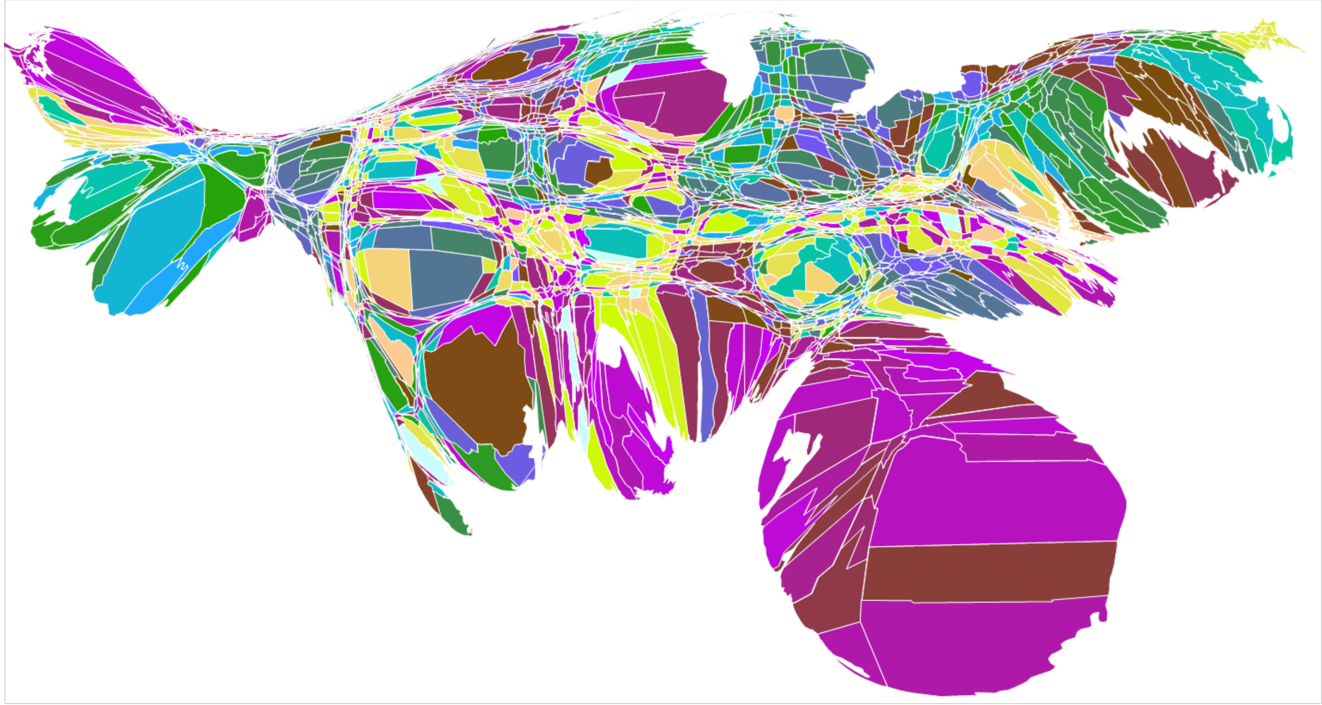
Catastrophe Modeling – Lessons from Recent Experience

Stephen Mildenhall

March 22, 2013



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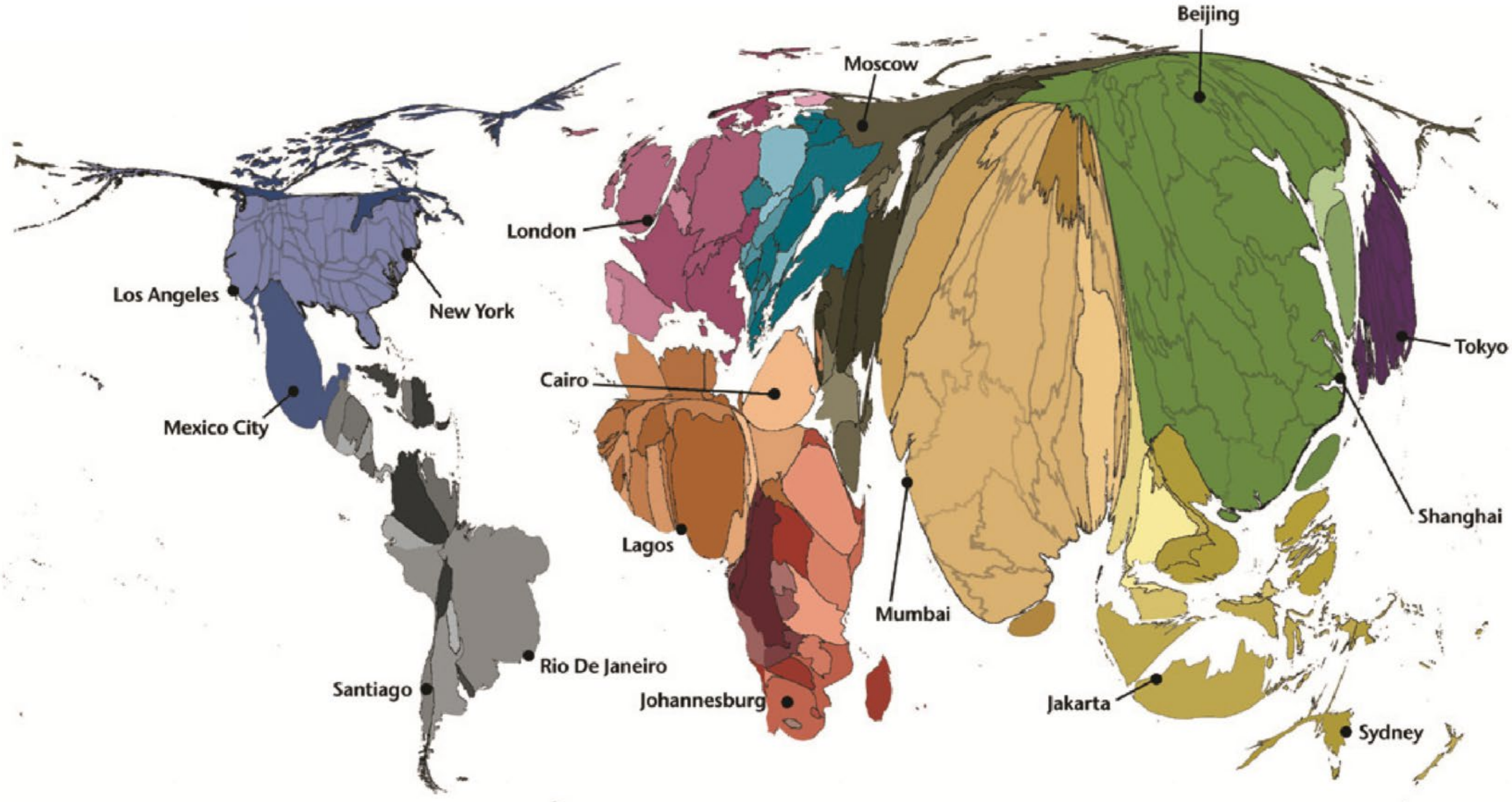
Population



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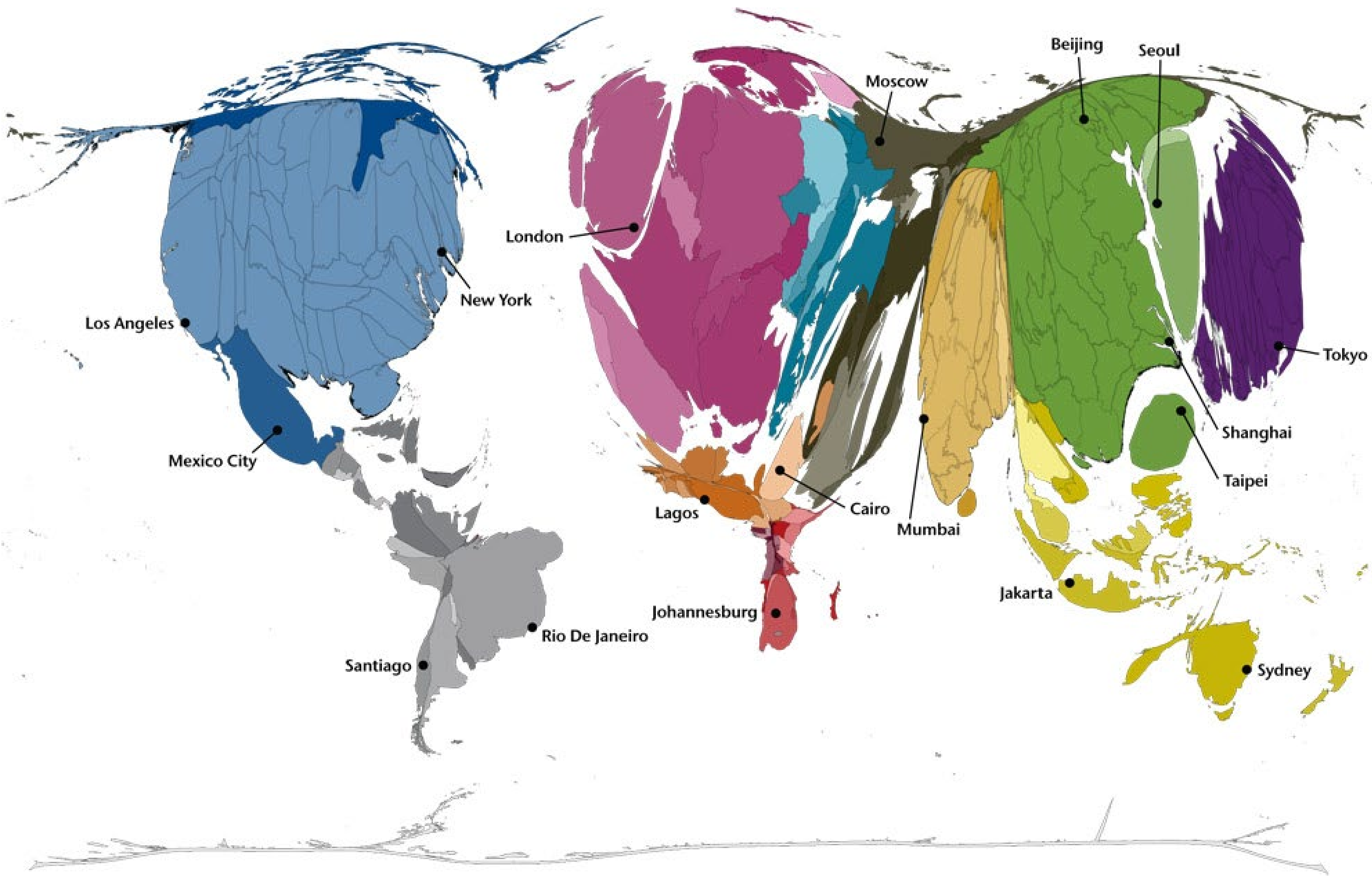
GDP



