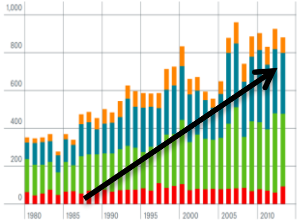
Are We at War with the Weather?

From Science, Finance, and Psychology to Value Creation

Erwann O. Michel-Kerjan, PhD

Executive Director
Center for Risk Management, The Wharton Business School
&
Chairman
OECD Secretary-General Board on Financial Management of Catastrophes

GridSmartCity Round Table 2014



Catastrophes and major crises are often conveniently labeled as *low-probability* or *impossible* events, “black swans”

$$P(\Omega) = P(\bigcup_{\omega\in\Omega}\{\omega\}) = \sum_{\omega\in\Omega} P(\omega) \cong 0$$

But are they still?


THE SHIITE FACTOR • HOT SUMMER MOVIES
Newsweek
TIME
EXTRA EDITION
AMERICA UNDER ATTACK
9:03 A.M.
Japan
EBOLA
WHAT YOU NEED TO KNOW


2
4
6
8
10
12
14
days left

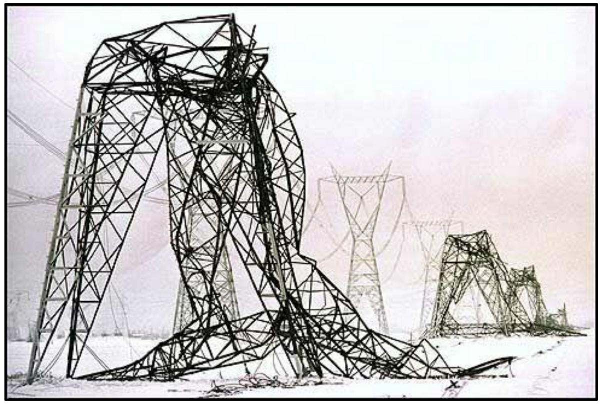

2
4
6
8
10
12
14
days left

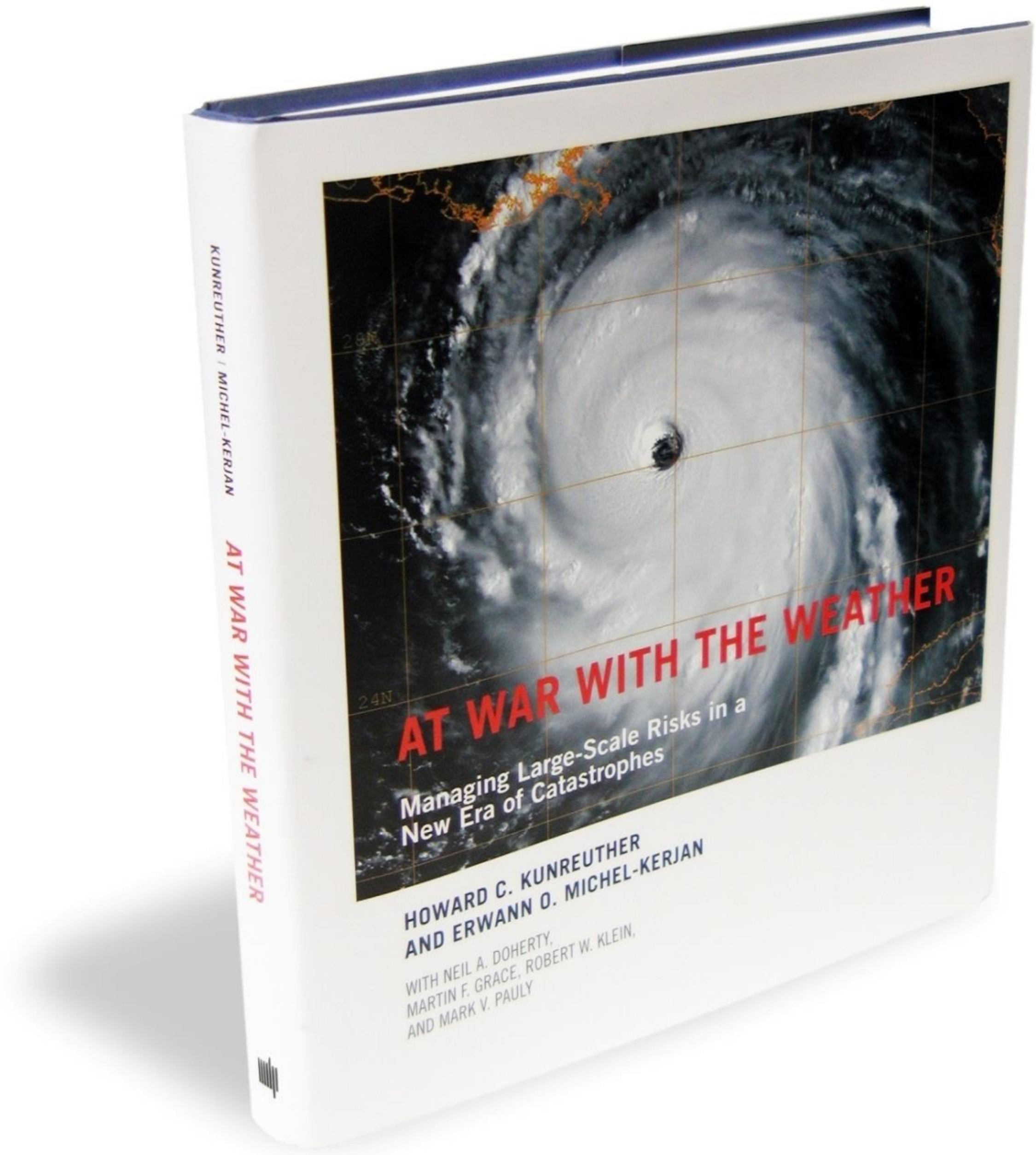
Problem:

