Natural Disasters: Forecasting and Nowcasting

Market Street
San Francisco
April 14, 1906

YouTube Video

John B Rundle

Distinguished Professor, University of California, Davis (www.ucdavis.edu)
Chairman, Open Hazards Group (www.openhazards.com)

San Francisco Earthquake

April 18, 1906 5:12 am PDT

EXTRA THE DAILY NEWS EXTRA

HUNDREDS DEAD!

Fire Follows Earthquake, Laying Downtown Section in Ruins--City Seems Doomed For Lack of Water

KNOWN DEAD

AT MECHANICS' PAVILION

Max Fenner, policeman, killed in collapse Essex Hotel.

Niece of Detective Dillon, killed in collapse, 6th and Shipley.

Unidentified woman, killed at 18 7th st.

Two unknown men, brought in autos.

OTHER DEAD

Five killed, 2 injured, in collapse of building at 239 Geary.

Frank Corali, buried, beneath basement floor of burning lodging house 5th and Mission. Heard crying "For God's sake, help me."

Seven firemen killed in collapse of brick power house Valencia and 7th.

John Wheley and son, killed in falling house, Steiner and Germania ave.

James Whaley, wife, Nellie Whaley, Marie Whaley, same address, badly injured.

Unidentified man, buried in remains Valencia-st. Hotel.

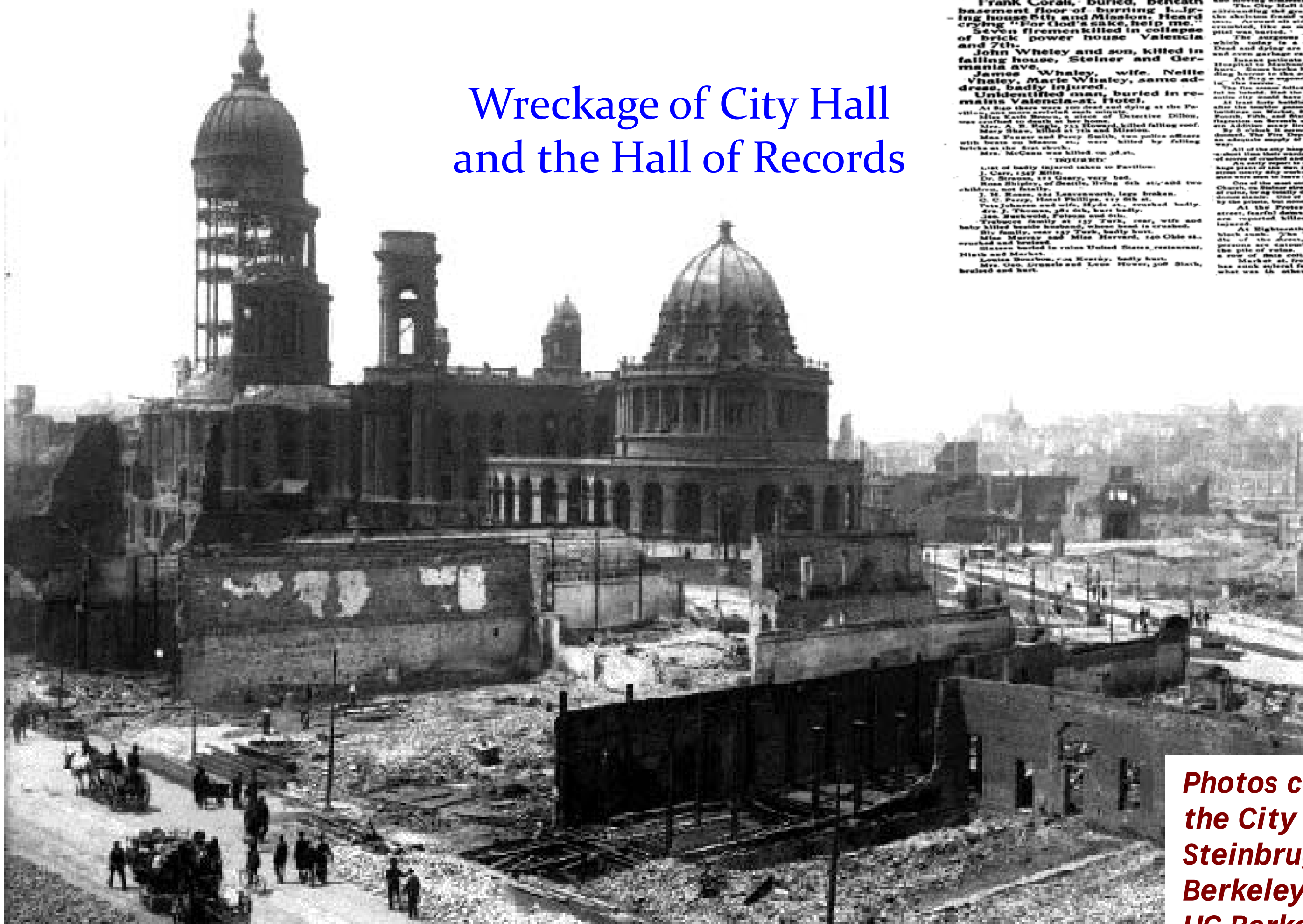
THEATER WRECKED

BRIEF IDEA OF DISASTER

IN OAKLAND

THIS EDITION ISSUED FROM 1808 MISSION ST. WHERE COPIES MAY BE HAD.

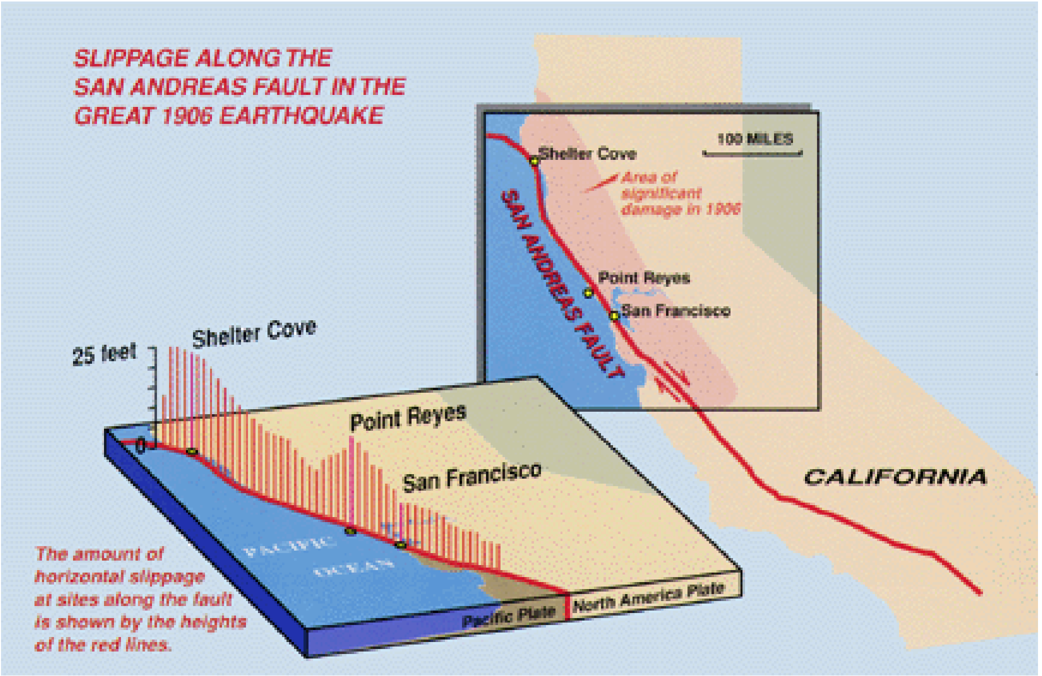
Wreckage of City Hall and the Hall of Records

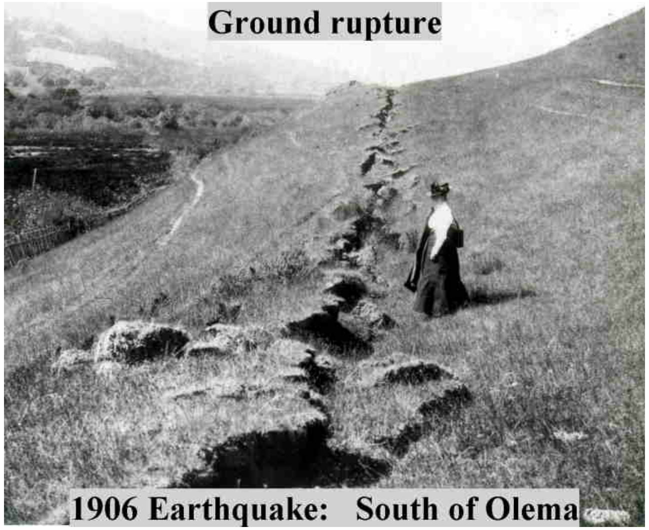


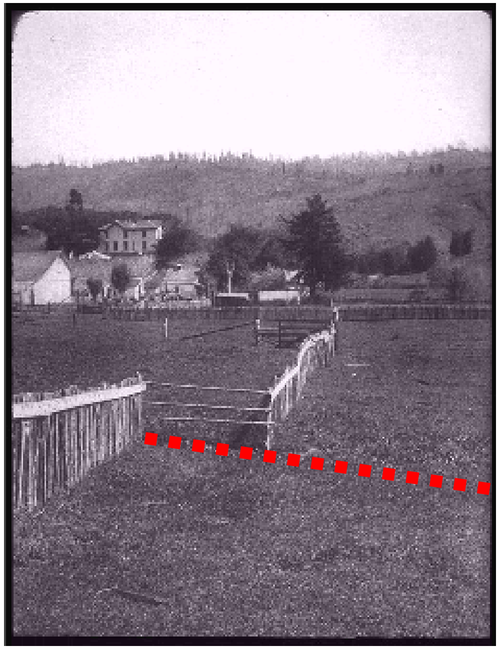
Photos courtesy of the Museum of the City of San Francisco; the Steinbrugge Collection of UC Berkeley; and the Bancroft Library, UC Berkeley

The Great 1906 San Francisco Earthquake Extended for ~ 350 km Along the San Andreas Fault in Northern California.

Horizontal offsets of as much as 8 meters were observed.



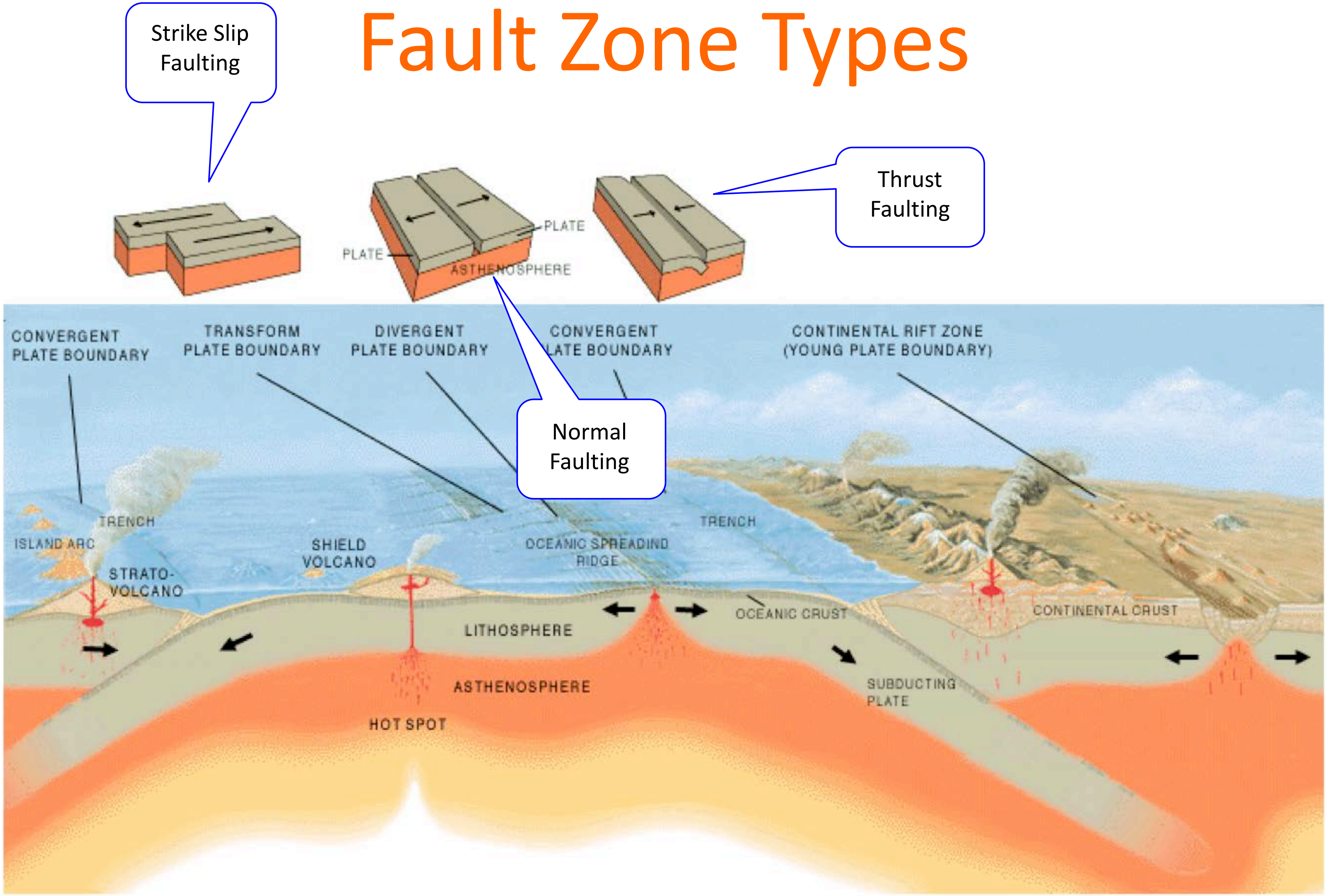


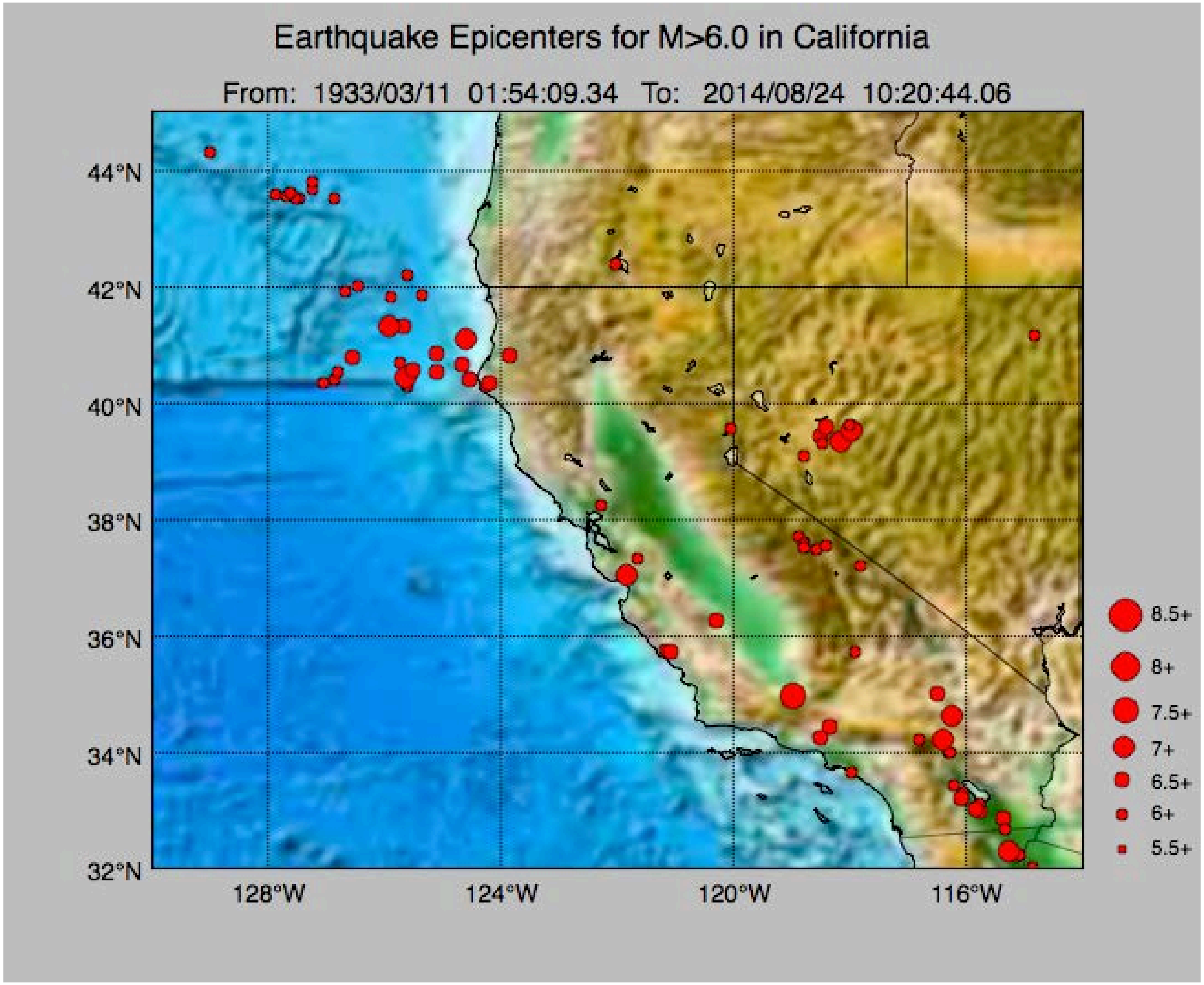


Wayne Thatcher, US Geological Survey

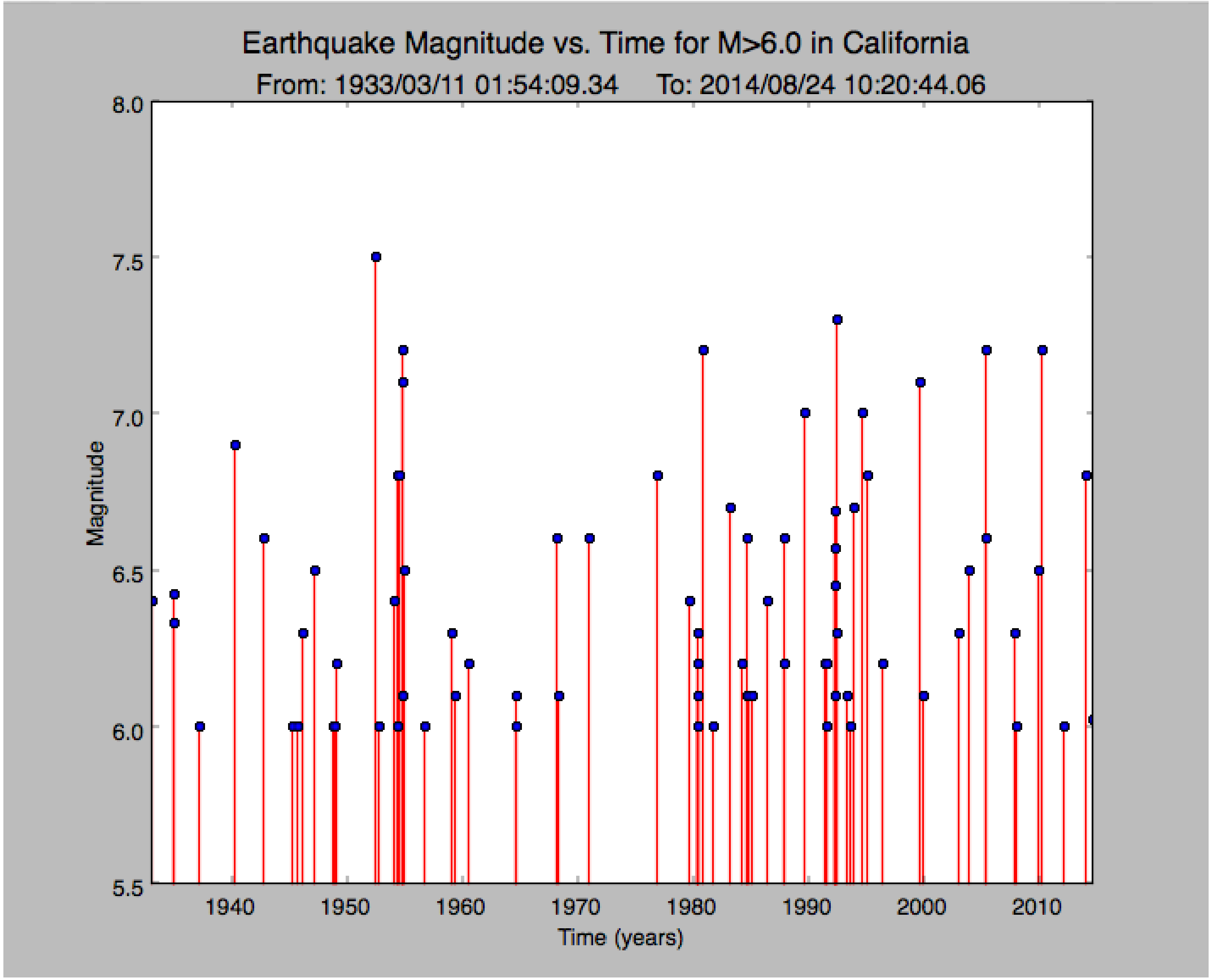
Three coupled spatial scales visible: 1. Fault length (~430 km); 2. Slip (~m); 3. Rupture thickness (~cm)

Fault Zone Types



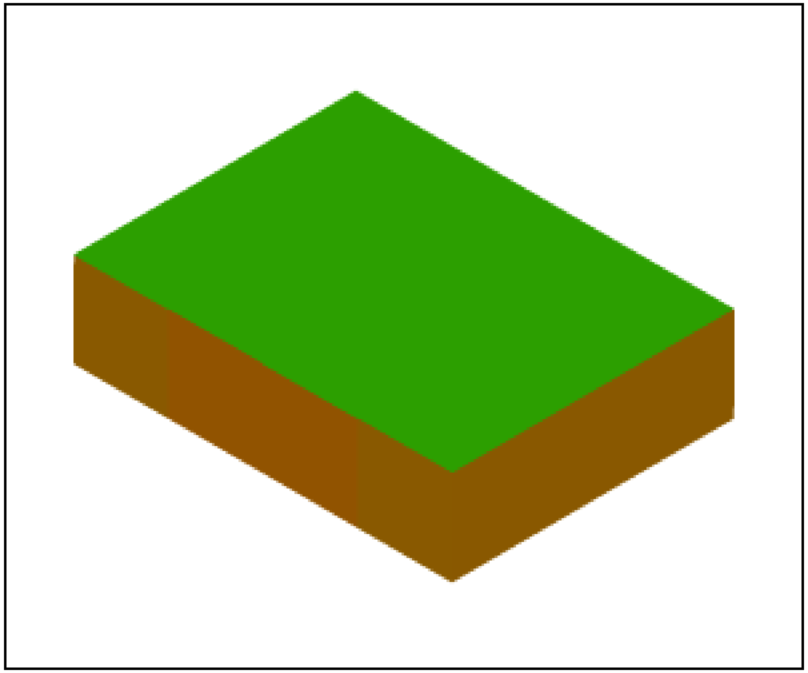


Earthquake Epicenters for M>6.0 in California
From: 1933/03/11 01:54:09.34 To: 2014/08/24 10:20:44.06
44°N
42°N
40°N
38°N
36°N
34°N
32°N
128°W
124°W
120°W
116°W
8.5+
8+
7.5+
7+
6.5+
6+
5.5+


Earthquake Magnitude vs. Time for M>6.0 in California
From: 1933/03/11 01:54:09.34   To: 2014/08/24 10:20:44.06
Magnitude
8.0
7.5
7.0
6.5
6.0
5.5
1940
1950
1960
1970
1980
1990
2000
2010
Time (years)

The Earthquake ”Cycle”

(Courtesy P.B. Rundle)



“Strike-slip” Earthquakes (mainly horizontal motion)

Section 1

"All the News That's Fit to Print."