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Moscow
London
New York
Los Angeles
Tokyo
Shanghai
Mexico City
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Cairo
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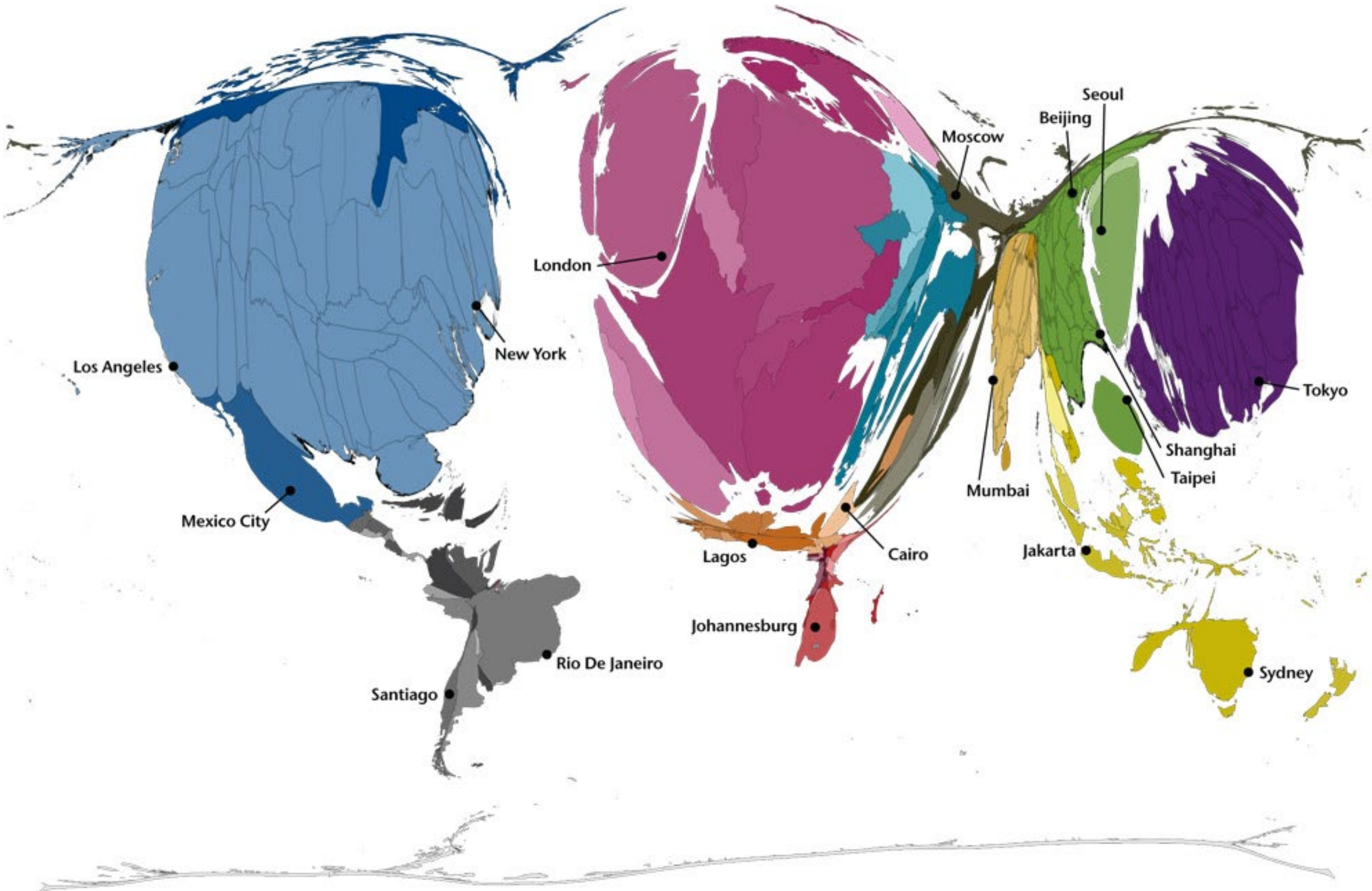
Mumbai
Jakarta
Johannesburg
Rio De Janeiro
Santiago
Sydney

Wealth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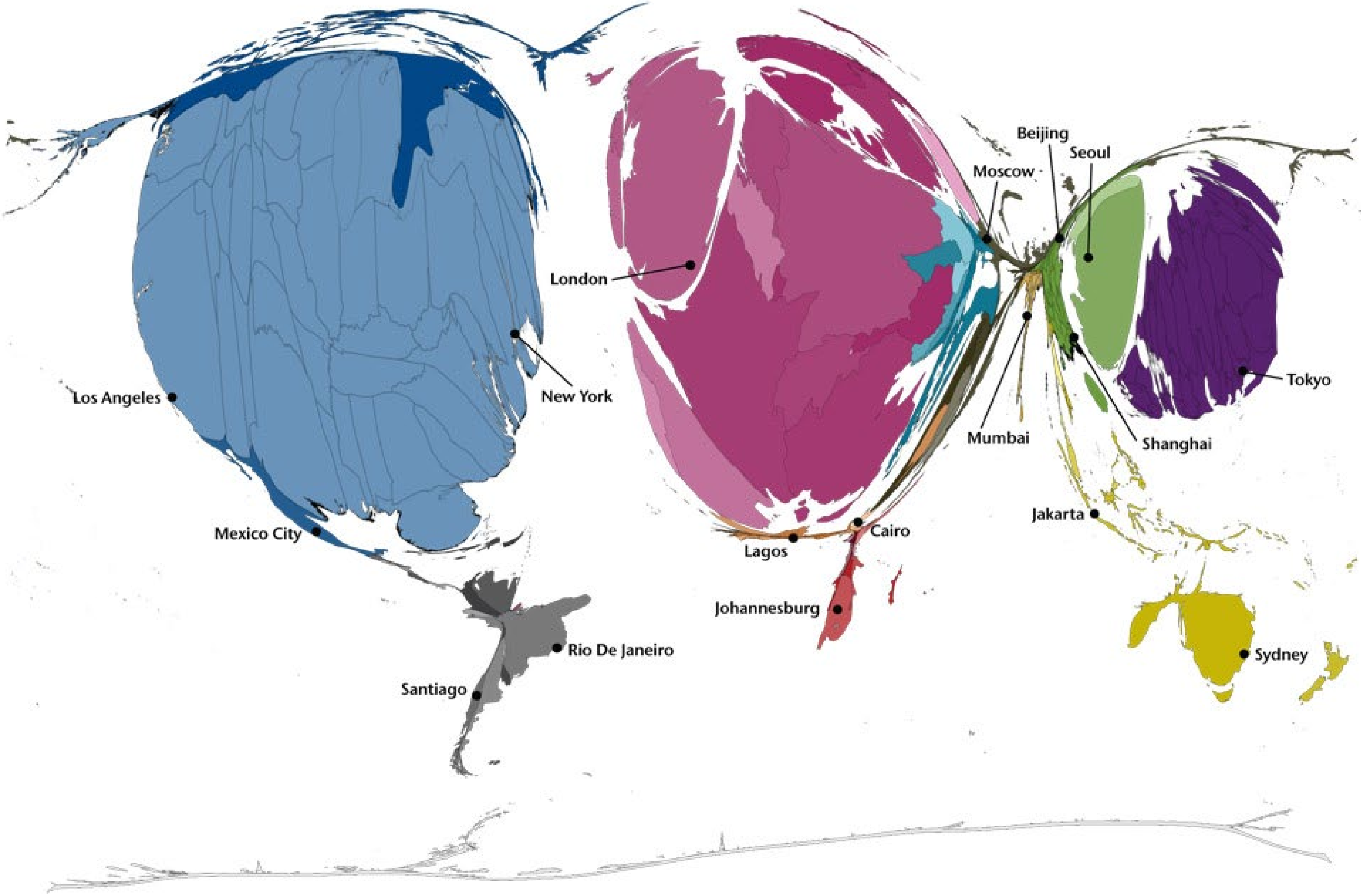
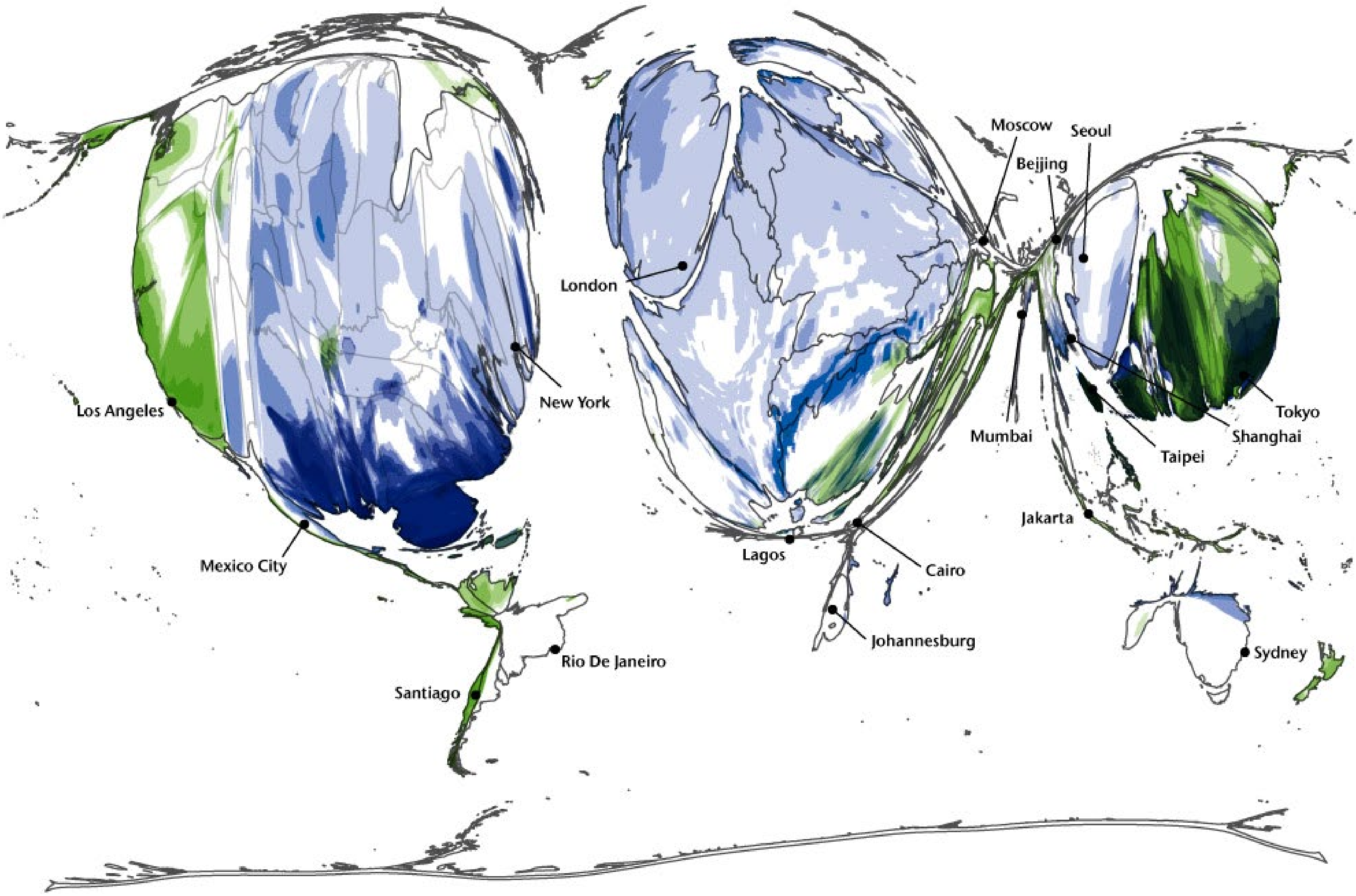
Insurance Penetration



Wind and Earthquake Insurance Penetration Transformation



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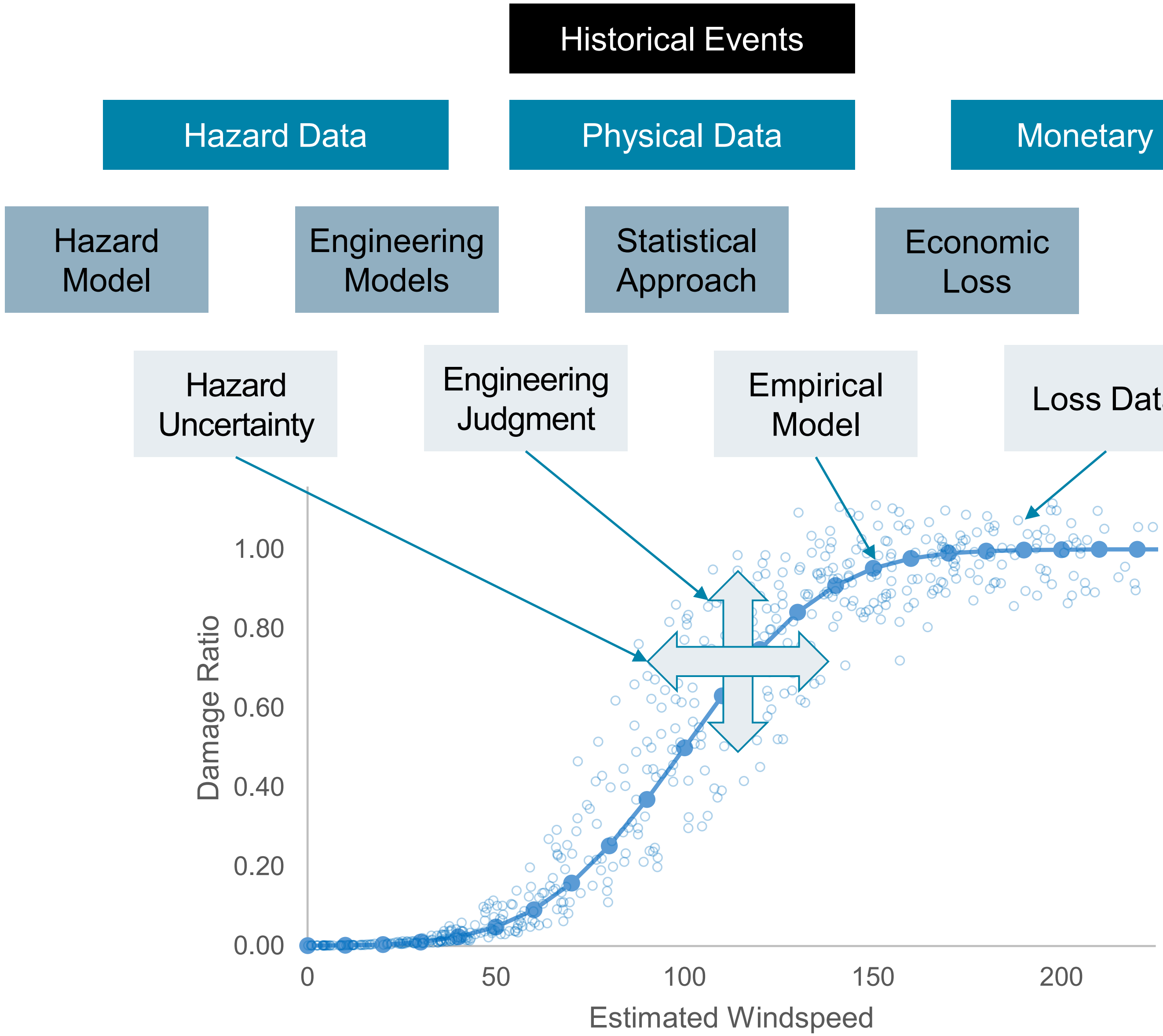
Modeling Problem: All Inputs are Noisy Estimates



