Man and Nature: Partners in Disasters

May 31, 2007

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Toulouse Conference

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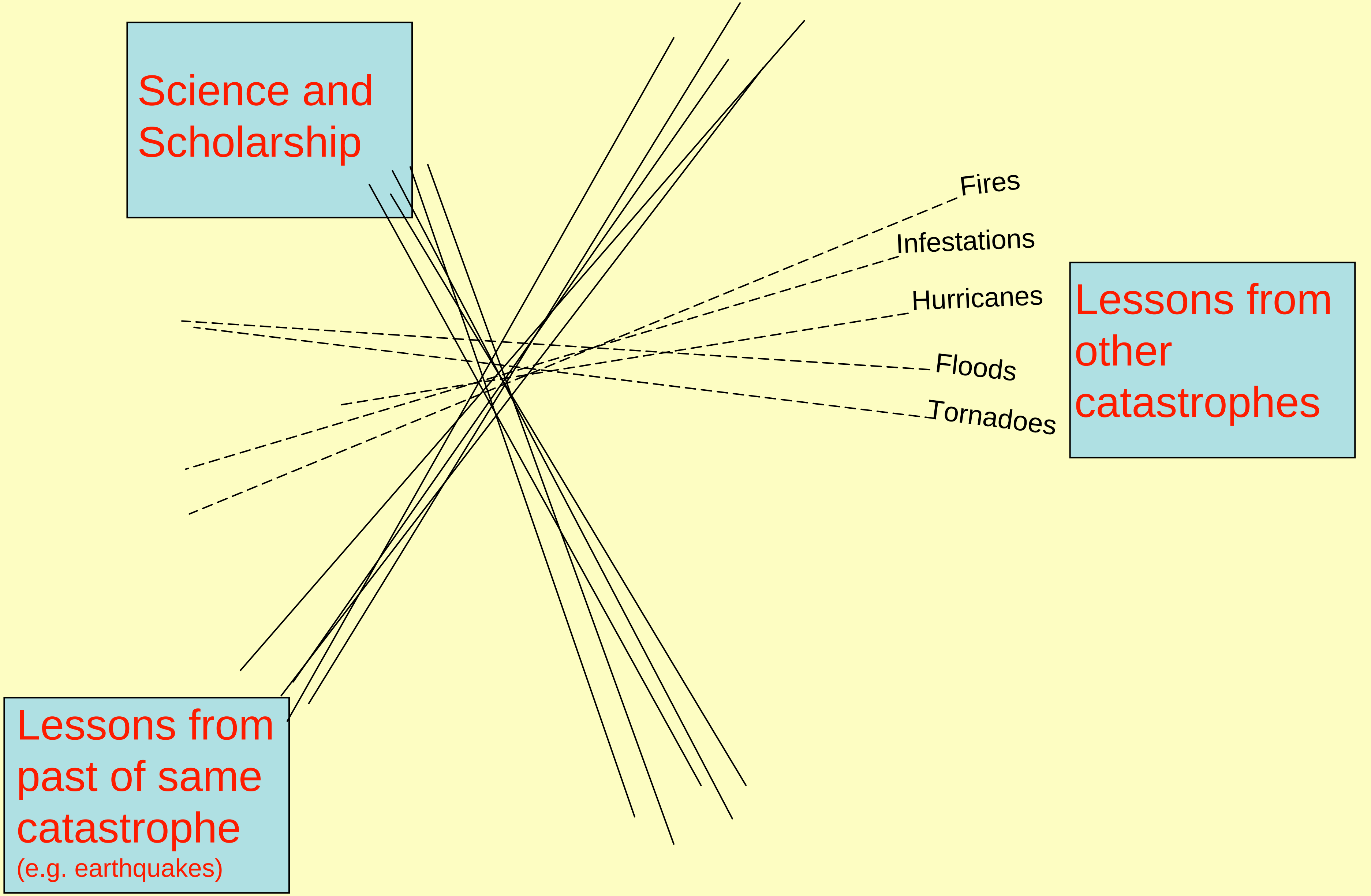
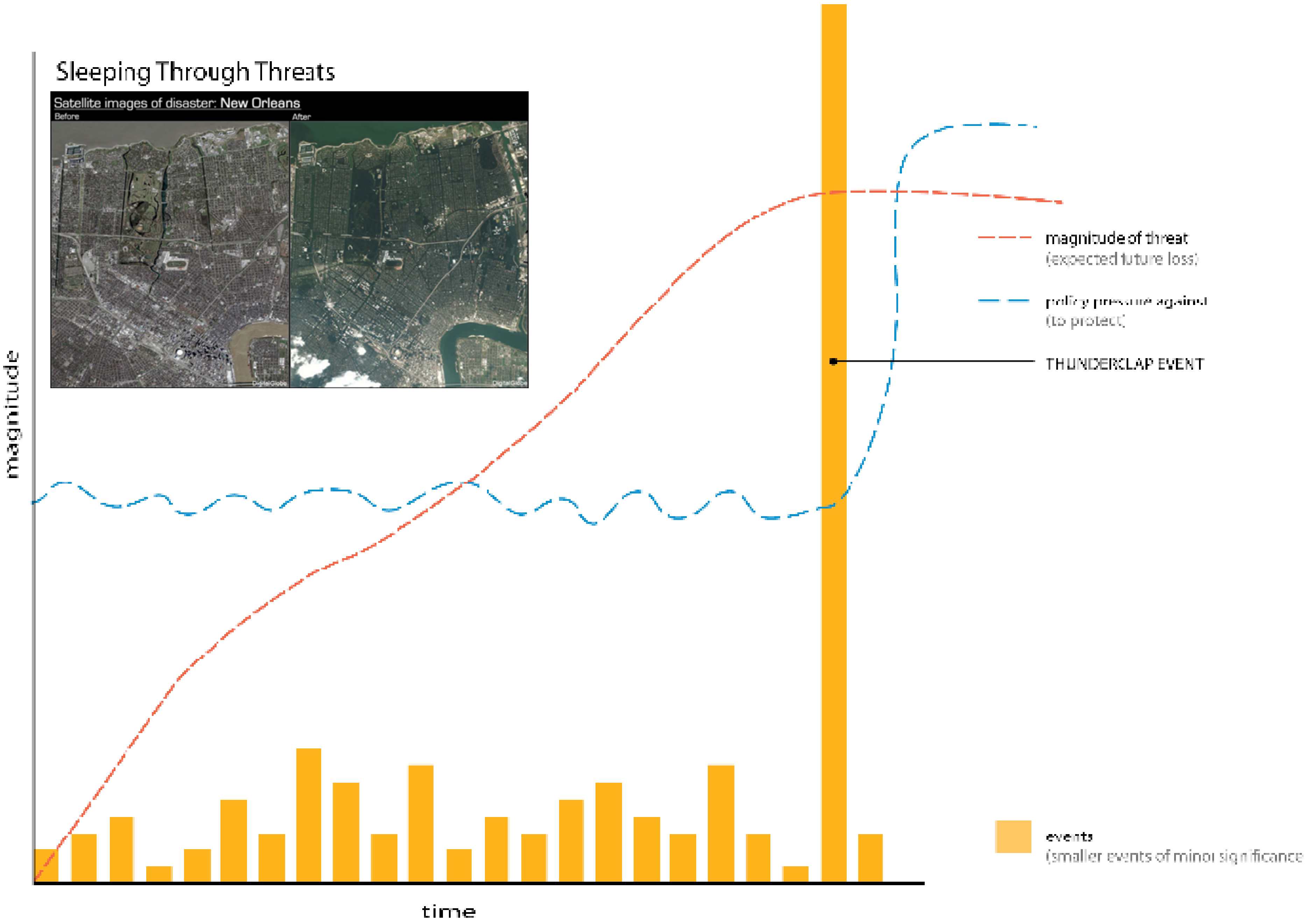
Four Major Points

1. Triangulated Tracings
2. Acting Before, During, and After Disasters
3. JARring Actions
4. Fat Tails

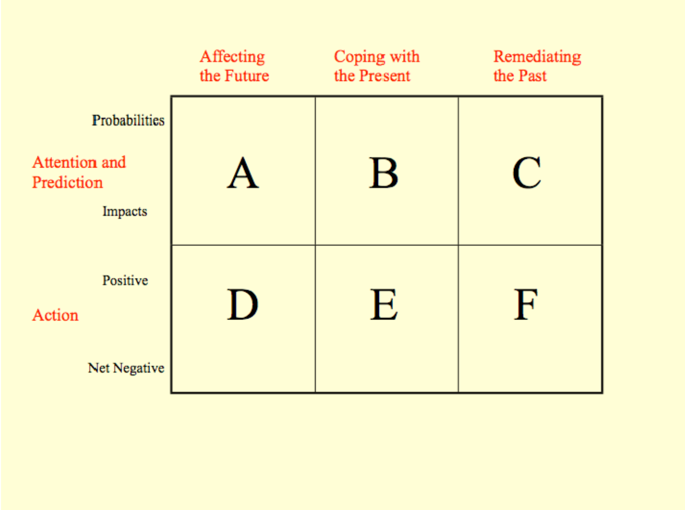
Triangulated Tracings





Sleeping Through Threats
Satellite images of disaster: New Orleans
Before
After
magnitude
time
magnitude of threat
(expected future loss)
policy pressure against
(to protect)
THUNDERCLAP EVENT
events
(smaller events of minor significance

		Affecting the Future	Coping with the Present	Remediating the Past
Attention and Prediction	Probabilities Impacts	A	B	C
Action	Positive Net Negative	D	E	F



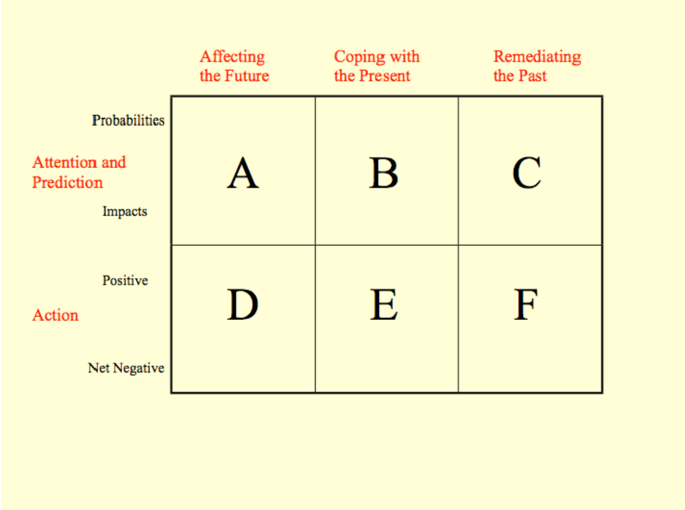
Affecting the Future

Attention and Prediction

A

Probabilities
markets, e.g., fiscal solutions
blue ribbon studies, e.g., IPCC
academic analyses, e.g., KSG
prediction markets?