The risk architecture
is changing faster,
but we’ve only just started
to recognize it

Focus for Today:

Extreme Weather Events





Kunreuther & Michel-Kerjan
MIT Press

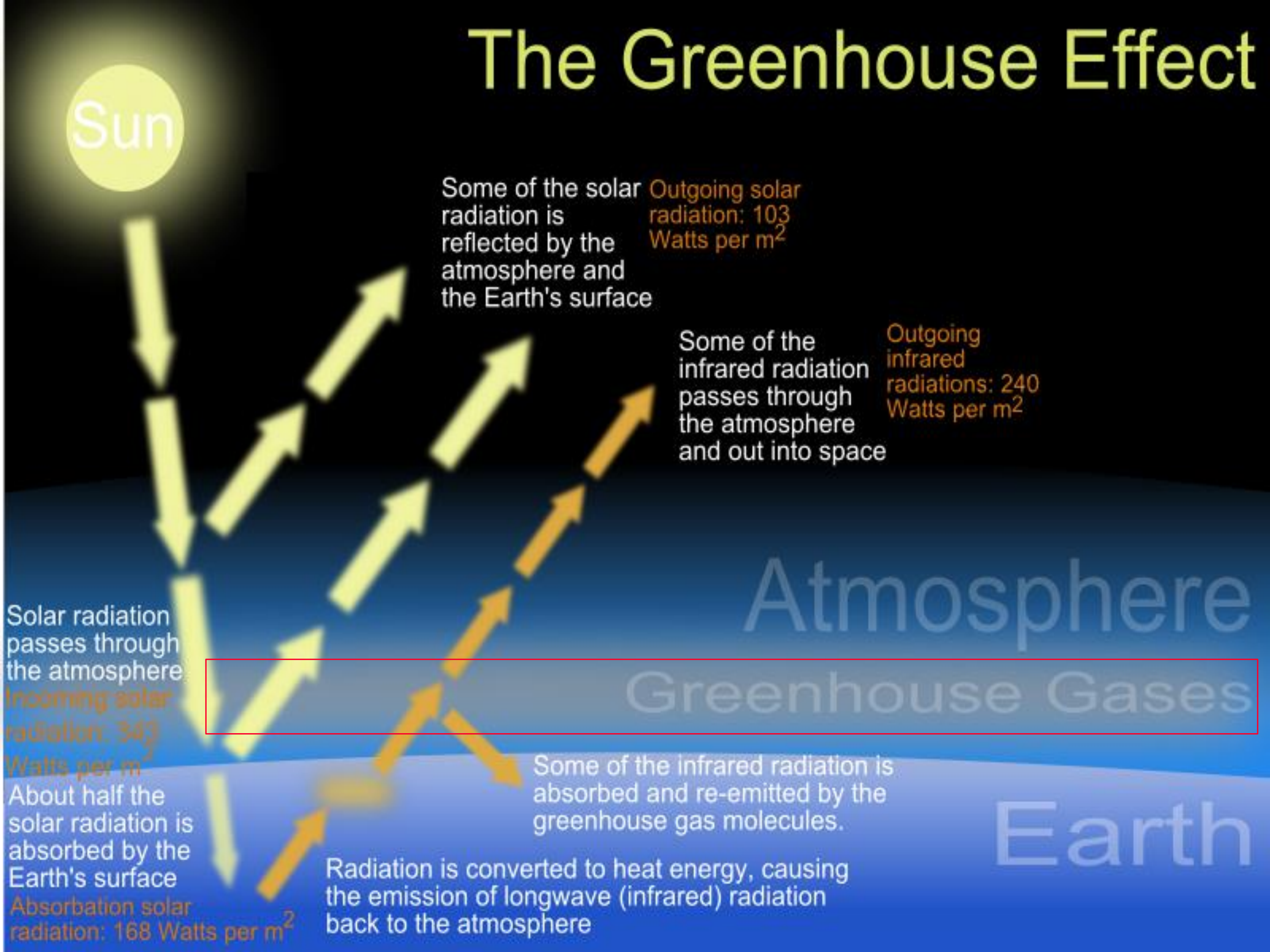
Winner of the Kulp-Wright award for the best risk management book