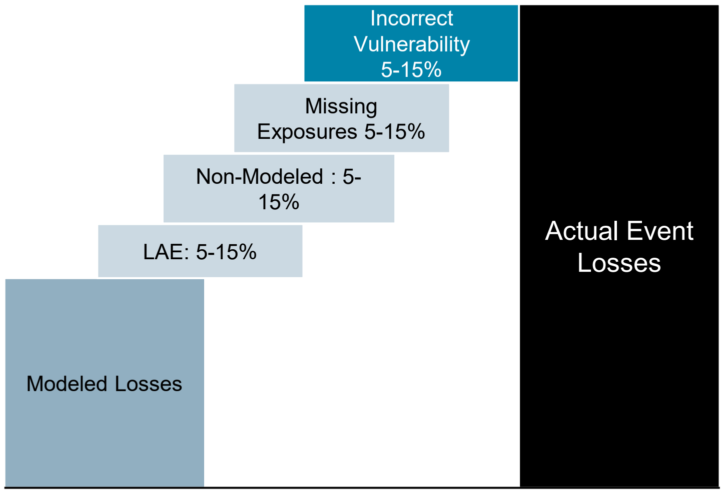
Data Quality: What Matters? U.S. Hurricane Case Study

Iteration	Description	% Change in Gross AAL	100 yr	250 yr
1)	Sample Portfolio	0%	0%	0%
7)	– update year built to 2010	-17%	-15%	-14%
10)	– update all coverages by dividing by .85	15%	14%	14%
6)	– update year built to 1970	11%	10%	9%
2)	– update all risk characteristics to unknown but occupancy – update occupancy to general commercial	5%	8%	9%
5)	– update construction to unknown	5%	5%	4%
16)	– update unknown yr built to most common	-4%	-4%	-4%
14)	– update unknown constructions to most common	3%	3%	3%
12)	– update construction to reinforced concrete for locations with unknown construction and with num stories < 3	-3%	-3%	-3%
3)	– update year built to unknown	2%	3%	3%
13)	– update construction to Steel for locations with unknown construction and with num stories < 3	-2%	-2%	-2%
8)	– update construction to steel frame for locations with num stories > 4	-1%	-1%	-1%
17)	– update unknown num stories to most common	1%	1%	1%
11)	– update construction to masonry for locations with unknown construction and with num stories < 3	1%	1%	1%
4)	– update # stories to unknown	0%	1%	1%
9)	– update construction to steel frame for locations with num stories > 7	-1%	-1%	-1%
15)	– update unknown occupancy to most common	0%	0%	0%

- Most variables are “engineering judgment”
- Sensitivities indicate insured value and year built should be priorities in US hurricane models

Model Miss: Catastrophe Model Performance (2004-05 & 08 Hurricanes)

- Model miss is the difference between the estimated actual observed loss and the modeled loss (actual / modeled)
- Underwriting and risk management should reflect management's best estimate of catastrophe losses
- Raw model losses may need to be modified based on actual experience
- Model miss uncomfortable fact: models are still not fully predictive

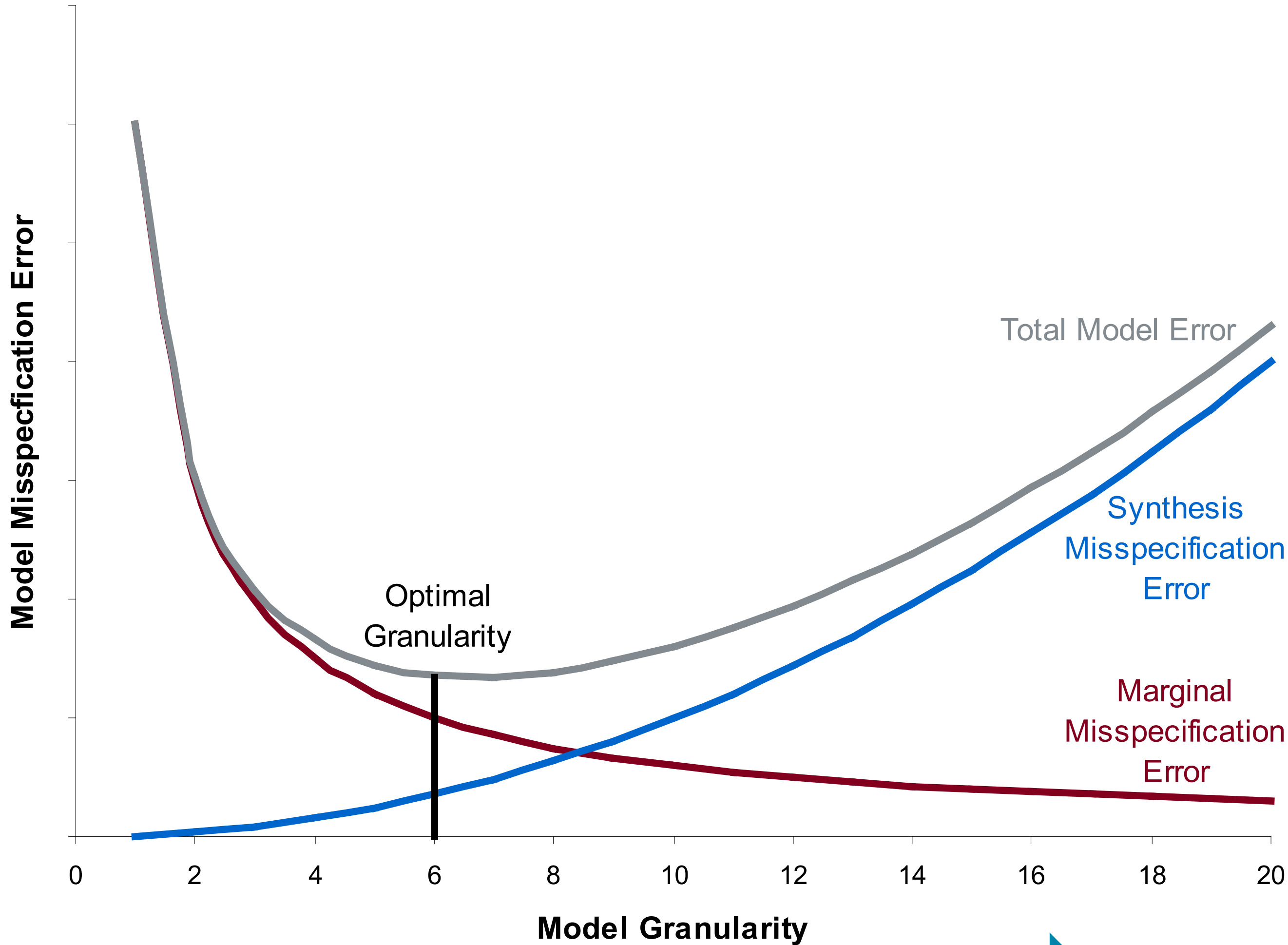


	Model A1	Model A2	Model B1	Model B2
Personal / Small Commercial	1.38	1.46	1.55	1.33
Large Commercial	2.07	1.62	2.24	2.20
Total	1.55	1.50	1.72	1.55

Purpose and Appropriate Granularity to Drive Robust Answer

PML
Estimation

EASY



AAL
Estimation

HARD

Sales, marketing & u/w pressure

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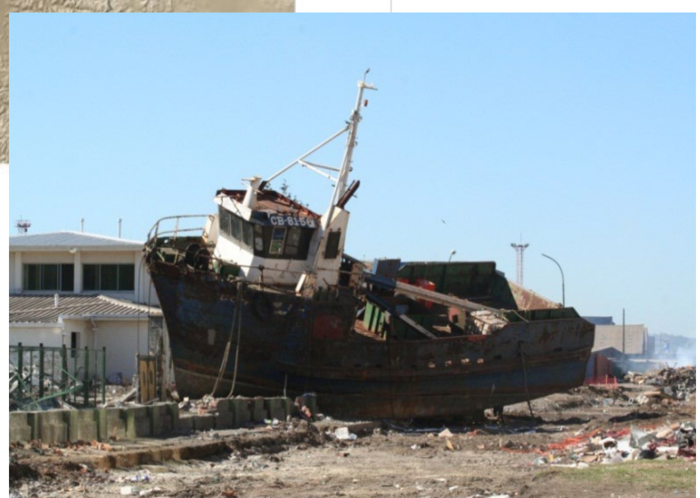
M 8.8 Chile Earthquake of Feb 27, 2010
Event Expected – Tsunami Damage a Real Surprise

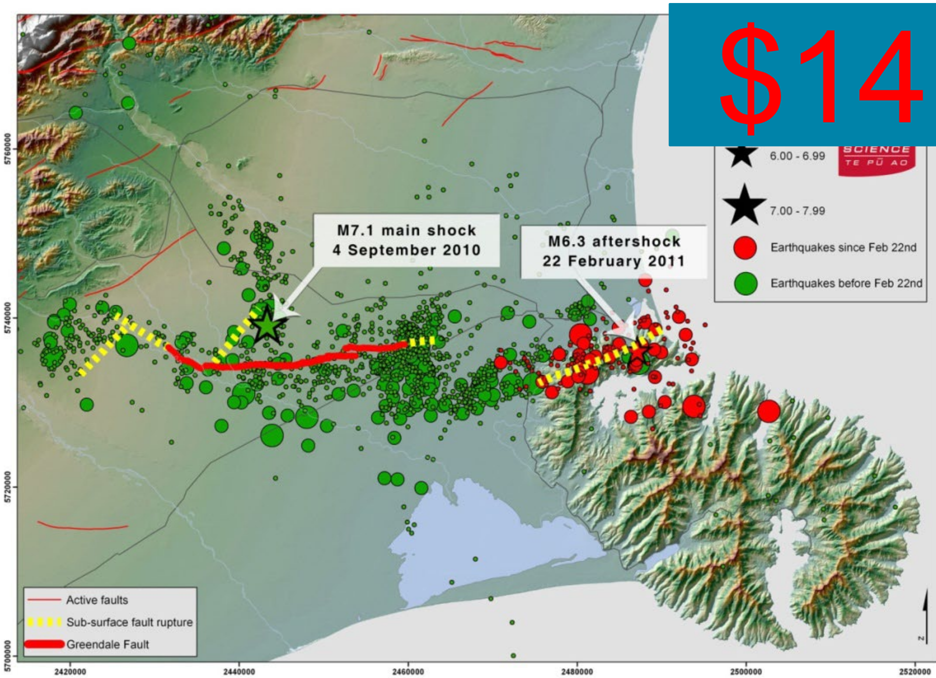
$9.0B



- **Expected event**
  - Earthquake filled the ‘gap’ between prior historical events that ruptured regions to the North and South
- **562 fatalities & 12,000 injuries**
  - At least 370,000 houses, 4,013 schools, 79 hospitals and 4,200 boats damaged or destroyed by the earthquake and tsunami
- **Wide-spread contents and non-structural damage**
  - Attributable to duration of strongest phase of ground shaking (close to a minute of violent motion)

Source: National Geographic, Impact Forecasting

M 6.3 Christchurch Earthquake of Feb 22, 2011
Like Northridge, Christchurch Quake Occurred on an Unknown Fault



$14.1B

6 September 2010 Last updated at 07:28 ET

New Zealand earthquake 'damaged 100,000 homes'

Despite the widespread damage caused by the earthquake, no-one was killed

Almost two-thirds of the 160,000 homes in and around Christchurch have been damaged by Saturday's earthquake, New Zealand's prime minister has said.

