EARTH 390

Playing against nature: defending society against natural hazards in a very uncertain world

Seth Stein

June 6, 2013

NYT

In Flooded Europe, Familiar Feelings and New Questions

German flood prevention still can't prevent floods

GERMANY FIGHTS BACK FLOODS

Germany has repeatedly experienced massive flooding over the past decades. What were the political consequences and why are there still problems with flood control?

3

German minister calls for rethink on flood protection

GERMANY FIGHTS BACK FLOODS

Environment minister Peter Altmaier has reacted to Germany's record floods by calling fo rivers to be given more room to buffer their floodwaters, if necessary through removal of riverside homes and relocation of dikes.

Germany record floods along the Elbe and Danube - just over a decade after its Elbe flood disaster in 2002 - were described by Environment Minister Peter Altmaier on Tuesday as "alarming" evidence that "extreme weather events" had become more frequent and required drastic hydrological remedies.

"We must give up the idea that a "100-year flood" only happens once every 100 years," Landsberg said Recovery work this time round would take up to three years and cost Germany at least 10 billion euros ($13.2 billion), he estimated.

http://www.dw.de/german-minister-calls-for-rethink-on-flood-pr...

CQ:

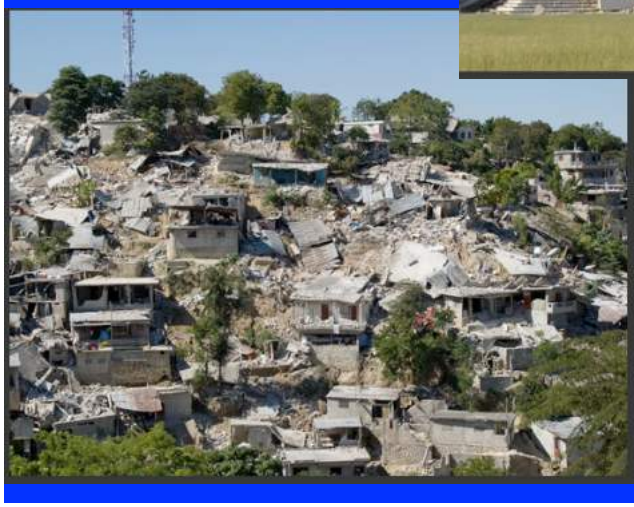
Two neighboring nations: different responses

- **What are the differences?**
- **What causes them?**
- **Which responses are most like the U.S's?**

Haiti 1/12/2010 M 7.0

Haiti 1/12/10

M 7.0



Earthquakes don't kill people: Buildings kill people

Behind the News — January 12, 2012 01:04 PM http://www.cjr.org/behind_the_news/one_year_later_haitian_ea...

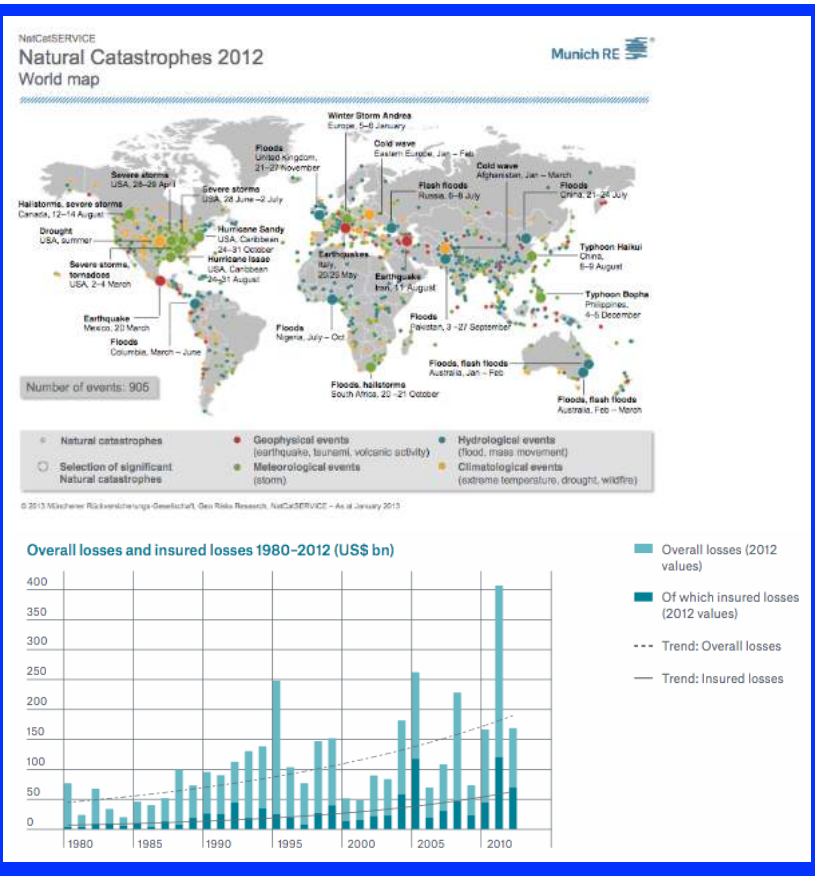
Two Years Later, Haitian Earthquake Death Toll in Dispute

The official death toll of the quake is 316,000, according to the Haitian government. It's a number that was arrived at mysteriously. In the first year after the quake, the government had set the death toll at 230,000, and the media and NGOs widely repeated the figure. On the first anniversary in January 2011, the 316,000 number was made official without explanation by then-prime minister Jean-Max Bellerive.

The story around Haiti's earthquake death toll has only grown murkier and more controversial in the last year. In October 2010, a report was published in the journal *Medicine, Conflict and Survival* that estimated the probable death toll at 158,000 people. It received little media coverage. In May 2011, Agence France-Presse received a copy for an unpublished report originally commissioned by the United States Agency for International Development, which suggested the number might possibly be as low as 46,000.

CQ: What may cause the different numbers? Do the numbers matter?

Lecture 1 9

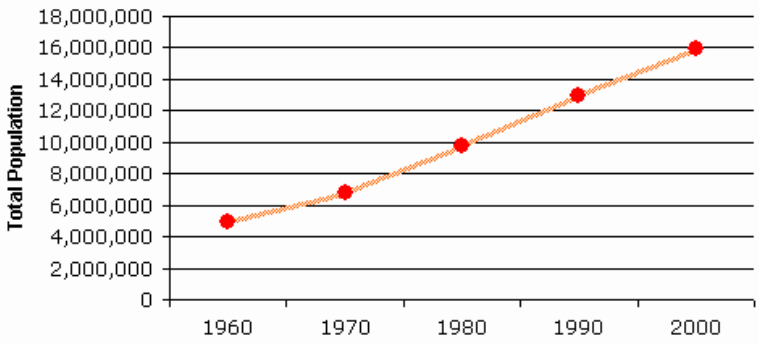


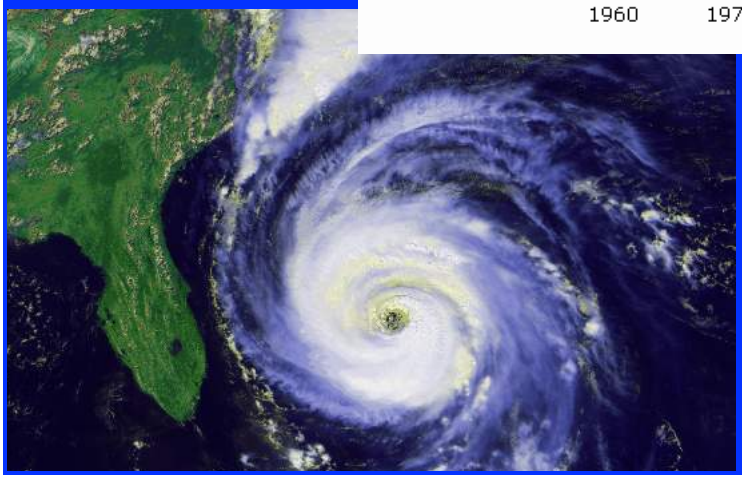
CQ: Why are disaster losses increasing with time?

PAN 1.1

Lecture 1 10

Florida





MIT blackjack team https://www.youtube.com/watch?v=QflVqavHHM0

Society is playing a high-stakes game of chance against nature in a uncertain world

We want to

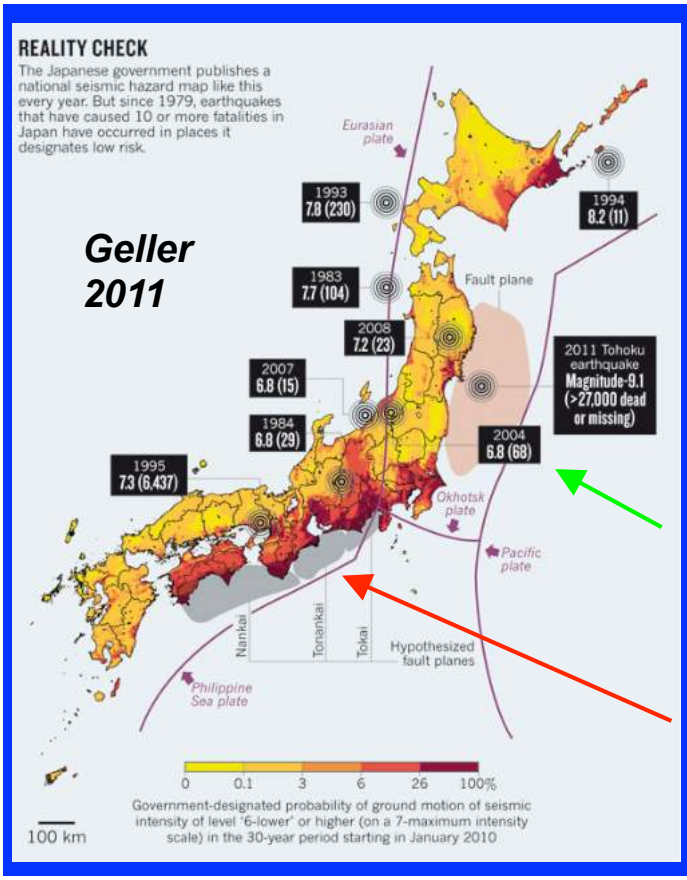
- ***assess*** **the hazard - how often dangerous events happen & how large they will be**
- ***mitigate*** **or reduce the risk - the resulting losses.**

Despite steady advances in hazard science & engineering

Often nature surprises us, when an earthquake, hurricane, or flood is bigger or has greater effects than expected from hazard assessments.

In other cases, nature outsmarts us, doing great damage despite expensive mitigation measures, or making us divert resources to address a minor hazard.

Tohoku, Japan 3/2011 M 9.1



Hazard assessment failed

2010 map predicts probability of strong shaking in next 30 years

But: 2011 M 9.1 Tohoku, 1995 Kobe M 7.3 & others in areas mapped as low hazard

In contrast: map assumed high hazard in Tokai "gap"

In Japan, Seawall Offered a False Sense of Security

Ko Sasaki for The New York Times

A ship that was swept ashore in the tsunami of March 11, damaging part of a breakwater, seen Wednesday in Kamaishi, Japan, 50 miles south of Taro. More Photos »

By NORIMITSU ONISHI
Published: March 31, 2011

TARO, Japan — So unshakable was this town's faith in its sea wall and its ability to save residents from any tsunami that some rushed toward it after a 9.0-magnitude earthquake struck off the coast of northeast Japan on the afternoon of March 11.

NY Times 3/31/2011

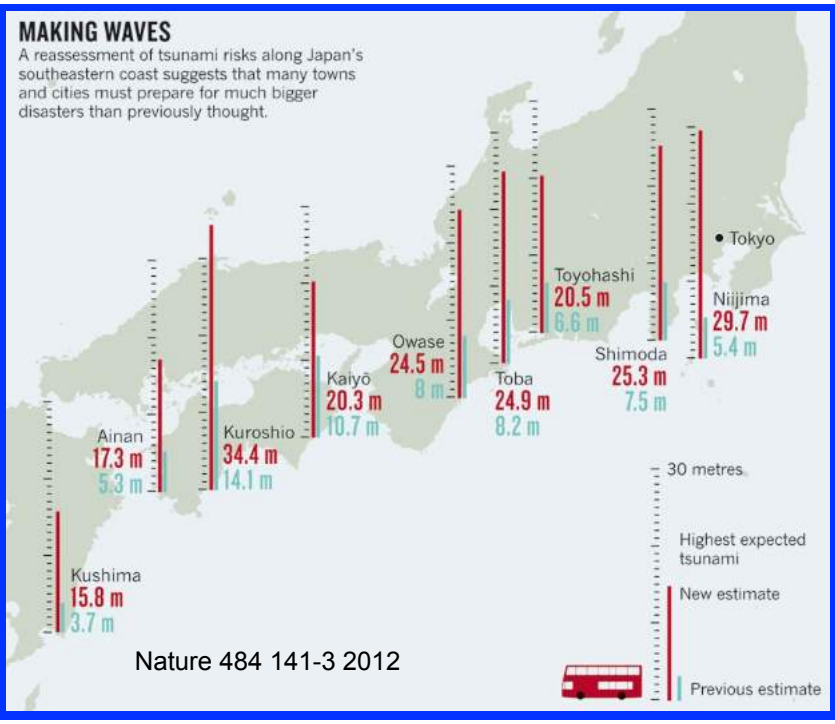
Mitigation failed

Expensive seawalls - longer than Great Wall of China -proved ineffective

Tsunami overtopped 10m high sea walls, causing more than 15,000 deaths and $210 billion damage.

Tsunami simulations scare Japan

Updated risk assessment warns country to prepare for much larger earthquakes and waves.



Nature 484 141-3 2012

PAN 1.3

INTERNATIONAL | 4/02/2012 @ 12:13PM | 6,642 views

BTW, Get Ready for a 34 Meter Tsunami

Forbes

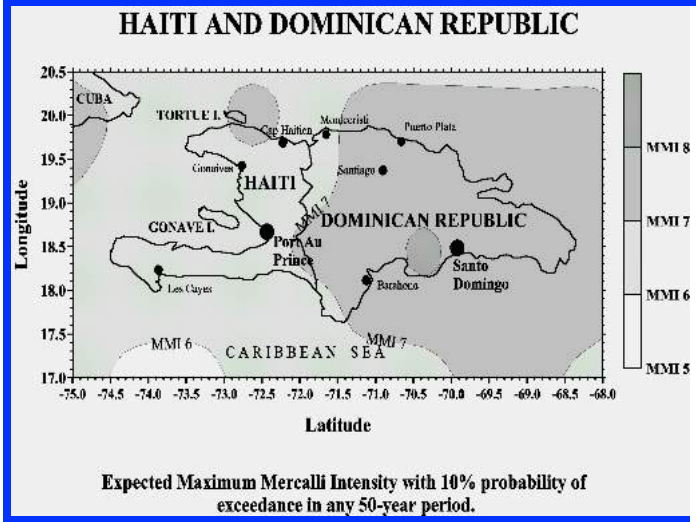
The policy question, in the words of Japanese economist H. Hori, is

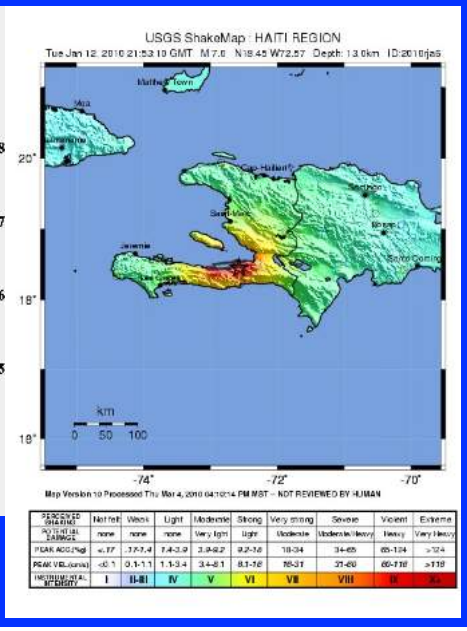
"What should we do in face of uncertainty? Some say we should spend our resources on present problems instead of wasting them on things whose results are uncertain. Others say we should prepare for future unknown disasters precisely because they are uncertain."

CQ: What do you think?

2001 hazard map

2010 M7 earthquake shaking much greater than predicted for next 500 years

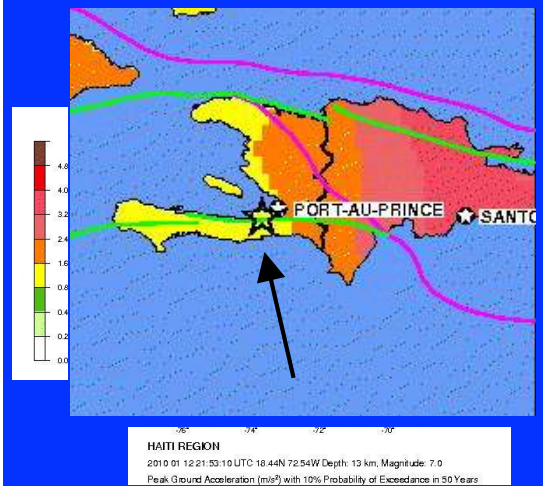




http://www.oas.org/cdmp/document/seismap/haiti_dr.htm

New maps made after a large earthquake that earlier maps missed

Before 2010 Haiti M7 ***After 2010 Haiti M7***



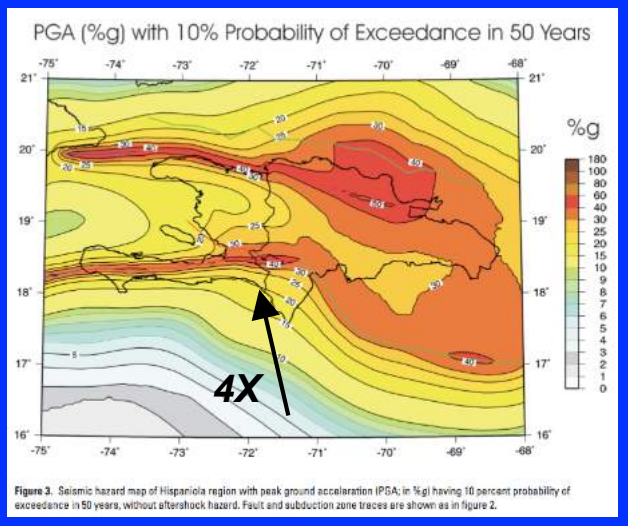
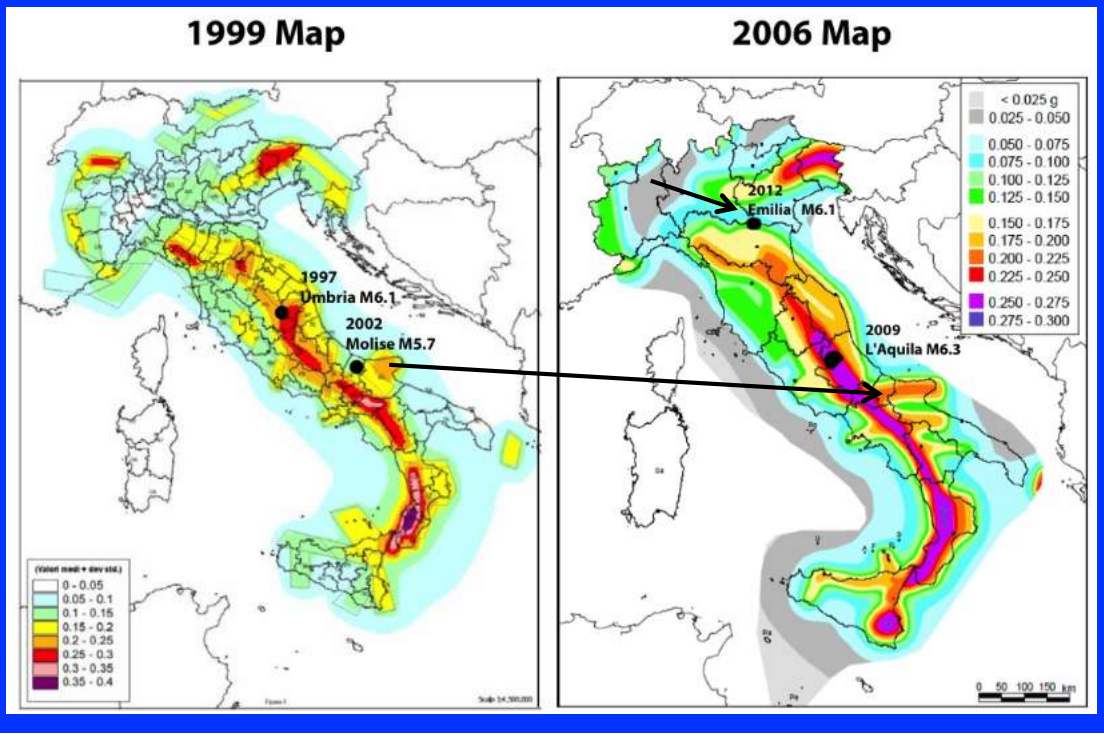


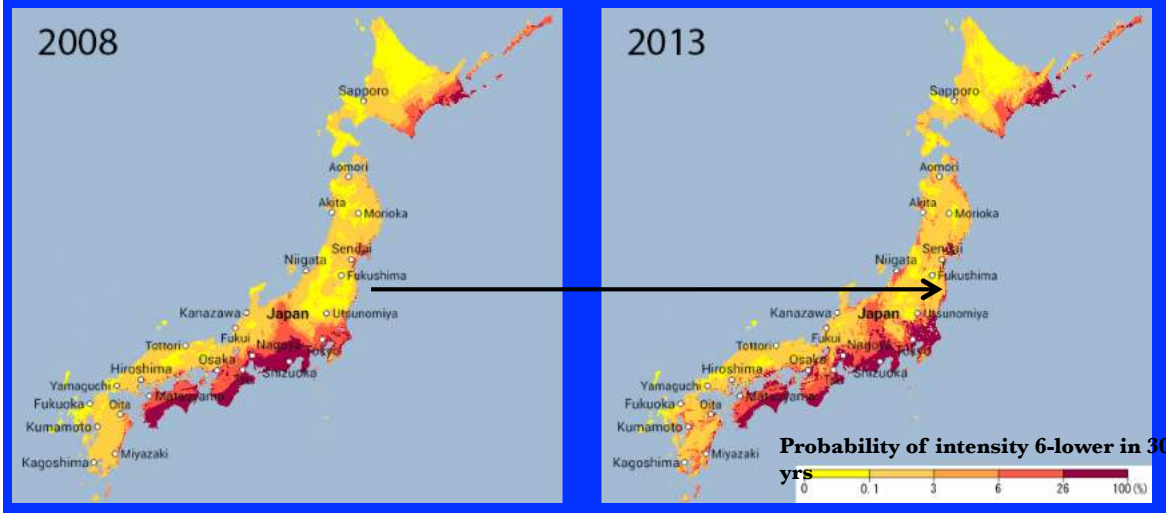
Figure 3. Seismic hazard map of Hispaniola region with peak ground acceleration (PGA; in %g) having 10 percent probability of exceedance in 50 years, without aftershock hazard. Fault and subduction zone traces are shown as in figure 2.

Frankel et al, 2010

Italian maps, which predicted the expected shaking in the next 500 years, require updating within a decade.



Japanese maps required updating within a decade.



http://www.j-shis.bosai.go.jp/map/?lang=en

When & what to change?

Fermi estimation: hazards and risks

In dealing with complicated questions with large uncertainties, critical thinking is important. Often, the challenge is to get a sense of about how large quantities are.

A good approach is to consider the order of magnitudes involved. This process is sometimes called "Fermi estimation" after Nobel Prize winning physicist Enrico Fermi, who used to ask students on qualifying exams questions like "How many piano tuners are in Chicago?"

CQ:

About much do Americans spend each year on Halloween?

Estimate answers using only orders of magnitude

Students have useful experienc e

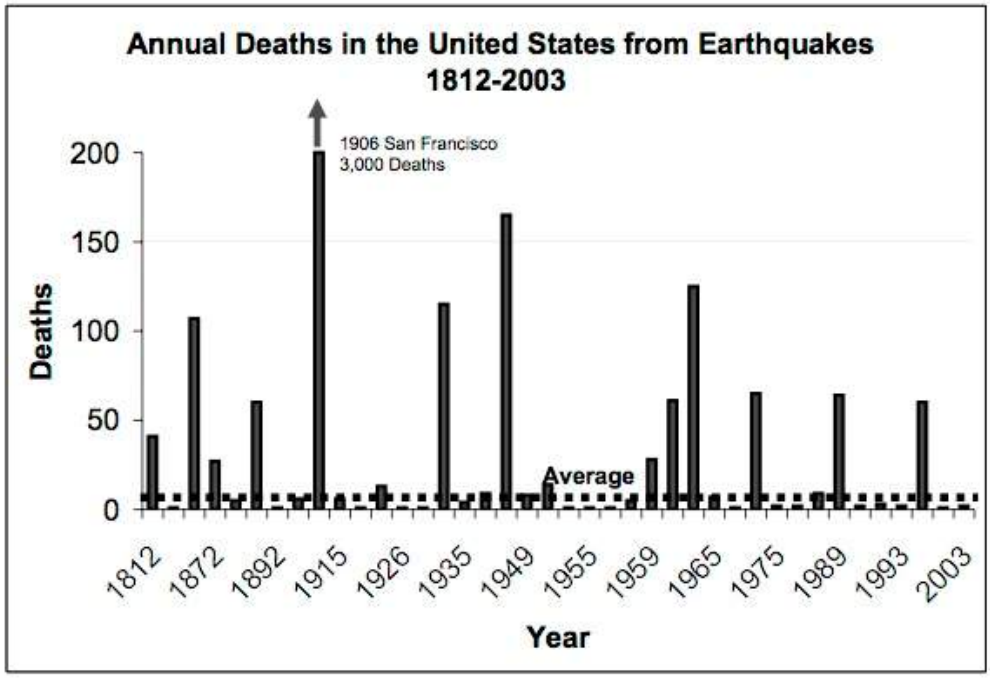
CQ

Estimate the order of magnitude - 1, 10, 100, or 1000 - of the number of deaths per year in the U.S. caused by bears, sharks, bees, snakes, deer, horses, and dogs.

A good way is to put them in the relative order you expect, and then try to estimate numerical values.





PAN 1.7

US Natural hazards

- Earthquakes aren't a major cause of deaths in the U.S.

- Severe weather is about 25 times more dangerous than earthquakes.

-Earthquakes rank at the level of in-line skating or football, and severe weather is at the level of bicycle accidents.

- Both are major causes of property damage

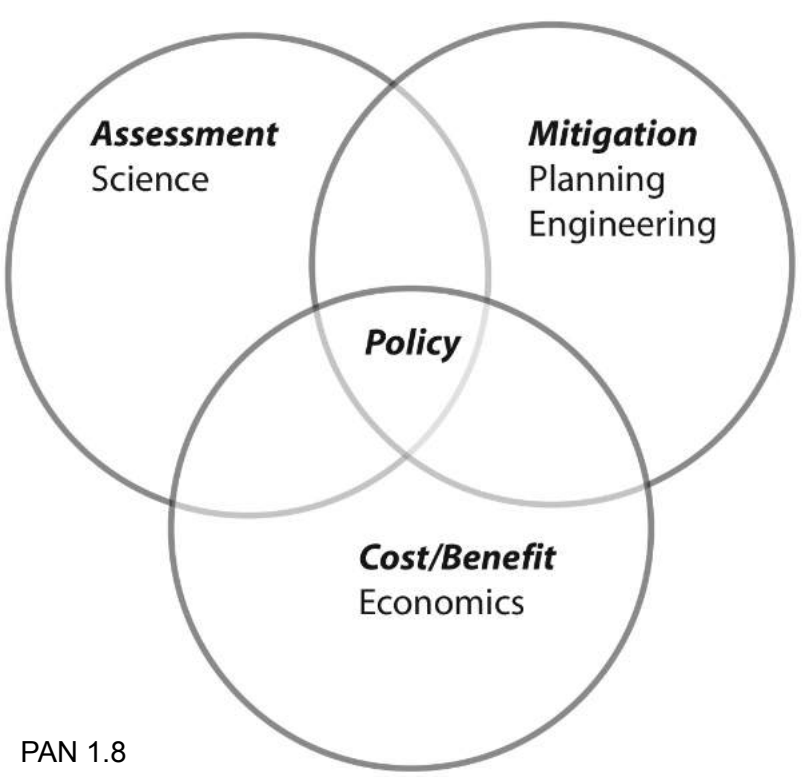
Lecture 1 27

PAN T1.1

Table 1.2-3. Some causes of death in the United States, 1996.

Heart Attack	733,834
Cancer	544,278
Stroke	160,431
Lung disease	106,143
Pneumonia/Influenza	82,579
Diabetes	61,559
Motor vehicle accidents	43,300
AIDS	32,655
Suicide	30,862
Liver disease/Cirrhosis	25,135
Kidney disease	24,391
Alzheimer's	21,166
Homicide	20,738
Falling	14,100
Poison	10,400
Drowning	3,900
Fires	3,200
Suffocation	3,000
Bicycle accidents	695
Severe Weather[1]	514
In-line skating[2]	25
Football[2]	18
Skateboards[2]	10
Earthquakes (1811-1983)[3]	9
Earthquakes (1984-1998)	9

[1]From the National Weather Service (property loss due to severe weather is $10-15 B/year, comparable to the Northridge earthquake, and individual hurricanes can go up to $25 B.



PAN 1.8

Lecture 1 28

CQ: If you had an additional $75 billion worldwide (about 15% of global aid spending), how would you spend it to best improve public health & safety?

Of the options, where does natural hazard mitigation rank? What would you do?

1. Nutrition supplements
2. Malaria treatment
3. Childhood immunization
4. Deworming school children
5. Tuberculosis treatment
6. Research to enhance crop yields
7. ***Natural hazard warning systems***
8. Improving surgery
9. Hepatitis B immunization
10. Providing low cost heart attack drugs

CQ: Do you wear a helmet while bicycle riding? Why or why not?

2: When Nature Won

July 5, 2012

NY Times

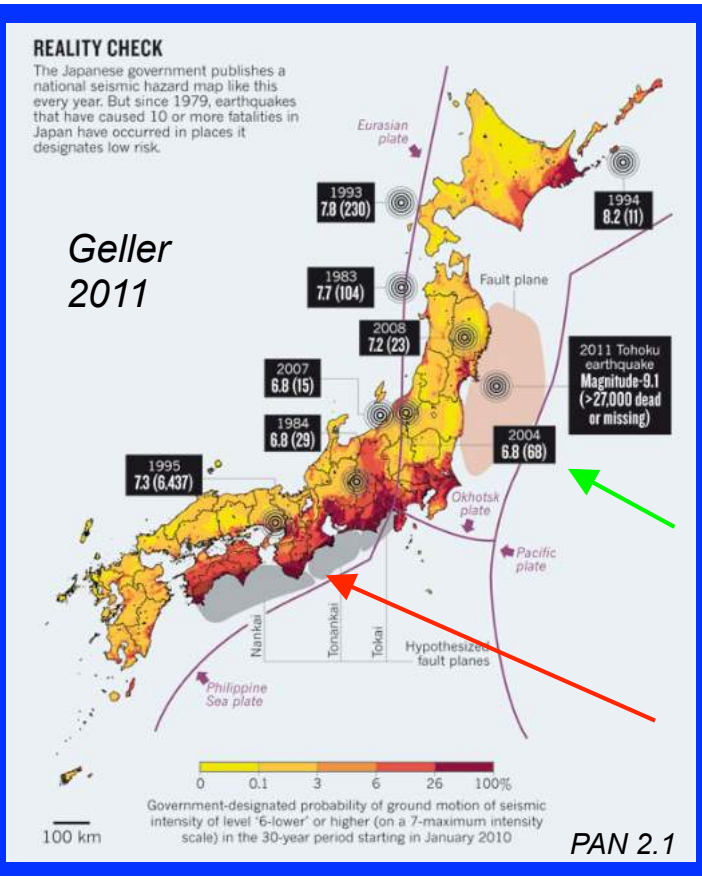
Inquiry Declares Fukushima Crisis a Man-Made Disaster

By HIROKO TABUCHI

TOKYO — The nuclear accident at Fukushima was a preventable disaster rooted in government-industry collusion and the worst conformist conventions of Japanese culture, a parliamentary inquiry concluded Thursday.

The report, released by the Fukushima Nuclear Accident Independent Investigation Commission, challenged some of the main story lines that the government and the operator of the Fukushima Daiichi Nuclear Power Plant have put forward. Most notably, the report said the plant's crucial cooling systems might have been damaged in the earthquake on March 11, 2011, not only in the ensuing tsunami. That possibility raises doubts about the safety of all the quake-prone country's nuclear plants just as they begin to restart after a pause ordered in the wake of the Fukushima crisis.

"It was a profoundly man-made disaster — that could and should have been foreseen and prevented," said Kiyoshi Kurokawa, the commission's chairman, in the report's



Geller 2011

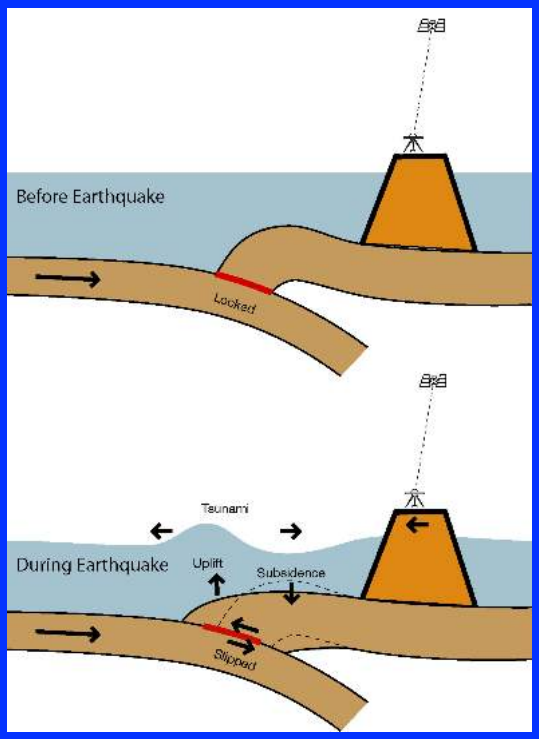
PAN 2.1

2010 map predicts probability of strong shaking in next 30 years

But: 2011 M 9.1 Tohoku, 1995 Kobe M 7.3 & others in areas mapped as low hazard

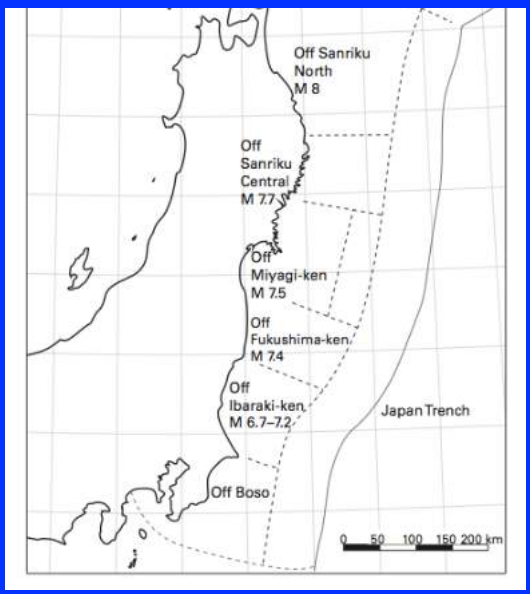
In contrast: map assumed high hazard in Tokai "gap"

Earthquake cycle on locked subduction zone



PAN 2.2

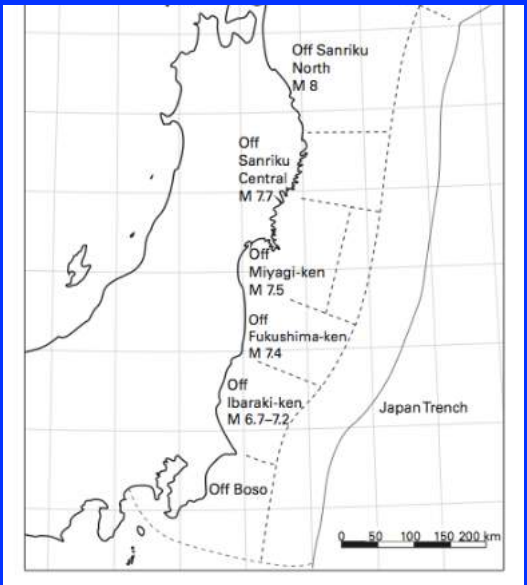
Hazard model divided trench into segments



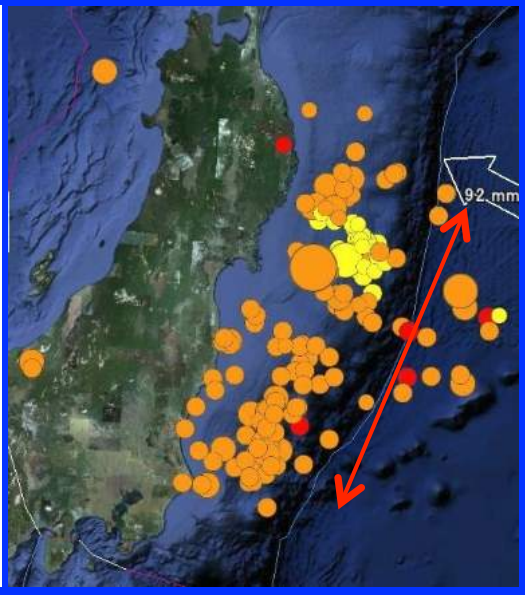
These were assumed to break individually in future earthquakes

Expected Earthquake Sources
50 to 150 km segments
M7.5 to 8.2
(Headquarters for Earthquake Research Promotion)

Giant earthquake broke many segments



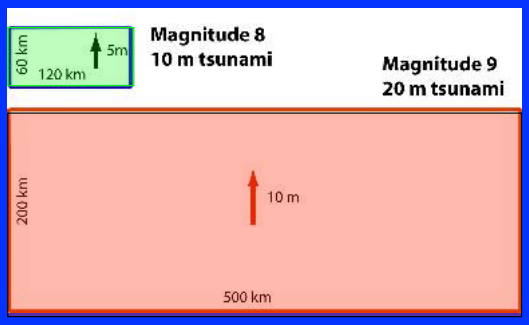
Expected Earthquake Sources
50 to 150 km segment
M 6.7 to M 8
(Headquarters for Earthquake Research Promotion)



2011 Tohoku Earthquake
450 km long fault, M 9.1
(Aftershock map from USGS)

PAN 2.3

Planning assumed maximum magnitude 8 Seawalls 5-10 m high



Stein & Okal, 2011

Tsunami runup approximately twice fault slip (Plafker, Okal & Synolakis 2004)

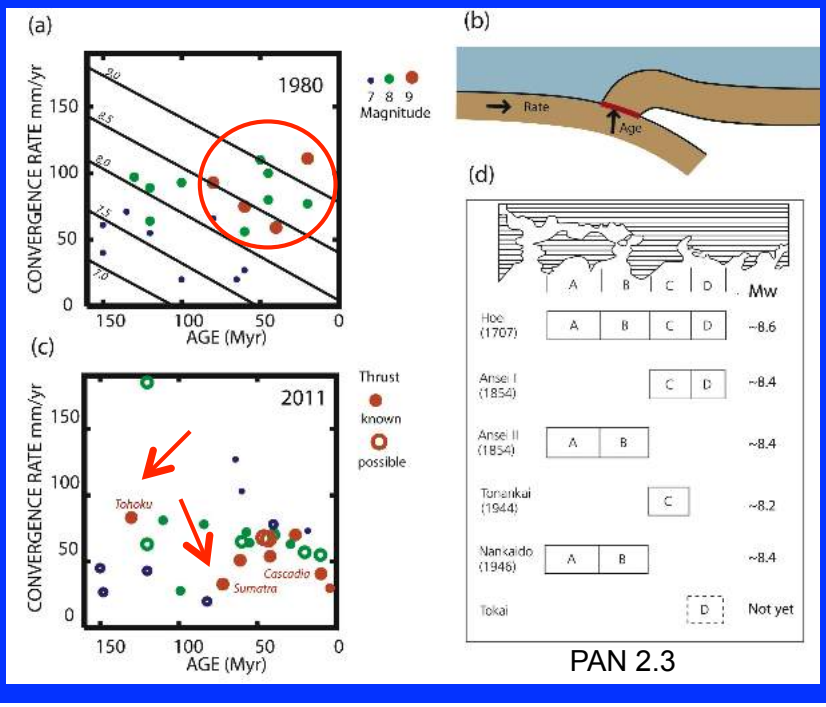
M9 generates much larger tsunami

NYT

CNN

PAN 2.3

Assumed lack of M9s in record seemed consistent with model that M9s only occur where lithosphere younger than 80 Myr subducts faster than 50 mm/yr (Ruff and Kanamori, 1980)

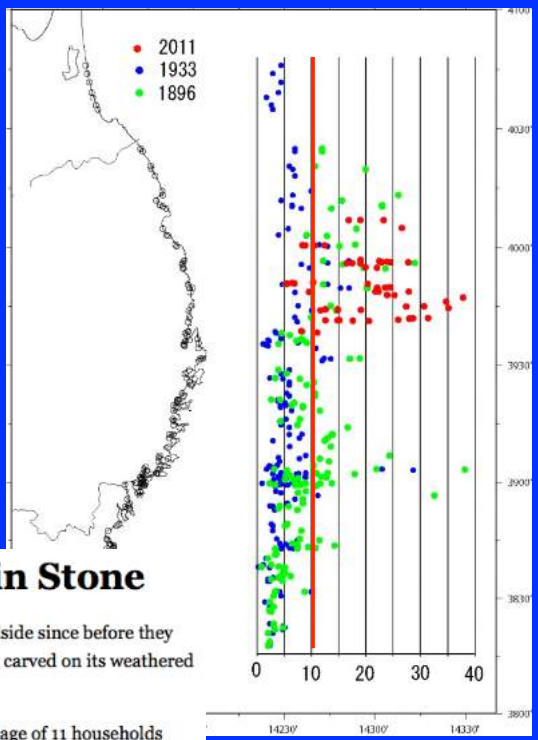


PAN 2.3

Disproved by Sumatra 2004 M9.3 and dataset reanalysis (Stein & Okal, 2007)

Short record at most SZs didn't include larger multisegment ruptures

Didn't consider historical record of large tsunamis



Tsunami Warnings, Written in Stone

By MARTIN FACKLER

ANEYOSHI, Japan — The stone tablet has stood on this forested hillside since before they were born, but the villagers have faithfully obeyed the stark warning carved on its weathered face: "Do not build your homes below this point!"

Residents say this injunction from their ancestors kept their tiny village of 11 households safely out of reach of the deadly tsunami last month that wiped out hundreds of miles of Japanese coast and rose to record heights near here. The waves stopped just 300 feet below the stone.

NYT 4/20/11

In Japan, Seawall Offered a False Sense of Security

Ko Sasaki for The New York Times

A ship that was swept ashore in the tsunami of March 11, damaging part of a breakwater, seen Wednesday in Kamaishi, Japan, 50 miles south of Taro. More Photos »

By NORIMITSU ONISHI
Published: March 31, 2011

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RECOMMEND
TWITTER
LINKEDIN
E-MAIL

NY Times 3/31/2011

Mitigation failed

Expensive seawalls - longer than Great Wall of China -proved ineffective

Tsunami overtopped 10m high sea walls, causing more than 15,000 deaths and $210 billion damage.

CQ: What caused the disaster? How could it have been avoided?

June 24, 2011

‘Safety Myth’ Left Japan Ripe for Nuclear Crisis

Over several decades, Japan’s nuclear establishment has devoted vast resources to persuade the Japanese public of the safety and necessity of nuclear power. Plant operators built lavish, fantasy-filled public relations buildings that became tourist attractions. Bureaucrats spun elaborate advertising campaigns through a multitude of organizations established solely to advertise the safety of nuclear plants. Politicians pushed through the adoption of government-mandated school textbooks with friendly views of nuclear power.