www.AtWarWithTheWeather.com

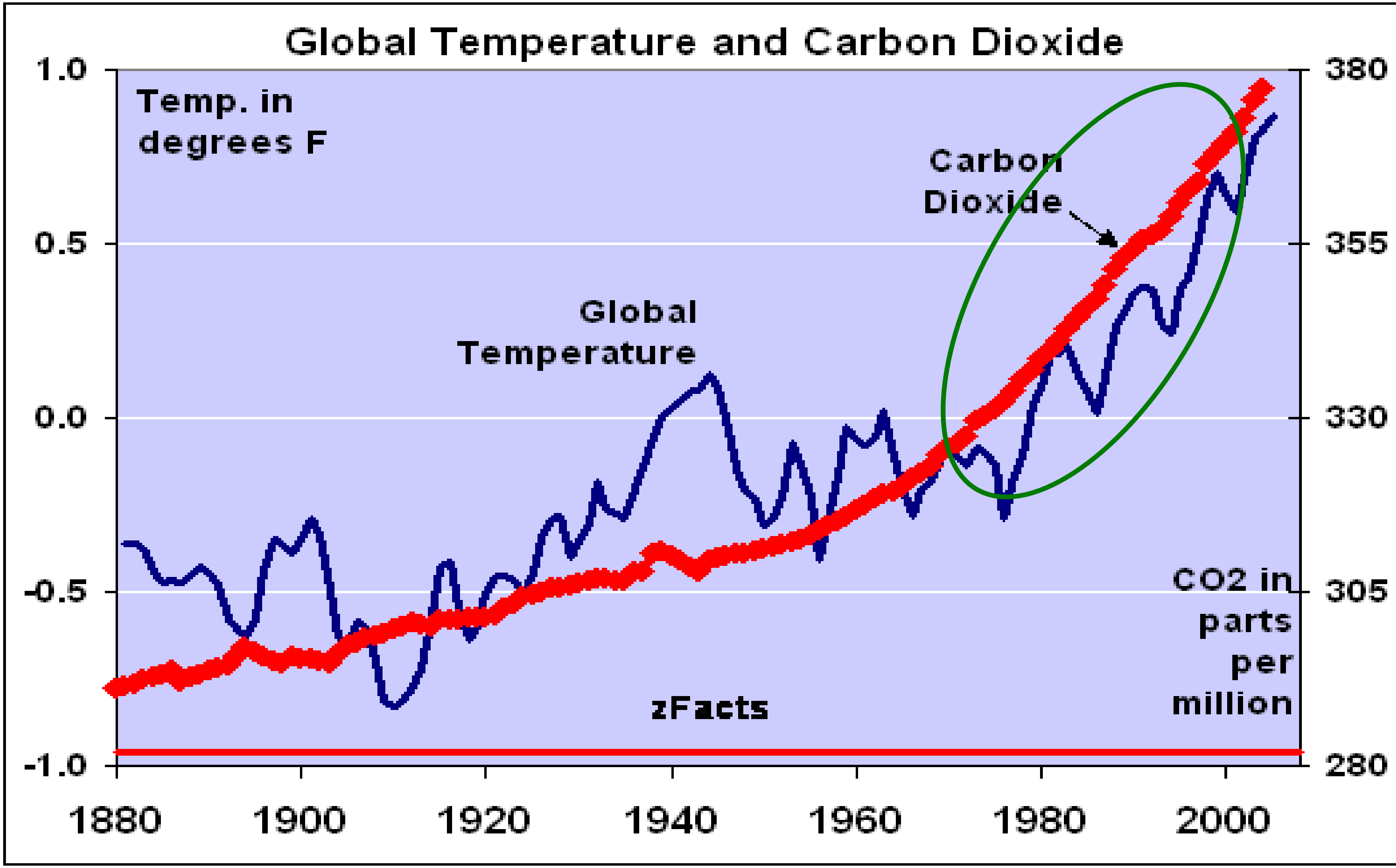
Be Smarter About the Topic

Tool # 1:

Understand the key drivers of the new risk architecture—things don't "just" happen