- **181 fatalities and 2,000 injuries**
  - The NZ EQC has recorded nearly 160,000 claims
- **Geotechnical event**
  - Widespread liquefaction, ground subsidence and ground failure main drivers of loss
- **Unexpected event**
  - Considered an aftershock of the M 7.1 Darfield earthquake of September 4, 2010. **Both faults were previously unknown**. Christchurch earthquake occurred on a fault with no surface expression (like Northridge)

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Source: BBC, New Zealand GNS

M 9 Tohoku, Japan Earthquake of March 11, 2011
Completely Unexpected Event in World's Most Geologically Studied Area

$36.2B

- **Unexpected event**
  - Tectonic potential exists, but no historical precedent for such a large magnitude event
- **15,382 fatalities, 5,364 injuries**
  - At least 540,000 homes and other structures damaged or destroyed by earthquake and tsunami
- **Tsunami key loss driver**
  - Shallow-sea tsunami barriers existed but proved inadequate
  - Tsunami, not ground shaking, responsible for incidents at nuclear power plants

Source: Impact Forecasting

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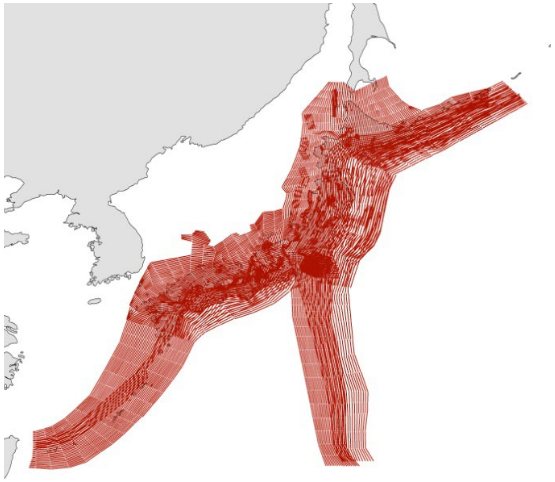
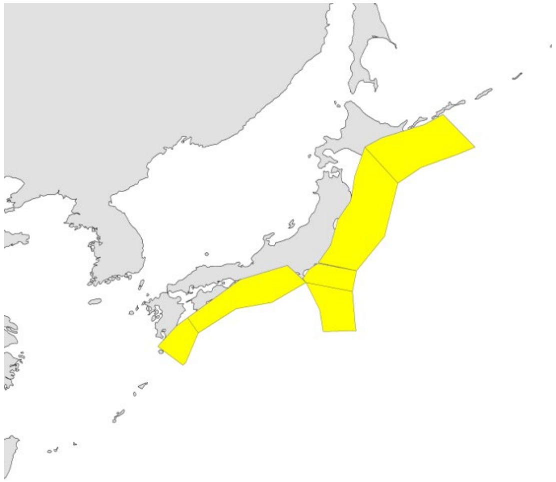
Select Tsunamigenic Earthquakes

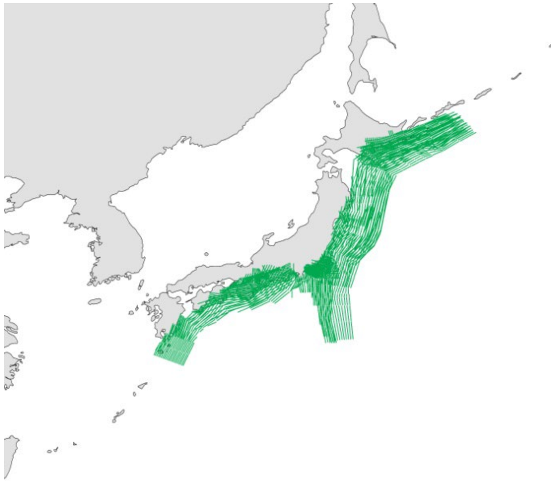
- Select earthquakes from RMS event set that lie within tsunami source zones



RMS EQ event set



Tsunami source zones
Based on historical tsunami since 685 AD



RMS Eqs within tsunami source zones

A. Mw 7.0 – Mw 7.9 and up to 20km depth (2,196 events selected)
B. Mw 8.0 – Mw 8.6 and up to 35km depth (163 event selected)
C. Mw 8.7+ and up to 50km depth (10 events selected)

2,369 earthquakes in RMS event set considered tsunamigenic (~8% of event set)

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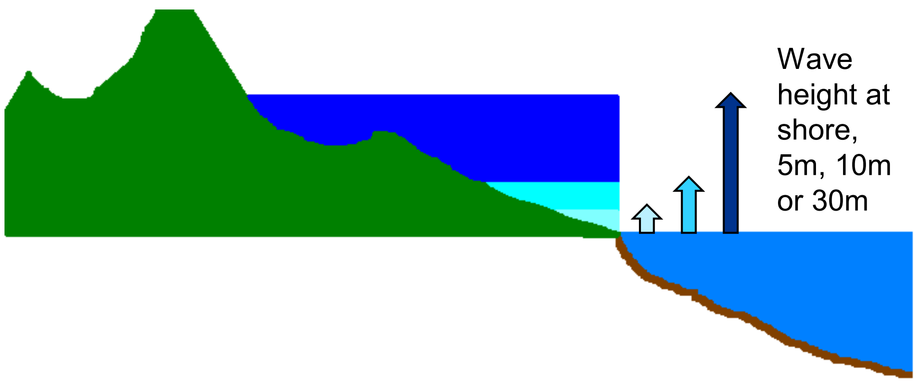
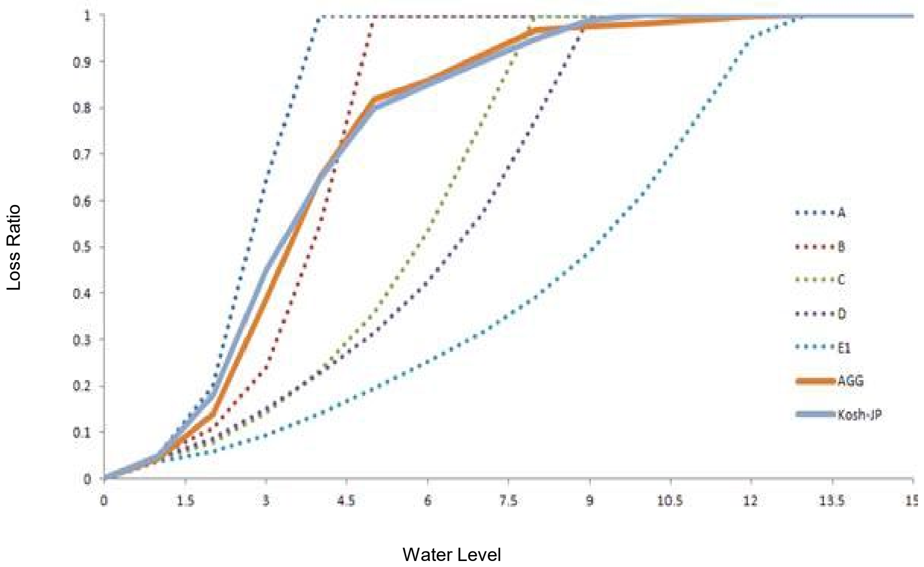
Tsunami Hazard and Loss At City And Ward Level

- Three tsunami wave heights are modelled across the whole of the east coast of Japan
  A. 5m tsunami wave
  B. 10m tsunami wave
  C. 30m tsunami wave

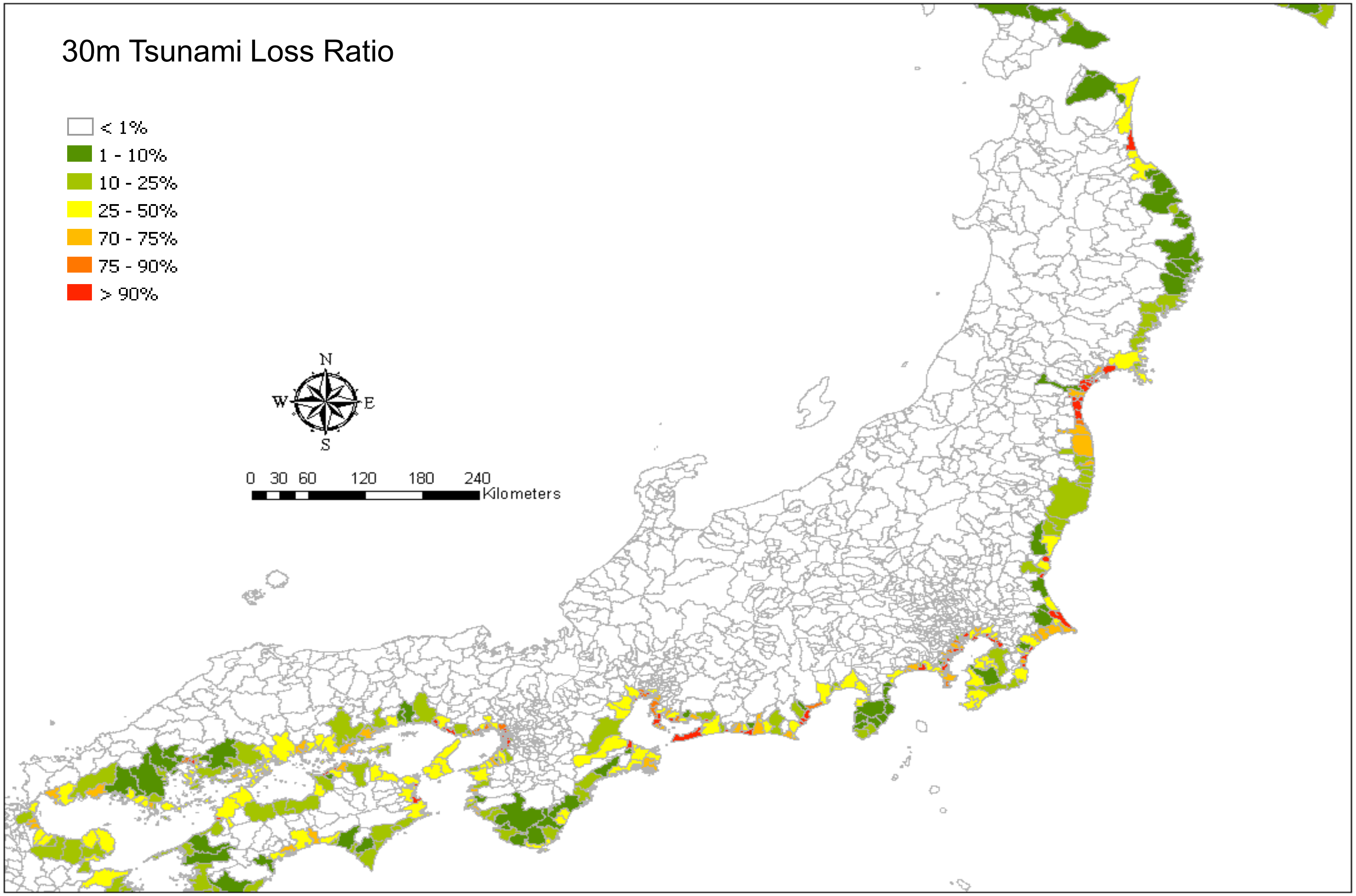
Water level across City/Ward
= difference between wave height and topography





- Calculate Average Water Level (AWL) across each City/Ward
- Not all waves cause tsunami hazard at each City/Ward; if topography at shore is > modelled wave height then there is no tsunami
- Loss ratio calculated based on the AWL at each City/Ward for each of the three tsunami using damage function for Tohoku from Professor Koshimura (solid blue line)

Tsunami Loss At City And Ward Level



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Revised Exceeding Probability Loss Curves

- Ground up analysis run on Commercial, Industrial and Residential IED portfolios

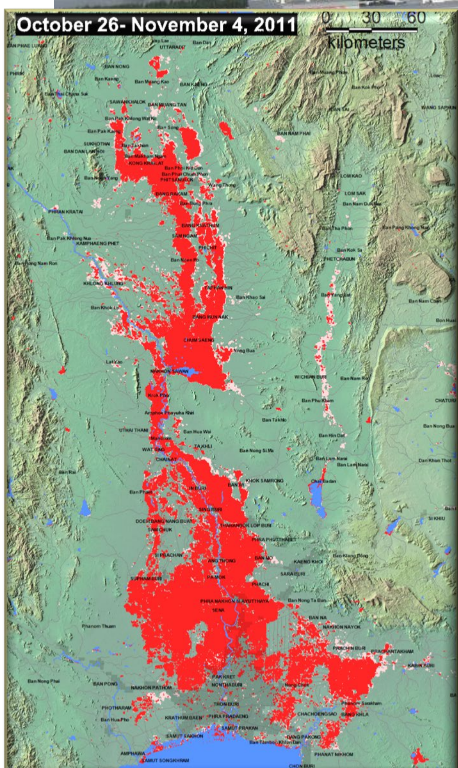
Percentage difference between TS+EQ exceedance probability curve, and EQ only