The New York Times.

THE WEATHER
Partly cloudy today; Monday unsettled; probably showers.
Temperature yesterday—Max. 82.2, min. 65.
For full weather report see Page 22.

Section 1

VOL. LXXII....No. 23,962. NEW YORK, SUNDAY, SEPTEMBER 2, 1923. Including Rotogravure Section in two parts—Book and Magazine Section. FIVE CENTS In Manhattan, Bronx and Brooklyn | Elsewhere TEN CENTS

GREAT EARTHQUAKE AND FIRE RAVAGE TOKIO AND YOKOHAMA; MANY PERISH, BUILDINGS COLLAPSE; SURVIVORS FLEE IN PANIC; ITALY SEIZES TWO MORE ISLANDS; LEAGUE TAKES UP THE CASE

COAL STRIKE FORCES 100 PER CENT. TIE-UP; RECESS IN PARLEYS

All of 158,000 Miners, Except Maintenance Men, Drop Tools and Quit.

DISPUTANTS CONFER AGAIN

Meet With Pinchot for Half an Hour and Then Adjourn Until Wednesday.

GOVERNOR MORE HOPEFUL

Expects Rest to Help His Cause, and Meanwhile Asks Expression of Public Opinion.

Special to The New York Times.

HARRISBURG, Pa., Sept. 1.—There is a total suspension of work today in the anthracite coal fields. Reports received here by anthracite operators and miners indicated that all but 4,000 of the 158,000 hard coal miners had walked out. Those who remained to work are the maintenance men whose duty it is to keep the mines free of water and gas and to prevent cave-ins.

Representatives of the operators and the miners met Governor Pinchot for half an hour today and decided to reconvene on Wednesday at 2 P. M. The Governor expressed himself as very much

Policeman Slain as He Orders Four to Move; Eyewitness Gives Names of Two Assailants

The list of policemen murdered in the performance of their duty was increased last night when Patrolman John E. Egan of the Westchester Station was shot three times and killed at the northwest corner of Benson and Tremont Avenues, the Bronx.

With the murders of Patrolman Reynolds and Romanella still unsolved and apparently no clue to the identity of the man who killed them at Sixty-fourth Street and Second Avenue, several months ago, the police were spurred into new activity last night by the news of Patrolman Egan's murder.

Arrests of the men implicated in the Egan murder are expected momentarily by the police. They say they have the names of two, one of whom did the killing.

Through the aid of a young woman who was passing when the policeman was murdered, detectives of the Sixth Inspection District, working under Acting Captain Henry Bruckman, learned what occurred.

Egan was doing special duty in plain clothes, an assignment that carries a roving commission to patrol anywhere within the precinct on the watch for vice, gambling or disorderly persons. The patrolman was on the southeast corner of Benson and Tremont Avenues shortly after 10 o'clock when he saw four men standing on the northwest corner.

As he noticed them they started scuffling among themselves, but whether in play or earnest could not be learned. He walked over to them and ordered them to leave. As he did so, one of the men, whose name was given to the police, struck the patrolman a blow in the face with his fist. As the four men sprang at him Egan threw off his coat and fought back. He shouted to the men that they were under arrest and drew his pistol. One of the four men, whose name also was given to detectives by the young woman, snatched the revolver away from him and fired.

As the patrolman turned toward him the man fired again and Egan sank to the ground. As he collapsed the man with the pistol fired again. Egan, falling, had turned slightly away from the man and the third bullet, the one which is believed to have killed him, struck him in the left side of the back.

As the patrolman fell the four men turned and ran, the man with the patrolman's pistol still holding the weapon. In the excitement that followed no one noticed which way they went. It is believed they ran a short distance and then hired a taxicab.

Patrolman Egan had been a policeman for a little more than a year. About three months ago he received commendation for a spectacular bit of police work when while riding a Police Department horse he chased a runaway horse for almost five miles through Bronx streets and was injured while bringing the runaway to a halt. He was 24 years old and lived at 1222 Boynton Avenue, the Bronx, with his wife and two children.

PHYSICIANS DENY HYLAN HAS CANCER

Dr. John J. McGrath, President of Bellevue Hospital, Visits

ALIENS ON FOUR SHIPS TOO SOON TO ENTER

Most of 1,896 Who Arrived Before Instead of After Mid-

MORE GREEK ISLANDS SEIZED

Italian Forces Occupy Paxos and Antipaxos, Strategic Points.

GREEK STEAMER FIRED ON

Channel Is Under Blockade, Italian Submarine Commander Tells Merchantman.

NO MORE SEIZURES LIKELY

But Rome Orders Other Naval Units to Lower Adriatic Ready for Action.

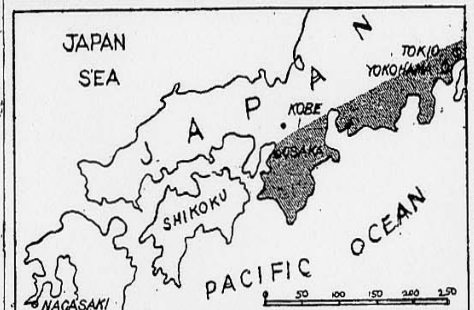
ROME, Sept. 1 (Associated Press).—The small islands of Paxos and Antipaxos, part of the Ionian group, in the vicinity of Corfu, have been occupied by the Italians.

The Government here has officially announced that the occupation of Corfu probably will be the limit of Italian advances for the enforcement of sanctions and that consequently there probably will be a short breathing spell.

A message received by way of Corfu says the Greek ships at Phaleron have been moved to Salamis.

Italian naval units which had been stationed at Spezia and Venice, however, now are steaming for Southern Adriatic waters in full war status, and eight transports are held in readiness in case

AREA OF EARTHQUAKE DAMAGE IN JAPAN.



Coolidge Cables Sympathy to Emperor of Japan; Navy Orders Vessels to Yokohama for Relief

WASHINGTON, Sept. 1.—President Coolidge tonight addressed to Emperor Yoshihito of Japan a message of sympathy on the part of himself and the American people for the sufferers from the earthquake in Japan.

The President's message read:

> At the moment when the news of the great disaster which has befallen the people of Japan is being received, I am moved to offer you in my own name and that of the American people the most heartfelt sympathy, and to express to your Majesty my sincere desire to be of any possible assistance in alleviating the terrible suffering to your people.

Orders were given tonight to the American Asiatic squadron to rush ships to Yokohama to assist in relief measures.

Admiral Anderson, commanding the fleet, was instructed to use all possible speed in dispatching the vessels and their commanders to render every aid possible.

The Asiatic fleet is now near Port Arthur, and Admiral Eberle, Chief of Naval Operations, said it was probable that Admiral Anderson had already dispatched a squadron of destroyers to Yokohama, where an American naval hospital is located. He added, however, that in order to assure the presence of American relief ships there, specific orders were dispatched.

FIRES RAGE IN WHOLE TOKIO DISTRICT

All Yokohama Burning and Neighboring Towns Are Involved as Water Systems Are Wrecked--Business Suspended.

TREMENDOUS LOSS OF LIFE AND PROPERTY INDICATED

700 Are Killed in the Asakusa Tower---People Flee to Ships---Earthquake Centres in the Extinct Volcano of Fuji---Cables Interrupted.

SAN FRANCISCO, Sept. 1 (Associated Press).—Tokio is afire, many buildings of the city have collapsed, the water system is destroyed, the loss of life is heavy, all traffic has been suspended and the flames are spreading to surrounding towns, following a terrific earthquake, according to a message received here tonight by the Radio Corporation of America from the superintendent of the company's station at Tomioka.

[Other messages report that the whole city of Yokohama is burning and that great loss of life and property has been caused.]

The Radio Corporation's superintendent said he obtained his information from a morning paper at Sendai, a large seacoast town about 200 miles north of Tokio. Tomioka is about 144 miles north of Tokio.

Casualties Very Heavy.

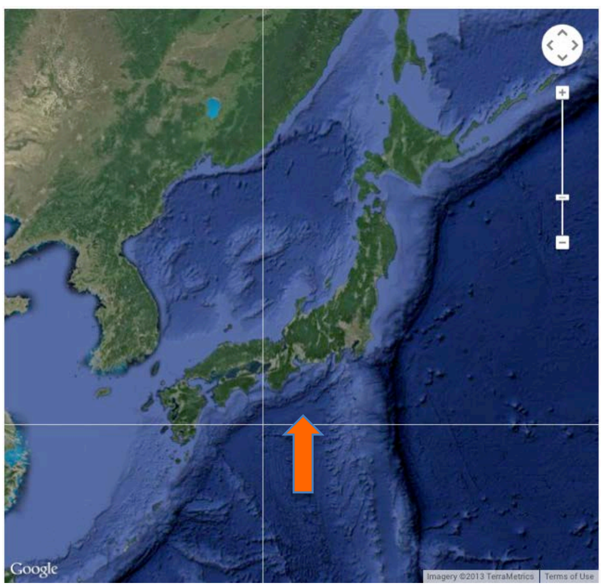
The message read:

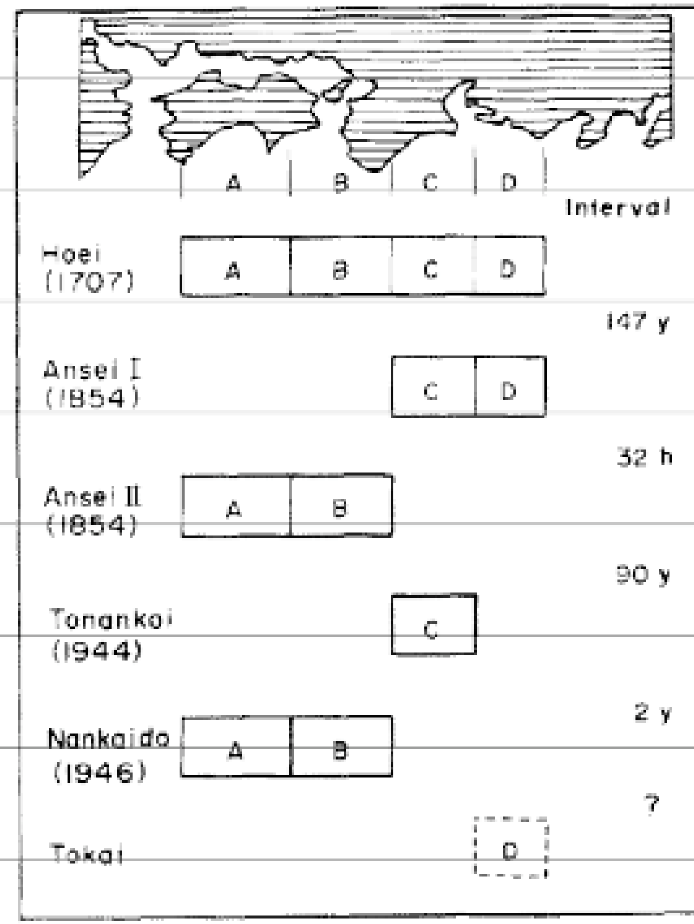
"Severe earthquake Tokio and vicinity at noon yesterday.

Earthquakes in Nankai Trough, Japan

M Ando, Tectonophysics, v27, p112 (1975)

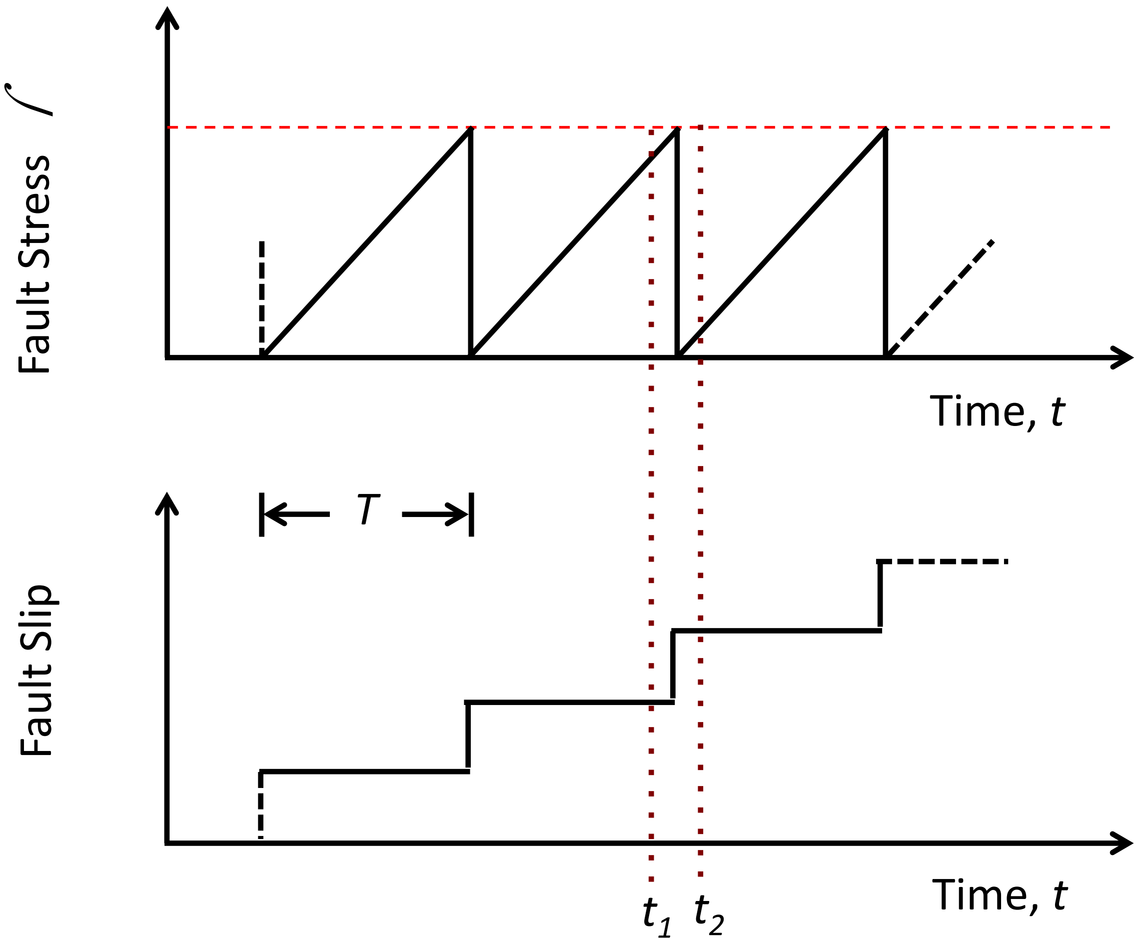
- Data from historic writings in Japan
- Basic ideas of the earthquake "cycle" essentially started here

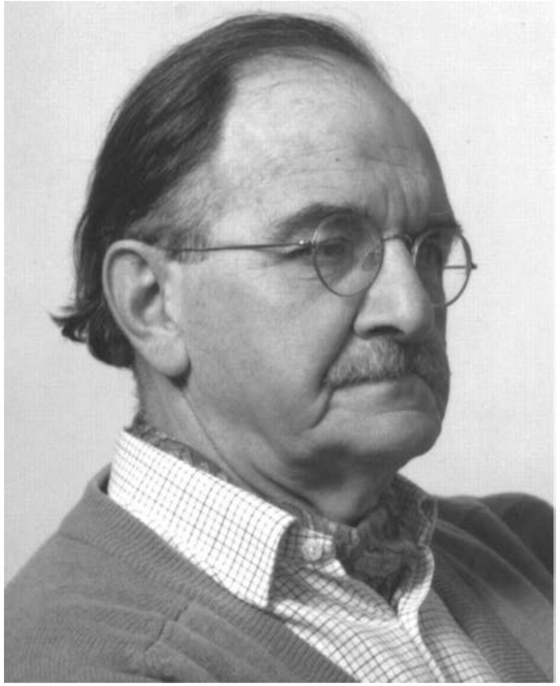




Idealized Model of Elastic Rebound on a Fault

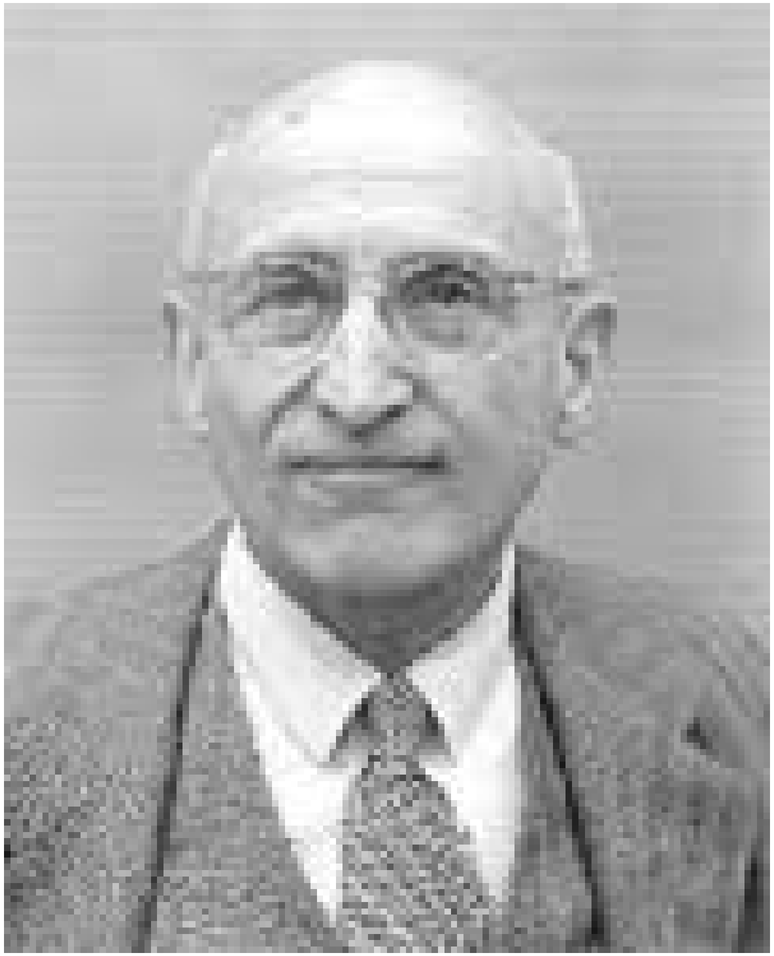
Report of the 1906 Earthquake Investigation (1910)





Harry Fielding Reid (1859-1944)

Gutenberg-Richter Relation (1942)(Frequency-Magnitude Relation)



Beno Gutenberg (1889-1960)

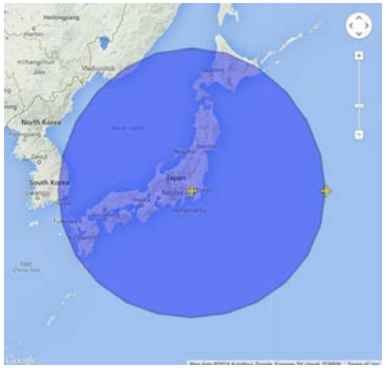
Charles Richter (1900-1985)

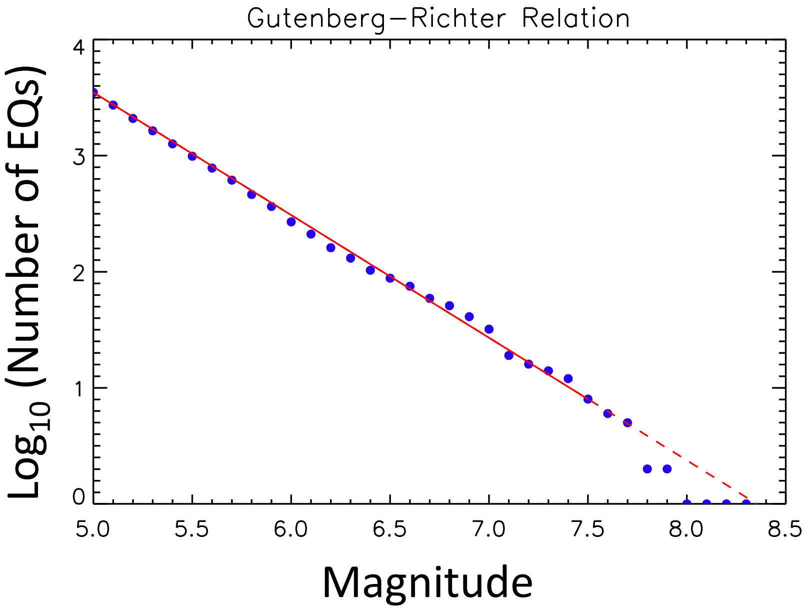
Gutenberg-Richter Relation

Statistics Before and After 3/11/2011

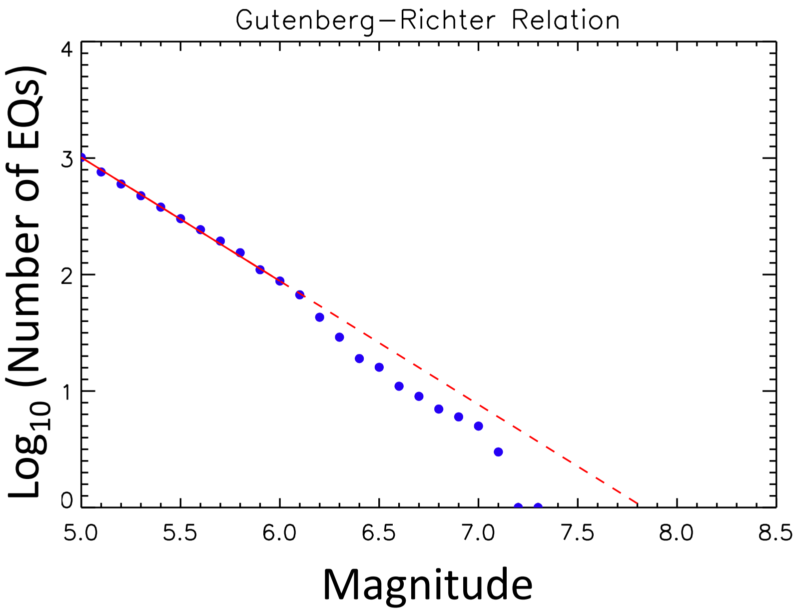
Radius of 1000 km Around Tokyo (Accessed July 1, 2015)