The result was the widespread adoption of the belief — called the “safety myth” — that Japan’s nuclear power plants were absolutely safe. Japan single-mindedly pursued nuclear power even as Western nations distanced themselves from it.

June 24, 2011

‘Safety Myth’ Left Japan Ripe for Nuclear Crisis

"If you walk across this country, you’ll find 54 nuclear reactors
School textbooks and commercials told us they were safe.
It was always a lie, it’s been exposed after all
It was really a lie that nuclear power is safe.”

K. Saito

THE NATIONAL DIET OF JAPAN
FUKUSHIMA NUCLEAR ACCIDENT INDEPENDENT INVESTIGATION COMMISSION
(NAIIC)

"the subsequent accident at the Fukushima Daiichi nuclear power plant cannot be regarded as a natural disaster. It was a profoundly man-made disaster — that could and should have been foreseen and prevented. Our report catalogues a multitude of errors and willful negligence that left the Fukushima plant unprepared for the events of March 11. ...

What must be admitted – very painfully – is this was a disaster 'Made in Japan'... Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience, our reluctance to question authority, our devotion to 'sticking with the program', our groupism, and our insularity.

THE NATIONAL DIET OF JAPAN
FUKUSHIMA NUCLEAR ACCIDENT INDEPENDENT INVESTIGATION COMMISSION
(NAIIC)

"The accident was the result of collusion between the government, the regulators and TEPCO, and the lack of governance by said parties. They effectively betrayed the nation's right to be safe from nuclear accidents. Therefore, we conclude that the accident was clearly "manmade." We believe that the root causes were the organizational and regulatory systems that supported faulty rationales for decisions and actions, rather than issues relating to the competency of any specific individual.

Replacing people or changing the names of institutions will not solve the problems. Unless these root causes are resolved, preventive measures against future similar accidents will never be complete. "

THE NATIONAL DIET OF JAPAN
FUKUSHIMA NUCLEAR ACCIDENT INDEPENDENT INVESTIGATION COMMISSION
(NAIIC)

CQ

Are these problems unique to Japan?

Why or why not?

What are examples?

Post-Tohoku debate: why do hazard maps sometimes fail?

SEISMOLOGY

Seismic Crystal Ball Proving Mostly Cloudy Around the World

Failing at quake prediction, seismologists tried making fuzzier forecasts, but Japan's megaquake is only the latest reminder of the method's shortcomings

20 MAY 2011 VOL 332 SCIENCE www.sciencemag.org

Blindsided by Ferocity Unleashed by a Fault

NYT 3/21/11

By KENNETH CHANG

On a map of Japan that shows seismic hazards, the area around the prefecture of Fukushima is colored in green, signifying a fairly low risk, and yellow, denoting a fairly high one.

But since Japan sits on the collision of several tectonic plates, almost all of the country lies in an earthquake-risk zone. Most scientists expected the next whopper to strike the higher-risk areas southwest of Fukushima, which are marked in orange and red.

One explanation

Hazard assessment is fundamentally sound, big events are rare but expected "black swans"

If so, everything's fine.

Implication: no need to change anything!

Japan Revives a Sea Barrier That Failed to Hold

Ko Sasaki for The New York Ti

Japan's Failed Breakwaters: Nori Onishi reports on the failure of breakwater systems in protecting against large waves along Japan's coastline.

By NORIMITSU ONISHI
Published: November 2, 2011

KAMAISHI, Japan — After three decades and nearly $1.6 billion, work on Kamaishi's great tsunami breakwater was completed three years ago. A mile long, 207 feet deep and jutting nearly 20 feet above the water, the quake-resistant structure made it into the Guinness World Records last year and rekindled fading hopes of revival in this

RECOMMEND
TWITTER
LINKEDIN
COMMENTS (27)

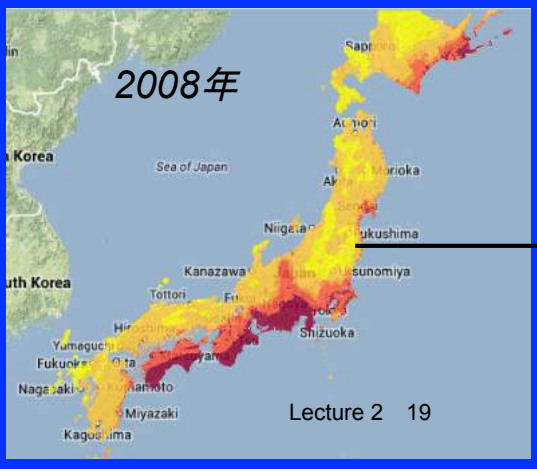
NY Times 11/2/2011

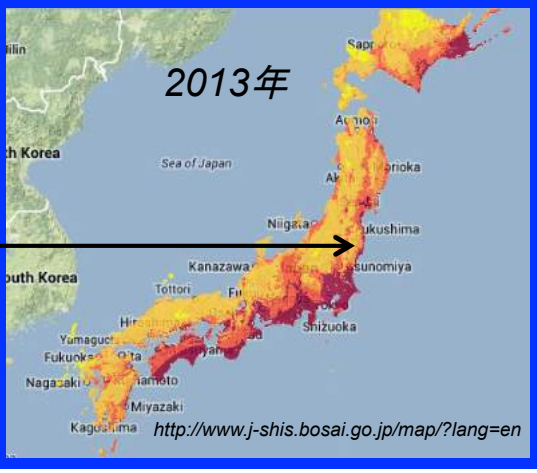
Too expensive to rebuild for 2011 sized tsunami

>100 $B for new defences only slightly higher than old ones

"In 30 years there might be nothing left there but fancy breakwaters and empty houses."

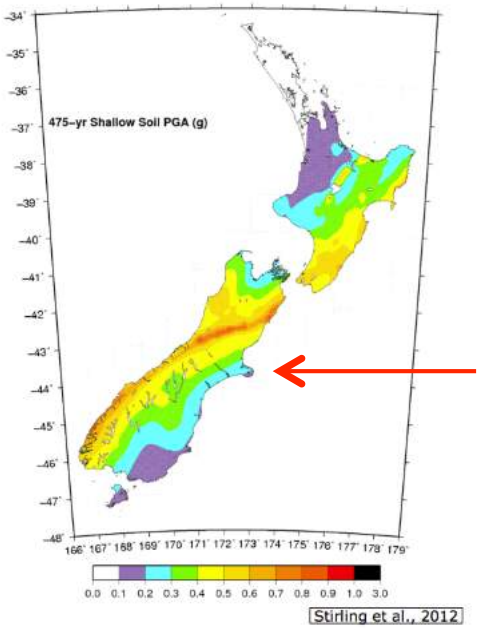
However, if everything's fine, maps should not be remade after big events in mapped low-hazard areas





Lecture 2 19

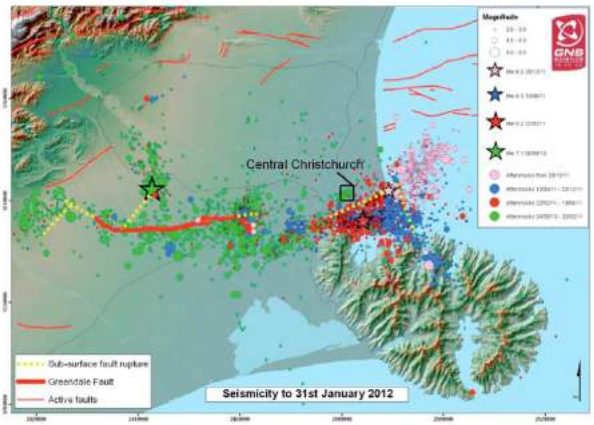
http://www.j-shis.bosai.go.jp/map/?lang=en



Stirling et al., 2012

Darfield earthquake (*M* 7.1)
Christchurch earthquake (*M* 6.3)

Both generated by hidden faults.



Shortly after earthquakes, calm consideration of costs & benefits returns

nzherald.co.nz *March 4, 2011*

Editorial: Quake work needs limits and balance

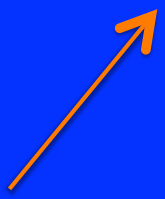
Mandatory quake-proofing of all New Zealand buildings would, however, be hugely expensive. Proponents say this would be worthwhile if even one life is saved, let alone the hundreds lost in Christchurch. But the need for preparedness must be balanced so as not to be out of all proportion to the degree of risk.

In the aftermath of such an event, there can be a heightened sense of alarm, which triggers a desire to do whatever is required to prevent a repeat, no matter how extreme or costly. A lesson of Christchurch Cathedral is that whatever the precautions, a set of circumstances can render them ineffective.

On balance, therefore, it seems reasonable to retain the status quo on older buildings, and insist on earthquake strengthening only when they are being modified.

CQ: How do you respond to this? Do you agree or disagree, and why or why not?

3: Nature Bats Last

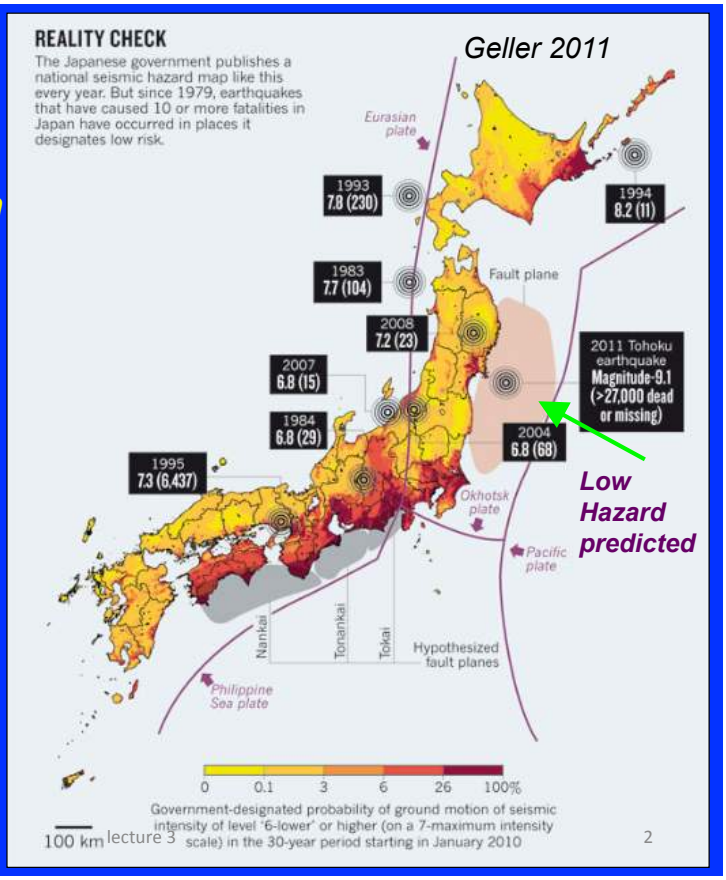


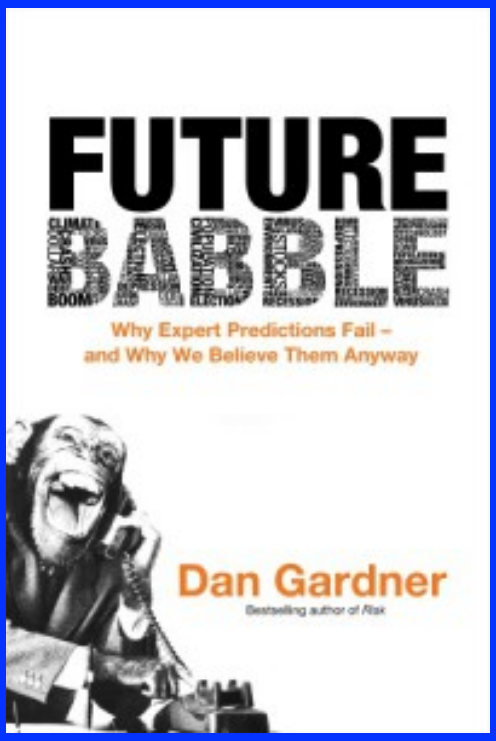
In Shakespeare's *Henry IV*,

Glendower says *"I can call spirits from the vasty deep"*

Hotspur replies *"Why, so can I, or so can any man; but will they come when you do call for them?"*

Similarly, we make detailed hazard assessments, but often nature acts differently

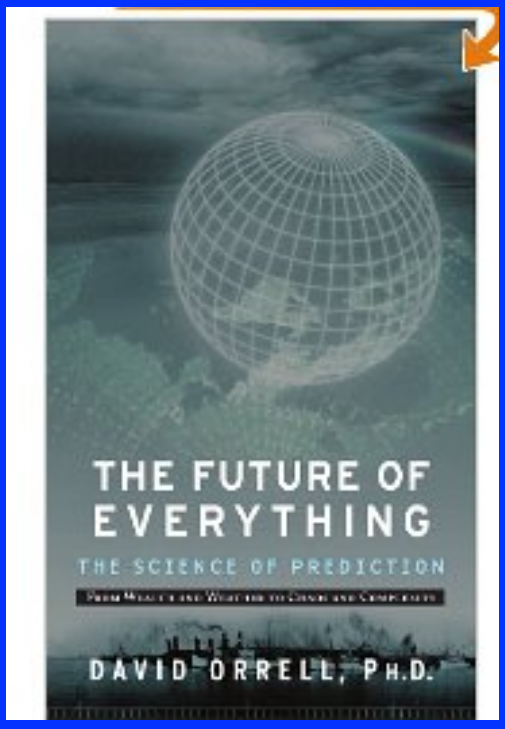




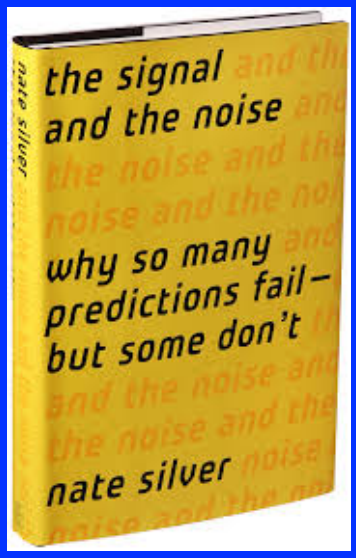
"They're wrong a lot, these experts.

History is littered with failed predictions.

Whole books can be filled with them. Many have."

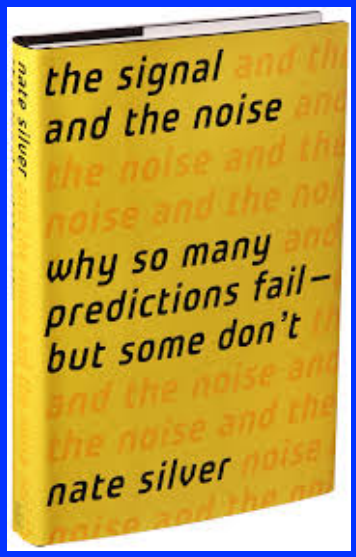


"While scientists have had great success in squinting through microscopes at the smallest forms of life, or smashing atoms together in giant particle accelerators, or using telescopes to look forward in space and backwards in time at the formation of distant galaxies, their visions into the future have been blurred and murky. As a result, projections tend to go astray."



"The most calamitous failures of prediction usually have a lot in common. We focus on the signals that tell a story about the world as we would like it to be, not how it really is...

We make approximations and assumptions about the world that are much cruder than we realize. We abhor uncertainty, even when it is an irreducible part of the problem we are trying to solve."



"When you make a prediction that goes so badly, you have a choice of how to explain it. One path is to blame external circumstances - what we might think of as bad luck. Sometimes this is a reasonable choice or even the correct one.

When the National Weather Service says there is a 90% chance of clear skies, but it rains instead and spoils your golf outing, you can't really blame them. Decades of historical data shows that when the Weather Service says there is a 1 in ten chance of rain, it really does rain about 10% of the time.

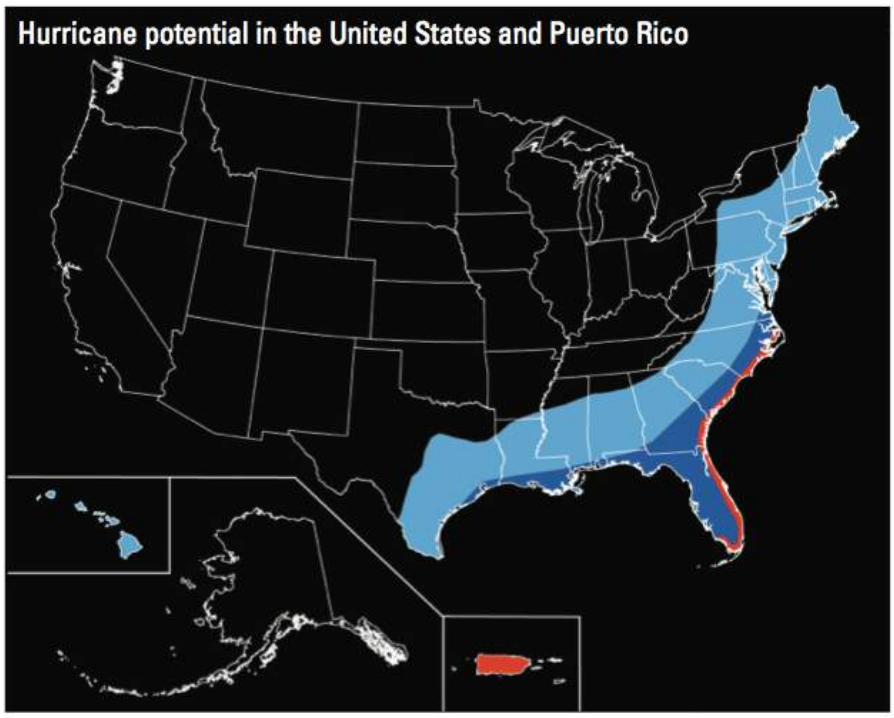
This explanation becomes less credible when the forecaster does not have a history of successful predictions and when the magnitude of his error is larger. In these cases, it is more likely that the fault lies with the forecaster's model of the world and not with the world itself."

hours	***tsunami warning***
days	***hurricane forecast***
months	***volcano prediction***
years	***volcano forecast***
centuries	***earthquake hazard forecast***

success

PAN 3.5

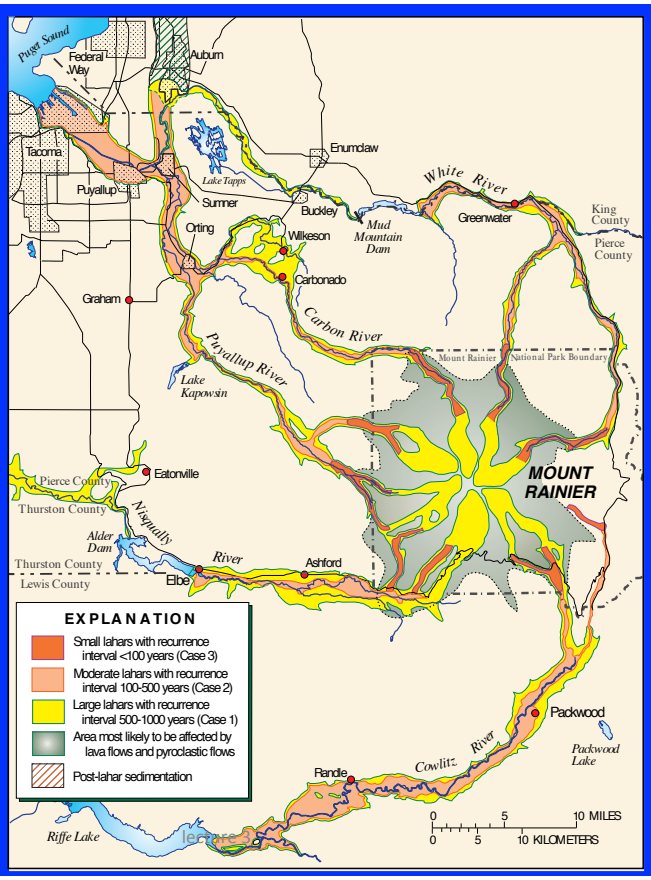
PAN 3.1



The number of hurricanes expected to occur during a 100-year period based on historical data—light blue area, 20 to 40; dark blue area, 40 to 60; red area, more than 60. Map not to scale. Source: the National Atlas and the USGS

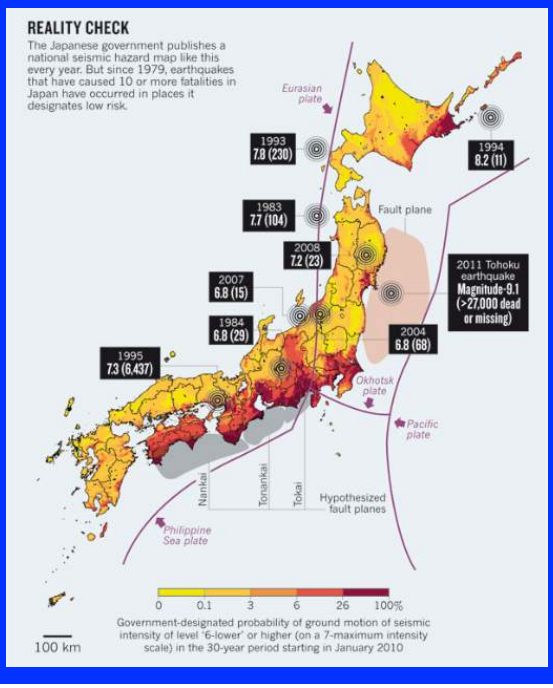
PAN 3.2: Volcanic hazard map for the Mount Rainier, Washington area. (USGS)

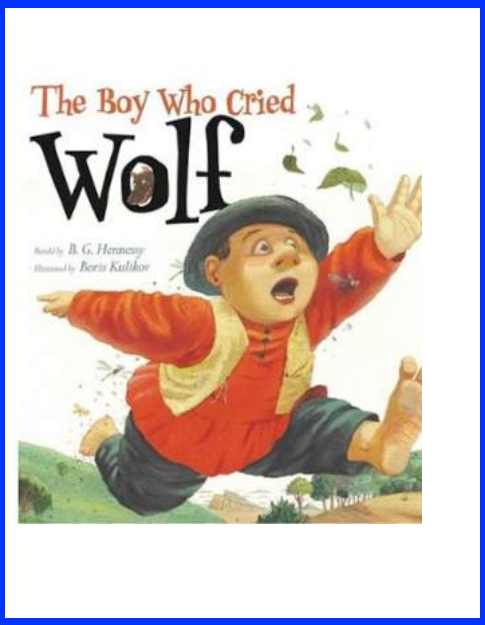
PAN 3.2



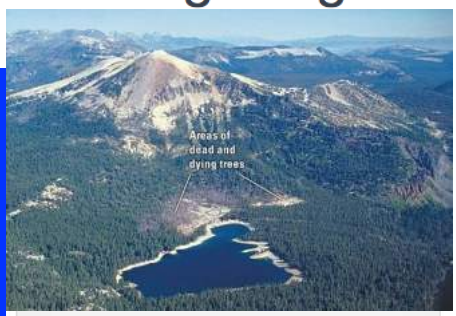
The area around Mt. St. Helens, Washington, was evacuated before the giant eruption of May 1980 (Figure 3.4), reducing the loss of life to only 60 people, including a geologist studying the volcano and citizens who refused to leave.

A *false negative* is an unpredicted or underpredicted hazard, which can cause loss of life and property. A *false positive* is an overpredicted hazard, which can waste resources spent on excessive mitigation and cause businesses to locate elsewhere.





Perils of prediction: are scientists prepared to warn the public about geologic hazards?



Science News

6/15/91

The town of Mammoth Lakes doesn't look kindly on federal geologists. In this quiet ski-center community nestled at the foot of California's Sierra Nevada range, residents have even coined their own name for the U.S. Geological Survey.

They call it the U.S. Guessing Society.

The town's antipathy toward the USGS has stewed for almost a decade, ignited in 1982 by a series of federal announcements and media reports about a potential volcanic eruption, which residents blame for a subsequent nose dive in the local economy. Only recently has the local real estate market climbed back up to its pre-1982 level, they say.

The local economy collapsed, said Glenn Thompson, Mammoth Lakes' town manager. Housing prices fell 40 percent overnight. In the next few years, dozens of businesses closed, new shopping centers stood empty and townspeople left to seek jobs elsewhere. (NYT 9/11/90)

Santorini, Greece, Eruptions:

3 to 4 caldera eruptions in past 600 ka

Last caldera (Minoan) eruption
- ~1650 BC
- Likely from northern zone

Recent activity
- Over past 1000 yrs
- Small pyroclastic and phreatic eruptions dominated
- Forming Palea and Nea Kameni.

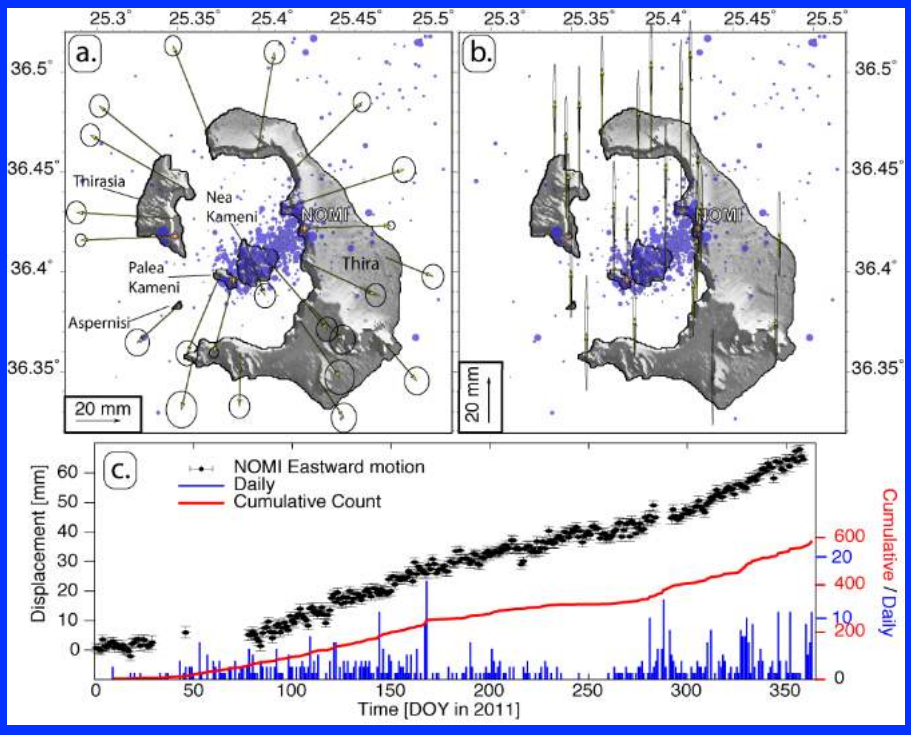
[Heiken and McCoy, 1984; Druitt *et al.*, 1989], from A. Newman

GPS surveys

2006, 2008, 2010

Photo from A. Newman, Georgia Tech

GPS & Seismicity show inflation



from A. Newman

CQ: Imagine that the inflation continues, and a volcano alert issued, depressing vacation home prices by 50%

Some friends of yours are getting together to buy the house shown, at a huge discount.

Would you participate? Why or why not?

Scientists defend warning after tsunami nonevent

The warning was ominous, its predictions dire: Oceanographers issued a bulletin telling Hawaii and other Pacific islands that a killer wave was heading their way with terrifying force and that "urgent action should be taken to protect lives and property."

But the devastating tidal surge predicted after Chile's magnitude 8.8-earthquake for areas far from the epicenter never materialized. And by Sunday, authorities had lifted the warning after waves half the predicted size tickled the shores of Hawaii and tourists once again jammed beaches and restaurants.

Was Hawaii's tsunami warning overblown?

01:45 PM

Share 4 Yahoo! Buzz Share E-mail Save

2/27/2010

City spends $330,000 responding to potential threat

Economic loss ?

What if weekday?

EOS Eos, Transactions, American Geophysical Union 46, 411, 2011

Forum

Interviews with survivors of Tohoku earthquake provide insights into fatality rate

Some coastal residents ignored the tsunami warning - which proved correct and actually underestimated the tsunami size - because of past false positives.

Researchers who interviewed residents noted that in the previous four years, sixteen warnings or alerts had issued for "small or even negligible tsunamis. These frequent warnings with overestimated tsunami height influenced the behavior of the residents."

As a result, new techniques are being introduced to give better real-time estimates of tsunami heights.

Traditional skepticism

"Only fools and charlatans predict earthquakes"
Charles Richter (1900-1985)

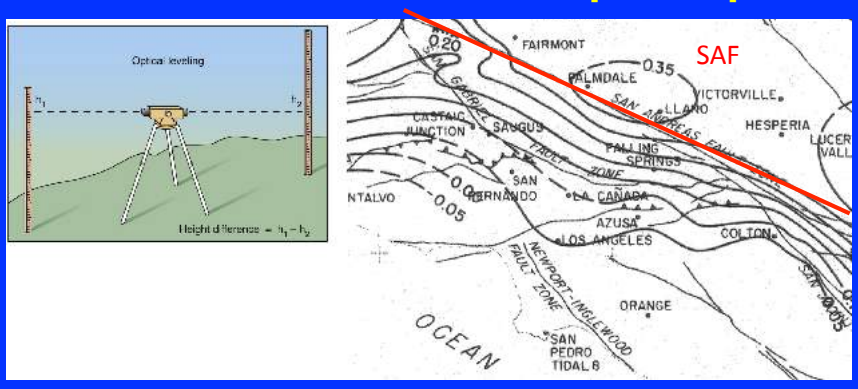
1970's optimism

Scientists will *"be able to predict earthquakes in five years."*
Louis Pakiser , U.S. Geological Survey, 1971

***"We have the technology to develop a reliable prediction system already in hand."* Alan Cranston, U.S. senator, 1973**

***"The age of earthquake prediction is upon us"* U.S. Geological Survey, 1975**

1975 PALMDALE BULGE – uplift reported



USGS director stated that *"a great earthquake" would occur "in the area ... possibly within the next decade"* that might cause up to 12,000 deaths, 48,000 serious injuries, 40,000 damaged buildings, and up to $25 billion in damage. California Seismic Safety Commission stated that *"the uplift should be considered a possible threat to public safety"* and urged immediate preparations…

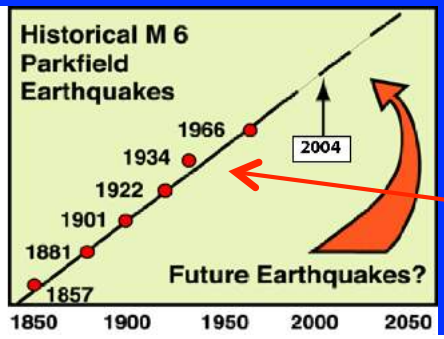
39 years later, nothing yet..

PARKFIELD, CALIFORNIA SEGMENT OF SAN ANDREAS

M 5-6 earthquakes about every 22 years: 1857, 1881, 1901, 1922, 1934, and 1966

In 1985, expected next in 1988; U.S. Geological Survey predicted 95% confidence by 1993

Occurred in 2004 (16 years late)



Discounting misfit of 1934 quake predicted higher confidence

RESEARCH NEWS

Parkfield Quakes Skip a Beat

Seismologists' first official earthquake forecast has failed, ushering in an era of heightened uncertainty and more modest ambitions

Science, 10/8//04

SEISMOLOGY

Parkfield Keeps Secrets After A Long-Awaited Quake

Last week's moderate-to-strong earthquake in central California has justified seismologists' belief that Parkfield (population 37) was the place to wait for a sizable quake they could study. "It's right in the very middle of our network," says geophysicist Malcolm Johnston of the U.S. Geological Survey (USGS) in Menlo Park, California, about the densest fault-monitoring system in the world. It cost more than $10 million over 20 years. "We got great stuff," says Johnston.

But they didn't get it entirely right. When seismologists began the Parkfield Earthquake Prediction Experiment in the 1980s, they expected to capture the next magnitude 6 in unprecedented detail within a few years. Instead, they had to wait 2 decades, a delay that casts additional doubt on models of predictable seismic behavior. And far from providing practical experience in the nascent science of short-term earthquake prediction, Parkfield 2004 seems to have given no warning that would lend hope to the field of short-term quake forecasting. All in all, Parkfield has driven home the point that even one of the world's best behaved fault segments can be pretty cantankerous.

"Parkfield is geophysics' Waterloo. If the earthquake comes without warnings of any kind, earthquakes are unpredictable and science is defeated. " (The Economist)

No precursors in seismicity (foreshocks), strainmeters, magnetometers, GPS, creepmeter

$30 million spent on "Porkfield" project

What's going wrong?

WHY CAN'T WE PREDICT EARTHQUAKES?

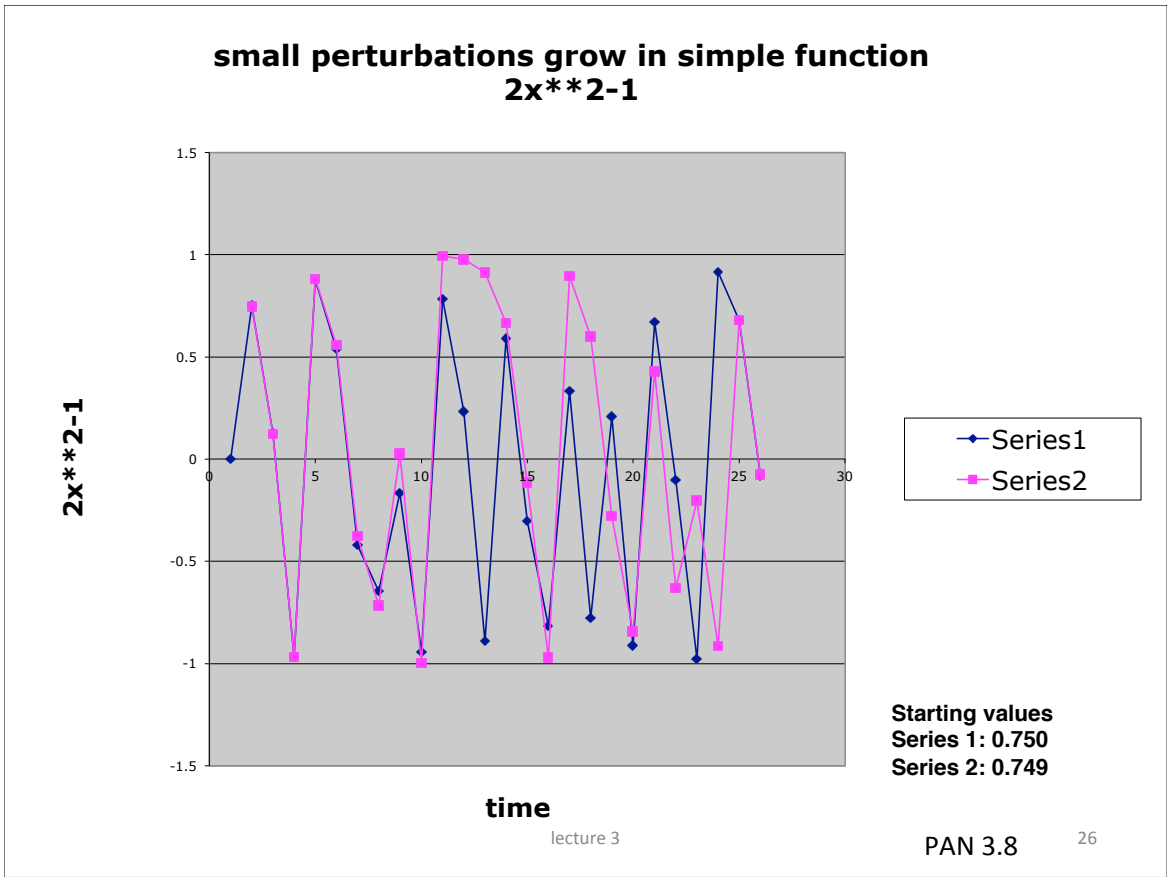
So far, no clear evidence for consistent changes in physical properties (precursors) before earthquakes.

Maybe lots of tiny earthquakes happen frequently, but only a few grow by random process to large earthquakes

In chaos theory, small perturbations can have unpredictable large effects - flap of a butterfly's wings in Brazil might set off a tornado in Texas

If there's nothing special about the tiny earthquakes that happen to grow into large ones, the time between large earthquakes is highly variable and nothing observable should occur before them.

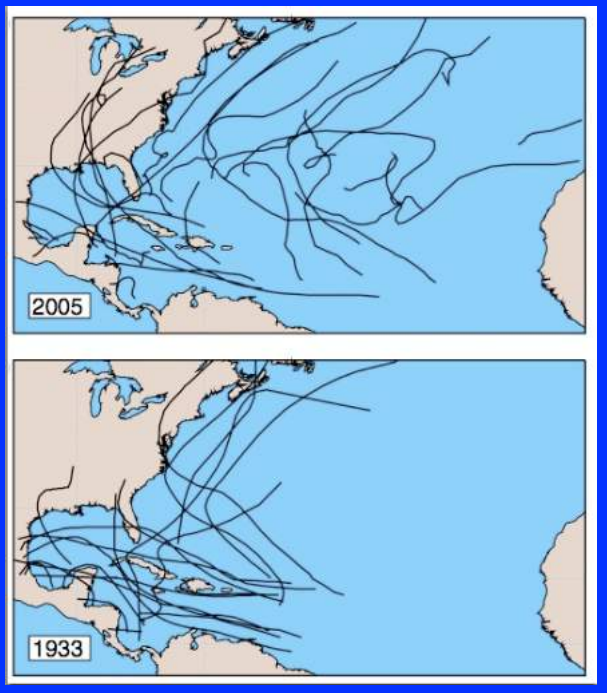
If so, earthquake prediction is either impossible or nearly so.



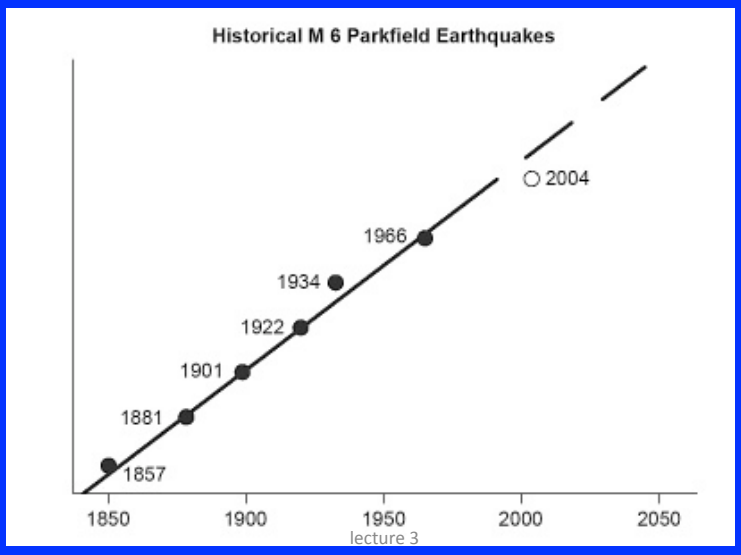
Insights from weather forecasting

Admit fundamental limits to how accurate forecasts can be.

If weather weren't chaotic, every year storms would form on the same date & follow the same tracks
(Lorenz, 1995)



CQ: How might you try to determine whether the fact that earthquakes near Parkfield occurred for a while about 22 years apart reflects an important aspect of the physics of this particular part of the San Andreas, or just an apparent pattern that arose by chance?



4: Uncertainty and Probability

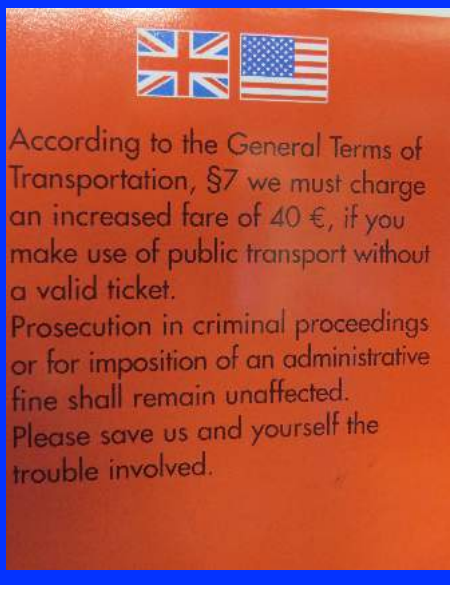
"The scientist has a lot of experience with ignorance and doubt and uncertainty, and this experience is of very great importance, I think.

When a scientist does not know the answer to a problem, he is ignorant. When he has a hunch as to what the result is, he is uncertain. And when he is pretty damn sure of what the result is going to be, he is still in some doubt.

We have found it of paramount importance that in order to progress, we must recognize our ignorance and leave room for doubt."

Richard Feynman, 1988

CQ: If you are caught riding the U-bahn without a ticket, you will be fined 40 Euros. What is the expected cost of getting caught? If a ticket costs 2 Euros, does it make sense to buy a ticket? Do you buy a ticket? Why or why not?



CQ:

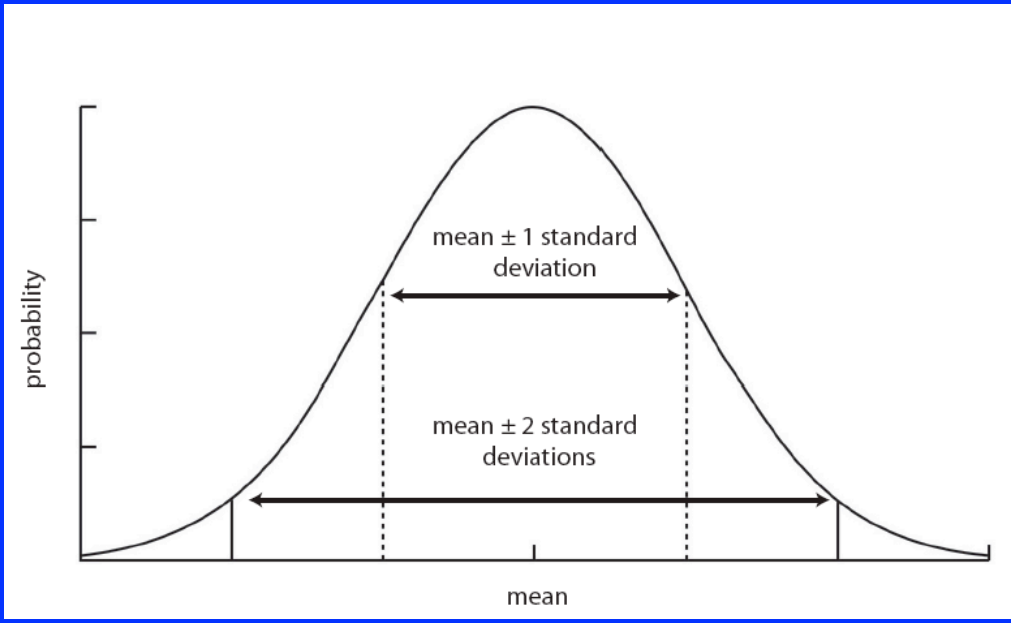
Flip a coin twice and record the outcome – did you get at least one head?