Return Period	Commercial	Industrial	Residential
1 in 2	0%	0%	1%
1 in 5	1%	0%	1%
1 in 6	2%	0%	1%
1 in 8	4%	2%	1%
1 in 10	5%	6%	4%
1 in 12	5%	9%	7%
1 in 15	4%	10%	8%
1 in 20	3%	10%	10%
1 in 25	4%	10%	10%
1 in 50	4%	7%	8%
1 in 100	3%	3%	5%
1 in 150	2%	1%	3%
1 in 200	3%	1%	2%
1 in 250	3%	1%	2%
1 in 300	3%	2%	3%
1 in 500	7%	9%	4%
1 in 1000	9%	13%	9%
1 in 5000	11%	11%	8%
1 in 10000	11%	17%	10%

- Maximum loading on the EP curve from tsunami is **17%** at high return periods (Industrial)
- Loading varies at different return periods with no consistent pattern
- Only **1,085** earthquakes loaded for tsunami out of over 18,000 in the analyses
- Losses to the majority of events remain unchanged

Thailand Floods of 2011
Known Unknown Event, Non-modeled "Gray Swan"

$15.9B



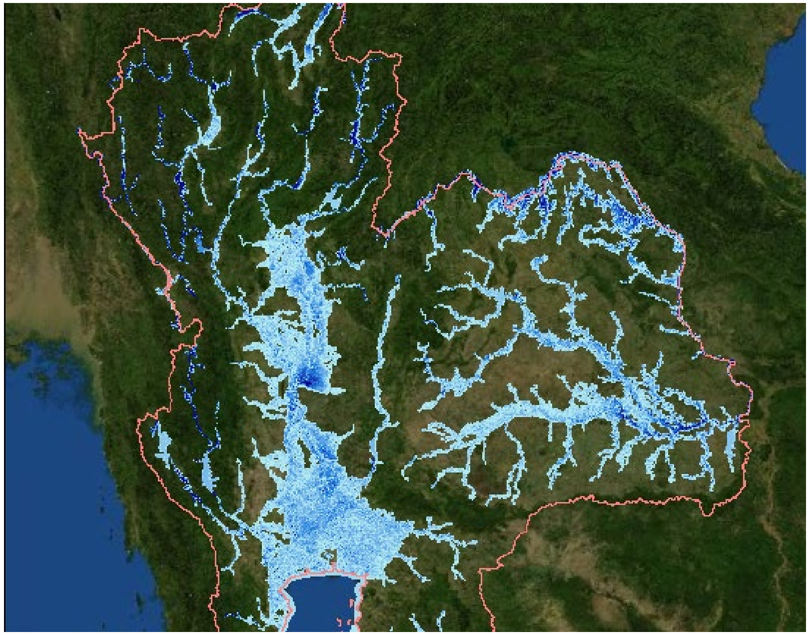
- **Perfect Storm**
  - Conditions aided by natural and human factors
  - Potential exists, fooled by historical loss experience
- **Record impacts**
  - 13M+ people affected
  - 1.96M houses damaged
  - $46.5B economic losses
  - $15.9B insurance losses
- **Industrial estates key loss driver**
  - 75% of insurance losses
  - 6 large estates damaged
  - JIA shares 75% loss
  - Global supply chains affected

Source: Impact Forecasting, US Marine Corps, Dartmouth Flood Observatory, The Guardian

Return Period for 2011 Thailand Flood Event

- Return periods vary with the question and specification
  - Event definition
  - Location
- Estimates vary with method used
  - Actual return period does not!
- Meteorological basis
  - Record monsoon rainfall of 1328mm since 1951 in northern region
  - RP: 52 yrs by Gumbel distribution
- Hydrological basis
  - Record river flow by volume since 1956 at gauge station C2
  - RP: 77 yrs by average of select distributions
- Insurance loss
  - RP: 150 - 250 yrs, depending on value taken for insured loss, adjustments for man made factors

Flood defenses: before and after 2011 flood



250 year hazard map

US Severe Weather Spring, 2011

Event Date	Event Location	# of Deaths	# of Struct-ures/ Claims	Econ. Loss Estimate (Billions USD)	Insured Loss Estimate (Billions USD)
4/3-4/5	Midwest, Southeast, Plains	9	225,000	2.0	1.6
4/8-4/11	Midwest, Southeast, Plains	0	275,000	2.3	1.5
4/14-4/16	Plains, Southeast, Midwest	48	150,000	2.5	1.7
4/19-4/21	Plains, Southeast, Midwest	0	100,000	0.6	0.4
4/22-4/28	Southeast, Plains, Midwest	344	650,000	7.0	5.1
5/10-5/13	Midwest, Southeast	2	50,000	0.3	0.2
5/21-5/27	Plains, Midwest, Southeast	183	550,000	6.5	4.9
5/28-6/1	Plains, Midwest, Northeast	3	25,000	0.5	0.3
	Totals	589	2,020,000	21.7	15.7

$15.7B

- **Very active first 6 months of 2011**
  - 589+ fatalities from severe weather = ten times higher than 56 YEARLY average
  - 80 confirmed EF-3 or higher (136+ mph) tornadoes = nearly double 42 YEARLY average
- **Record losses**
  - $2+B insured loss becomes costliest natural disaster for Alabama = April 25-28 tornado outbreak
  - $2B insured: old record = 2004 Hurricane Ivan

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Mid-Point Break Opinion Poll
With Which of the Following Statements do You Agree?

1. The world is getting hotter, especially since 1975

2. The level of CO_2 in the atmosphere is higher than it has been for the last [650,000] years

3. Man-made activities are driving the high levels of CO_2

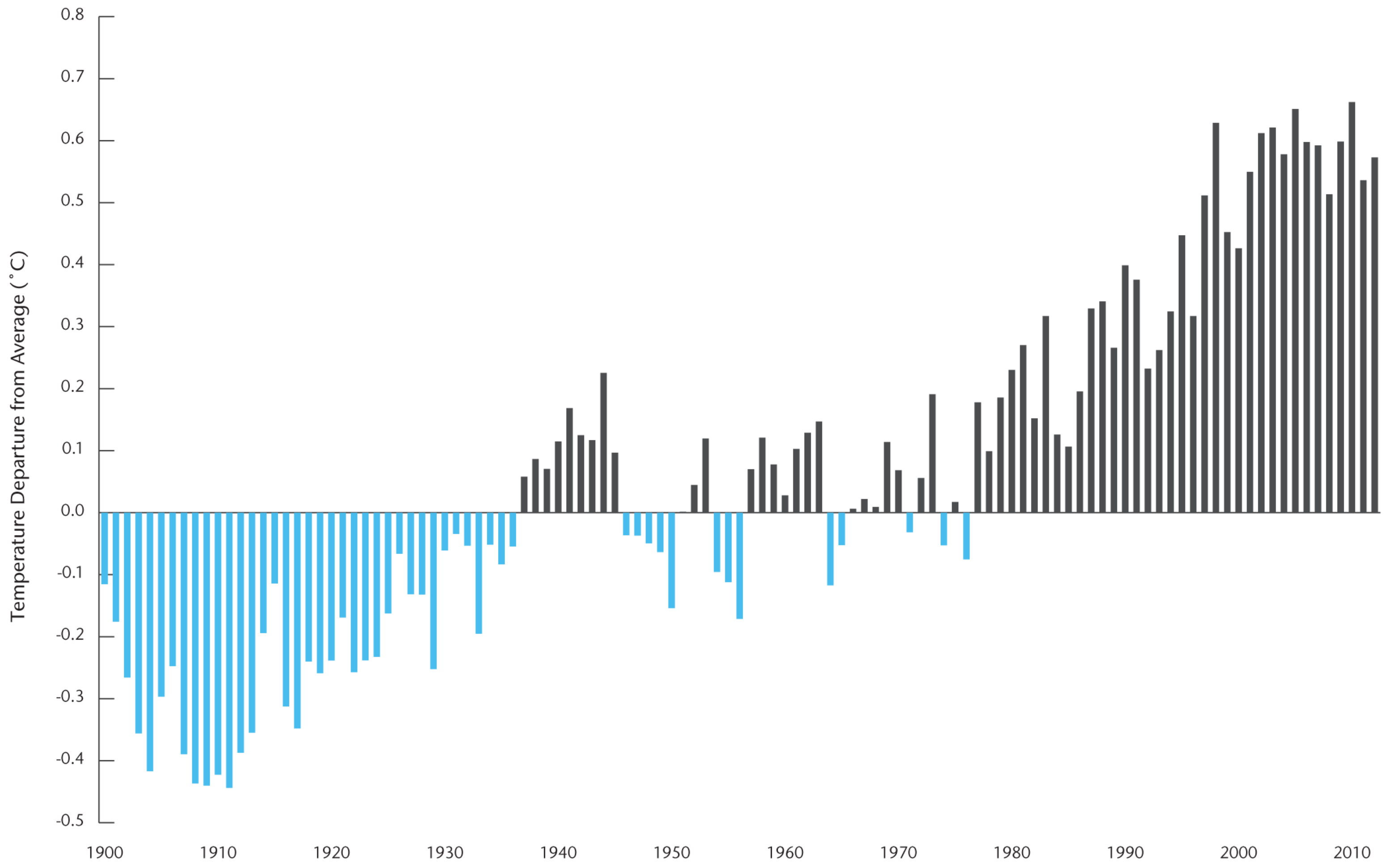
4. There is a connection between the recent high temperatures and high levels of CO_2

5. Recent high temperatures are driving an increased frequency of severe weather in the US

Consensus Answers

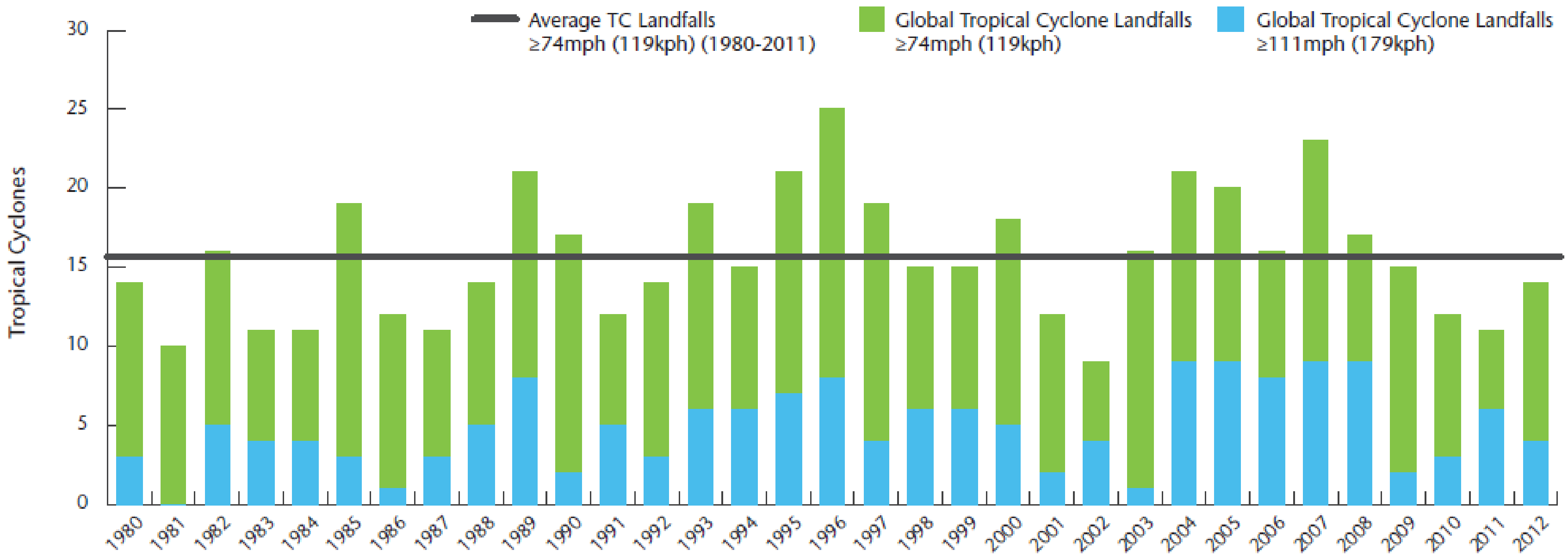
1. Fact question: true (next slide)
2. True per ice-core records (Emanuel, What we Know About Climate Change)
3. General scientific consensus, increase coincides with the industrial revolution
4. General scientific consensus; recent high temperatures are not within the range of non-anthropomorphic random fluctuations (solar output, volcanos, etc.) per multiple climate models
5. Unclear

Global Land and Ocean Temperature Anomalies: 1960-2012



Source: Impact Forecasting 2013 Climate Report, from NOAA's National Climatic Data Center; The NCDC anomalies are provided as departures from the 20th century average (1901-2000).
ftp://ftp.ncdc.noaa.gov/pub/data/anomalies/annual.land_ocean.90S.90N.df_1901-2000mean.dat

Global Tropical Cyclone Landfalls (1980-2012)



- Fourth year in a row of below average cyclone landfalls
  - Return to near-normal Category 3+ cyclone landfalls (5)

