A Richter Scale for the Markets

Image Courtesy NHK

John B Rundle

University of California, Davis (www.ucdavis.edu)

Santa Fe Institute (www.santafe.edu)

Open Hazards Group (www.openhazards.com) & Seismic Funds LLC

About Me

- Born: Somerville, NJ 1950
- 1953-1955 Father was a Hurricane Hunter, Bermuda
- Interested in Astronomy in high school (built a telescope)
- BSE, Princeton University, 1972
- MS,PhD Geophysics, UCLA, 1973, 1976
- 1977-1990 Sandia Labs
- 1990-1993 Lawrence Livermore National Labs
- 1993-2002 University of Colorado, Boulder
- 2002-present University of California, Davis
- Startup company in risk management, 2009-
  (www.openhazards.com)

Image Courtesy NHK

Image Courtesy NHK

Major Earthquakes World Wide – 2010-2011

(January 1, 2010 – September 16, 2011)

Earthquake	Date	Magnitude	Deaths	Loss
Solomon Islands	January 3, 2010	7.1	0	$Millions
Ferndale, CA	January 10, 2010	6.5	0	$Millions
Port-au-Prince, Haiti	January 12, 2010	7.0	> 200,000	$8-$13 Billion
Okinawa	February 27, 2010	7.0	0	$Millions
Maule, Chile	February 27, 2010	8.8	> 450	$10-$30 Billion
Mexicali (Baja), MX	April 4, 2010	7.2	2-3	> $100 Million
Nias, Sumatra, IN	April 5, 2010	7.7	0	$Millions
Solomon Islands	April 11, 2010	7.1	0	$0
Yushu, China	April 14, 2010	6.9	2700	>$100 Million (?)
Christchurch, NZ	September 4, 2010	7.1	0	$1-$4 Billion
Christchurch, NZ	February 22, 2010	6.3	181	$12 Billion?
Tohoku, Japan	March 11, 2011	9.0	~27,000	$300 Billion?

A Richter Scale for Markets

Nicholas Felton

By ERIC DASH
Published: July 31, 2010

It's tempting to pull out the old earthquake metaphor when talking about the latest financial crises. How else to describe the economic devastation — the tremors in the subprime mortgage market, the seismic collapse of Lehman Brothers, and the aftershocks reverberating in Europe?

But some academics are now taking the metaphor seriously, pursuing a new approach to economics they call econophysics. The field represents a significant break from traditional economics, by studying financial earthquakes in much the same way geologists study those on terra firma. "New approaches are needed to address the fundamental and practical challenges of our financial, economic and social system," a group of econophysicists wrote recently in an open letter to George Soros, the billionaire investor and philanthropist.

Macroeconomists construct elegant theories to inform their understanding of crises. Econophysicists view markets as far more messy and complex — so much so that the beauty and logic of economic theory is a poor substitute. Drawing on the tools of the natural sciences, they believe that by sorting through an enormous amount of data, they can work backward to find the underlying dynamics of economic earthquakes and figure out how to prepare for the next one.

Financial crises are difficult to predict, the econophysicists say, because markets are not, as some traditional economists believe, efficient, self-regulating and self-correcting. The periodic upheavals are the result of a cascade of events and feedback loops, much like the tectonic rumblings beneath the Earth's surface.

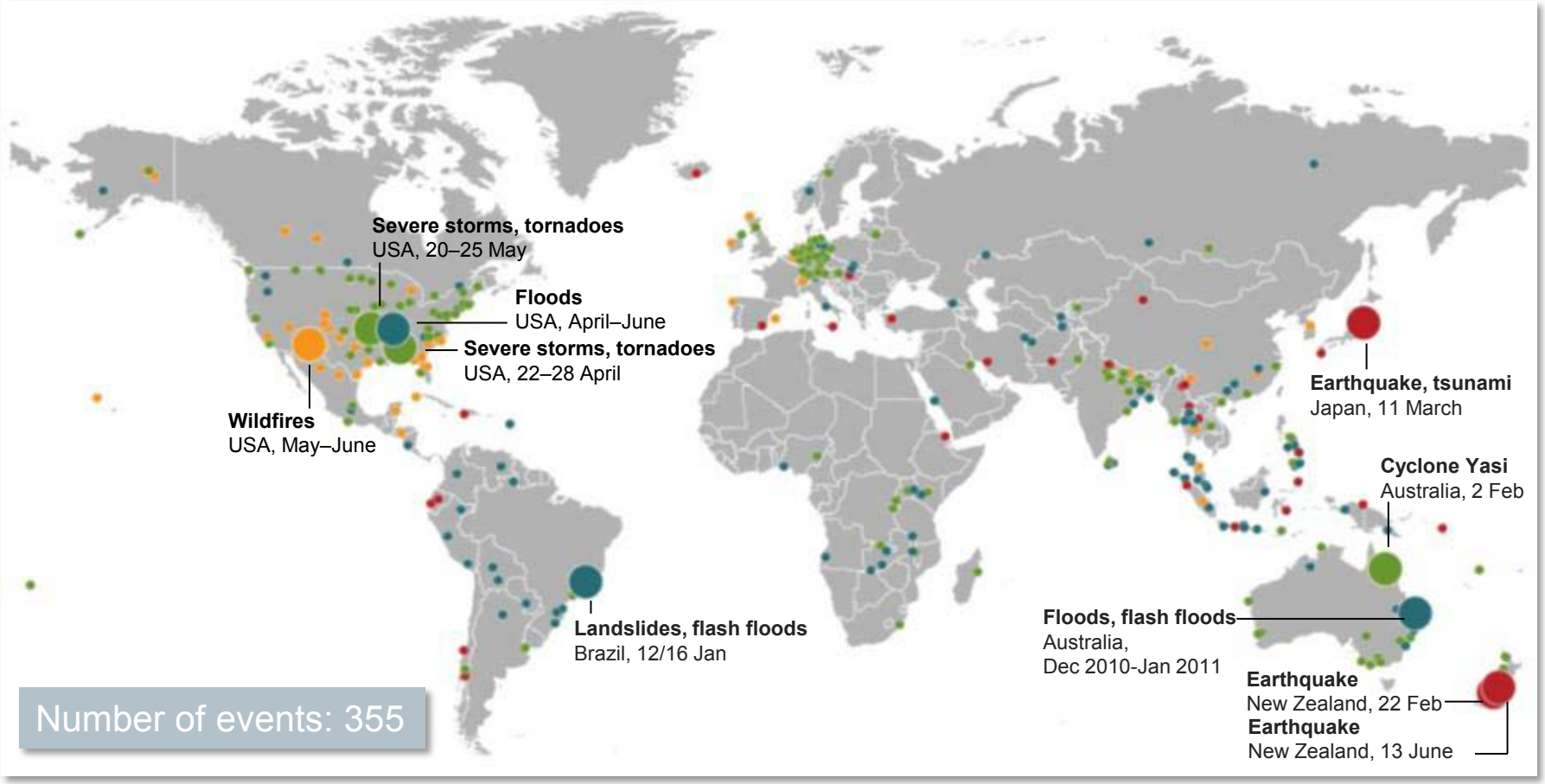
4. Pulling an All-Nighter for the College Ap
5. Bucks: How to Find Cheaper College Textbooks
6. Portugal Gives Itself a Clean-Energy Makeover
7. Paul Krugman: America Goes Dark
8. Bob Herbert: The Horror Show

Topics

- Complexity and the Santa Fe Institute
- Fat Tails (“Tail Risk”)
- Risk & Uncertainty
- Earthquakes
- Applications to the Markets

Natural loss events January – June 2011

World map



- **Natural catastrophes**
- **Selection of significant loss events (see table)**
- **Geophysical events** (earthquake, tsunami, volcanic activity)
- **Meteorological events** (storm)
- **Hydrological events** (flood, mass movement)
- **Climatological events** (extreme temperature, drought, wildfire)

Source: MR NatCat*SERVICE*

Worldwide Natural Disasters 1980 – 2011

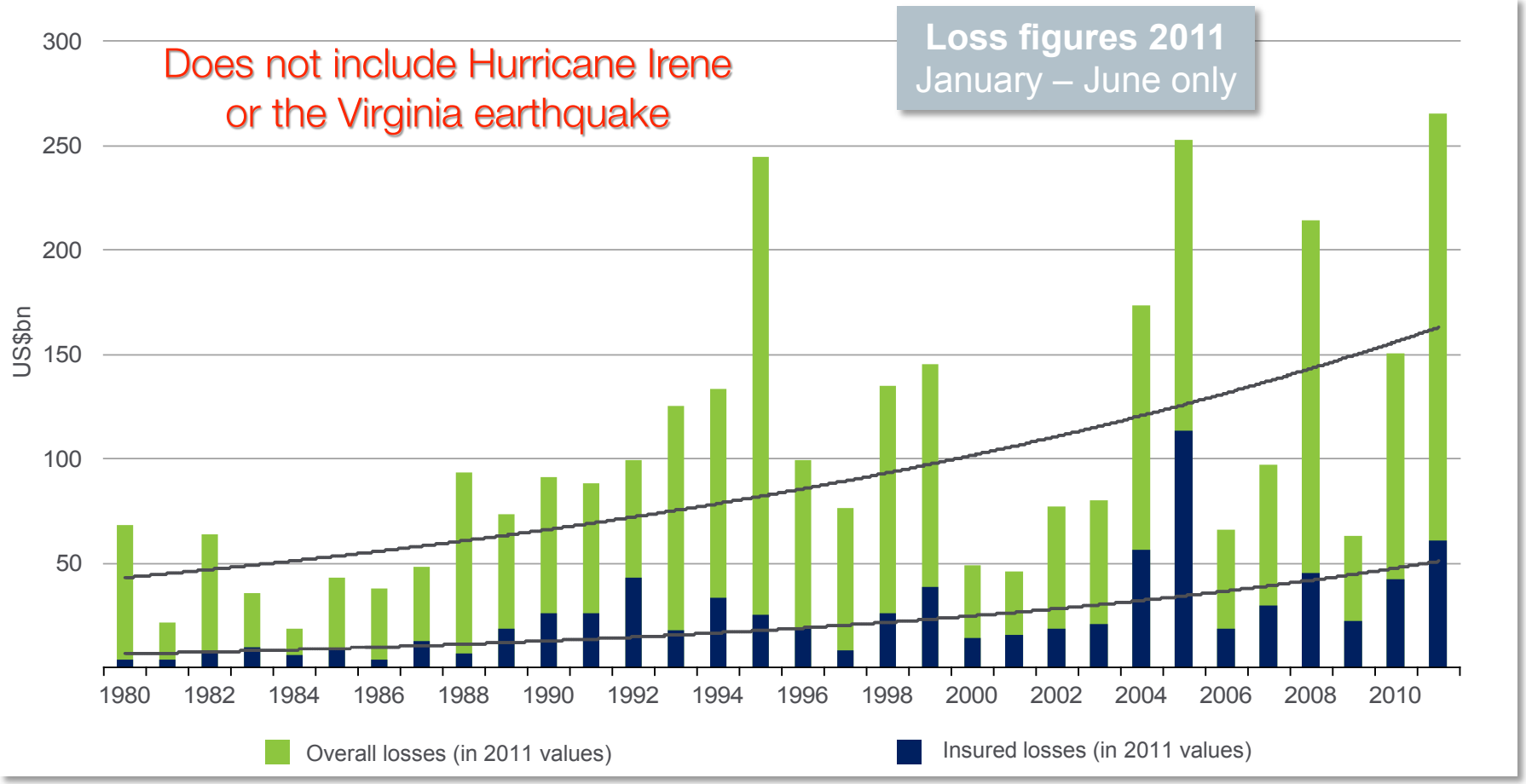
Overall and Insured Losses

Impacts

Loss Trends (Munich Re, 2011)

Munich RE

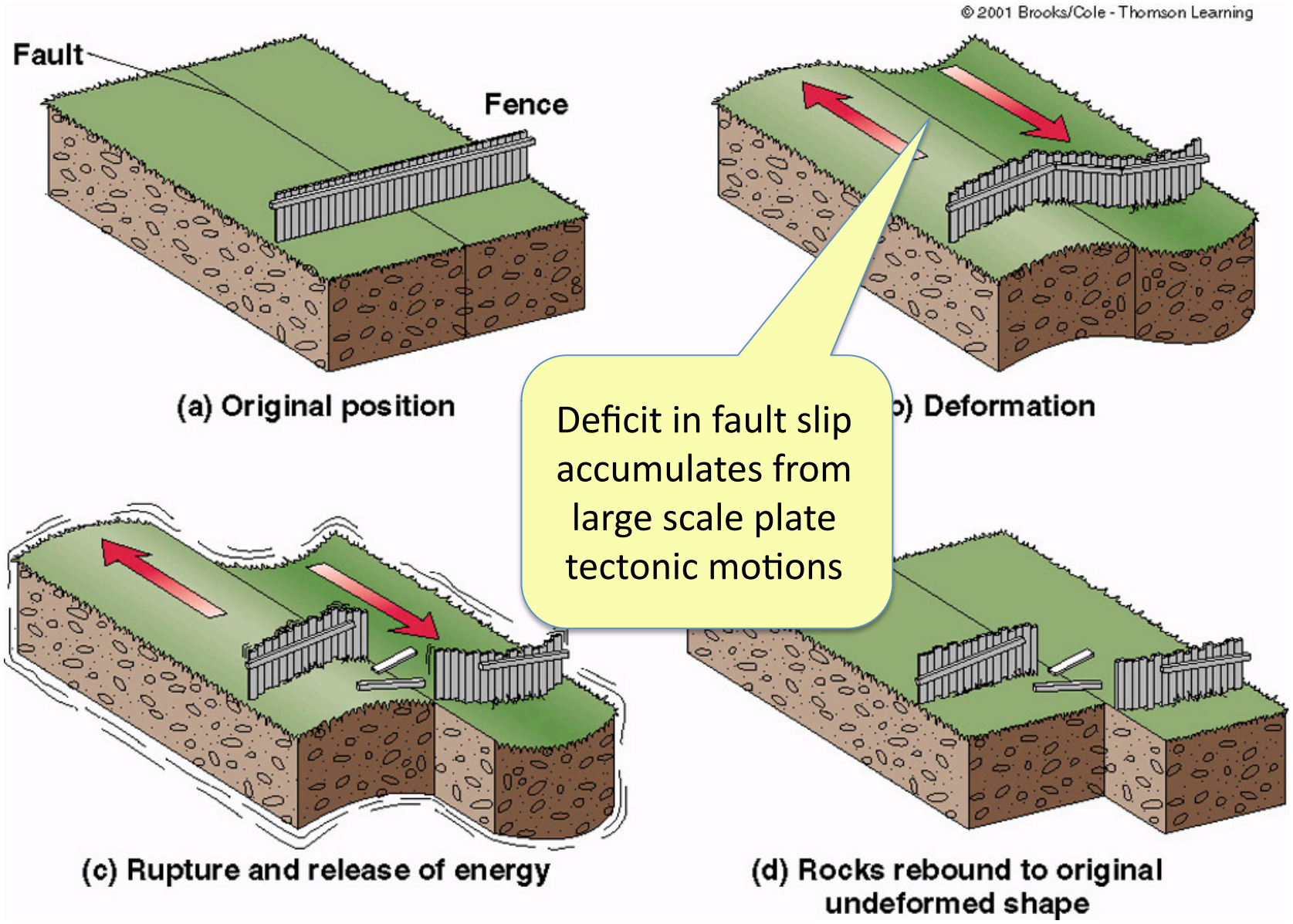
Losses in 2011: Overall = US$ 265bn ; Insured = US$ 60bn