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)

On Earthquake 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

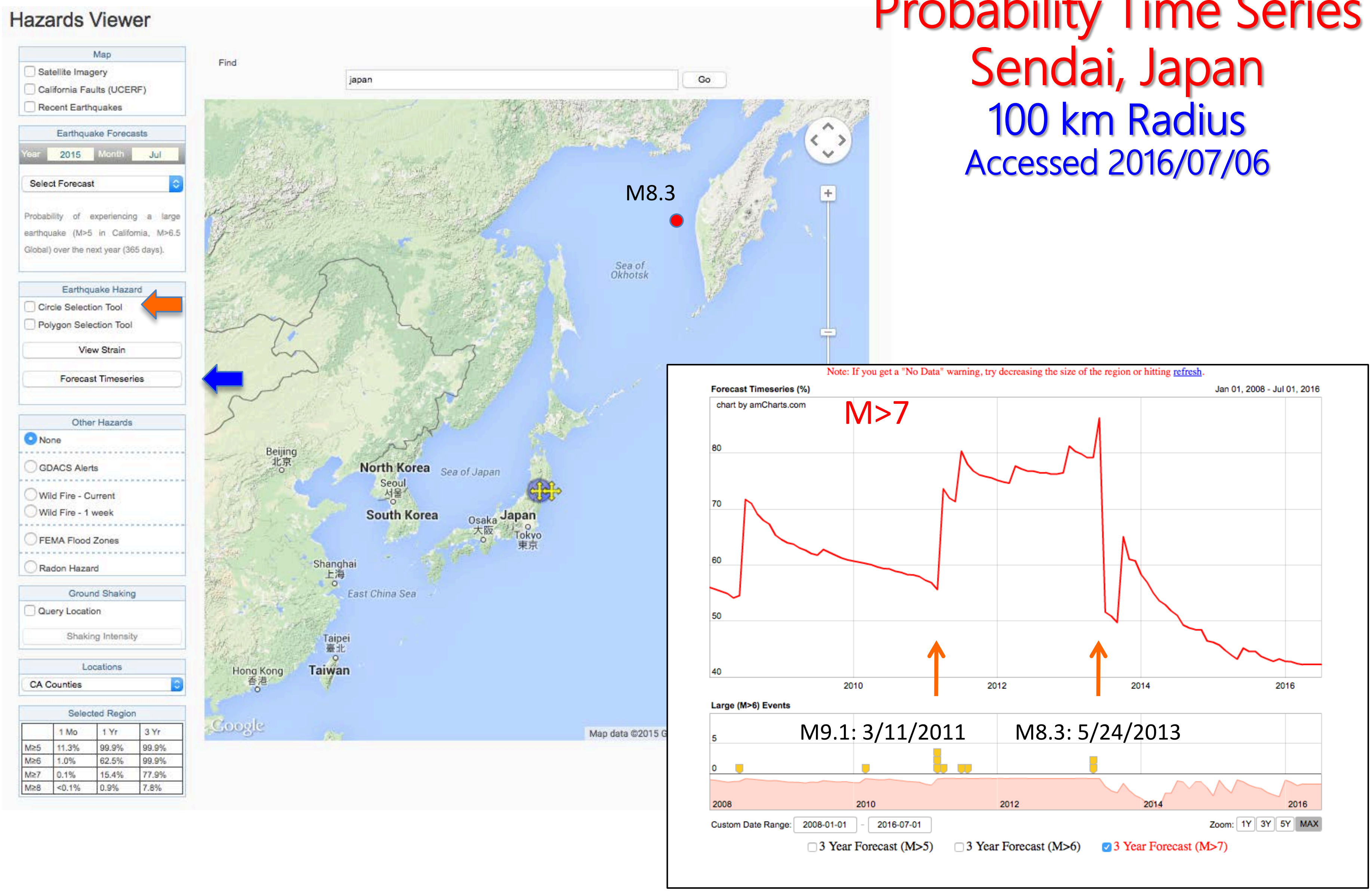
Natural Time Weibull Forecast

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

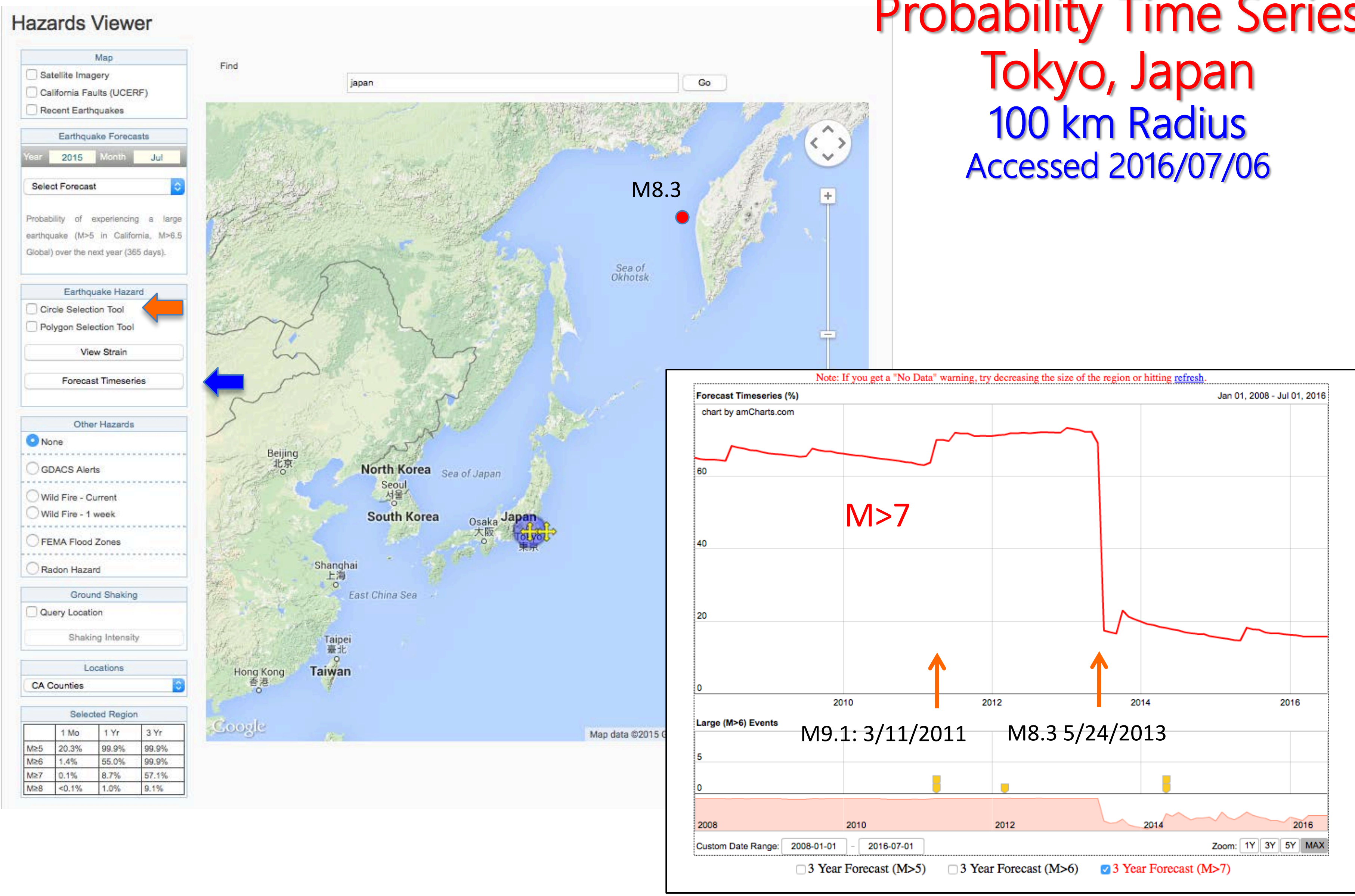
- Data from ANSS catalog + other real time feeds
- Based on "filling in" the Gutenberg-Richter magnitude-frequency relation
- Example: for every ~1000 M>3 earthquakes there is 1 M>6 earthquake
- Weibull statistics are used to convert large-earthquake deficit to a probability
- Fully automated
- Backtested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


User login
Main
Prepare
Explore
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
Are you a
Find out a
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.

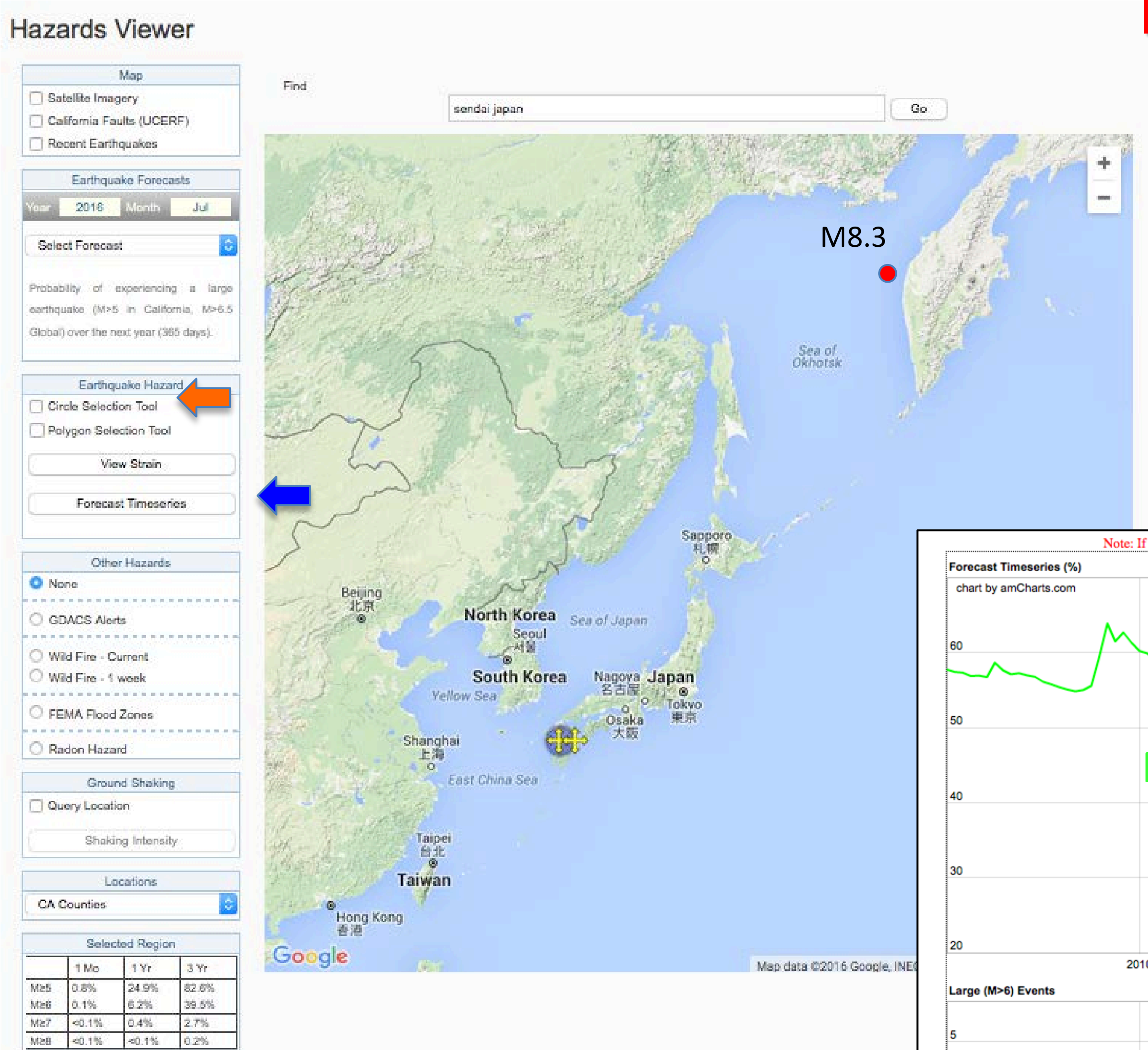
Probability Time Series
Sendai, Japan
100 km Radius
Accessed 2016/07/06