Impacts
studies mentioned above
FAT TAILS (Normal misleading)
too many 12-foot men
future terrorist losses



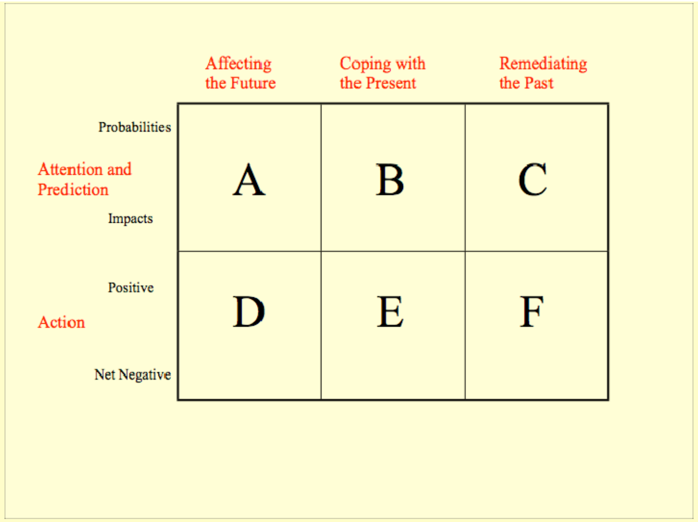
Affecting the Future

Action

D

Positive
protection
planning
mitigation
risk spreading

Net Negative
JARring actions



Remediating the Past

Probabilities

Attention and Prediction

Impacts

C

- Dribble versus blast consequences
- Risk uncertainty and ignorance
- Ticking bombs
- global warming
- pine beetles
- monocultures
- Sleeping dogs
- brownfields
- risk, economic development
- mine wastes abandoned
- Alarm clock events
- Yellowstone 1988
- France summer 2003
- 9/11/01

		Affecting the Future	Coping with the Present	Remediating the Past
Attention and Prediction	Probabilities / Impacts	A	B	C
Action	Positive / Net Negative	D	E	F

Remediating the Past

F

Action

Positive

Who pays--who owns losses?
Unclear responsibility
brownfields, generations of polluters
Local, regional, or national
Now or later
Bottom up or centralized allocation
Voluntary, litigated (payment from others) or taxation
Property right in status quo-
e.g., grandfathering risks

Net Negative

After-the-fact payments
Versus insurance, subsidized insurance
Politics and distortion
HAZWRAP nuclear waste sites
People versus places restored

JARring Actions

- Acronym: Jeopardize Assets that are Remote
- A particular type of externality: cost imposed on others who are spatially or temporally distant
- Could also be distant due to the probabilistic nature of imposed costs

The Problem

Normal mechanisms to control externalities (e.g., liability, contracting, political regulations for those in jurisdiction) do not work well for JARring actions.

Policy Challenges

- Hard to assign responsibility for consequences → plausible deniability
- Collective action problems
- People tend to look for local causes
- Scientific uncertainty
- Hard to calculate changes in risk levels

JARring Actions that Increase Flood Risks for Others

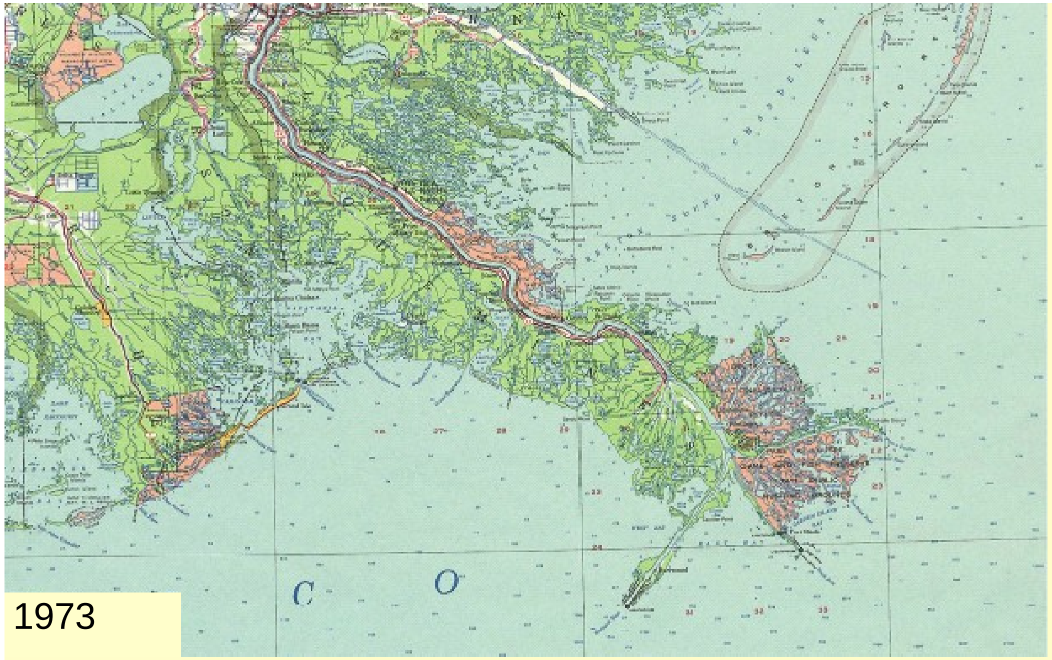
- Filling wetlands
- Increasing impervious surface area
- Construction of dams + levees/poor planning and design decisions
- Increasing drainage of agricultural land

One Example:Loss of a Storm Buffer

Louisiana contains about 40% of the country's wetlands but is also home to 80% of the country's wetland loss; since 1900 over 1 million acres have vanished.

(PHOTO BY ELLIS LUCIA / The Times-Picayune)

Even accounting for several small restoration projects underway, it is estimated that another 513 square miles (a little over 328,000 acres) of land will be lost by 2050.

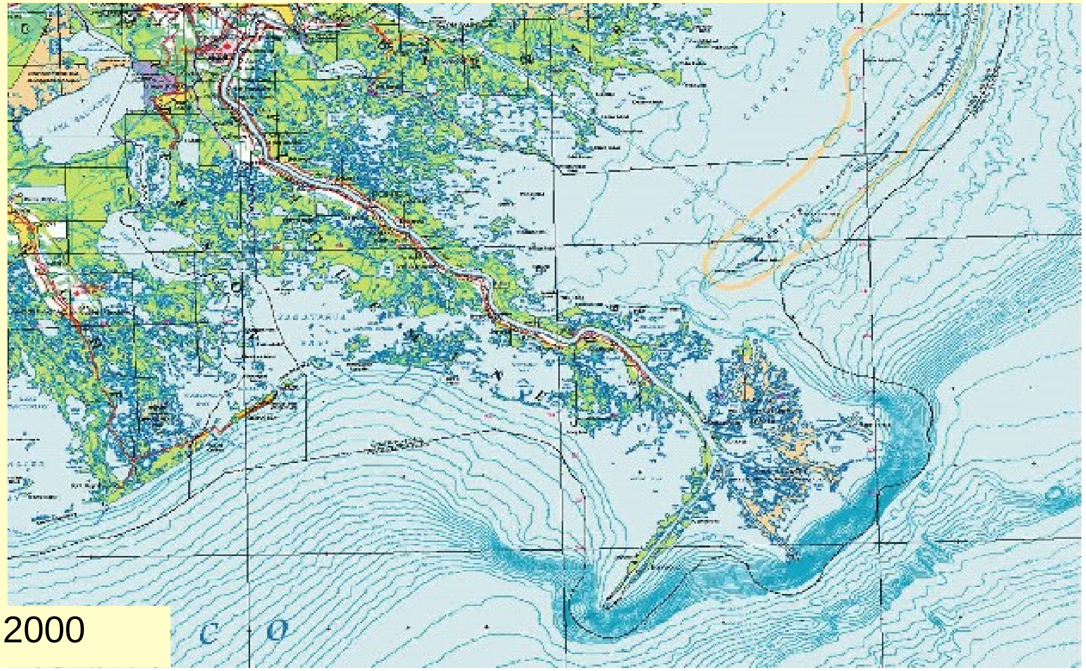


1973

Tracking the Loss

The rate of wetland loss has dropped from a high of about 40 square miles per year in the 1960s to 24 square miles per year today.