Source: MR NatCat*SERVICE*

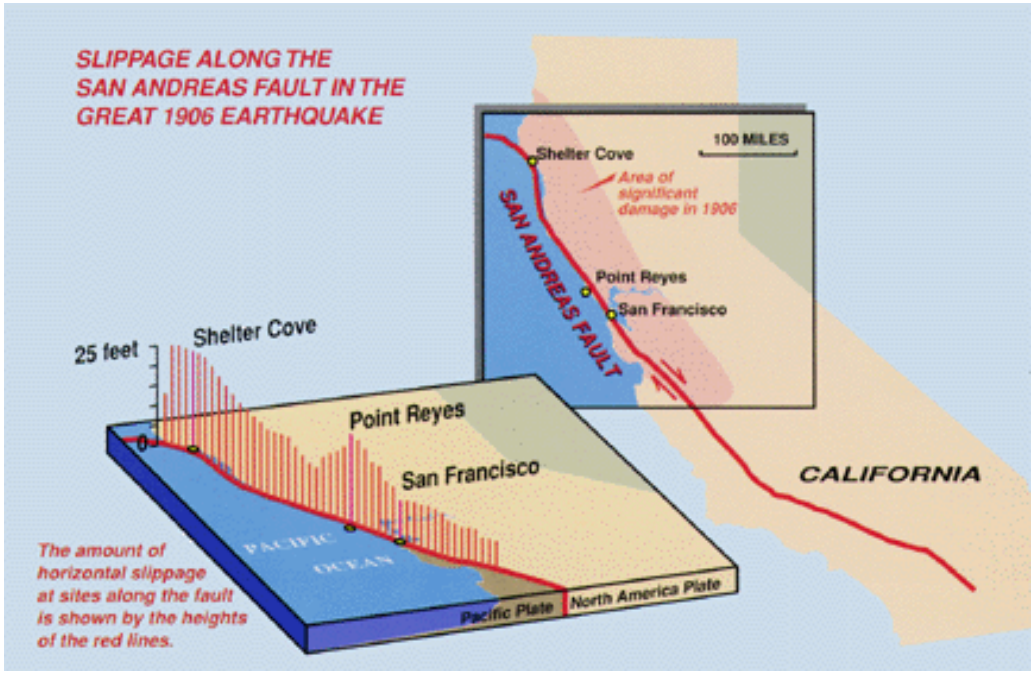
1906 San Francisco Earthquake M~8

Earthquake Cycle

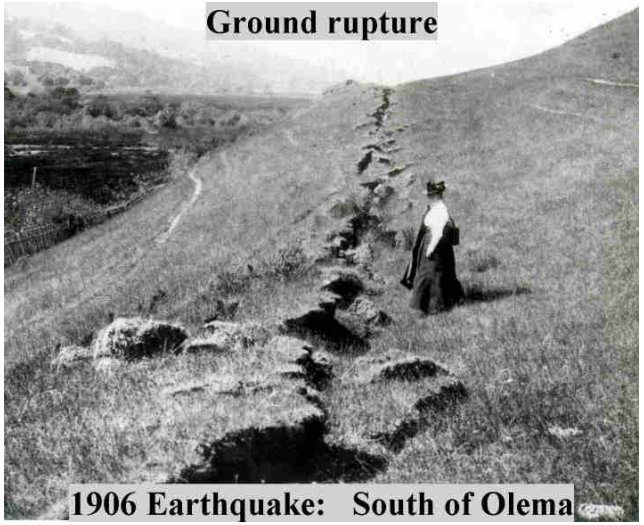


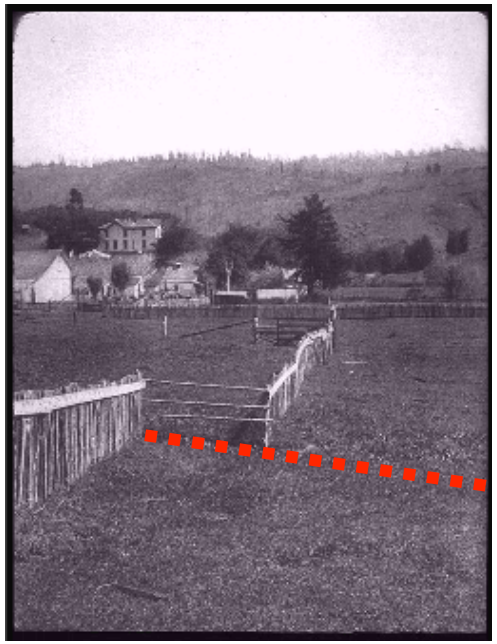
The Great 1906 San Francisco Earthquake Extended for ~ 350 km Along the San Andreas Fault in Northern California.

Horizontal offsets of as much as 8 meters was observed.



Wayne Thatcher, US Geological Survey



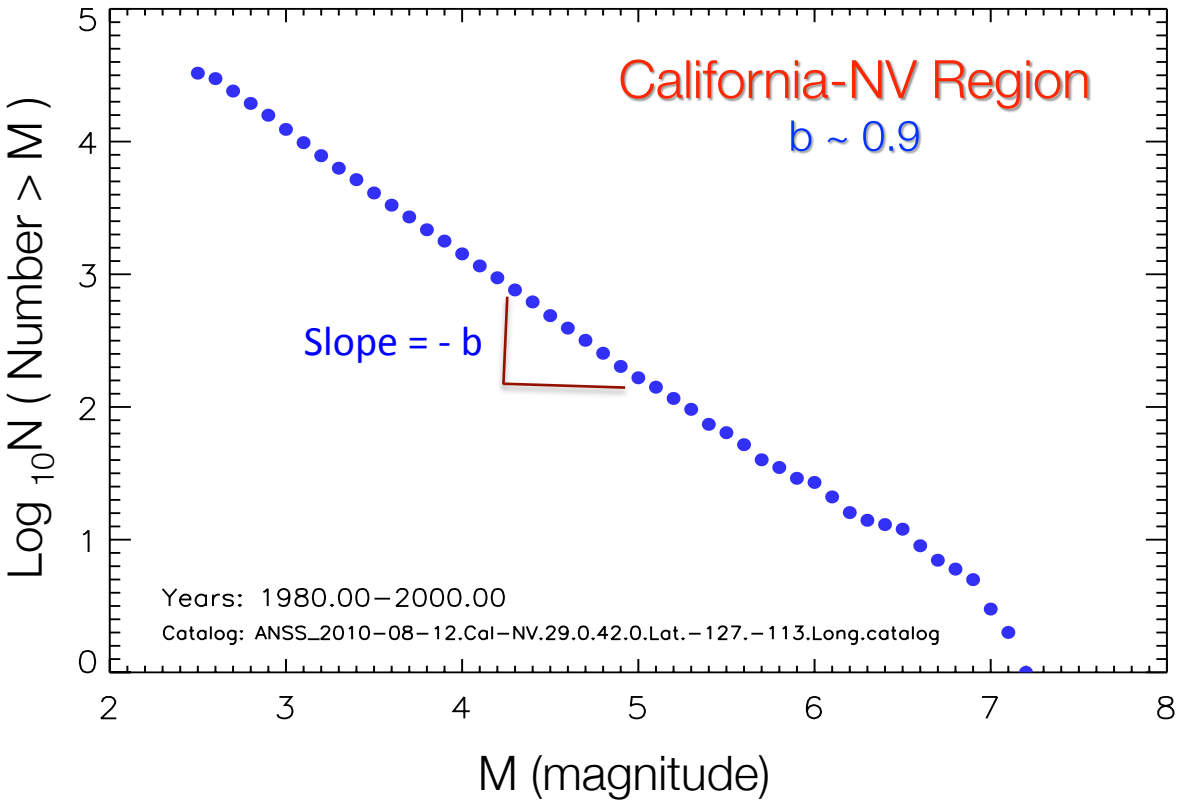


Frequency-Magnitude Relation

Gutenberg-Richter frequency-magnitude relation for California-Nevada

$$M = \frac{2}{3} Log_{10} W - 6.0$$

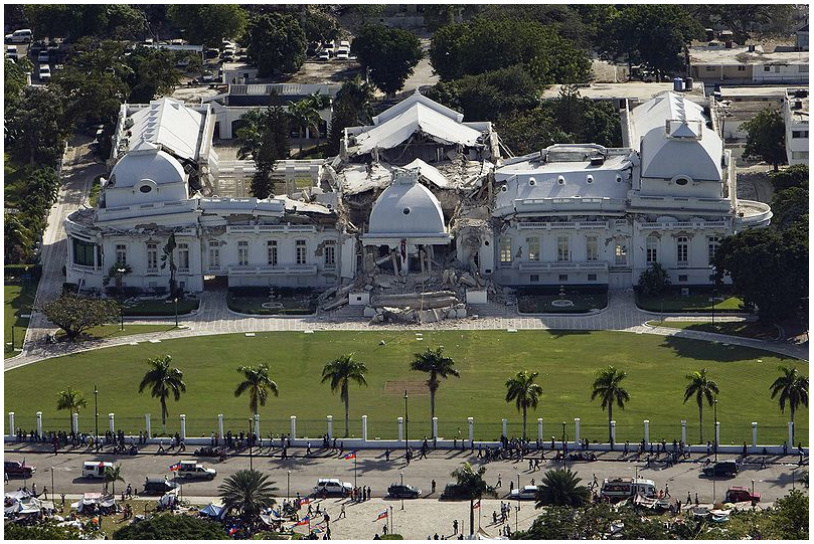
W = Seismic Moment
= Energy Released



$$N \propto W^{-2b/3}$$

Fat-Tailed Statistics

Risk = Hazard x Vulnerability



Haiti: January 12, 2010
M = 7.1
>200,000 dead
~ $12 Billion Loss

New Zealand: September 4, 2010
M = 7.1
0 dead
$1 - $4 Billion Loss

A Little Bit of Theory: Phase Transitions

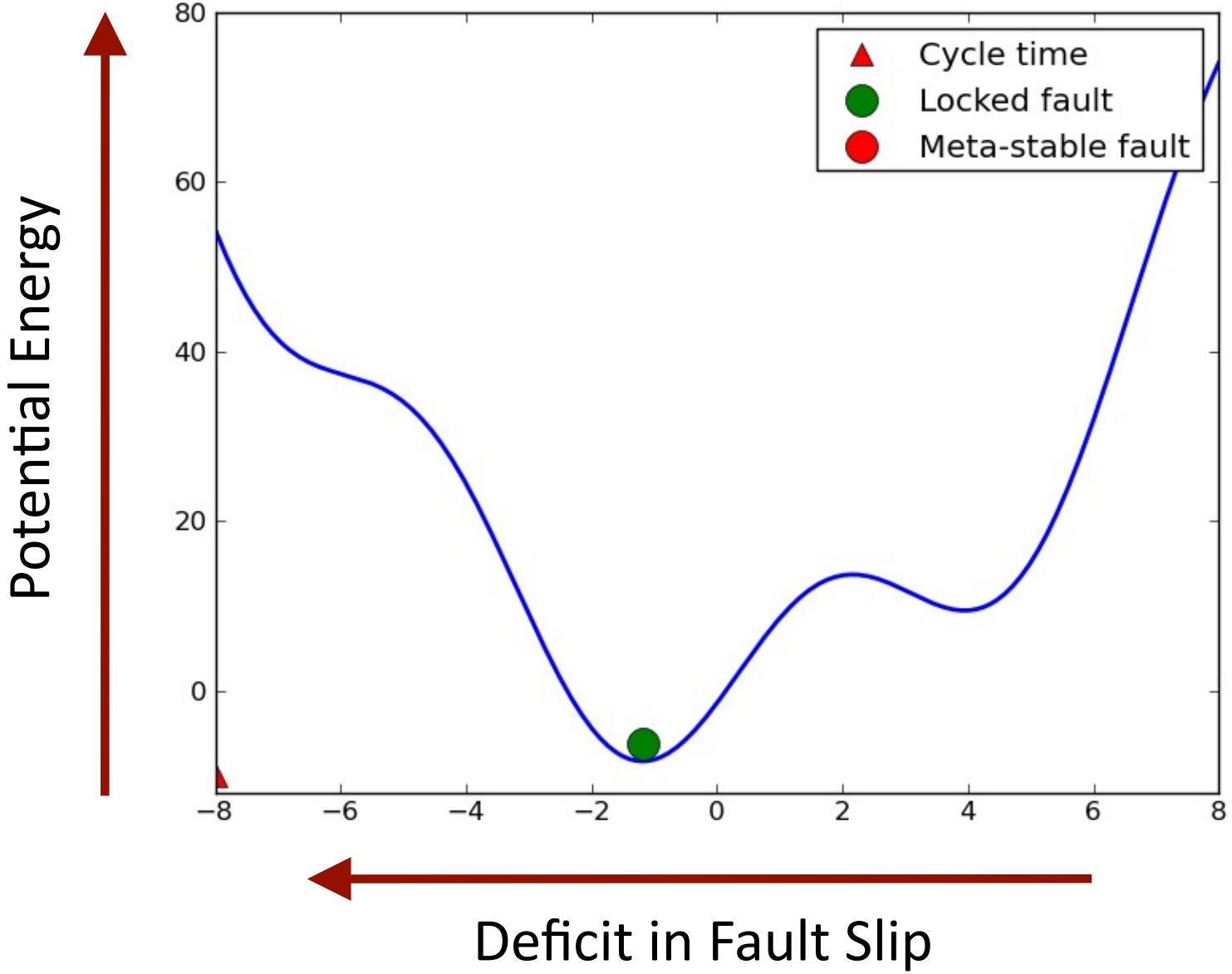
2nd Order Transitions:

- System resides at "critical point"
- Transitions of any size possible at any time (Black Swans)
- Power law statistics

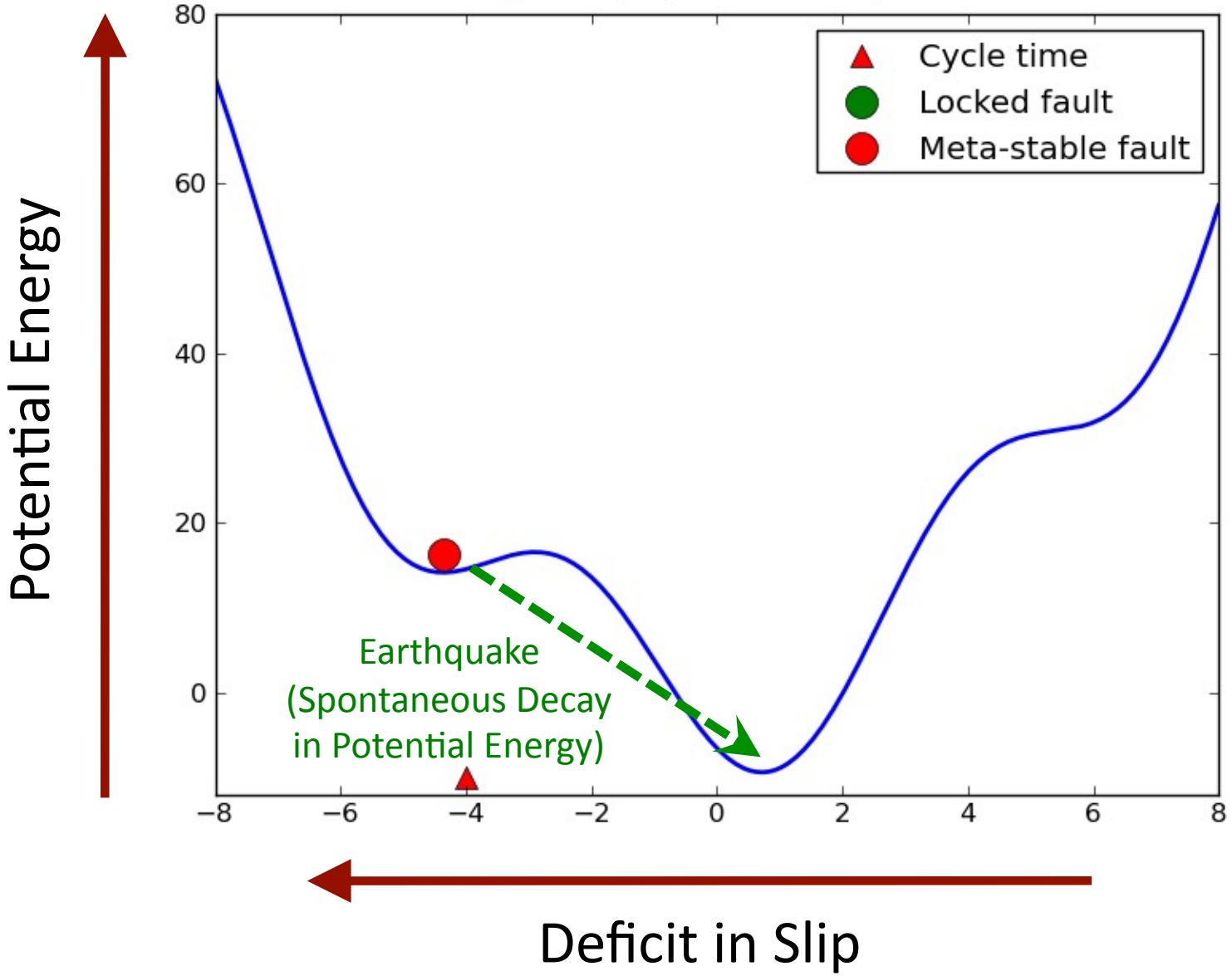
1st Order Transitions (Nucleation):

- System approaches and recedes from critical point (cycles)
- "Metastable states" are possible
- Power law statistics when interactions are long-range

Earthquakes: Increase in Potential Energy Driven by Large Scale Plate Tectonic Motions



Potential Energy Accumulates Late in Cycle

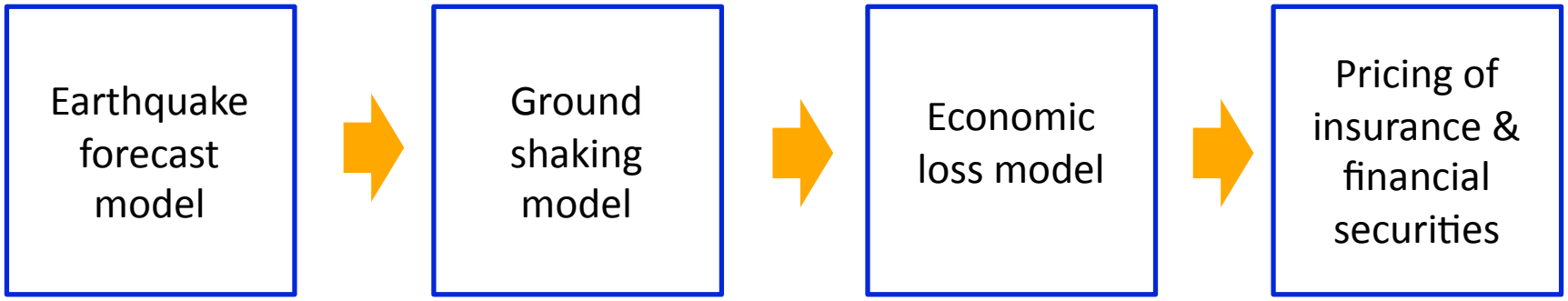


Risk Management as Currently Practiced

Oriented at selling earthquake insurance & financial products

California earthquake insurance:

- 15% deductable
- Often expensive
- Only 8-10% of California residents carry it



Earthquake forecast model	Ground shaking model	Economic loss model	Pricing of insurance & financial securities
Poisson	Attenuation	LEP curves	CAT Bonds
Log Normal	PGA	Building damage	SPVs
BPT	Surface geology	Socioeconomic data	Warrants
Fault models	Basin structure	Supply chain disruption	Traders
Pattern Analysis	Etc.	Lost income	Hedge Funds
AMR		Lifelines	Options
ETAS		Etc.	Muni Bonds
RIPI			Equities
Etc.			Etc.

Working Group on California Earthquake Probabilities 2007

Method requires many tens of scientists over ~4 years to produce a single 30 year forecast.

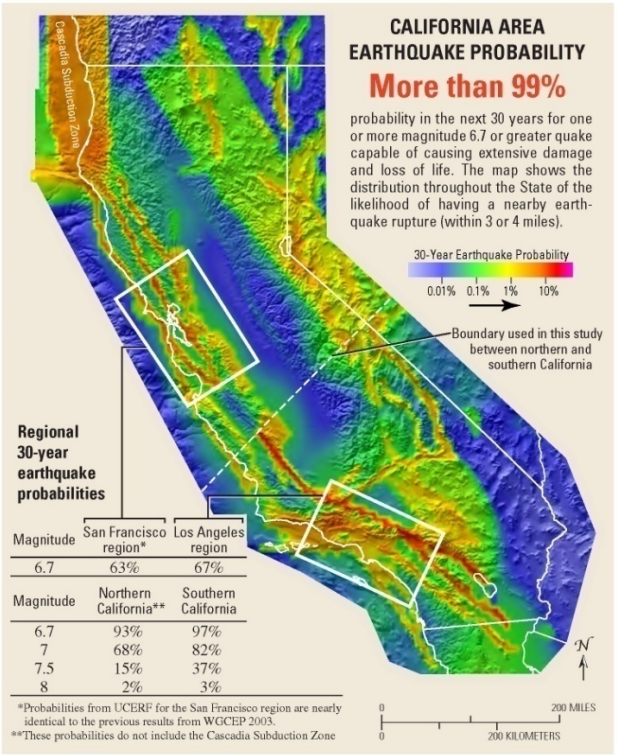
Approx. 2000 model parameters whose values are set using “expert opinion”.

Method cannot be automated (because it uses expert opinion) so the forecast cannot be backtested.

USGS science for a changing world

Forecasting California's Earthquakes—What Can We Expect in the Next 30 Years?

In a new comprehensive study, scientists have determined that the chance of having one or more magnitude 6.7 or larger earthquakes in the California area over the next 30 years is greater than 99%. Such quakes can be deadly, as shown by the 1989 magnitude 6.9 Loma Prieta and the 1994 magnitude 6.7 Northridge earthquakes. The likelihood of at least one even more powerful quake of magnitude 7.5 or greater in the next 30 years is 46%—such a quake is most likely to occur in the southern half of the State. Building codes, earthquake insurance, and emergency planning will be affected by these new results, which highlight the urgency to prepare now for the powerful quakes that are inevitable in California's future.



Regional 30-year earthquake probabilities

Magnitude	San Francisco region*	Los Angeles region
6.7	63%	67%

Magnitude	Northern California**	Southern California
6.7	93%	97%
7	68%	82%
7.5	15%	37%
8	2%	3%

*Probabilities from UCERF for the San Francisco region are nearly identical to the previous results from WGCEP 2003.
**These probabilities do not include the Cascadia Subduction Zone

What Is an Earthquake Rupture Forecast?

Californians know that their State is subject to frequent—and sometimes very destructive—earthquakes. Accurate forecasts of the likelihood of quakes can help people prepare for these inevitable events. Because scientists cannot yet make precise predictions of the date, time, and place of future quakes, forecasts are in the form of the probabilities that quakes of certain sizes will occur during specified periods of time.

In our daily lives, we are used to making decisions based on probabilities—from weather forecasts (such as a 30% chance of rain) to the annual chance of being killed by lightning (about 0.0003%). Similarly, earthquake probabilities derived by scientists can help us plan and prepare for future quakes.

Earthquake forecasts for California have been developed in the past by multidisciplinary groups of scientists and engineers, each known as a “Working Group on California Earthquake Probabilities” (WGCEP 1988, 1990, 1995, 2003). However, those forecasts were limited to particular regions of California. Because of this, WGCEP 2007 was commissioned to develop an updated, statewide forecast, the latest result of which is the Uniform California Earthquake Rupture Forecast, Version 2, or “UCERF” (U.S. Geological Survey (USGS) Open-File Report 2007-1437, http://pubs.usgs.gov/of/2007/1437/). Organizations sponsoring WGCEP 2007 include the USGS, California Geological Survey, and the Southern California Earthquake Center. The comprehensive new forecast builds on previous studies and also incorporates abundant new data and improved scientific understanding of earthquakes.

When an earthquake occurs, two things happen—a fault ruptures (a crack in the Earth's crust gives way and slips under tectonic pressure) and seismic waves, caused by this sudden fault motion, radiate out like ripples from a pebble tossed into a pond. The shaking that occurs as seismic waves pass by causes most quake damage. The strength of the waves depends partly on the quake's magnitude, which is a function of the size of the fault that moves and the amount of slip.

The UCERF study's goal was to determine probabilities for different parts of California of earthquake ruptures of various magnitudes, but not to estimate the likelihood of shaking (“seismic hazard”) that will be caused by these quakes. This distinction is important, because even areas in the State with a low probability of fault rupture can experience shaking and damage from distant, powerful quakes.