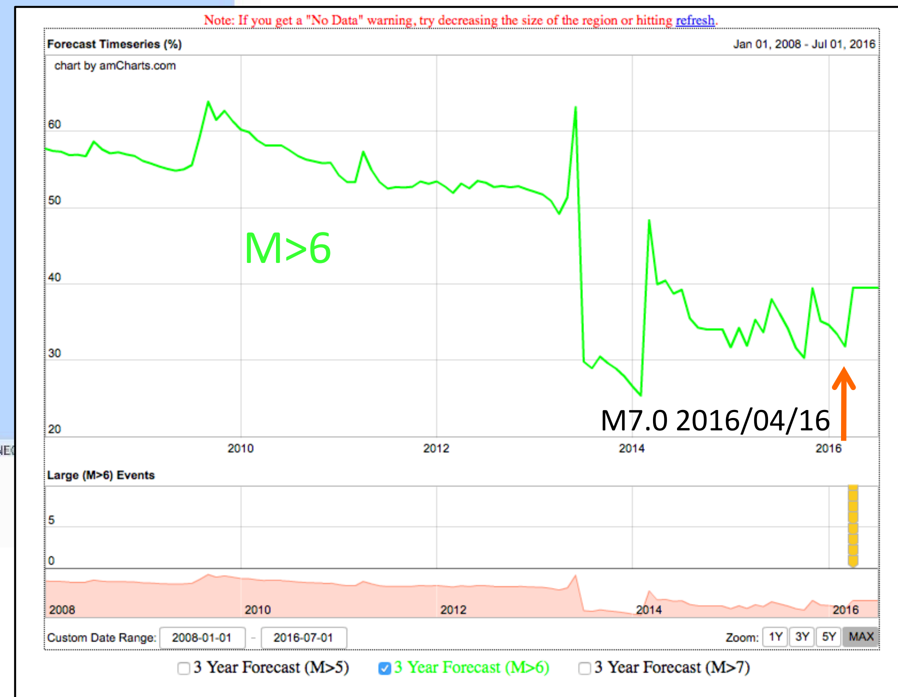


Probability Time Series
Tokyo, Japan
100 km Radius
Accessed 2016/07/06



Probability Time Series
Kumamoto, Japan
100 km Radius
Accessed 2016/07/06

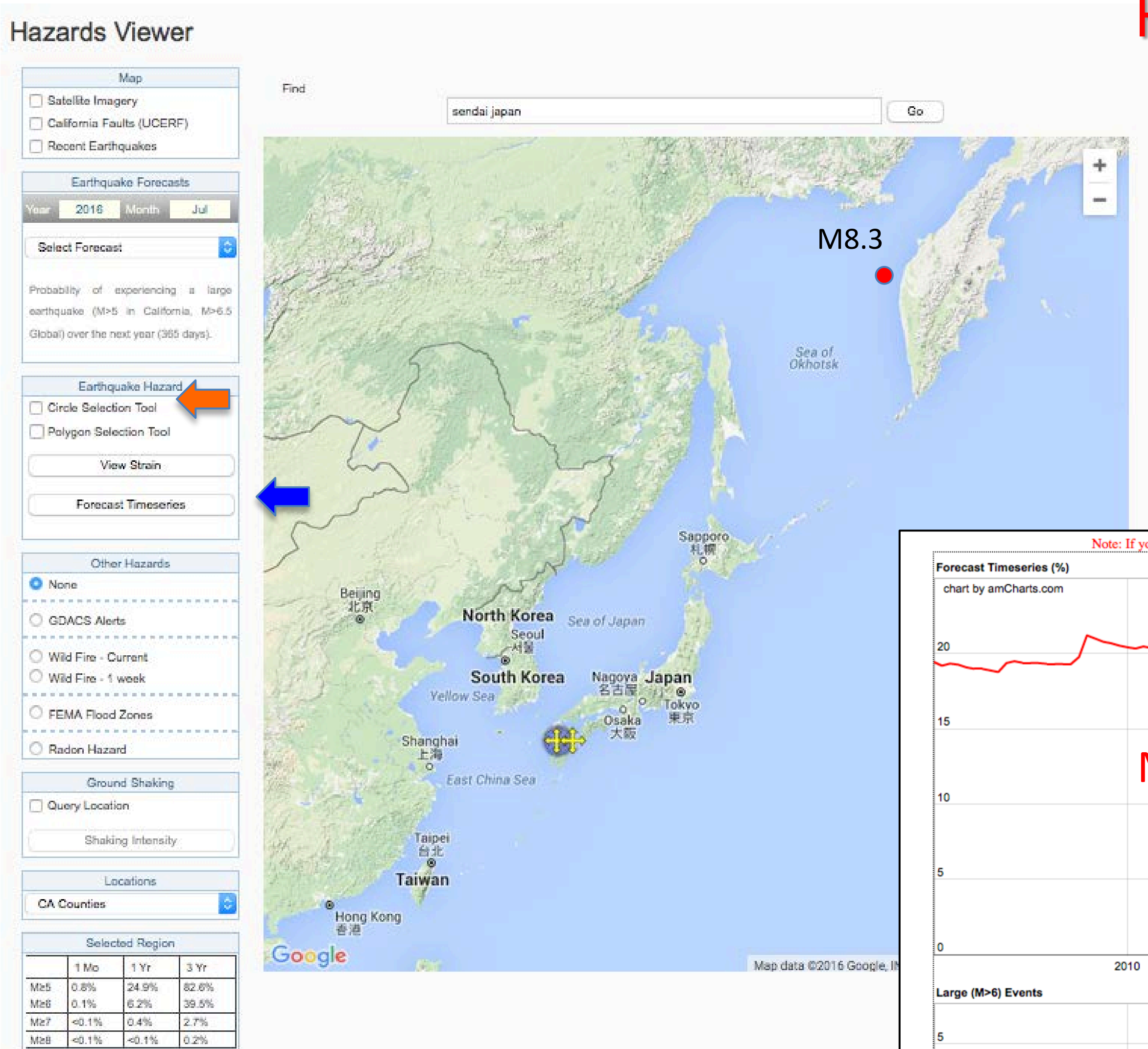




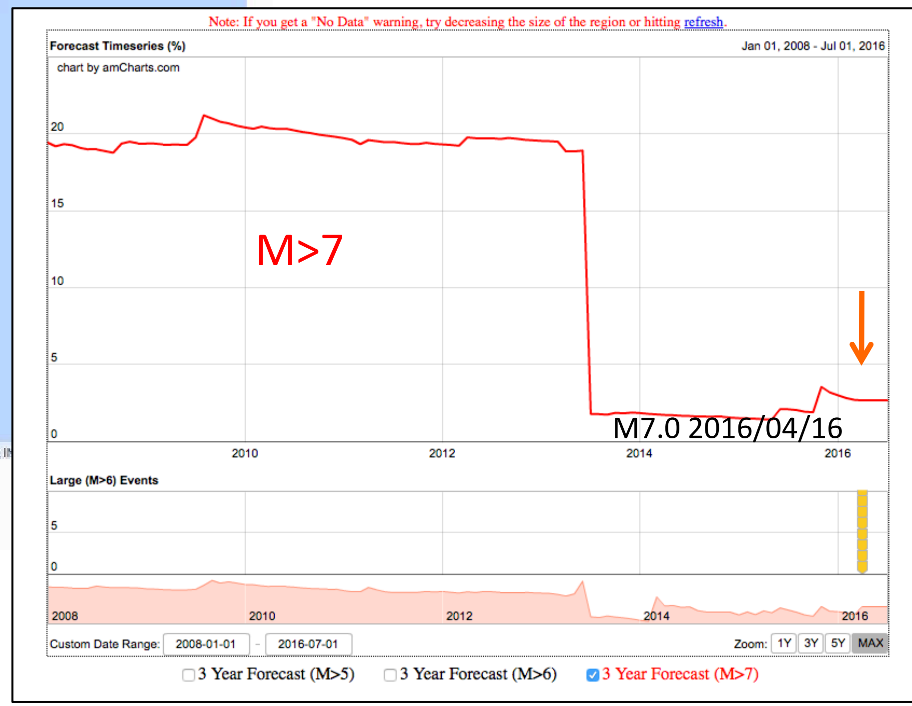
Probability Time Series Kumamoto, Japan

100 km Radius

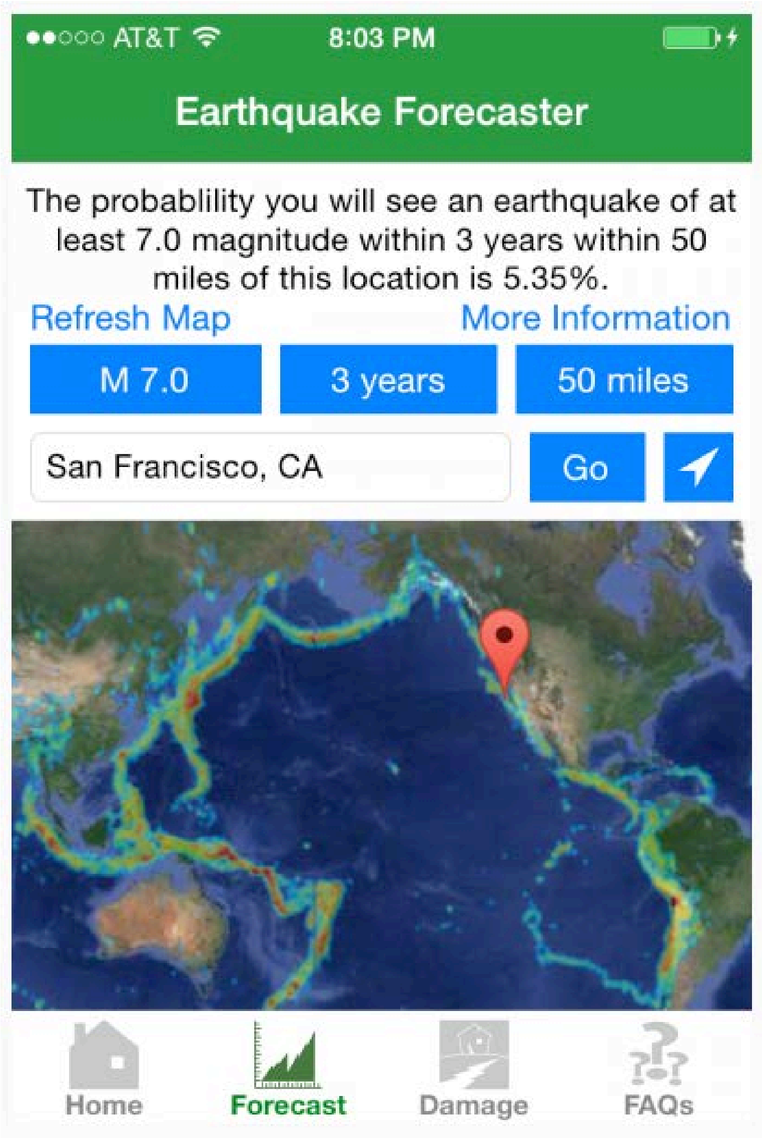
Accessed 2016/07/06

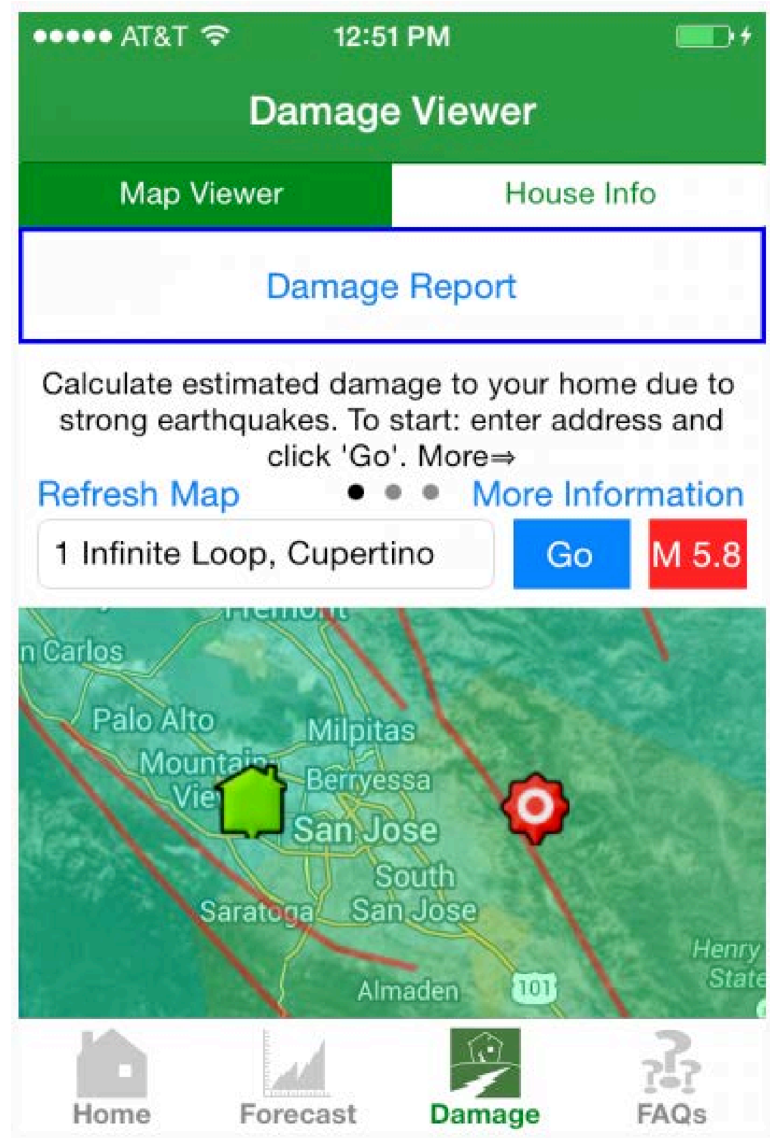


Low probability at time of occurrence. Poor data or model problems?



QuakeWorks Mobile App (iOS)
(Courtesy D.E. Rundle)



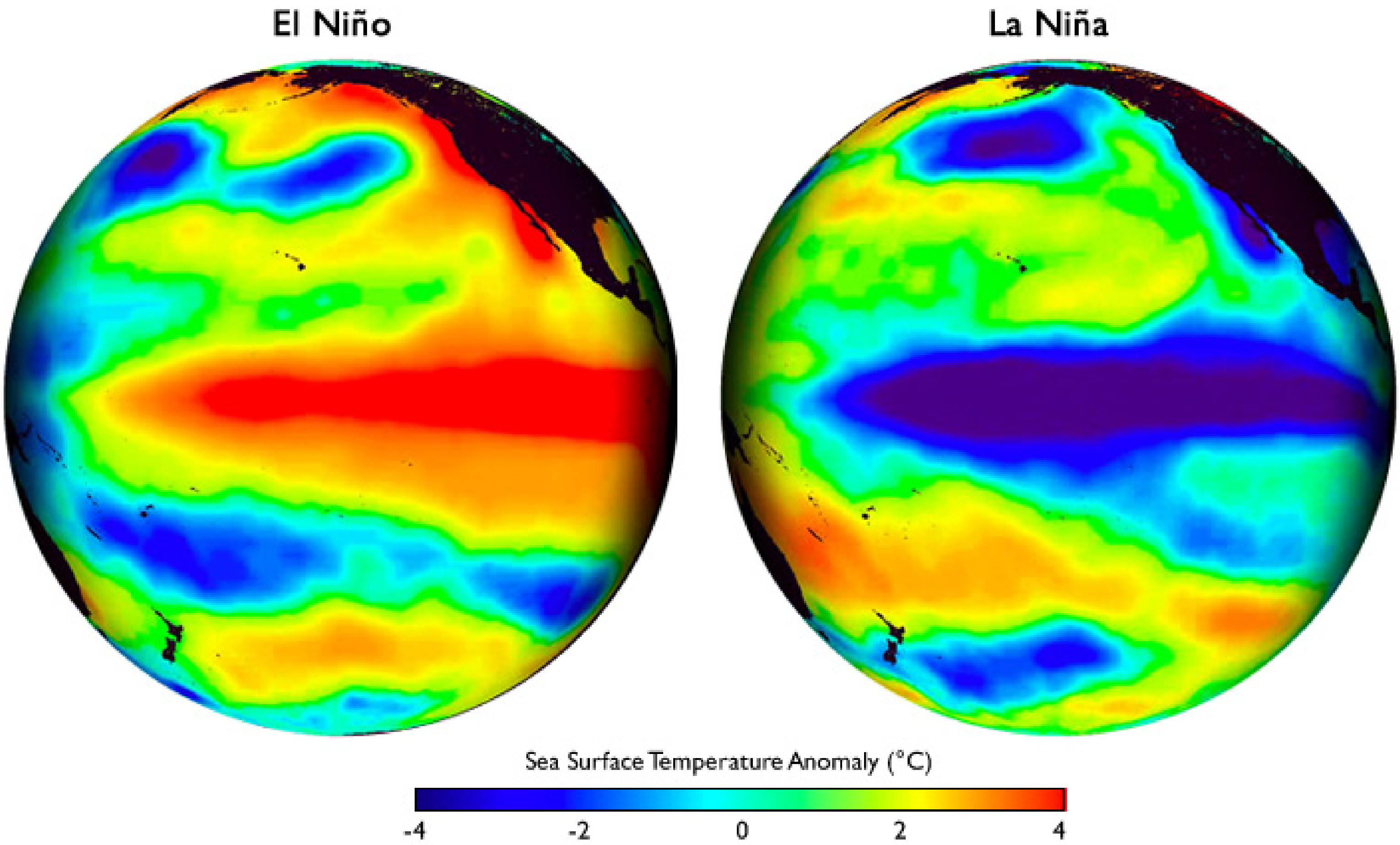


NowCasting

- Natural hazards tend to occur in cycles of activity
  - Earthquakes
  - El Nino Southern Oscillation (ENSO)
  - Pacific Decadal Oscillation (PDO)
- Forecasting is a probability of future activity in the hazard cycle
- Nowcasting describes the current state of the hazard cycle
- The term "Nowcasting" was first used to describe the current state of the economic/business cycle

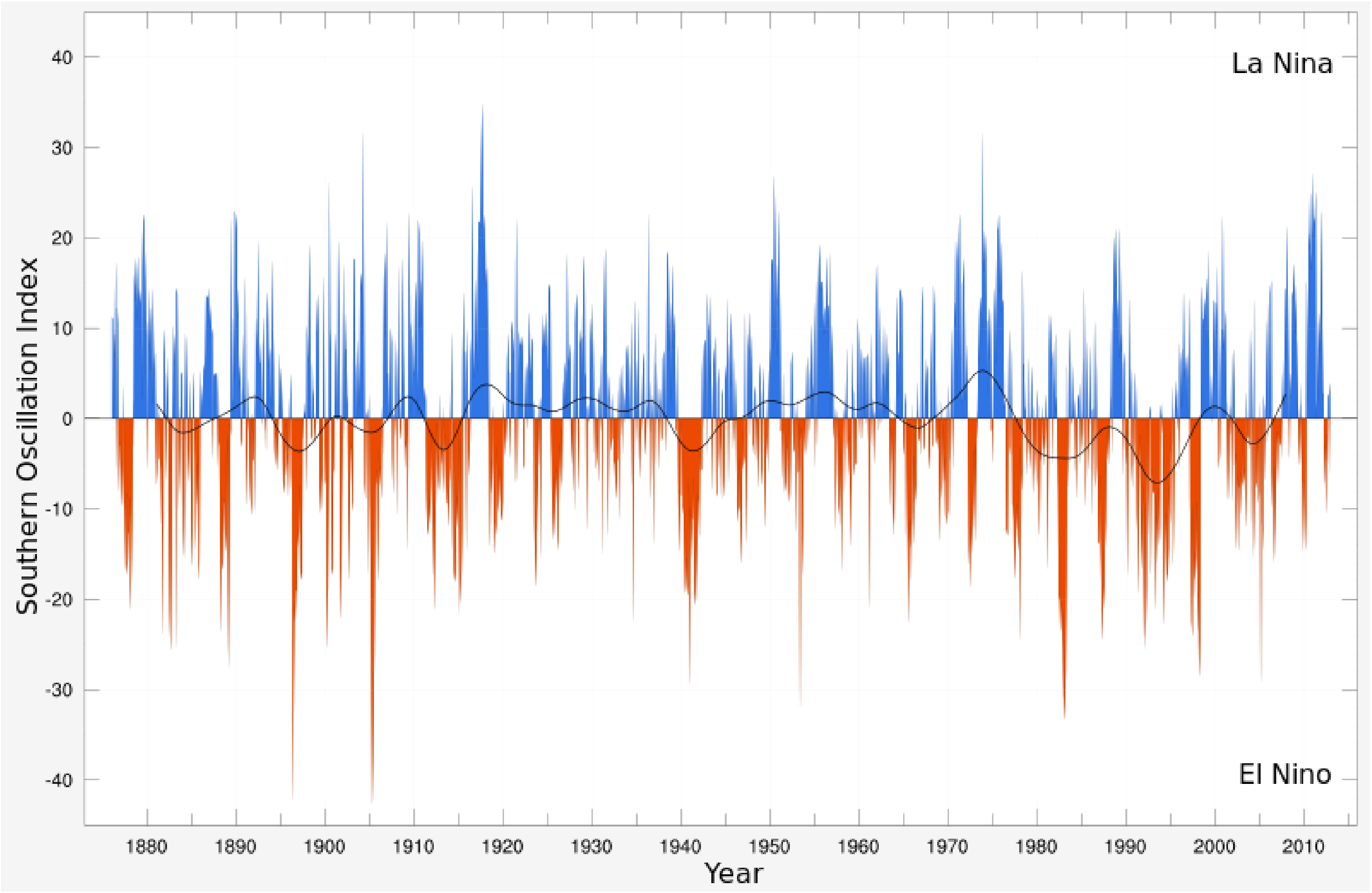
ENSO: El Nino and La Nina

http://www.climate.gov



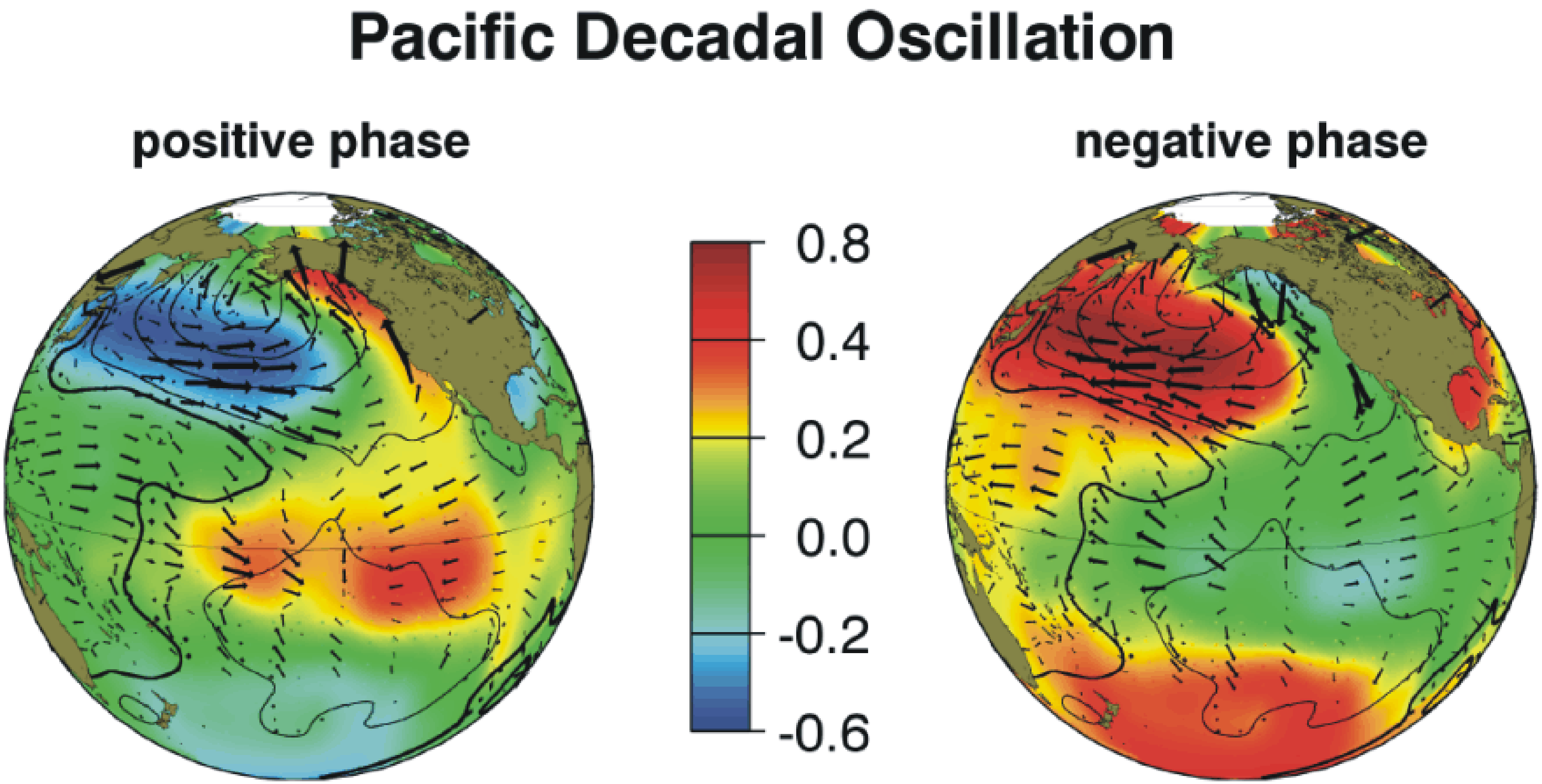
ENSO: Time Series

http://en.wikipedia.org/wiki/El_Nino



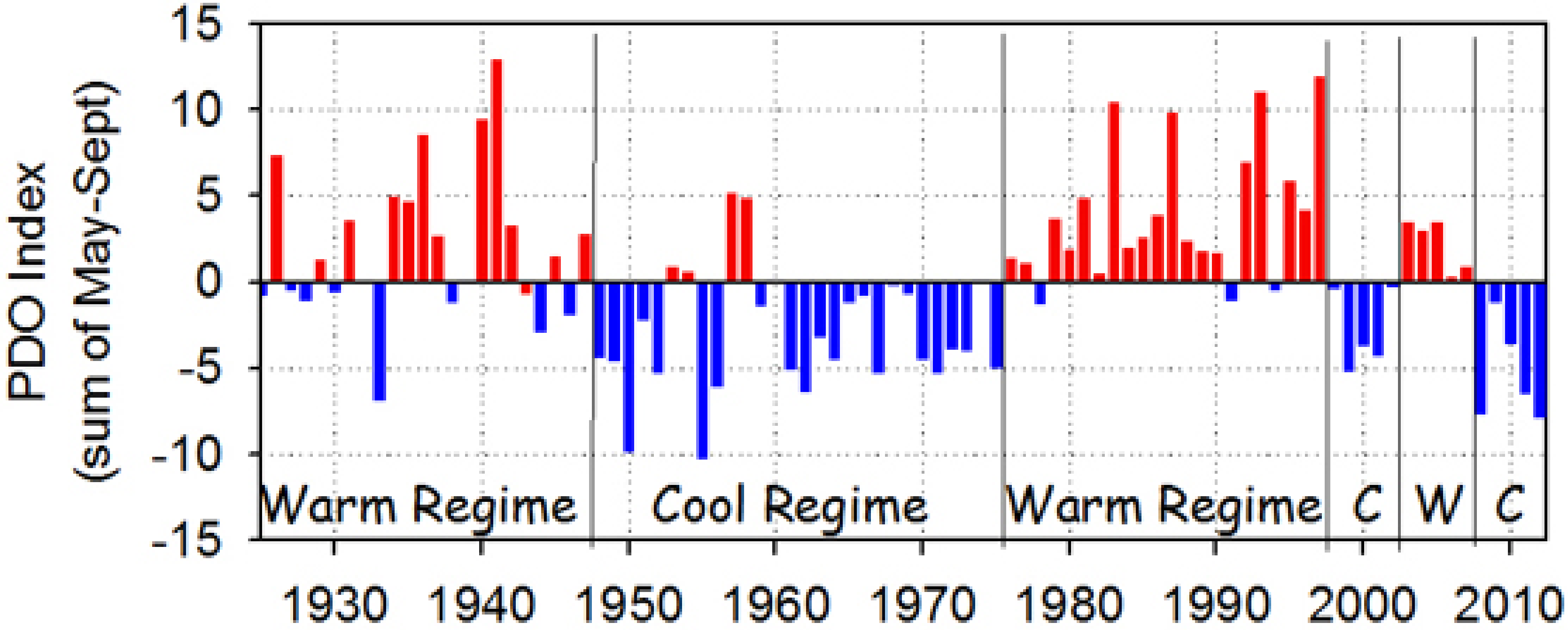
PDO

http://cses.washington.edu

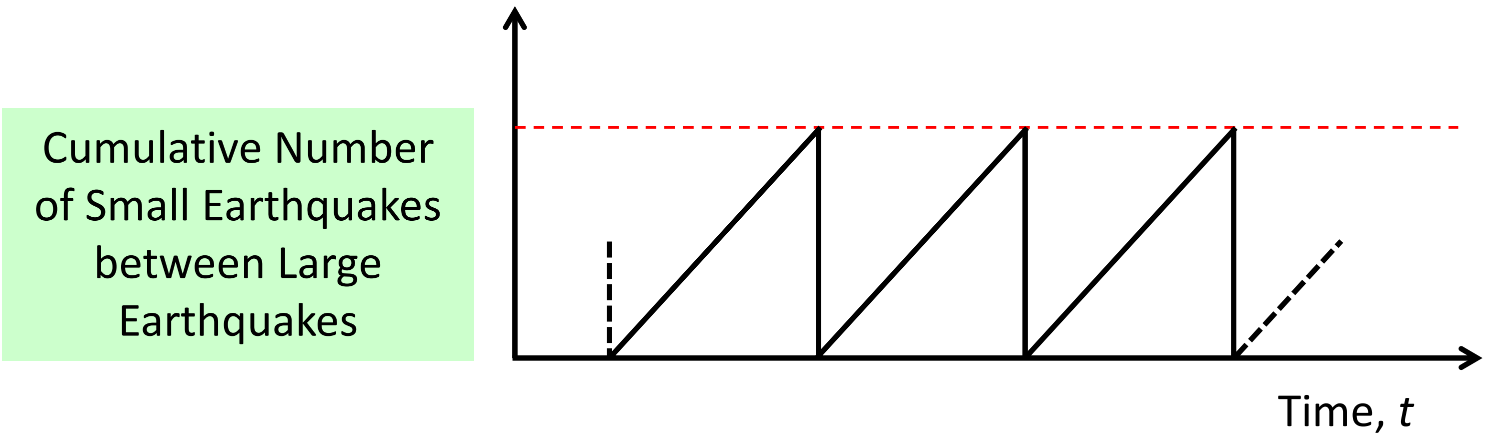


PDO Time Series

http://www.nwfsc.noaa.gov



Idealized Model of the Earthquake Cycle



- If we count the number of small earthquakes since the last large earthquake, we expect it to increase with time (Gutenberg-Richter relation)
- So the count of small earthquakes can be viewed as a marker for the increase of stress and consequently the hazard level

