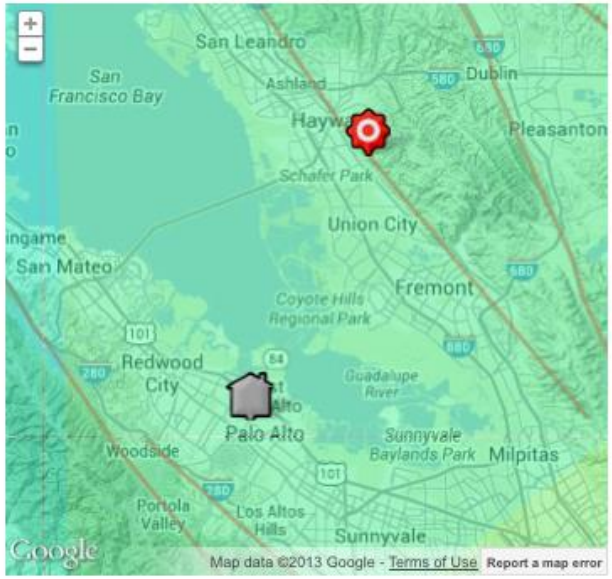
Damage Factor: 0.1432

Step 1: Locate House

Step 2: Describe House

Step 3: Place Sample Earthquake

Drag the red earthquake marker to the desired location for your sample earthquake. Don't forget to specifiy a magnitude!



Magnitude: 7.0

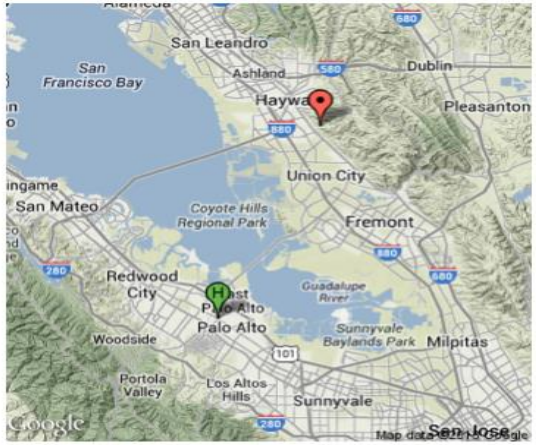
Create Report

1. First, locate your house. You can do this by holding down on the green house marker in "Step 1" and dragging it to your home's location. You can also enter your street address in the search box.
2. Next, describe your house. You can do this by filling out the table in "Step 2". Initial guesses at appropriate values are supplied by Zillow.com.
3. Finally, place a sample earthquake to check for possible damage. You can do this by holding down on the red earthquake marker in "Step 3" and dragging it close to your home's location. The closer you place the earthquake, the more damage you'll see. You can also select a magnitude for the sample earthquake.