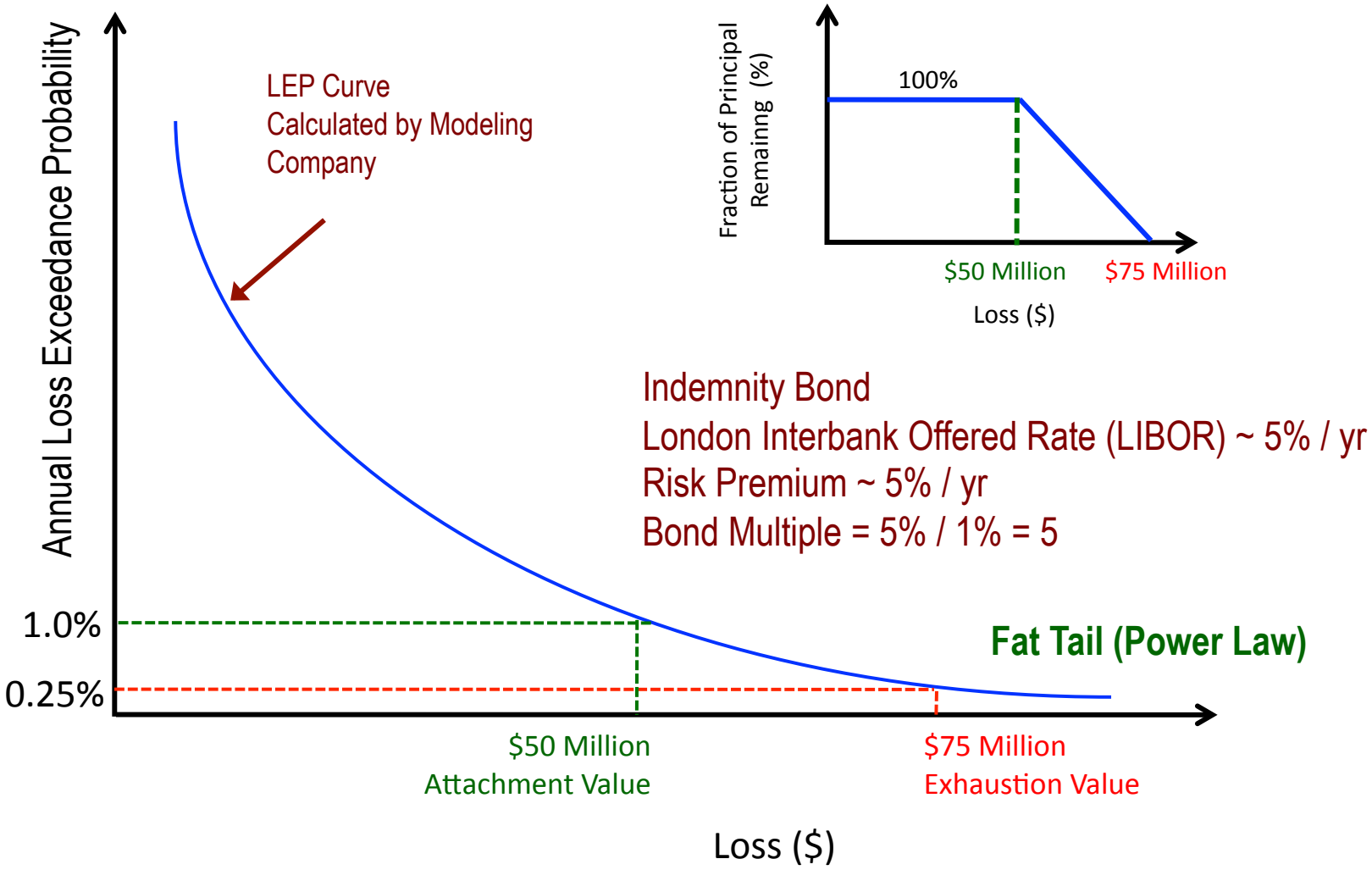
U.S. Department of the Interior
U.S. Geological Survey

USGS Fact Sheet 2008-3027
2008

Financial Strategies for Dealing with Risk: Example

Hypothetical $75 Million Single-Peril Earthquake Cat Bond

If no earthquake occurs, cat bond returns principal + LIBOR + risk premium after 2 years



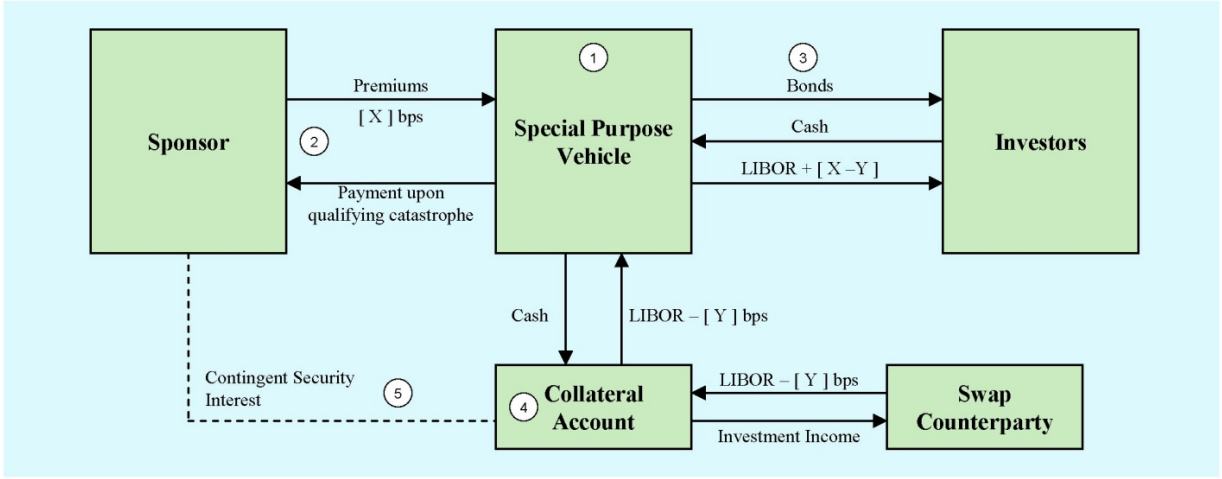
Securitized Cat Bond Structure

Issuer XYZ

- **The basic Catastrophe Bond structure has become market standard for both Sponsors and Investors**

Cat Bond Structure Diagram

Schematic and Cash Flows



Transaction Details

1. The Sponsor sets up a Special Purpose Vehicle ("SPV") to issue bonds to Investors
2. The Sponsor buys catastrophe protection from the SPV to cover defined catastrophic risk and pays the SPV [X] bps per annum in premium for the coverage
3. The SPV sells bonds to capital markets investors paying a coupon equal to LIBOR + [X-Y] in return for cash
4. The SPV places the proceeds from the sale of the bonds in a Collateral Account and enters into a total return swap with an eligible counterparty, receiving LIBOR – [Y] bps in exchange for the investment income of the Collateral Account
5. In case a Loss Event occurs, the Sponsor has a contingent security interest in the Collateral Account and has the ability to withdraw an amount as defined in the bond's terms

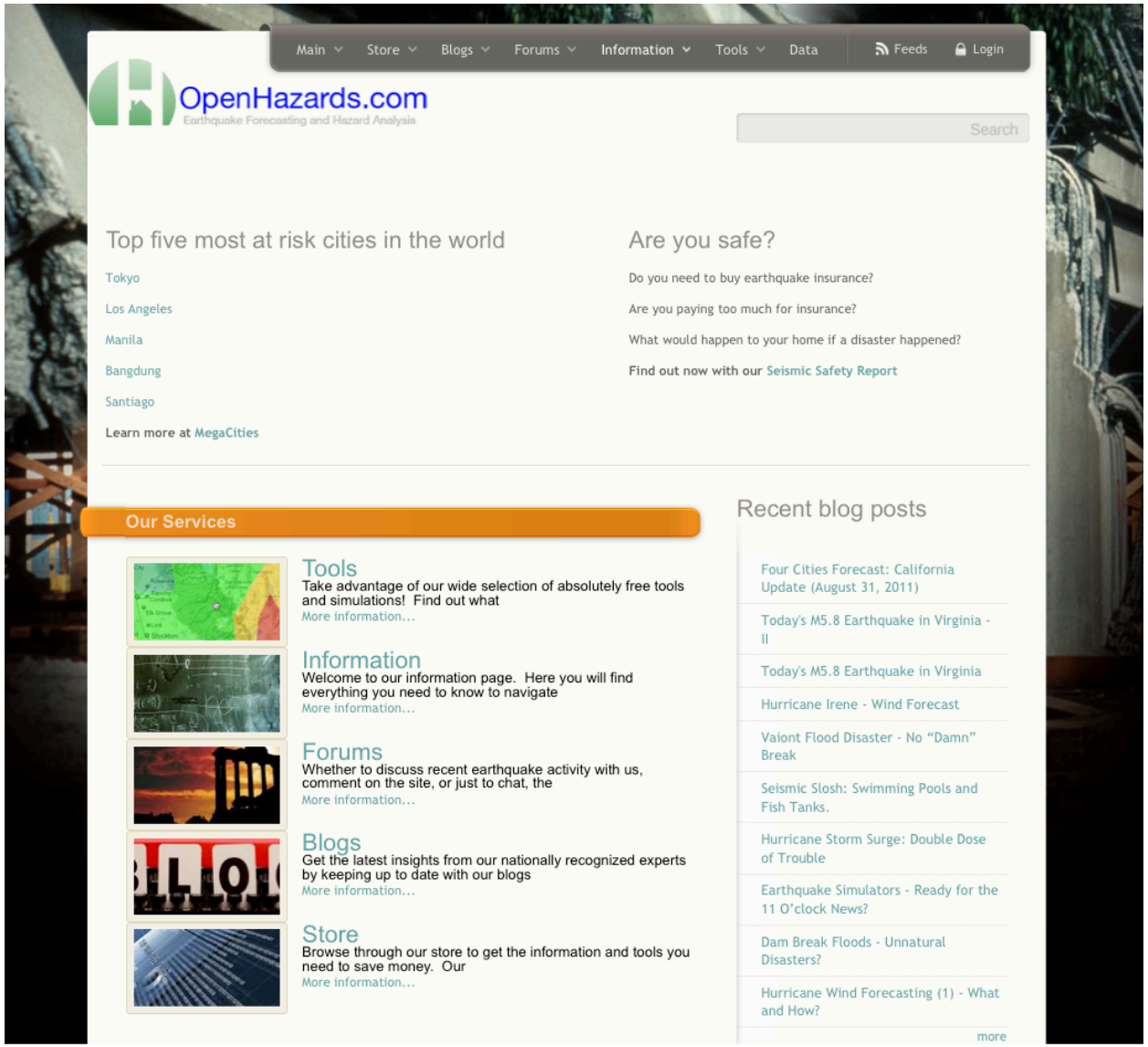
Morgan Stanley

Personal Risk Management

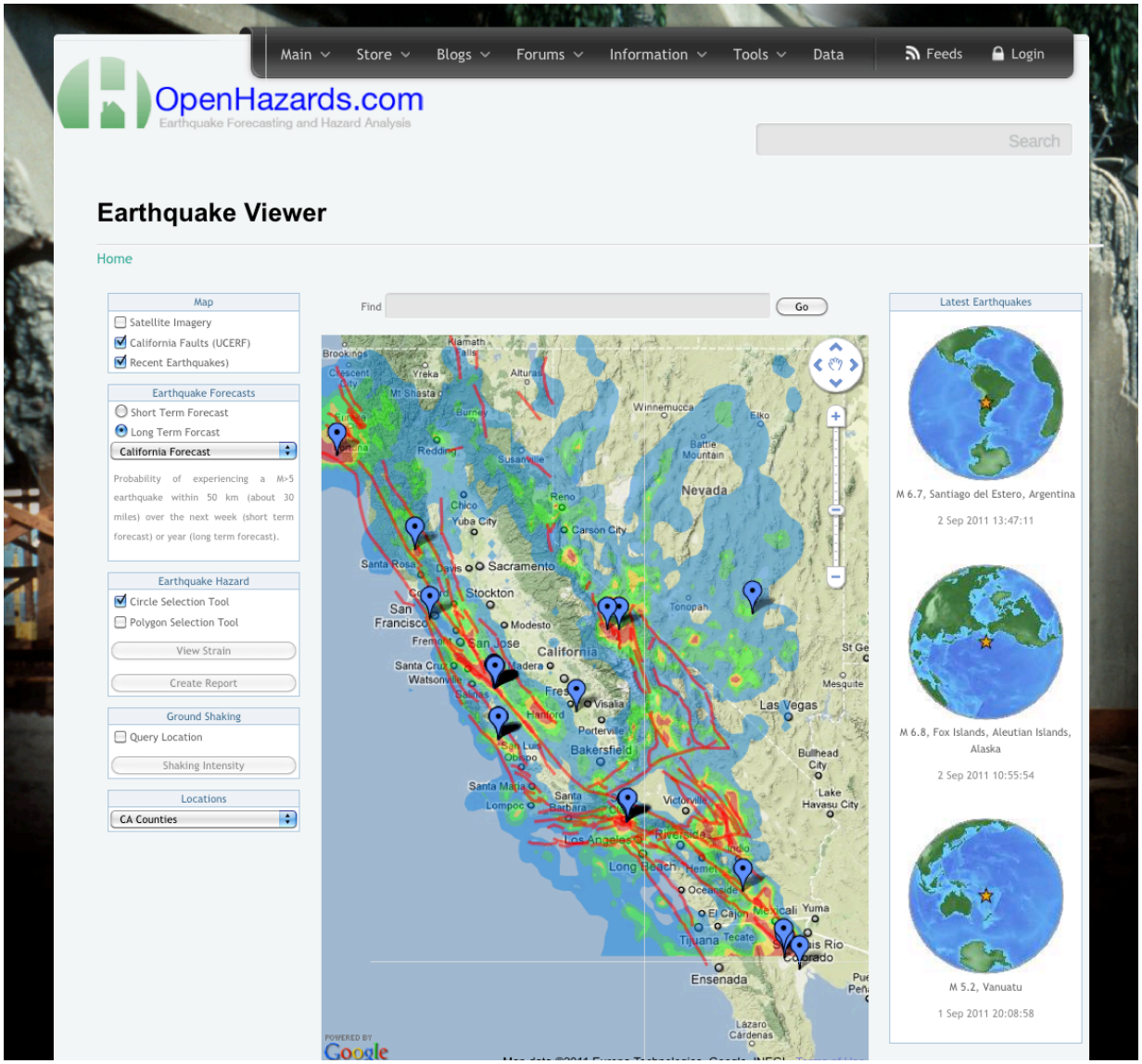
Currently, risk management is done by big corporations for big corporations