- Seventh consecutive year without a landfalling major hurricane in the US

Source: Impact Forecasting 2013 Climate Report

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Super Storm Sandy

- Largest diameter: 945 miles
  - Previous record: 920 miles, 2010's Hurricane Igor
- Largest wave in New York Harbor: 32.5 feet
  - Previous record: 25.0 feet, 2011's Hurricane Irene
- Second NE event in two years for which hurricane deductibles did not apply
  - Deductible language variable across companies
  - Wind speed, hurricane category, etc.
  - Events do not drive tail, but generally not modeled correctly
- "2/3 of all New York City homes damaged by Super Storm Sandy were outside of FEMA's existing 100-year flood zone."
  - Wall Street Journal
  - Estimate flood return period: 90 years
- "With respect to storm surge [in Sandy], we think the SLOSH model generally performed well, and we calibrated our US storm surge expectations from that."
  - Kean Driscoll, CEO, Validus Re

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Super Storm Sandy: Insurance Loss Estimates

PCS

- Claims: ~ 1,152,000
- Insured Loss Estimate: $18.75 billion, excluding $6B+ NFIP losses
  - Personal Lines Claims: $6.997 billion (average claim: $6,558)
  - Commercial Lines Claims: $9.024 billion (average claim: $44,563)
  - Automobile Lines Claims: $2.729 billion (average claim: $10,894)

Impact Forecasting

- $16 to $22 billion
- 80 to 90 Year Return Period

AIR

- $16 to $22 billion
- ~85 Year Return Period

RMS

- $20 to $25 billion
- ~90 Year Return Period (NY, NJ)

EQECAT

- $10 to $20 billion
- 70 to 90 Year Return Period

Industry wind event return period: 5-10 years

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Aon Benfield Super Storm Sandy Model Miss Analysis

- 52 companies analyzed for Hurricane Sandy Loss
- Flood exposures used where available
- Standard (non-hurricane) deductibles used where available
- Model miss would increase with hurricane deductibles and with flood sub limits

Hurricane Sandy Actual Loss / Modeled Loss

	Personal and Small Commercial		Complex Commercial Lines		Total	
	Model A	Model B	Model A	Model B	Model A	Model B
Median	1.45	1.50	1.88	2.63	1.50	1.58
Average	1.74	4.89	3.90	3.90	2.38	4.40

2004-05, 08 Hurricanes, Actual Loss / Modeled Loss

	Model A1	Model A2	Model B1	Model B2
Personal / Small Commercial	1.38	1.46	1.55	1.33
Large Commercial	2.07	1.62	2.24	2.20
Total	1.55	1.50	1.72	1.55

The Problem of Modeling Coastal Storm Surge Flood Model

- Storm surge depends on many variables, not just storm intensity

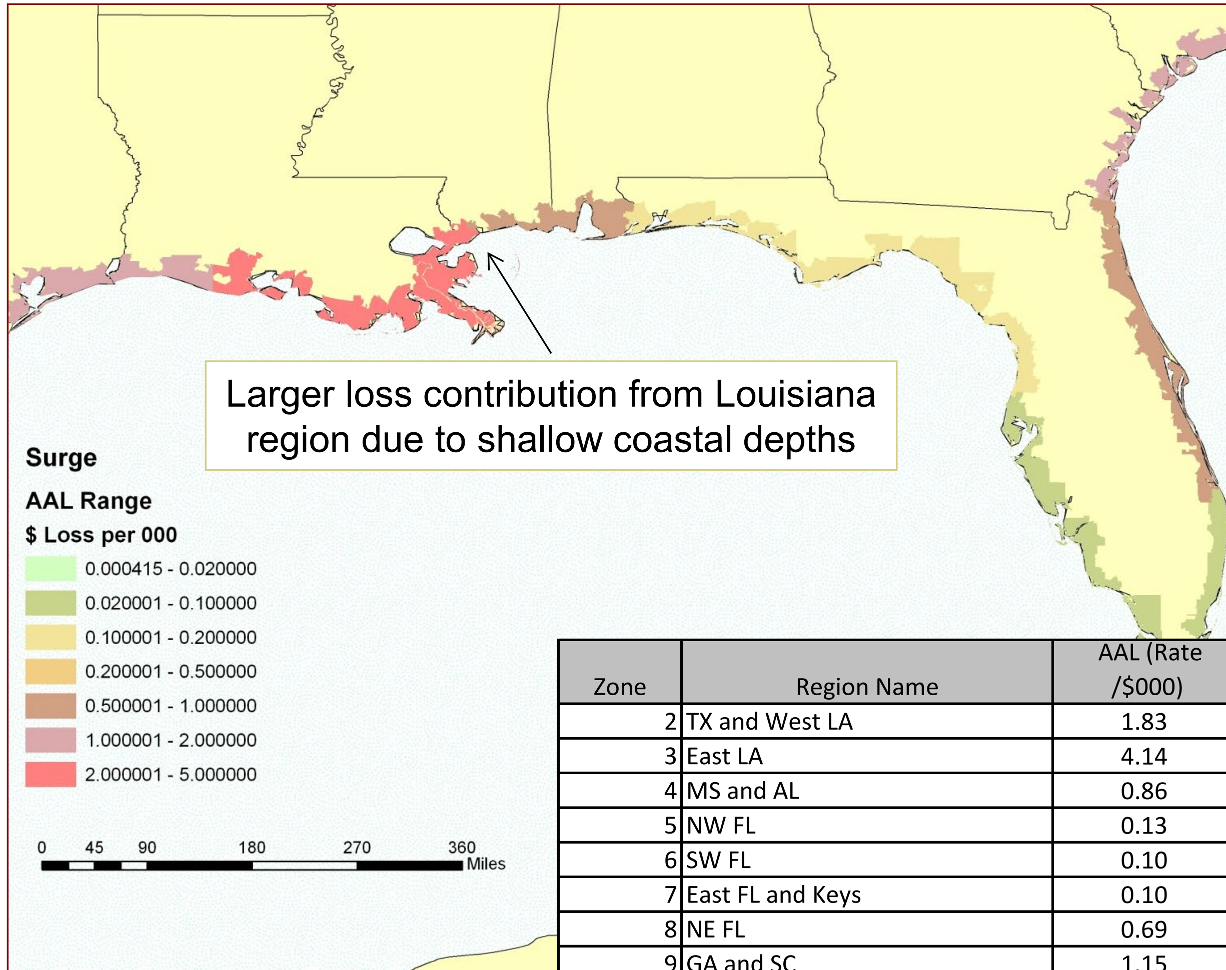
Event	Category	Surge
Sandy	n/a	14 feet
Irene	1	11 feet
Ike	2	20 feet
Katrina	3	28 feet
Charley	4	8 feet

- Storm surge model must incorporate
  - Central pressure
  - Storm intensity and size – over entire lifetime
  - Forward velocity and angle to coast
  - Shape and bathymetry of coastline
  - Local coastal features

- NOAA developed the SLOSH (Sea, Lake and Overland Surges from Hurricane) model to estimate storm surge in 30+ basins based on these key storm inputs
  - SLOSH is applied “live” to storms for emergency preparedness by FEMA

Impact Forecasting Coastal Storm Surge Flood Model

- IF storm surge model applies SLOSH methodology to each of the 26,000 hurricane events in its catalog
- 10,000 hours CPU computation time
- IF model simulates entire storm track history to provide needed inputs
- SLOSH model applied to Sandy after-the-fact by other modeling firms to produce credible loss estimates



Zone	Region Name	AAL (Rate /$000)
2	TX and West LA	1.83
3	East LA	4.14
4	MS and AL	0.86
5	NW FL	0.13
6	SW FL	0.10
7	East FL and Keys	0.10
8	NE FL	0.69
9	GA and SC	1.15

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Aon Benfield Katrina Regression Study Recap

	Katrina Study Loss Percent Ranges*		YE 1:100 PML Disclosure Mean % Equity*		
Sector	Pct Equity	Pct Prospective Consensus Earnings	2009	2010	2011
Insurers	3% to 6%	21% to 34%	5%	4%	4%
Reinsurers	12% to 19%	107% to 110%	15%	17%	13%

* Shown on a net after tax basis

- The average 100 year PML risk tolerance disclosure for primary and reinsurance companies is in-line with Aon Benfield's post-Katrina study
- Global Cat risk tolerances have remained relatively stable since Katrina
- Study largely calibrated on stand-alone P&C entities

- **Are losses from Sandy consistent with Katrina tolerances?**

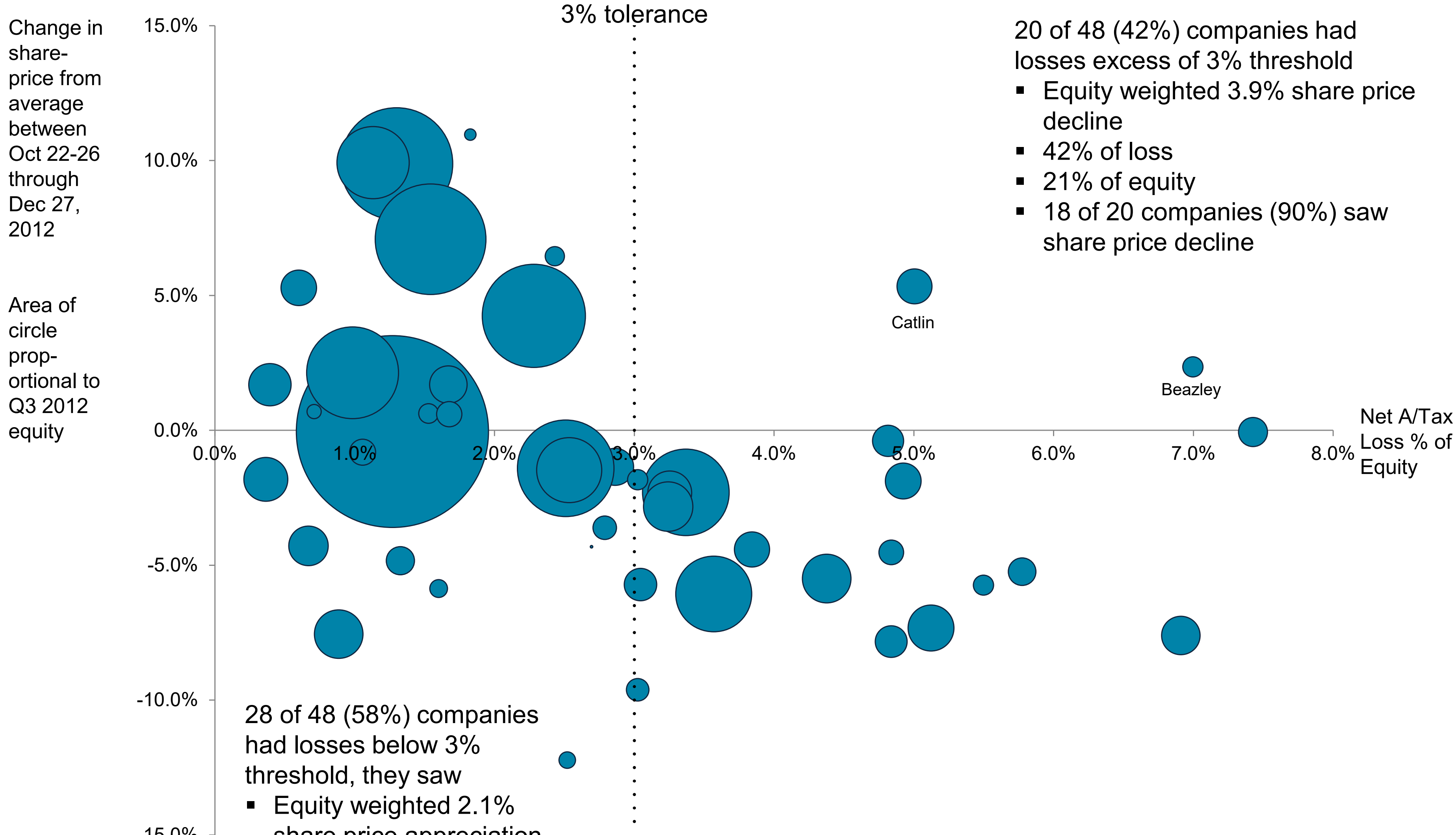
Super Storm Sandy Validates Katrina Regression Risk Tolerance

Market Impact of Sandy Loss

Net After-Tax Loss:	Number of Companies	Average Sandy Loss (% Equity)	Relative Share Price Performance
less than 3% threshold	28 (58%)	1.5%	+2.1%
greater than 3% threshold	20 (42%)	4.2%	–3.9%
All Companies	48 (100%)	2.1%	6 point differential

- **Yes, market results from Sandy are consistent with the lower end of the Katrina study tolerance**