An area of wetlands close to the size of Manhattan is lost annually off the Louisiana coast, or about one football field of wetlands is lost every 38 minutes



2000

Source: http://www.publichealth.hurricane.lsu.edu/Louisiana%20Coastal%20Land%20Loss.htm

Causes of Loss:
Lack of Sediment Reaching Gulf

sediment stuck behind dams

Sources: http://www.lewis-clark.org/content/content-article.asp?ArticleID=1412

http://www.industcards.com/hydro-usa-ne-dakotas.htm

Source: http://marine.usgs.gov/fact-sheets/LAwetlands/lawetlands.html

Sediment Sent to Sea

Nine major shipping lanes

8,000 mile network of canals to facilitate exploration

deadly levels of saltwater infiltration into freshwater marshland

Subsidence due to lack of sediment, exacerbated by withdrawals of oil and natural gas

Dredging of Canals

MRGO
(Mississippi River Gulf Outlet)

http://www.saveourlake.org/wetlands.htm

source: www.saveourlake.org

- MRGO is 76 miles long (Panama Canal is 50 miles), and required the removal of 60 million more cubic yards of earth than did the Panama Canal.
- Panama Canal = 14,000 vessels per year, $400 million annual tolls
- MRGO = < 5 ships per day, $0 tolls, $13 million to $37 million per year just to keep it dredged.
- Construction completed in 1965 - killed more than 11,000 acres of cypress swamps and turned over 20,000 acres of brackish marsh into saline marsh (saltwater intrusion), killing all freshwater vegetation and wildlife.

The 2000 floods in Britain

- 10,000 homes and businesses were flooded
- According to the BBC, rainfall in the fall of 2000 was the highest since 1766 when record keeping began
- 5 million people in Britain and Whales are at risk from flooding; £214 billion in property is at risk

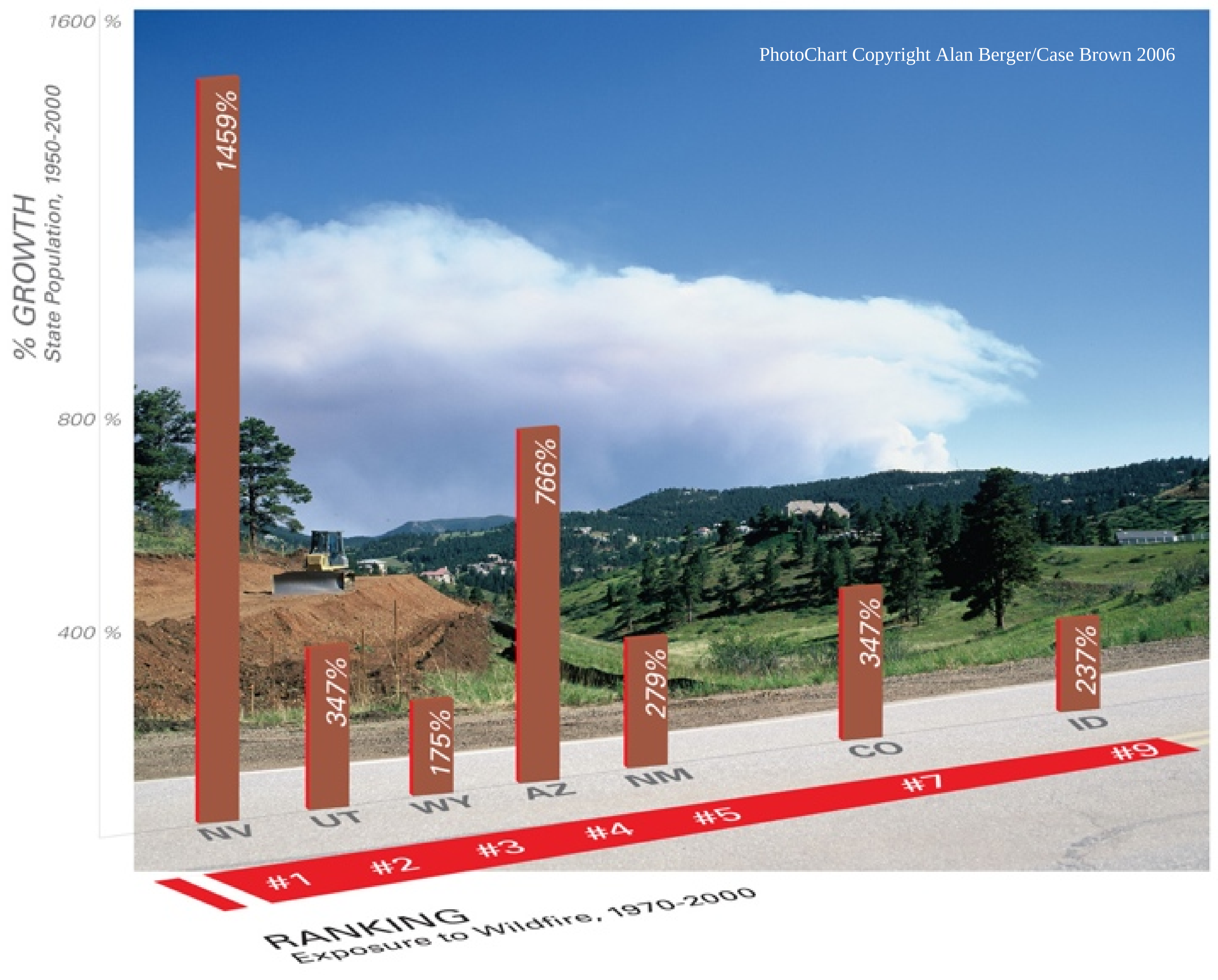
Images from Cambridge University Centre for Risk in the Built Environment http://www.arct.cam.ac.uk/curbe/floods.html

Issues Left to the Audience
(Due to time limitations)

- Government Action Needed
- Possible Policy Responses
- Incentives, Insurance and Planning for the Future

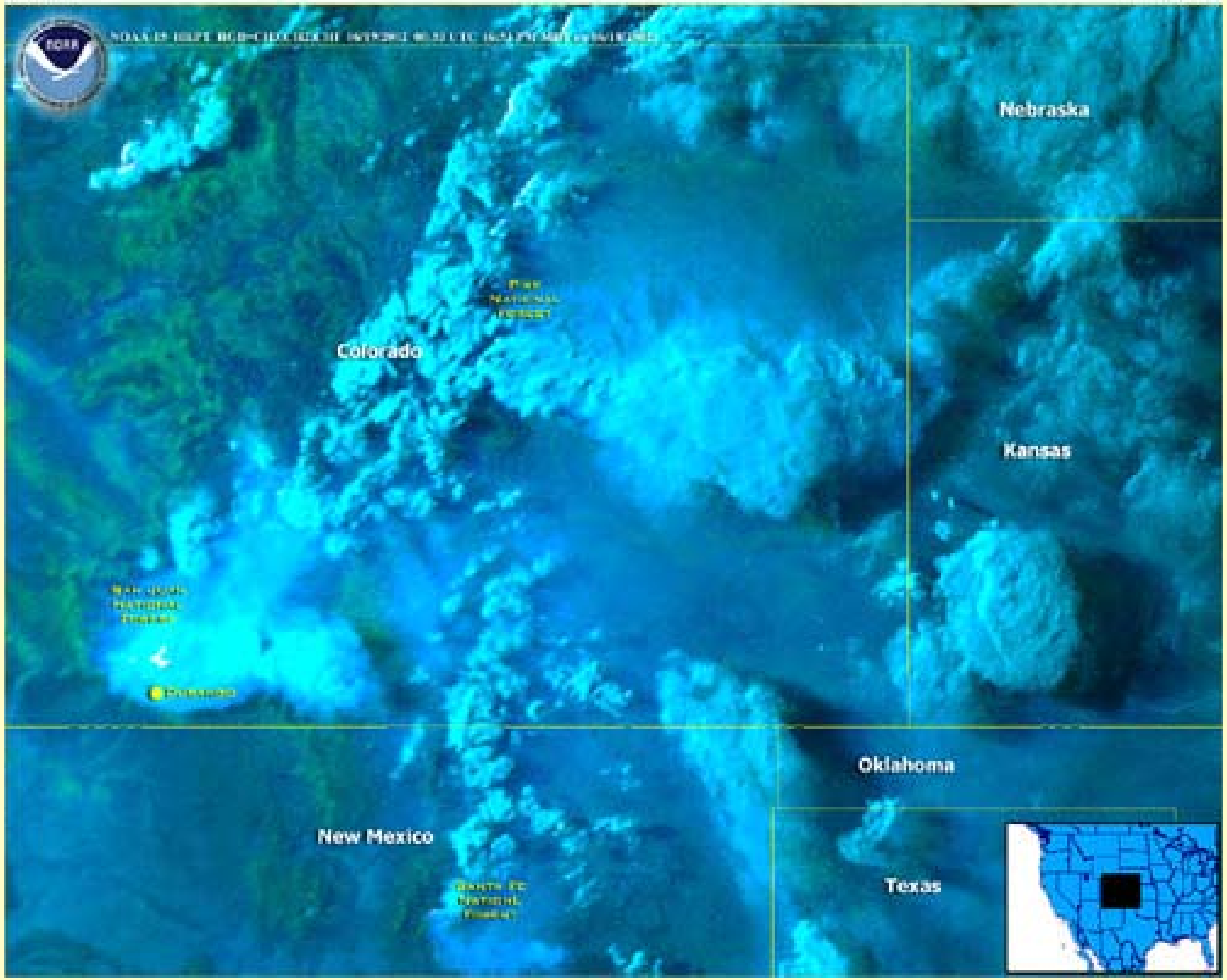
What’s Wrong with This Picture?

Housing along south side of Phoenix South Mountain Park, Chandler/Phoenix, Arizona. (From Drosscape: Wasting Land in Urban America, 2006. Alan Berger)


PhotoChart Copyright Alan Berger/Case Brown 2006
% GROWTH
State Population, 1950-2000
1600 %
800 %
400 %
1459%
347%
175%
766%
279%
347%
237%
NV
UT
WY
AZ
NM
CO
ID
#1
#2
#3
#4
#5
#7
#9
RANKING
Exposure to Wildfire, 1970-2000

Heat signatures (red) and smoke (light blue haze) are visible from fires burning in Colorado and New Mexico. The Hayman Fire has burned 135,000 acres in Pike National Forest, CO and was 40% contained. The Missionary Ridge Fire has scorched 44,330 acres ten miles north of Durango, CO in San Juan National Forest and was 25% contained. The Roybal/Trampas Fire has scorched 4,300 acres in Santa Fe National Forest and was 5% contained. This information is from the National Interagency Fire Center Incident Management Situation Report from 06/19/2002.