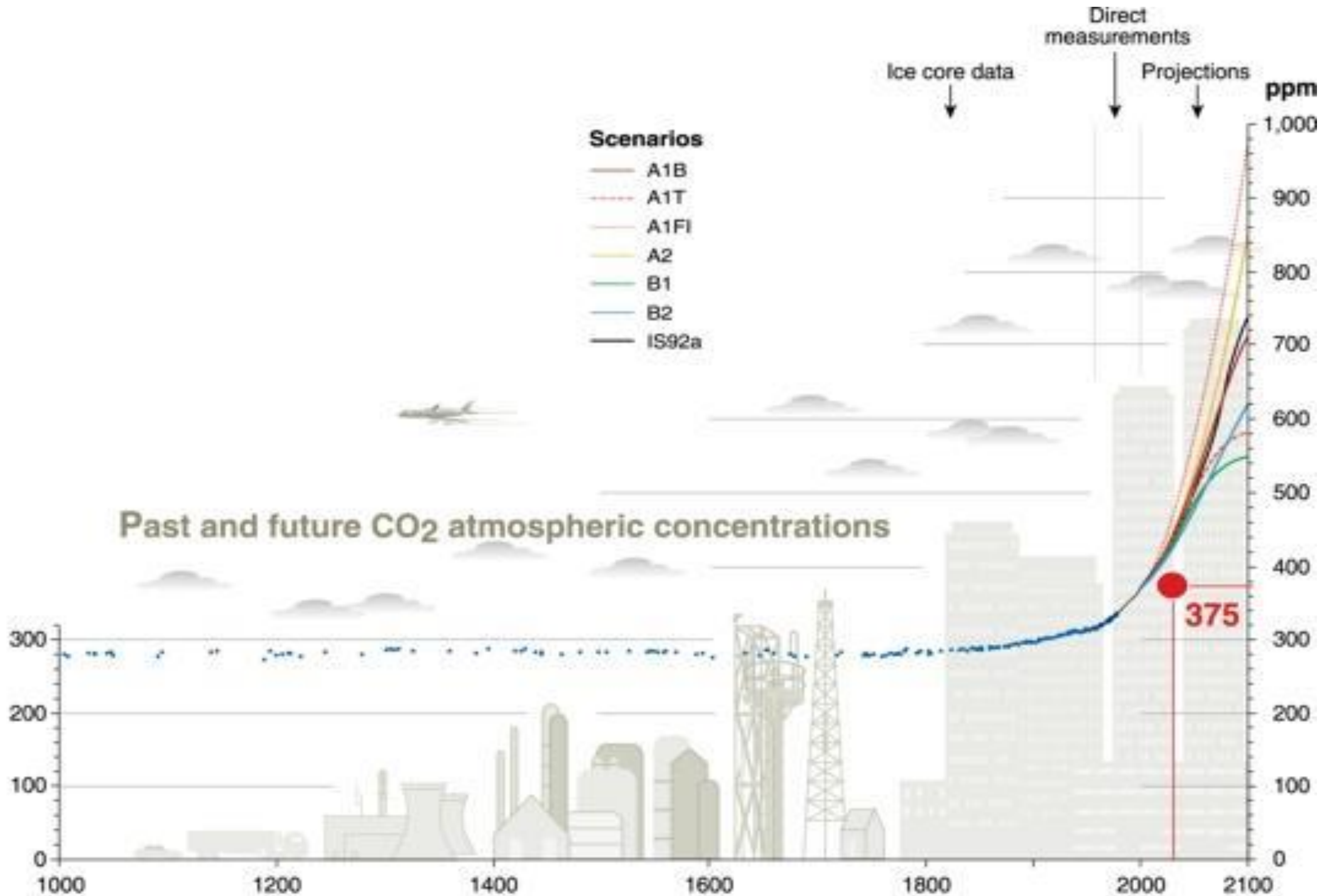

The Greenhouse Effect
Sun
Some of the solar radiation is reflected by the atmosphere and the Earth's surface
Outgoing solar radiation: 103 Watts per m2
Some of the infrared radiation passes through the atmosphere and out into space
Outgoing infrared radiations: 240 Watts per m2
Atmosphere
Greenhouse Gases
Solar radiation passes through the atmosphere
Incoming solar radiation: 343 Watts per m2
About half the solar radiation is absorbed by the Earth's surface
Absorbation solar radiation: 168 Watts per m2
Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules.
Radiation is converted to heat energy, causing the emission of longwave (infrared) radiation back to the atmosphere
Earth

Link between CO_2 concentration in the Atmosphere and Earth Temperature: Highly Correlated