Combine all of class' tosses to see what fraction came up heads

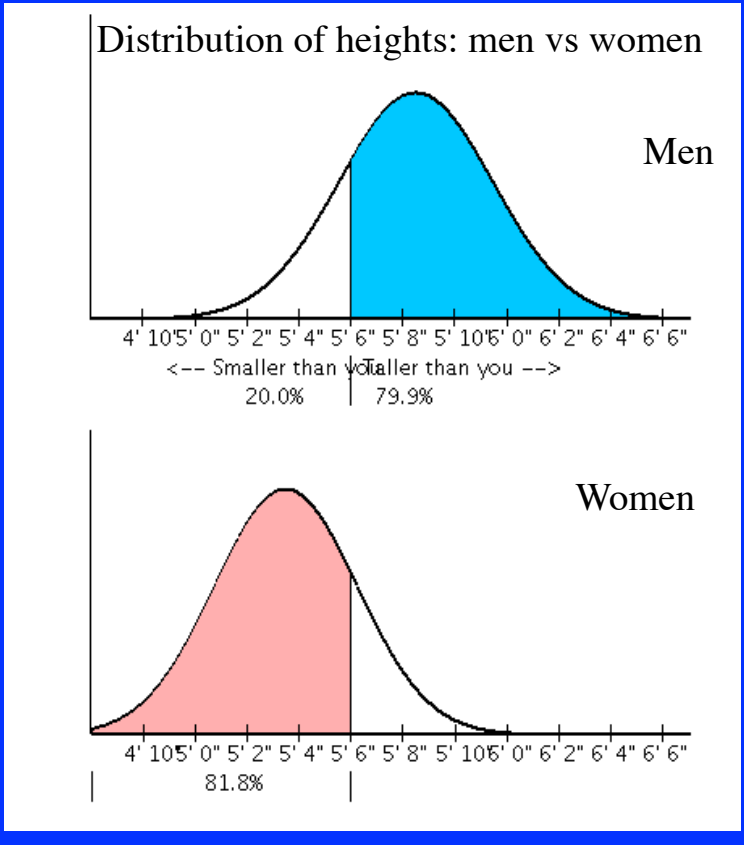
BBC 6 June 2013

Asked if he had not taken a risk building a business in the flood-prone inner city, Mr. Schacha shook his head. "The flood of a century is supposed to happen once in a lifetime," he said. "Not once every 10 years."

Gaussian distribution

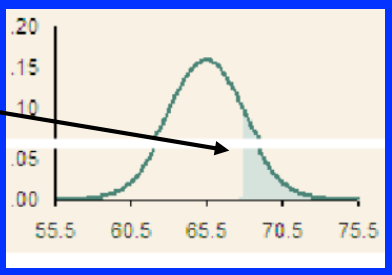


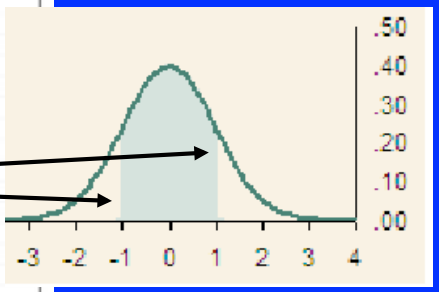
PAN 4.1: Probability of observing specific values from a Gaussian parent distribution.



EXCEL: normal distribution

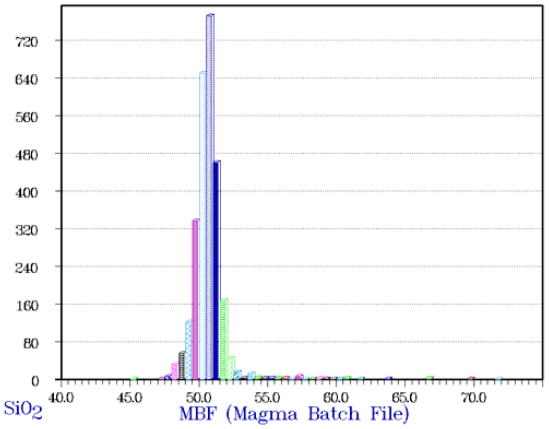
	A	B	C	D	E	F
1					CUMULATIVE DISTRIBUTION	
2					NORMDIST(x,mean,sdev)=prob	
3		x	mean	sdev	NORMDIST(B4,C4,D4,TRUE)	
4		66	65.5	2.5	0.58	
5						
6						
7					INVERSE OF CDF	
8					NORMINV(prob,mean,sdev)=x	
9		prob	mean	sdev	NORMINV(B10,C10,D10)	
10		0.58	65.5	2.5	66.0	
11						
12						
13					GET Z FROM X	
14					STANDARDIZE (x, mean,sdev)=z	
15		x	mean	sdev	STANDARDIZE(B16,C16,D16)	
16		66	65.5	2.5	0.20	
17						
18						
19					CDF FOR Z	
20					NORMSDIST(z)=prob	
21		z			NORMSDIST(B22)	
22		1			0.84	
23		-1			0.16	
24						
25						
26					z for given probability (inverse NORMSDIST)	
27					NORMSINV(prob)=z	
28		prob			NORMSINV(B28)	
29		0.25			-0.67	
30		0.75			0.67	





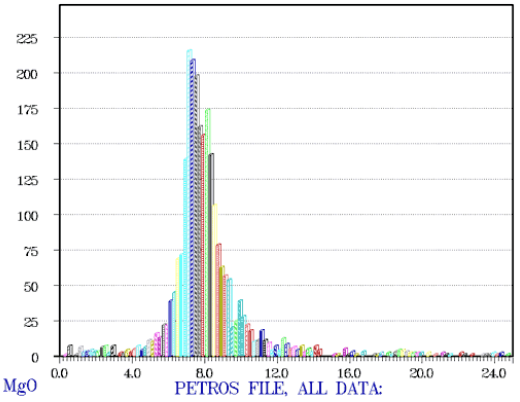
9

SMITHSONIAN INSTITUTION VOLCANIC



Oceanic crust variability

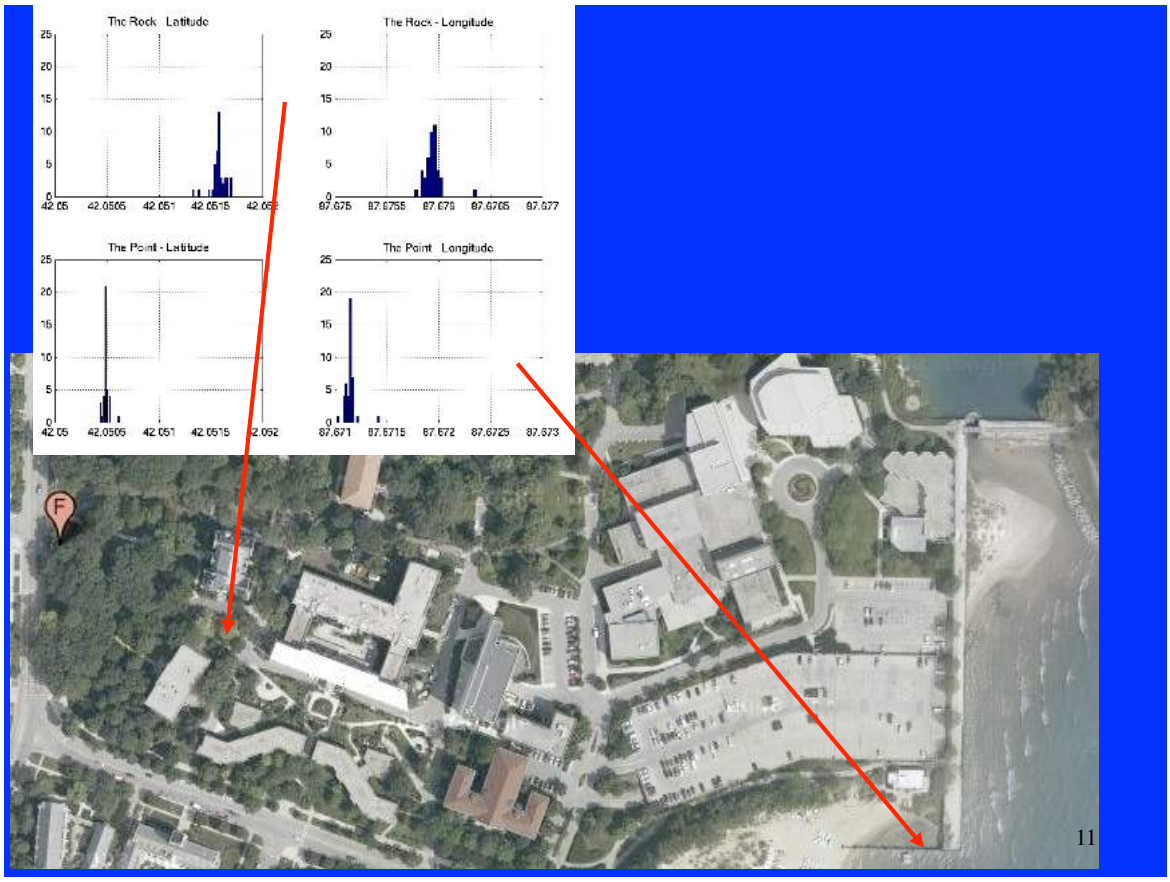
MAR BASALTS.



Basalt generally has a composition of 45-55 wt% SiO2, 2-6 wt% total alkalis, 0.5-2.0 wt% TiO2, 5-14 wt% FeO and 14 wt% or more Al2O3. Contents of CaO are commonly near 10 wt%, those of MgO commonly in the range 5 to 12 wt%.

http://www.geokem.com/earths_average_composition.html

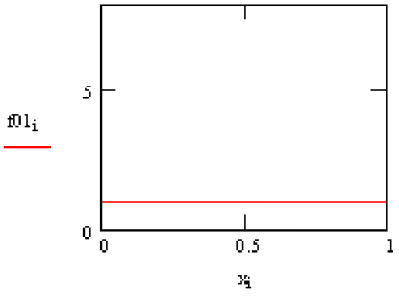
10



11

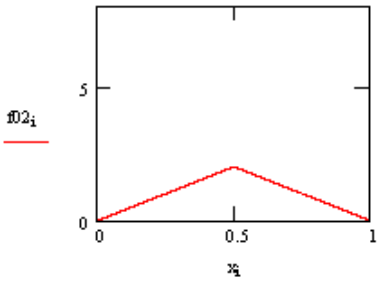
Numerical demonstration of Central Limit Theorem

Starting nonnormal distribution

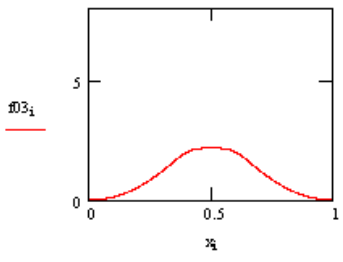


NonNormal Distribution of X

Sum of two-point averages

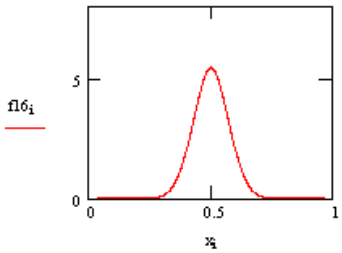


Distribution of Xbar when sample size is 2



Distribution of Xbar when sample size is 3

Sum of 3-point averages

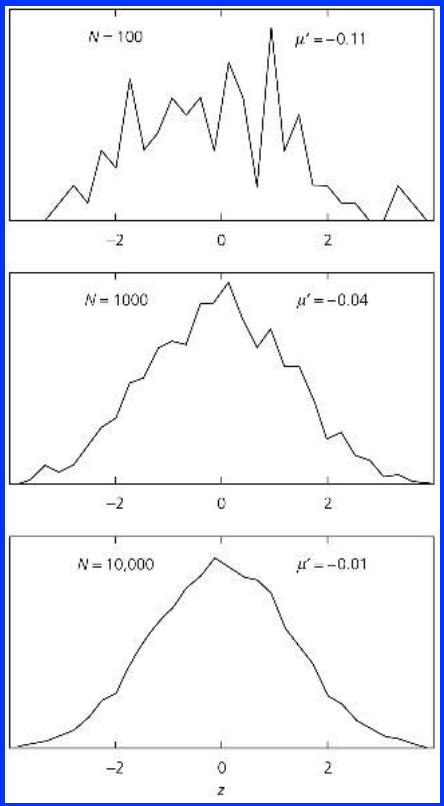


Distribution of Xbar when sample size is 16

Sum of 16-point averages

http://www.statisticalengineering.com/central_limit_theorem.htm

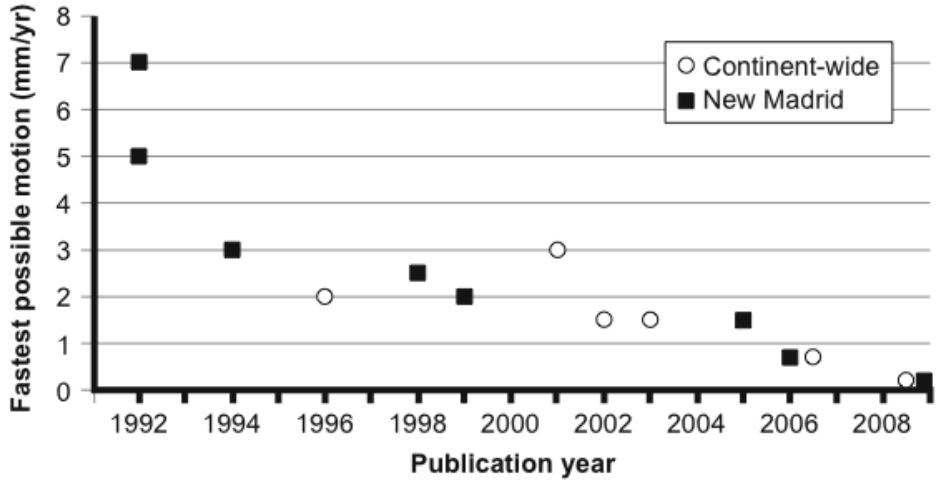
12



PAN 4.2: Histogram of the results of drawing *N* samples from a Gaussian parent distribution with mean zero and a unit standard deviation.

For small numbers of samples the observed distribution can look quite different from the parent distribution and the sample mean μ' differs from that of the parent distribution.

As the number of samples increases, the observed distribution looks increasingly like the parent distribution. (Stein and Wysession, 2003)



PAN 4.3: Maximum rate of motion in and across the New Madrid seismic zone shown by successively more precise GPS measurements. (Calais and Stein, 2009)

CQ: A challenge for medical researchers involves "cancer clusters," communities that have higher-than-expected cancer rates. Some clusters would be expected to occur purely from chance, because of 100 communities, 5% should have rates that are significantly higher at 95% confidence, etc. How could one try to identify which clusters result from factors other than chance?

Shallow uncertainty - we don't know what will happen, but know the odds (pdf). The past is a good predictor of the future. *We can make math models that work well.*

Deep uncertainty - we don't know the odds (pdf). The past is a poor predictor of the future. *We can make math models, but they won't work well*.

Shallow uncertainty is like estimating the chance that a batter will get a hit. His batting average is a good predictor.

Deep uncertainty is like trying to predict the winner of the World Series next baseball season. Teams' past performance give only limited insight into the future.

Prob(sinking) = 0

Expected Prob(loss) = 1/100,000
Actual ~ 2/100 : 2000 x

Due to deep uncertainty

Predicted natural or other disaster probabilities are often very inaccurate

The world is more complicated than we think or admit

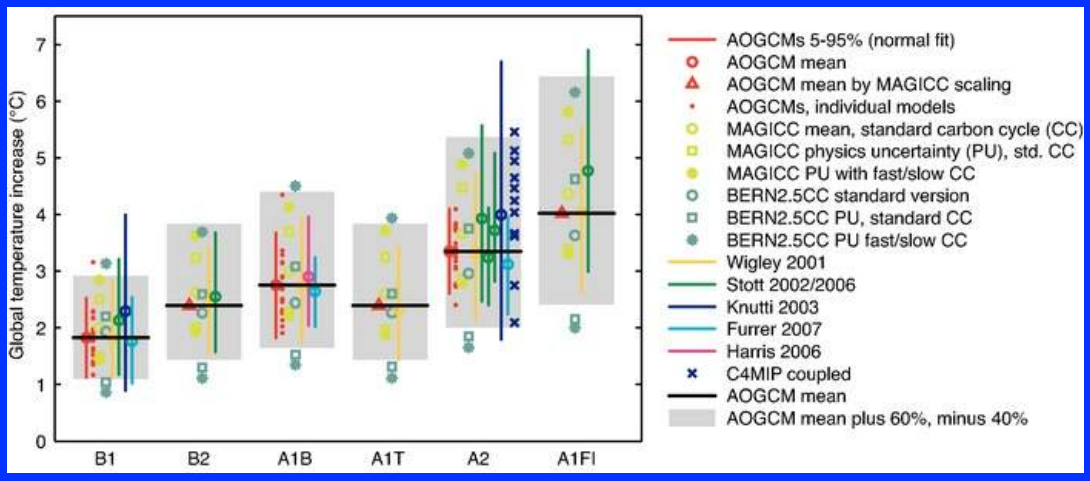
Boeing 787 Dreamliner batteries

Boeing "concluded that they were likely to emit smoke less than once in every 10 million flight hours.

Boeing 787 Dreamliner batteries

Boeing "concluded that they were likely to emit smoke less than once in every 10 million flight hours.

Once the planes were placed in service, the batteries overheated and emitted smoke twice, and caused one fire, after about 50,000 hours of commercial flights."
(NYT, 2/7/13)



PAN 5.2: Comparison of the rise in global temperature by the year 2009 predicted by various climate models. For various scenarios of carbon emissions - B1, B2, , etc. - the vertical band shows the different predicted warming. (IPCC, 2007)

"**Some of the most troubling risk management challenges of our time are characterized by deep uncertainties**.

Well-validated, trustworthy risk models giving the probabilities of future consequences for alternative present decisions are not available

The relevance of past data for predicting future outcomes is in doubt; experts disagree about the probable consequences of alternative policies – or, worse, reach an unwarranted consensus that replaces acknowledgment of uncertainties and information gaps with groupthink

Policymakers (and probably various political constituencies) are divided about what actions to take to reduce risks

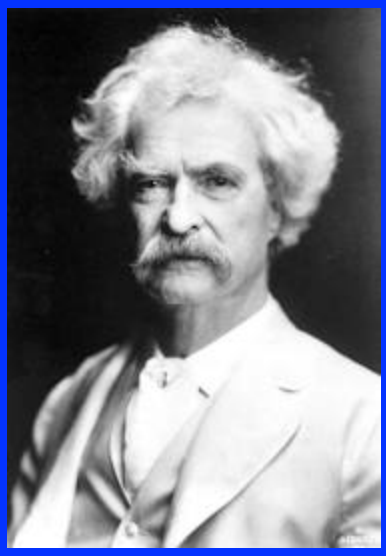
Passions run high and convictions of being right run deep in the absence of enough objective information to support rational decision analysis "

Cox (2012)

5:**Communicating what we know and don't**

"When in doubt tell the truth. It will confound your enemies and astound your friends."

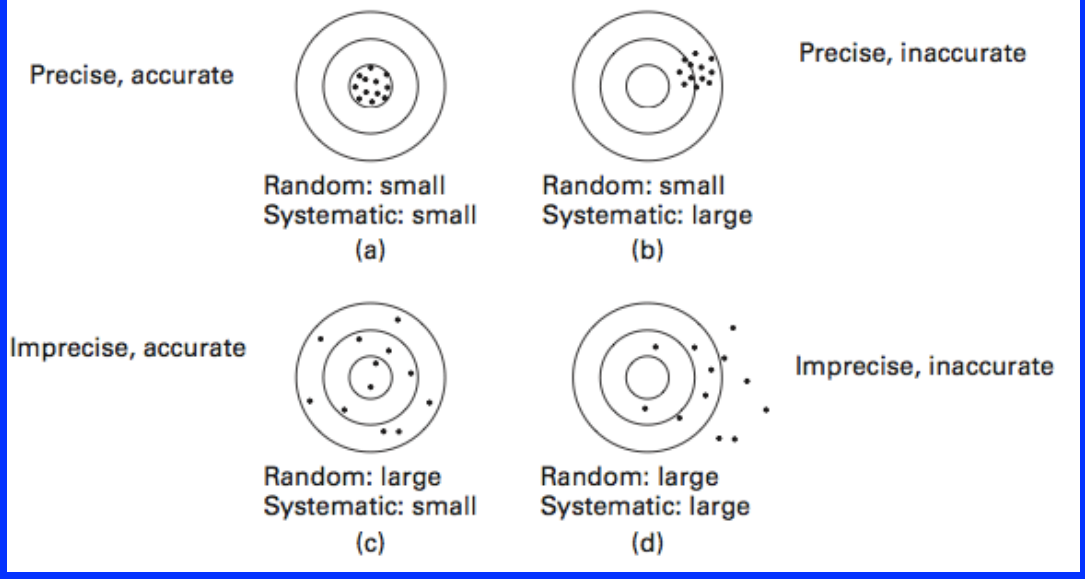
Mark Twain



What do we mean by

Precision

Accuracy



PAN 5.4

Hurricane Irene evacuation defended by New York mayor Michael Bloomberg

Politicians issued dramatic warnings but their fears were unfounded and some say they went too far

Chris McGreal in Washington
guardian.co.uk, Sunday 28 August 2011 15.44 EDT

A larger | smaller

Hurricane Irene dumped vast amounts of water on the eastern US at the weekend, cut electricity to millions of people and prompted warnings of extensive flash flooding further inland.

But ultimately the storm failed to deliver the catastrophic blow politicians had feared when they ordered the evacuation of more than 2 million people, shut down public transport in New York and other cities, and put the military on alert.

If it had been a weekday,

Major cost

2008:

Hurricane Ike predicted to hit Miami

PAN 5.1

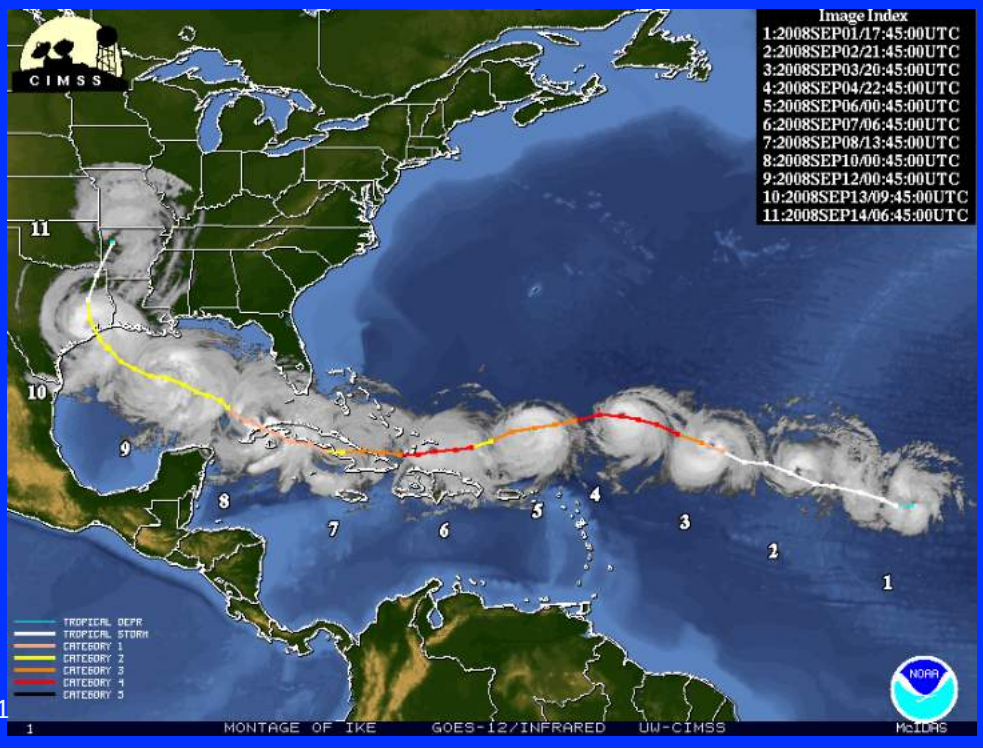
Hurricane Ike Projected Path:Hurricane Ike Track

By Dylan on Sep 5, 2008 in US News | | ShareThis |

Hurricane Ike Projected Path:Hurricane Ike Track **- Hurricane Ike is currently a Category 3 hurricane with winds of 125 mph as of 5 a.m. EDT Friday. The national hurricane center revealed that Hurricane Ike will keep on weakening but is still a dangerous hurricane.Hurricane Ike is located about 460 miles north of the Leeward Islands and will hit the Turks and Caicos Islands and the Bahamas on Sunday.**

Hurricane Ike Projected Path:Hurricane Ike Track

Ike's actual track



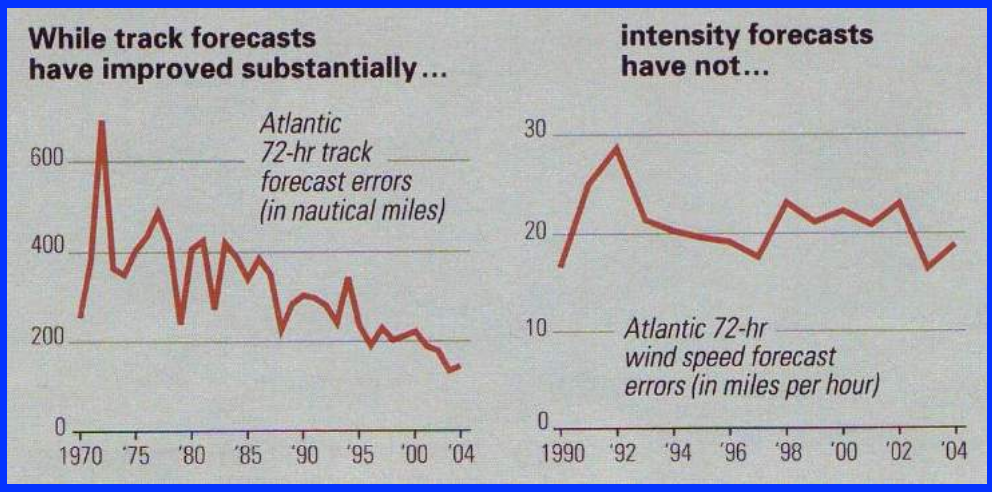
PAN 5.1

Why are hurricane forecasts still so rough?

For example, we do not know for sure whether Irene will make landfall in the Carolinas, on Long Island, or in New England, or stay far enough offshore to deliver little more than a windy, rainy day to East Coast residents.

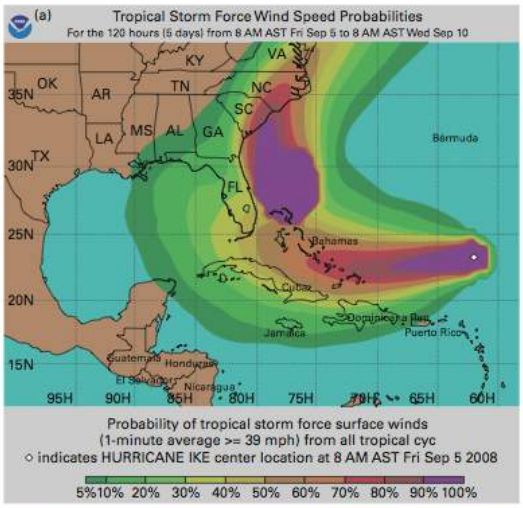
Nor do we have better than a passing ability to forecast how strong Irene will get. In spite of decades of research and greatly improved observations and computer models, our skill in forecasting hurricane strength is little better than it was decades ago. Why is this so, and how should we go about making decisions in the context of uncertain forecasts?

K. Emanuel CNN 8/26/11



National Geographic 8/06

CQ: How would you assess whether the fact that Hurricane Ike moved outside its forecast track represented a problem with the forecast or just chance?



PAN 5.1

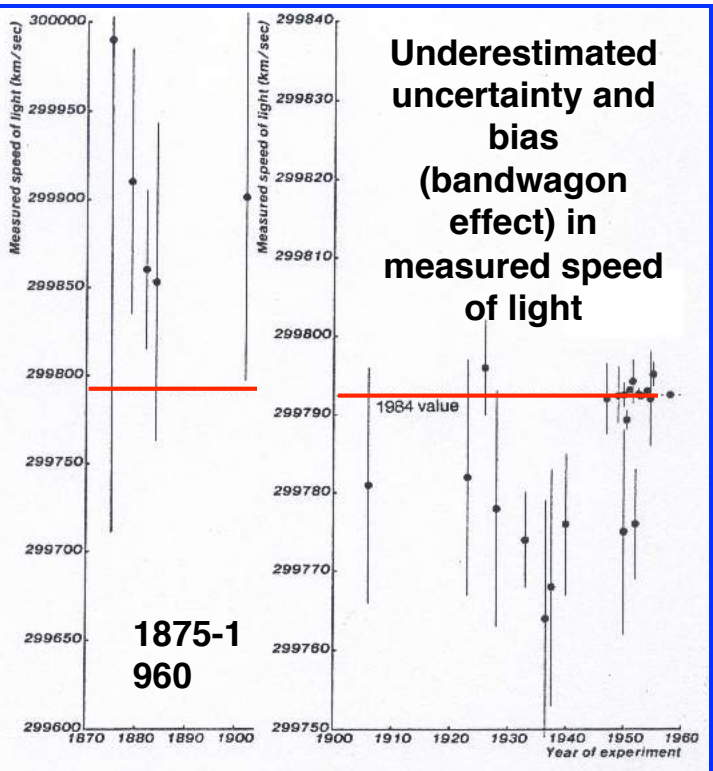


Figure 4.1. Experimental measurements of the speed of light between 1875 and 1960. Vertical bars show reported uncertainty as standard error. Horizontal dashed line represents currently accepted value. Less than 50% of the error bars enclose the accepted value, instead of the expected 70%. From Henrion and Fischoff, 1986.

Underestimated uncertainty and bias (bandwagon effect) in measured speed of light

Uncertainties are hard to assess and generally underestimated

Systematic errors often exceed measurement errors

PAN 5.3

9

CQ: Describe one of your experiences with the "bandwagon effect."

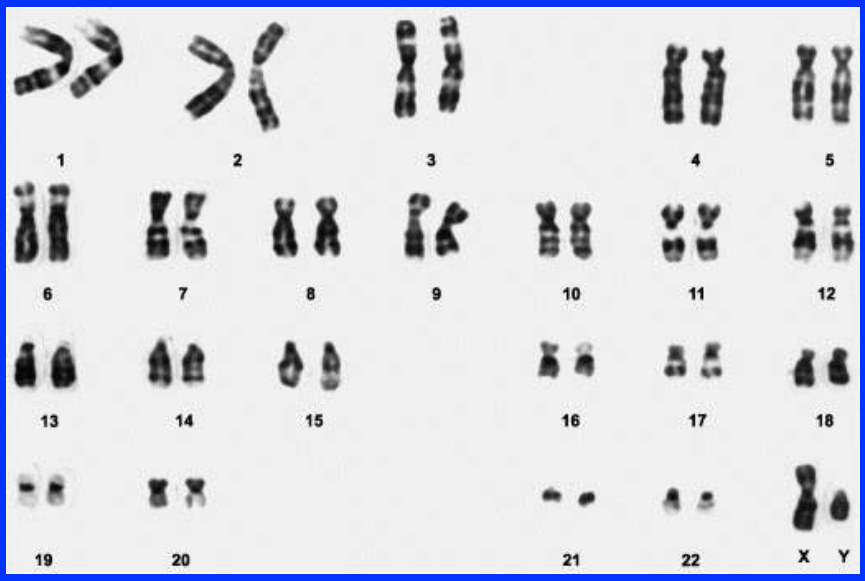
Bandwagon effect

From Wikipedia, the free encyclopedia

The **bandwagon effect** is a well documented form of groupthink in behavioral science and has many applications.[*which?*] The general rule is that conduct or beliefs spread among people, as fads and trends clearly do, with "the probability of any individual adopting it increasing with the proportion who have already done so".[1] As more people come to believe in something, others also "hop on the bandwagon" regardless of the underlying evidence.

A literal "bandwagon", whence the metaphor is derived.

Systematic uncertainty is larger than we think: number of human chromosome pairs



1921-1955: 24 **Now: 23**

Confirmation Bias

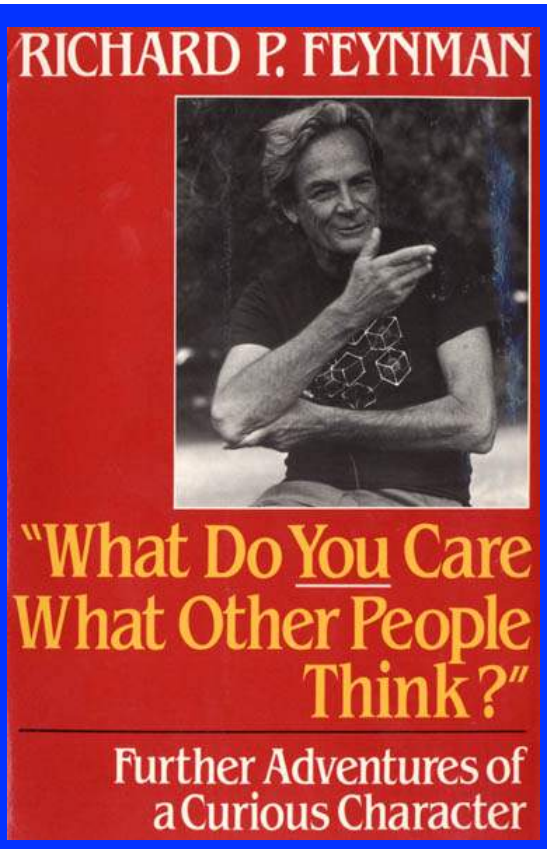
We see what we expect to see, or accept data that fit our view and ignore data that do not

"Human understanding, once it has adopted an opinion, collects any instances that confirm it, and though the contrary instances may be more numerous and more weighty, it either does not notice them or else rejects them, in order that this opinion will remain unshaken." (Francis Bacon , AD 1620)

It's fooling ourselves, but hard to avoid.
"It's not what you don't know that hurts you – it's what you know that isn't so."

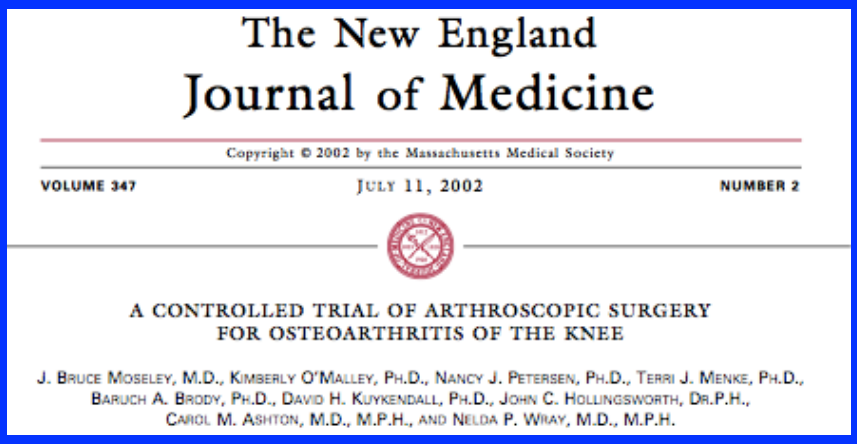
Richard Feynman (1986) explained that scientists have learned that

"whether they like a theory or they do not like a theory is not the essential question. Rather, it is whether or not the theory gives predictions that agree with the experiment. It is not a question of whether a theory is philosophically delightful, or easy to understand, or perfectly reasonable from the point of view of common sense."



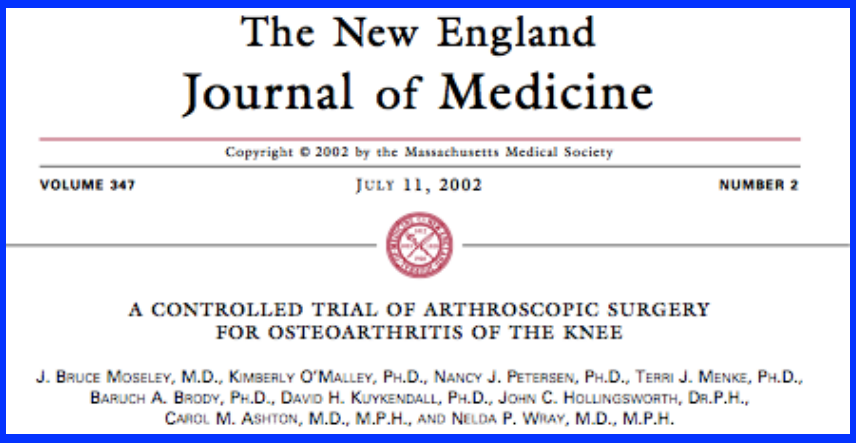
Testing analogy: evidence-based medicine objectively evaluates widely used treatments, often with embarrassing results

Although more than 650,000 arthroscopic knee surgeries at a cost of roughly $5,000 each were being performed each year



Testing analogy: evidence-based medicine objectively evaluates widely used treatments, often with embarrassing results

Although more than 650,000 arthroscopic knee surgeries at a cost of roughly $5,000 each were being performed each year, a controlled experiment showed that "the outcomes were no better than a placebo procedure."



The New England
Journal of Medicine

VOLUME 347 JULY 11, 2002 NUMBER 2

A CONTROLLED TRIAL OF ARTHROSCOPIC SURGERY FOR OSTEOARTHRITIS OF THE KNEE

J. BRUCE MOSELEY, M.D., KIMBERLY O'MALLEY, PH.D., NANCY J. PETERSEN, PH.D., TERRI J. MENKE, PH.D., BARUCH A. BRODY, PH.D., DAVID H. KUYKENDALL, PH.D., JOHN C. HOLLINGSWORTH, DR.P.H., CAROL M. ASHTON, M.D., M.P.H., AND NELDA P. WRAY, M.D., M.P.H.

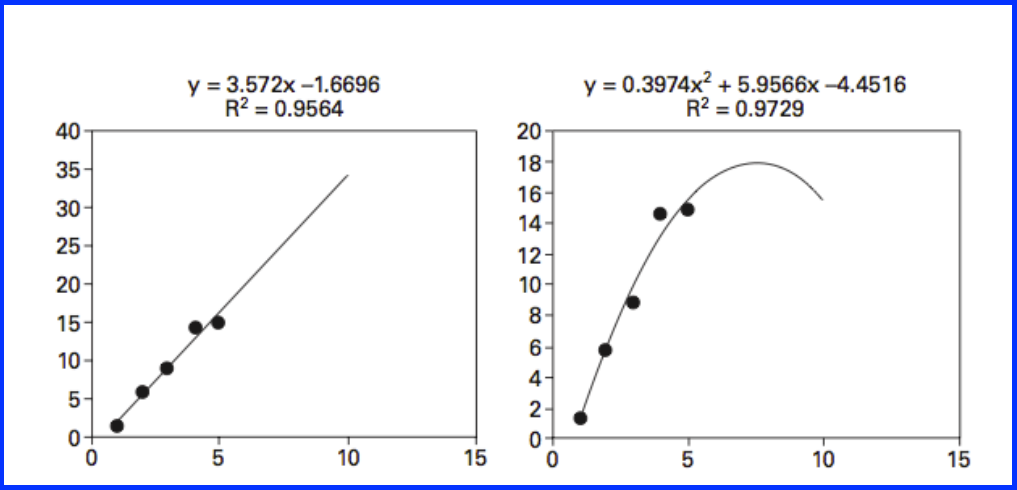
Insights from weather forecasting

Adopt specific criteria for "good" and "bad" forecasts

"it is difficult to establish well-defined goals for any project designed to enhance forecasting performance without an unambiguous definition of what constitutes a good forecast."
(Murphy, 1993)

Overparameterized model (overfit data):

Given a trend with scatter, fitting a higher order polynomial can give
a better fit to the past data but a worse fit to future data



Linear fit *Quadratic fit*

Ike predicted to bring certain death

P(death)=1

Hurricane Ike's 9-Foot Floods to Bring "Certain Death"

Willie Drye
for National Geographic News
September 12, 2008

Hurricane Ike's expected massive storm surge and flooding have prompted National Weather Service officials to issue a rare and chilling "certain death" warning as the storm barrels toward the Texas coast tonight.

(See Hurricane Ike photos.)

Enlarge Photo

Printer Friendly
Email to a Friend

SHARE What's This?
Digg
StumbleUpon
Reddit

"We rarely issue this warning unless there is a severe, impending catastrophe," said Chris Sisco, a meteorologist at the National Hurricane Center in Miami. "It's very serious."

The warning reads: "Neighborhoods that are affected by the storm surge ... and possibly entire coastal communities ... will be inundated during the period of peak storm tide.

"Persons not heeding evacuation orders in single-family, one- or two-story homes may face certain death. ... Widespread and devastating personal property damage is likely elsewhere."

Sisco said Ike's storm surge—a mound of water created by a hurricane's winds—could reach 20 feet (6.1 meters) around the center of the storm.

Actual deaths: < 50 of 40,000

Error 800x

Why Hurricane Ike's "Certain Death" Warning Failed

Willie Drye
for National Geographic News
September 26, 2008

As residents of Galveston, Texas, were allowed to return to the devastated island this week, experts puzzled over why tens of thousands of others had remained during Hurricane Ike—despite the National Weather Service's "certain death" warning.

Among the possible explanations: memories of a chaotic 2005 evacuation, an anti-government attitude, and a false sense of security fueled by TV news and the abundance of hurricane data on the Web.

Enlarge Photo

Printer Friendly
Email to a Friend

SHARE What's This?
Digg

(See full Hurricane Ike coverage: photos, stories, and videos.)

Avoiding Chaos

Gene Hafele, director of the Houston-Galveston National Weather Service office, said about 500,000 people in and around Galveston were in a mandatory evacuation zone, and only about 300,000 left.

Bill Read, director of the National Hurricane Center in Miami, estimated there were about 140,000 people in the smaller, "certain death" zone. About 70 percent of those residents evacuated. That left nearly 40,000 people to contend with the worst of the storm surge.

CQ: Why did about 40% of the people ordered to leave ignore the order and warning? What lesson do you think they drew?

http://news.nationalgeographic.com/news/2008/09/080926-hurricane-ike-evacuation.html

A good hazard communication approach:

Say what you know

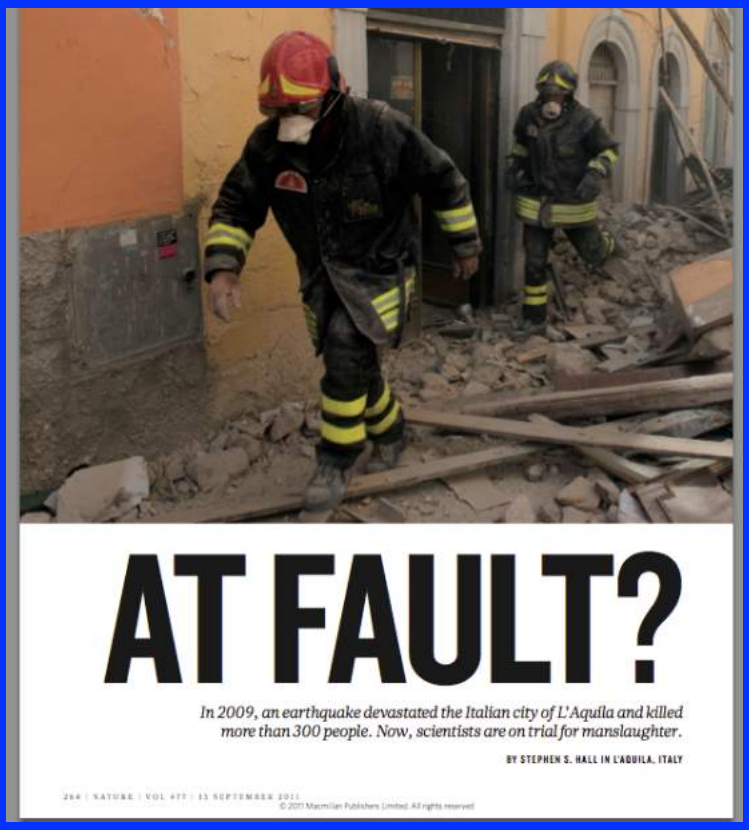
Say what you don't know

Say what you think

Say which is which and why

CQ: Write a short public statement - less than 200 words - that you would have given to the public if you had been working for the National Weather Service as Hurricane Ike approached Galveston Island. Your goal is to realistically describe the situation and make sensible recommendations.