Risk Assessment For User Generated Home Values

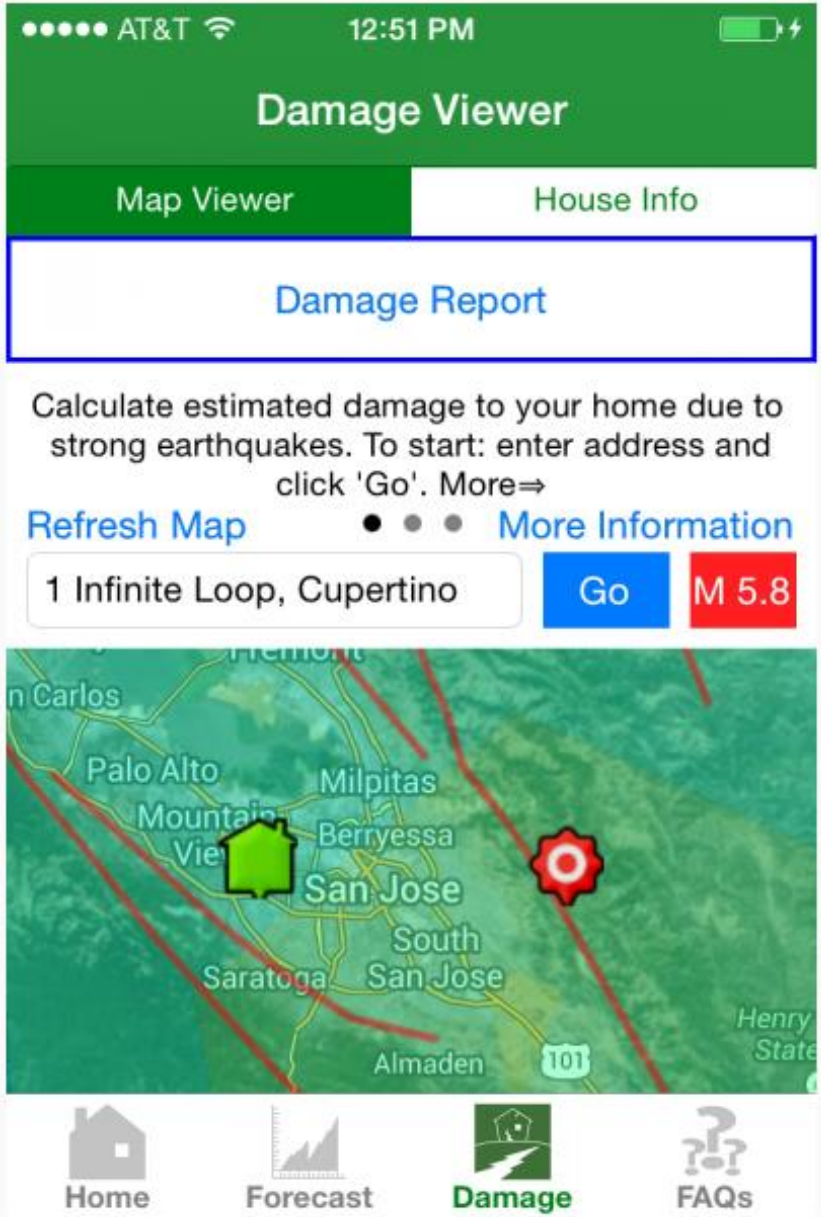
Report Generated: Fri Jul 05 2013 14:18:41 GMT-0700 (PDT)

Your test earthquake produced a simulated peak ground acceleration (PGA) of 18.658%g at your home location. Given your description, the damage factor (DF) for this event is 0.1432. This means on average you would experience $87,000 in damage (assuming a home value of $605,972).



Address:	498 Fulton Street, Palo Alto, CA 94301
Earthquake Location:	37.642°N, -122.050°E
Magnitude:	7.0
Estimated PGA (%g):	18.658
Damage Factor:	0.1432
Estimated Damage:	$87,000

QuakeWorks Mobile App (iOS)



Collaborative Social Network - social.openhazards.com

John | Private messages | Members › John

Members | Create content | Settings | Search

Profile | Account settings | Bookmarks | My dashboard | Features | Invitations | Messages | Notifications | OpenID | My guestbook | Subscriptions | Customize dashboard | Edit my profile

My Status | Add custom

My Status Page

200 characters allowed

This is your personal Facebook-style status update box. Create relationships with other users to share your status here...

Attach: CAPTCHA: no challenge enabled

Share

John

No financial hazards yet...

Bernanke: Fed to begin tapering bond purchases later this year

Federal Reserve Chairman Ben Bernanke said the central bank anticipates beginning tapering bond purchases later this year but that policy will remain accommodative and could change depending on the incoming economic data.

1 day ago Edit Delete

Comment

John

An interesting story on the financial system...