Sources: IPCC

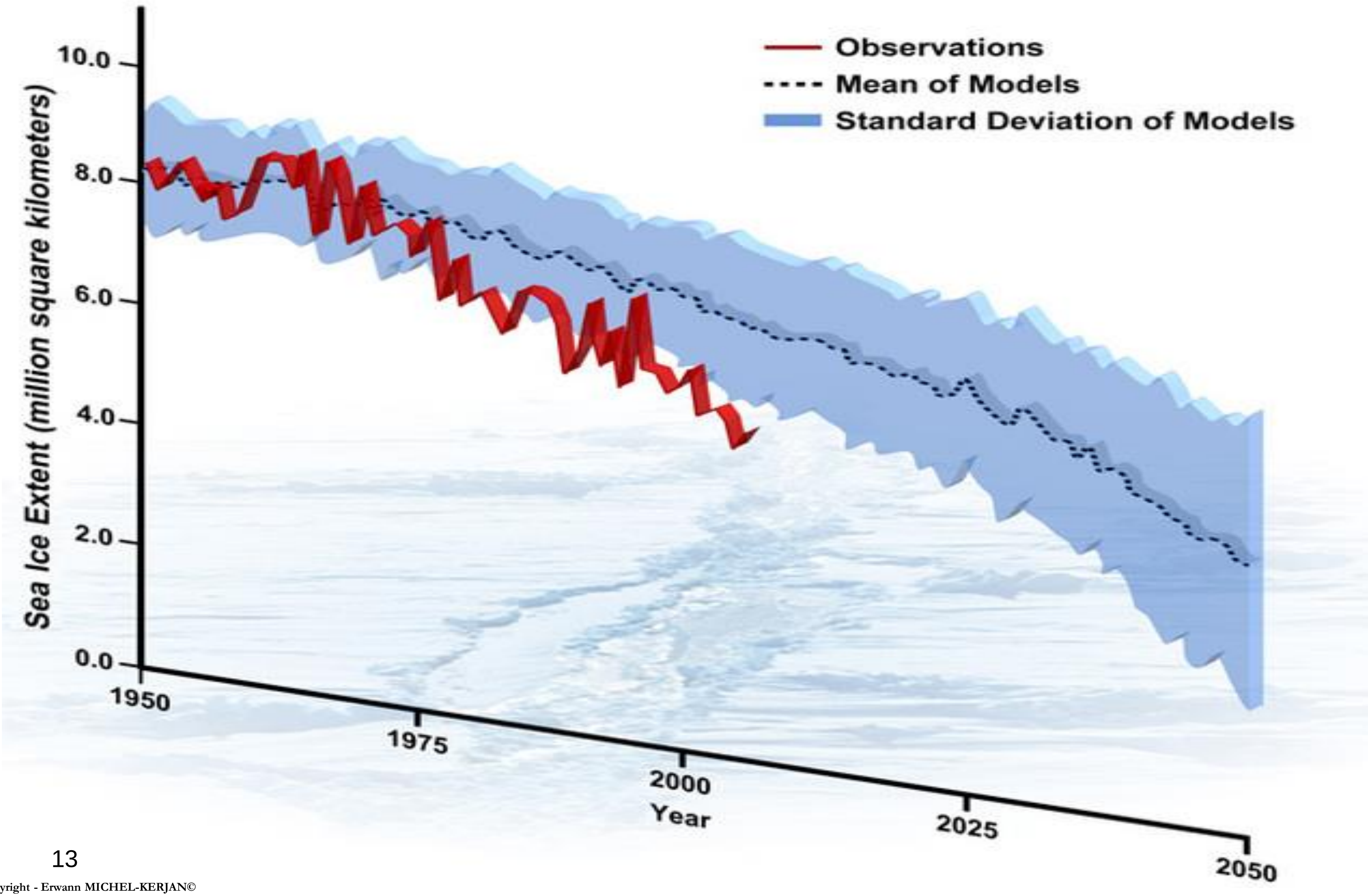
Taking a longer view