CREDIT: NOAA



Historically Significant Wildland Fires 1988-1999
Continental U.S.

Date	Name	Location	Acres	Significance
1988	Yellowstone	Montana and Idaho	1,585,000	Large Amount of Acreage Burned
1988	Canyon Creek	Montana	250,000	Large Amount of Acreage Burned
June 1990	Painted Cave	California	4,900	641 Structures Destroyed
June 1990	Dude Fire	Arizona	24,174	6 Lives Lost 63 homes destroyed
October 1991	Oakland Hills	California	1,500	25 Lives Lost and 2,900 Structures Destroyed
August 1996	Cox Wells	Idaho	219,000	Largest Fire of the Year
1998	Flagler/St. John	Florida	94,656	Forced the evacuation of thousands of residents
August 1999	Dunn Glen Complex	Nevada	288,220	Largest Fire of the Year
September - November 1999	Kirk Complex	California	86,700	Hundreds of people were evacuated by this complex of fires that burned for almost 3 months

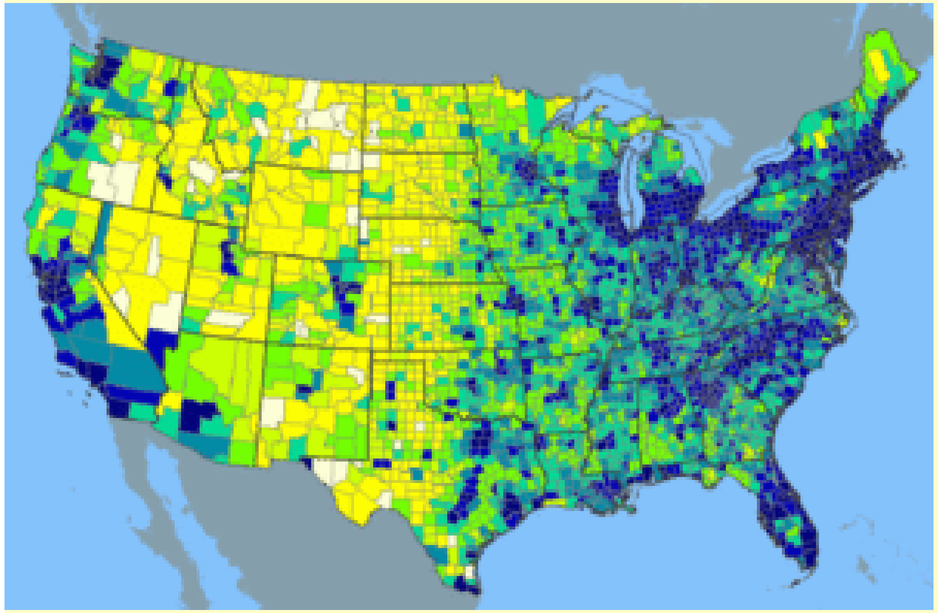
FAT TAILS: Observe massive multiple of largest to next in three categories:

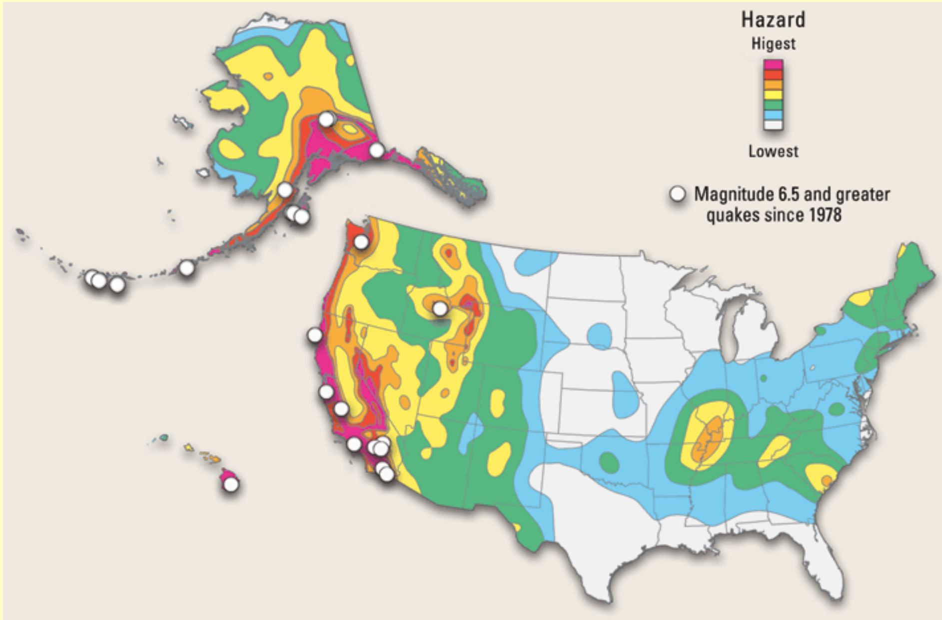
Largest fire of year, people evacuated, and structures destroyed.

Earthquakes and People

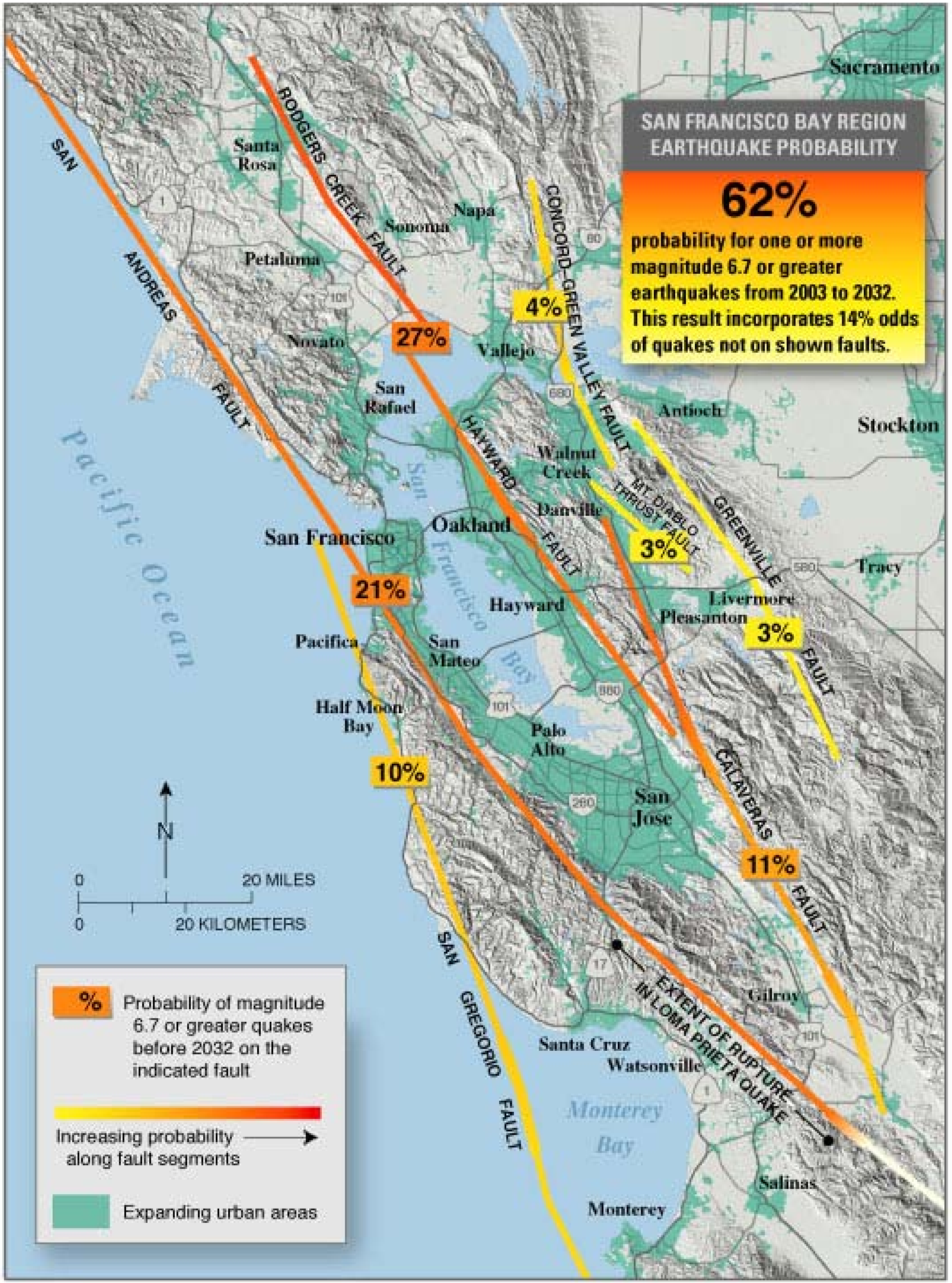
- We routinely build in areas at risk from earthquakes – consider the Bay Area.
- This is largely because earthquakes are an “amenity risk.”
- Amenity Risks: risks that have associated with them a benefit
- Compare to Noxious Risks