Enjoy it while it lasts: Bank earnings face trouble

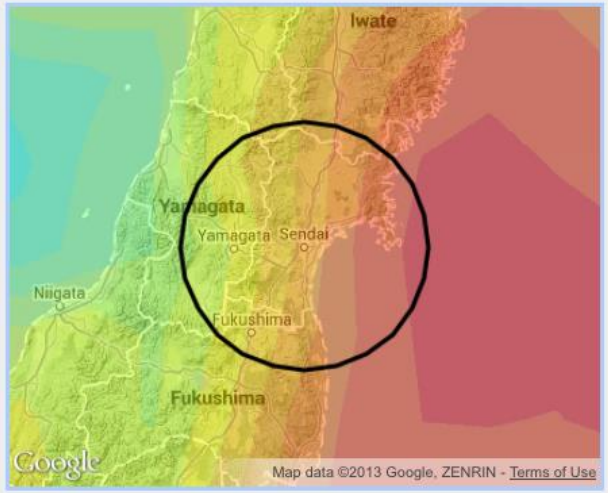
Welcome to the Open Hazards Social Network

Edit

Welcome to the Open Hazards Social Network! Planning for and responding to disasters depends on establishing strong collaboration and social networks. On this site you can post content to a Facebook-style status stream and your colleagues and neighbors can see it. You can join a group to add content, or to upload, discuss, and share images and information with others. You can also add a new group and invite others to join. When you join or create a group, you will see a video providing instruction on how to use groups and the site in general. Feel free to rearrange boxes on dashboard pages using the "Customize Dashboard" button at the top right. You can find instructions on how to do this at: https://community.openatrium.com/documentation-en/node/23. We hope you find this site useful in preparing for and responding to natural disasters.

My Personal Earthquake Forecast

Sendai,japan Go



APRU Multihazards Group: A Moderated Group

John | Private messages | Groups › APRU Multihazards Group

Dashboard | Create content | Settings | Search

Dashboard | Add custom | Customize dashboard

Recent activity

Thursday, Jul 11

9:29am JohnBR commented on APRU Multihazards Group

Calendar

July 2013

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

Upcoming events

No upcoming events found.

John

- Add user
- Features
- Guestbooks
- Help

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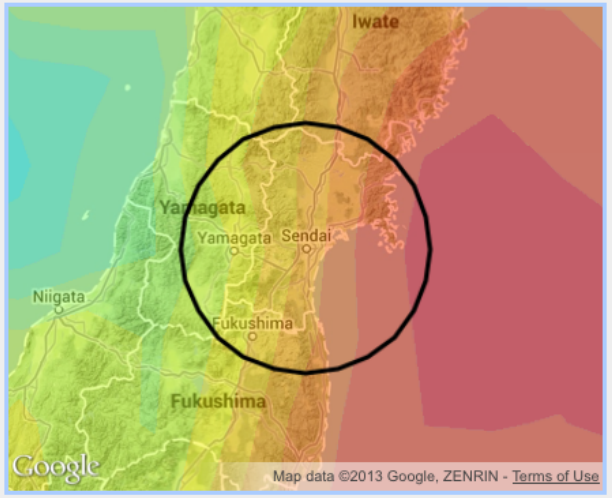
My Personal Earthquake Forecast

Sendai, Japan Go



Probability of Earthquake Within 50 Miles of Sendai, Miyagi Prefecture, Japan

My Personal Group: A Private (Closed) Group

John | Private messages | Groups › Johns Personal Group

Dashboard | Create content | Settings | Search

Dashboard | Add custom | Customize dashboard

Recent activity 1 of 3 Next

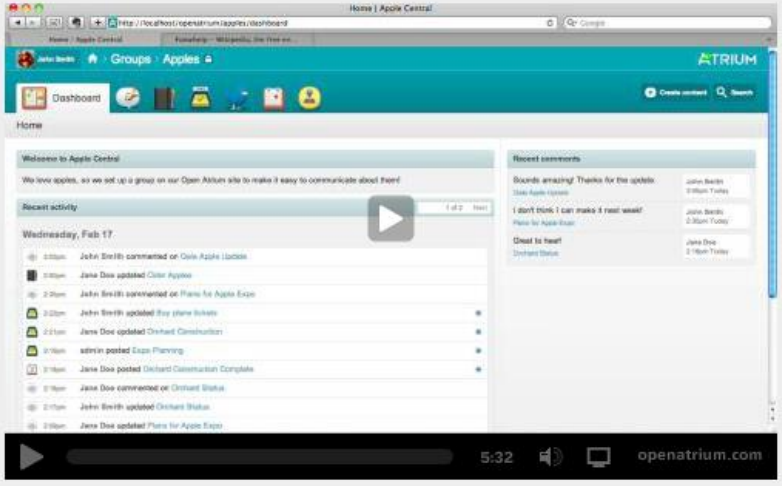
Monday, Jul 15

10:26pm	John posted	Program
10:24pm	John posted	Lecture 1
10:23pm	John posted	APRU Summer School 2013