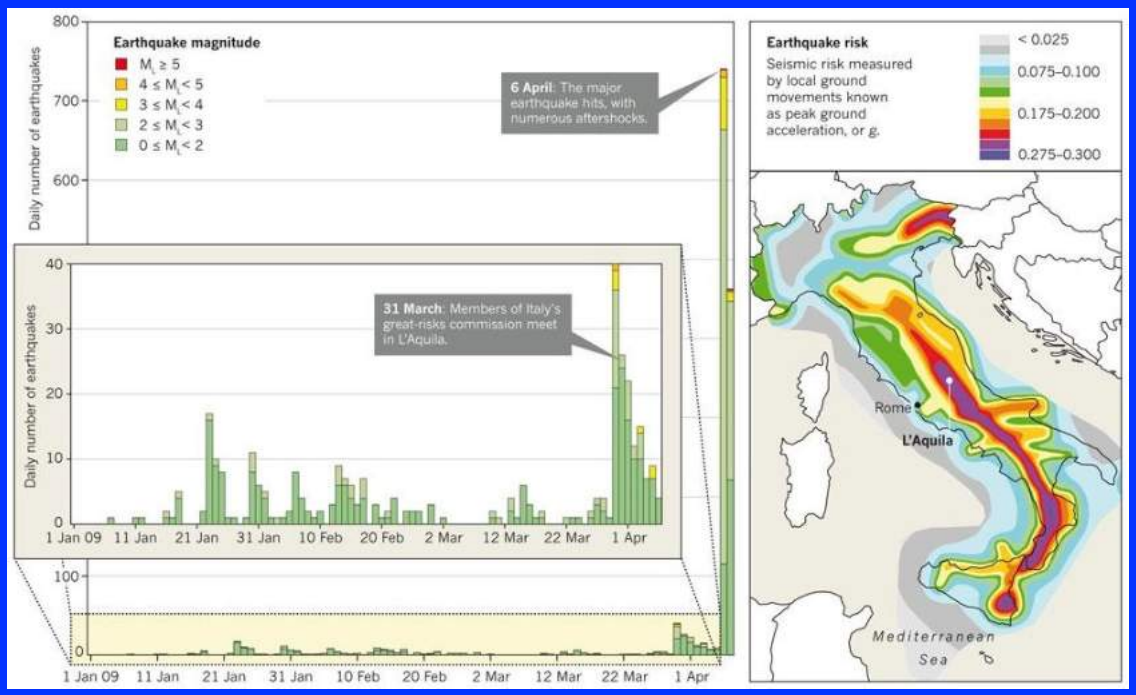
September 17, 2008 - Piles of debris are lined up along the seawall on Galveston Island where Hurricane Ike made landfall



AT FAULT?

In 2009, an earthquake devastated the Italian city of L'Aquila and killed more than 300 people. Now, scientists are on trial for manslaughter.

BY STEPHEN S. HALL IN L'AQUILA, ITALY



PAN 5.6: Left: Number of earthquakes and their magnitudes in the L'Aquila area, during period leading up to the large April 6, 2009 earthquake. Right: earthquake hazard map of Italy. (Hall, 2011)

PAN 5.6

CQ: Write a short public statement - less than 200 words - that you would have given to the public if you had been working for the Italian civil protection authorities during the L'Aquila earthquake swarm. Given the public concern that a large earthquake may occur soon, your goal is to realistically describe the situation. What would you say when people ask what they should do?

"The reliance on mathematical models has done tangible damage to our society in many ways. Bureaucrats who do not understand the limitations of modeled predictions often use them... Agencies that depend on project approvals for their very survival (such as the U.S. Army Corps of Engineers) can and frequently do find ways to adjust the model to come up with correct answers that will ensure project funding. Most damaging of all is the unquestioning acceptance of the models by the public because they are assured that the modeled predictions are the way to go."

Nature 447, 35-37 (3 May 2007)

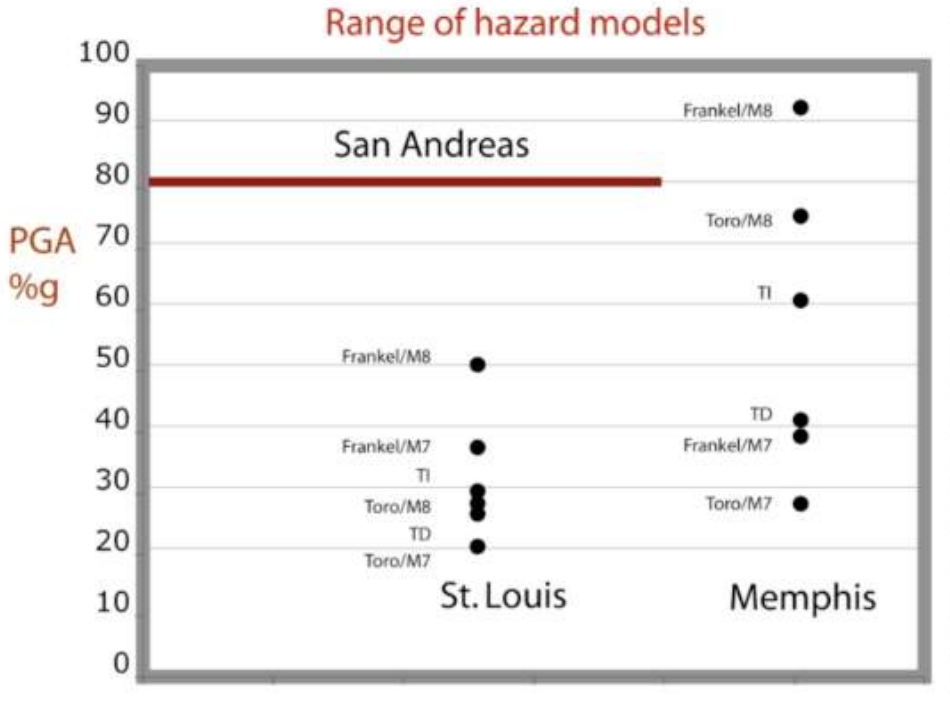
Useless Arithmetic: Why Environmental Scientists Can't Predict the Future by Orrin Pilkey & Linda Pilkey-Jarvis Columbia University Press: 2007.

"Above all, users of predictions, along with other stakeholders in the prediction process, must question predictions. For this questioning to be effective, predictions must be as transparent as possible to the user. In particular, assumptions, model limitations, and weaknesses in input data should be forthrightly discussed. Institutional motives must be questioned and revealed... The prediction process must be open to external scrutiny.

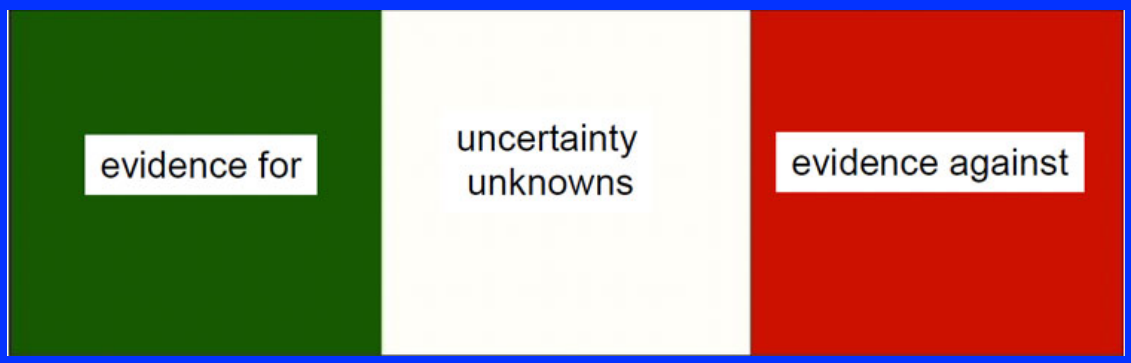
Openness is important for many reasons but perhaps the most interesting and least obvious is that the technical products of predictions are likely to be "better" - both more robust scientifically and more effectively integrated into the democratic process - when predictive research is subjected to the tough love of democratic discourse...

Uncertainties must be clearly understood and articulated by scientists, so users understand their implications. If scientists do not understand the uncertainties - which is often the case - they must say so. Failure to understand and articulate uncertainties contributes to poor decisions that undermine relations among scientists and policy makers."

Sarewitz et al. (2000)



PAN 5.7: Comparison of earthquake hazard, described as peak ground acceleration as a percentage of the acceleration of gravity expected with 2% risk in 50 years, predicted by various assumptions. (Stein et al., 2012)



Green evidence for	White uncertainty	Red evidence against
50%	30%	20%

PAN 5.8

Challenge: Users want predictions even if they're poor

Future Nobel Prize winner Kenneth Arrow served as a military weather forecaster. As he described,

"my colleagues had the responsibility of preparing long-range weather forecasts, i.e., for the following month. The statisticians among us subjected these forecasts to verification and found they differed in no way from chance. The forecasters themselves were convinced and requested that the forecasts be discontinued.

Challenge: Users want predictions even if they're poor

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"my colleagues had the responsibility of preparing long-range weather forecasts, i.e., for the following month. The statisticians among us subjected these forecasts to verification and found they differed in no way from chance. The forecasters themselves were convinced and requested that the forecasts be discontinued.

The reply read approximately: "The commanding general is well aware that the forecasts are no good. However, he needs them for planning purposes."

Gardner, D., Future Babble: *Why Expert Predictions Fail - and Why We Believe Them Anyway*, 2010

CQ: Drug company biologists who examined the results of important scientific studies about cancer have found that less than a quarter of the results can be replicated. What might be the causes of these problems?

easily marginalised as soft and wayward. But irreproducibility is much more widespread. A few years ago scientists at Amgen, an American drug company, tried to replicate 53 studies that they considered landmarks in the basic science of cancer, often co-operating closely with the original researchers to ensure that their experimental technique matched the one used first time round. According to a piece they wrote last year in *Nature*, a leading scientific journal, they were able to reproduce the original results in just six. Months earlier Florian Prinz and his colleagues at Bayer HealthCare, a German pharmaceutical giant, reported in *Nature Reviews Drug Discovery*, a sister journal, that they had successfully reproduced the published results in just a quarter of 67 seminal studies.

6: Human disasters

The essence of the this-time-it's-different syndrome is simple. It is rooted in the firmly held belief that financial crises are things that happen to other people in other counties at other times; crises do not happen to us, here, and now. We are doing things better, we are smarter, we have learned from past mistakes."

C. Reinhart and K. Rogoff, *This Time Is Different*

Prob(sinking) = 0

Richard Feynman

"It appears that there are enormous differences of opinion as to the probability of a failure with loss of vehicle and of human life. The estimates range from roughly 1 in 100 to 1 in 100,000. The higher figures come from the working engineers, and the very low figures from management…
Since 1 part in 100,000 would imply that one could put up a shuttle every day for 300 years expecting to lose only one, we could properly ask what is the cause of management's fantastic faith in the machinery.. One reason may be an attempt to assure the government of NASA perfection and success in order to assure the supply of funds. The other may be that they sincerely believed it to be true, demonstrating an almost incredible lack of communication between themselves and their working engineers."

Feynman argued that the engineers' estimate of the risk, 1000 times greater or 1/100, was more realistic.

"NASA owes it to the citizens from whom it asks support to be frank, honest, and informative, so these citizens can make the wisest decisions for the use of their limited resources. For a successful technology, reality must take precedence over public relations, for nature cannot be fooled."

Seven years later


BBC


BBC

CQ: Although the space shuttle was a new program, how could more risk assessments been made?

Boeing 787 Dreamliner batteries

Boeing "concluded that they were likely to emit smoke less than once in every 10 million flight hours.

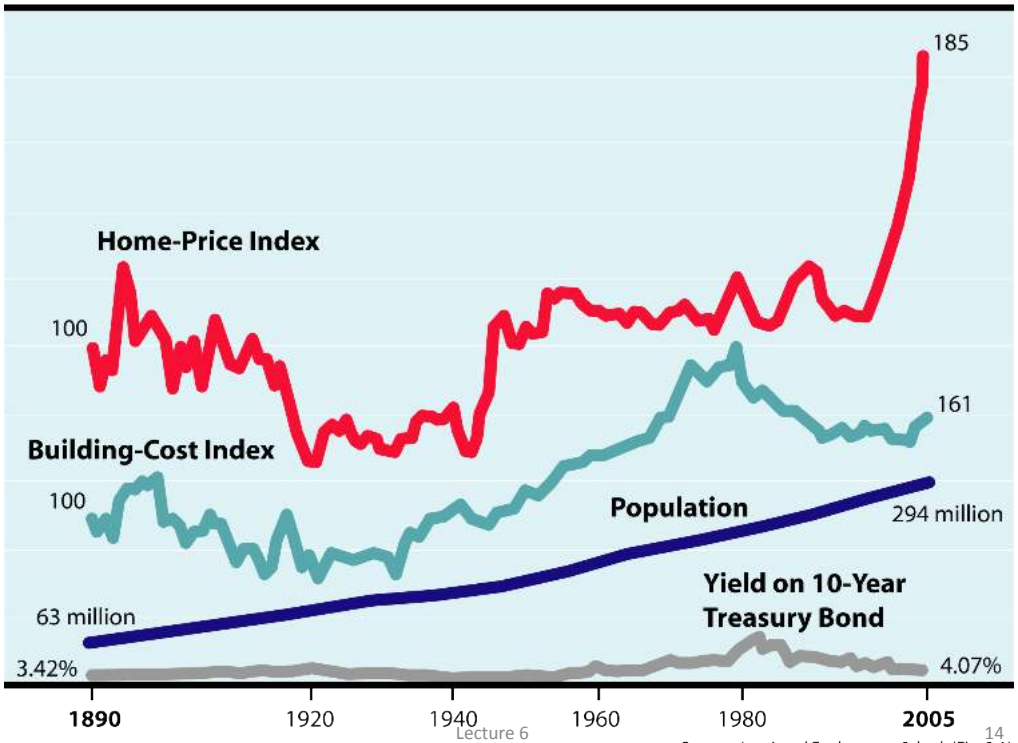
Boeing 787 Dreamliner batteries

Boeing "concluded that they were likely to emit smoke less than once in every 10 million flight hours.

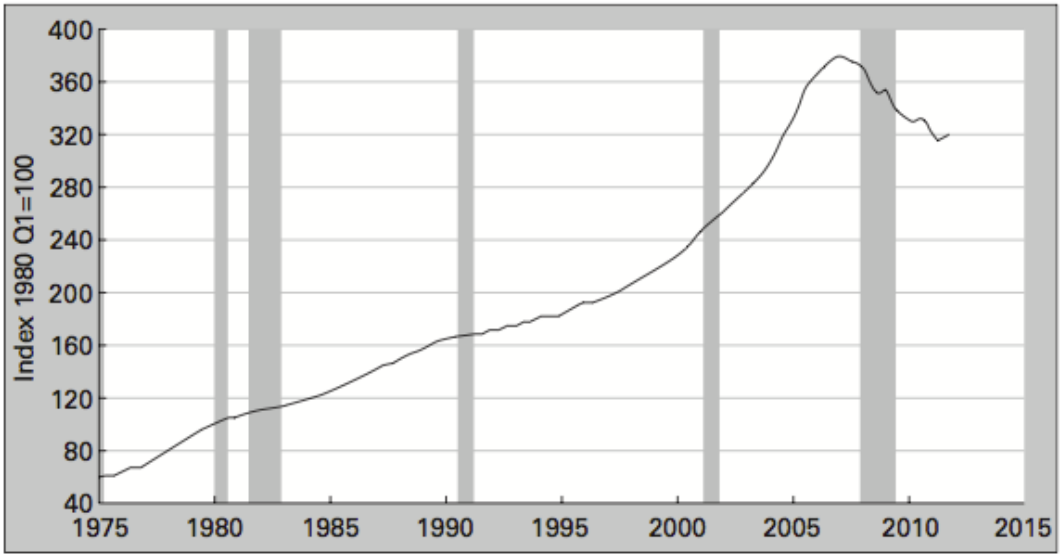
Once the planes were placed in service, the batteries overheated and emitted smoke twice, and caused one fire, after about 50,000 hours of commercial flights."
(NYT, 2/7/13)

25 July 1956

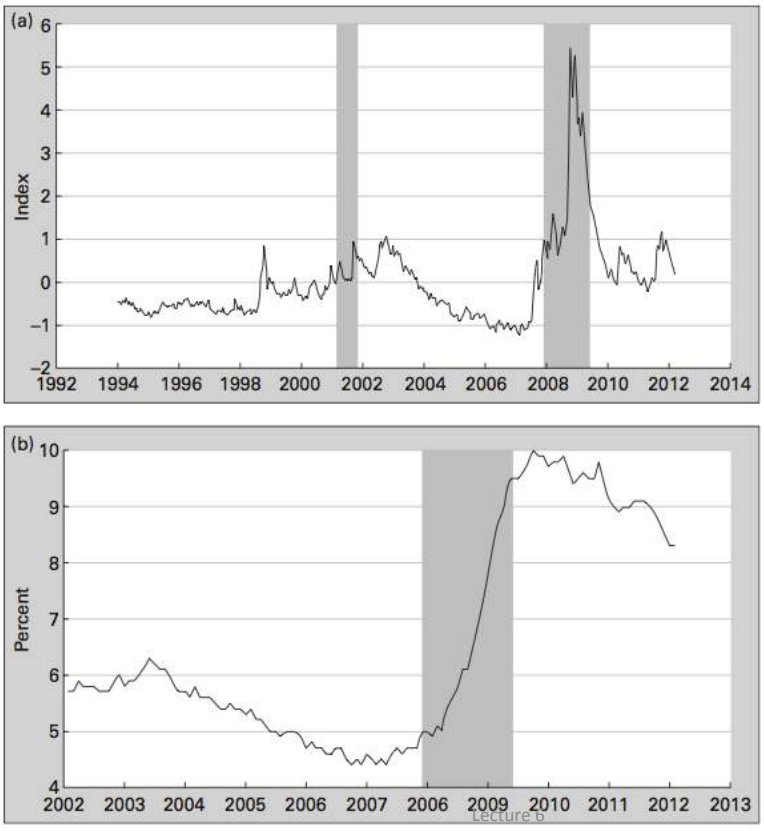
Inflation-adjusted U.S. home prices, Population, Building costs, and Bond yields (1890–2005)



Source: *Irrational Exuberance*, 2d ed. (Fig. 2.1)



PAN 6.2. U.S. house price index from 1975 - 2011. Prices are nominal, i.e. not adjusted for inflation. (Federal Reserve Bank of St. Louis)



PAN 6.3: Financial Stress Index (top) and unemployment rate (bottom) showing effects of the 2008 disaster. (Federal Reserve Bank of St. Louis)

Inside the Fed in 2006: A Coming Crisis, and Banter

By BINYAMIN APPELBAUM

WASHINGTON — As the housing bubble entered its waning hours in 2006, top Federal Reserve officials marveled at the desperate antics of home builders seeking to lure buyers.

The officials laughed about the cars that builders were offering as signing bonuses, and about efforts to make empty homes look occupied. They joked about one builder who said that inventory was "rising through the roof."

But the officials, meeting every six weeks to discuss the health of the nation's economy, gave little credence to the possibility that the faltering housing market would weigh on the broader economy, according to transcripts that the Fed released Thursday. Instead they continued to tell one another throughout 2006 that the greatest danger was inflation — the possibility that the economy would grow too fast.

"We think the fundamentals of the expansion going forward still look good," Timothy F. Geithner, then president of the Federal Reserve Bank of New York, told his colleagues when they gathered in Washington in December 2006.

NYT 1/12/2012

Days Before 2007 Crisis, Fed Officials Doubted Need to Act

By BINYAMIN APPELBAUM

WASHINGTON — Federal Reserve officials in August 2007 remained skeptical that housing foreclosures could cause a financial crisis, just days before the Fed was jolted into action, according to transcripts that the central bank published Friday.

The Daily Telegraph

Friday, October 7, 2011 ••• telegraph.co.uk Irish Republic € 1.15 No 48,6

Financial crisis is worst the world has ever faced

Bank of England starts printing money again to save economy from recession

Duke's late-night date with Paltrow

Immigrant i pet cat row was shoplifte

By Tom Whitehead, Victoria Ward and Mark Hughes

THE illegal immigrant allowed to stay in Britain partly because he owned a cat was given a police caution for shoplifting, *The Daily Telegraph* can disclose.

Ranzo Avila, who was at the centre of a row among senior Tories, overstayed his student visa but was allowed to stay in Britain after an immigration judge ruled in his favour in 2008. He concluded that the Bolivian's right to family life would be breached because he was in an established relationship – reinforced by the fact that the couple had bought a cat.

Immigration court records showed that he first came to the attention of officials after being arrested for

Secretary, that a been allowed to Britain because *The Daily Teleg* yesterday how th a role in the cas judge in the 200 suggested that s him from the pe "mental distress now 36, had arg to a family life u of the European on Human Right had been with h for four years.

Judge James D their joint owner named Maya rei quality of their l suggested that s them could caus emotional traum

INSIDE

Clarke 'regrets' attack on Home

In Germany, Little Appetite to Change Troubled Banks

By JACK EWING
Published: August 9, 2013

"Germany was actually hit very hard by the financial crisis," said Jörg Rocholl, president of the European School of Management and Technology, a business school in Berlin. But the debate about the future of banking in Germany is "alarmingly nonintense," Mr. Rocholl said.

Banks in Germany invested in seemingly every bad asset that came their way, including American subprime assets and Greek bonds. "There is no sense of pride that Germans were especially thorough or prudent," said Sven Giegold, a German who is a member of the Economic and Monetary Affairs Committee in the European Parliament.

The New York Times August 10 2013

Lax lenders

After the financial crisis, German banks required more bailout cash than banks in any European country except Britain, underlining the shortcomings of the German banking sector.

TOTAL BANK BAILOUTS APPROVED
2008 to Sept. 2012

	TOTAL, BILLIONS	AS A PERCENTAGE OF 2011 G.D.P.
Britain	€873	50.0%
Germany	646	25.1
Denmark	613	256.1
Spain	575	53.6
Ireland	571	365.2
France	371	18.6
Belgium	359	97.4
Netherlands	313	52.0
Sweden	162	41.8
Italy	130	8.2
Greece	129	59.9
Austria	94	31.3
Portugal	77	45.0
Poland	68	18.3
Finland	54	28.5
Slovenia	13	35.4
Hungary	10	10.3
Latvia	9	46.2
Luxembourg	9	20.9
Cyprus	5	27.0
TOTAL E.U.	5,086	40.3

WIRED MAGAZINE: 17.03

Recipe for Disaster: The Formula That Killed Wall Street

By Felix Salmon 02.23.09

In the mid-'80s, Wall Street turned to the quants—brainy financial engineers—to invent new ways to boost profits. Their methods for minting money worked brilliantly... until one of them devastated the global economy.

A third similarity to natural disasters is that the hazard and vulnerability were not recognized, as a result of using erroneous models.

Since the 1970s, sophisticated mathematical models were used to develop arcane new financial instruments. Few within the industry beyond their practitioners, termed "quants," understood how the models worked.

Nonetheless, as described by Fischer Black, a leader in developing them, the models were "accepted not because it is confirmed by conventional empirical tests, but because researchers persuade one another that the theory is correct and relevant." This acceptance was illustrated by the award in 1997 of the Nobel Prize in economics to Myron Scholes and Robert Merton for work based upon Black's.

HAZARD OVERESTIMATED: Y2K

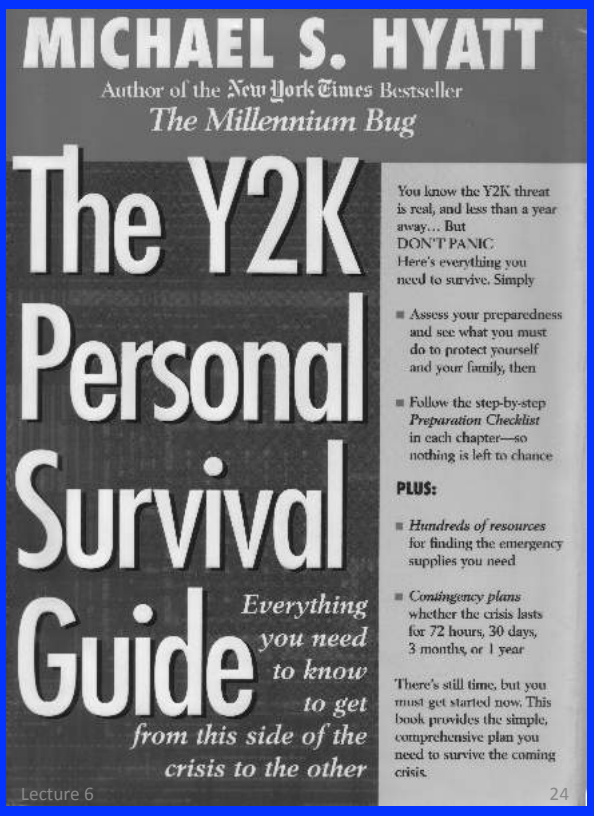
Much ado made that on January 1, 2000 computer systems would fail, because dates used only two digits

U.S. & other governments established major programs

Estimated $300 billion spent on preparations

Few major problems occurred, even among businesses and countries who made little or no preparation

CQ: Why do you think the Y2K scare was taken so seriously?



GROUPTHINK

A common problem in policy making, a consensus approach that often causes errors.

Members of a group start with absolute belief that they are right.

They talk only to each other, convince each other using specious arguments, pressure others to agree, refuse to consider clear evidence that contradicts their views, and ignore outside advice.

The more they talk to each other, the more convinced they become.

NEGLECTING UNCERTAINTY BIASES HAZARD ESTIMATES

1976 SWINE FLU "APORKALPSE"

CDC reported "strong possibility" of epidemic. HEW thought *"chances seem to be 1 in 2"* and *"virus will kill one million Americans in 1976."*

President Ford launched program to vaccinate entire population despite critics' reservations

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President Ford launched program to vaccinate entire population despite critics' reservations

40 million vaccinated at cost of millions of dollars before program suspended due to reactions to vaccine

About 500 people had serious reactions and 25 died, compared to one person who died from swine flu

Bird flu pandemic 'could kill 150m'

James Sturcke
guardian.co.uk, Friday 30 September 2005 10.23 EDT

A global influenza pandemic is imminent and will kill up to 150 million people, the UN official in charge of coordinating the worldwide response to an outbreak has warned. David Nabarro, one of the most senior public health experts at the World Health Organisation, said outbreaks of bird flu, which have killed at least 65 people in Asia, could mutate into a form transmittable between people.

"The consequences in terms of human life when the pandemic does start are going to be extraordinary and very damaging," he said.

Bush v. Bird Flu

By Mike Allen | Tuesday, Nov. 01, 2005

TIME U.S.

In announcing plans today to prepare the nation for combating a future worldwide wave of bird flu, President Bush used vocabulary and tactics that are familiar from his confrontation with global terrorism. "Our country has been given fair warning of this danger to our homeland—and time to prepare," the President said during a jaunt up to the National Naval Medical Center in Bethesda, Md. Heavy spending has been a cornerstone of Bush's 9/11 response, and he geared up for a new threat by asking Congress for $7.1 billion in emergency funding for vaccines and antiviral medicines—even more than the record amount the Senate had approved in September. In another echo of national security policy, Bush is trying to go to the source overseas, where a pandemic would originate, by offering other countries incentives to identify and report outbreaks before they spread.

★★★★★ **Preparing for the Bird Flu**

By H. F. Corbin TOP 500 REVIEWER VINE VOICE on February 5, 2006

Why Take the Chance?

The Bird Flu is real. It's deadly. And it's spreading. Within the next year it could threaten your home, your livelihood, your family and even your life. It may not become the pandemic many experts now fear, but do you really want to take the chance of being totally unprepared?

While this book has fewer than a hundred pages, it is packed full of useful information, information that may save your life. Dr. Woodson discusses the bird flu, comparing it to the flu pandemic of 1918-1919, vaccines and what you can do in preparation for a possible pandemic. He suggests that you make sure that you have a will and life insurance, that you get both a flu shot (against the usual seasonal flu) and a Pneumovax vaccination-- while these do not prevent you from getting avian flu, you will be protected from flu and pneumonia, thus making your chances of surviving bird or avian flu much better-- and that you stock up on nonperishable foods, medical supplies and other necessities such as flashlights and shortwave radios. The author includes lists of supplies you will need, along with a section called "Flu Survival Kit." There is also an informative chapter on how to care for a flu victim, should you find yourself in that position. (In the event of a major pandemic hospitals will be overwhelmed.) The book also has other resources listed on the subject of bird flu, a series of maps showing the rapid spread of the earlier 1918 pandemic across the United States and concludes with endnotes to support the author's statements.

CQ: How should we evaluate whether a threatened disaster, like swine flu, bird flu, or Y2K, should be treated as a serious threat?

7: How Much is Enough?

parallels - world news

In Tsunami's Wake, Fierce Debate Over Japan's 'Great Wall'

The government wants to build sea walls in northeastern Japan that will stretch for more than 200 miles and be 30-feet high in places. Some say the cost is too high and it will ruin the beaches.

Lucy Craft for NPR

NPR March 11, 2014

Opponents say the walls — although financed by the national government — would saddle struggling local governments with crushing maintenance costs. They say less drastic alternatives, such as moving communities to high ground or developing better evacuation techniques, have not been given enough attention.

Nearly half of Japan's coastline has been armored against erosion and storms. Much of it, opponents say, is useless pork-barrel spending, like a proposal to build $20 million sea walls on four uninhabited islands with no commercial value.

Satoquo Seino of Kyushu University says the sea-wall issue in northeastern Japan is already changing national policy.

"This is the first time Japan has seen a concerted movement against building sea walls. Until now it was just a local problem," Seino said.

Japan Revives a Sea Barrier That Failed to Hold

Ko Sasaki for The New York Ti

Japan's Failed Breakwaters: Nori Onishi reports on the failure of breakwater systems in protecting against large waves along Japan's coastline.

By NORIMITSU ONISHI
Published: November 2, 2011

KAMAISHI, Japan — After three decades and nearly $1.6 billion, work on Kamaishi's great tsunami breakwater was completed three years ago. A mile long, 207 feet deep and jutting nearly 20 feet above the water, the quake-resistant structure made it into the Guinness World Records last year and rekindled fading hopes of revival in this

RECOMMEND
TWITTER
LINKEDIN
COMMENTS (27)

NY Times 11/2/2011

Choosing policy involves politics & economics as well as science

Too expensive to rebuild for 2011 sized tsunami

>100 $B for new defences only slightly higher than old ones

"In 30 years there might be nothing left there but fancy breakwaters and empty houses."

Less expensive strategies (land use & warning systems) probably better

CQ: If you were mayor of a coastal town in Japan, how would you evaluate the plans for new seawalls? What policy would you favor and why?

THE NEW ORLEANS
HURRICANE PROTECTION SYSTEM:

What Went Wrong and Why

A Report by the American Society of Civil Engineers
Hurricane Katrina External Review Panel

A storm of Hurricane Katrina's strength and intensity is expected to cause major flooding and damage. A large portion of the destruction from Hurricane Katrina was caused not only by the storm itself, however, but also by the storm's exposure of engineering and engineering-related policy failures. The levees and floodwalls breached because of a combination of unfortunate choices and decisions, made over many years, at almost all levels of responsibility.

- The hurricane protection system was designed for meteorological conditions (barometric pressure and wind speed, for example) that were not as severe as characteristic of a major Gulf Coast hurricane.

- No single agency was in charge of hurricane protection in New Orleans. Rather, responsibility for the maintenance and operation of the levees and pump stations was spread over many federal, state, parish, and local agencies.

- The hurricane protection system was constructed as individual pieces – not as an interconnected system – with strong portions built adjacent to weak portions, some pump stations that could not withstand the hurricane forces, and many penetrations through the levees for roads, railroads, and utilities. Furthermore, the levees were not designed to withstand overtopping.

The Precautionary Principle

United Nations Educational, Scientific and Cultural Organization

World Commission on the Ethics of Scientific Knowledge and Technology (COMEST)

Rio Declaration
(United Nations 1992)

'In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.'

How much mitigation is enough?

Defending against natural hazards is similar to defending against human enemies: need to chose among options to address poorly known threats

"How to spend our defense dollars and how much to spend is a good deal more complicated than is often assumed... You have to consider a very wide range of issues… You cannot make decisions simply by asking whether something might be nice to have. You have to make a judgment on how much is enough."

R. McNamara, Secretary of Defense, 1961

Multidisciplinary systems analysis approach

"is a reasoned approach to highly complicated problems of choice in a context characterized by much uncertainty; it provides a way to deal with different values and judgments …It is not physics, engineering, mathematics, economics, political science, statistics…yet it involves elements of all these disciplines. It is much more a frame of mind"

(Enthoven and Smith, 1971).

Systems Analysis

What's the problem?
What do we know & not know?

What are we trying to accomplish?
What strategies are available?
What are the costs & benefits of each?
What is an optimum strategy given uncertainty?

In hazard mitigation, as in defense, our goal is to decide *how much is enough.*

Example (1968): how large must U.S. nuclear force be to deter U.S.S.R. nuclear attack?

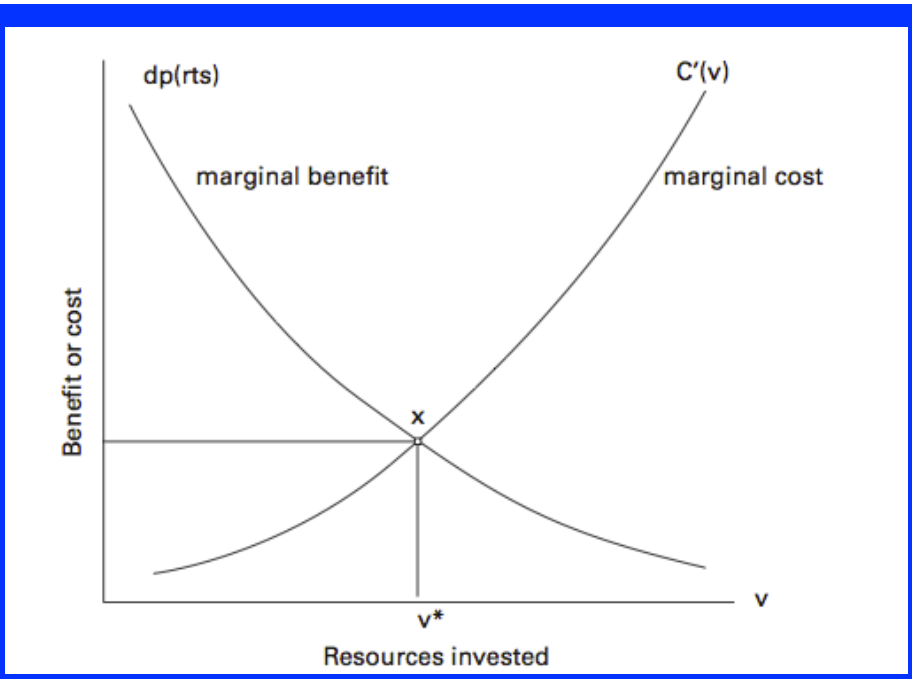
Criterion: inflict unacceptable damage even after attack

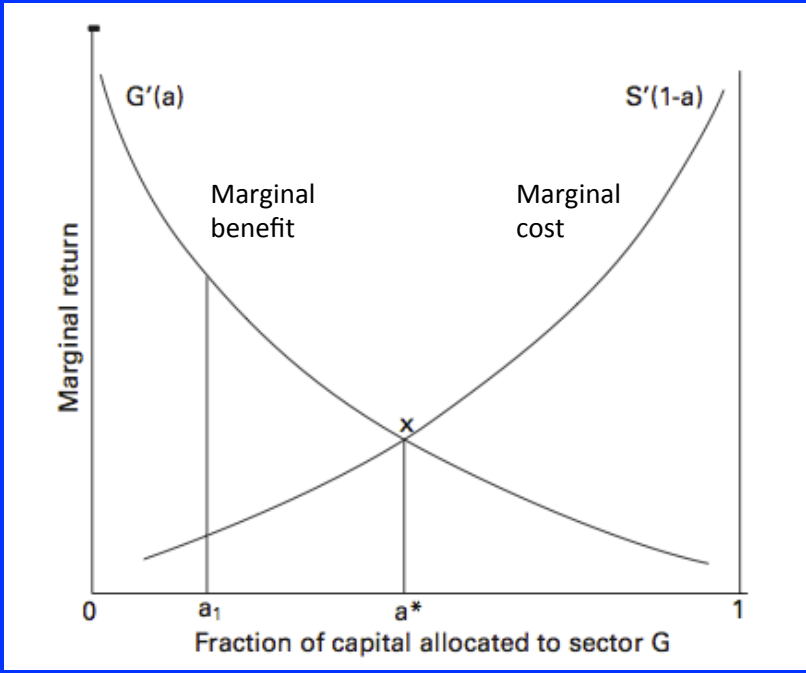
1-megaton equivalent, deliverable warheads	% Industrial capacity destroyed
100	59
200	72
400	76
800	77
1200	77
1600	77

Enthoven and Smith, 1971

PAN T7.1

Costs of exceeding 400 Mt offer little "benefit"





PAN 7.2. Marginal return on capital invested for sectors G and S. a* is the optimum allocation of capital between the sectors.

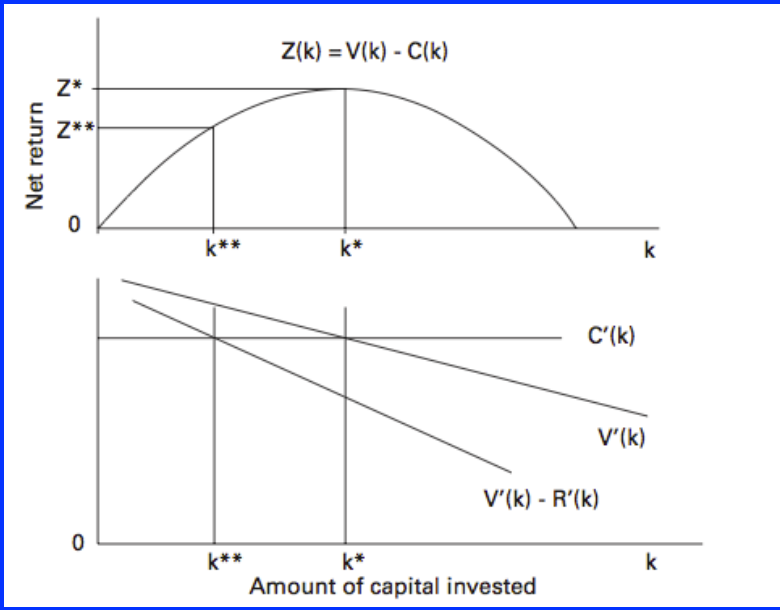
Risk Aversion

Risk aversion can be described as a case in which one will not accept a fair bet, in which chances of winning and losing are equal.

For example, imagine you are invited to bet on flipping a coin, so you win $h if a head turns up, and lose the same amount if a tail turns up. Because the two outcomes are equally likely, this is a fair bet. If *h* was small, say $1, you would probably accept the bet.

However, if *h* is a large sum, you would be reluctant to take the bet, because you could lose a lot. You only accept the bet if you win more, say *h* + *R*, if a head occurs than the h you lose on a tail.

The difference R needed for you to take the bet represents risk aversion.



PAN 7.3. Top: In the absence of uncertainty and risk aversion, the maximum return less the cost of capital occurs for *Z(k*) = V(k*) – C(k*).* Bottom: This optimum occurs where the marginal return equals the marginal cost of capital, *V'(k*) = C'(k*).* Including uncertainty and risk aversion reduces the optimum to k, given by *V'(k**) - R'(k**) = C'(k**)* .**

Present and Future value

In natural hazards planning, we use resources today to address possible future threats. It is thus important to consider the difference between the value of a sum today and in the future. If we take a sum today, y(0), and invest so it grows at an interest rate i, it will be worth

$$y(t) = y(0)(1+i)^t$$ at a future time t

$100 invested at 5% interest will be worth $432 in thirty years, because of compounding - we earn interest both on the original sum and on the interest already earned. As an old line says, the eight wonder of the world is compound interest.

Conversely, the present value of a sum y(t) at time t in the future is

$$y(0)=y(t) / (1+i)^t$$

Assuming 5% interest, the present value of $100 thirty years from now is $23. The present value is how much we would invest today to get a certain sum at a future time.

These have to be included in evaluating how much to spend today to reduce future damage. For example, it would not make sense to spend $50 today to avoid $100 damage 100 years from now, because $50 is more than the present value, $0.77. Investing the $50 would yield much more than $100. The issue is more complicated when considering reducing damage that can occur in any year between now and a future time.

Typical projects have costs and benefits spread out over time.

For example, a hurricane protection system involves large initial costs and annual maintenance costs. The benefits, reduced losses if a major hurricane strikes, occur in the future. The costs and benefits can be compared using the present value of net benefits

$$PVNB = \Sigma_{t=0\ to\ T} (B_t - C_t)/(1+i)^t = L_T D_T$$

Assume the major costs are incurred in year 0, and from then on annual costs and benefits are the same.

We don't know when there will be benefits, so we use the average rate of major events, such as the rate of storms of different sizes, to find the probability that one will happen in any one year. The expected benefit, the sum of the probabilities of an event of a given size times the anticipated loss reduction in such an event, is

$$PVNB = C_0 + (B_T - C_T) \Sigma_{t=1 \text{ to } T} \, 1/(1+i)^t = C_0 + (B_T - C_T) D_T$$

$$D_T = \Sigma_{t=1 \text{ to } T} \, 1/(1+i)^t \approx 1/i \quad \text{for T large}$$

For interest rate i=0.05, D_T = 15.4 for 30 years, and 19.8 for 100 years.

$$D_T = \Sigma_{t=1 \text{ to } T} \, 1/(1+i)^t \approx 1/i \quad \text{for T large}$$

reflects the decreasing present value of future benefits. The expected net benefit over 30 years, for 5% interest, is 15 times the annual benefit, not 30 times. Beyond 100 years, there is little and eventually no net increase in benefit, because the present value is so small.

However, it still can make sense to prepare for events that might happen less often than once every 100 years, because they could happen next year or ten years from now.

Valuing lives

Some of mitigating hazards comes down to how much society is willing to spend to save lives, so difficult choices involving lives often have to be cast in financial terms.

One way is to compare the cost of saving lives in various ways. Although these estimates have uncertainties, often the differences are large enough to show that some methods are more cost-effective than others.

For example, it has been estimated that seat belts in cars cost about $30,000 for each life saved, while air bags cost about $1.8 million for each life saved.

We value our own lives when we decide how much life insurance to buy. Hence as adults get older, they typically reduce the amount of life insurance they carry.

We also value our lives by deciding how much to spend on safety features in cars or other products we buy. For example, if we will pay $50 but no more for a feature that has a 1/100,000 chance of saving our lives, we are implicitly valuing our lives at $5 million.

Typically, the value used by U.S. government agencies to decide whether to require a life-saving measure is about $5 million per life. Thus a proposal to require mattresses less likely to catch fire was estimated to cost $343 million, but was viewed favorably because it was estimated to save 270 lives per year. In contrast, seat belts are not required on school busses because they were estimated to save one life per year at a cost of $40 million.

CQ: Germany is debating a speed limit for the autobahn system to save lives. In general, lower speeds save lives.