Comparing population density to earthquake hazard





Source: Wikipedia, USGS


SAN FRANCISCO BAY REGION EARTHQUAKE PROBABILITY
62%
probability for one or more magnitude 6.7 or greater earthquakes from 2003 to 2032. This result incorporates 14% odds of quakes not on shown faults.
SAN ANDREAS FAULT
RODGERS CREEK FAULT
CONCORD-GREEN VALLEY FAULT
HAYWARD FAULT
MT DIABLO THRUST FAULT
GREENVILLE FAULT
CALAVERAS FAULT
SAN GREGORIO FAULT
EXTENT OF RUPTURE IN LOMA PRIETA QUAKE
27%
4%
21%
3%
3%
10%
11%
Sacramento
Santa Rosa
Napa
Sonoma
Petaluma
Novato
Vallejo
San Rafael
Antioch
Stockton
Walnut Creek
Danville
San Francisco
Oakland
Tracy
Livermore
Pleasanton
Hayward
Pacifica
San Mateo
Half Moon Bay
Palo Alto
San Jose
Gilroy
Santa Cruz
Watsonville
Salinas
Monterey
Pacific Ocean
San Francisco Bay
Monterey Bay
N
0
20 MILES
0
20 KILOMETERS
% Probability of magnitude 6.7 or greater quakes before 2032 on the indicated fault
Increasing probability along fault segments
Expanding urban areas

Source: USGS

Potential Disaster: Earthquake in Istanbul

- Scientists predict large earthquake likely in next 30 years
- 1000 mile faultline running east to west
- Population of up to 15 million
- Higher rents in safer areas
- Many buildings do not conform to building codes

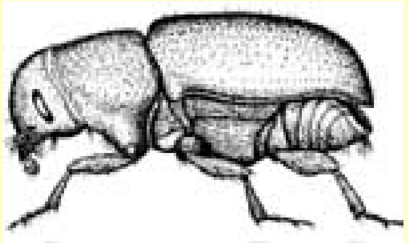
Source: http://archives.cnn.com/2000/NATURE/04/28/istanbul.quake.enn/

Largest and Deadliest Earthquakes by Year 1990-2005

	Largest Earthquakes				Deadliest Earthquakes			
Year	Date	Magnitude	Fatalities	Region	Date	Magnitude	Fatalities	Region
2005	03/28	8.7	1,313	Northern Sumatra, Indonesia	10/08	7.6	80,361	Pakistan
2004	12/26	9.0	283,106	Off West Coast of Northern Sumatra	12/26	9.0	283,106	Off West Coast of Northern Sumatra
2003	09/25	8.3	0	Hokkaido, Japan Region	12/26	6.6	31,000	Southeastern Iran
2002	11/03	7.9	0	Central Alaska	03/25	6.1	1,000	Hindu Kush Region, Afghanistan
2001	06/23	8.4	138	Near Coast of Peru	01/26	7.7	20,023	India
2000	11/16	8.0	2	New Ireland Region, P.N.G.	06/04	7.9	103	Southern Sumatera, Indonesia
1999	09/20	7.7	2,297	Taiwan	08/17	7.6	17,118	Turkey
1998	03/25	8.1	0	Balleny Islands Region	05/30	6.6	4,000	Afghanistan-Tajikistan Border Region
1997	10/14	7.8	0	South of Fiji Islands	05/10	7.3	1,572	Northern Iran
	12/05	7.8	0	Near East Coast of Kamchatka				
1996	02/17	8.2	166	Irian Jaya Region Indonesia	02/03	6.6	322	Yunnan, China
1995	07/30	8.0	3	Near Coast of Northern Chile	01/16	6.9	5,530	Kobe, Japan
	10/09	8.0	49	Near Coast of Jalisco Mexico				
1994	10/04	8.3	11	Kuril Islands	06/20	6.8	795	Colombia
1993	08/08	7.8	0	South of Mariana Islands	09/29	6.2	9,748	India
1992	12/12	7.8	2,519	Flores Region, Indonesia	12/12	7.8	2,519	Flores Region, Indonesia
1991	04/22	7.6	75	Costa Rica	10/19	6.8	2,000	Northern India
	12/22	7.6	0	Kuril Islands				
1990	07/16	7.7	1,621	Luzon, Philippine Islands	06/20	7.4	50,000	Iran

FAT TAILS: Observe massive multiple of largest to next in fatalities.

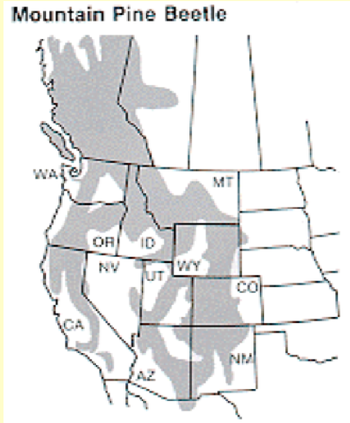
Mountain Pine Beetles



Dendroctonus ponderosae

Mountain Pine Beetles

- Largest infestation in North American history
- Infest area in British Columbia three times the size of Maryland



- 12 western states
- Attacks older, overcrowded, even-aged trees - perfect food resulting from past foresting activities
- Result of wildfire suppression and forest management flaws
- Associated with warming winters (global warming?)
- Timber companies may benefit, millions of trees to be removed
- 80% of the coniferous forest in the American West is predicted to be die due to MPB over next 100 years

By 2250 most of the natural resources will be mined out of the western U.S., leaving over 100,000 square miles of altered landscape.

Trapper Mine (surface coal). 2000.Western Colorado.(From *Reclaiming the American West*, Alan Berger)

166. **Bingham Canyon Mine** (copper). 2000. Near Salt Lake City, Utah.(From *Reclaiming the American West*, Alan Berger)

Top taxpayer liability in the U.S.

Existing Financial Assurance (Bonding) = $33.2M

Estimated Cost to Reclaim at $50,000/Acre = $1.35B

Estimated Shortfall of Liability = $1.317B

Metal Mines

Pre-law and Post-law are determined state by state

Fat Tails

1. Most familiar individual outcomes, e.g., human heights, have small variability relative to the mean. We do not see 12-foot men.
2. Other outcomes are aggregates, with large numbers of trials. They also have low variability relative to the mean.
3. These are the models we carry in our head. But they are *fundamentally misleading* when we think about low probability catastrophes.
4. Catastrophes: low probability, single-event outcomes. Their magnitudes (acres lost to wildfire, people lost in a terrorist attack, damage due to a flooding incident have high variability relative to the mean.
5. The largest experience to date is a poor indicator for the size of the next catastrophe larger than that, or even for expected losses.
6. Prior to 9/11, the most people lost to a terrorist attack in the U.S. was below 300. Now the number is fewer than 3,000. But there is a good chance that 100,000 could be lost, or many more.
7. Theme of Martin Weitzman review of Stern Report. Report perhaps right for wrong reason. Need protection against outlier event. (Focuses more on risk aversion, whereas even with expected value there is a scary very distant right tail.)
8. 5-7 million deaths from Avian Flu. Why not 50,000 or 50 million?

UK Top 10 Natural Disasters

Number Killed

Disaster type	Date	No Killed
Wind Storm	4-Dec-1952	4,000
Extreme Temperature	Aug-2003	2,045
Slides	21-Oct-1966	140
Wind Storm	Jan-1990	85
Flood	15-Aug-1952	34
Epidemic	4-May-1985	34
Wind Storm	5-Jan-1991	28
Epidemic	Aug-1984	26
Wind Storm	24-Jan-1984	22
Wind Storm	14-Jan-1968	20

Economic Damages

Disaster type	Date	Damage US* (000's)
Flood	11-Oct-2000	5,900,000
Wind Storm	Jan-1990	4,893,350
Wind Storm	4-Jan-1998	1,991,400
Wind Storm	15-Oct-1987	1,700,000
Wind Storm	24-Oct-1998	665,400
Wind Storm	7-Jan-2005	650,000
Wind Storm	23-Dec-1995	600,000
Flood	9-Apr-1998	500,000
Wind Storm	26-Oct-2002	400,000
Wind Storm	28-Oct-2000	290,723

Source: EM-DAT: The OFDA/CRED International Disaster Database, www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium

France Top 10 Natural Disasters

Number Killed

Disaster type	Date	No Killed
Extreme Temperature	1-Aug-2003	14,947
Wind Storm	26-Dec-1999	92
Slides	16-Apr-1970	72
Wind Storm	Jan-1990	66
Wind Storm	22-Sep-1992	47
Earthquake	11-Jun-1909	46
Slides	10-Feb-1970	42
Flood	12-Nov-1999	36
Flood	30-Sep-1958	35
Flood	8-Jul-1977	26

Source: EM-DAT: The OFDA/CRED International Disaster Database, www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium

Economic Damages

Disaster type	Date	Damage US* (000's)
Wind Storm	26-Dec-1999	8,000,000
Extreme Temperature	1-Aug-2003	4,400,000
Wind Storm	Jan-1990	1,969,275
Wind Storm	16-Oct-1987	1,700,000
Drought	Jul-1989	1,600,000
Flood	2-Dec-2003	1,500,000
Flood	8-Sep-2002	1,190,000
Extreme Temperature	20-Apr-1991	772,000
Flood	17-Jan-1995	700,000
Flood	Mar-1983	604,000

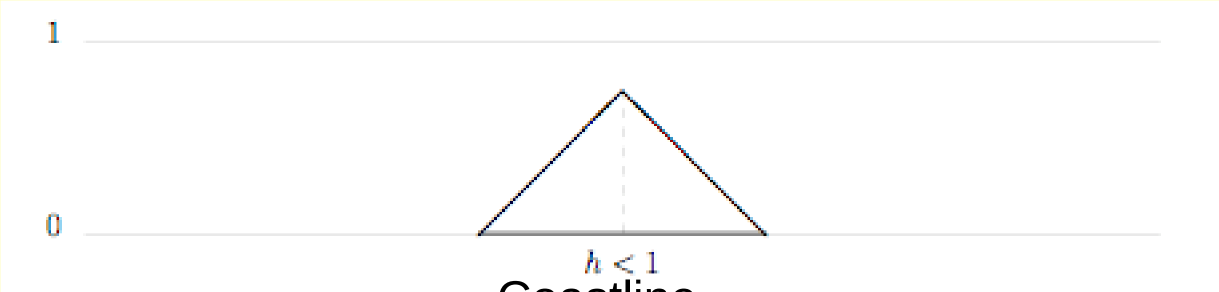
Winter Storms in Europe

- SwissRe calls them a "major catastrophe loss potential"
- e.g. December 1999 storms: Lothar and Martin
  - 80+ deaths
  - US $18 billion in damages
- AIR estimates Europe could experience storm with insured losses over €40 billion (about US$54 billion).