Method

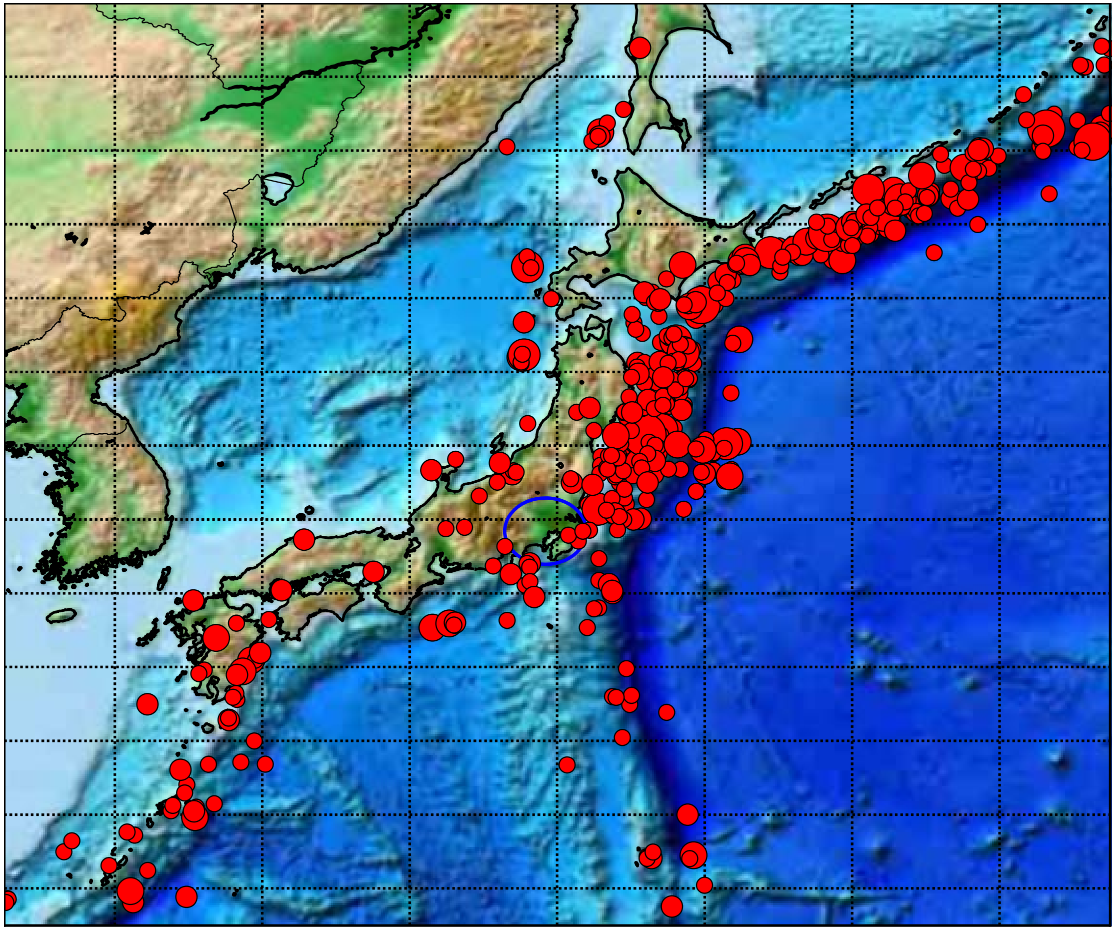
- Select a standard-sized region, either rectangular or circle, in an area where there have been many "large" earthquakes
- Consider only the "small" earthquakes M_S that occur between the "large" earthquakes M_L
- Define the fault system state or Earthquake Potential Score as the cumulative probability for the number of "small" earthquakes since the last "large" earthquake
- The Gutenberg-Richter law assures that as more "small" earthquakes occur, a "large" earthquake becomes more likely

Examples

- To compare global cities, we select a standard set of parameters
- We construct a 100 km radius circle around a city of interest
- For cities, we consider "large" earthquakes having $M_L > 6$
- The "small" earthquakes for city hazards are determined by the catalog completeness level:
  - For Global cities: $4 < M_S < 6$
  - For California cities: $3 < M_S < 6$

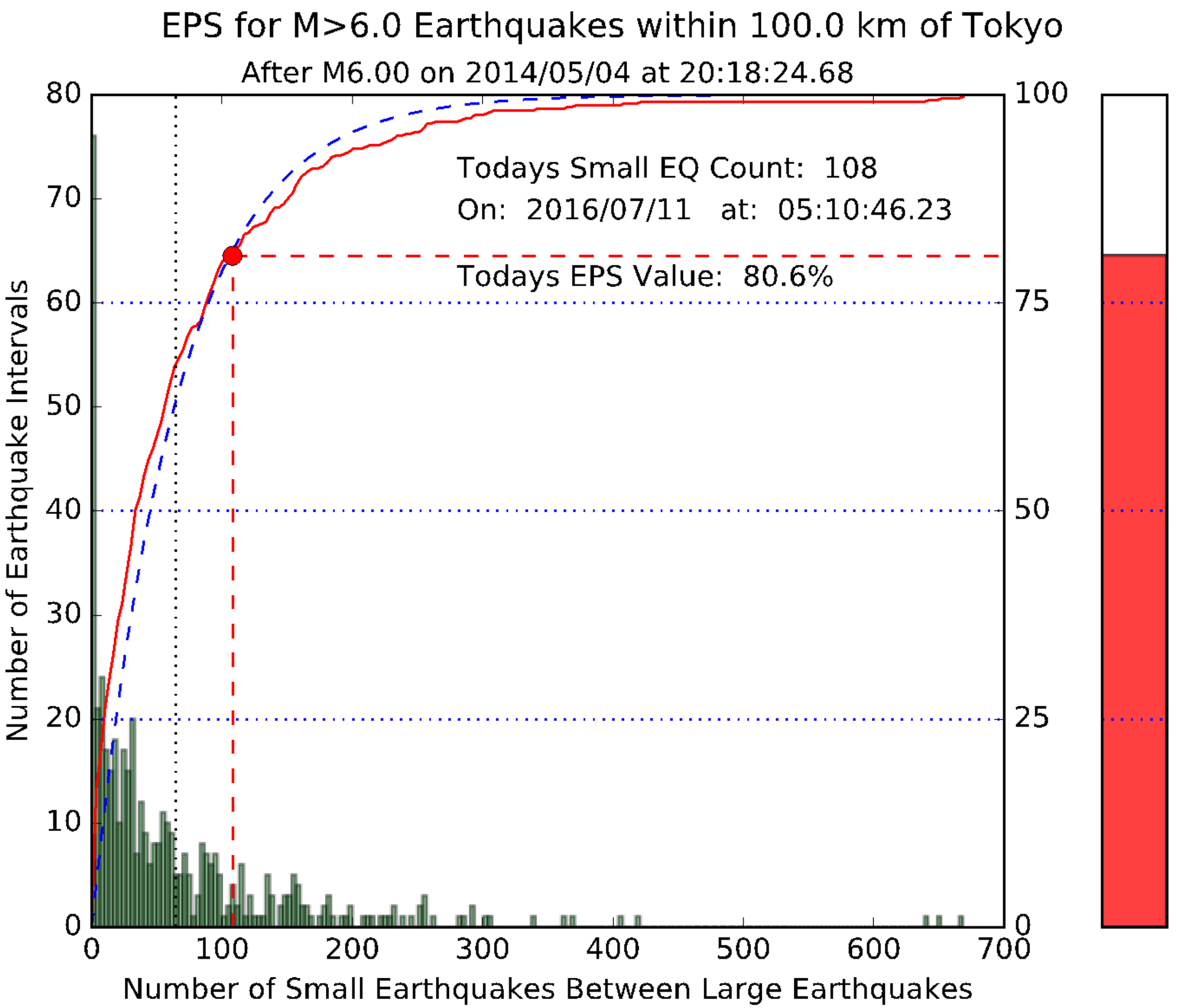
Earthquakes M>6.0 in Japan (Blue Circle = 100.0 km Radius)

0 km



Small: 4 < M_S < 6

Large: 6 < M_L

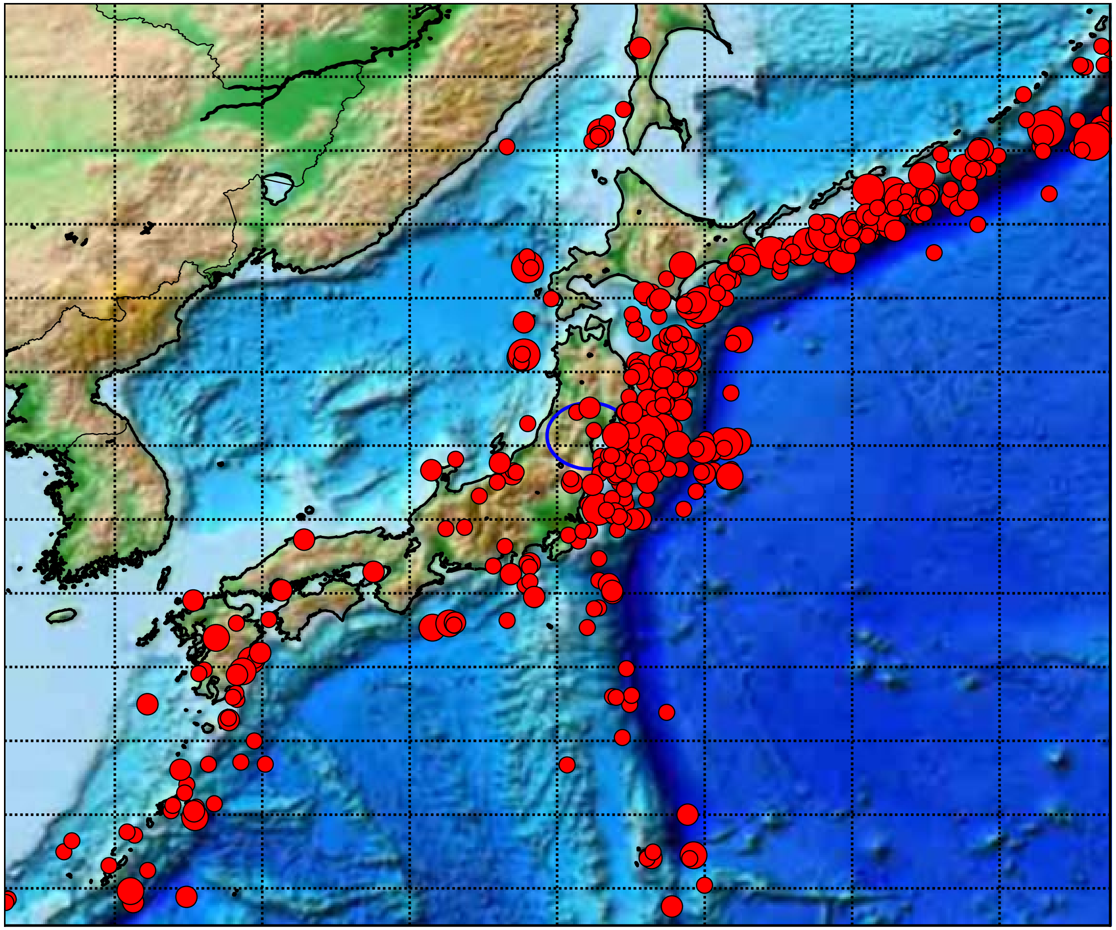


Small: $4 < M_S < 6$

Large: $6 < M_L$

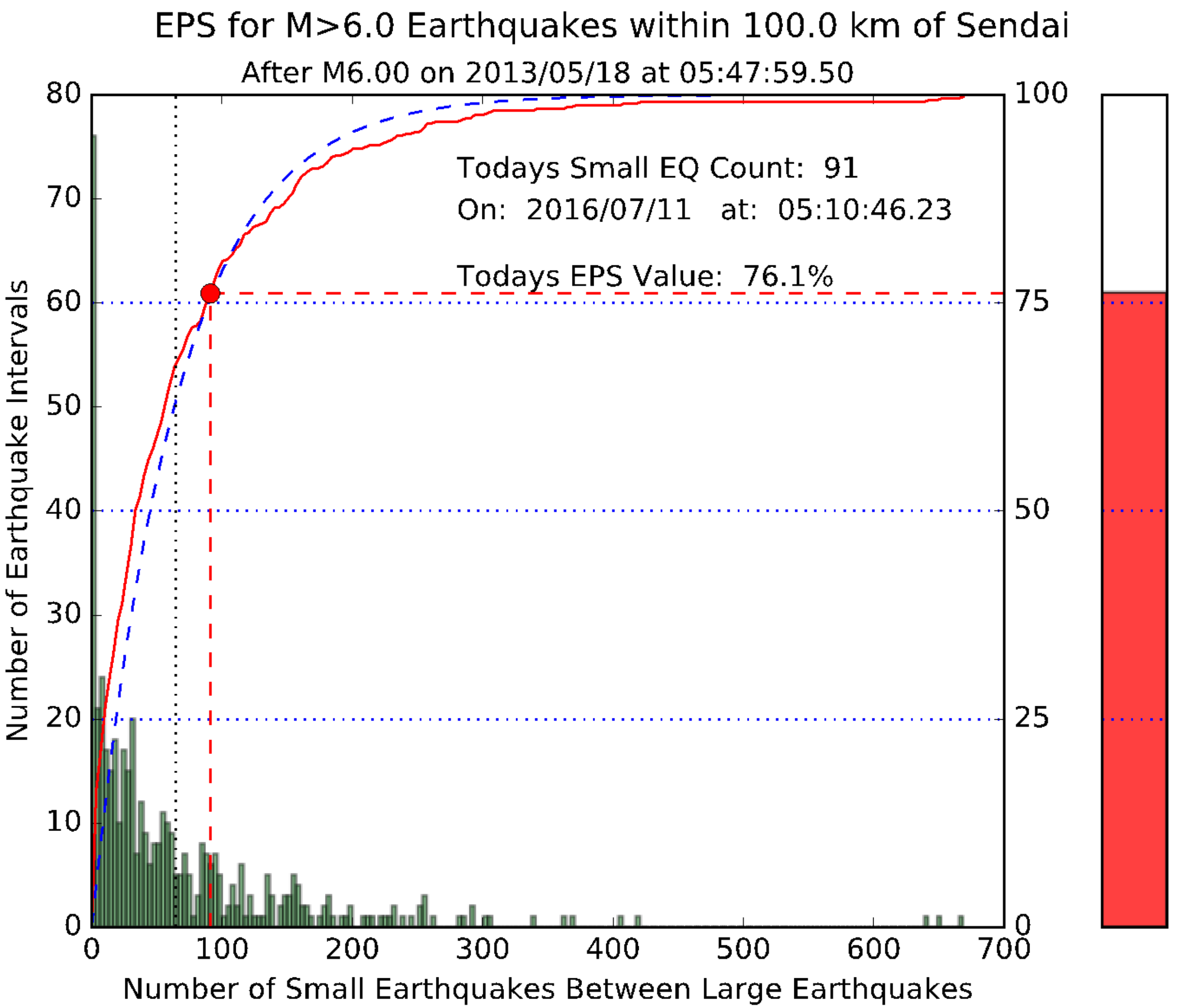
Earthquakes M>6.0 in Japan (Blue Circle = 100.0 km Radius)

0 km



Small: 4 < M_S < 6

Large: 6 < M_L

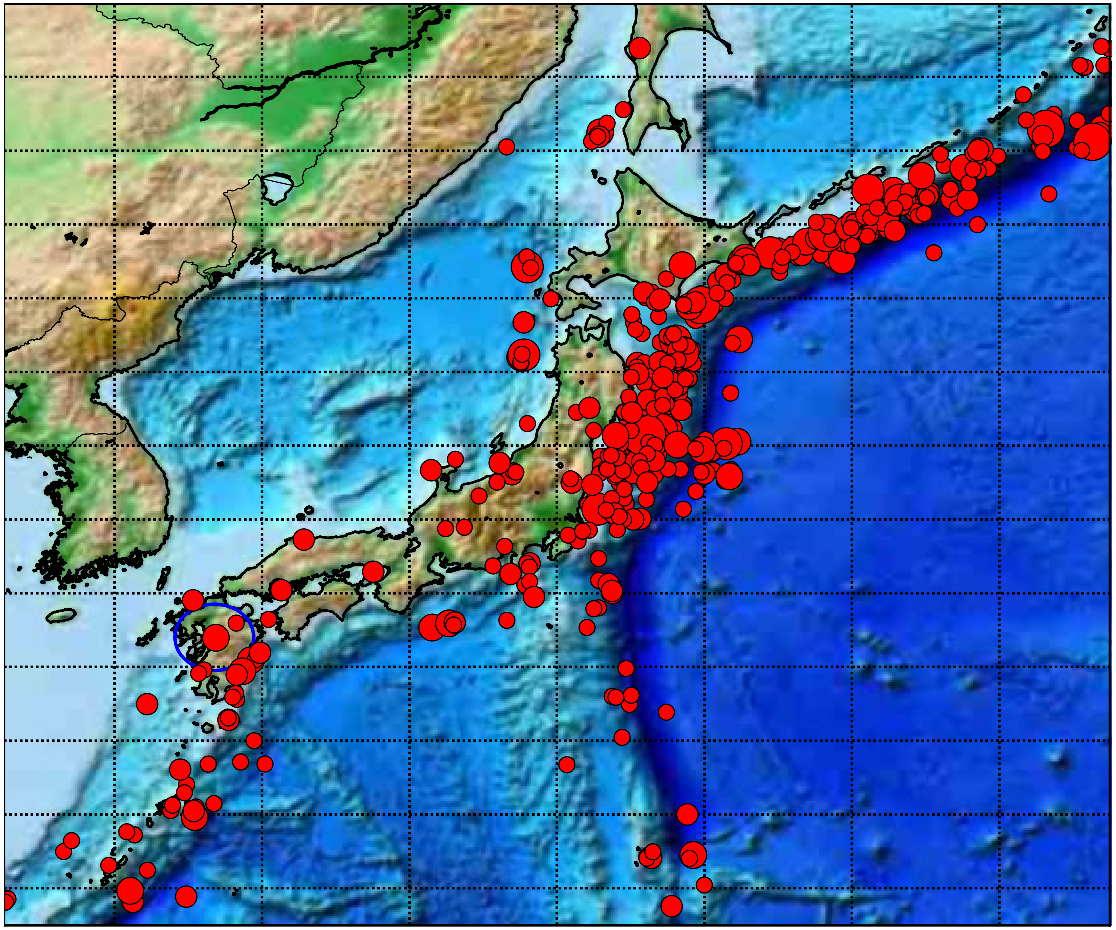


Small: $4 < M_S < 6$

Large: $6 < M_L$

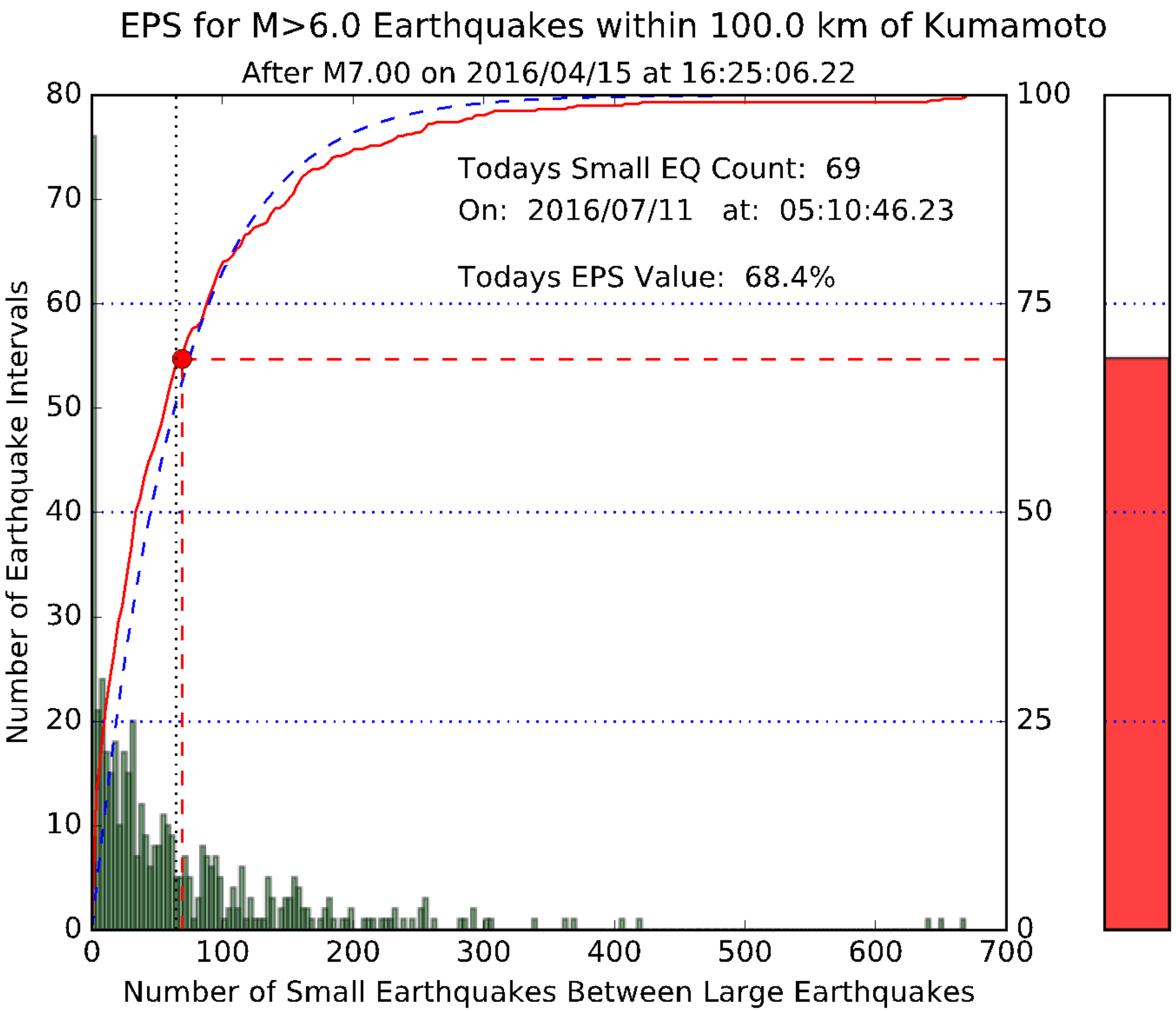
Earthquakes M>6.0 in Japan (Blue Circle = 100.0 km Radius)