For example, in 1991 130 km speed limit was introduced on a 167 km section of the A61 in Rheinland-Pfalz combined with a ban on overtaking heavy trucks. The result of both these measures was a 30% reduction in fatal and severe injury accidents.

Another datum is that the European Transport Safety Council found that of the 645 road deaths in Germany in 2006, 67% occurred on on motorway sections without limits and 33% on stretches with a permanent limit. However, 33% of German motorways have a permanent limit and 67% have either a temporary limit or none means that these figures.

How do you interpret these two pieces of information? Would you favor a speed limit or not? Why or why not?

Implications for Natural Hazard Mitigation

Although for natural hazards we rarely know enough to do detailed calculations, organized thinking about a problem that considers various options is likely to yield better decisions.

It is unrealistic to think that we can find an optimum strategy, but simple estimates can show which strategies make more sense than others and identify sensible strategies.

Some thoughts:

- We should think about the entire system, rather than isolated aspects. For example, considering whether building levees to protect communities from river flooding makes economic sense requires also considering the extent to which the levees promote further growth in vulnerable areas, which will eventually flood. Moreover, the levees raise water levels, so floods downstream will be higher. Sensible policy requires considering these factors together.

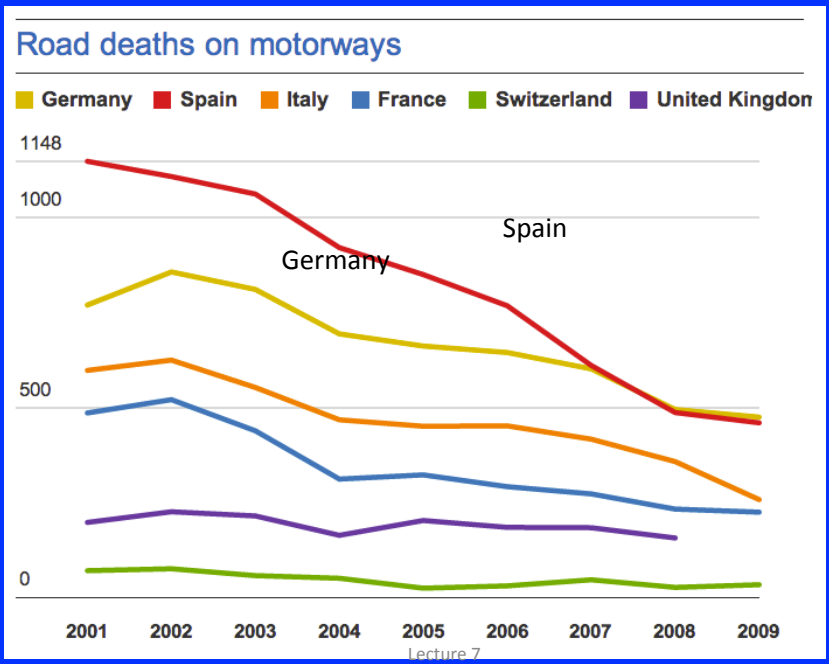
- Costs and benefits are hard to estimate precisely.

It is hard enough to estimate the value of the financial quantities involved, but even harder to value lives or intangibles such as the esthetic cost of building a huge seawall along an attractive shore. Different people and societies value things differently. Moreover, some people's costs are other people's benefits. Money spent on a seawall is a cost to society as a whole, but a benefit to the contractors who build it.

- Careful analysis is only useful if those making policy are willing to ask key questions and consider alternatives.

If those in charge are committed already to a policy – which is often the case in government – demonstrating its weaknesses is likely to have no effect.

CQ: Deaths from highway accidents been steadily in Europe. How would you decide what is causing this? What might cause the difference in the rate of decline between Spain and Germany?

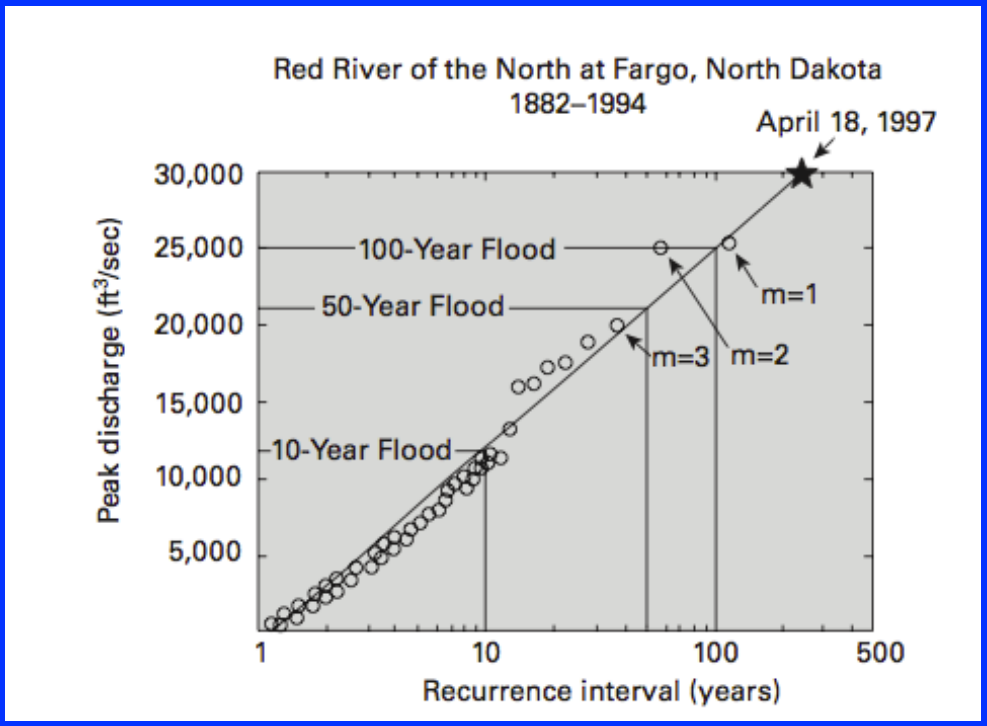


8: Guessing the odds

"All models are wrong. Some models are useful."

George Box, statistics pioneer

Fargo, ND
3/28/2012
Weather.com



PAN 8.1: Estimation of flood frequency from a long-term record (Baer, SERC).

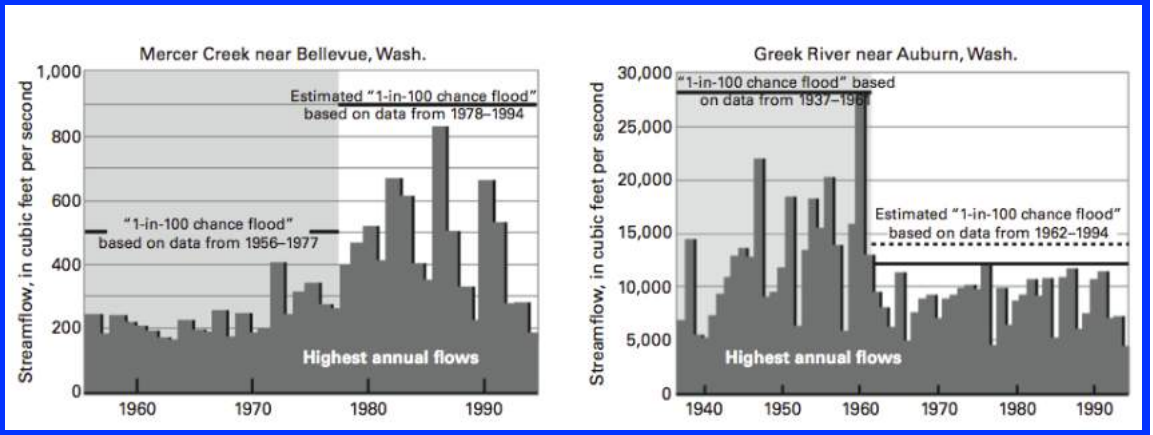
100 year flood

p – probability in 1 year = 1/100 = 0.01
q – probability of not happening in 1 year = 1-p
P(n,p) probability of at least 1 event in n years
= 1 – probability of none = $1 - q^n$

In 30 years P(30,p) = 0.26 = 26%
In 100 years P(100,p) = 0.63 = 63%

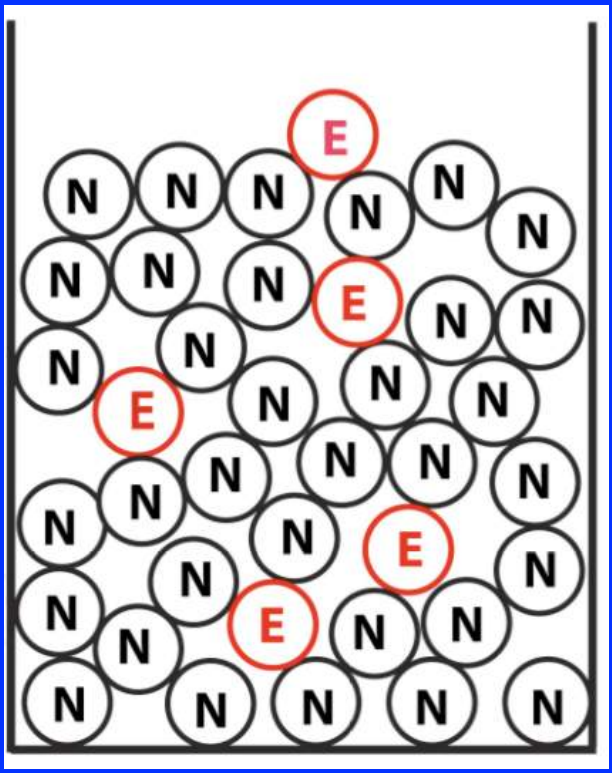
Contrary to our "intuition"

P(n,p) is not equal to np (100 x 0.01 = 1)



PAN 8.2: Changes in flood frequency due to human activity (Dinicola, 1996).

PAN 8.3: A model for the probability of an event is drawing a ball from an urn filled with balls, some labeled "E" for event and others labeled "N" for none. (Stein and Stein, 2013a)

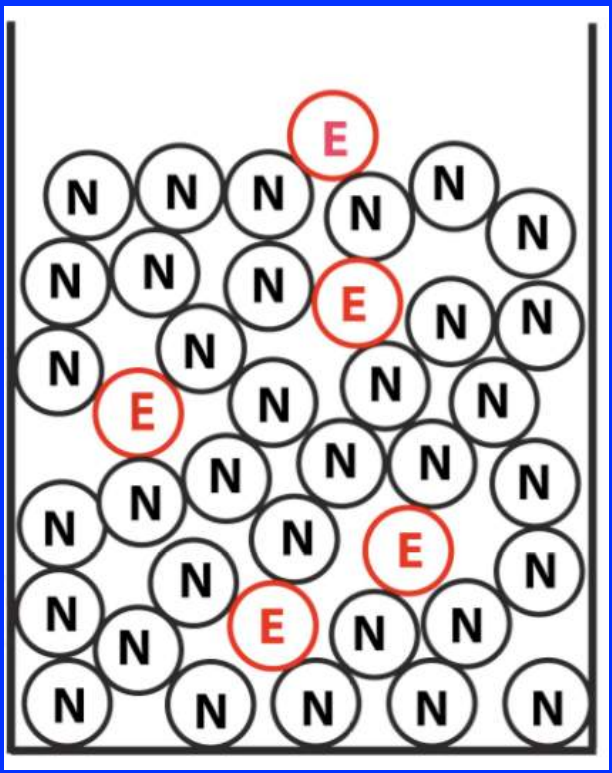


Time-independent probability

If after we draw a ball we put it back in, successive draws are independent because the outcome of one does not change the probability of what will happen in the next. Put another way, the system has no "memory."

The joint probability

$P(AB) = P(A)\,P(B)$



To estimate the probability of more than one event, we use the binomial probability distribution:

$$B(m, n, p) = C_{n,m} p^m q^{n-m} = \frac{n!}{m!(n-m)!} p^m q^{n-m}$$

giving the probability that in *n* trials there will be *m* events and (*n* − *m*) non-events.

p and *q* are the probabilities of an event and a non-event.

Cn,m is the number of ways we can have *m* events and *n* – *m* non-events, written in terms of factorials,
where $n! = n \times (n-1) \times (n-2) \ldots \times 3 \times 2 \times 1$ and $0! = 1$.

For example, in three trials we can get one event and two non-events in $C_{3,1} = 3!/(1!2!) = 3$ ways: ENN, NEN, or NNE, so we multiply p^1q^2 by 3.

The binomial distribution is complicated to compute, so an approximation is used when the number of trials *n* is large and the probability *p* of an event is small. In this case, because *n* >> *m*

$$\frac{n!}{(n-m)!} = \frac{n(n-1)\ldots(n-m+1)(n-m)!}{(n-m)!} = n(n-1)\ldots(n-m+1) \approx n^m.$$

and because *p* is small, we use a Taylor series

$$q^{n-m} = (1-p)^{n-m} = 1 - p(n-m) + p^2(n-m)(n-m-1)/2! + \ldots$$
$$\approx 1 - pn + (pn)^2/2! + \ldots \approx e^{-np}.$$

These let us replace the binomial distribution by another probability distribution that is easier to compute, called a *Poisson distribution*

$$P(m, t, \tau) = (t/\tau)^m e^{-t/\tau}/m!$$

The Poisson distribution can be written in terms of the probability of having m events in a time period t if on average they occur τ years apart. Because the expected number of events in the n trials is $np = t/\tau$,

$$P(m, t, \tau) = (t/\tau)^m e^{-t/\tau}/m! \tag{8.16}$$

The Poisson distribution is really a function of only two variables, the number of events m and the mean number expected $\mu = np = t/\tau$, so it is sometimes written as

$$P(m, \mu) = \mu^m e^{-\mu}/m!. \tag{8.17}$$

Poisson distributions are often used in hazard assessments. For example, between the years 1722 and 2005, 45 hurricanes are thought to have struck the central Gulf of Mexico coast, including New Orleans. These occurred on average 6.3 years apart, so the average number per year was 0.16. A Poisson model predicts that the probability that no hurricanes will strike in a year is $P(0, 0.16) = e^{-0.16} = 0.85$ or 85%, the probability of one is $P(1, 0.16) = 0.16\ e^{-0.16} = 0.136$ or 14%, and the probability of two is $P(2, 0.16) = (0.16)^2\ e^{-0.16}/2 = 0.011$ or 1%. The probability at least one will strike is one minus the probability that none will, 1– 0.85 or 15%.

In general, the probability of at least one event in t years if on average they occur τ years apart is 1 minus the probability of no events, so

$$P(m > 0, t, \tau) = 1 - P(0, t, \tau) = 1 - e^{-t/\tau} \approx t/\tau, \tag{8.18}$$

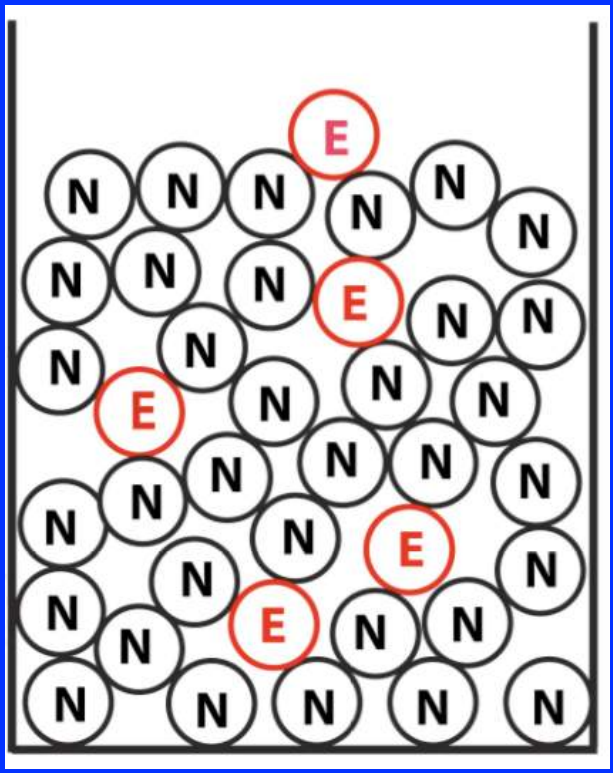
where the last step used the first term of the Taylor series expansion $e^{-x} \approx 1 - x$ and so is valid for $t << \tau$, or a time interval much shorter than the average time between events.

Thus if a large earthquake strikes an area on average every 100 years, a Poisson model predicts that the probability of one occurring in the next 10 years is $1 - e^{-10/100} = 0.095$, which is close to 10/100 or 0.1. However, estimating the probability of one occurring in the next 50 years requires using the full term $1 - e^{-50/100} = 0.39$, which differs from $50/100 = 0.5$ because 50 years is a large fraction of the average time, 100 years.

Poisson process used for time-independent probability

If after we draw a ball we put it back in, successive draws are independent because the outcome of one does not change the probability of what will happen in the next.

The system has no "memory,," so events can't be "overdue."



BBC NEWS

2005/02/11

Number 53 brings relief to Italy

The elusive number 53, blamed for several deaths and bankruptcies, has finally popped up in the Venice lottery after a two-year wait.

Italians had bet more than 3.5bn euros (£2.4bn), hoping that 53 would turn up, in what became a national obsession.

Last month a woman drowned herself in the sea off Tuscany after she bet the family savings on 53, Reuters reports.

And police said a man living near Florence shot his wife and son and then himself because of his number 53 debts.

The Italian national lotto invites bets of any amount on numbers from 1 to 90 in bi-weekly draws.

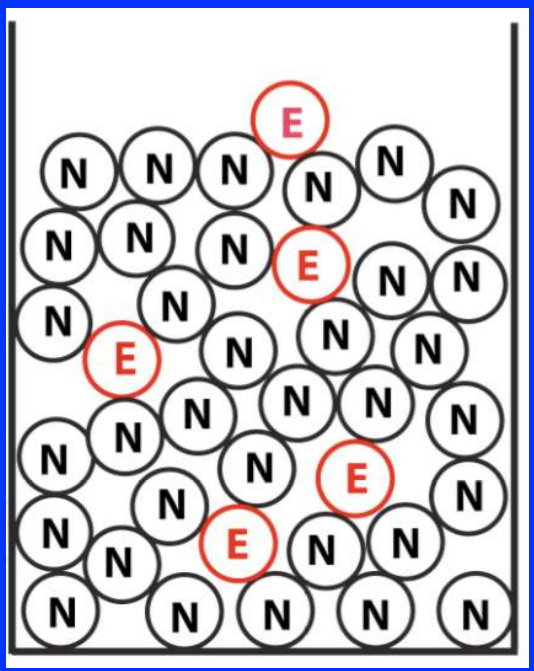
The draws take place in 10 cities across the country. For each draw, 50 numbers are picked, five in each of 10 cities.

A consumer group, Codacons, recently urged the government to ban the number 53 from the draw, to halt the country's "collective psychosis".

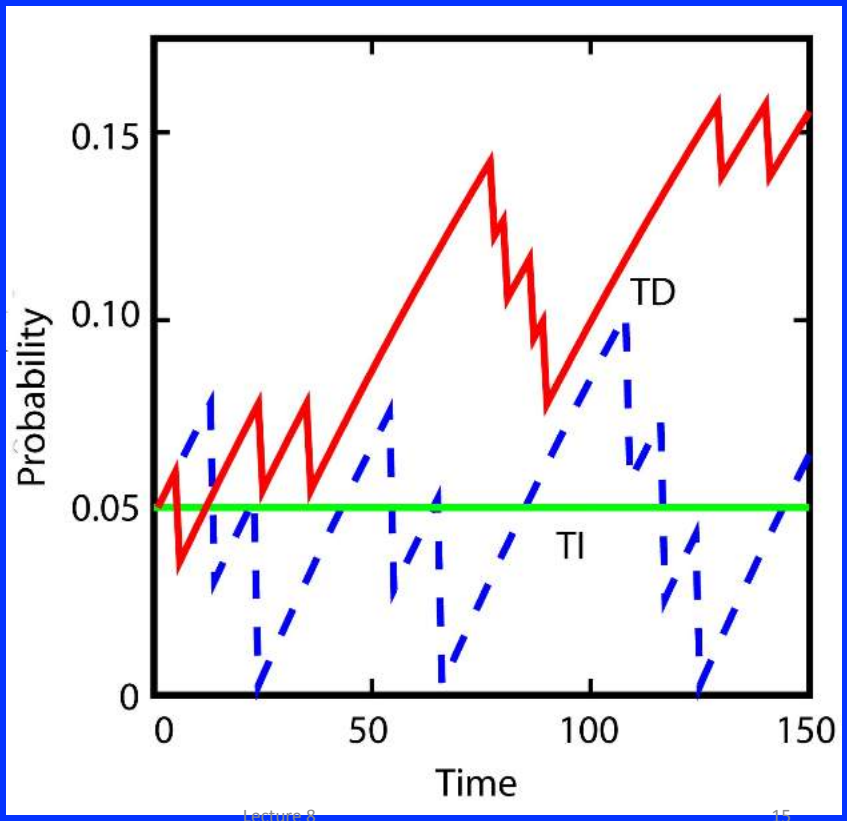
CQ: Give an example you have encountered of the "gambler's fallacy" and explain why it was wrong.

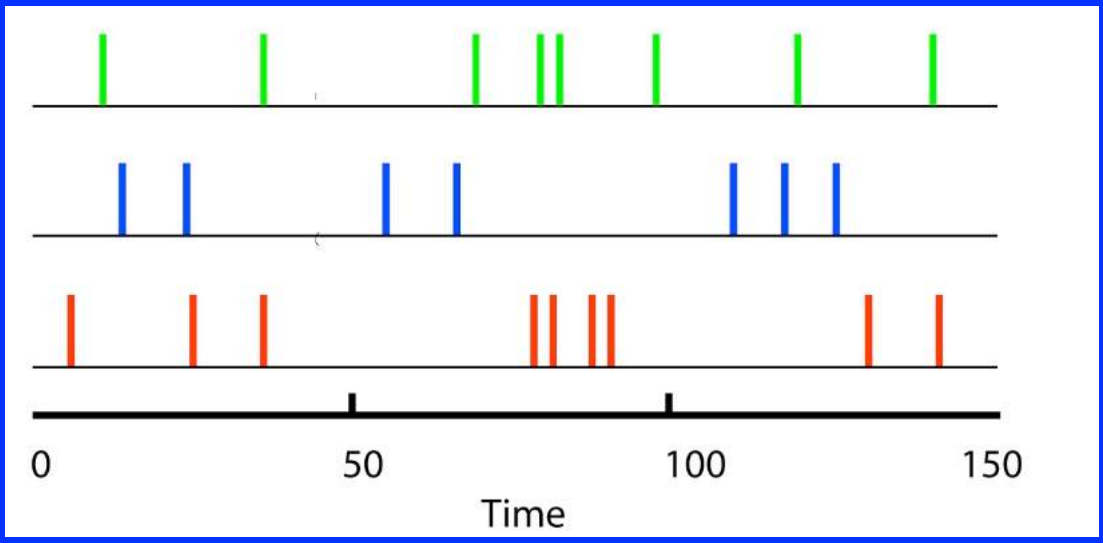
Time-dependent probability

We can add a number a of E-balls after a draw when an event does not occur, and remove r E-balls when an event occurs. This makes the probability of an event increase with time until one happens, after which it decreases and then grows again. Events are not independent, because one happening changes the probability of another.



PAN 8.4: Comparison of the probability of an event as a function of time for time-independent (solid line) and time-dependent (dashed lines) urn models. (Stein and Stein, 2013a)





PAN 8.5: Sequence of events as a function of time for the time-independent (top line) and time-dependent (lower lines) urn model runs in Figure 8.4. (Stein and Stein, 2013a)

Met Office apologises for warning of 'dry spell' before wettest April on record

The Met Office has admitted its advice to the Government to prepare for a dry spell before the wettest April on record last year was "not helpful" and long term forecasts in general are not always right.

It turned out to be the wettest April since records began in 1910. Photo: REUTERS/Olivia Harris

http://www.telegraph.co.uk/topics/weather/9961052/Met-Office-ap...

CQ: In March 2012, Britain's Meterological Office told the government *"The forecast for average UK rainfall slightly favours drier than average conditions for April-May-June, and slightly favours April being the driest of the three months."* Water companies prepared for water shortages.

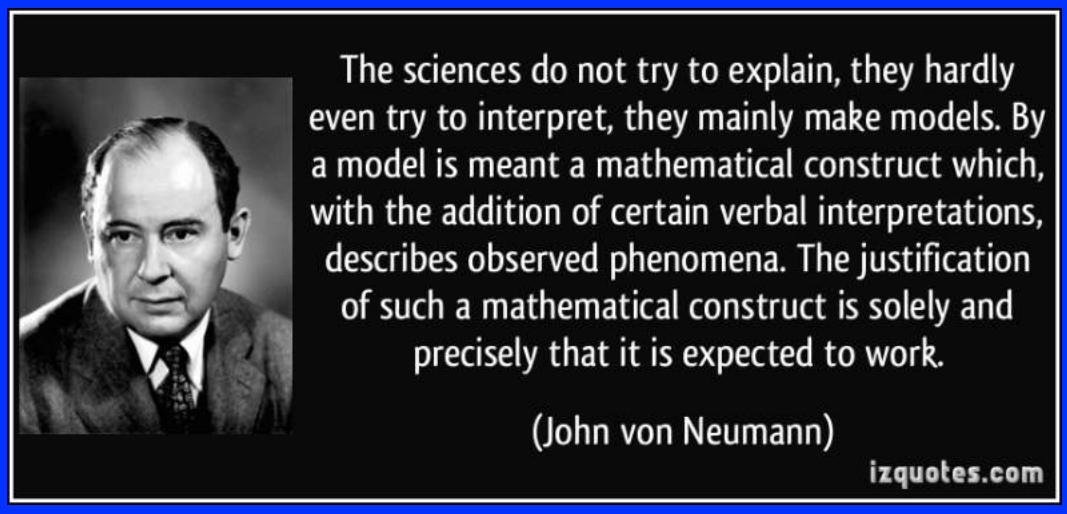
Later, the office admitted that *"Given that April was the wettest since detailed records began in 1910 and the April-May-June quarter was also the wettest, this advice was not helpful."*

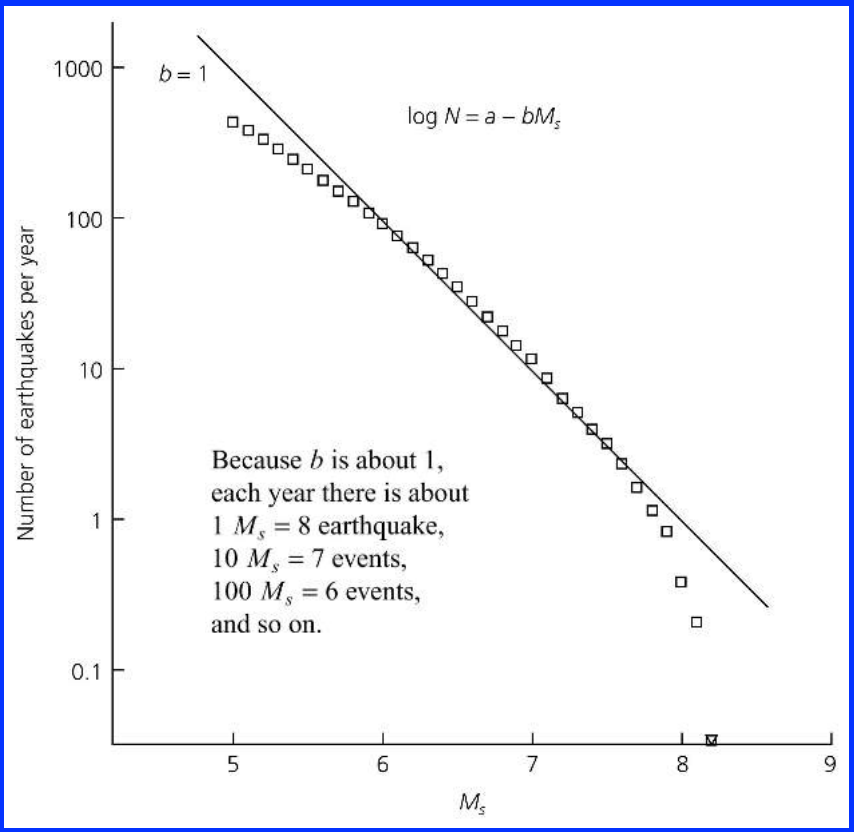
Its chief scientist stated "*The probabilistic forecast can be considered as somewhat like a form guide for a horse race. It provides an insight into which outcomes are most likely, although in some cases there is a broad spread of outcomes, analogous to a race in which there is no strong favourite. Just as any of the horses in the race could win the race, any of the outcomes could occur, but some are more likely than others.*"

How do you respond to these statements? What - if anything - would you suggest doing differently?

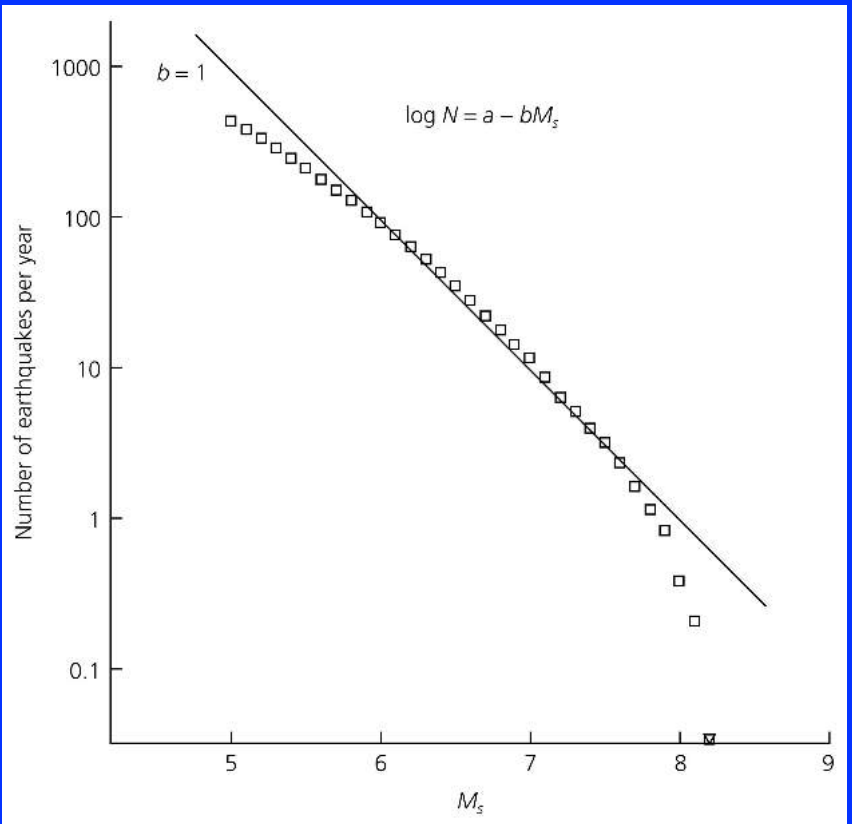
9: When's the next earthquake?

"With four parameters I can fit an elephant, and with five I can make him wiggle his trunk."
John von Neumann, mathematician





PAN 9.1: Frequency-magnitude plot for ~13,000 earthquakes with surface wave magnitude Ms ≥ 5.0 during 1968-1997. The line shown, with slope b about 1, fits the data reasonably well. (Stein and Wysession, 2003)



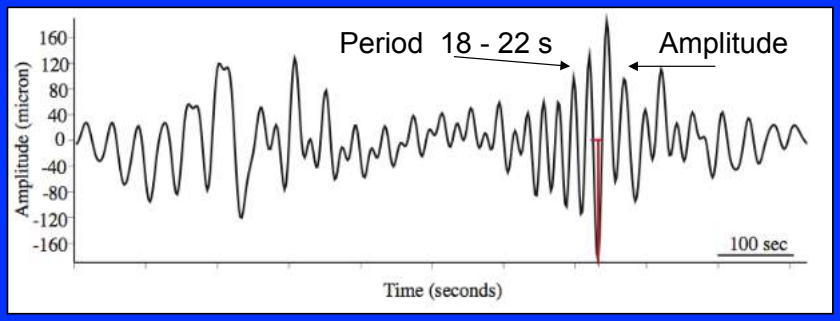
CQ: Why are the observed numbers of the largest and smallest earthquakes are less than predicted by the linear relation?

Surface wave magnitude (measured using the largest amplitude, zero to peak, of the surface waves):

$M_s = \log(A/T) + 1.66 \log \Delta + 3.3$ (general form)

$M_s = \log A_{20} + 1.66 \log \Delta + 2.0$ (for 20 second period Rayleigh waves)

(Δ is in degrees)



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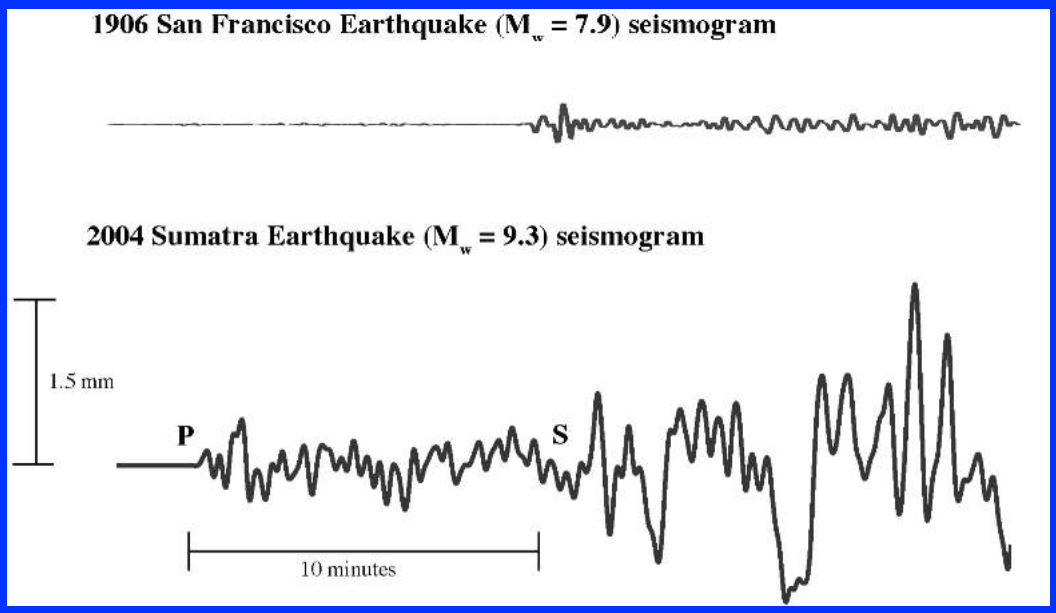
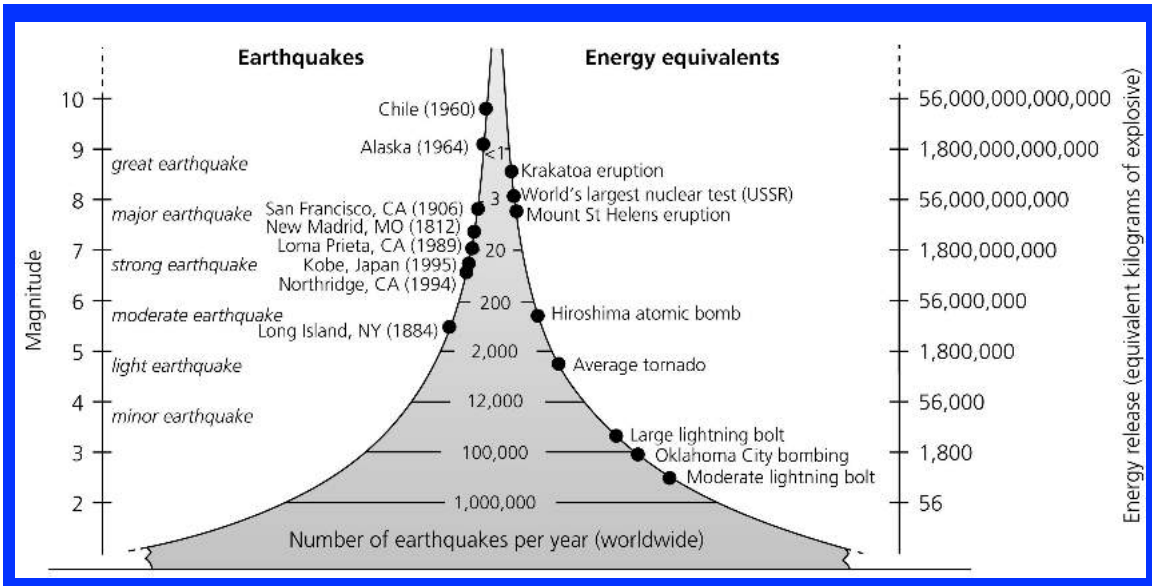


PAN 9.2: Comparison of seismograms for the 1906 San Francisco and 2004 Sumatra earthquakes, shown on the same scale. (Richard Aster)



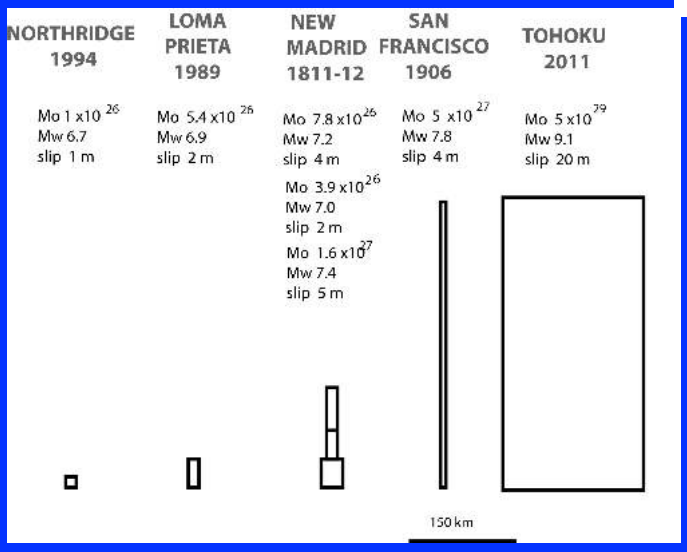
PAN 9.3: Comparison of earthquakes with different magnitudes in terms of how often they happen and the energy they release. (Stein and Wysession, 2003; after IRIS)

COMPARE EARTHQUAKES USING SEISMIC MOMENT M_0

$$M_0 = \mu \bar{D} S$$

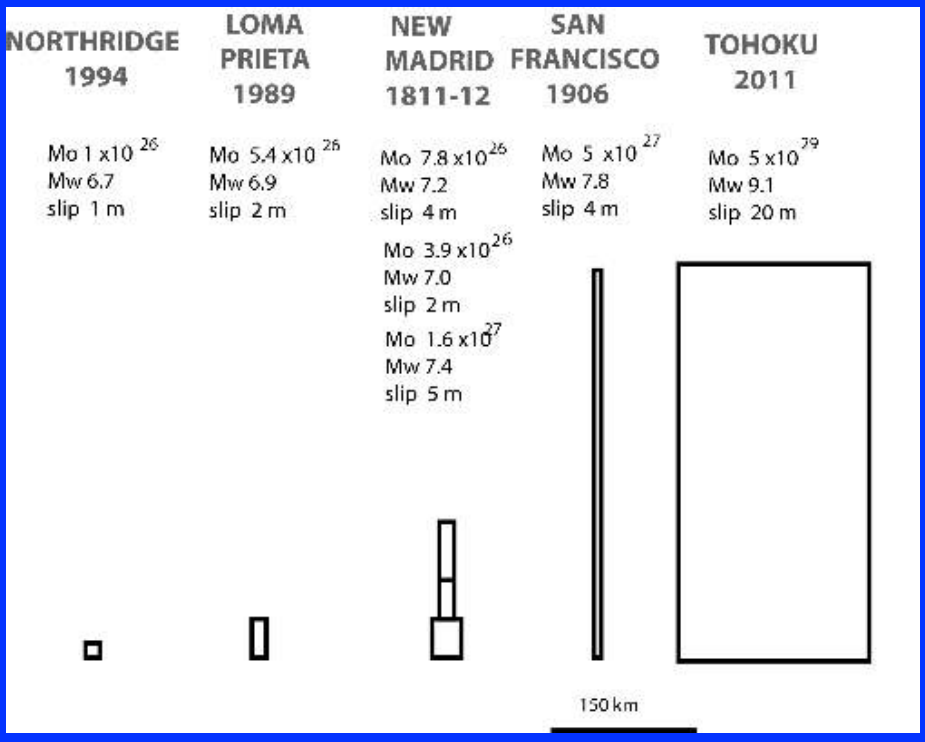
$\bar{D}$ = average slip (dislocation)

S = "average" fault area

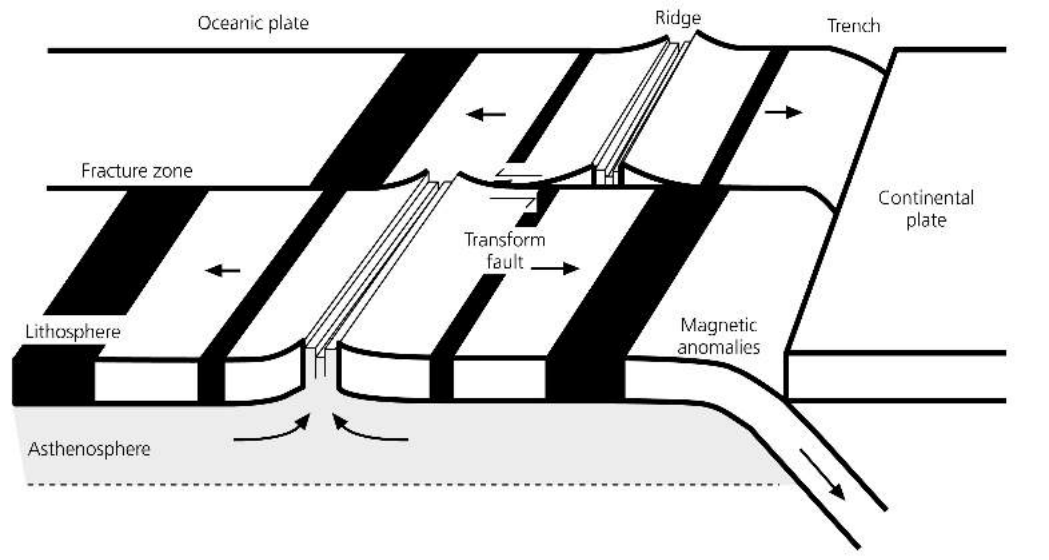


- Magnitudes, moments (dyn-cm), fault areas, and fault slips for several earthquakes
- Alaska & San Francisco differ much more than M_s implies
- M_0 more useful measure
- Units: dyne-cm or Nt-M
- Directly tied to fault physics
- Doesn't saturate

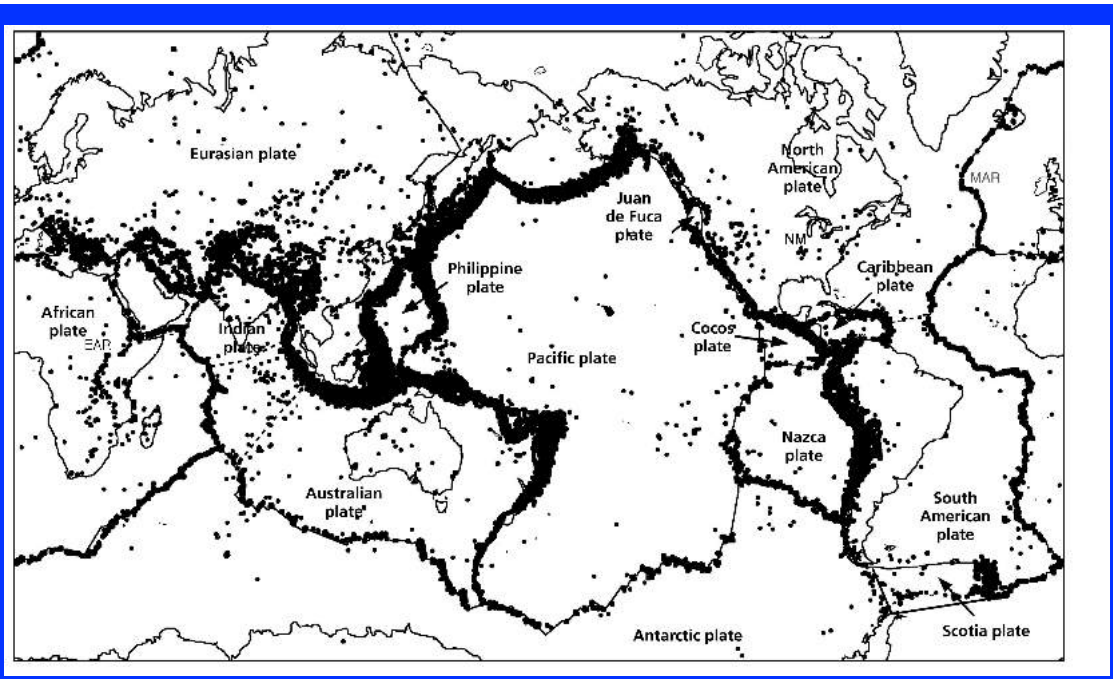
Stein & Wysession, 2003



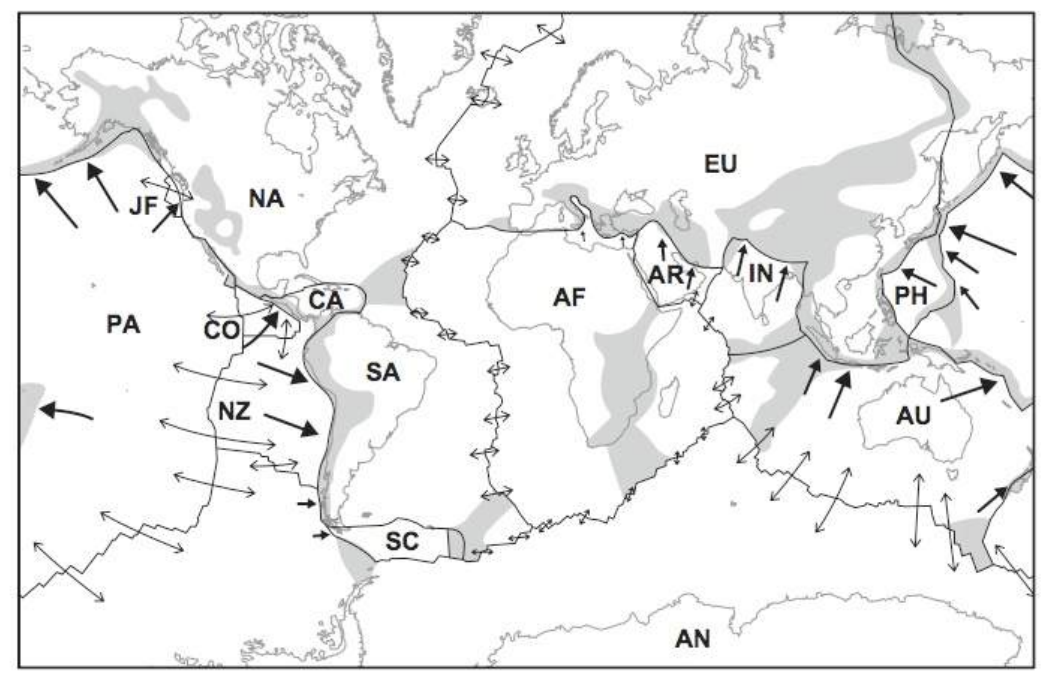
CQ: Why is the Tohoku earthquake so much bigger than the 1906 one?