Thursday, Jul 11

8:44am	John posted	Personal Earthquake Forecast
8:41am	John posted	Home Damage Estimator

Welcome to Johns Personal Group



Add Blog entry | Add ICal Feed

Welcome to the Open Hazards Social Network Edit

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Hey, where is everybody? refresh

Talking to: no one

TYPE HERE:

CAPTCHA: no challenge enabled

Calendar

July 2013

M	T	W	T	F	S	S
1	2	3	4	5	6	7

Verification and Validation

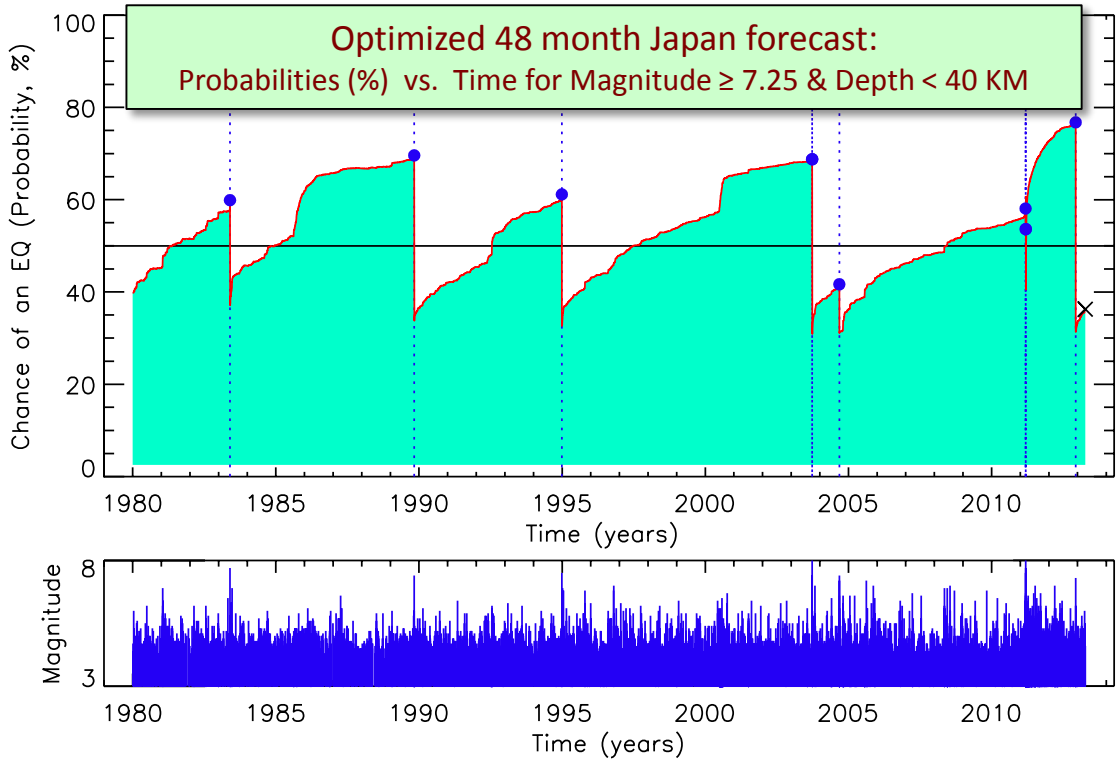
http://www.cawcr.gov.au/projects/verification/

- Australian site for weather and more general validation and verification of forecasts
- Common methods are Reliability/Attributes diagrams, ROC diagrams, Briar Scores, etc.

Verification: Example

Japan NTW Forecast

Assumes Infinite Correlation Length



Optimal forecasts via backtesting, with most commonly used verification testing procedures.

Forecast Date: 2013/04/10