0 km



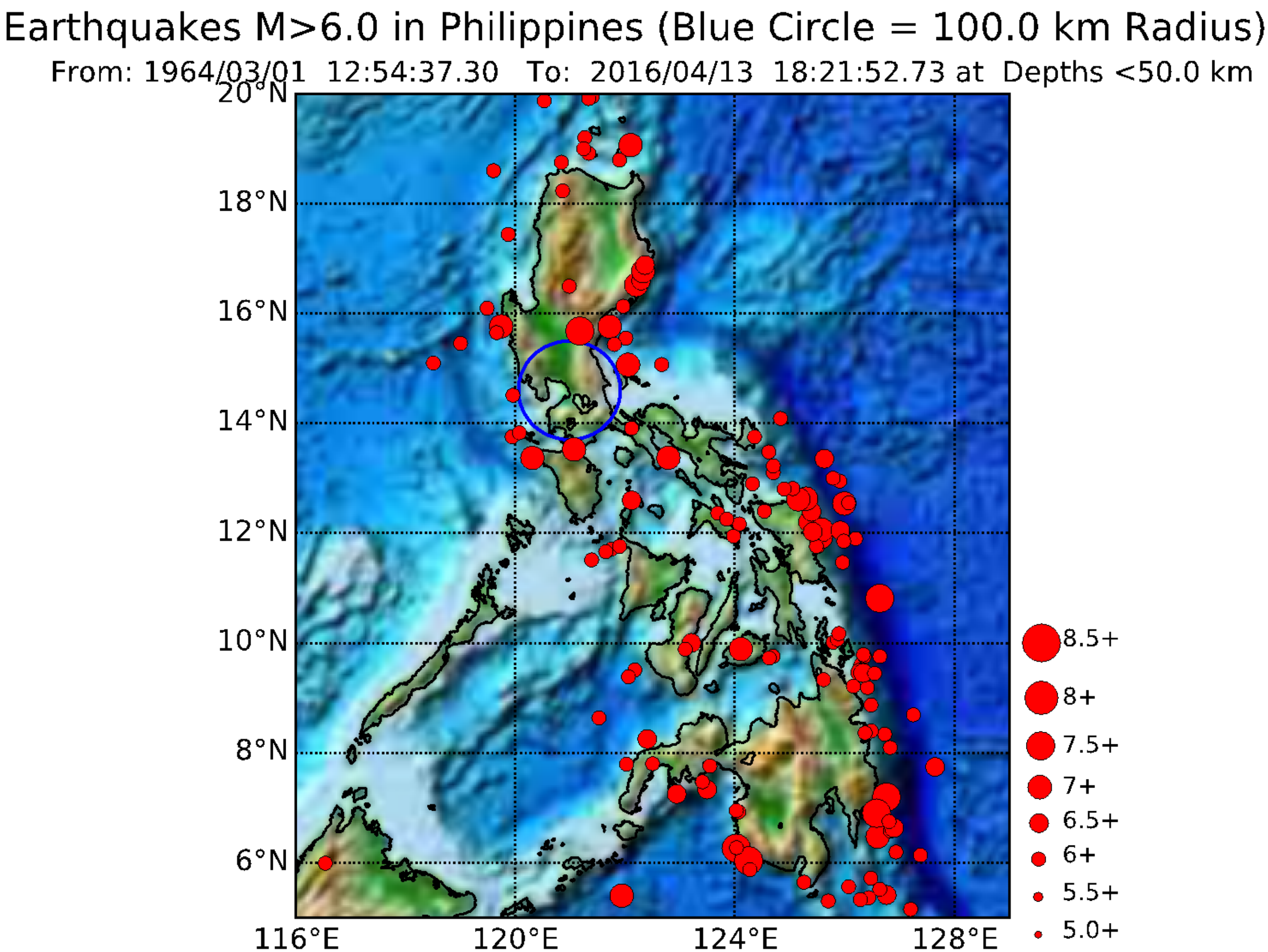
Small: 4 < M_S < 6

Large: 6 < M_L



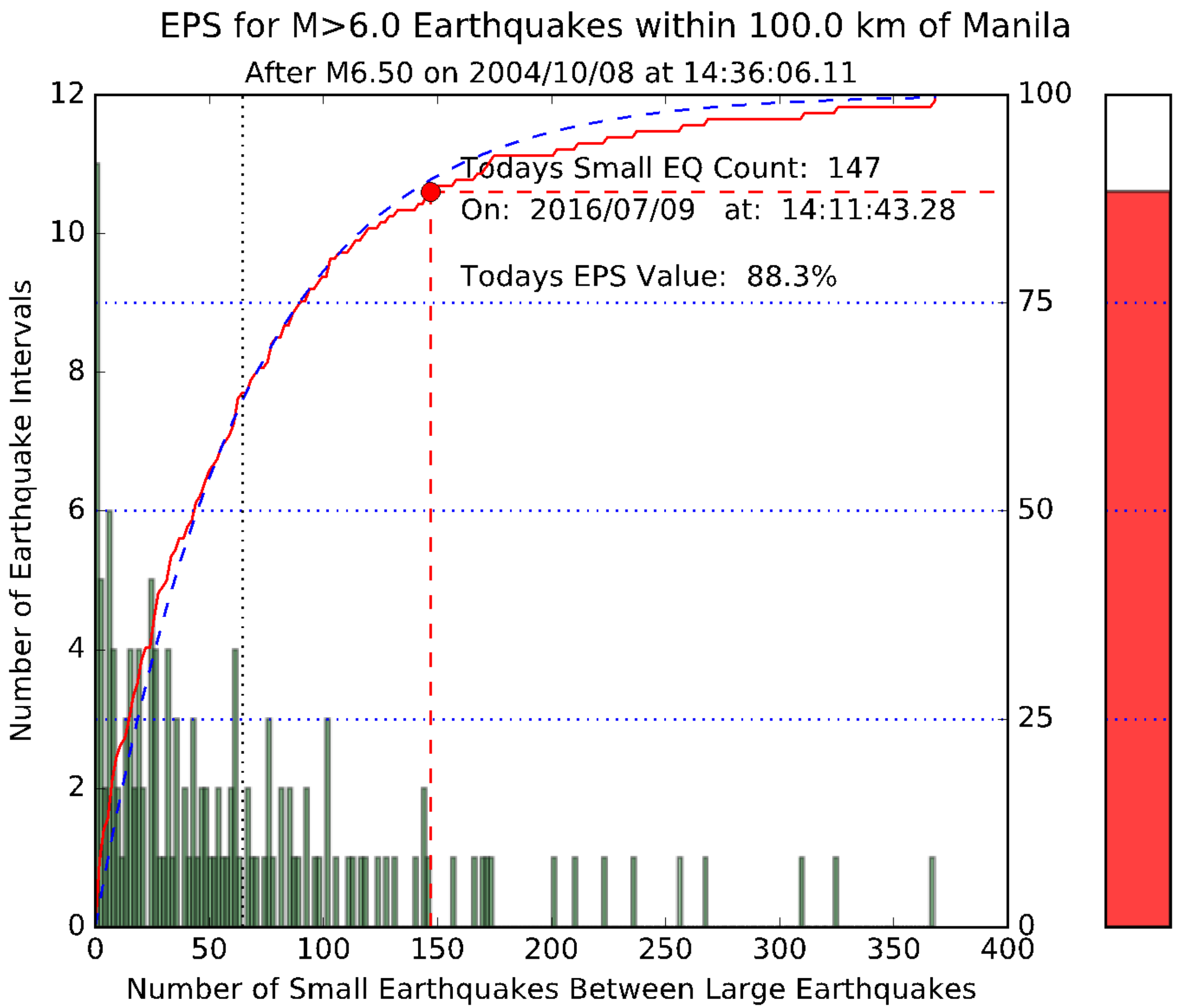
Small: 4 < M_S < 6

Large: 6 < M_L



Small: $4 < M_S < 6$

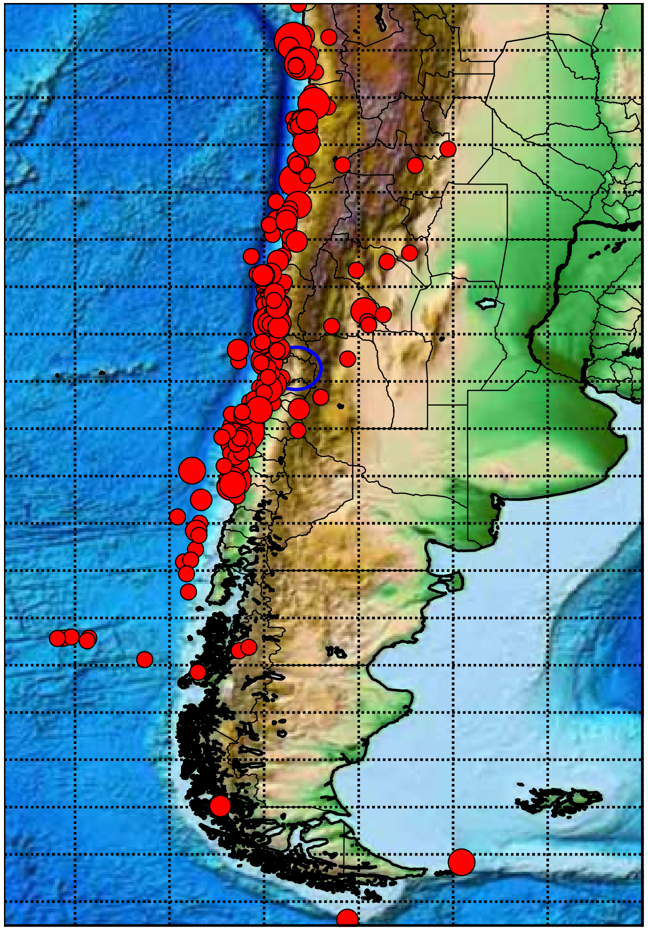
Large: $6 < M_L$



Small: $4 < M_S < 6$

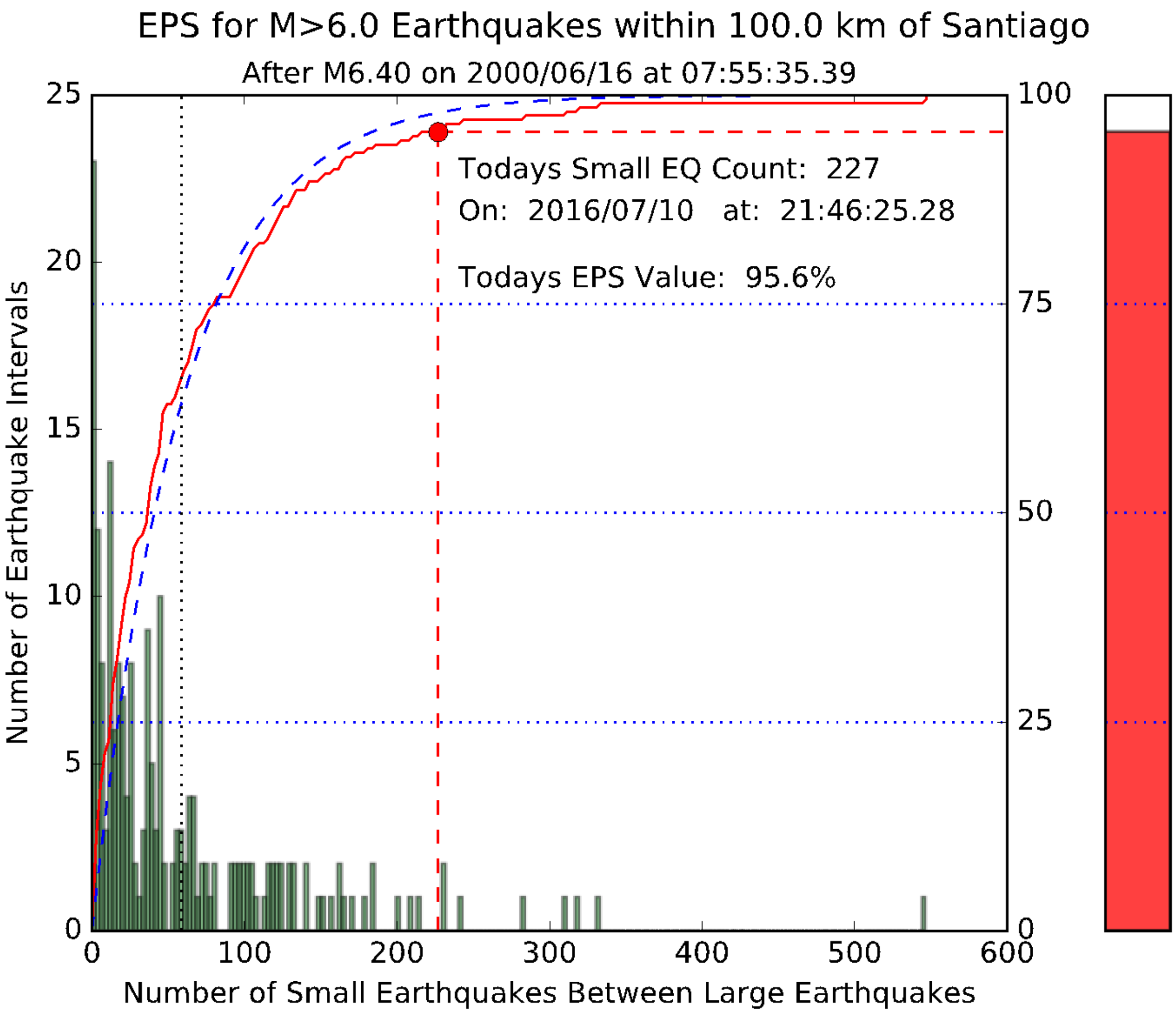
Large: $6 < M_L$

arthquakes M>6.0 in Chile (Blue Circle = 100.0 km Radius)