Modern social networking technology together with web-based information and tools has enabled a new era of Personal Risk Management

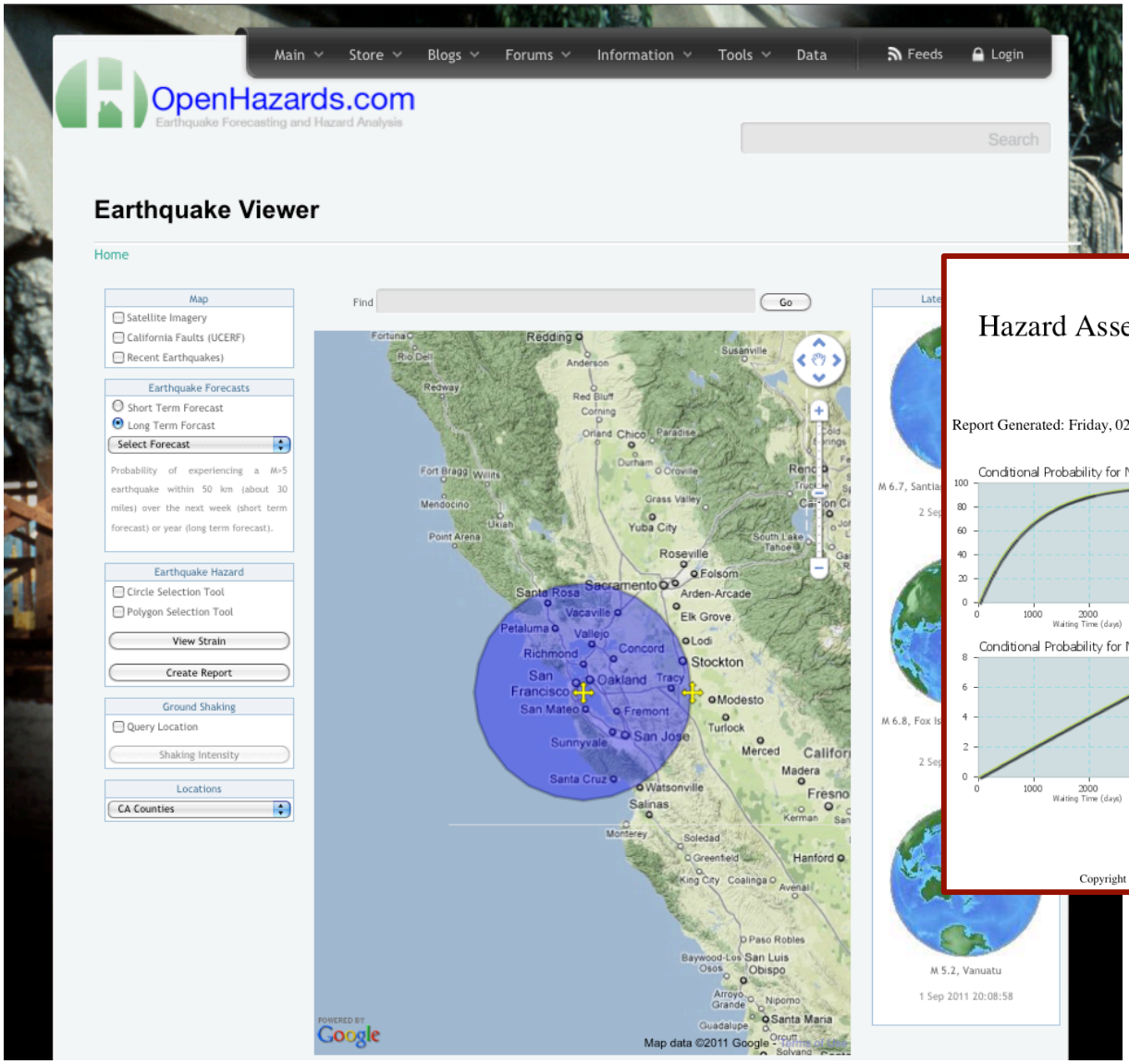
Personal Risk Management Web Site

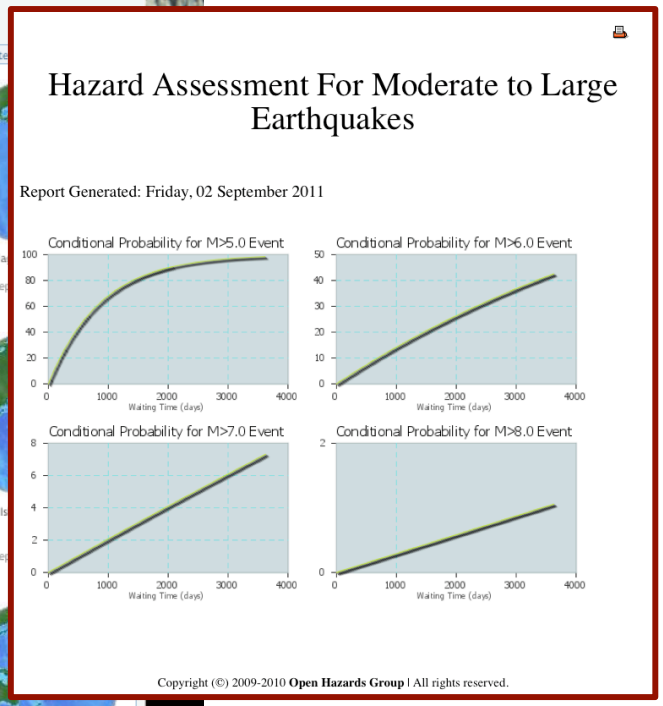


Hazard Viewer Tool

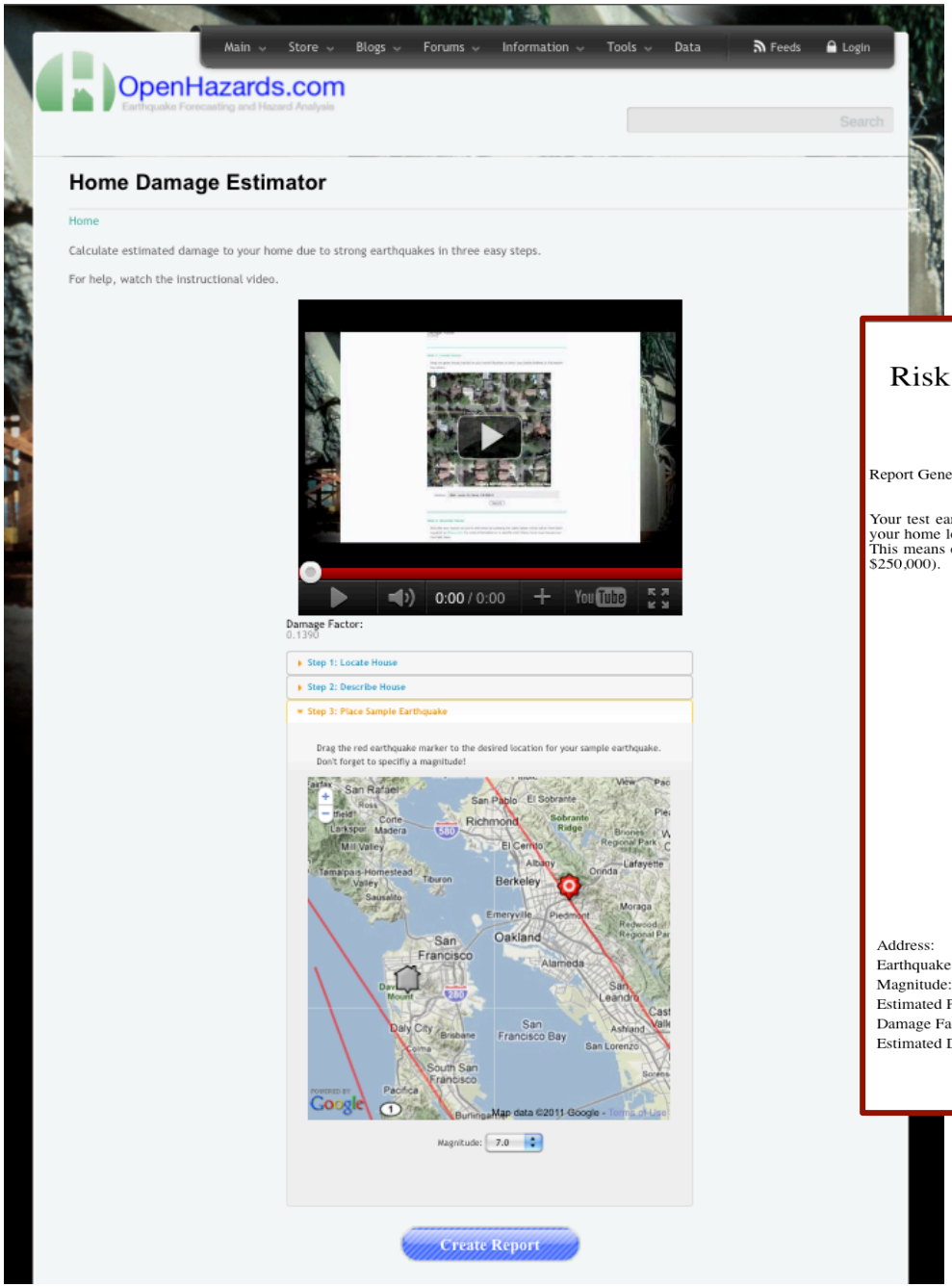


Hazard Viewer Tool





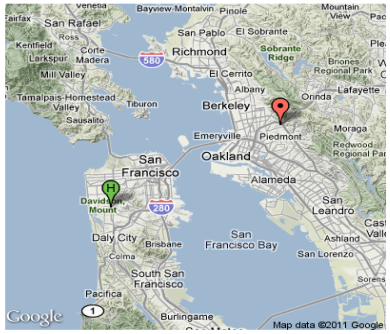
Home
Damage Estimator



Risk Assessment For User Generated Home Values

Report Generated: Fri Sep 02 2011 11:19:18 GMT-0700 (PDT)

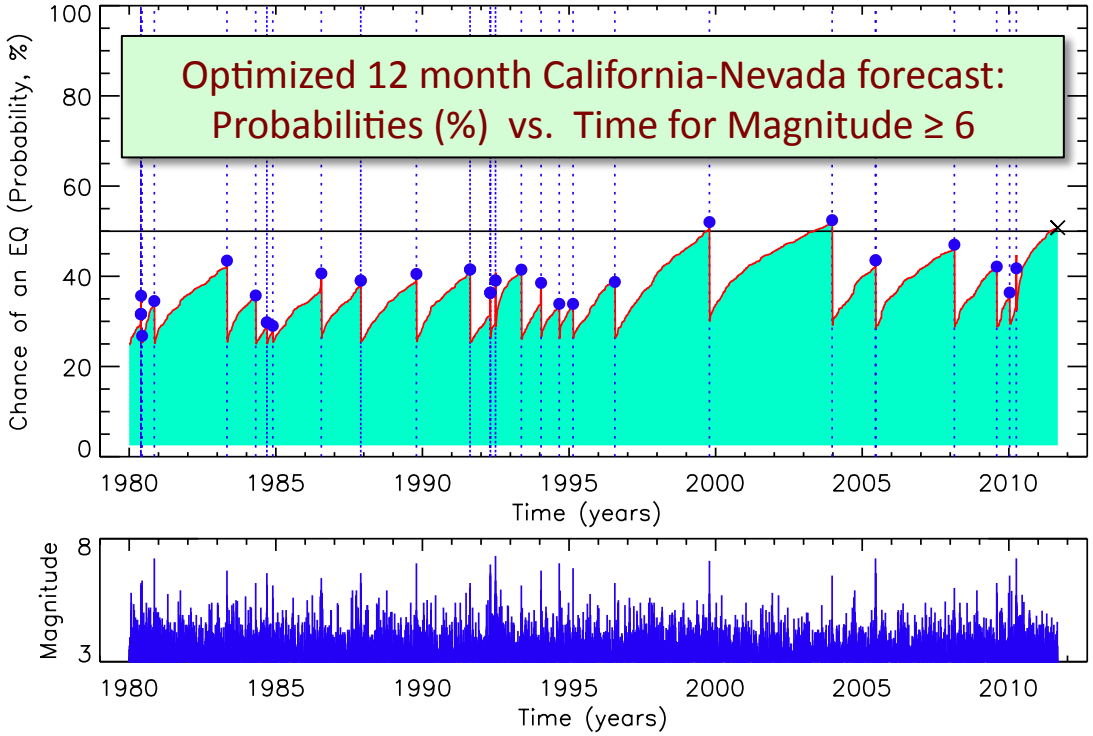
Your test earthquake produced a simulated peak ground acceleration (PGA) of 17.943%g at your home location. Given your description, the damage factor (DF) for this event is 0.1390. This means on average you would experience $35,000 in damage (assuming a home value of $250,000).