Example of forest loss from a winter storm. Source: SwissRe, "Storm over Europe – An underestimated risk "

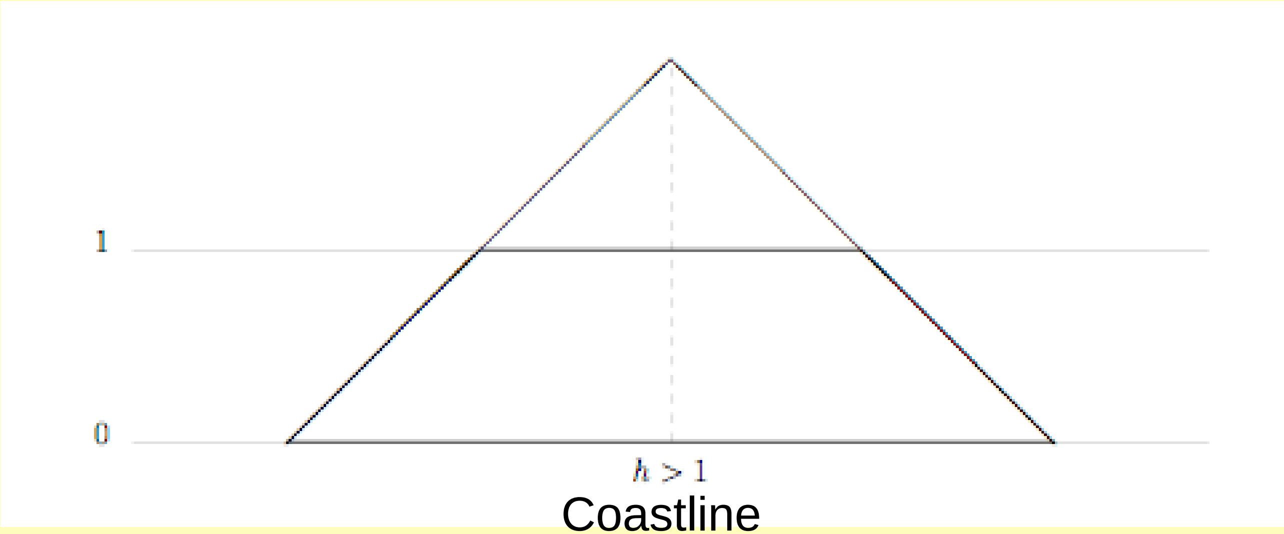
Model of Damages

Fraction Destroyed



Coastline

Fraction Destroyed



Coastline

Power Law Result

Now, suppose that h has a Pareto distribution with parameters (c_0, k):

$$\Pr(h \le c) = 1 - \left(\frac{c_0}{c}\right)^k, \quad \text{for } c_0 \le c < \infty.$$

k = 3/2

log (1-Pr(A≤a))

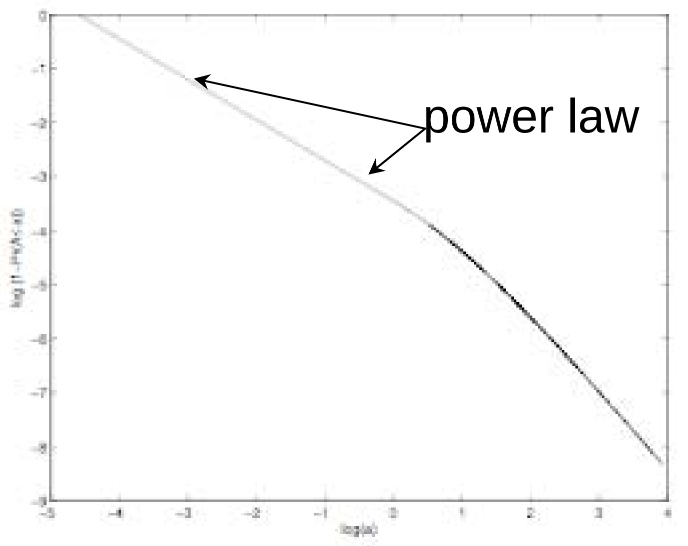
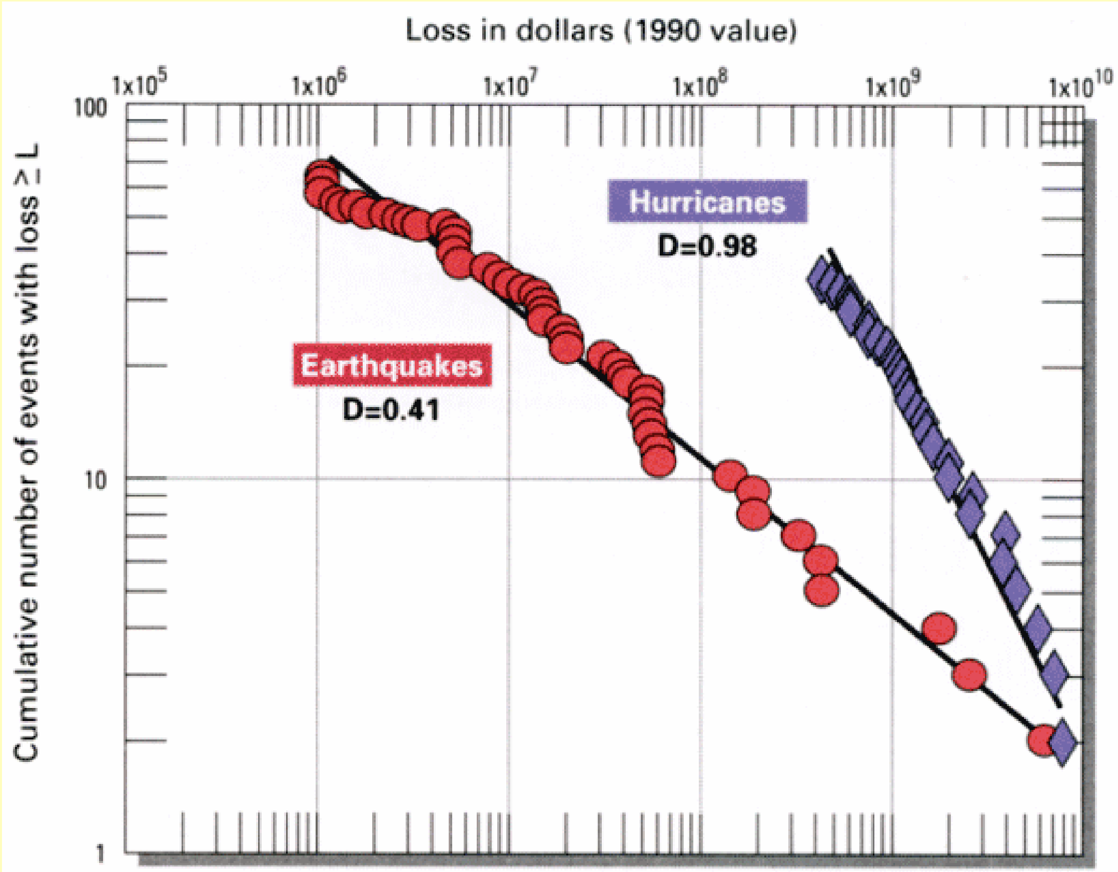


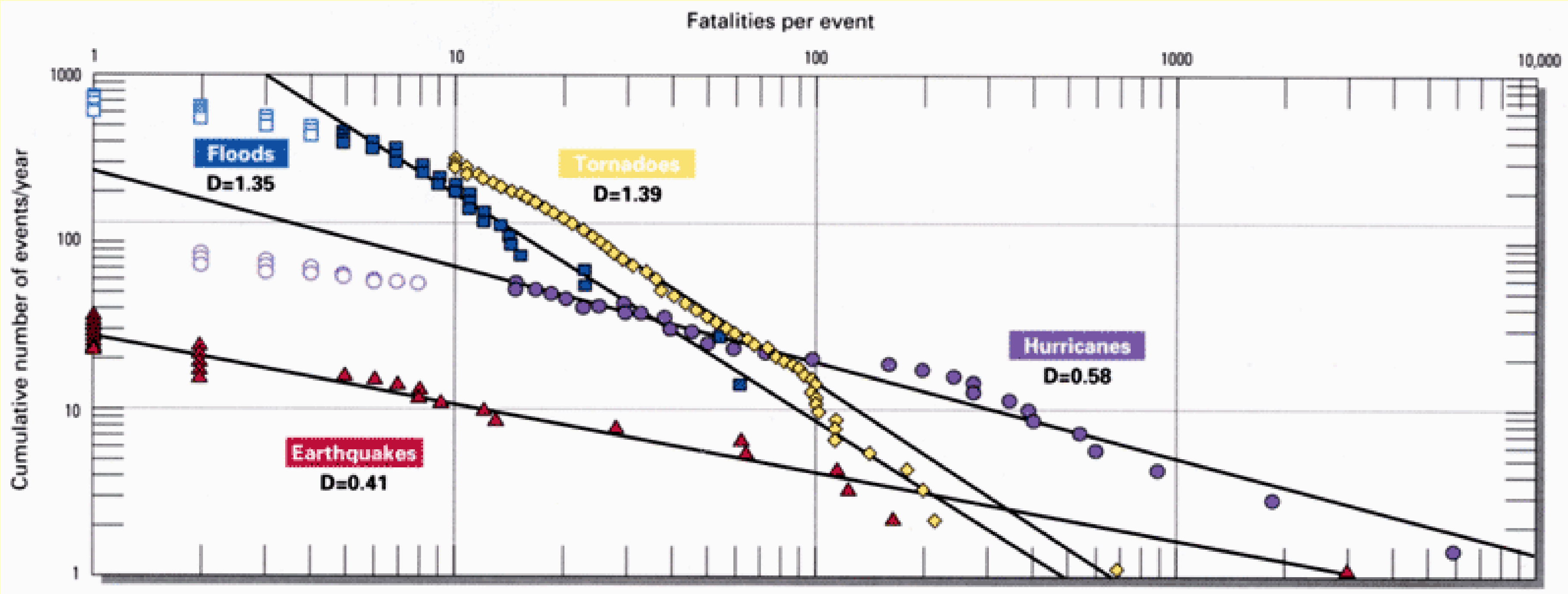
Figure 1: Log survival function

Power Law: $p(x)=Cx^D$

$$\log(p(x)) = \log(C) + D\log(x)$$



Source: Barton, C. and S. Nishenko (2003). Natural Disasters—Forecasting Economic and Life Losses. USGS Fact Sheet. Available online at: http://pubs.usgs.gov/fs/natural-disasters/index.html