PAN 9.5: Types of plate boundaries in oceanic lithosphere. Oceanic lithosphere is formed at ridges and subducted at trenches. At transform faults, plates slide by each other. (Stein and Wysession, 2003)



PAN 9.6: Map of major plates and earthquake locations, shown by dots. The earthquakes outline most plate boundaries. "NM" marks New Madrid. "MAR" is Mid-Atlantic Ridge. "EAR" marks the East African Rift. (Stein and Wysession, 2003)



PAN 9.7: Major plates and the relative motion at their boundaries. Arrow lengths show the speed. Diverging arrows show spreading at mid-ocean ridges. Single arrows on the subducting plate show convergence. Stippled areas are diffuse plate boundary zones. (Gordon and Stein, 1992)

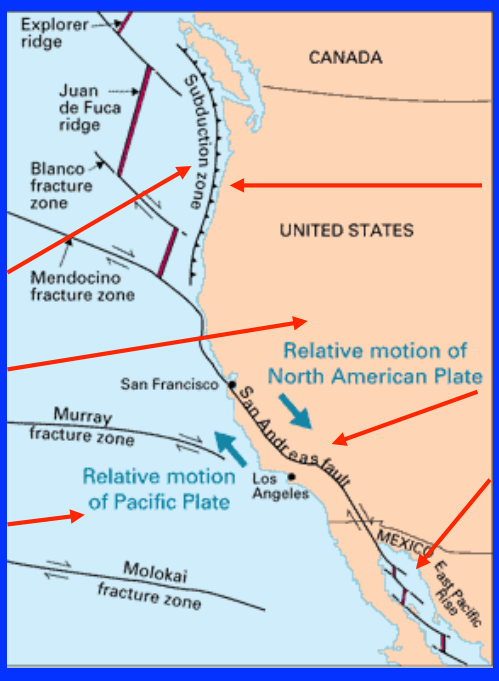
WESTERN NORTH AMERICA

Three Plates:

Juan de Fuca

North America

Pacific



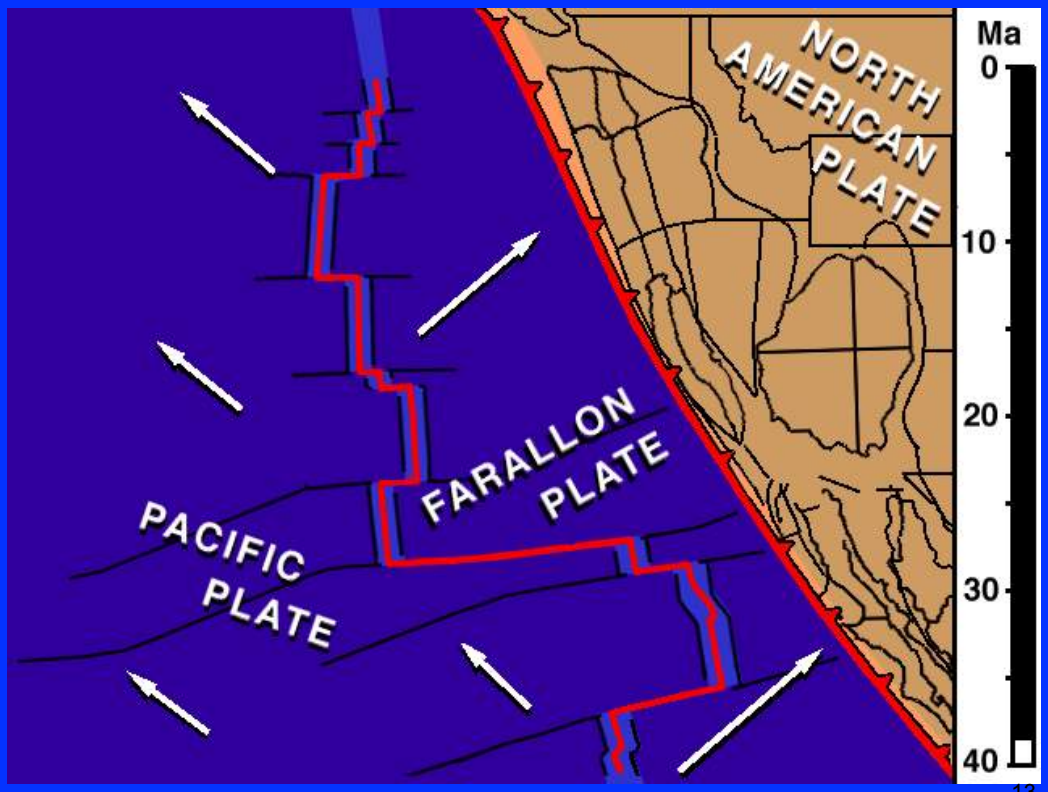
Three Boundaries:

Cascadia subduction zone

San Andreas transform

Gulf of California spreading center

12



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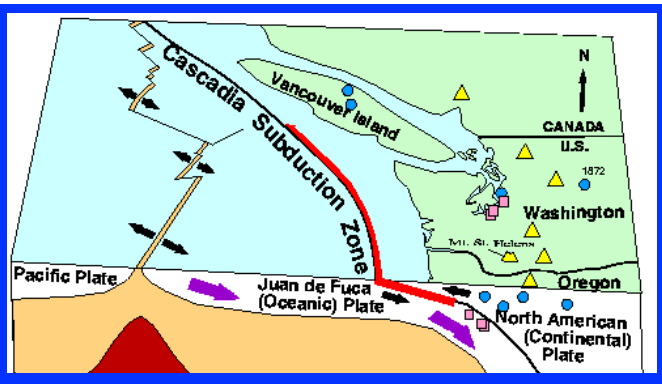
Atwater website

JUAN DE FUCA PLATE SUBDUCTING BENEATH NORTH AMERICA



2001 Nisqually earthquake ($2B damage)

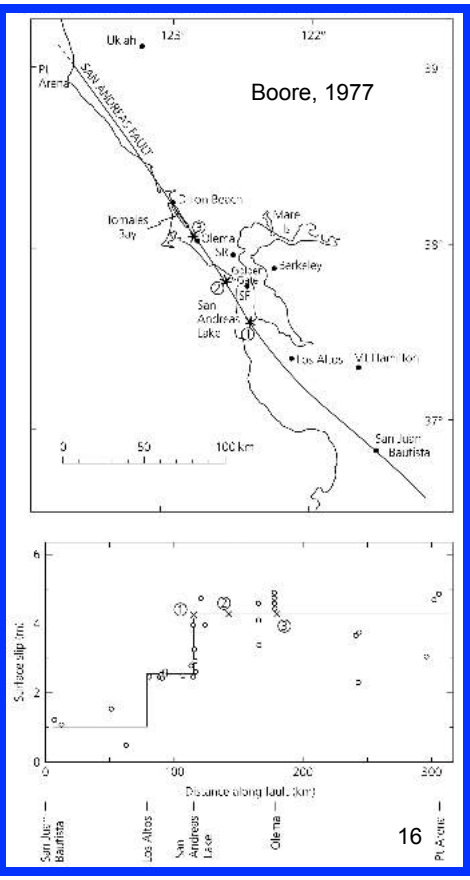
SAN ANDREAS FAULT

San Francisco Bay Area

1906 SAN FRANCISCO EARTHQUAKE (magnitude 7.8)

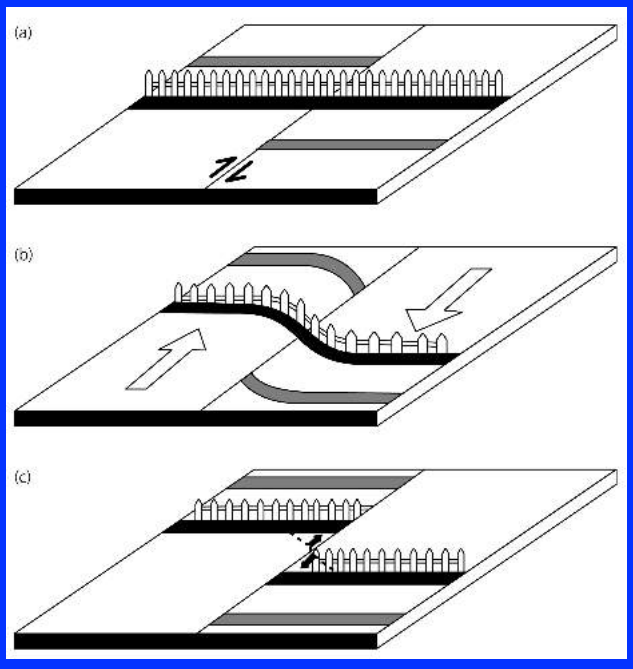
~ 4 m of slip on 450 km of San Andreas
~2500 deaths, ~28,000 buildings destroyed (most by fire)

Catalyzed ideas about relation of earthquakes & surface faults

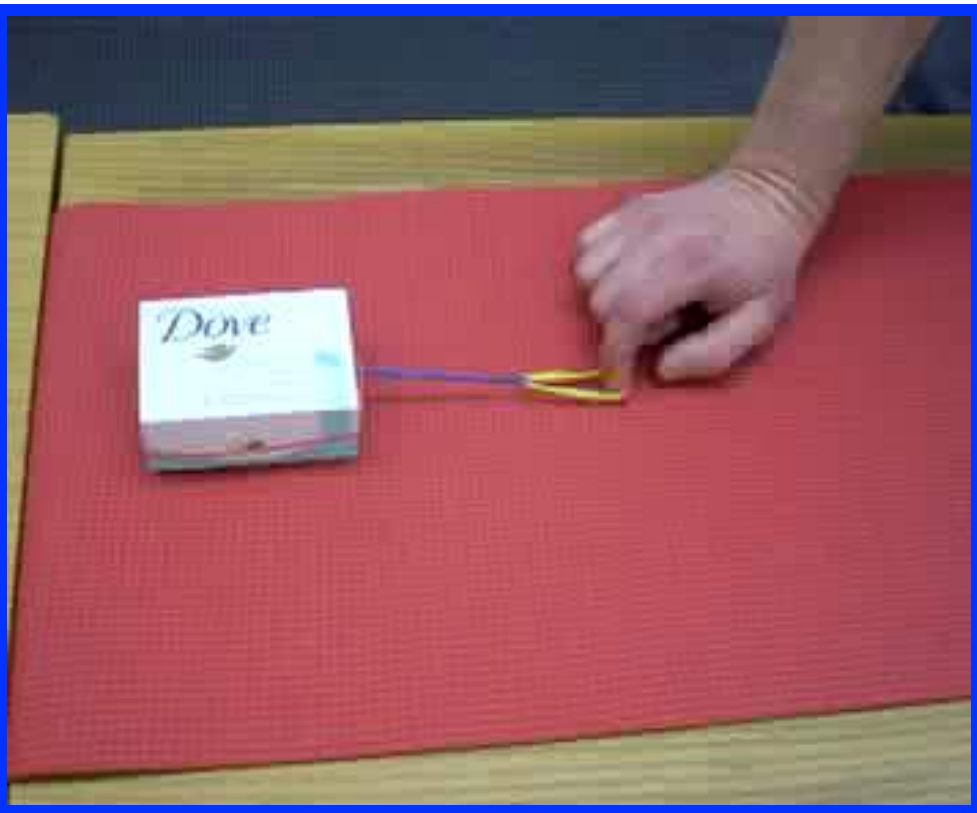


16

PAN 9.8: Left: Ground breakage along the fault trace. Right: A fence offset by the earthquake. (Commission report)



PAN 9.9: How elastic rebound works is shown by the history of a fence across a fault. (Stein and Wysession, 2003)



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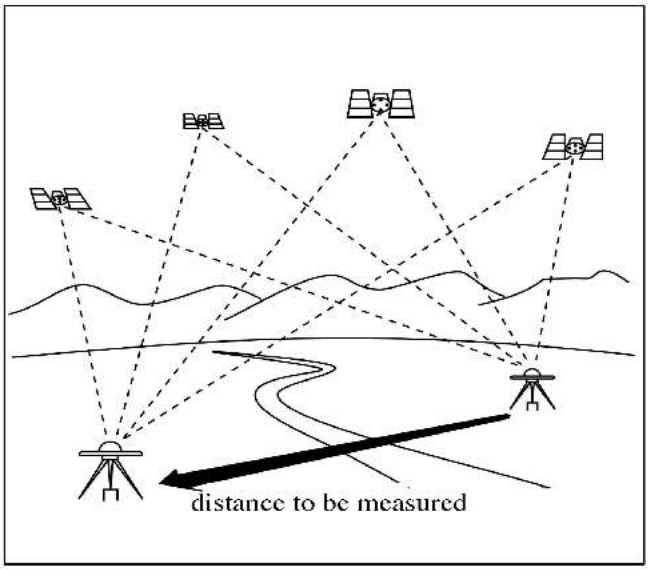
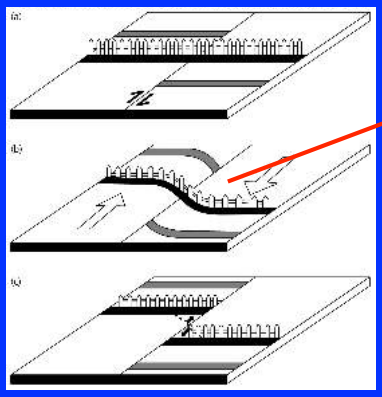
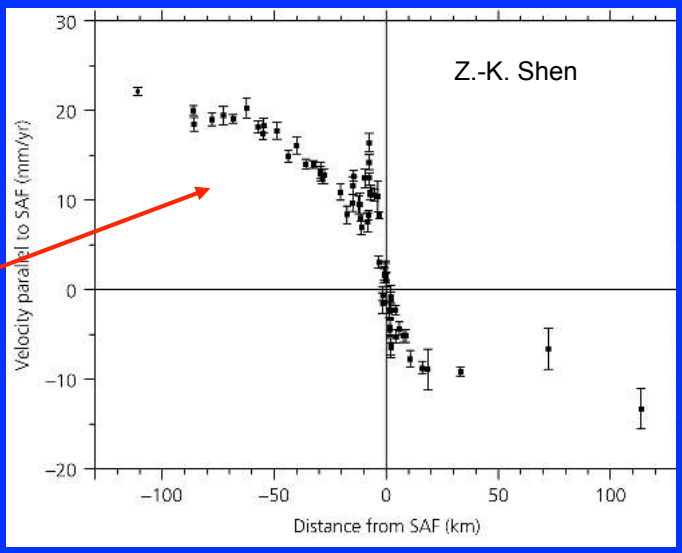


PAN 9.11: Using GPS signals, the positions of receivers measured over time give very precise velocities.

GPS site motions show deformation accumulating across the San Andreas that will be released in future earthquakes

Like a deformed fence





CQ: How fast is the motion?

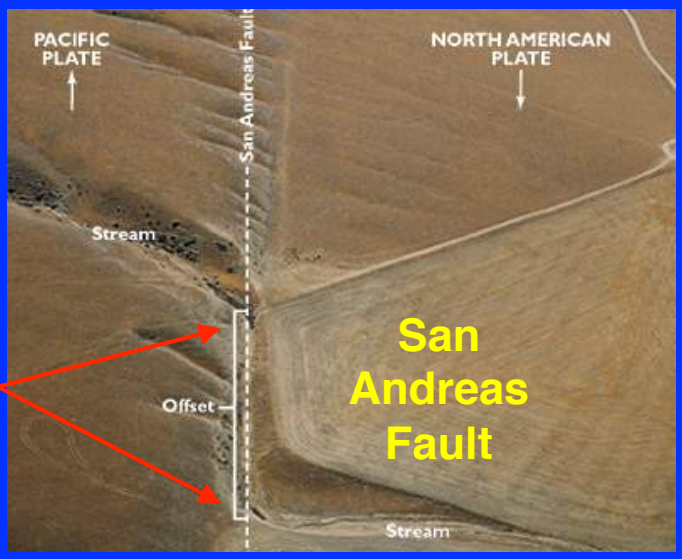
CQ: Longer term slip rate and earthquake recurrence on the San Andreas Fault

Wallace Creek is offset by 130 m

This offset developed over 3700 years

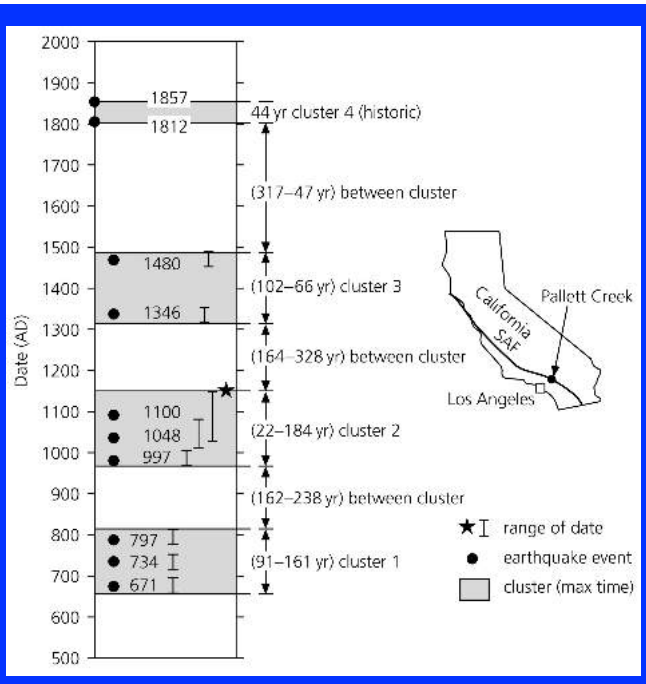
What's the average fault slip rate?

If this happens in large earthquakes with about 4 m slip, how often on average should they occur?



DD 9.8

Extend earthquake history with paleoseismology



M>7 mean 132 yr σ 105 yr

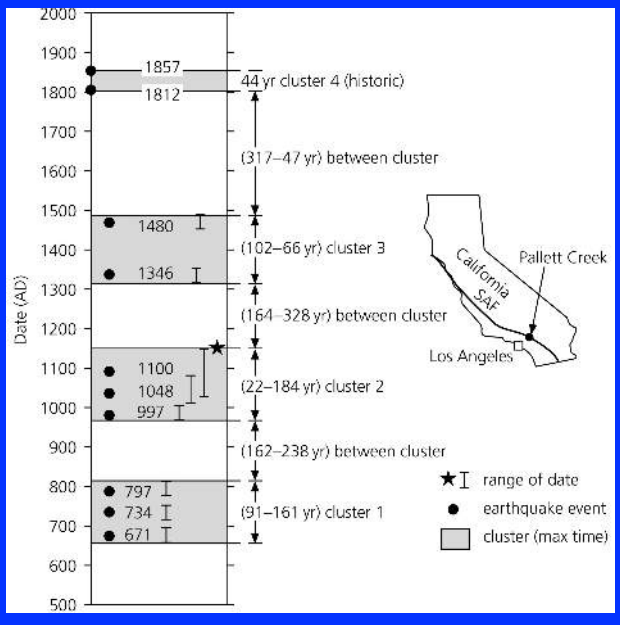
PAN 9.12

23

CQ: What would you tell residents about the prospect of a big earthquake? What does this say about predicting earthquakes?

"We are predicting another massive earthquake certainly within the next 30 years and most likely in the next decade or so."

W. Pecora, U.S. Geological Survey Director, 1969



M>7 mean 132 yr σ 105 yr

24

POISSON DISTRIBUTION

TIME INDEPENDENT MODEL OF EARTHQUAKE PROBABILITY

Used to describe rare events: include volcanic eruptions, radioactive decay, and number of Prussian soldiers killed by their horses

The simplest model describes earthquake occurrence by a *Poisson distribution* often used to describe rare events.[4]

We assume that the probability of n large earthquakes in an area or on a fault during time t is

$$p(n, t, \tau) = (t/\tau)^n \, e^{-t/\tau} \, / \, n!$$

where $1/\tau$ is the number expected in a year from the regional Gutenberg-Richter distribution or some variant, so τ is the mean recurrence time.

The probability of one or more earthquakes is found from the probability that none will happen using the certainty ($p = 1$) that an earthquake either will or will not happen, so

$$p(n \geq 1, t, \tau) = 1 - p(0, t, \tau) = 1 - e^{-t/\tau} \approx t/\tau,$$

where the last step used the Taylor series expansion $e^x \approx 1 - x$ and so is valid for $t \ll \tau$.

In this model, the probability that an earthquake will occur in an interval of time t starting from now does not depend on when "now" is, because a Poisson process has no "memory". On average, earthquakes are separated by time τ, but when the last earthquake occurred has no effect.

TIME INDEPENDENT (POISSON) VERSUS TIME DEPENDENT MODEL

The Poisson model is the simplest null hypothesis against which we can compare other models. However, its time-independence in which earthquakes are implicitly random events is not appealing, because almost all of our seismological instincts favor earthquake cycle models, in which strain builds up slowly from one major earthquake to the next.[5]

If so, the probability of a large earthquake should be small immediately after a large earthquake, and then grow with time. This is described by time-dependent models in which the probability of a large earthquake a time t after the past one is given by a probability density distribution $p(t, \tau, \sigma)$ that depends on the average and variability of the recurrence times, described by the mean τ and the standard deviation σ.

In other words, p gives the probability that the recurrence time for this earthquake will be t, given an assumed distribution of recurrence times.

GAUSSIAN DISTRIBUTION

TIME DEPENDENT MODEL OF EARTHQUAKE PROBABILITY

Probability of large earthquake a time t after the past one is p(t, τ, σ)

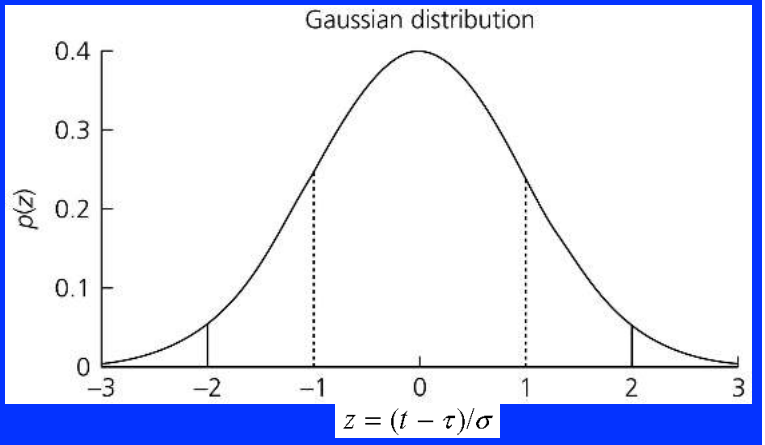
Depends on average and variability of recurrence times, described by the mean τ and standard deviation σ

p is probability that recurrence time for this earthquake will be t, given an assumed distribution of recurrence times.

This approach can be used with any assumed probability density function. The simplest is to assume that earthquake recurrence follows the familiar *Gaussian* or *normal* (bell curve) distribution

$$p(t, \tau, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[\frac{-1}{2}\left(\frac{t-\tau}{\sigma}\right)^2\right].$$

This distribution is often described using the normalized variable $z = (t - \tau)/\sigma$ describing how far, in terms of the standard deviation, t is from its mean.



CONDITIONAL PROBABILITY

Use the fact that we know the next earthquake hasn't already happened

The cumulative probability that the earthquake will occur by time T since the past earthquake is found by integrating the density function

$$P(T) = \int_0^T p(t, \tau, \sigma)\, dt.$$

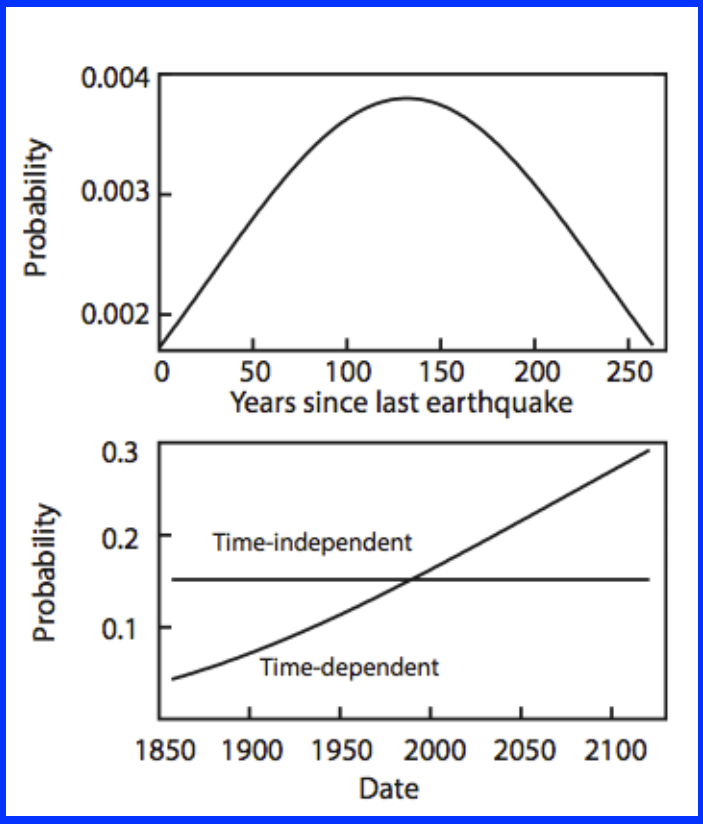
To estimate how likely an earthquake is between now and some future time, use the *conditional probability* that the earthquake will occur between time T_0 (now) and a future time T, given the condition that it has not yet happened by time T_0.

Bayes' theorem states that $P(A|B)$, the conditional probability of event A given that event B has occurred, is the ratio of the joint probability $P(A, B)$ of both A and B to $P(B)$, the probability of event B:

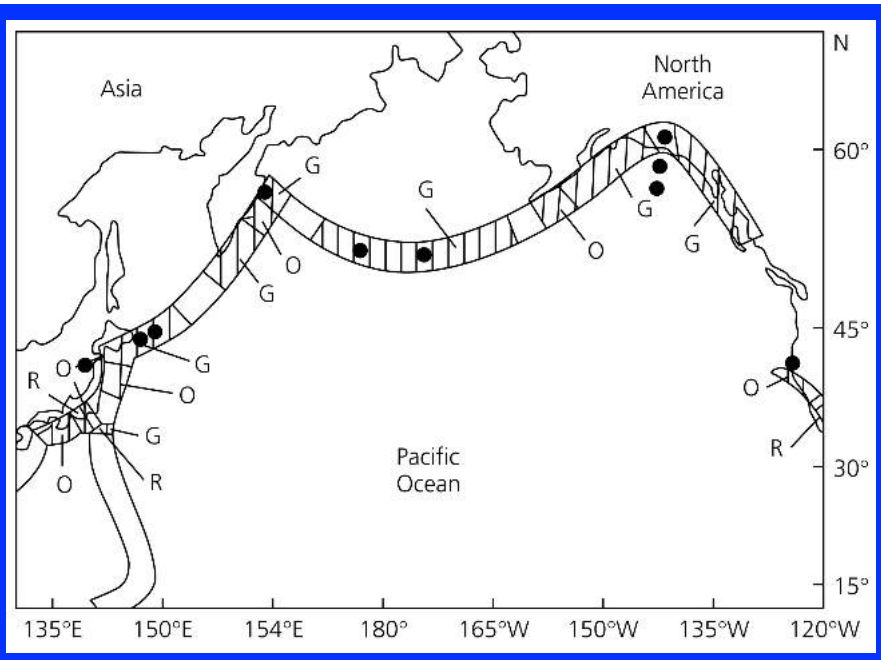
$$P(A|B) = P(A, B) / P(B).$$

Thus the conditional probability $C(T, T_0)$ that the earthquake will occur between T_0 and T is the ratio of the probability that it will occur in that interval to the probability that it has not yet happened by T_0, which is just 1 minus the probability that it has. Hence

$$C(T, T_0) = (P(T) - P(T_0)) / (1 - P(T_0)).$$



PAN 9.13: Top: Gaussian probability density function for recurrence times. Bottom: Conditional probability that the earthquake will occur in the next twenty years for two different models.

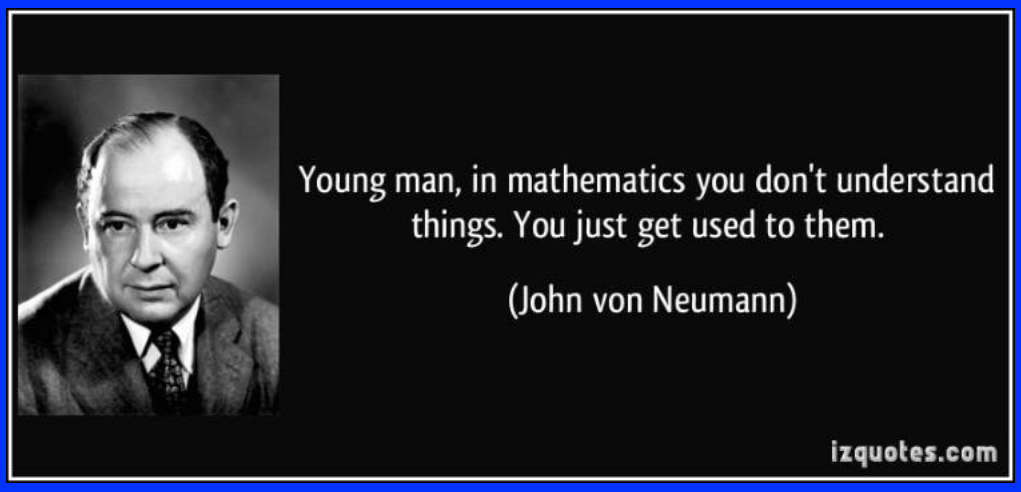


PAN 9.14: Portion of the seismic gap map used by Kagan and Jackson (1991) to test the gap hypothesis. The shaded segments of the plate boundaries had been assigned seismic potentials of high (red, R), intermediate (orange, O), and low (green, G). Unshaded segments were regarded as having uncertain potential. During the ten years following the map's publication, ten large (M > 7) earthquakes (dots) occurred in these regions. None were in the high- or intermediate- risk segments, and five were in the low-risk segments.

In 1906 G. K. Gilbert posed the crucial question

"*Must the citizens of San Francisco and the bay district face the danger of experiencing within a few generations a shock equal to or even greater than the one to which they have just been subjected? Or have they earned by their recent calamity a long immunity from violent disturbance? ...*

If a forecast of immunity shall not be warranted, the public should have the benefit of that information, to the end that it shall fully heed the counsel of those who maintain that the new city should be earthquake-proof. "



10: Assessing Hazards

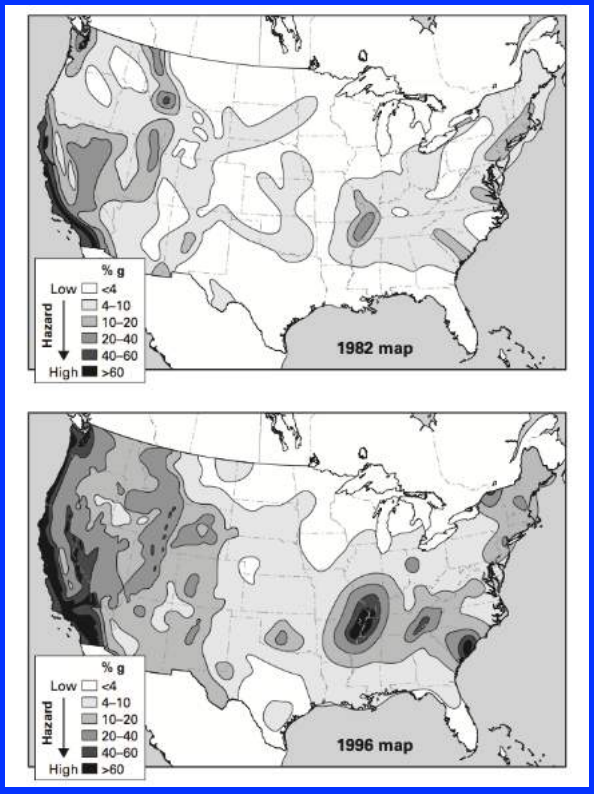
"There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know."

U.S. Secretary of Defense Donald Rumsfeld

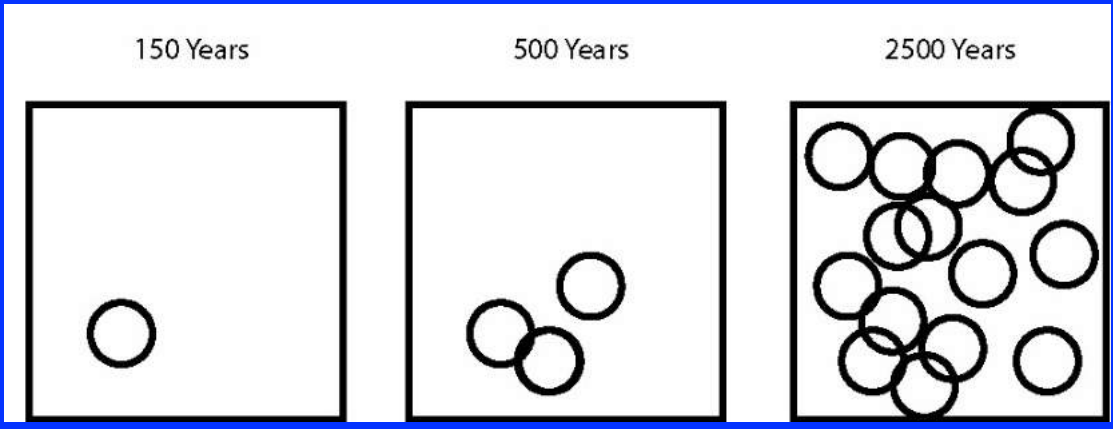
A natural hazard is not a physical quantity that can be measured. Instead it is a numerical metric chosen for use in mitigation planning and then estimated using a combination of data, the historical record, and models that are assumed to describe aspects of the process in question. As a result, how large a hazard is depends first on how it is defined.

Planning for floods, for example, is based on the water level expected on average at least once in a certain time period, typically 100 or 500 years, or equivalently at a certain probability in a given year. Depending on the application, different measures can be used. Following coastal flooding in 1953 that killed over 1,800 people, the Netherlands has installed systems to protect again the largest flood expected every 10,000 years. The same storm led to the construction of a moveable barrier in the Thames River, designed to protect London from flooding by the largest storm surge expected every 1,000 years.

http://www.youtube.com/watch?v=Dvg2asACsG0



PAN 10.1: Comparison of the 1982 and 1996 U.S. Geological Survey earthquake hazard maps for the US. The predicted hazard is shown as a percentage of the acceleration of gravity. Redefining the hazard raised the predicted hazard in the Midwest from much less than in California to even greater than California's. (Stein, 2010)



PAN 10.2: Schematic illustration showing how the predicted earthquake hazard increases for longer time window. The circles show areas within which shaking above a certain level will occur. (Stein, 2010)

Hazard maps are hard to get right: success depends on accuracy of four assumptions over 500-2500 years

Where *will large earthquakes occur?*

When *will they occur?*

How large *will they be?*

How strong *will their shaking be?*

Uncertainty & map failure result because these are often hard to assess

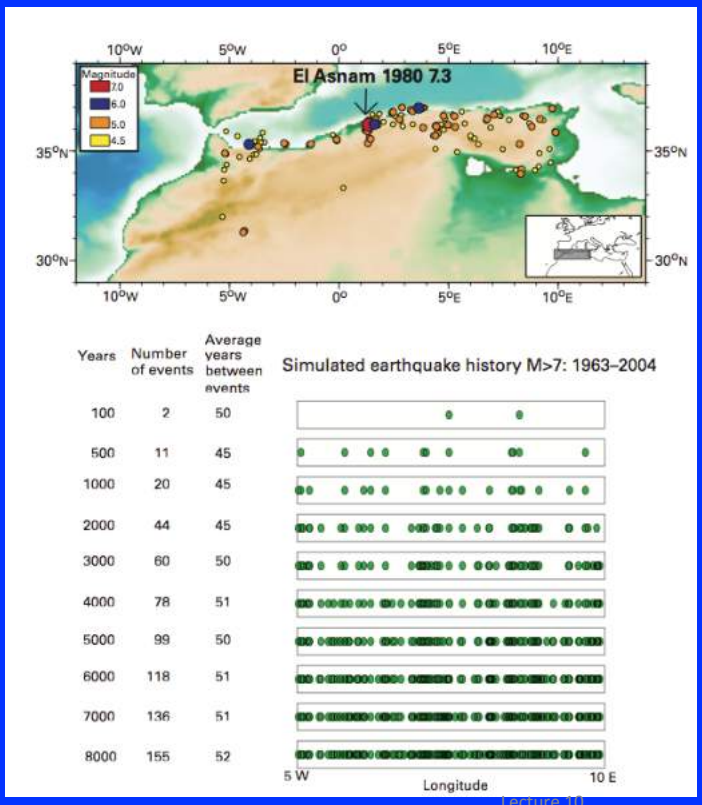
Hazard maps are hard to get right: success depends on accuracy of four assumptions over 500-2500 years

***Where** will large earthquakes occur?*

***When** will they occur?*

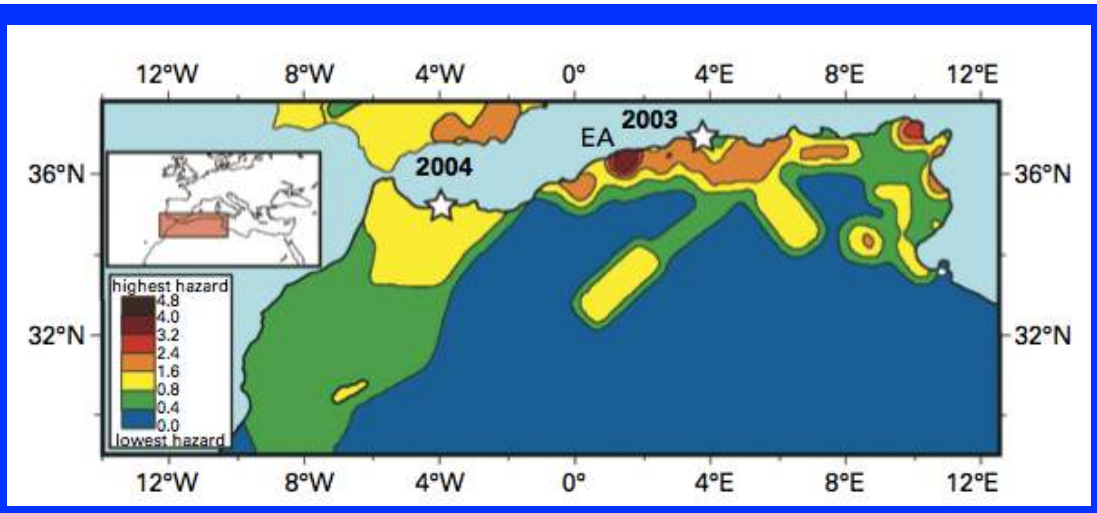
***How large** will they be?*

***How strong** will their shaking be?*

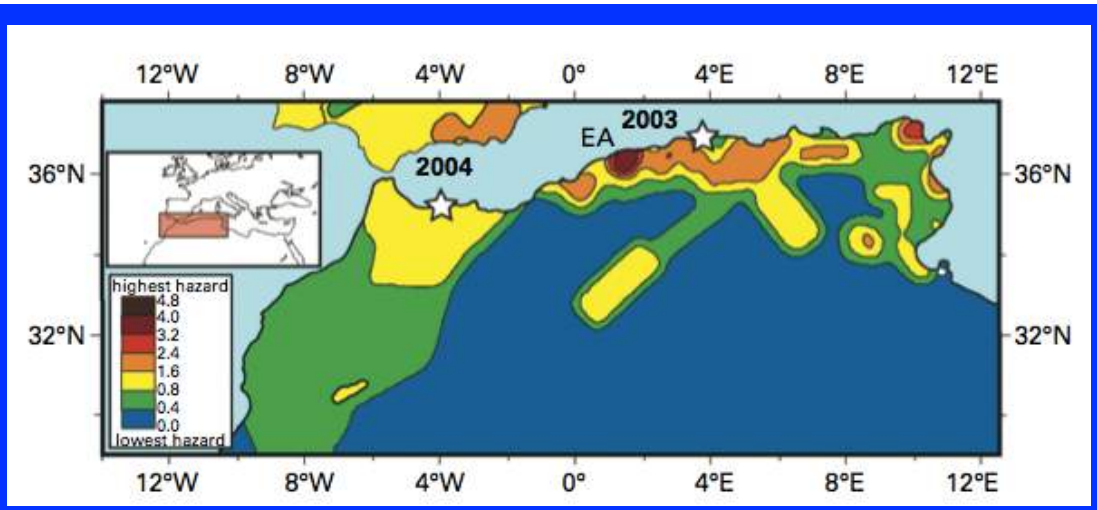


PAN 10.3: Seismicity along the North Africa plate boundary for 1963-2004.