Address:	21st Ave, San Francisco, CA 94132
Earthquake Location:	37.846°N, -122.231°E
Magnitude:	7.0
Estimated PGA (%g):	17.943
Damage Factor:	0.1390
Estimated Damage:	$35,000

New Forecast Model

- Count number of small earthquakes since the last large earthquake
- Use a standard probability model (e.g., Weibull) to quantify probabilities
- Select best parameters in probability model based on backtesting
- Example following

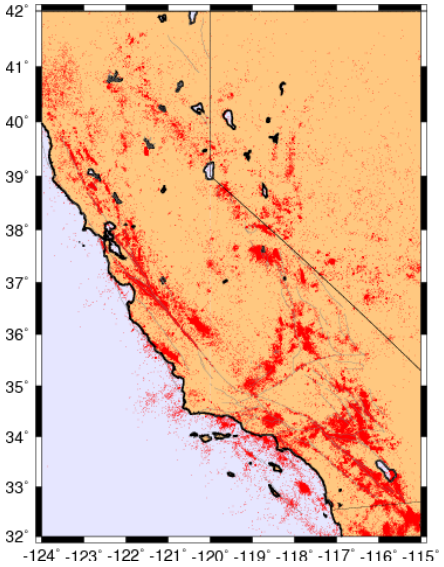


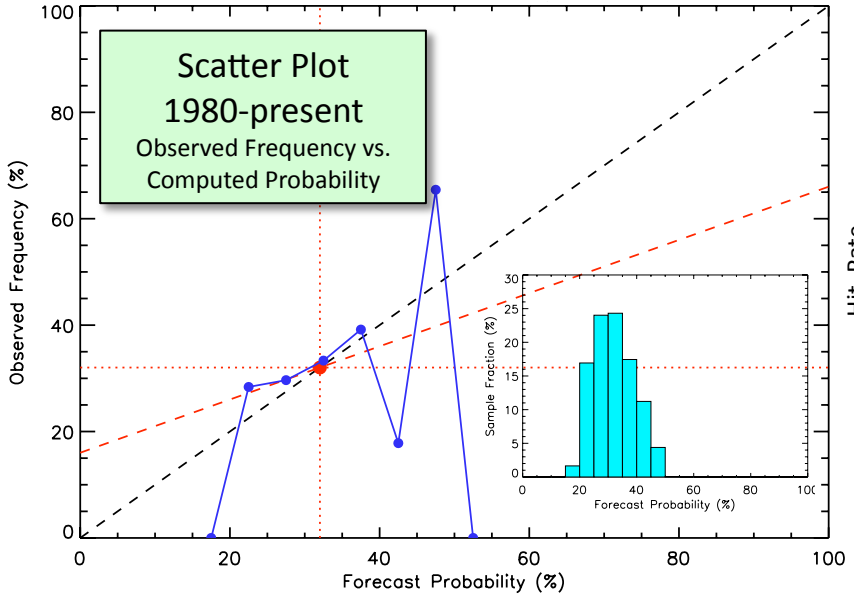
New EQ Forecast Technology

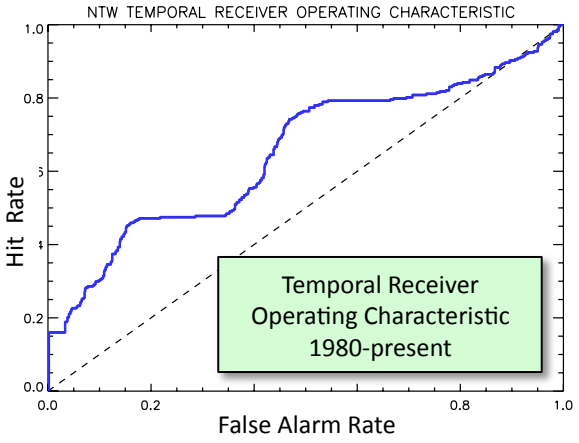
(Open Hazards Group)

Optimal forecasts via backtesting, using common validation and verification testing procedures.

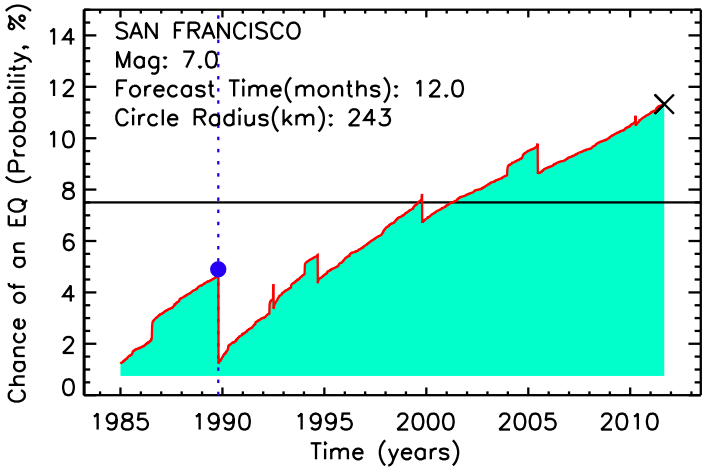
Forecast Date: 2011/08/31

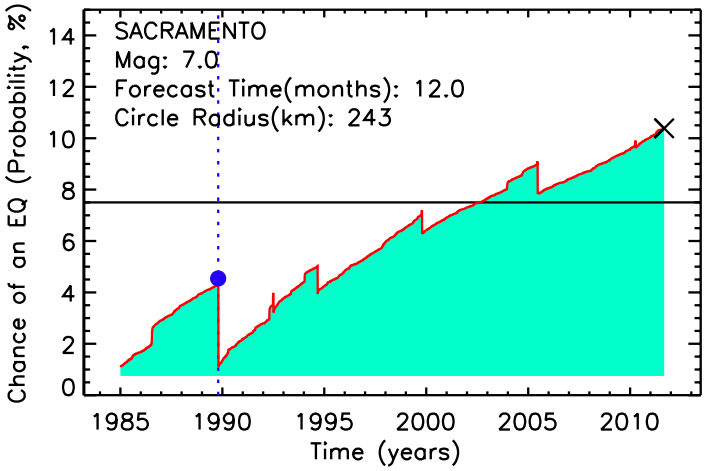


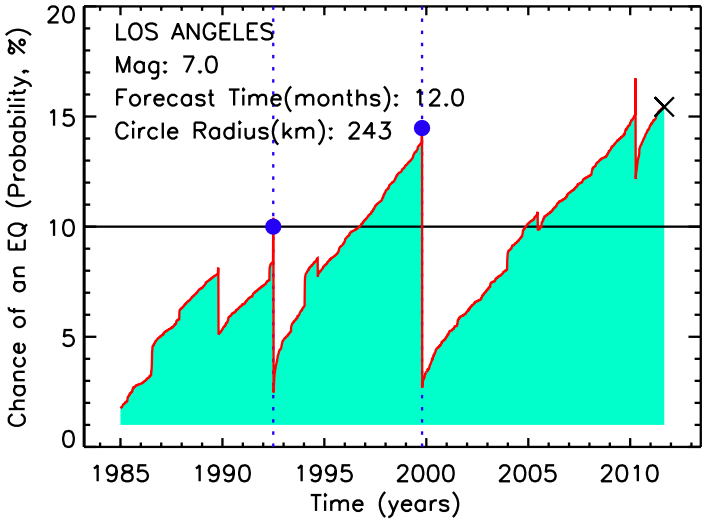


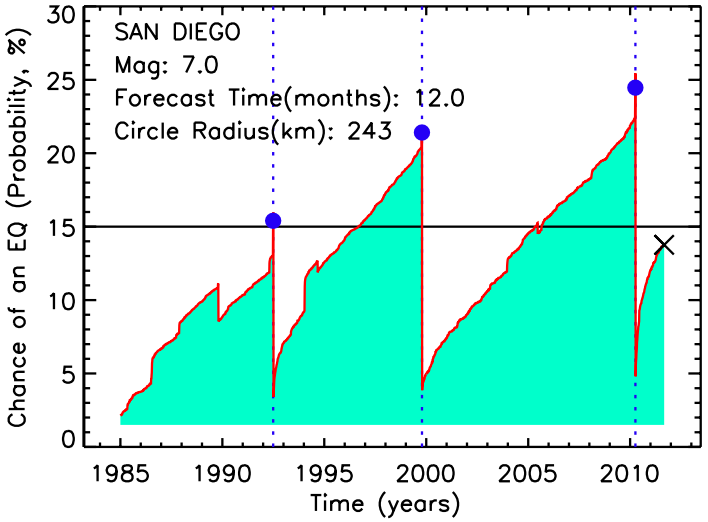


California Four Cities Forecast – M>7, Distance < 150 Miles, Within 12 Months









Applications to the Markets

NEWS ANALYSIS

In Euro Zone, Banking Fear Feeds on Itself

By LANDON THOMAS Jr. and NELSON D. SCHWARTZ
Published: September 6, 2011

Remember the collapse of Lehman Brothers? Europeans certainly do.

RECOMMEND
TWITTER
LINKEDIN
COMMENTS (116)
SIGN IN TO E-MAIL
PRINT
SINGLE PAGE
REPRINTS
SHARE

Enlarge This Image

Left, Jorge Silva/Reuters; Tom White for the New York Times

"This crisis has the potential to be a lot worse than Lehman Brothers," said George Soros, the hedge fund investor, citing the lack of a pan-European body to handle an extreme banking crisis.

As Europe struggles to contain its government debt crisis, the greatest fear is that one of the Continent's major banks may fail, setting off a financial panic like the one sparked by Lehman's bankruptcy in September 2008.

European policy makers, determined to avoid such a catastrophe, are prepared to use hundreds of billions of euros of bailout money to prevent any major bank from failing.