Conclusions from Super Storm Sandy – For Actuaries



20 of 48 (42%) companies had losses excess of 3% threshold

- Equity weighted 3.9% share price decline
- 42% of loss
- 21% of equity
- 18 of 20 companies (90%) saw share price decline

28 of 48 (58%) companies had losses below 3% threshold, they saw

- Equity weighted 2.1% share price appreciation
- 58% of loss
- 79% of equity

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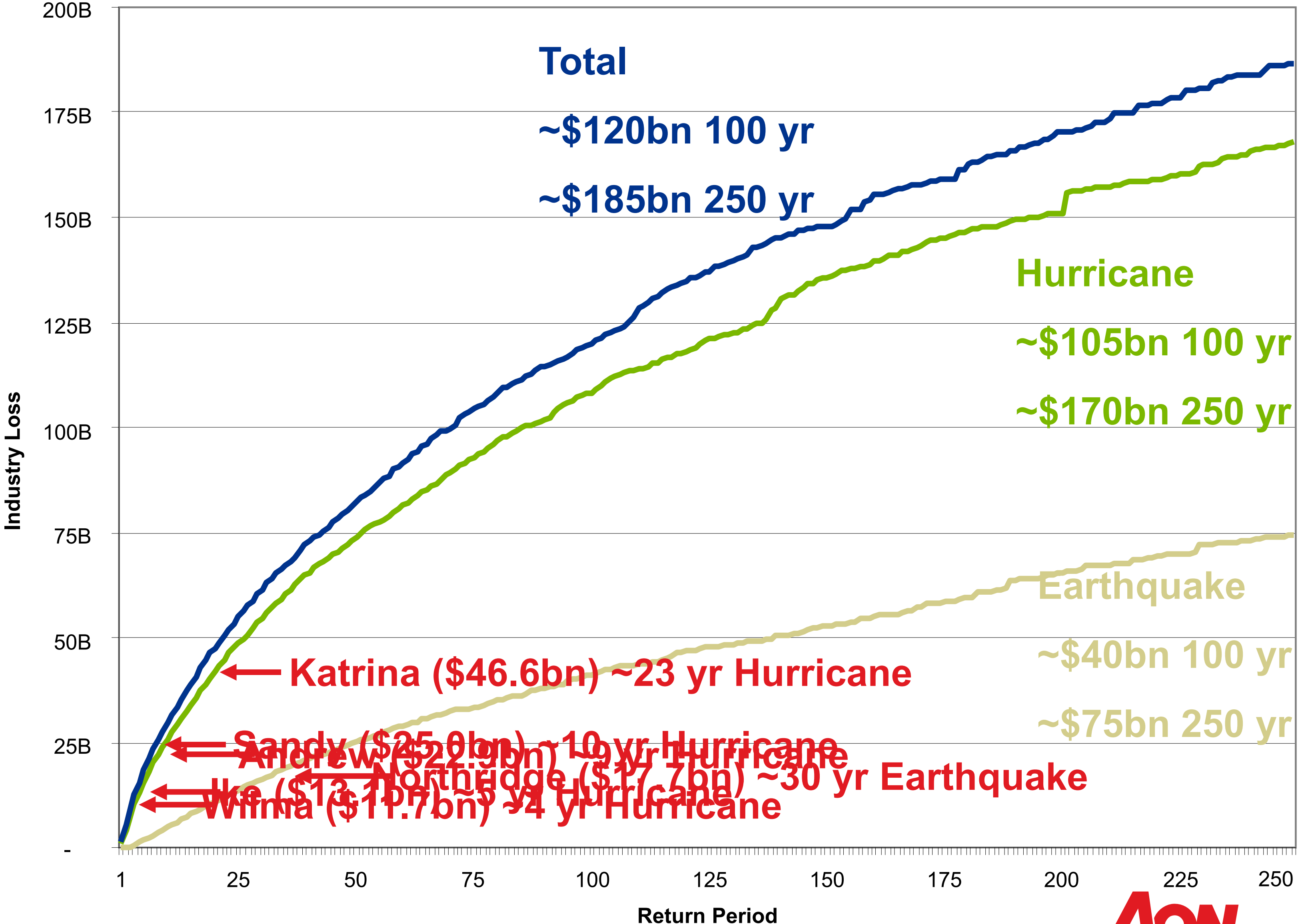
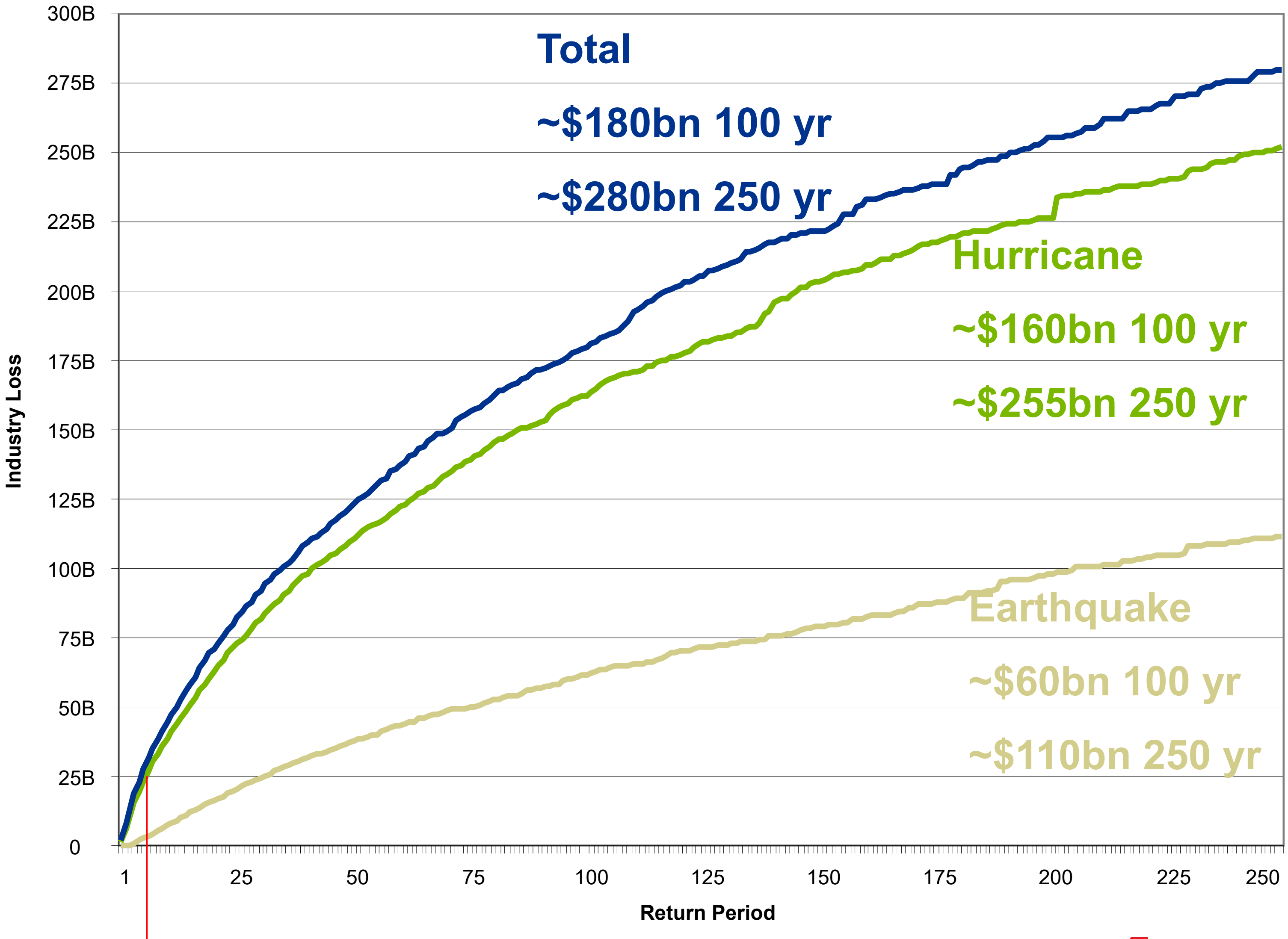
U.S. Industry Loss Estimates

Blended Model Approach



Adjusted Industry Loss Estimates
Blended Model Approach x 1.5



Sandy ~ 7 year return

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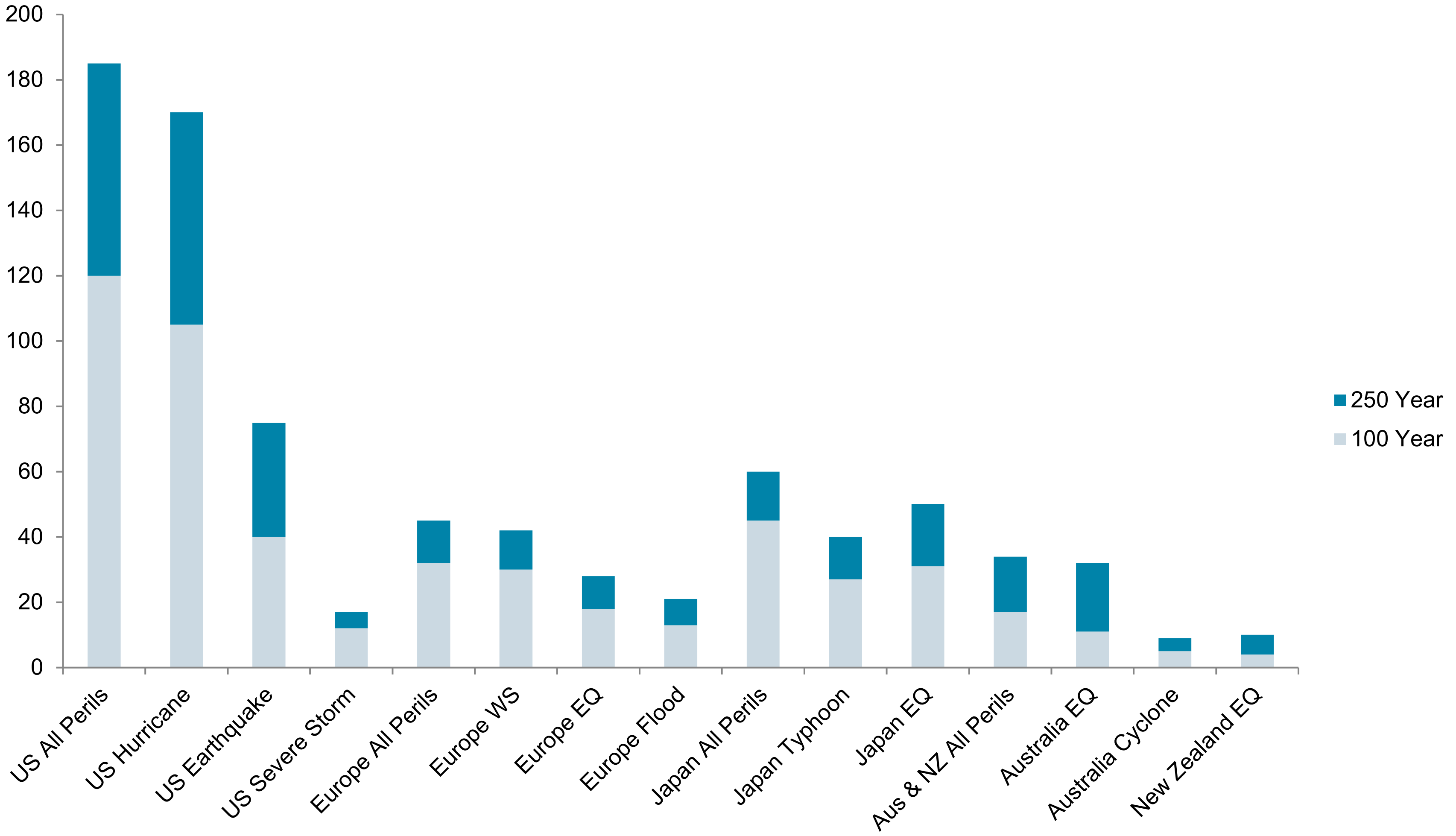
Global Industry Loss Estimates
Blended Model Approach, USD billion