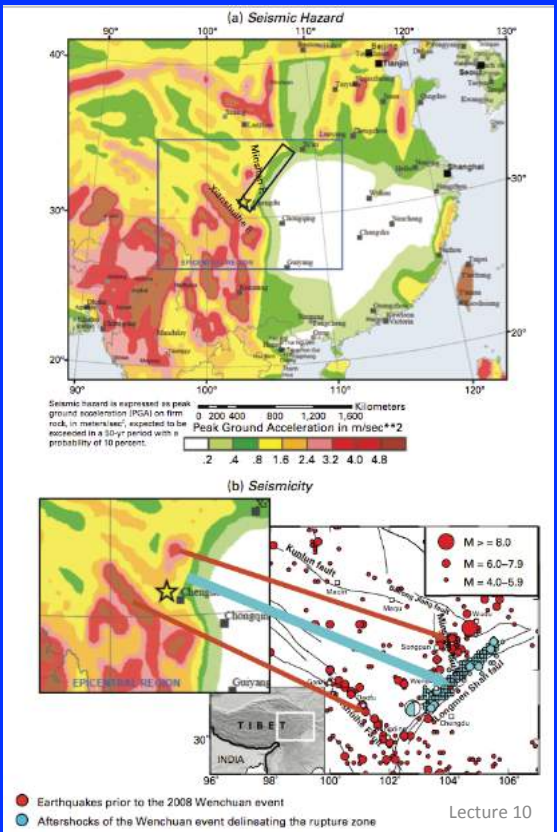
Simulations using a frequency-magnitude relation derived from these data predict that if seismicity is uniform in the zone, about 8,000 years of record is needed to avoid apparent concentrations and gaps. (Swafford and Stein, 2007)



PAN 10.4: Global Seismic Hazard Map (1999) for North Africa, showing peak ground acceleration in m/s² expected at 10% probability in 50 years. Note "bull-eye" at site of the 1980 Ms 7.3 El Asnam (EA) earthquake. The largest subsequent earthquakes to date, the May 2003 M 6.8 Algeria and February 2004 M 6.4 Morocco events (stars) did not occur in the predicted high hazard regions. (Swafford and Stein, 2007)

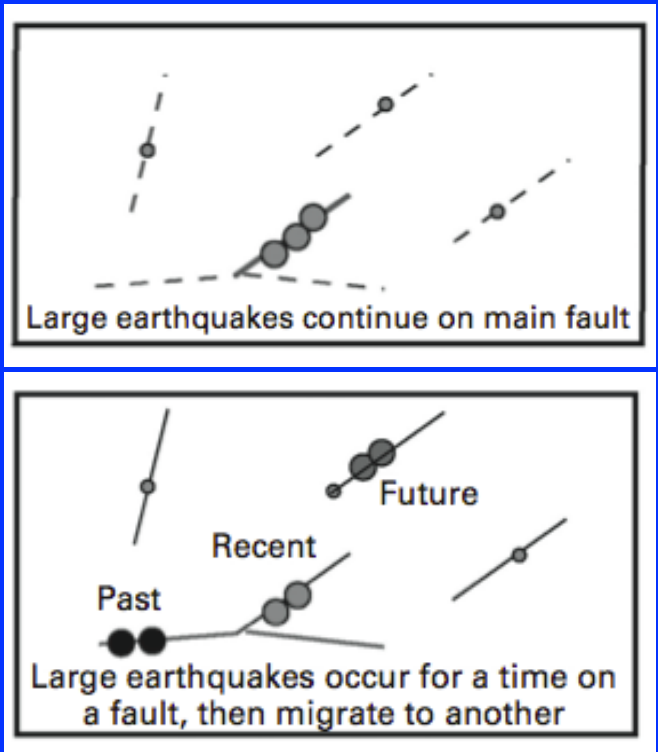


CQ: Earthquake hazard maps typically show high-hazard bull's-eyes at the locations of past large earthquakes. Are such maps being made with time-independent or time-dependent probabilities?

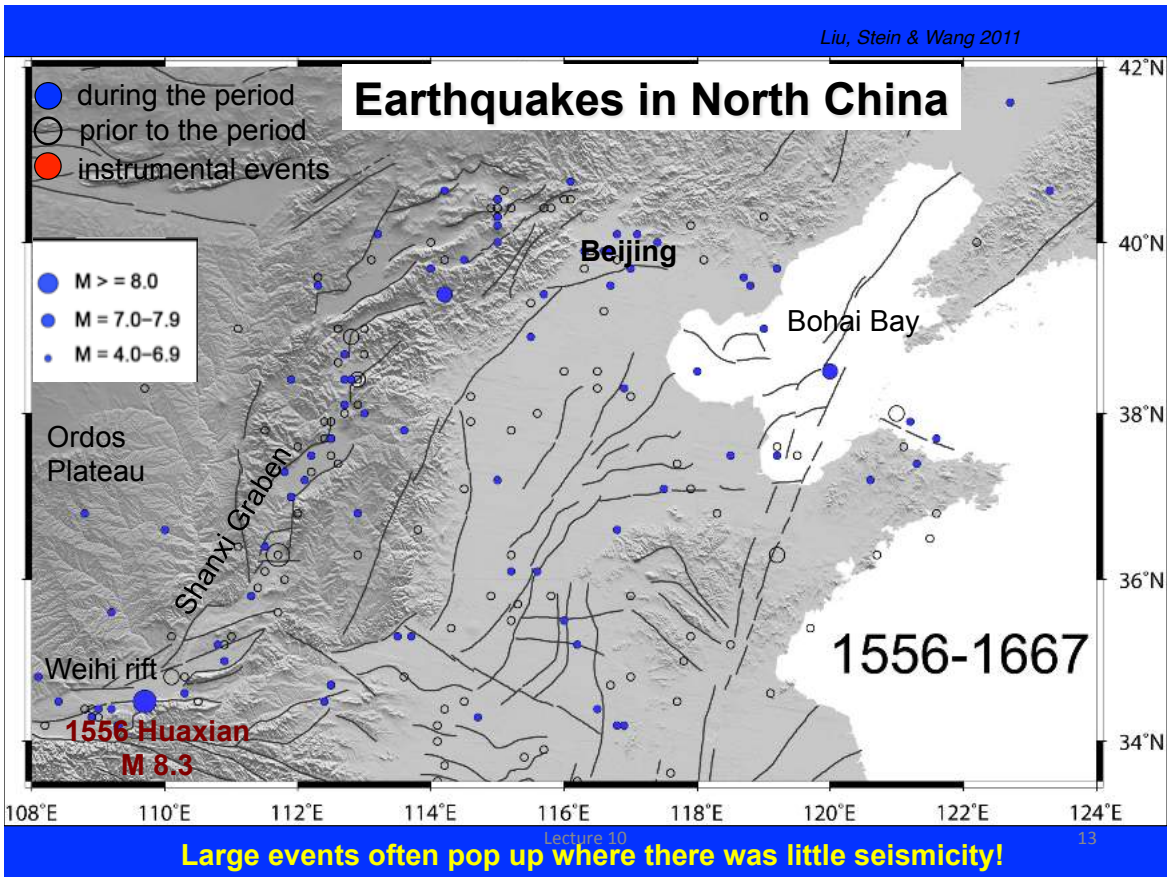


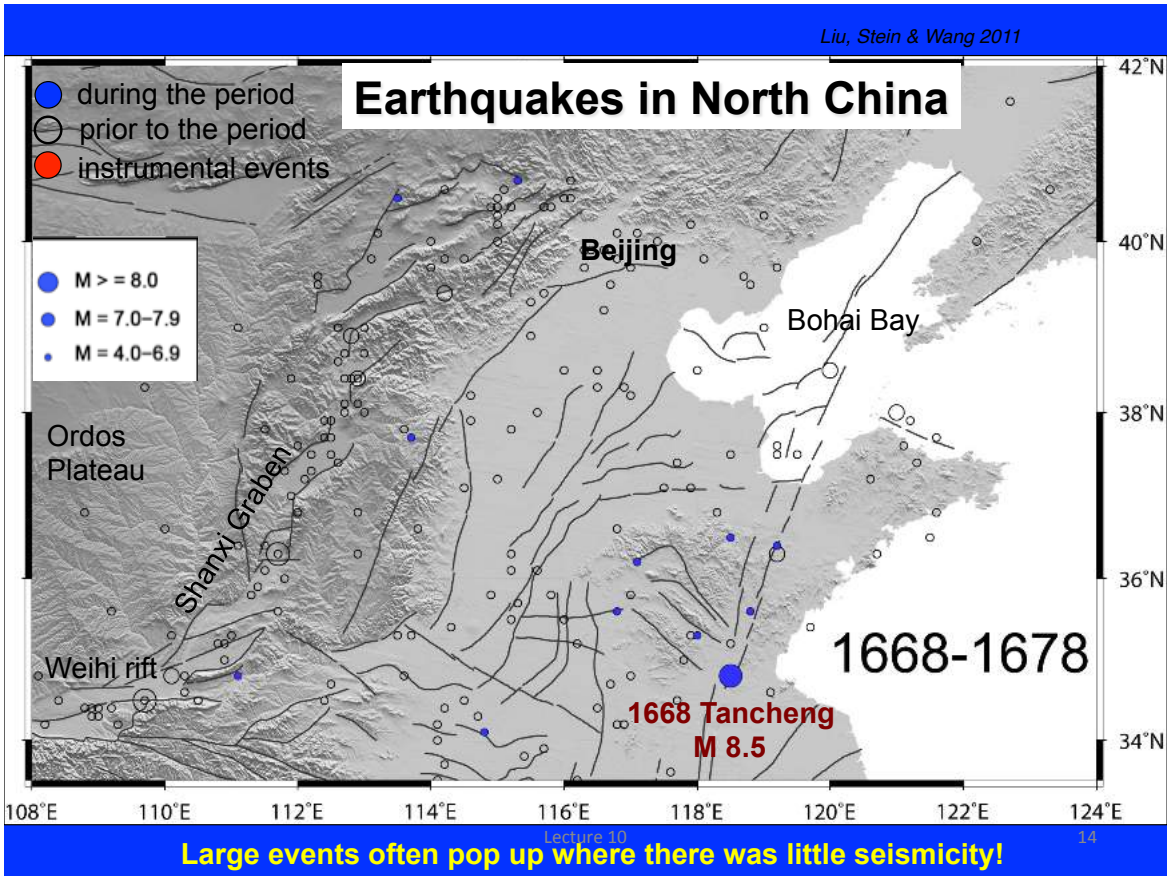
PAN10.5: (a) Seismic hazard map for China produced prior to the 2008 Wenchuan earthquake, which occurred on the Longmenshan Fault (black rectangle).

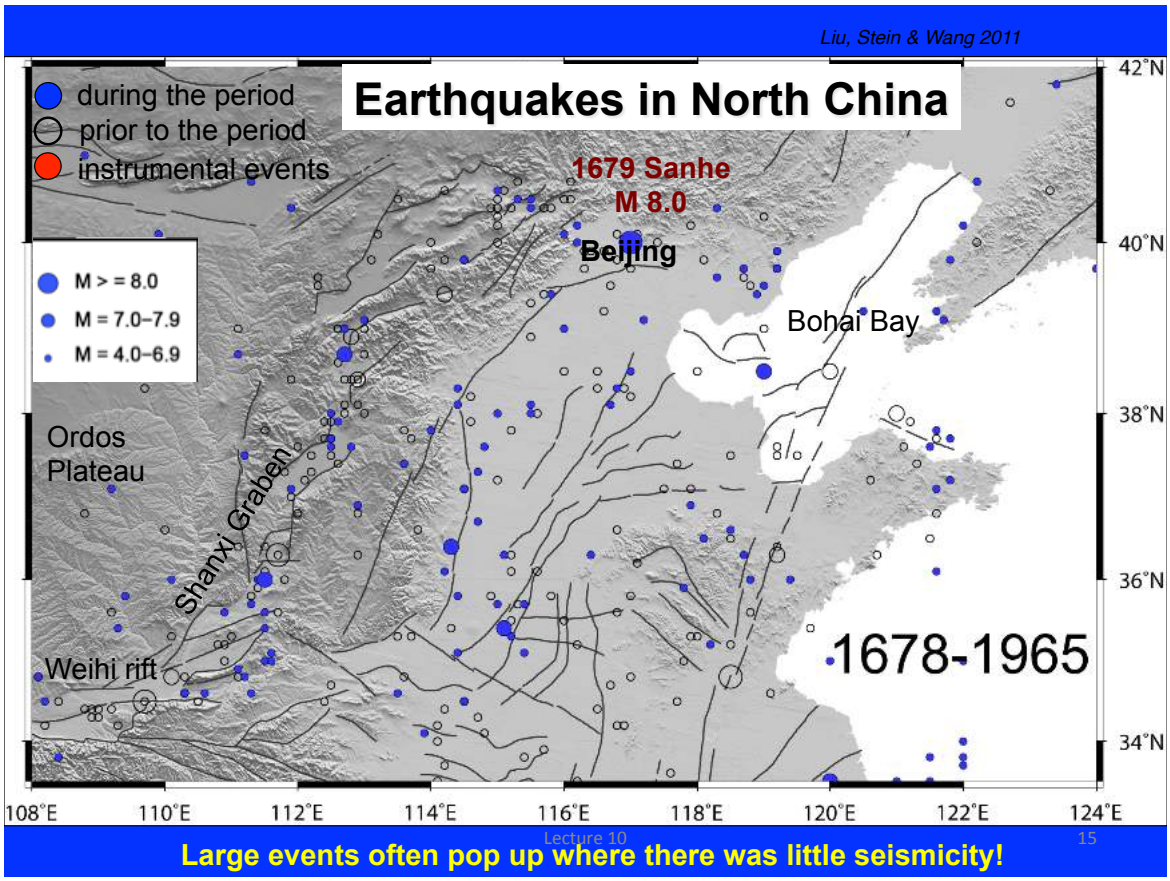
(b) Seismicity in the region. The hazard map showed low hazard on the Longmenshan fault, on which little instrumentally recorded seismicity had occurred before the Wenchuan earthquake, and higher hazard on faults nearby that showed more seismicity. (Stein et al., 2012)

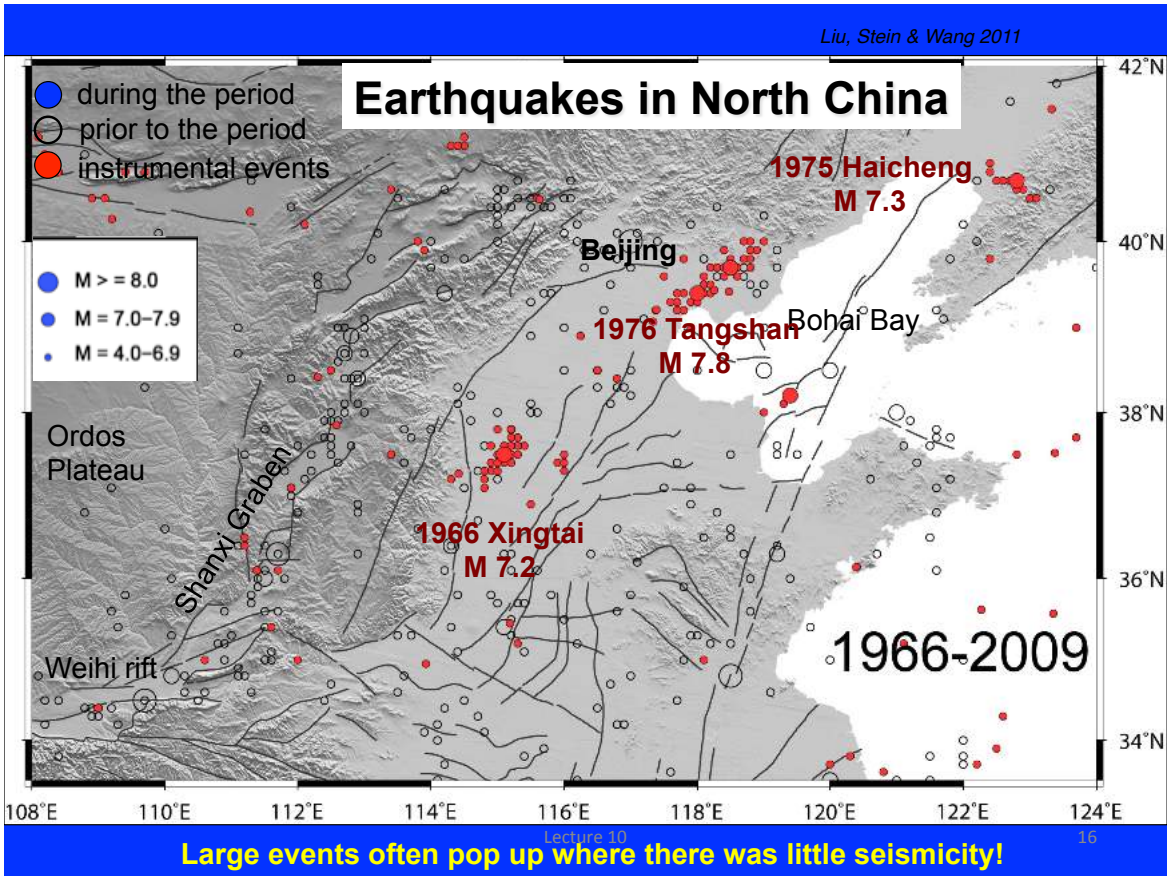


PAN 10.6: In many continental fault systems, it appears that rather than one main fault staying active for a long time (top), many faults turn on and off (bottom). (McKenna et al., 2007)

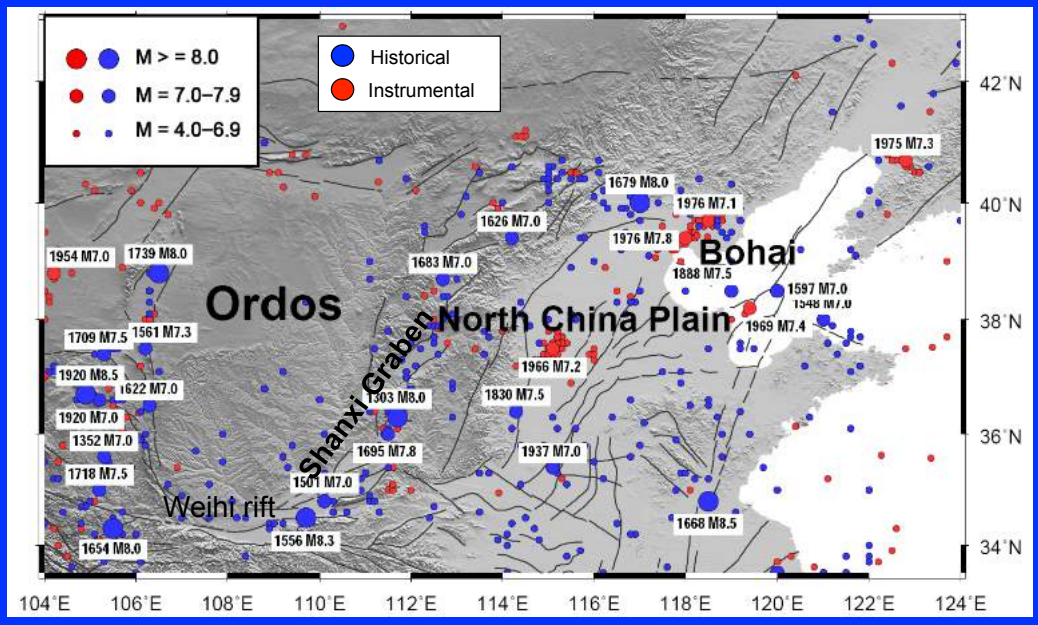

Liu, Stein & Wang 2011
Earthquakes in North China
during the period
prior to the period
instrumental events
M > = 8.0
M = 7.0–7.9
M = 4.0–6.9
Beijing
Bohai Bay
Ordos
Plateau
Shanxi Graben
Weihi rift
1556 Huaxian
M 8.3
1556-1667
42°N
40°N
38°N
36°N
34°N
108°E
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
Lecture 10
13
Large events often pop up where there was little seismicity!


Liu, Stein & Wang 2011
Earthquakes in North China
during the period
prior to the period
instrumental events
M > = 8.0
M = 7.0–7.9
M = 4.0–6.9
Beijing
Bohai Bay
Ordos
Plateau
Shanxi Graben
Weihi rift
1668 Tancheng
M 8.5
1668-1678
42°N
40°N
38°N
36°N
34°N
108°E
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
Lecture 10
14
Large events often pop up where there was little seismicity!


Liu, Stein & Wang 2011
Earthquakes in North China
during the period
prior to the period
instrumental events
M > = 8.0
M = 7.0–7.9
M = 4.0–6.9
1679 Sanhe
M 8.0
Beijing
Bohai Bay
Ordos
Plateau
Shanxi Graben
Weihi rift
1678-1965
42°N
40°N
38°N
36°N
34°N
108°E
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
Lecture 10
15
Large events often pop up where there was little seismicity!

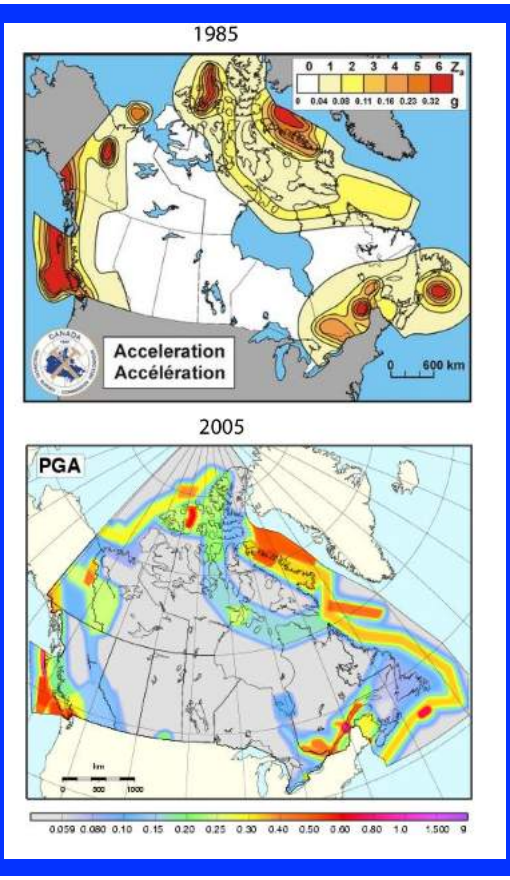

Liu, Stein & Wang 2011
Earthquakes in North China
during the period
prior to the period
instrumental events
M > = 8.0
M = 7.0–7.9
M = 4.0–6.9
1975 Haicheng
M 7.3
Beijing
1976 Tangshan
M 7.8
Bohai Bay
Ordos
Plateau
Shanxi Graben
1966 Xingtai
M 7.2
Weihi rift
1966-2009
42°N
40°N
38°N
36°N
34°N
108°E
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
Lecture 10
16
Large events often pop up where there was little seismicity!

No large (M>7) events ruptured the same fault segment twice in past 2000 years



In past 200 years, quakes migrated from Shanxi Graben to N. China Plain

Maps are like 'Whack-a-mole' - you wait for the mole to come up where it went down, but it's likely to pop up somewhere else.



PAN 10.8: Comparison of the 1985 and 2005 Geological Survey of Canada earthquake hazard maps of Canada.

The older map shows concentrated high hazard bull's-eyes along the east coast at the sites of the 1929 Grand Banks and 1933 Baffin Bay earthquakes, whereas the new map assumes that similar earthquakes can occur anywhere along the margin. (Stein et al., 2012)

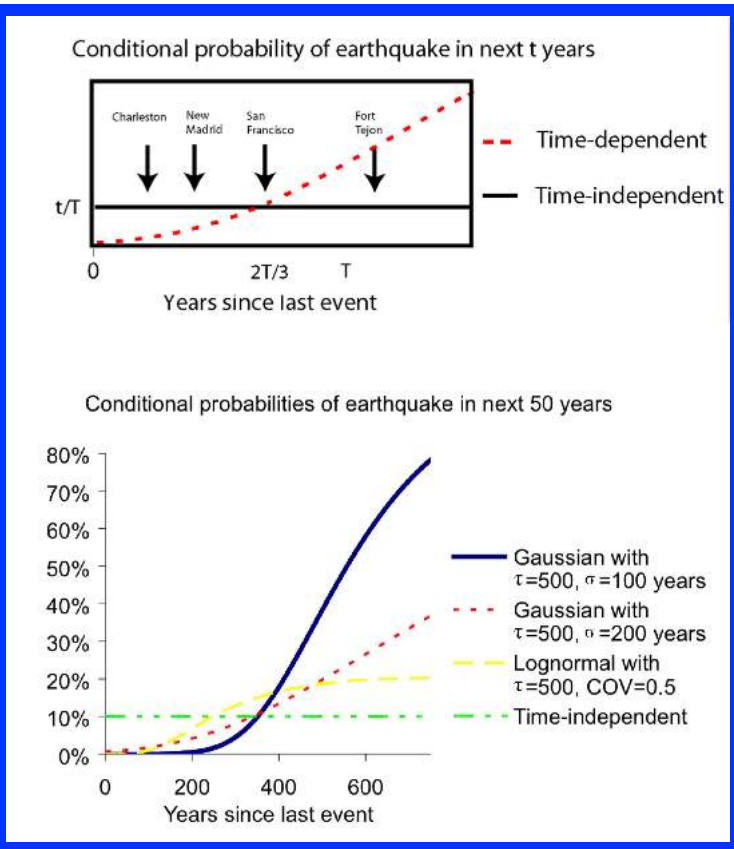
Hazard maps are hard to get right: success depends on accuracy of four assumptions over 500-2500 years

***Where** will large earthquakes occur?*

***When** will they occur?*

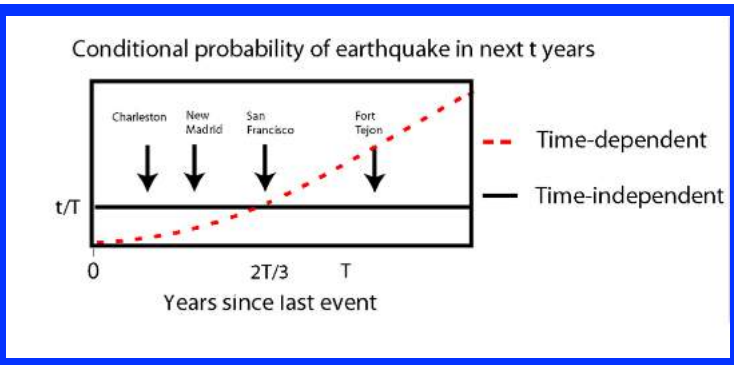
***How large** will they be?*

***How strong** will their shaking be?*

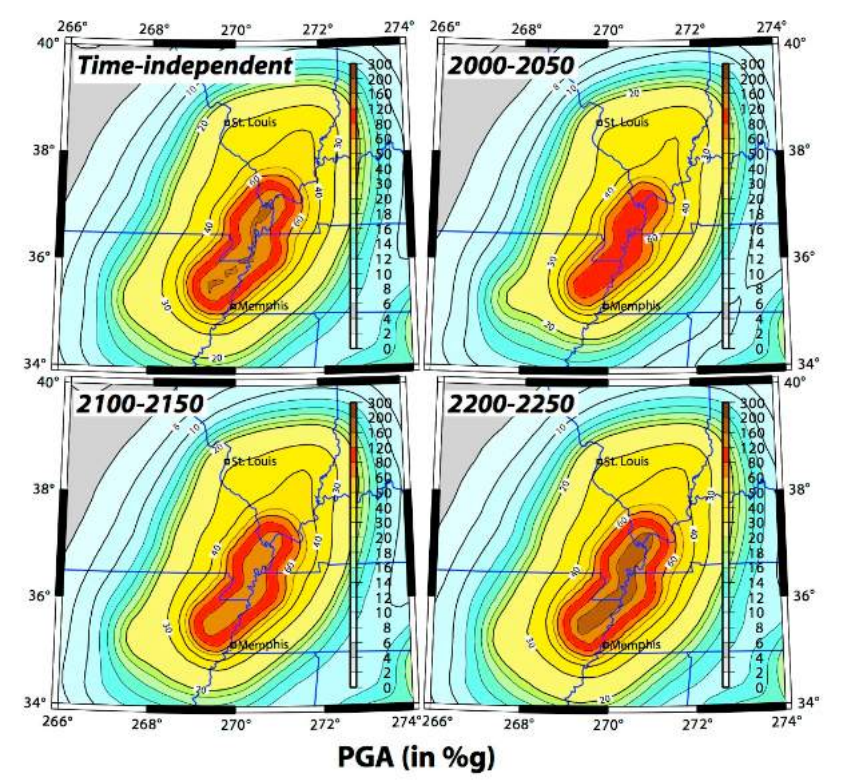


PAN 10.9: Top: Schematic comparison of time-independent and time-dependent models for different seismic zones.

Bottom: Comparison of the conditional probability of a large earthquake in the New Madrid zone in the next 50 years, assuming that the mean recurrence time is 500 years. (Hebden and Stein, 2009)



CQ: would you favor stronger and more expensive building standards near the "Fort Tejon" segment of the San Andreas fault than in San Francisco? Why or why not? Conversely, would you favor less stringent and less expensive standards after a large earthquake? Why or why not?



PAN 10.10: Comparison of hazard maps for the New Madrid zone.

Hazard maps are hard to get right: success depends on accuracy of four assumptions over 500-2500 years

Where *will large earthquakes occur?*

When *will they occur?*

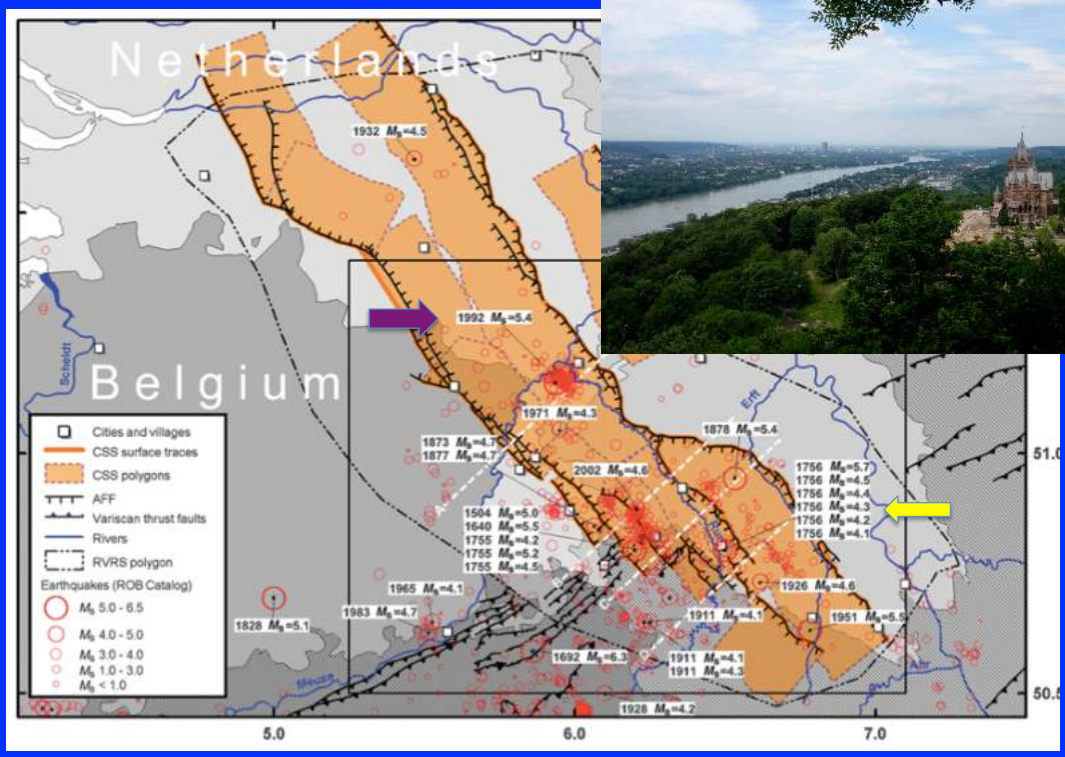
How large *will they be?*

How strong *will their shaking be?*

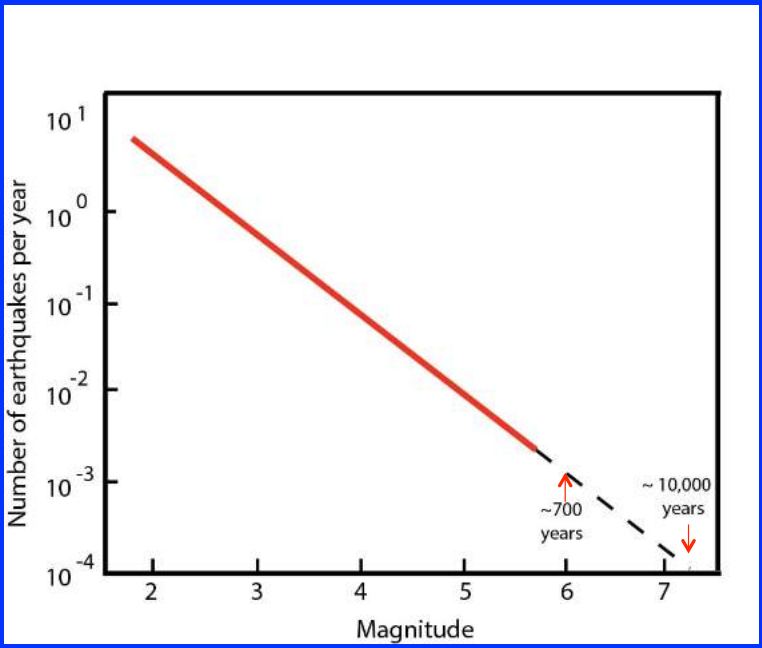
ROERMOND
13 avril 1992

ROERMOND
13 april 1992

Ms 5.4

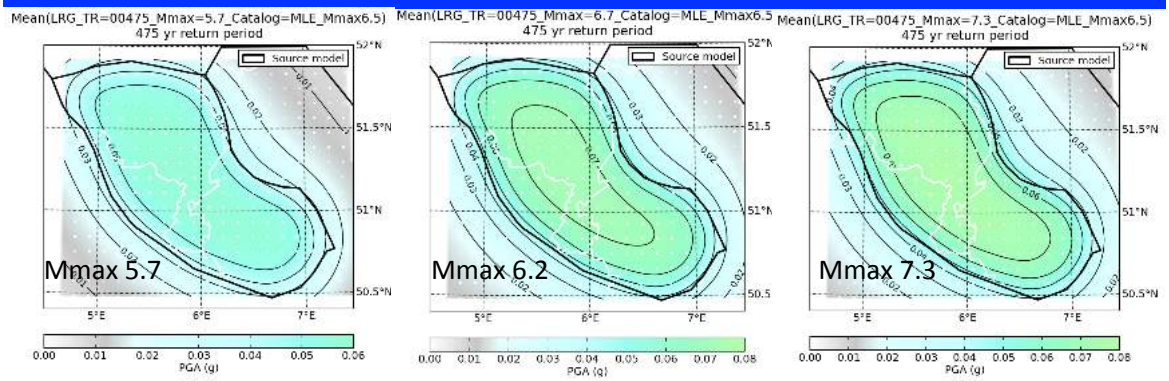


What's the maximum magnitude to expect in the Lower Rhine Graben?

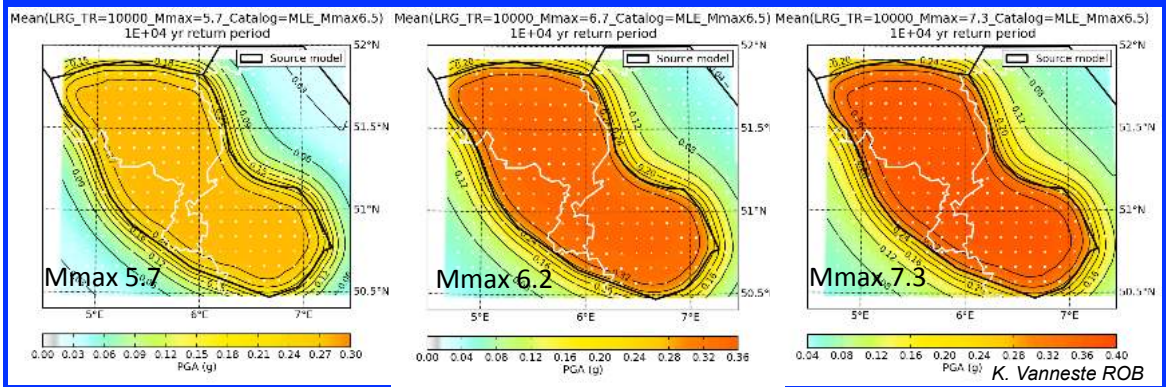


Nuclear plants designed for 1/10,000 yrs

Hazard map – 475 year return period



Hazard map – 10,000 year return period

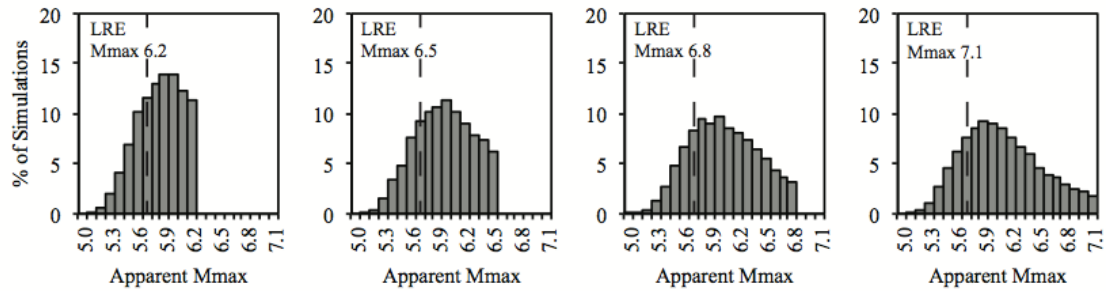


K. Vanneste ROB

Given 700 years of data, what Mmax would we observe if Mmax were really 6.2, 6.5, 6.8, 7.1?

Synthetic seismicity experiment – 10,000 catalogs
We generally miss the largest events and so underestimate Mmax

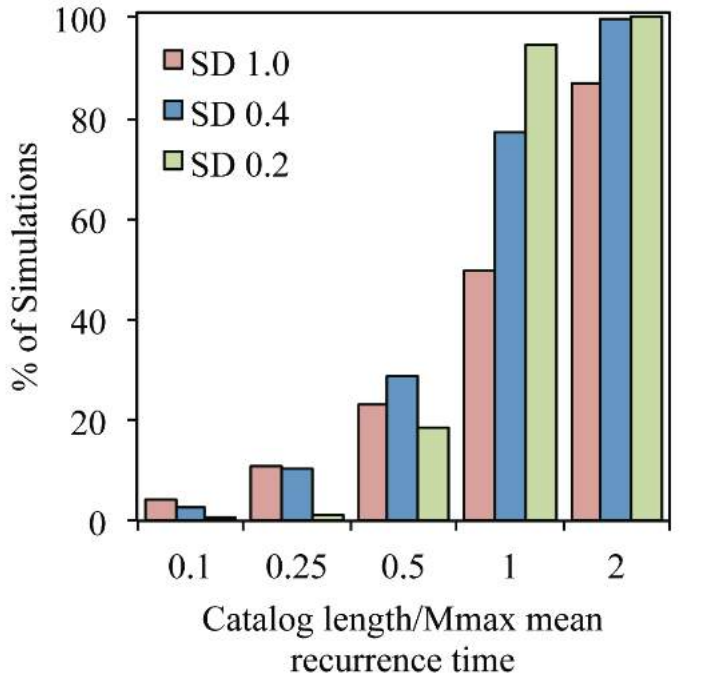
Most likely to observe Mmax ~6 with recurrence time ~ sample length



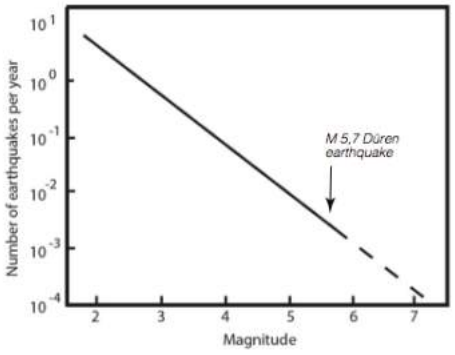
M. Merino, PhD thesis, 2014

A catalog shorter than an earthquake's mean recurrence time is likely to not contain an event of that size.

The largest earthquake observed likely reflects the length of the earthquake history used, even if larger earthquakes occur.