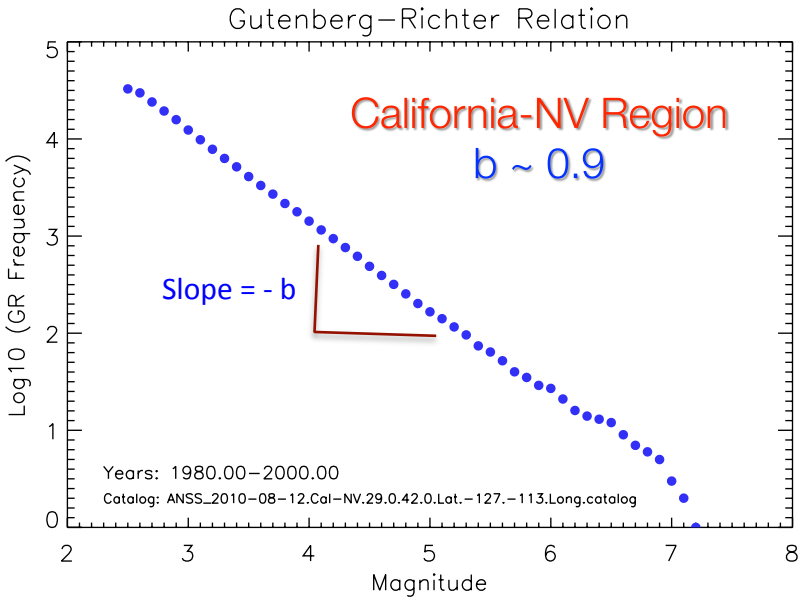
Frequency-Magnitude Relations

Earthquakes

Moment (Richter) Magnitude

$$M_W = 2/3 \; Log_{10} \; W - 6.0$$

W = Seismic Moment
= Energy Released

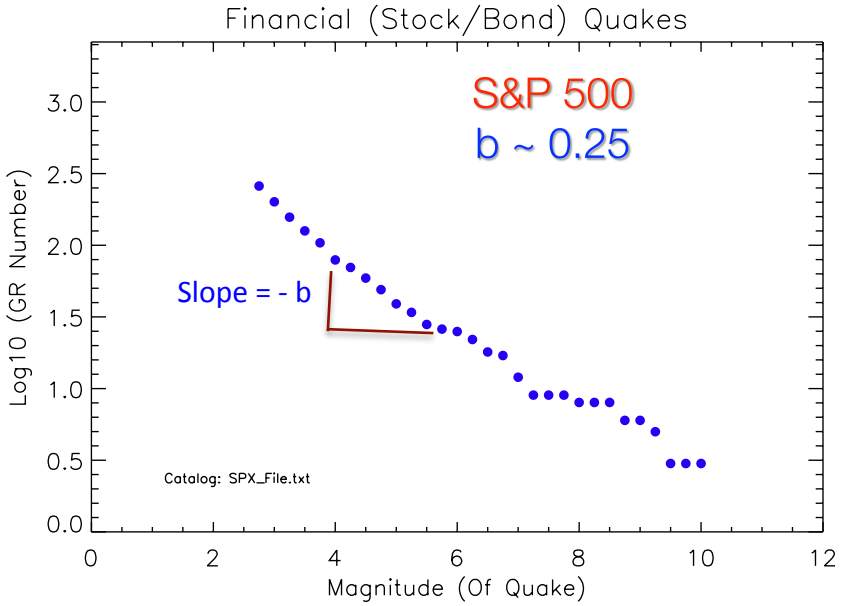


S&P 500 Quakes

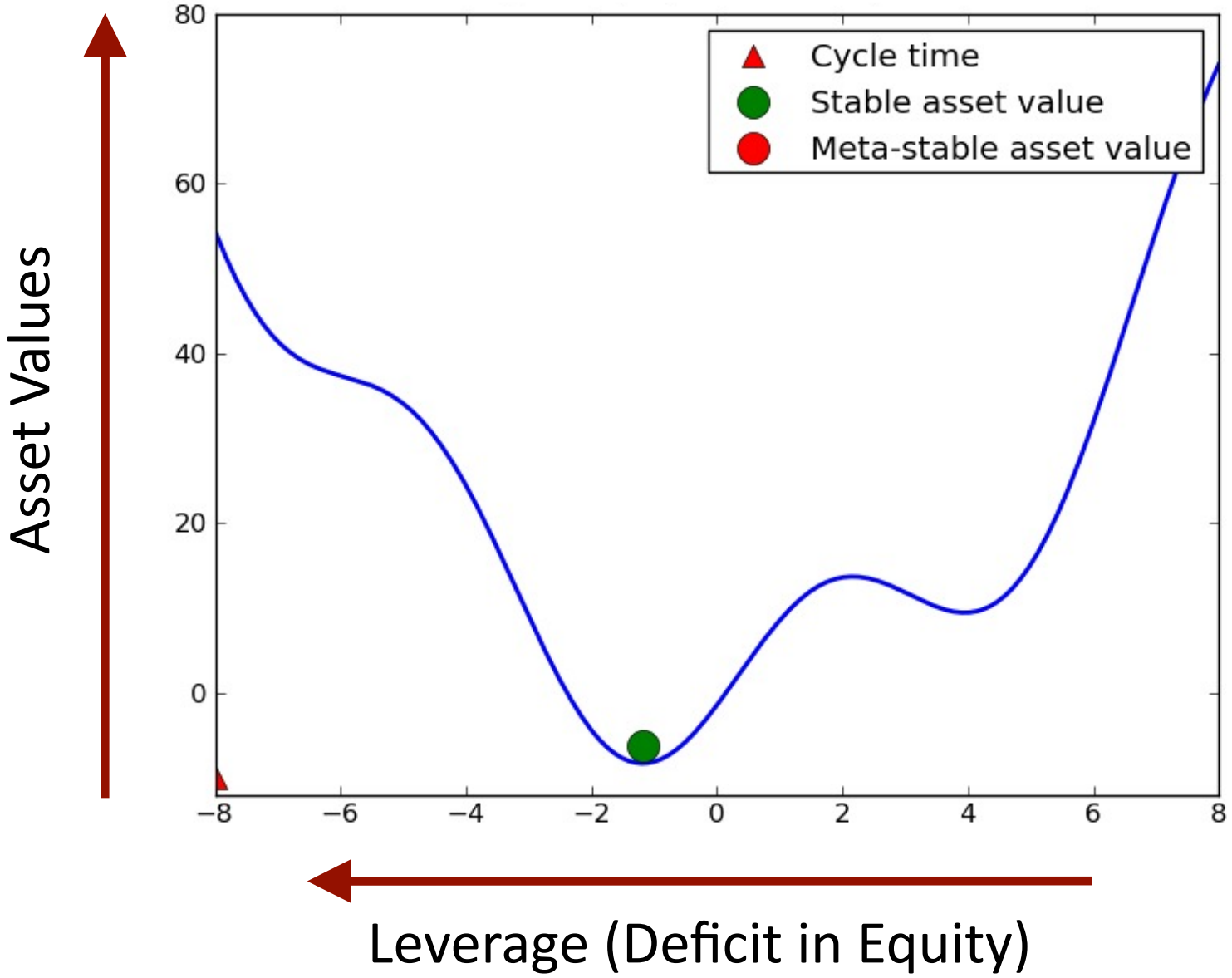
M=4 means ~ 4% move in SPX
(either up or down)

$$M_F = 100 \left| Log_e \frac{P_i}{P_{i-1}} \right|$$

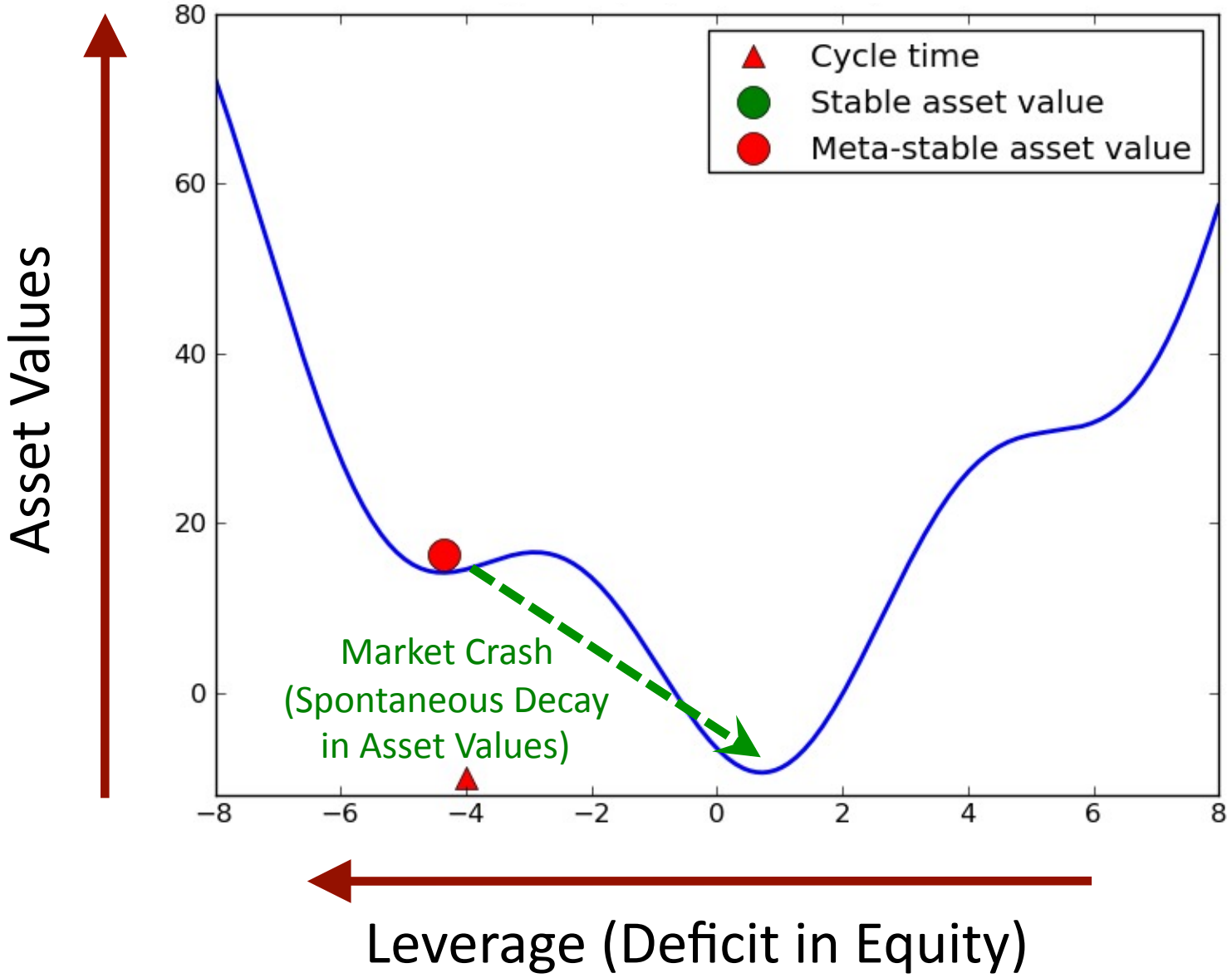
P_i = Closing Price, Day i



Markets: Increase in Asset Values
Driven by Growth Rate of the Money Supply



Asset Values Increase Late in Cycle

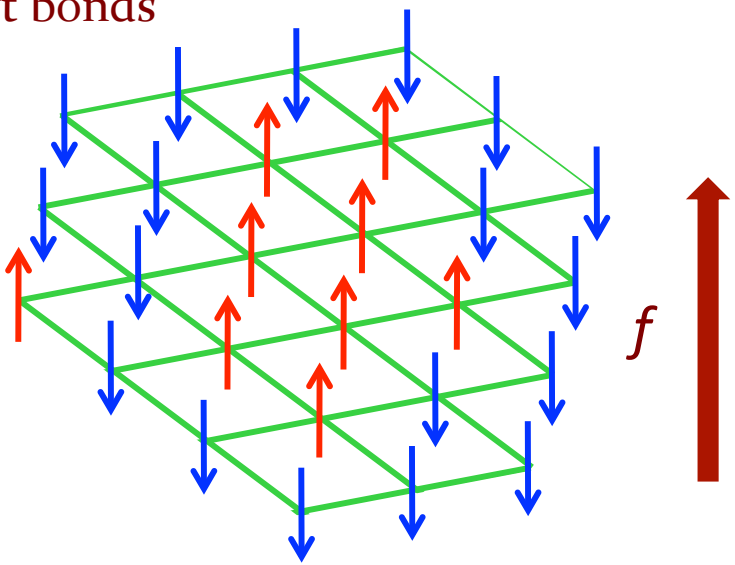


Digression I: Metaphor for the Markets

Investors are arrows :

↑ Owns only Govt. bonds ↓ Owns only stocks

ϕ is the fraction of total money deployed in Govt bonds



f is the real Fed funds rate

Liquidity L plays the role of "temperature"

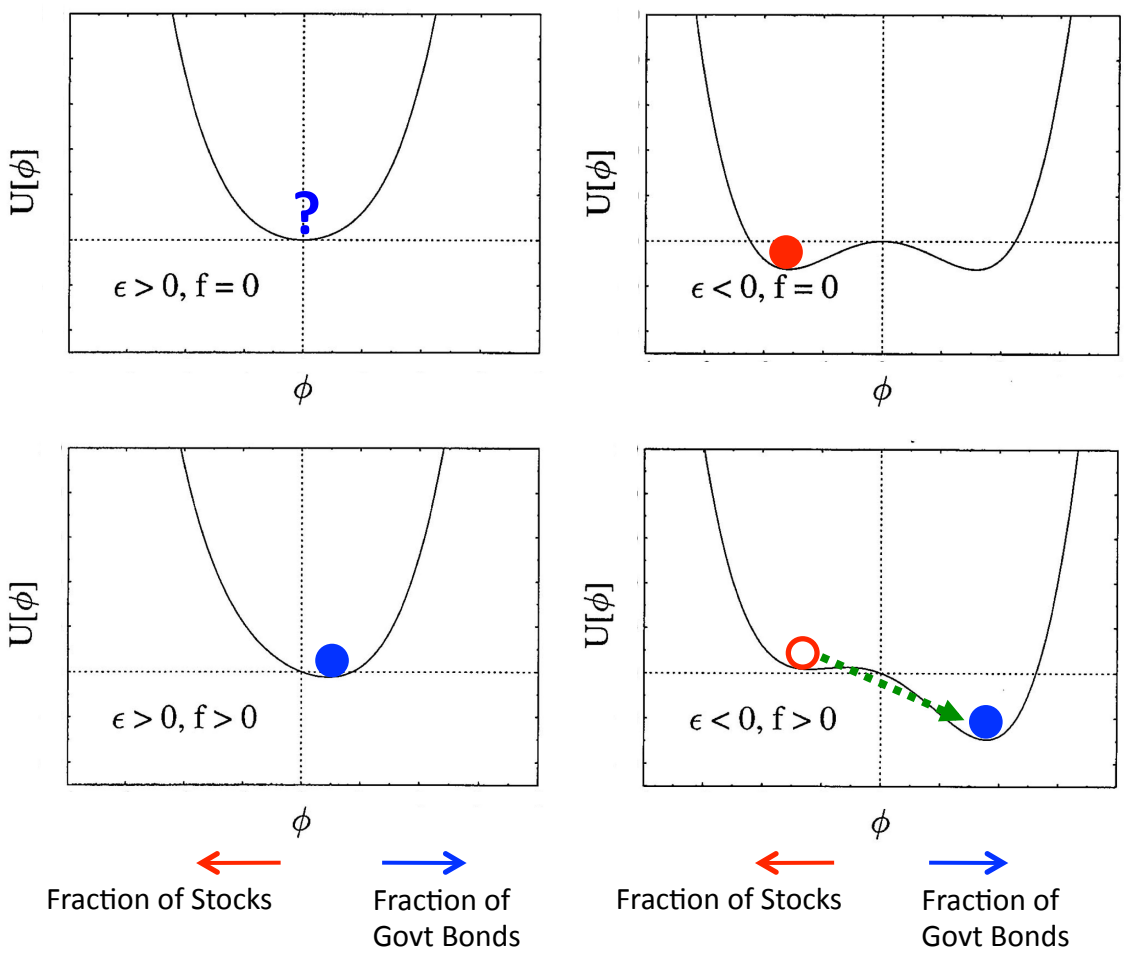
For example, we might have $L \propto (\text{LIBOR})^{-1}$

Investors "interact" with neighbors, strength J

Market Potential $U[\phi]$

Digression II: Simple Model of Investor Dynamics

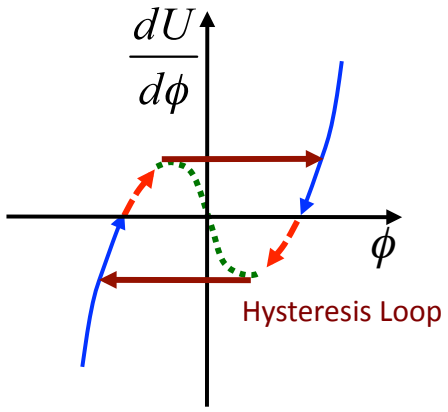
First order phase transitions – metastability, nucleation, hysteresis



f: Real Fed funds rate

L: Liquidity ∝ $(\text{LIBOR})^{-1}$

$\varepsilon \propto (L - L_C)$



● Bonds ●○ Stocks

Market Potential $U[\phi] = \varepsilon\,\phi^2 + \alpha\,\phi^4 - f\,\phi$

Digression III: Simple Model of Investor Dynamics

Before a 1st Order Phase Transition

Transition occurs via nucleation and growth of bubbles

Classical: Correlation lengths and times are small
Nonclassical: Correlation lengths and times $\rightarrow \infty$