Small: 4 < M_S < 6

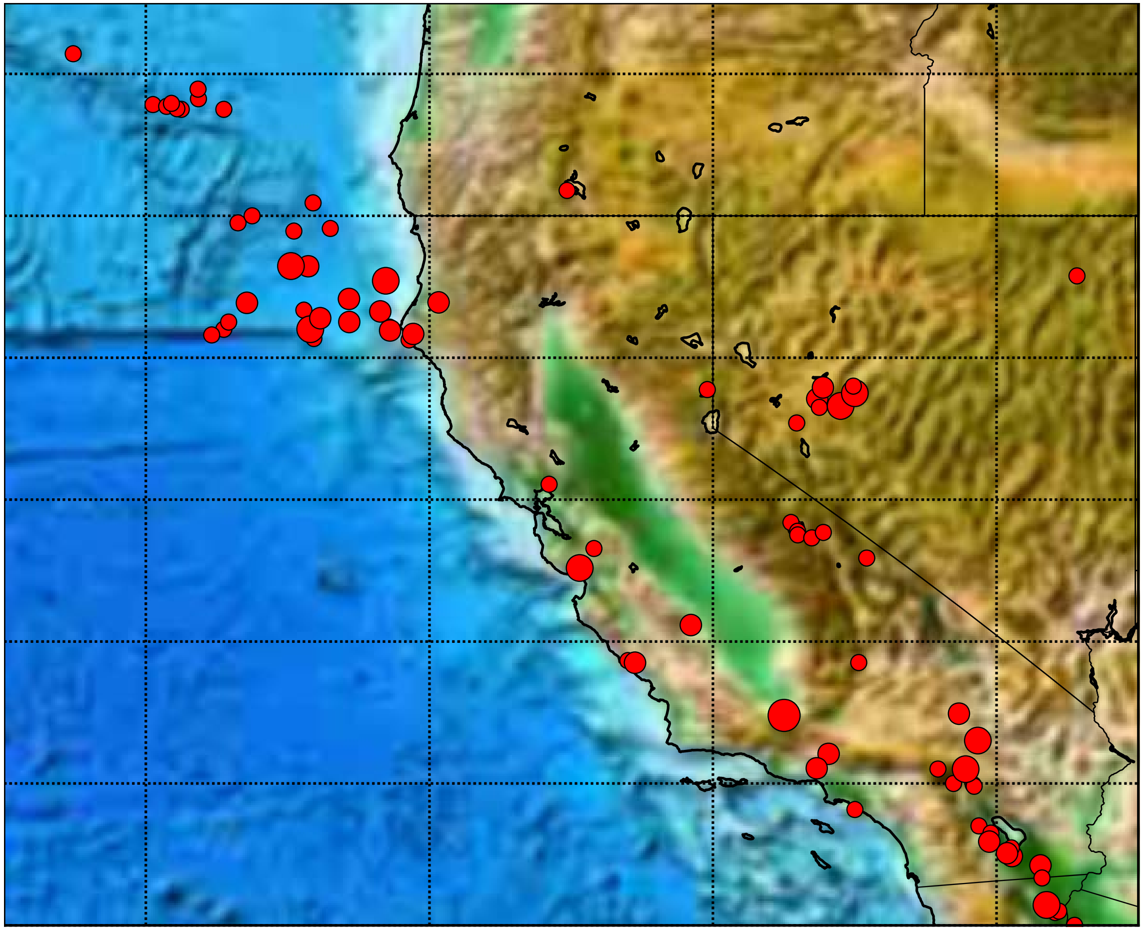
Large: 6 < M_L



Small: $4 < M_S < 6$

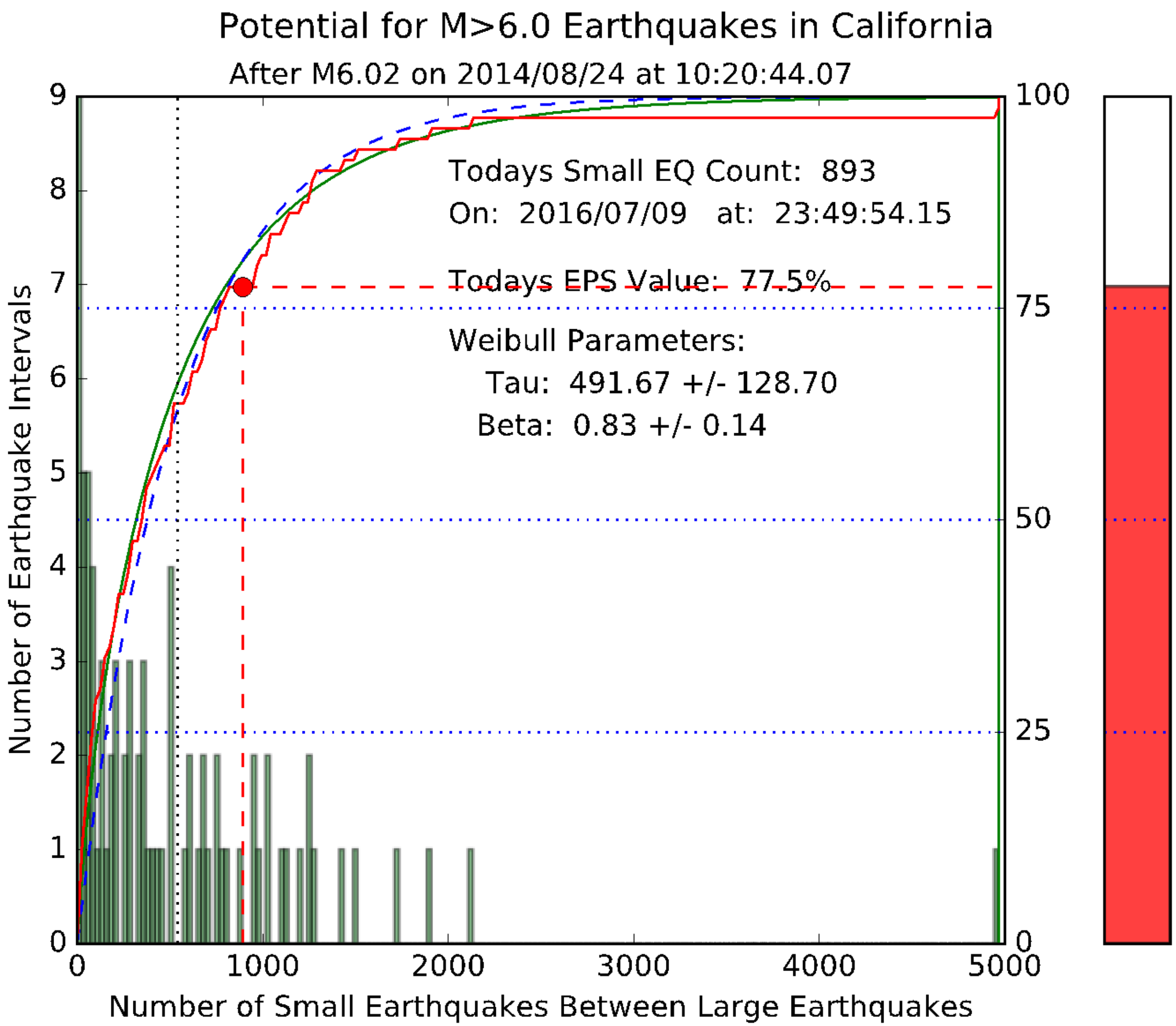
Large: $6 < M_L$

rthquake Epicenters for M>6.0 in California



Small: 3 < M_S < 6

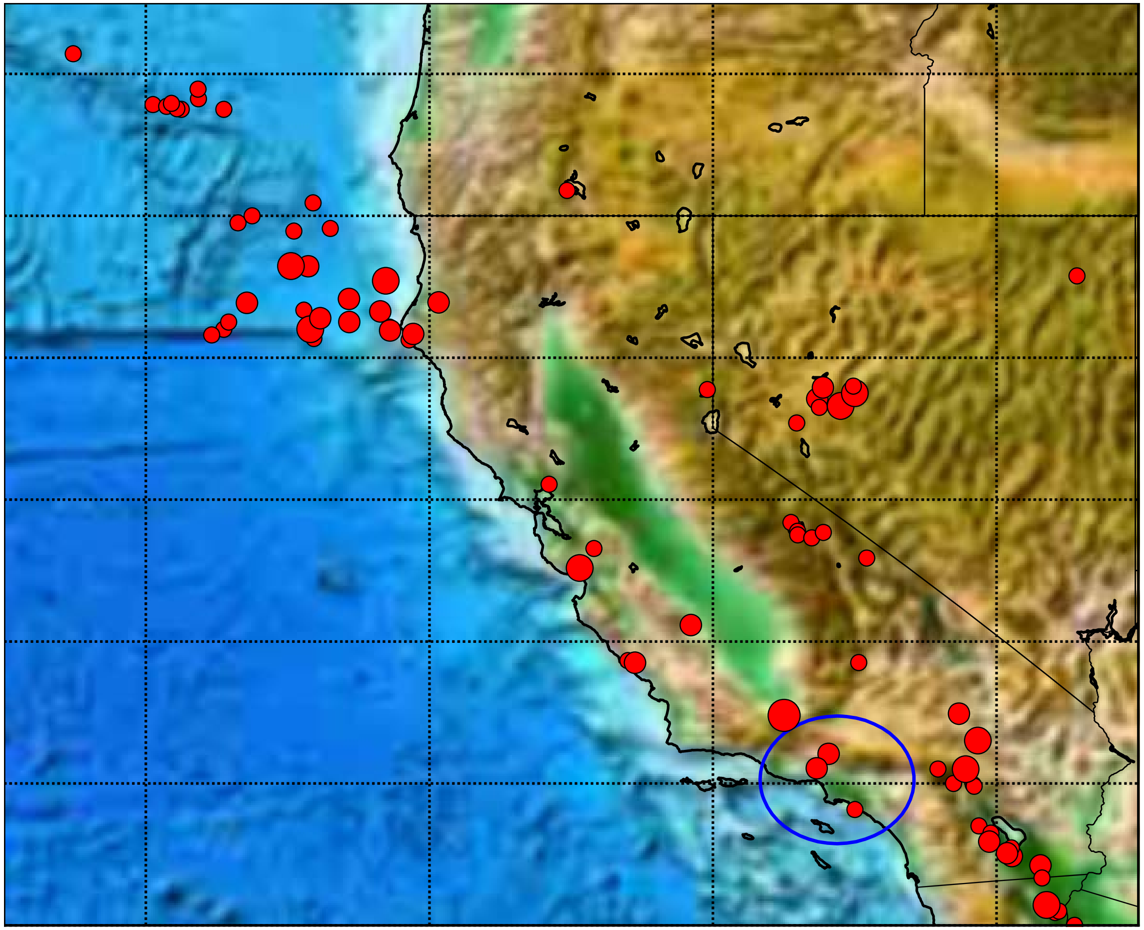
Large: 6 < M_L



Small: $3 < M_S < 6$

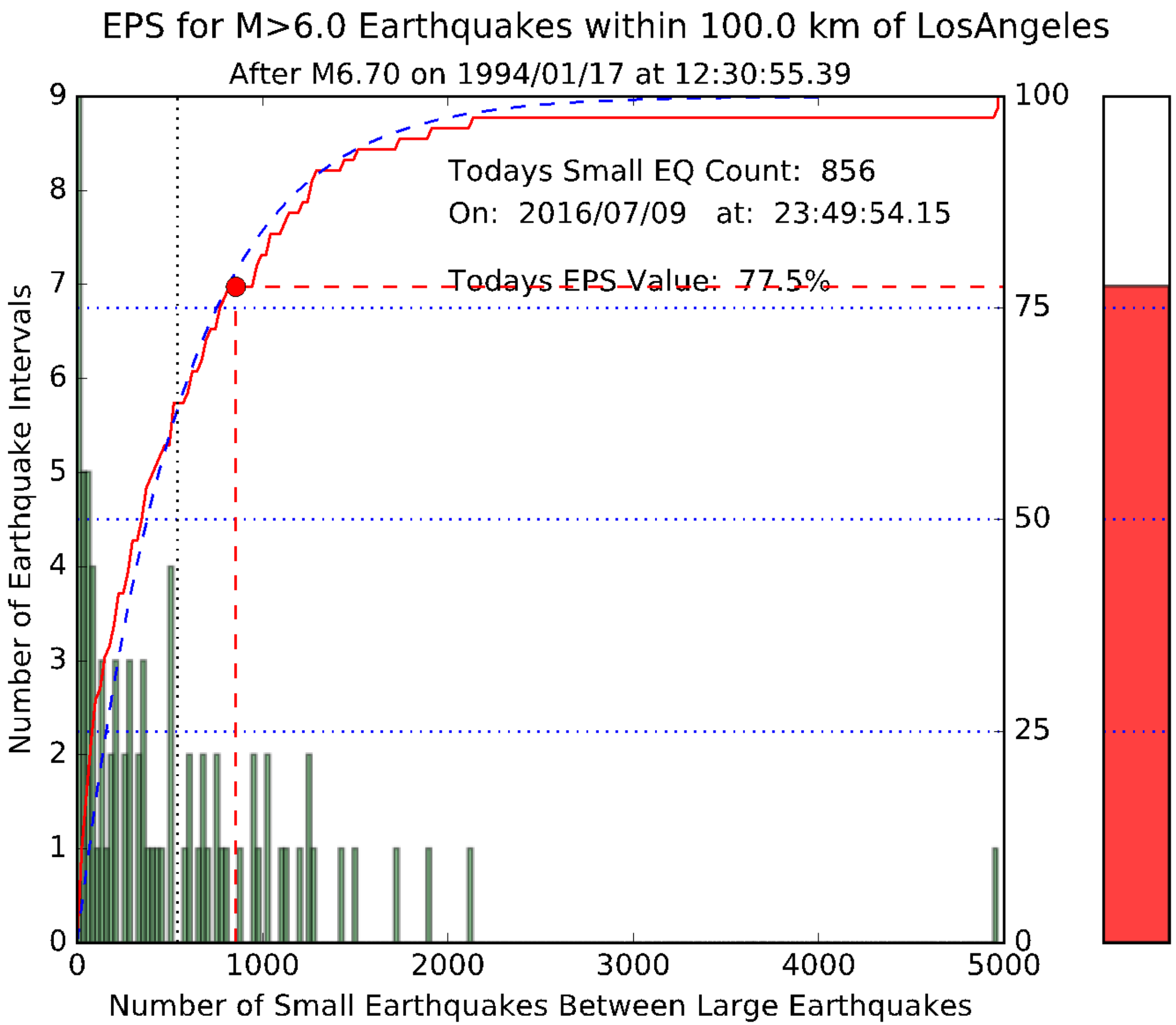
Large: $6 < M_L$

Earthquakes M>6.0 in California (Blue Circle = 100.0 km Radius)



Small: $3 < M_S < 6$

Large: $6 < M_L$

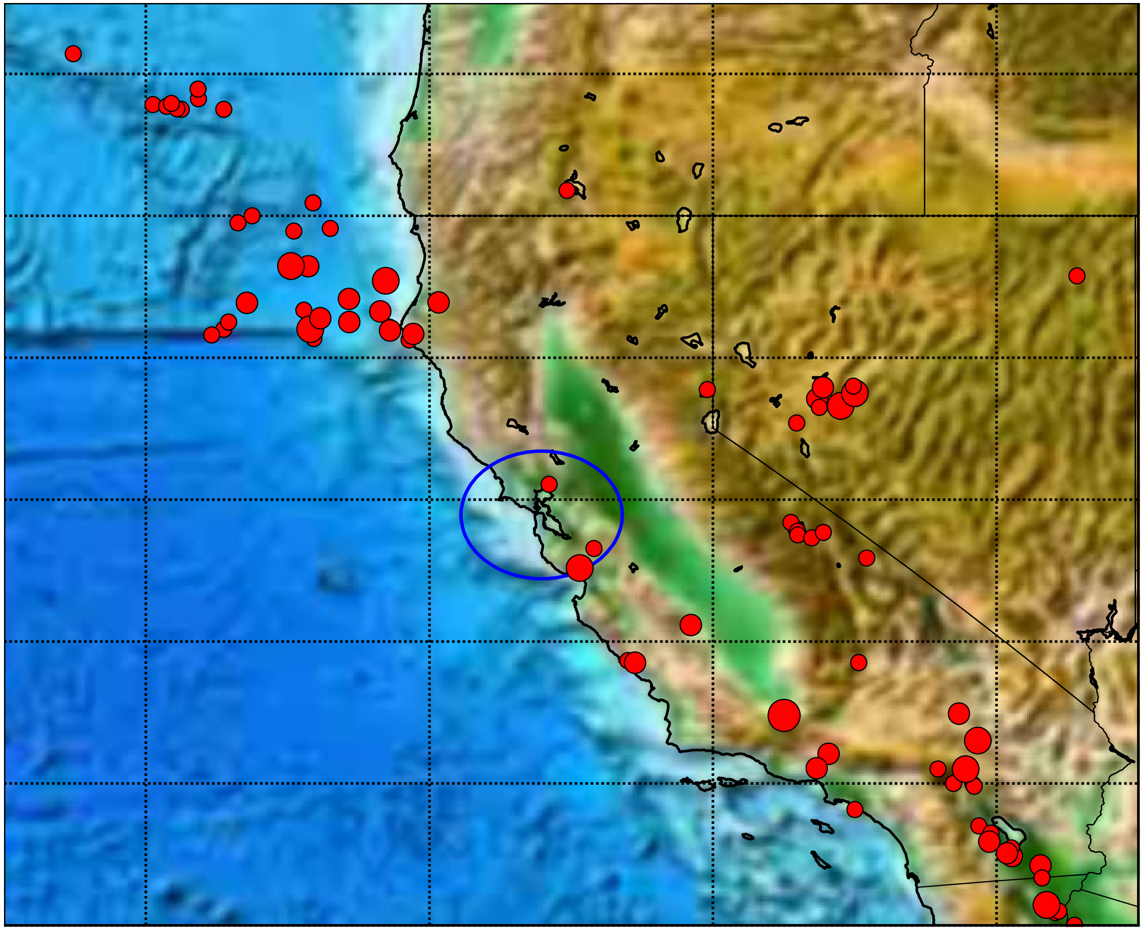


Small: $3 < M_S < 6$

Large: $6 < M_L$

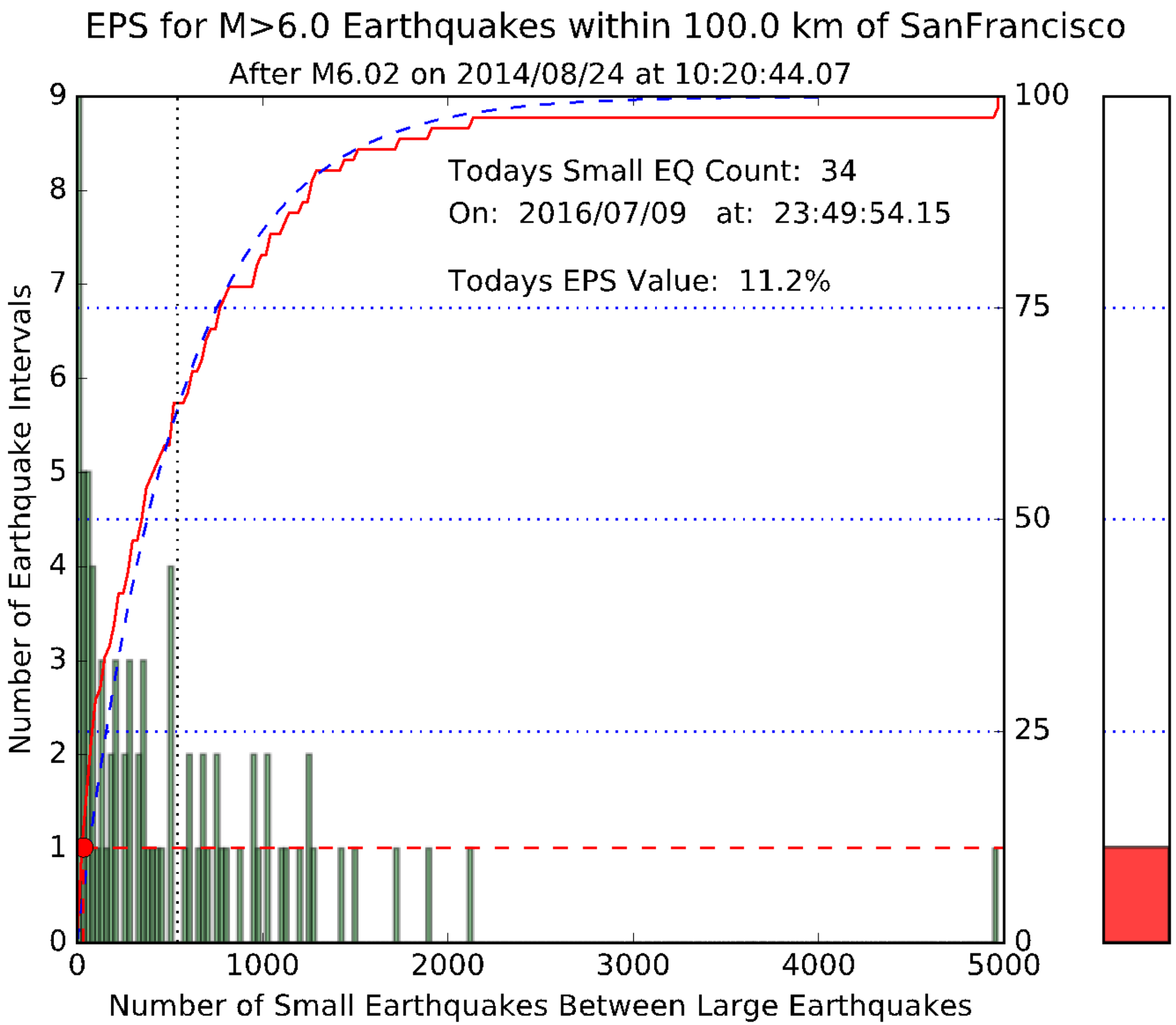
Earthquakes M>6.0 in California (Blue Circle = 100.0 km Radius)

m



Small: 3 < M_S < 6

Large: 6 < M_L



Small: $3 < M_S < 6$

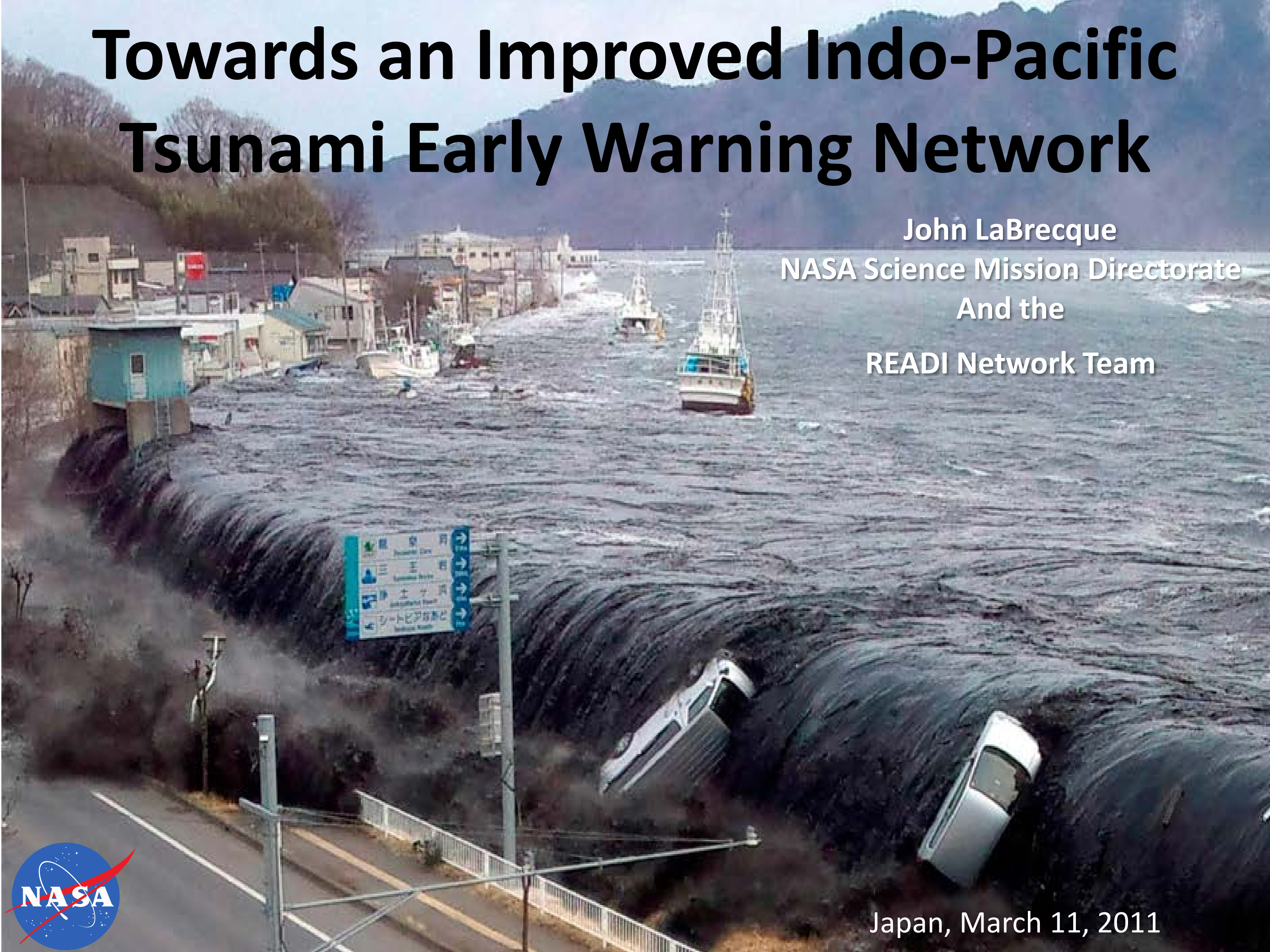
Large: $6 < M_L$

Summary so Far

- Forecasting: Computing the probability of future activity
- Nowcasting: Determining the current state of progress through the hazard cycle
- Now: Brief discussion of Global Navigation Satellite System Tsunami Early Warning System

Towards an Improved Indo-Pacific Tsunami Early Warning Network

John LaBrecque
NASA Science Mission Directorate
And the
READI Network Team



Japan, March 11, 2011

Banda Aceh, December 26, 2004

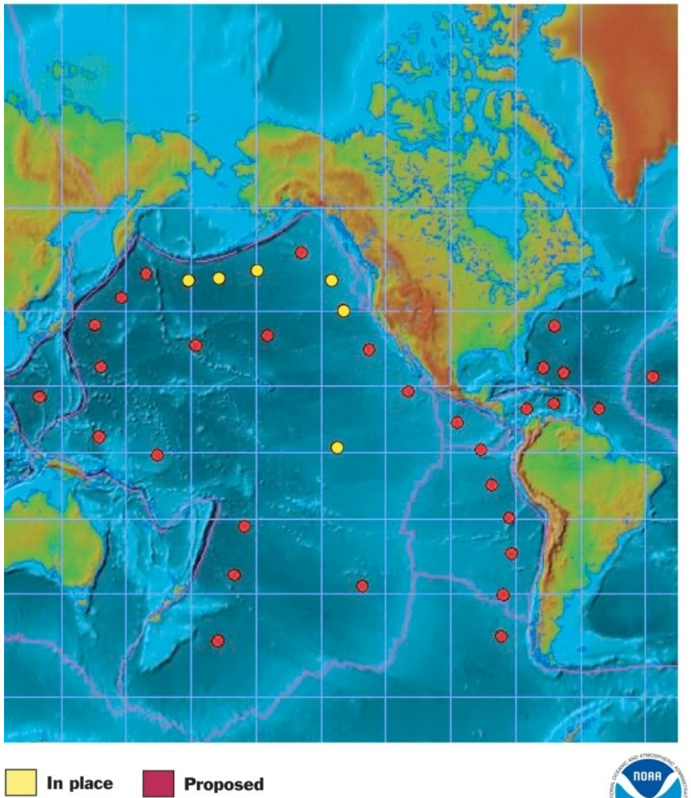

Global Navigation Satellite Systems (GNSS)
Can Track Tsunamis Across the Indo-Pacific

Current Tsunami Warning System

Earthquake-Magnitude-Based Tsunami Warnings
(NOAA's PTWC)

Mw less than 6.5 (Mw: Moment Magnitude)	Earthquake Message Only
Mw 6.5 to 7.5	Tsunami Information Bulletin
Mw 7.6 to 7.8	Regional Tsunami Warning
Mw > 7.8	Expanding Warning / Watch
Confirmed Teletsunami	Pacific-Wide Warning

Proposed DART Buoy System



Unfortunately,

1. Earthquake magnitude is not a good indicator of a resulting tsunami;
2. DART system has inherent delays.
3. Seismic Mw estimates require at 20 minutes or more

Indo-Pacific GNSS Disaster Early Warning Network

Pacific Basin Earthquakes and Volcanic Eruptions pose regional hazards that do not obey national boundaries.

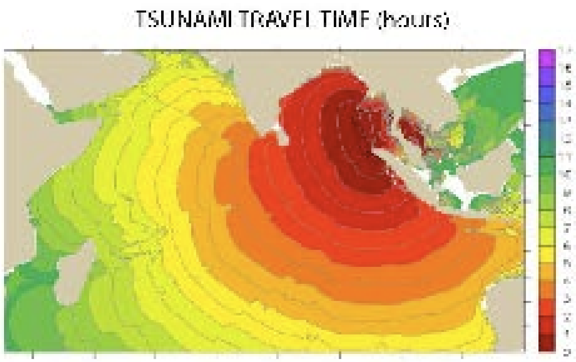
The Pacific Basin is ringed by subduction zones and violent volcanoes with demonstrated ability to generate large earthquakes and devastating tsunamis that propagate basin wide.

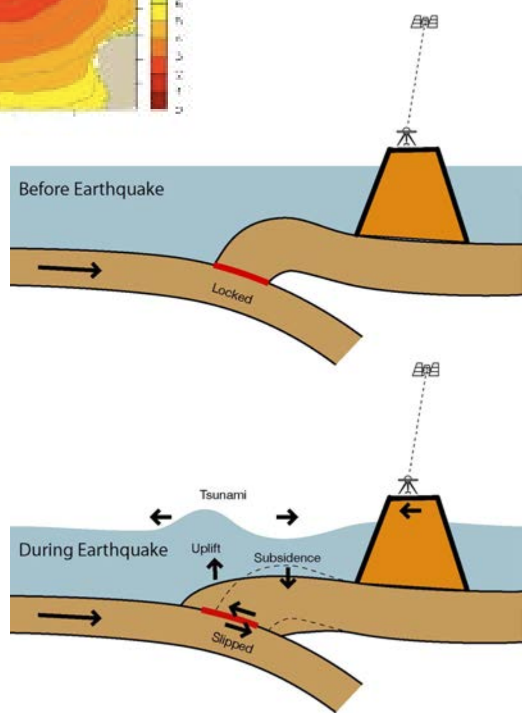
Dense GNSS regional networks are being deployed within the circum-Pacific and on Pacific Islands.