Merino, Stein, Adams, 2013



Kübler, Friedrich & Strecker, 2014

31

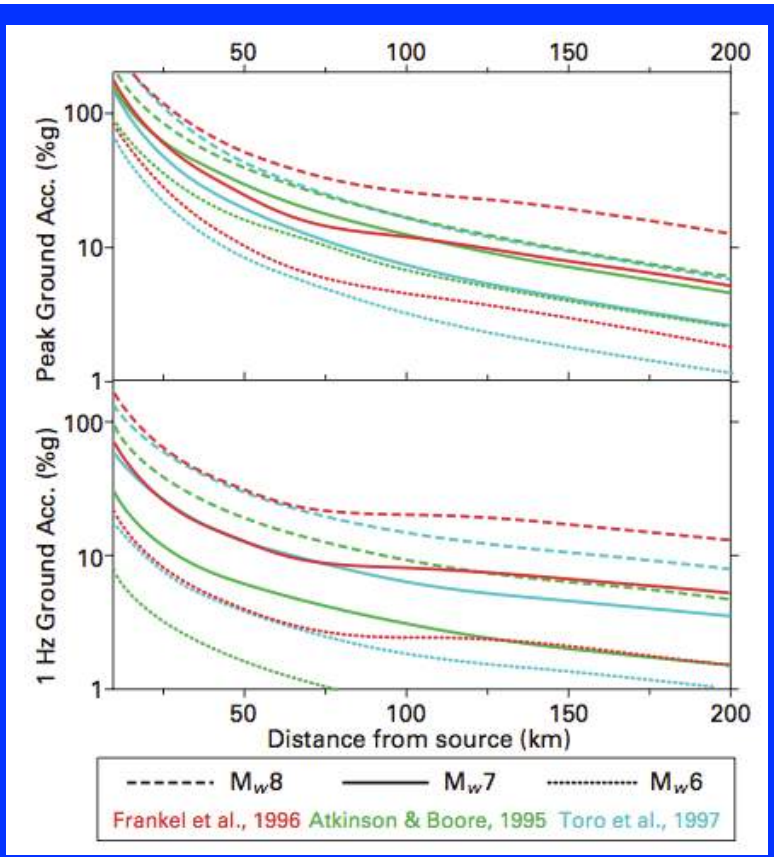
Hazard maps are hard to get right: success depends on accuracy of four assumptions over 500-2500 years

Where *will large earthquakes occur?*

When *will they occur?*

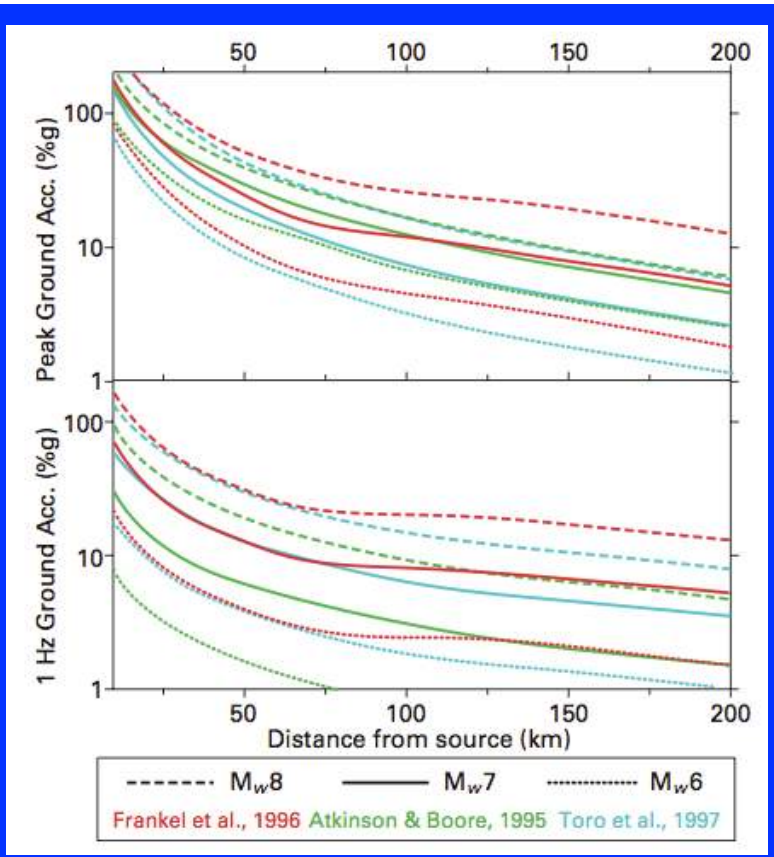
How large *will they be?*

How strong *will their shaking be?*

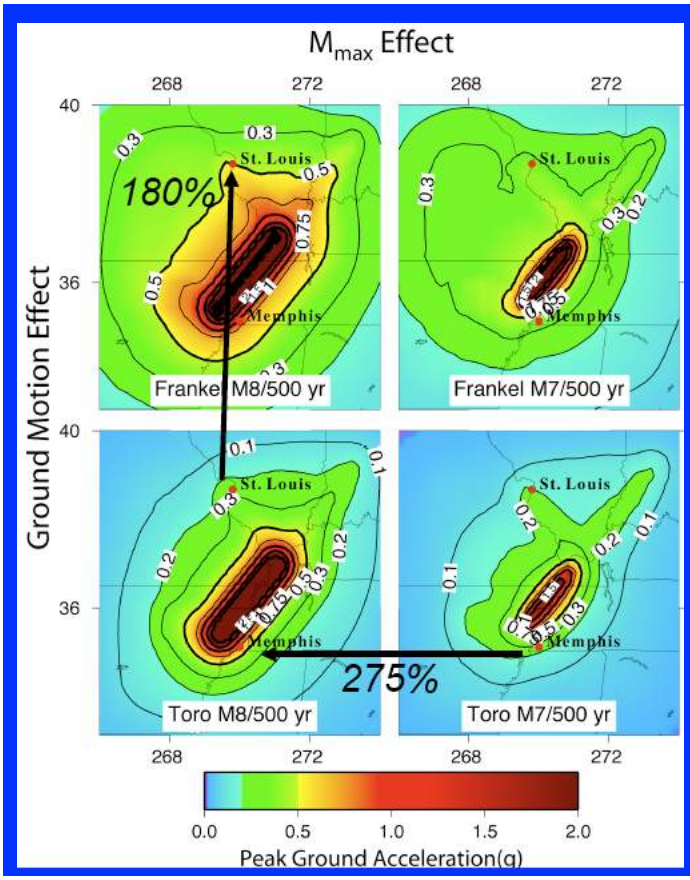


PAN 10.12: Comparison of ground motion (peak ground acceleration and 1 Hz) as a function of distance for different earthquake magnitudes predicted by three models for the central U.S.

For Mw 8, the Frankel et al. (1996) relation predicts significantly higher values than the others. (Newman et al., 2001)

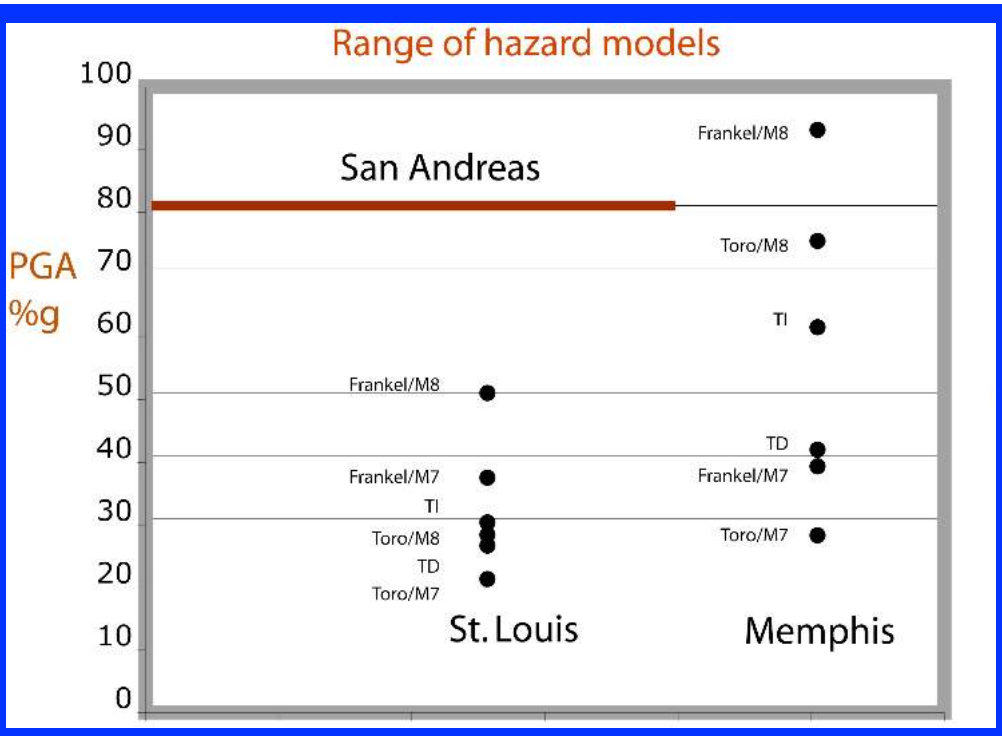


CQ: On physical grounds, why would you expect the shaking from an earthquake to decrease so rapidly with distance from the earthquake?

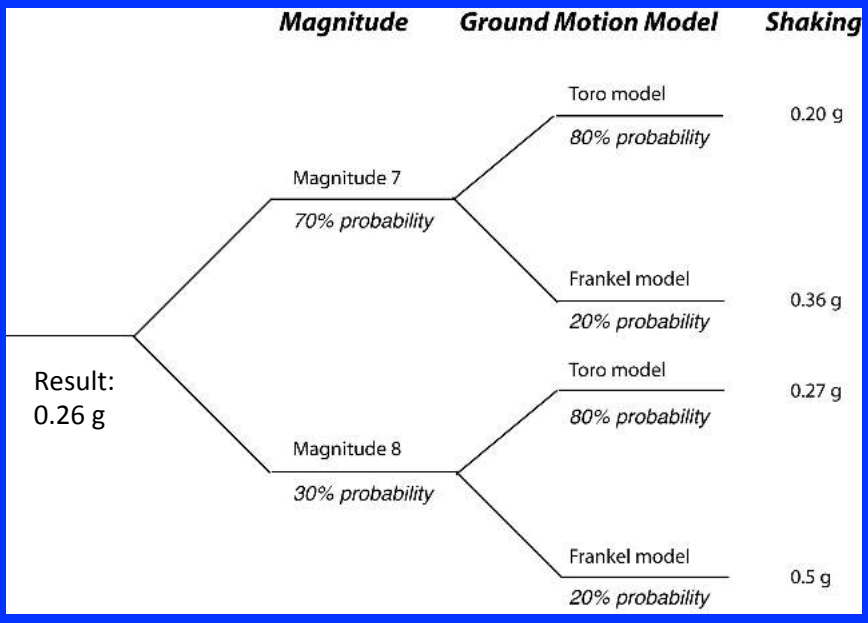


PAN 10.13: Comparison of ground motion (peak ground acceleration and 1 Hz) as a function of distance for different earthquake magnitudes predicted by three models for the central U.S.

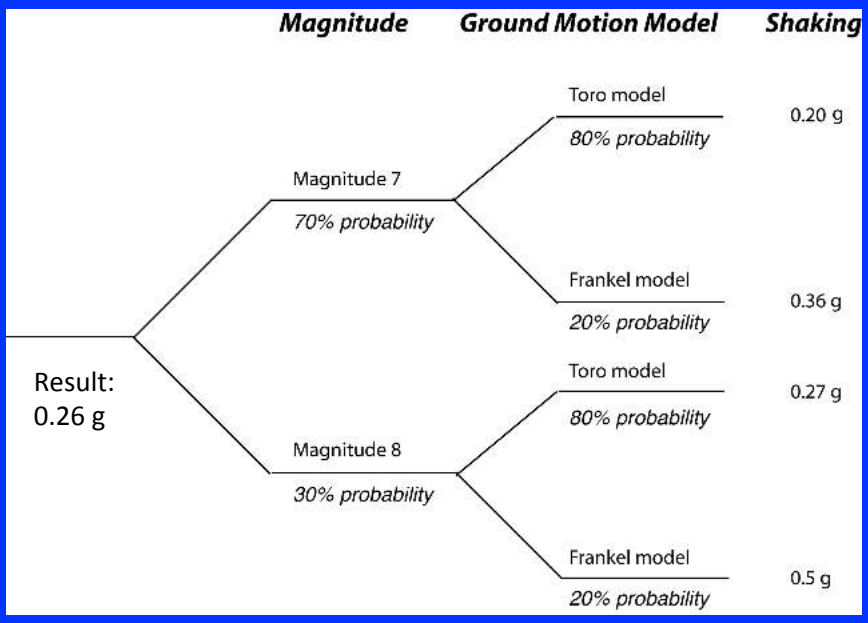
For M 8, the Frankel et al. (1996) relation predicts significantly higher values than the others. (Newman et al., 2001)



PAN 10.14: Comparison of the hazard at St Louis and Memphis predicted by the different hazard maps of the New Madrid zone.



PAN 10.15: Logic tree combining the four models in Figure 10.13 to predict shaking at St. Louis. These weights give a value of 0.26 g, or 26% of the acceleration of gravity (Stein, 2010).



CQ: How would you change the weights on the magnitude and ground motion model branches if you wanted to raise the hazard from 0.26 to 0.4 g? How could you lower it to 0.22 g?

11: Mitigating hazards

"I was learning that choices in war are rarely between good and bad, but between bad and worse."

Nathan Fick, *One Bullet Away: The Making of a Marine Officer*, 2006

CQ: People in Gottingen can leave their bicycles in the train station garage for 2 Euros per night, or park them outside for free. Which do you do and why?

CQ: Imagine that you are in charge of school construction in an earthquake-prone developing nation. How would you allocate your budget between building schools for towns without ones or making existing schools earthquake-resistant?

People address natural hazards via four strategies:

- Accept: decide that the risk is not large enough to justify the economic, political, or other costs of action to reduce its potential effects.

- Transfer: use insurance or another method to pass the risk to someone else.

- Avoid: minimize exposure to the risk.

- Mitigate: take other measures to reduce damage and losses.

For example, we can address river flooding by

doing nothing

insuring structures on the floodplain

banning development on the floodplain

or building levees to stop flooding.

Each has advantages and disadvantages, costs and benefits.

We need to chose strategies to address hazards. What to do for a specific hazard in a particular place is a complex question to which there is no full, right or unique answer.

People's accept most risks, because the costs of addressing them appear greater than those associated with not addressing them.

We pretty much have to, because we are constantly being warned of dangers: sharks, SARS, West Nile virus, terrorists, computer viruses, Lyme disease, killer bees, communists, fiscal cliffs, flesh-eating bacteria, fire ants, mad cow disease, the end of the Maya calendar, alien abductions, genetically modified food, anthrax, etc.

If we tried to address more than a small fraction of these, we would have no time or resources to do anything else.

Fortunately, very few turn out to be anywhere near as serious as claimed. As Best (2004) points out in More Damned Lies and Statistics,

"Apocalyptic claims do not have a good track record."

Insurance transfers risk from property owners to insurers – usually insurance companies or governments. The idea of insurance is spreading the risk. For example, car insurance premiums are low because many drivers pay a premium each year, but only a few have accidents and file claims that need to be paid.

To see the advantage of spreading the risk, consider that the total annual worldwide losses from natural disasters in 2012 were about $170 billion, or about $25 for each person on earth.

Beyond helping individuals who suffer losses, insurance is important for communities because after a disaster insurance compensates property owners for damage and thus provides funds for rebuilding. Thus developed nations, where most losses are covered by insurance, recover much faster than developing nations where losses are uninsured.

Insurance has limitations as a hazard mitigation method.

First, it reduces risks to property, but not to lives.

Second, insurance can be expensive. In the US, earthquake insurance policies typically only pay for damage that is more than 15% of a house's value, a level of damage which rarely happens. Given this deductible and the high cost of the insurance, 88% of homeowners in California – including many seismologists – do not have it, despite a state program to encourage it. In fact, the fraction of homeowners with earthquake insurance has been decreasing over time.

Customers cry foul as homeowner insurance costs jump, especially in hurricane areas

A major issue is that disasters could overwhelm insurance companies' ability to pay. They have to build up huge financial reserves to prepare for rare events whose impact is hard to predict.

This situation causes problems. Premiums for homeowners' insurance doubled in Florida between 2002 and 2007, tripling in some cases after the 2004–2005 hurricane season. Policyholders have had trouble collecting after hurricanes, and some insurance companies are refusing to sell policies in areas such as Florida.

CQ: According to the New York Times, a Californian owning a home valued at $332,000 was offered earthquake insurance for $3,170 per year with a 10% deductible. Would you have bought this coverage? Why or why not?

Is Earthquake Insurance Worth the Cost?

By ANN CARRNS

Jay Paul for The New York Times

Dishes damaged in the earthquake centered in Mineral, Va., in August.

One proposed solution is government insurance for all hazards. New Zealand's Earthquake Commission insures property owners against earthquakes, landslides, volcanic eruptions, tsunamis, storms, flood, or resulting fires. An advantage of such programs is they cover people who could not afford insurance and are thus most impacted by a disaster.

However, the costs are huge – the US federal flood insurance program was $18 billion in debt even before Hurricane Sandy.

Moreover, public insurance subsidizes development in dangerous places. Owning a home on a seaside barrier island prone to flooding and wind damage is a risky investment, but if it is insured, the owner risks only a small fraction of the home's value. Often, people collect insurance, rebuild in the same place, and collect again when disaster strikes. Although a private insurer would refuse to keep writing policies for these sites or charge very high premiums, a government insurer that does not have to make money will continue writing policies. This is good for the homeowner, but bad for society. It transfers risk to all the taxpayers, so people living in relatively safer areas subsidize those in more hazardous places.

CQ: Would you favor Germany having a mandatory national natural hazard insurance program analogous to New Zealand's? Why or why not? If yes, how should it be financed and operate?

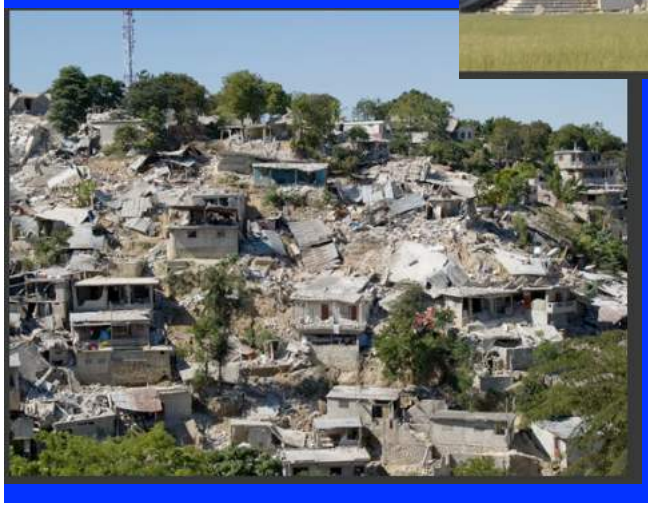
AVOIDING RISK

After parts of Hilo, Hawaii, were seriously damaged by tsunamis in 1946 and 1960, the twice-damaged areas were redeveloped as parks.

CQ: How should the risks of the evacuation process be factored into decisions as to whether to evacuate in cases like this?

Haiti 1/12/10

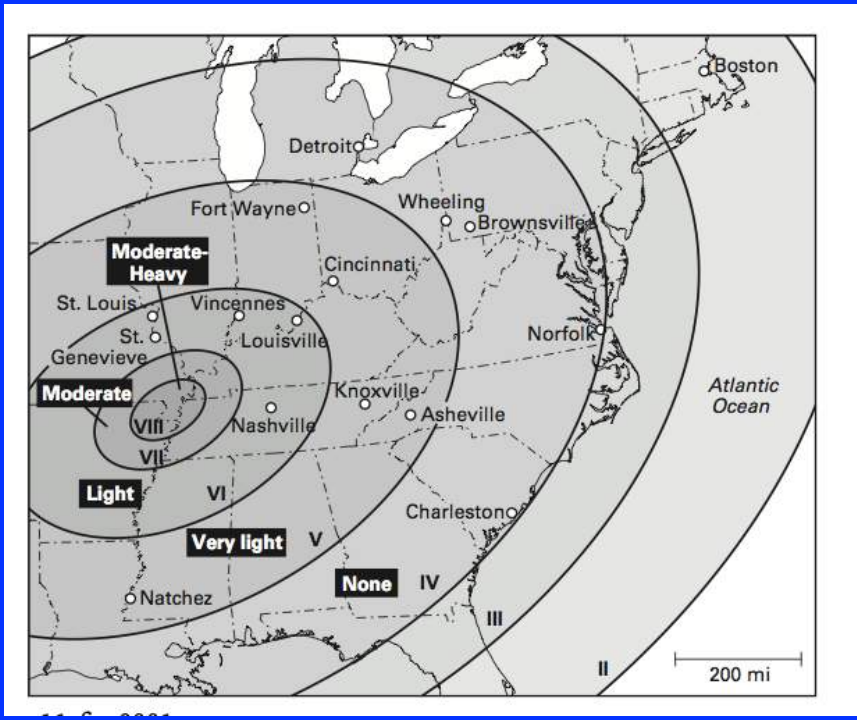
M 7.0



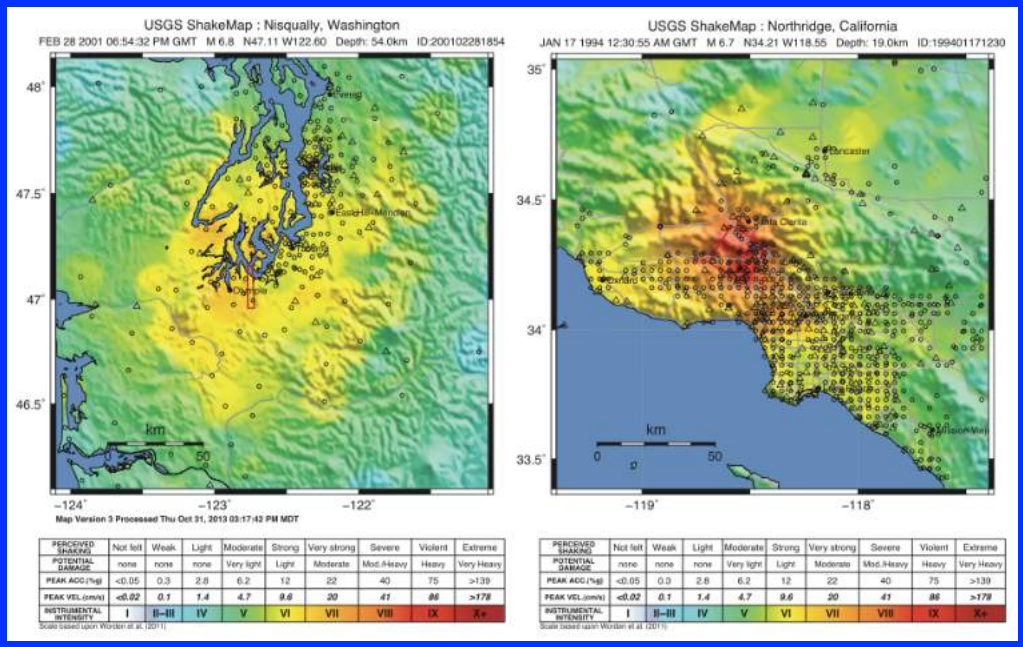
Earthquakes don't kill people, buildings kill people

Table 11.1: The Modified Mercalli Intensity Scale

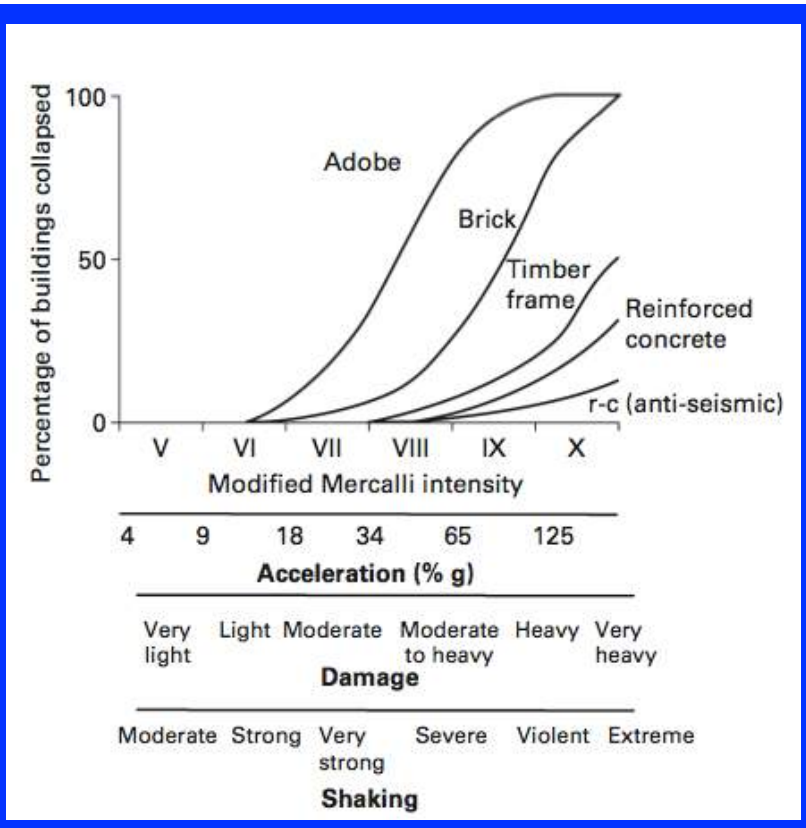
I. Shaking not felt, no damage: Not felt except by a very few under especially favorable conditions.
II. Shaking weak, no damage: Felt only by a few persons at rest, especially on upper floors of buildings.
III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV. Shaking light, no damage: Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. (0.015-0.02 g)
V. Shaking moderate, very light damage: Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop. (0.03-0.04 g)
VI. Shaking strong, light damage: Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. (0.06-0.07 g)
VII. Shaking very strong, moderate damage: Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. (0.10- 0.15 g)
VIII. Shaking severe, moderate to heavy damage: Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. (0.25-0.35 g)
IX. Shaking violent, heavy damage: Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. (0.5-0.55 g)
X. Shaking extreme, very heavy damage: Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. (more than 0.6 g)
XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII. Damage total: Lines of sight and level are distorted. Objects thrown into the air.



PAN 11.1: Intensity map for the first of the three major New Madrid shocks, December 1811.



CQ: Northridge was the costliest earthquake in U.S. history to date, with economic loss of about $40 billion. In contrast, loss in the Nisqually earthquake was about $2 billion. One death, a heart attack victim, was reported in the Seattle area, while 57 people died in the Northridge earthquake. What are the shaking differences? What may have caused them?



PAN 11.2: How vulnerable buildings are depends on the material used in their construction (Stein & Wysession, 2003)

ADOBE

12/03 Bam, Iran
M 6.6 27,000 deaths

BRICK

10/05 Pakistan M 7.6
80,000 deaths

CONCRETE

2/71 San Fernando,
California M 6.6 65 deaths

USGS

USGS

CQ: The owner of a large warehouse in Memphis, Tennessee, pointed out that the building is uninhabited, so any possible earthquake damage impacts only the owner. Hence instead of the government imposing a building code to protect against this damage, he proposed addressing the small risk involved through insurance, which would be much cheaper. Do you agree or disagree and why?

PAN 11.3: The Memphis Veterans' Administration hospital during reconstruction and seismic retrofitting. (Joseph Tomasello)

12: Choosing Mitigation Policies

"It is our choices that show what we truly are, far more than our abilities."

J. K. Rowling, *Harry Potter and The Chamber of Secrets*, 1999

https://www.youtube.com/watch?v=WGwiz80EaTs

Retrofitting California Hospitals

Following hospital collapses in 1971 San Fernando earthquake that caused ~50 deaths, California required seismic retrofits

Law assumed retrofits would be cheap

Retrofit cost close to that of new buildings

At least $24 B needed

No funding provided

After 40+ years, slow progress

Deadlines already extended

Won't be done before at least 2030

CQ: How many lives might this safe? Do you think this this a wise use of resources? If so, how should it be funded?

COST-BENEFIT ISSUES IN HAZARD MITIGATION

"There's no free lunch"

Resources used for one goal aren't available for another

This is easy to see in the public sector, where there are direct tradeoffs. Funds spent strengthening schools aren't available to hire teachers, upgrading hospitals may mean covering fewer uninsured (~$1 K/yr), stronger bridges may result in hiring fewer police and fire fighters (~$50 K/yr), etc...

COST-BENEFIT ISSUES IN HAZARD MITIGATION

“There's no such thing as other people's money”

Costs are ultimately borne by society as a whole

Imposing costs on the private sector affects everyone via reduced economic activity (firms don't build or build elsewhere), job loss (or reduced growth), and the resulting reduction in tax revenue and thus social services.

"The direct costs of federal environmental, health, and safety regulations are probably on the order of $200 billion annually, or about the size of all federal domestic, nondefense discretionary spending. The benefits of those regulations are even less certain. Evidence suggests that some recent regulations would pass a benefit-cost test while others would not."

Hahn, R., and R. E. Litan, *An Analysis of the Second Government Draft Report on the Costs and Benefits of Federal Regulations*, AEI-Brookings Joint Center, Washington, DC, 1998.

The Washington Post

Back to previous page

France drowning in rules and regulations, critics say

By Edward Cody, Published: April 16

Applied to business with equal bureaucratic fastidiousness, such rules and regulations prove even more expensive in the private sector. They cost the 27 European Union countries an average 3.7 percent of their gross domestic product a year, more than $10 billion in the case of France, and hold back an incalculable amount of new investment, according to the OECD.

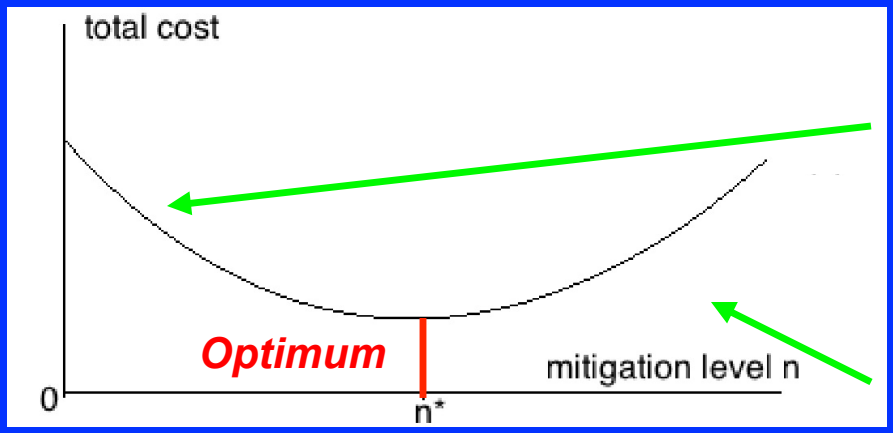
How much mitigation is enough?

Societally optimal level minimizes

total cost = sum of mitigation cost + expected loss

Expected loss = ∑ (loss in i_{th} expected event x assumed probability of that event)

For earthquake, mitigation level is construction code
Loss depends on earthquake & mitigation level



Stein & Stein, 2012

Compared to optimum

Less mitigation decreases construction costs but increases expected loss and thus total cost

More mitigation gives less expected loss but higher total cost

Worrying Beyond Hurricane Sandy

It is small comfort to sodden and stranded New Yorkers that Hurricane Sandy's flooding of the city's infrastructure, from power lines to subways to low-lying communities, was predicted in grimly precise detail by scientists in the latest state and city climate studies. Deeper and more frequent flooding from Rockaway to Lower Manhattan and the city's transit tunnels has been a repeated warning that largely went unnoticed by the public and most politicians.

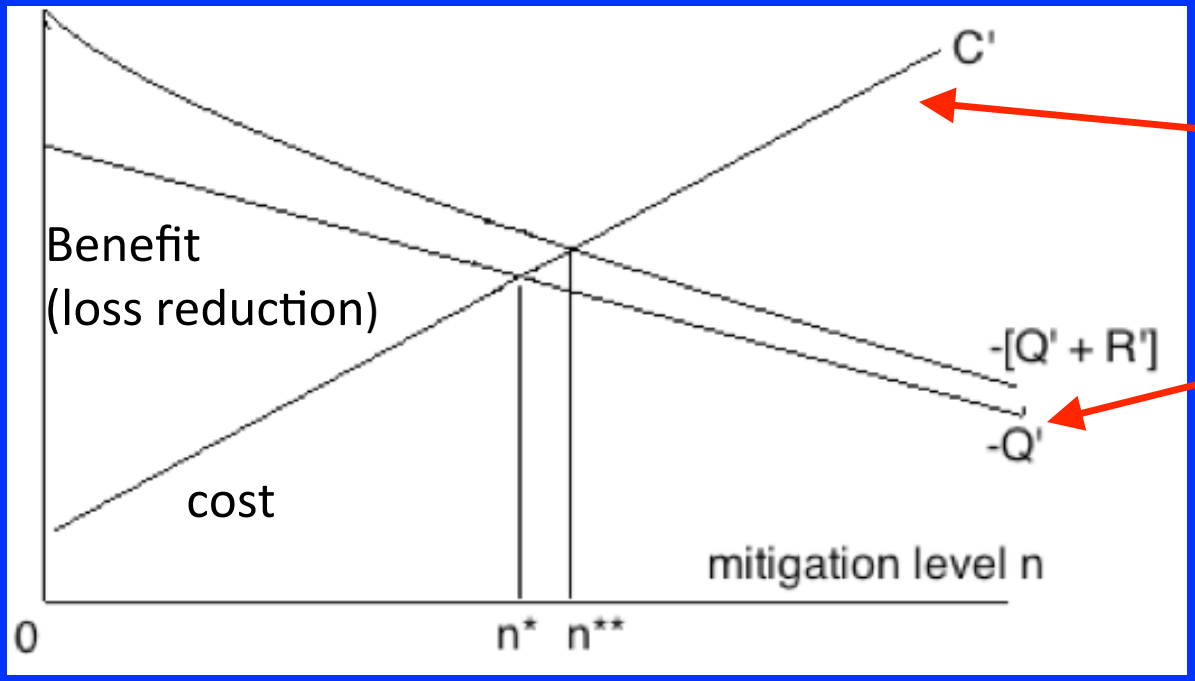
NYT
10/31/2012

CQ: Given the damage to New York City by the storm surge from Hurricane Sandy, possible options range from continuing to do little, through intermediate strategies like providing doors to keep water out of vulnerable tunnels, to building barriers to keep the surge out of rivers. Progressively more extensive mitigation measures cost more, but are expected to produce increasing reduction of losses in future hurricanes.

How would you develop a strategy to choose between the various proposed options? How would you include the anticipated but uncertain effects of global warming?

Including risk aversion & uncertainty

Consider marginal costs C' (n) & benefits Q' (n) (derivatives)



More mitigation costs more

But reduces loss

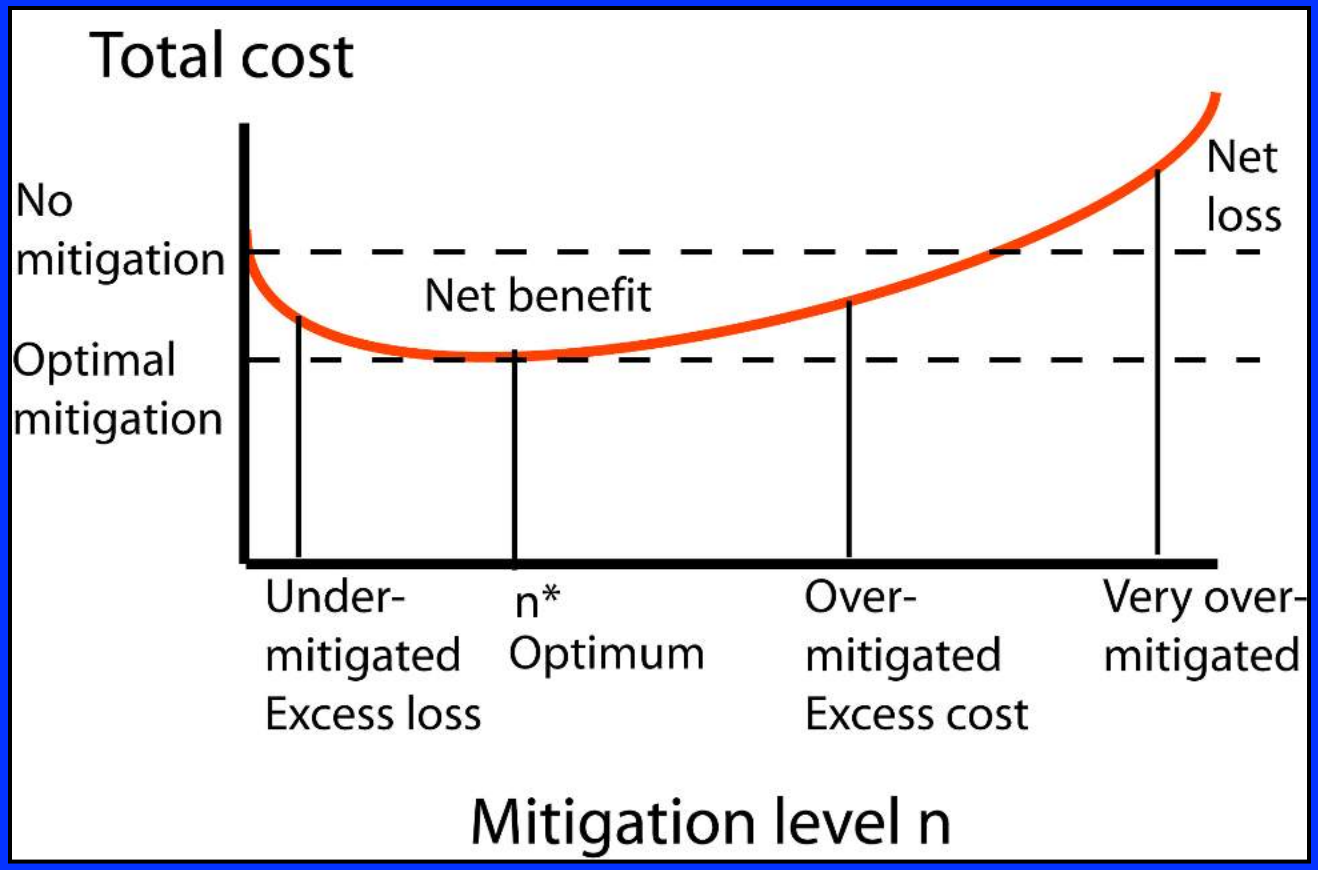
Optimum is where marginal curves are equal, n*

Uncertainty in hazard model causes uncertainty in expected loss. We are risk averse, so add risk term R(n) proportional to uncertainty in loss, yielding higher mitigation level n**

Crucial to understand hazard model uncertainty

Stein & Stein, 2012

Even without uncertainty, mitigation rarely will be optimal for societal reasons,but can still do some good



Net benefit
when mitigation lowers total cost below that of no mitigation
Net loss
when mitigation raises total cost above that of no mitigation

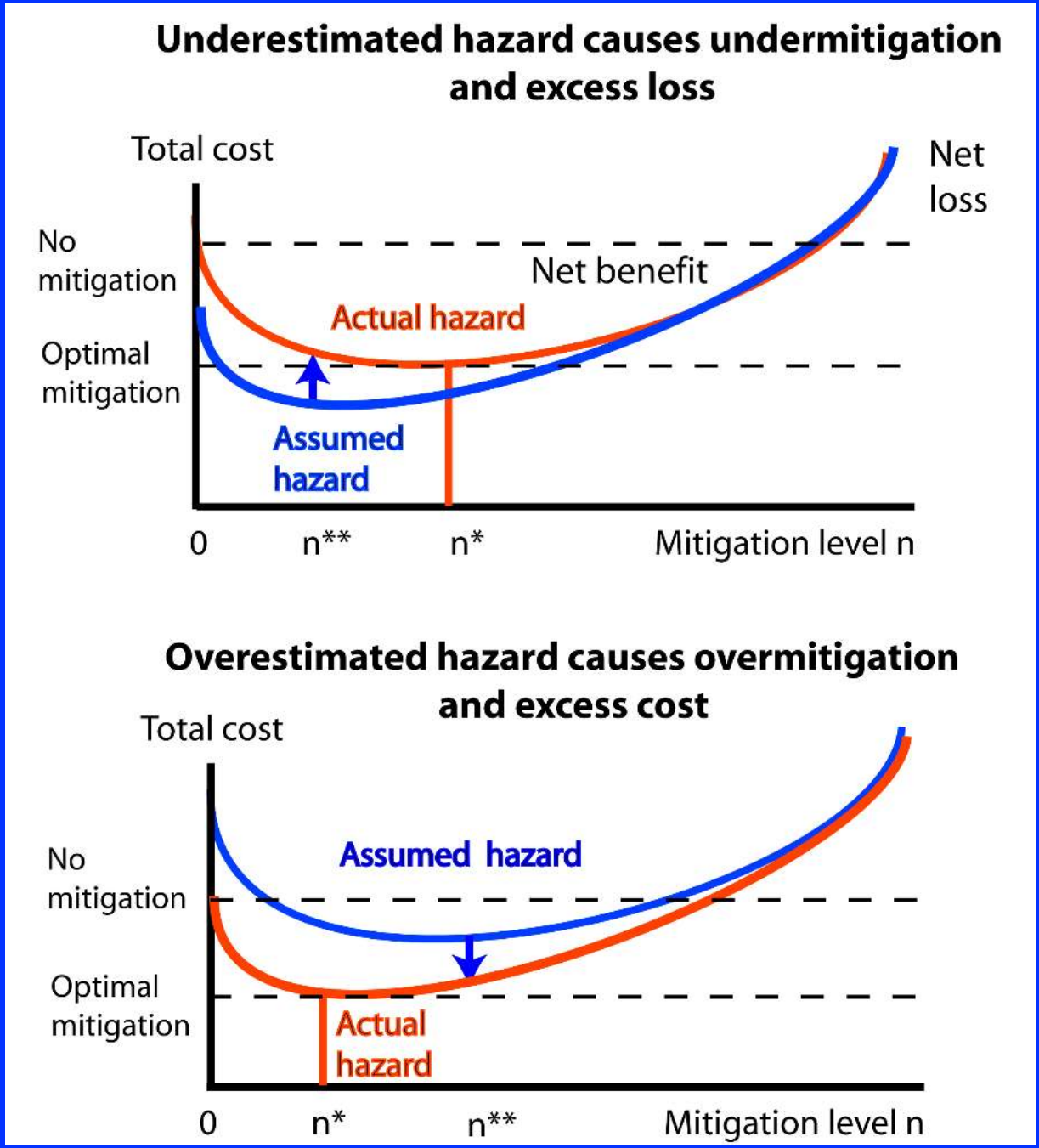
Within range,

inaccurate hazard estimates produce nonoptimal mitigation,

raising cost, but still do some good (net benefit)

Inaccurate loss estimates have same effect

Stein & Stein, 2013



November 30, 2013 NY Times

The Troubles of Building Where Faults Collide

The Los Angeles Times, based on its own survey published in October, said that up to 1,000 unreinforced concrete buildings were vulnerable, and it projected that 50 would collapse in a bad earthquake. The article included detailed assessments of many of the buildings at risk.

The release of the lists has revived a long debate about whether the city should require building owners to pay for making sure their buildings are safe. The cost of inspecting a building can reach $100,000; the bill for repairs can exceed the value of the building itself.

"It is always a risk-benefit analysis if you are being rational about it," said Carol Schatz, the president of the Central City Association of Los Angeles, a business group. "What is the risk o a catastrophic earthquake, and what is the cost to mitigate that risk? Is the cost a burden that a private property should bear alone?"

PROBLEM: UNFUNDED MANDATE

Property owners don't benefit (can't charge higher rent) & so resist

Maybe society should fund: Would public pay higher taxes for safety?

October 11, 2005 latimes.com : California

How Risky Are Older Concrete Buildings?

- State officials say many should be retrofitted for quakes. Others say cost would outweigh benefit.

By Sharon Bernstein, Times Staff Writer

Tens of thousands of older concrete buildings across California represent the state's largest remaining risk of serious damage in a major earthquake, seismic safety officials say.

Constructed as department stores, schools, parking structures and office buildings from the 1930s through the early 1970s, these buildings typically consist of large, open lower stories held up by unreinforced or poorly reinforced concrete pillars.

After several collapsed in the 1971 San Fernando earthquake, seismic safety codes were upgraded to require that any new concrete buildings be better constructed. Many seismic experts say preexisting structures — known as non-ductile concrete buildings — need to be retrofitted to bring them up to current standards.

"It's well recognized within the earthquake professional community that many California non-ductile concrete buildings are at unacceptable risk of collapse in moderately strong shaking," said Thomas Heaton, professor of engineering seismology at Caltech.

Because many of the older concrete buildings tend to be filled during the day with office workers, schoolchildren or people parking their cars, the death and injury toll from an earthquake that caused several of the structures to collapse could be staggering, said Heaton.

But building owners and business organizations have long fought efforts to require retrofits, arguing that the risk is overstated. And they say that in some cases, the cost of retrofits comes close to that of razing a building and starting over. Neither the state nor local governments have required that the structures be reinforced.

"If you're going to use a 'sky is falling' scenario, then maybe you can justify" a retrofit requirement, said Carol Schatz, president of the Central City Assn. "But if you're going to put a bunch of commercial property owners out of business in the process, what have you accomplished?"

Property owners and business associations opposed a proposal last year by City Councilmen Greig Smith and Alex Padilla to count the number of unreinforced concrete buildings in Los Angeles. The measure didn't make it out of a council committee.

CQ: If you were a student in Los Angeles, how much more would you pay in rent each month to live in an earthquake-safe building?