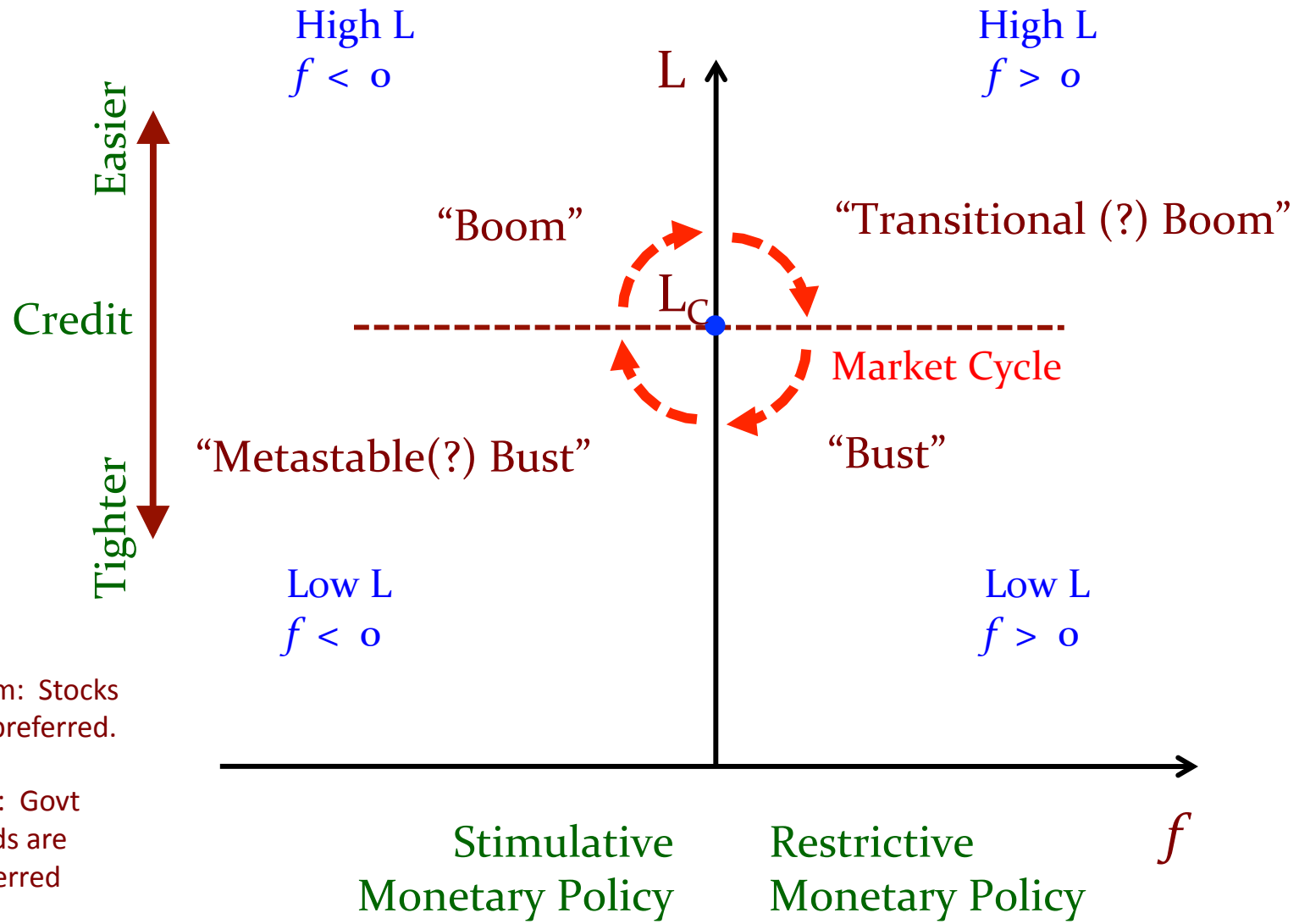
Large fluctuations (volatility is high) – Ginzburg Criterion

Risk function (of bubble formation):

Related to nucleation rate of bubbles,
Lifetime in the metastable state is inverse of nucleation rate

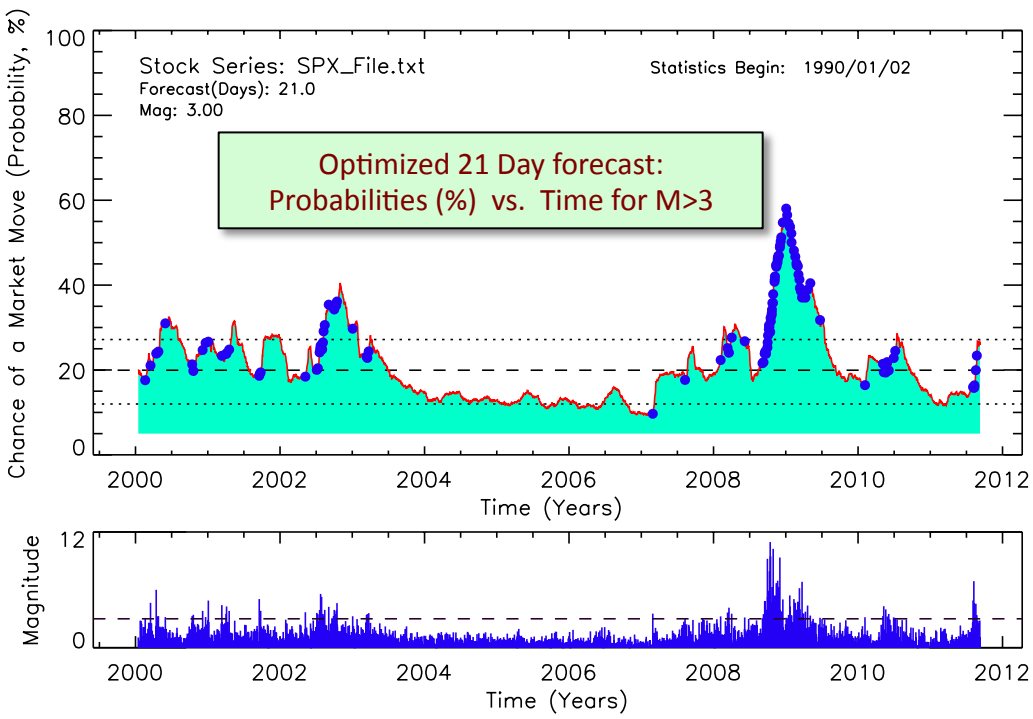
Scaling (fat tail) exponents can be calculated

Digression IV Phase Diagram



Boom: Stocks are preferred.

Bust: Govt bonds are preferred

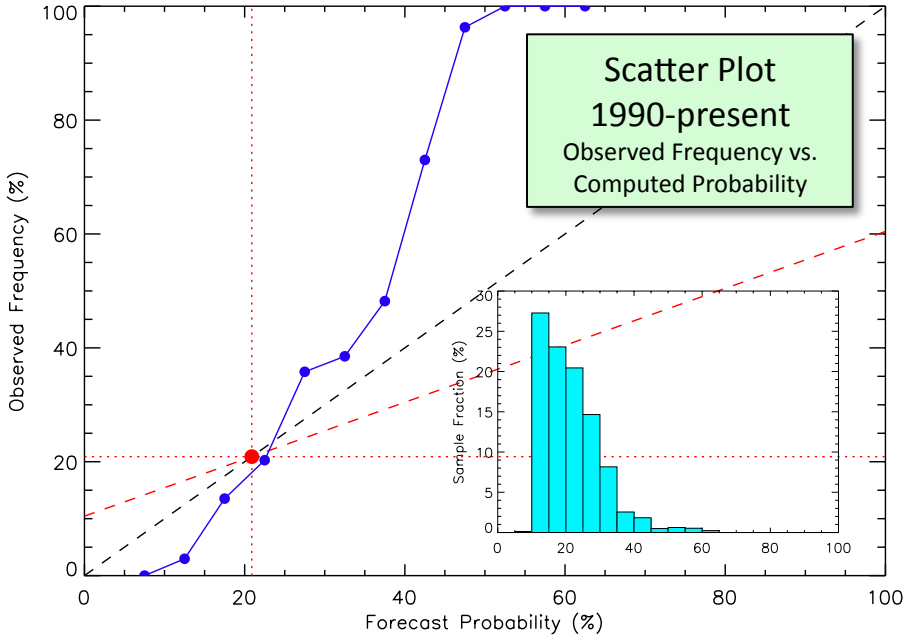


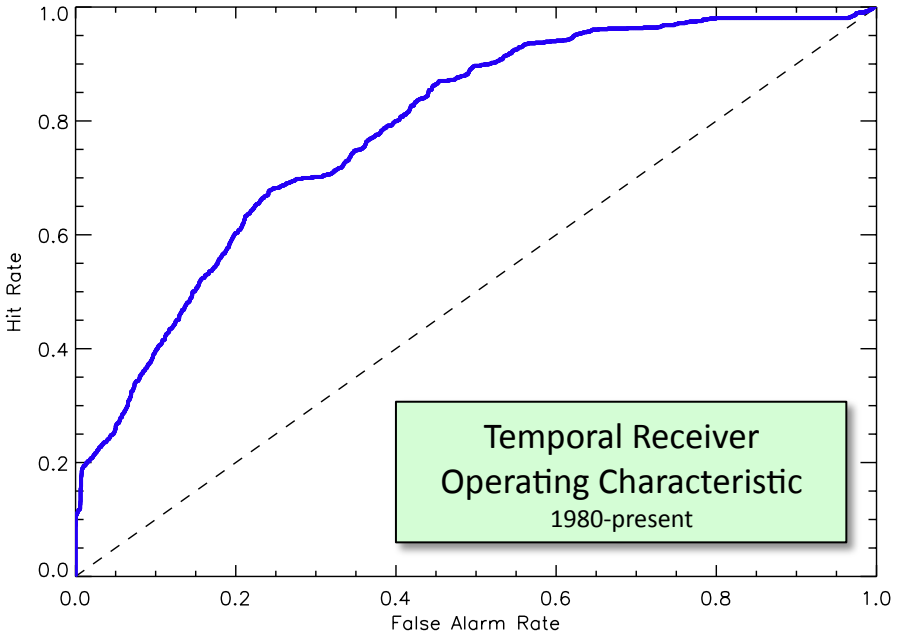
S&P 500 Forecast Technology

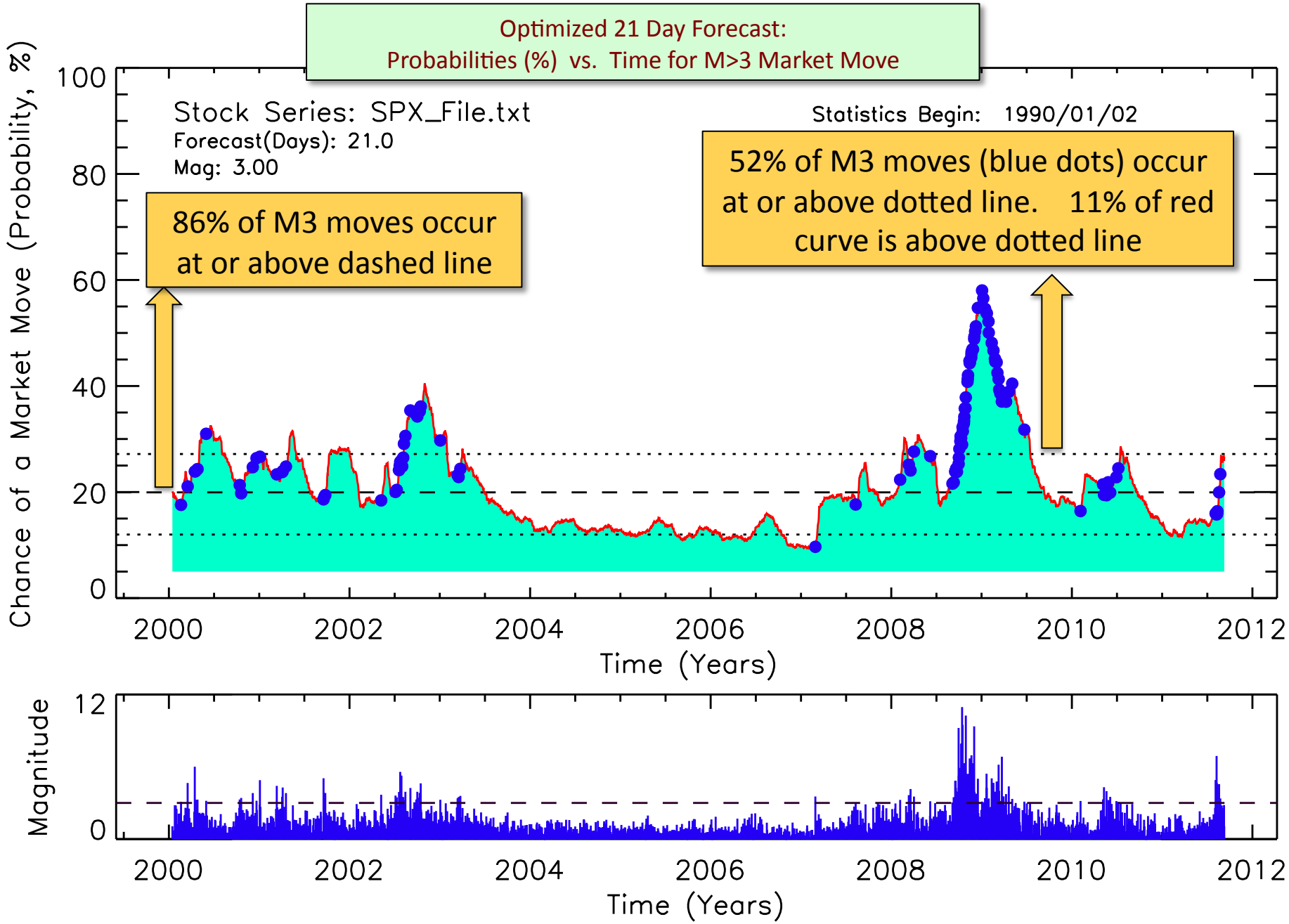
(Open Hazards Group)

Optimal forecasts via backtesting, using common validation and verification testing procedures.

Forecast Date: 2011/09/09






Optimized 21 Day Forecast:
Probabilities (%) vs. Time for M>3 Market Move
Stock Series: SPX_File.txt
Forecast(Days): 21.0
Mag: 3.00
Statistics Begin: 1990/01/02
86% of M3 moves occur at or above dashed line
52% of M3 moves (blue dots) occur at or above dotted line. 11% of red curve is above dotted line
Chance of a Market Move (Probability, %)
100
80
60
40
20
0
2000
2002
2004
2006
2008
2010
2012
Time (Years)
Magnitude
12
0
2000
2002
2004
2006
2008
2010
2012
Time (Years)

In Summary

- Personal risk management is upon us
- Markets have similarities to earthquakes (fat tails) – and earthquake science can be applied to the markets
- Santa Fe Institute fosters out-of-the-box thinking about critical problems of the 21st century