Communication infrastructure is available for near real time GNSS data distribution either continuous or event responsive.

Post Processing of regional geodetic data taken on December 26,2004 Demonstrated the Value of a Global Regional GNSS Real Time Network

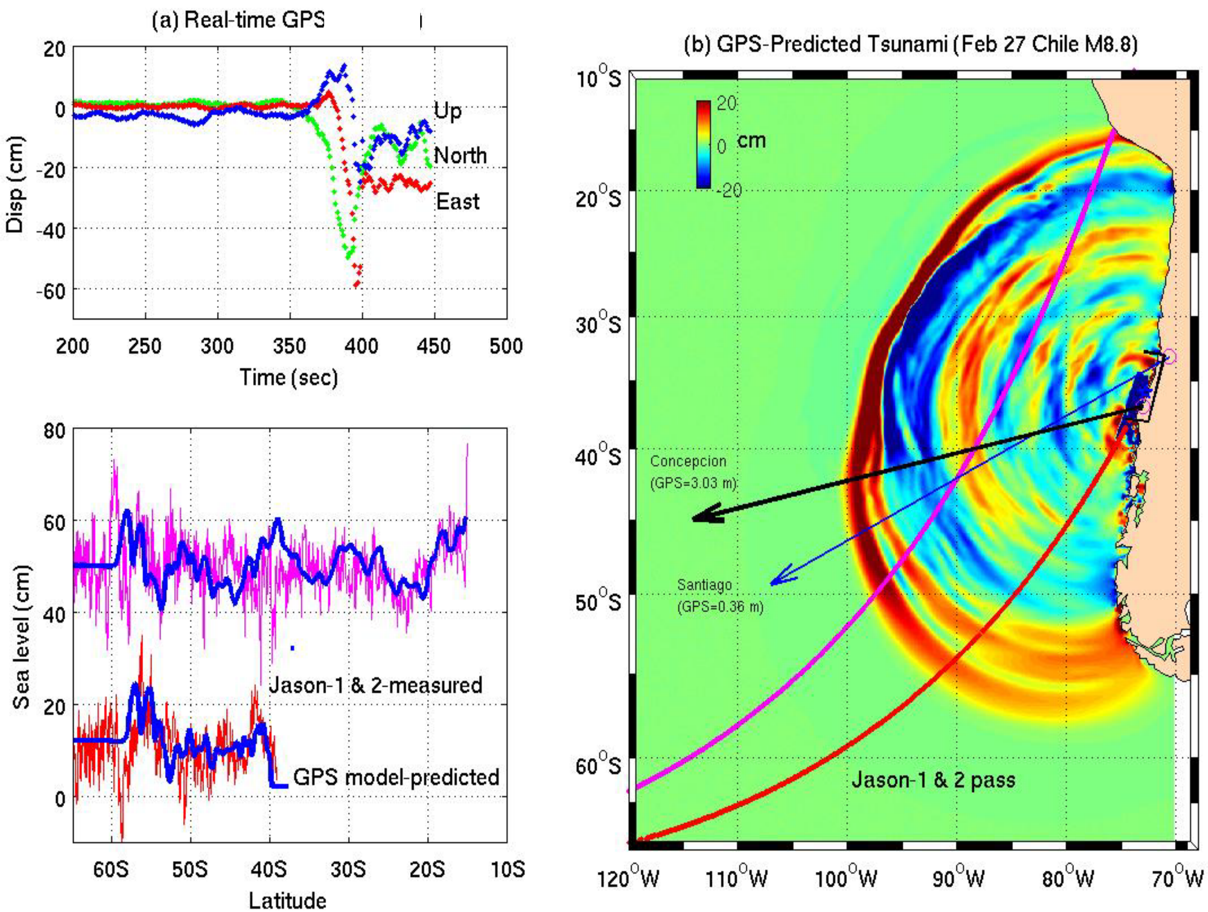
A Dense Global Real Time GPS Network would have warned of the Indian Ocean Tsunami within minutes- hours before the seismic analysis-





GPS station displacements on 26 December, 2004 observed by the International GNSS Service Network (IGS/GGOS). The largest arrow (SAMP) has been scaled down by a factor of two for clarity. Ref: Blewitt, Hammond, Kreemer, Plag, Stein, Okal, 2009,J. Geodesy.

February 27, 2010: Chile M8.8 Earthquake Demonstrated First Real Time GPS based Tsunami Prediction using GDGPS with NASA Applied Sciences funding to The GREAT Alert Project



(a): NASA's Global Differential GPS (GDGPS) measures the Chile M8.8 earthquake displacement in real time at Santiago.

(b): JPL GREAT alert team predicts a moderate sized tsunami using the real-time GPS and the Song tsunami generation model.

(c): NASA/CNES satellites Jason-1 and Jason-2 confirm the tsunami amplitude prediction of the GPS-based model prediction.

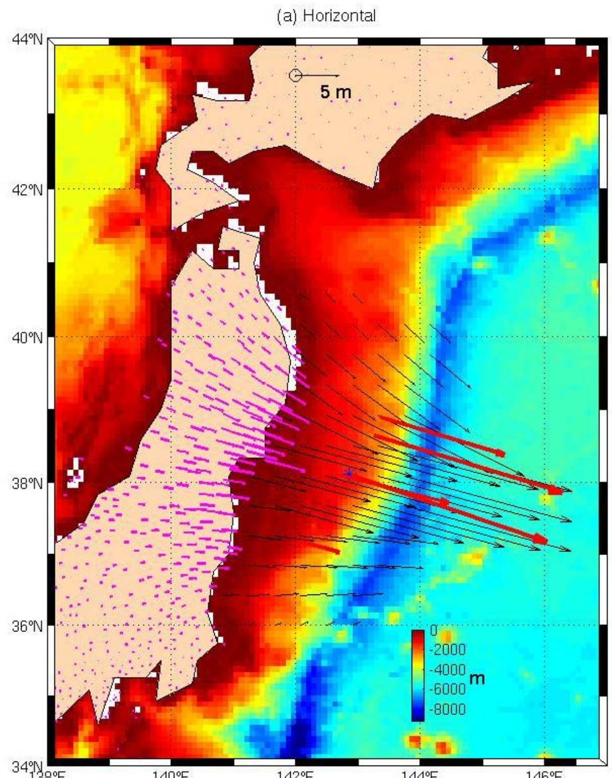
(d): Next steps: Strengthen real time GDPS network, automate models.

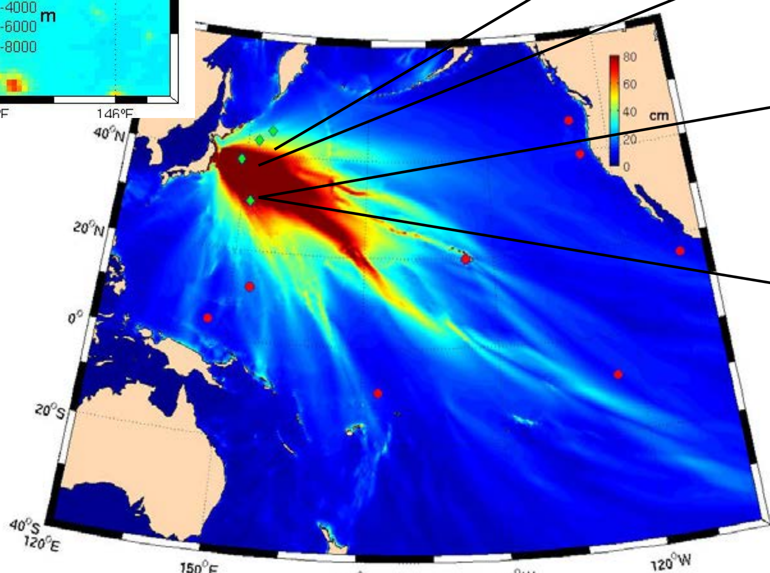
Tony Song , Yoaz Bar-Sever, et al. /JPL

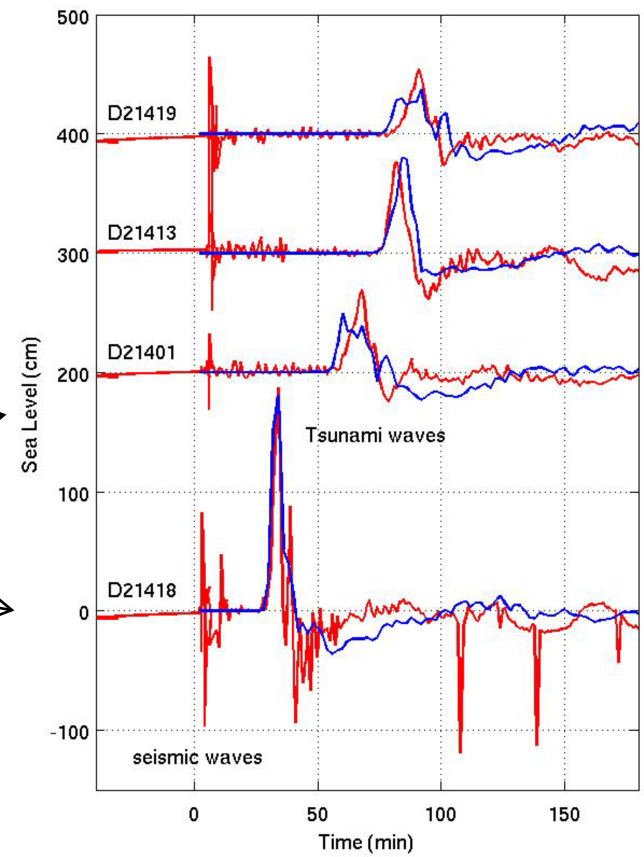
Song Y.T., 2007, Detecting tsunami genesis and scales directly from coastal GPS Stations, Geophys Res. Ltts.

The 2011 Tohoku-Oki Tsunami

There are about 1,200 GPS stations (GeoNet) on Japanese Islands. Study shows that they were capable of predicting the tsunami and could have saved more lives if were used (Song et al., GRL, 2012).

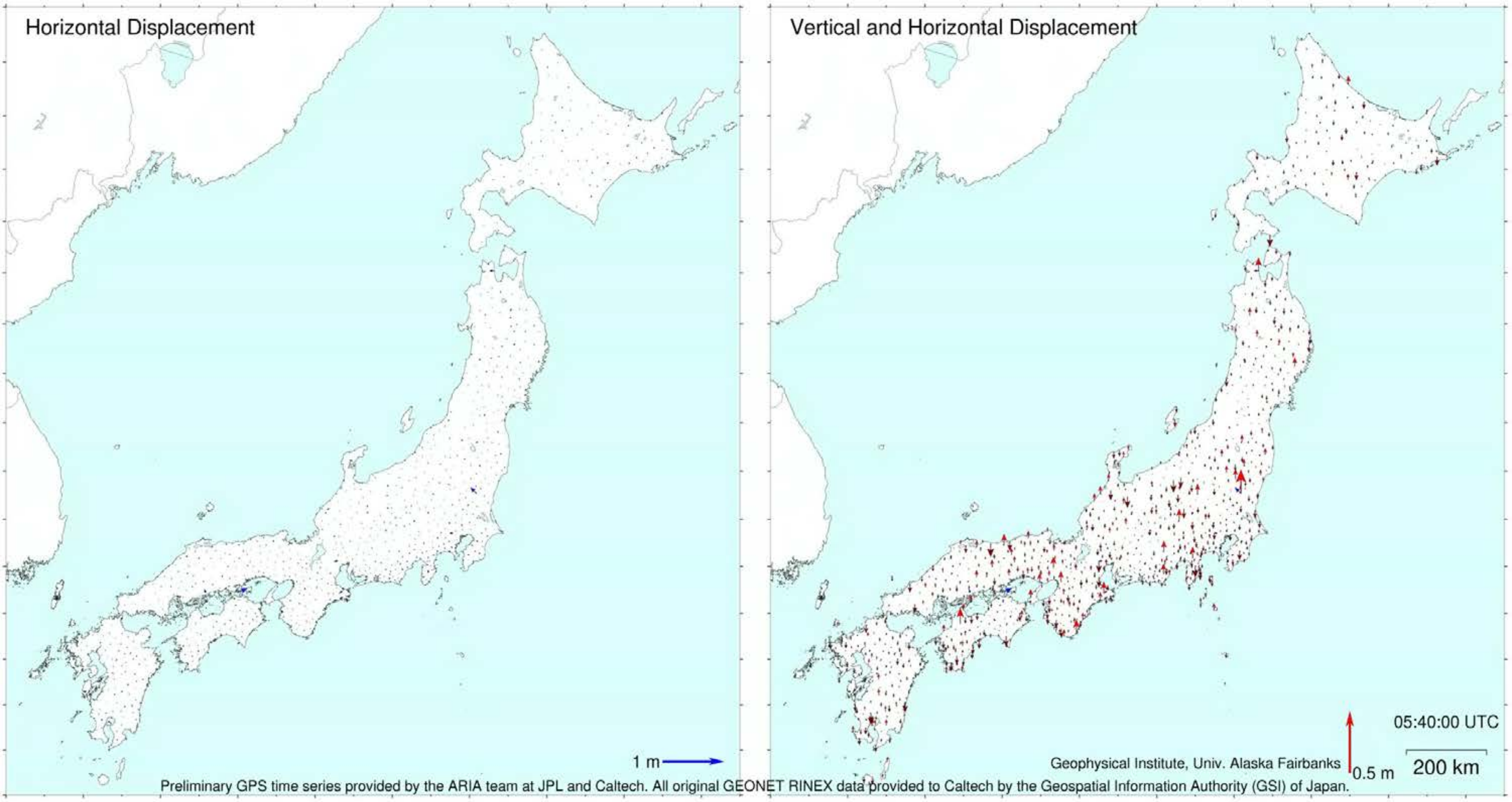






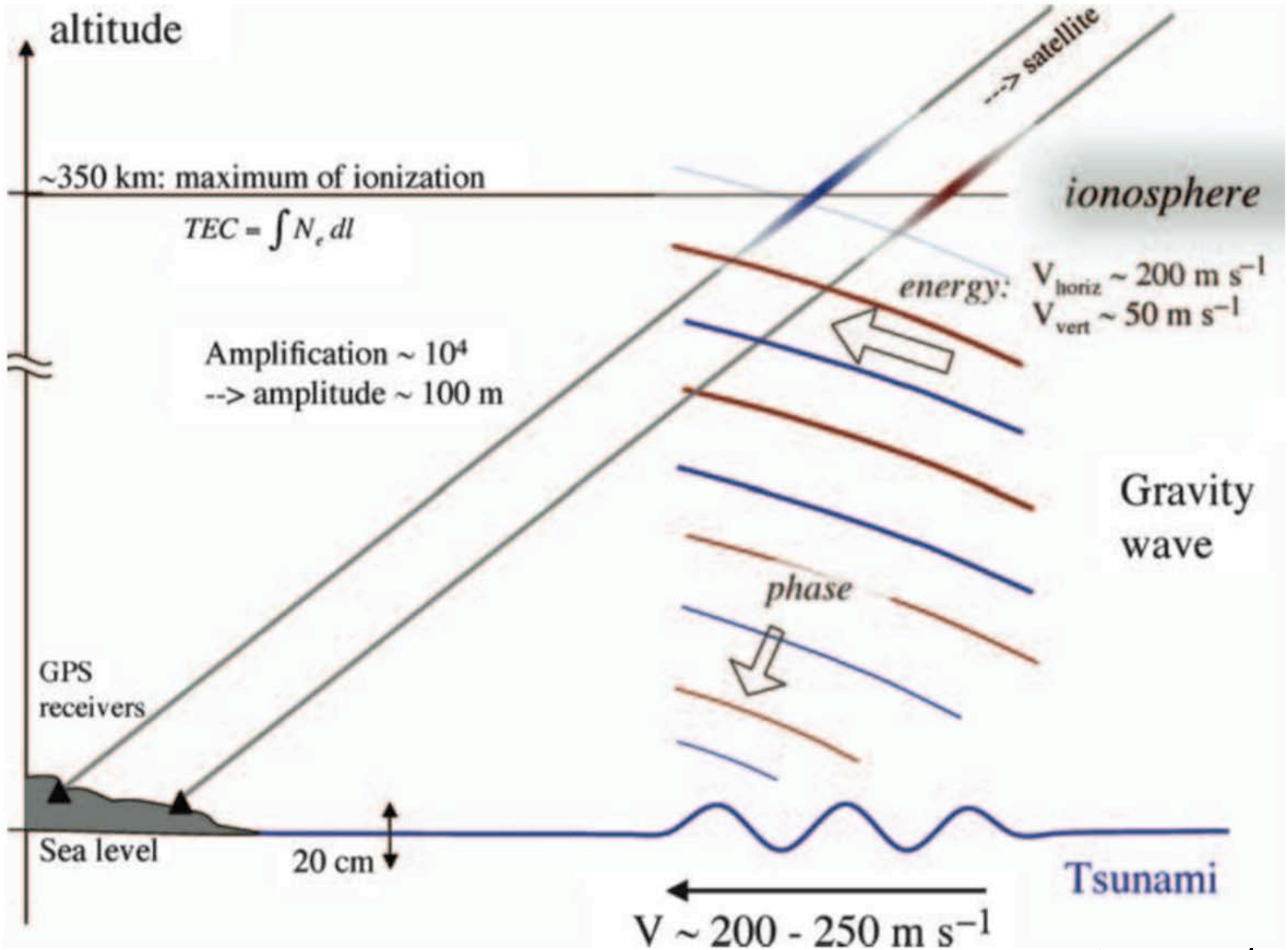
March 11, 2011:The GSI GEONET GPS Array

- **Demonstrated Capability to Predict a Tsunami**
- **First use of GPS to Predict**
- **First Observe the Resulting Tsunami**



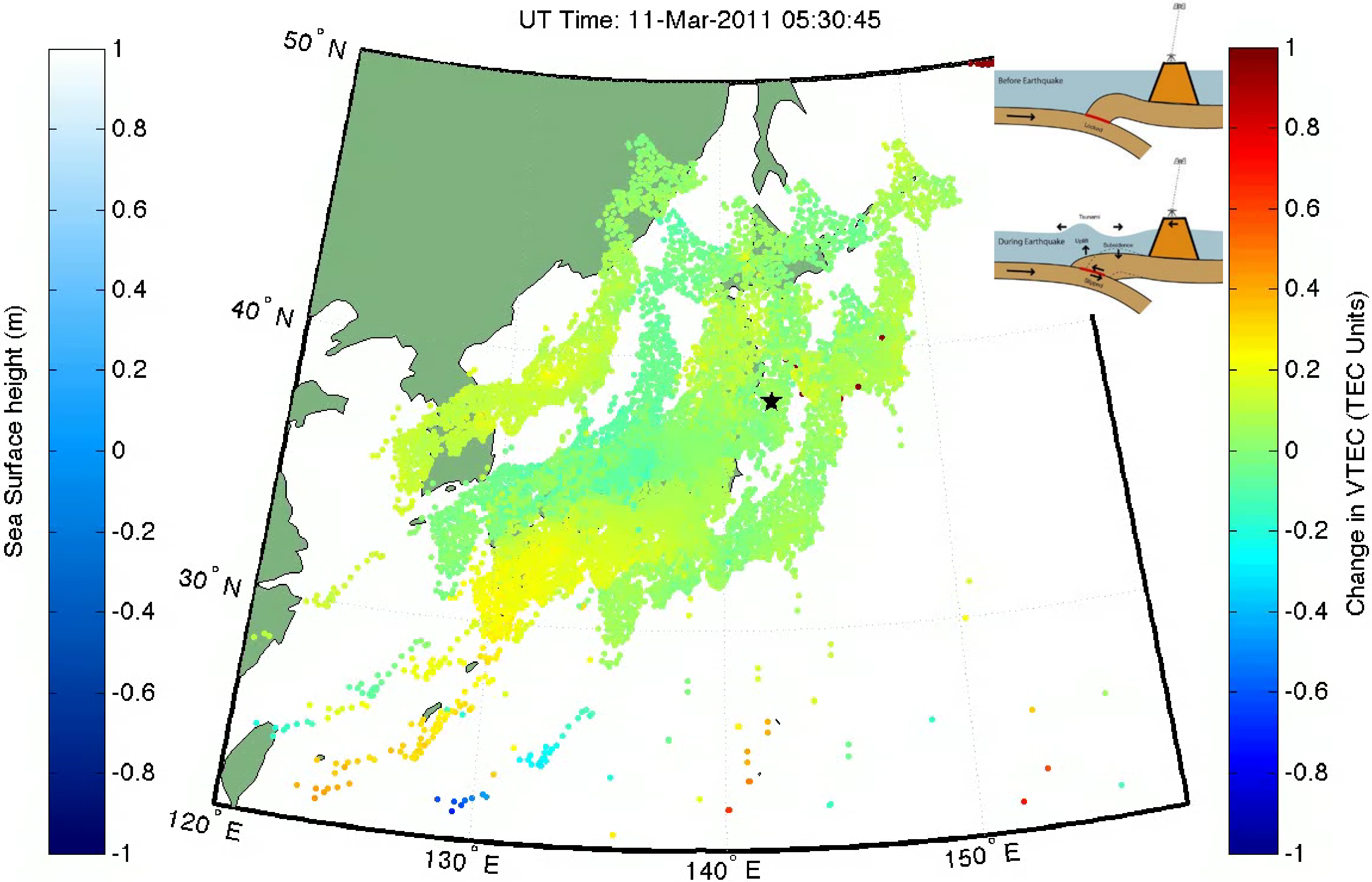
http://gps.alaska.edu/ronni/sendai2011.html: Ronni Grapenthin

The Tsunami Generated Displacement of the Ocean Surface Couples to the Ionosphere



From *Artru et al.,* 2005

GSI's GEONET Also Captured the Ionospheric Coupled Waves and Imaged the Tsunami Generation and Propagation-For the First Time



Ionospheric Response to Mw9.0 Tohoku Earthquake and Tsunami in Japan on March 11, 2011, A.Komjathy, D.A.Galvan, M.P Hickey, P.Stephens, Mark Butala, and A.Mannucci, (http://visibleearth.nasa.gov/view.php?id=77377)