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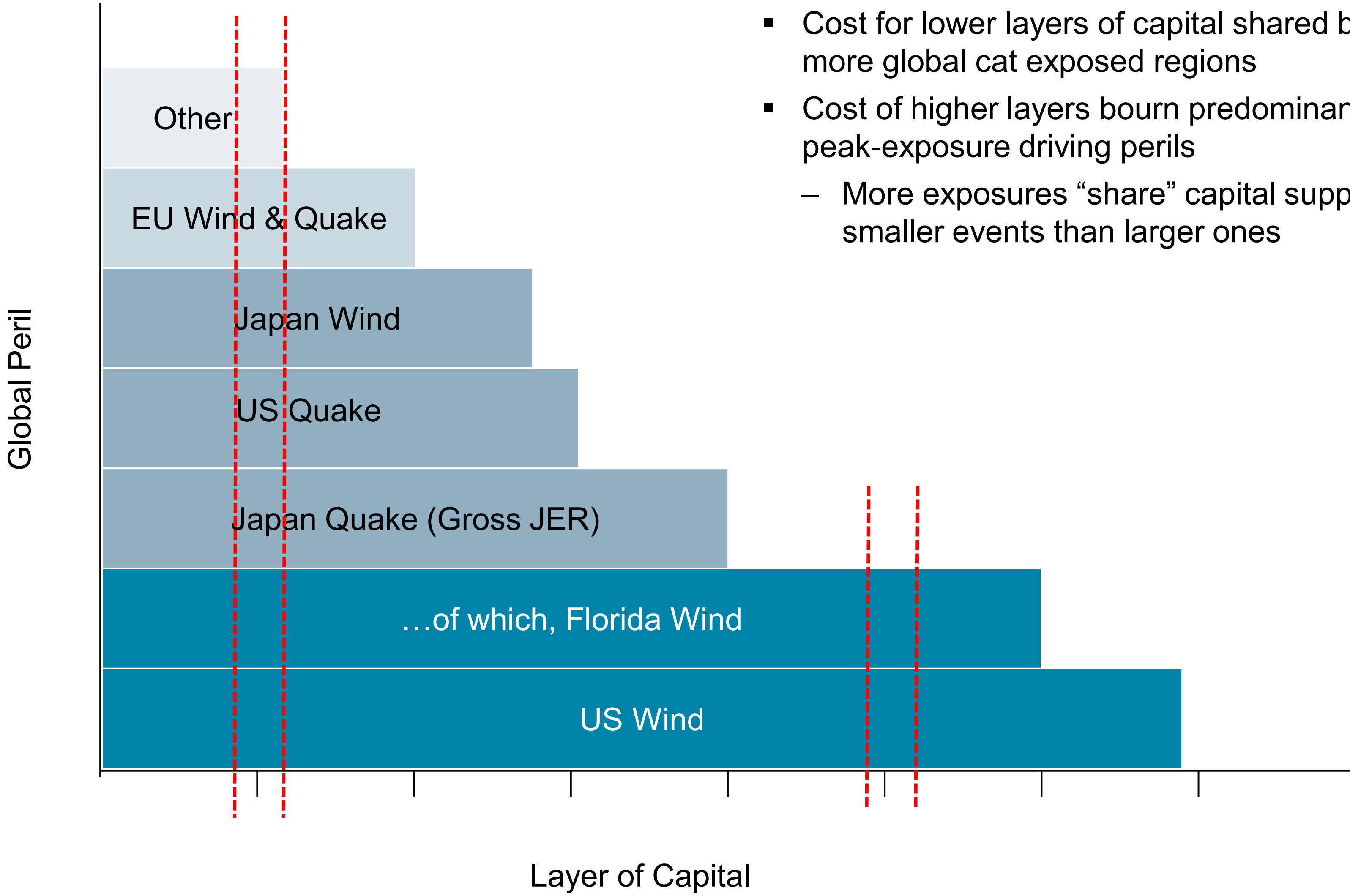
Allocation of Global Cost of Catastrophe Reinsurance Capacity



- Cost for lower layers of capital shared between more global cat exposed regions
- Cost of higher layers bourn predominantly by US peak-exposure driving perils
  - More exposures “share” capital supporting smaller events than larger ones

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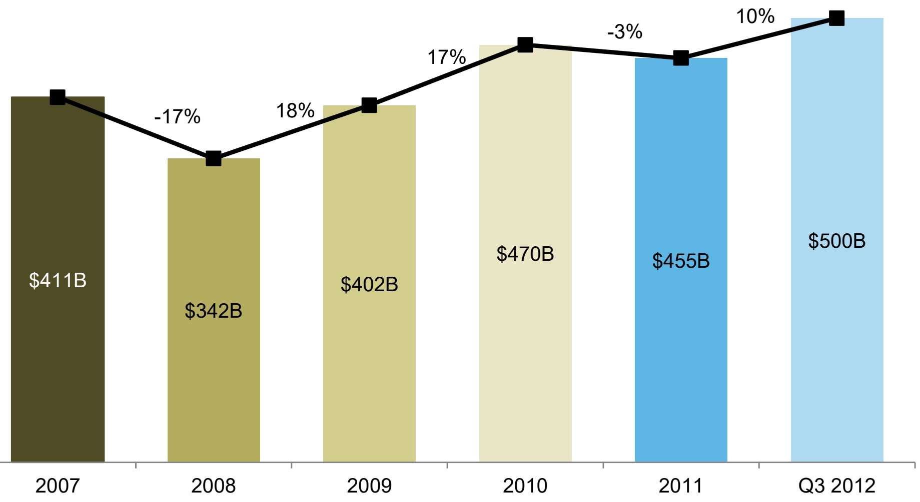
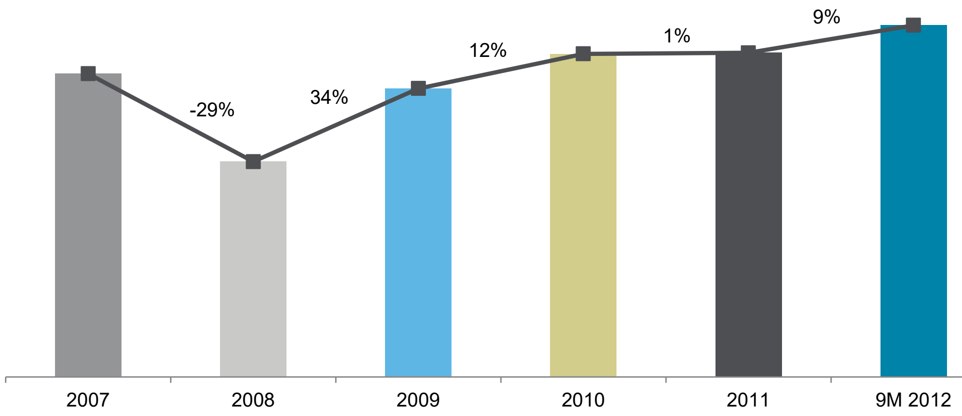
Reinsurer and Insurer Capital Change
USD Billions

- **Reinsurer Capital**
  - Continued to increase throughout the first 3 quarters of 2012 to a new peak level
  - Supply continues to exceed demand in most global regions



- **Insurer Capital**
  - Increased 9 percent from year end 2011 to Q3 2012
  - Reinsurance demand continues to be flat to down slightly in peak zones as capital increases and insurers continue to retain more risk



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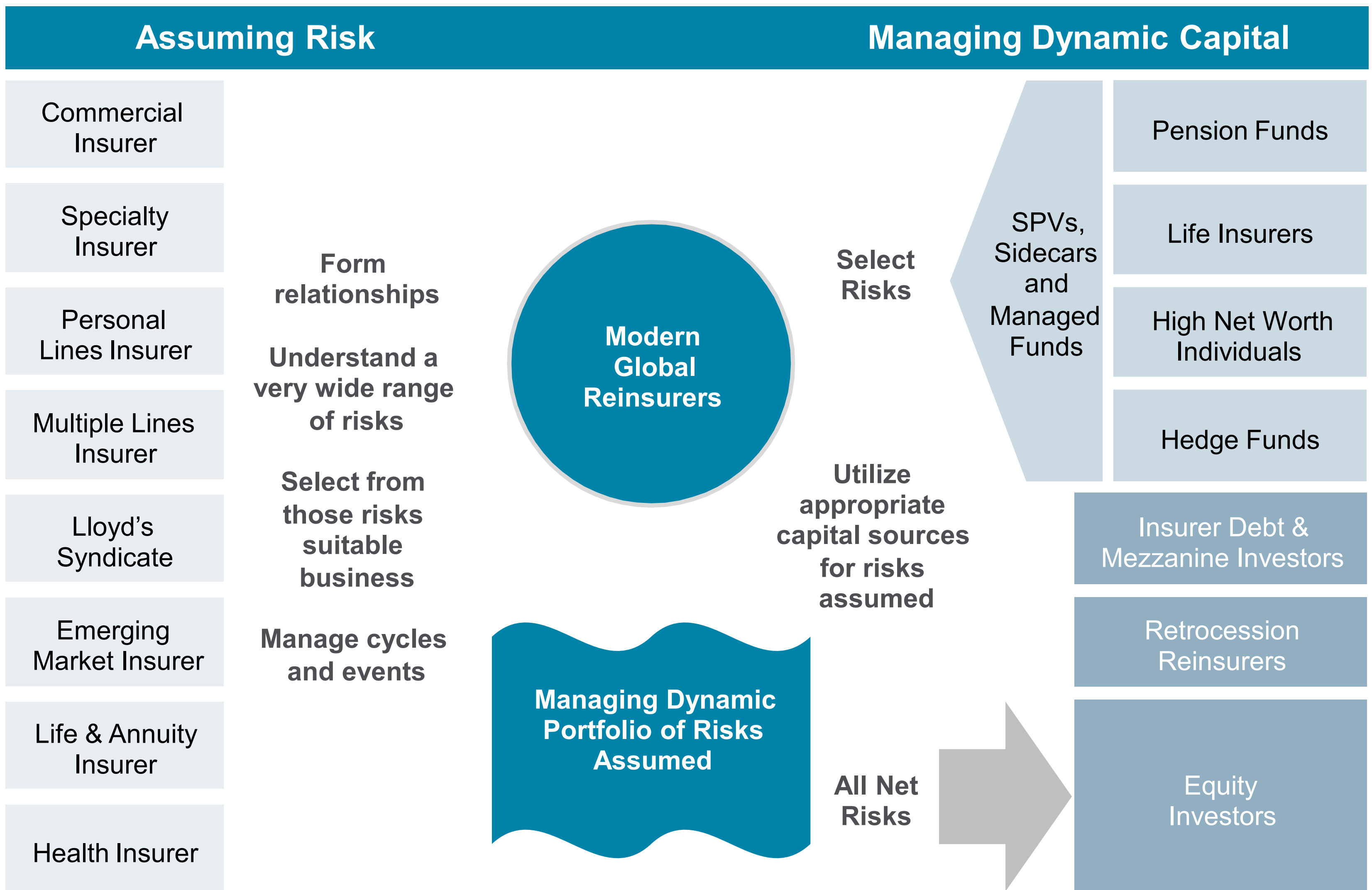
Modern Global Reinsurers and the Debt Challenge



Lessons From 2010-2012 Events

Event	Lessons
Chile Earthquake	It works! Known and expected fault, models conservative, reinsurance effectively protected solvency of local insurers
Christ Church Earthquakes	Unknown fault, crippling damage from liquifaction
Tohoku Earthquake	Unexpected event; Tsunami not modeled…modeling firms American
Thailand Flood	Unmodeled event: yes; surprising event: no; think beyond models
2011 US Severe Weather	New normal? Pricing problem or volatility problem?
Super storm Sandy	Flood, hurricane deductibles
…the next big event	Fool me once shame on you; fool me twice shame on me

- Cat models are the single most important innovation in insurance over the last fifty years
- Cat models have unequivocally improved industry pricing and risk management
- Cat models are so important because they provide a universal language for risk, used by insurers, regulators, rating agencies and investors … think how helpful that would be in casualty lines

The Way Forward: How Do We Improve the Usefulness of Modeling?

Risk Management	Pricing	Underwriting
▪ Cat models fit for purpose and provide reasonable estimates of PMLs ▪ PML estimation pretty easy: event size x density x damage ratio ▪ Cat models still have visible and invisible weak spots ▪ Nature will surprise ▪ Models will improve ▪ Unintended consequence: increased risk in non-modeled (casualty, reserves) areas	▪ Heisenberg uncertainty of modeling: event uncertainty vs. property uncertainty ▪ Intelligent discussion of standard error of estimator ▪ AAL estimation harder than PML, especially for high frequency events like severe convective storm ▪ Debt for equity substitution driven by comfort of models	▪ Unintended consequences ▪ Cat models have an insidious impact on the industry through a modeling monoculture ▪ ERM, capital modeling, tail risk vs. franchise risk ▪ Retreat from non-modeled risks ▪ Declining premium in insurance sector ▪ Big risks net (BP, Tepco)
▪ **Dire need for education**	▪ **The value of data: a distinction without a difference vs. truly granular design-driven approach?**	▪ **Expand universe of traditional models** ▪ **Broader notion of "model" and better use of soft data using big-data techniques**

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Actuaries should be more involved in Cat Modeling: design, build, calibrate, run, use, communicate

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Between 2010 and 2012 we saw a number of significant catastrophe events across different geographies. Some were modeled well, some poorly, and some not at all. This talk will discuss the modeling successes and failures of the last three years and talk about what we need to do to improve the usefulness of modeling in risk management, pricing and underwriting going forward.