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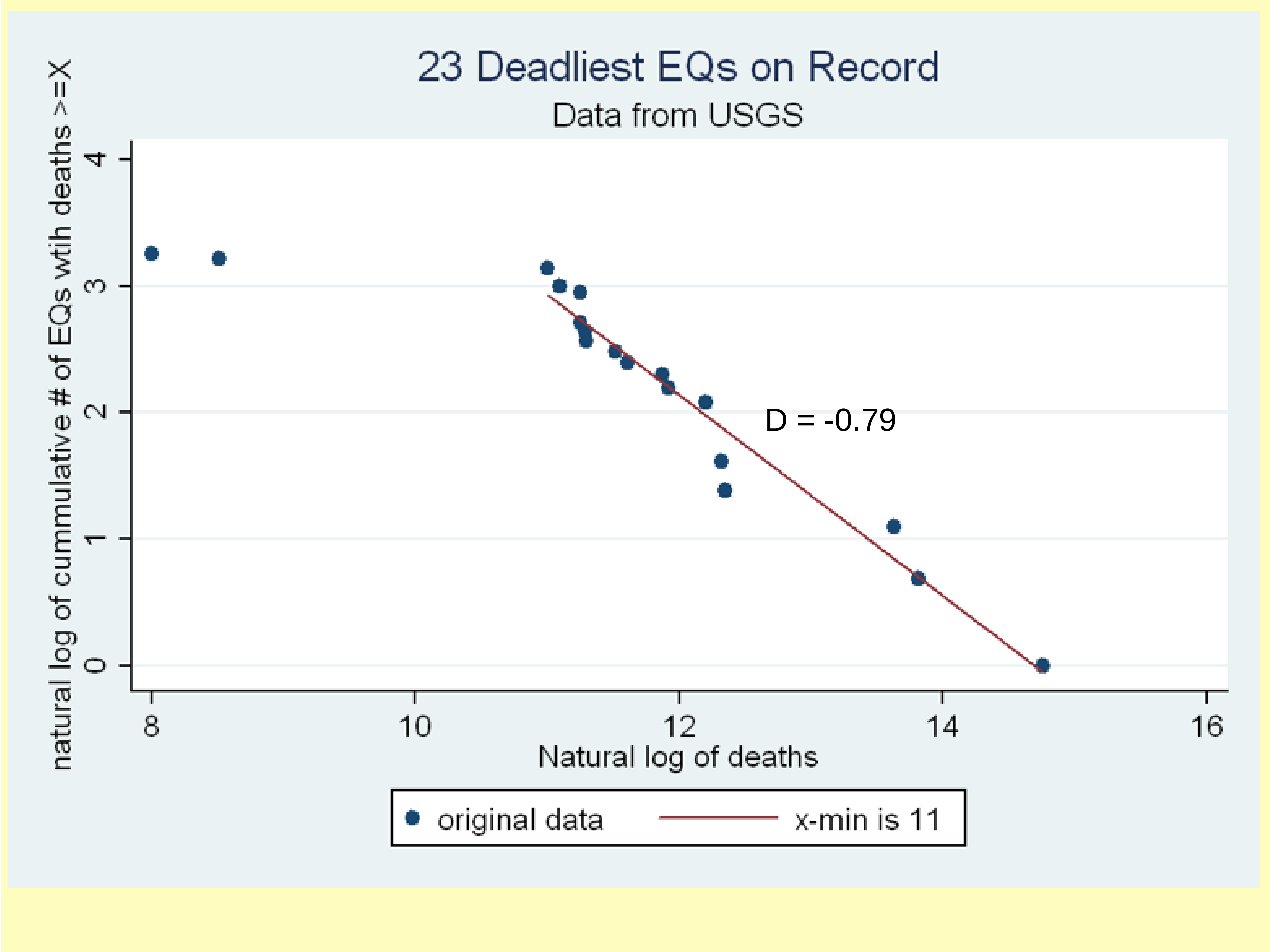
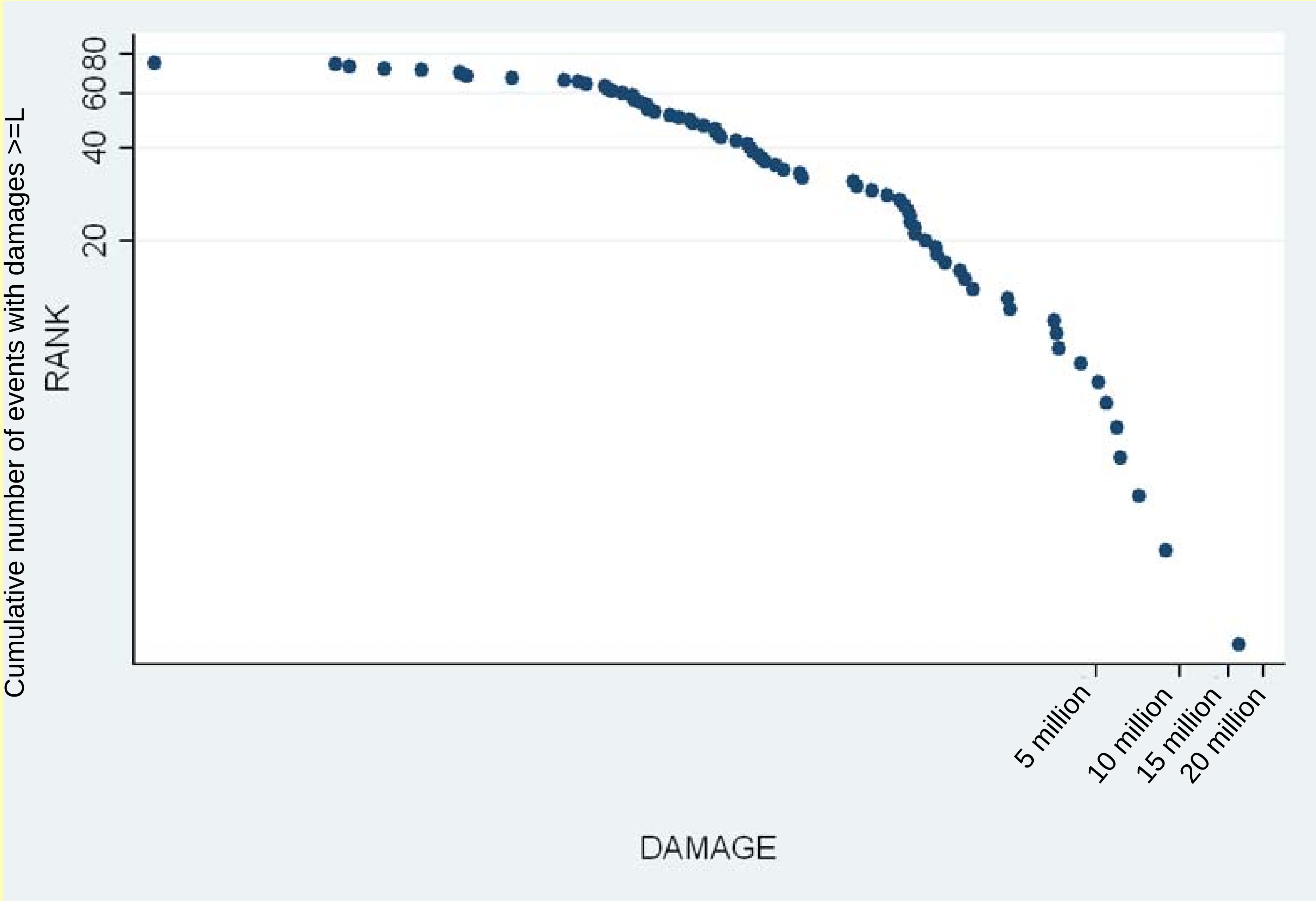


23 Deadliest EQs on Record
Data from USGS
natural log of cummulative # of EQs wtih deaths >=X
0
1
2
3
4
8
10
12
14
16
Natural log of deaths
D = -0.79
original data
x-min is 11

Yearly Total Damages from Floods in the United States



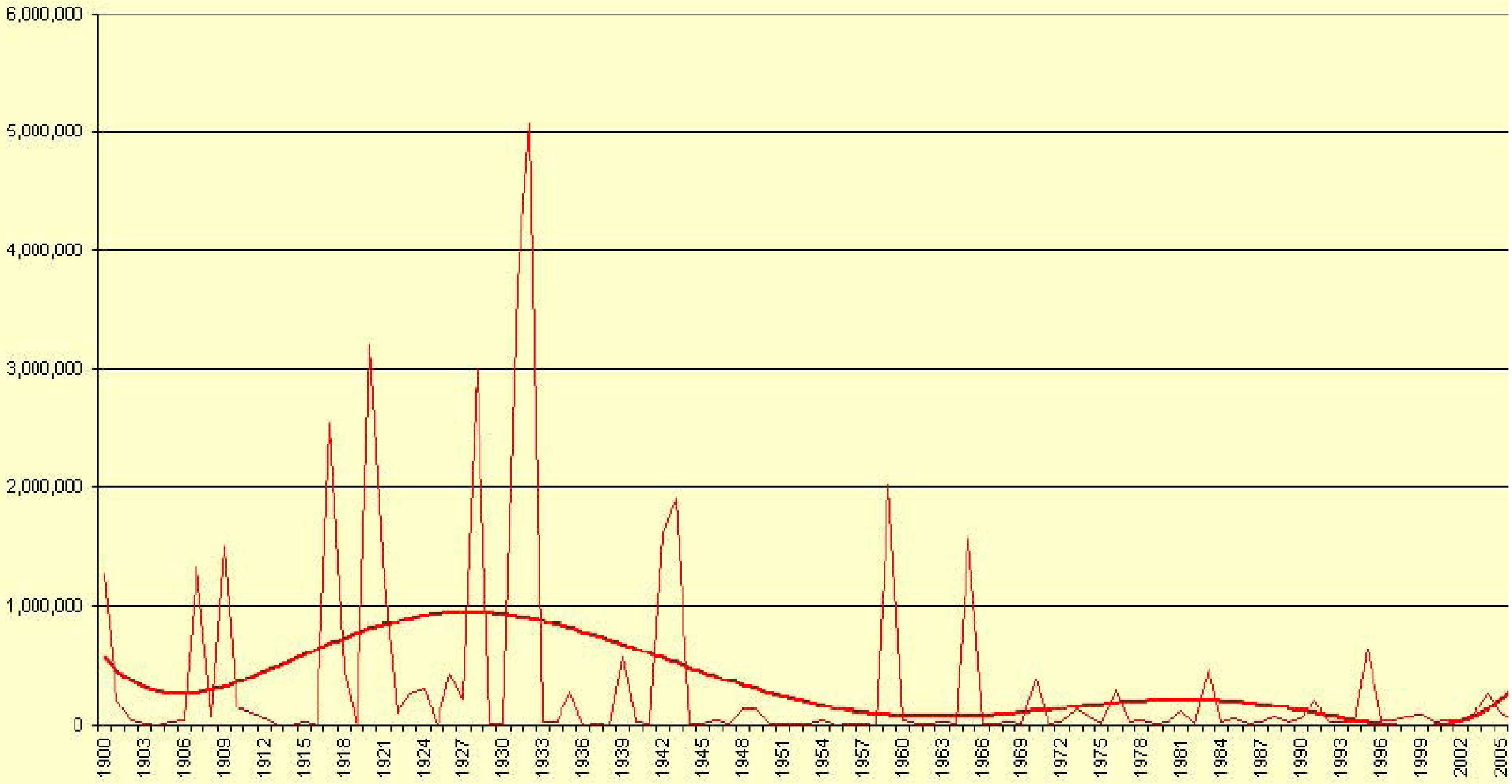
This is from flood damage data from a reanalysis of
National Weather Service estimates from 1926-2003.
Available online at: http://www.flooddamagedata.org/

Loss = Impact x Density

Impact=f(x)
Density=g(d)
Loss is integral of the two functions...

Future work
f(x) is being affected by human actions
g(d) is shifting to the right in many high-risk areas
g(d,x) becomes more concentrated as x increases

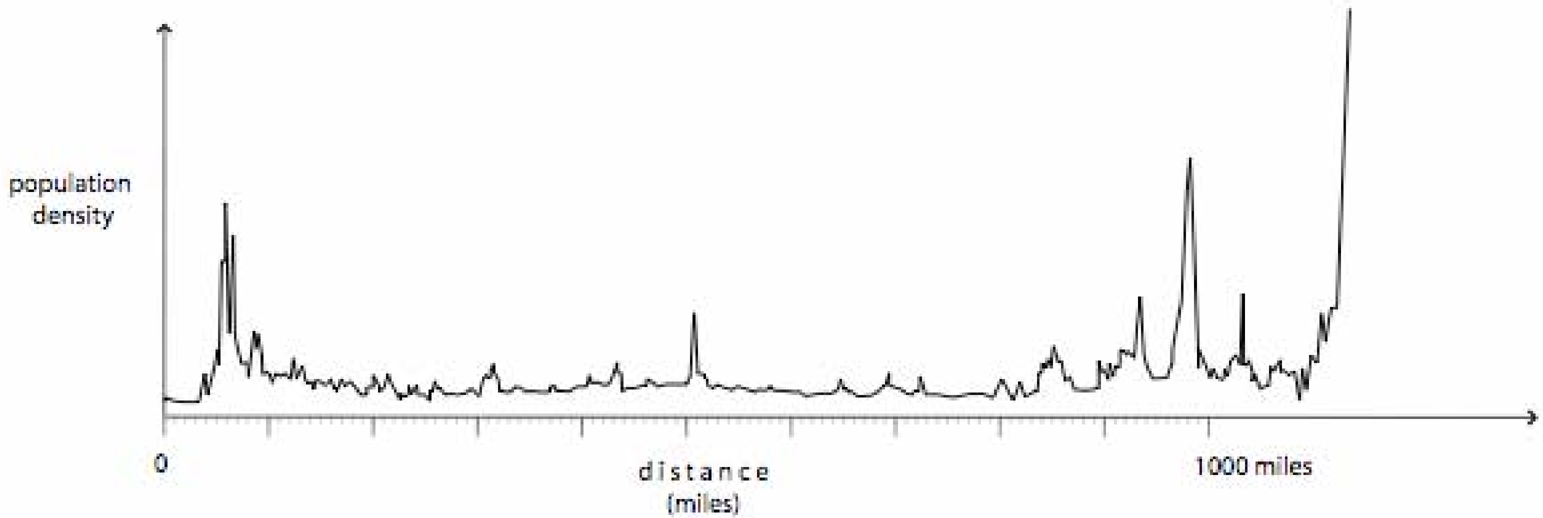
Total number of people reported killed by disasters: 1900 - 2006



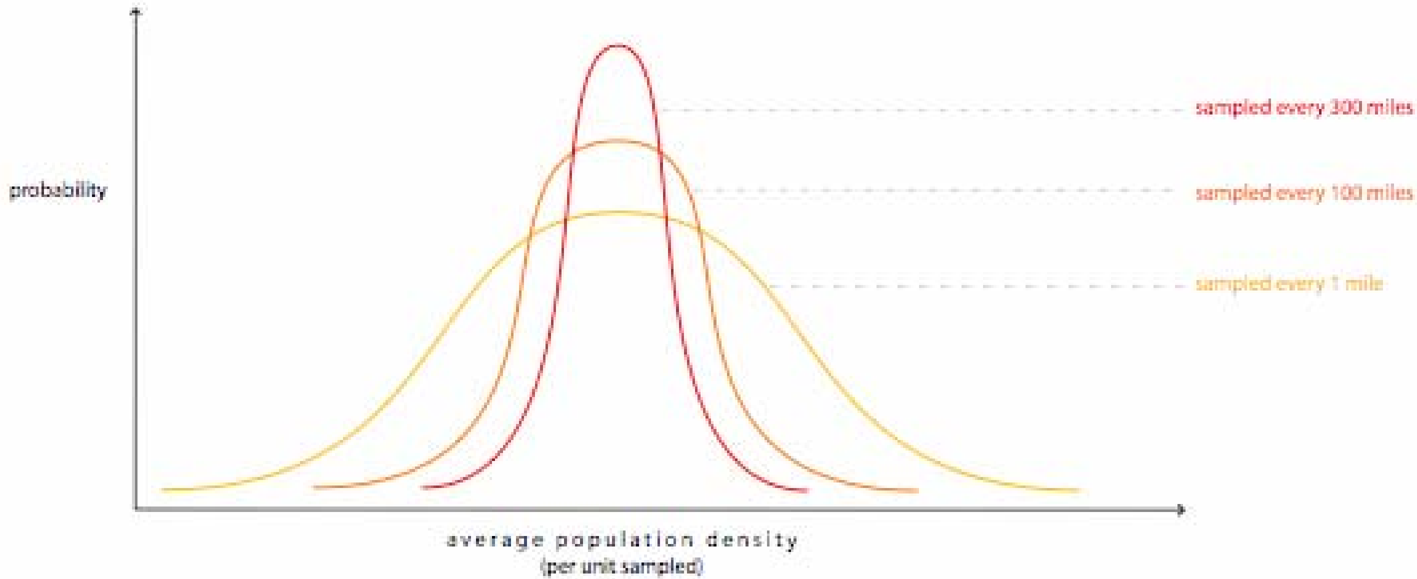
Equation for time trend-line : $y = 0.0003x^6 - 0.0919x^5 + 11.684x^4 - 687.31x^3 + 17937x^2 - 161530x + 709396$; $R^2 = 0.13$

Source : "EM-DAT : The OFDA/CRED International Disaster Database; www.em-dat.net - Université catholique de Louvain - Brussels - Belgium"

POPULATION DENSITY ALONG A COASTLINE



PROBABILITY DISTRIBUTION OF POPULATION DENSITY SAMPLES



JARring Actions
The Reality

While we can never contract with the future or accurately predict all of the consequences of our actions and policies, policymakers must extend their thinking about their impacts and the impacts of private entities beyond the local, the near term, the likely, and the recently newsworthy.

FAT TAILS
The Reality

Uncertainty abounds when we confront low probability events, often shrouded by the cloud of ignorance. Distributions of outcomes will not be known. Experience across classes of catastrophes and across disparate geographic realms indicates that such distributions are well described by fat-tailed distributions. The past is no longer prologue to the future; it is an underestimate. Where we have been surprised in the past, greater surprises must be expected in the future.