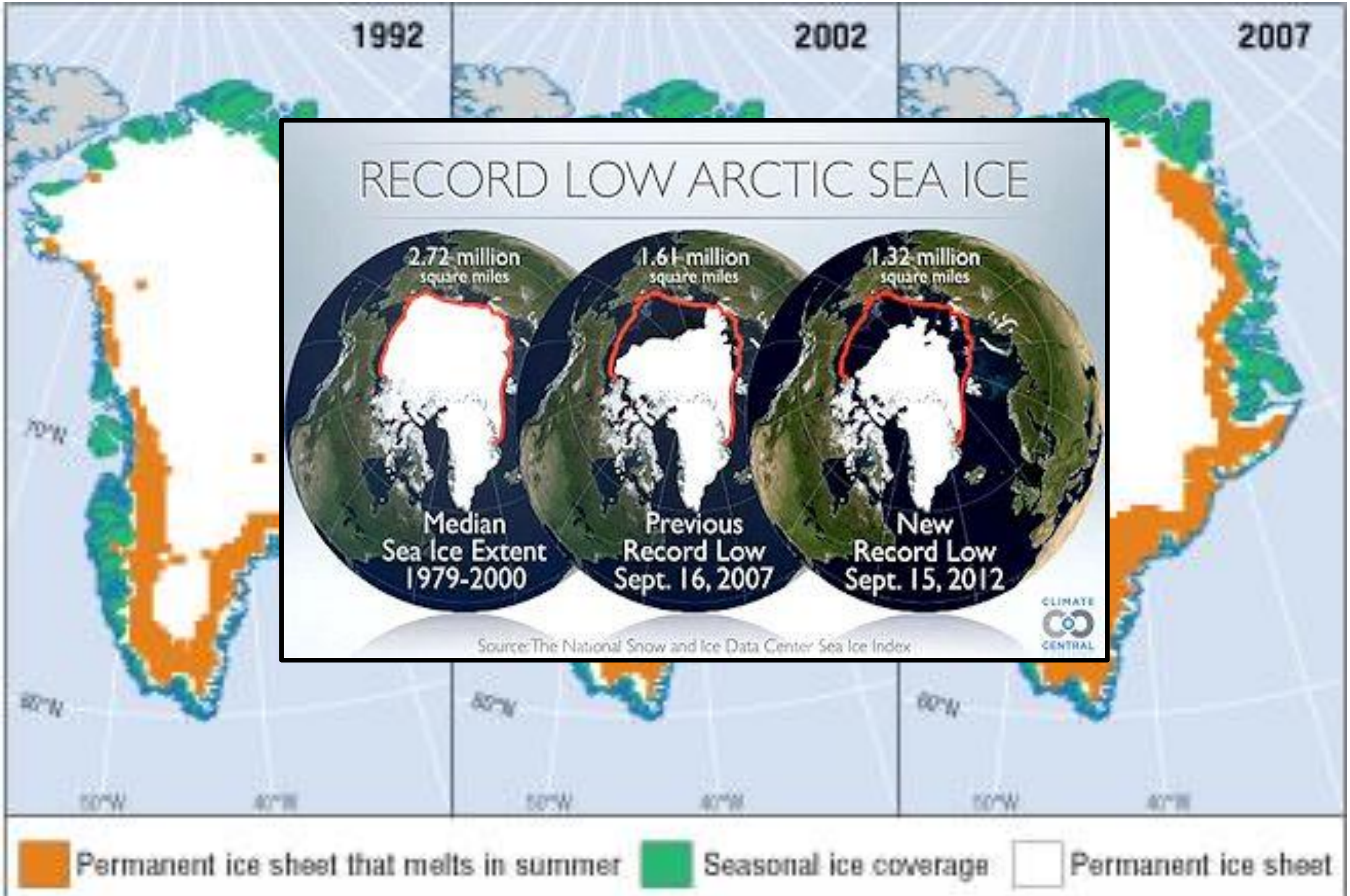
Sources: IPCC

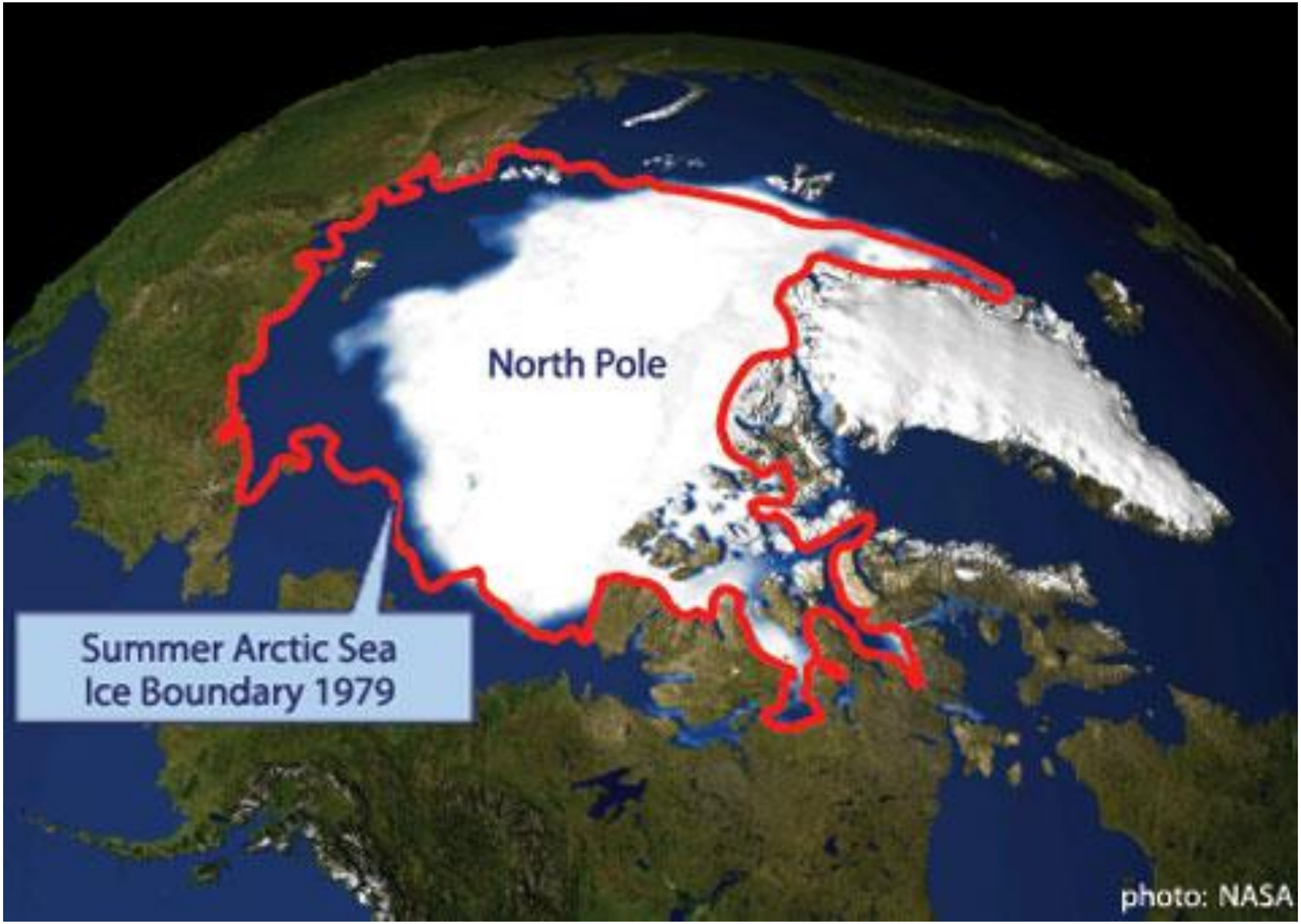
Erwann O. Michel-Kerjan©

Arctic September Sea Ice Extent: Observations and Model Runs



Is the Planet Melting?

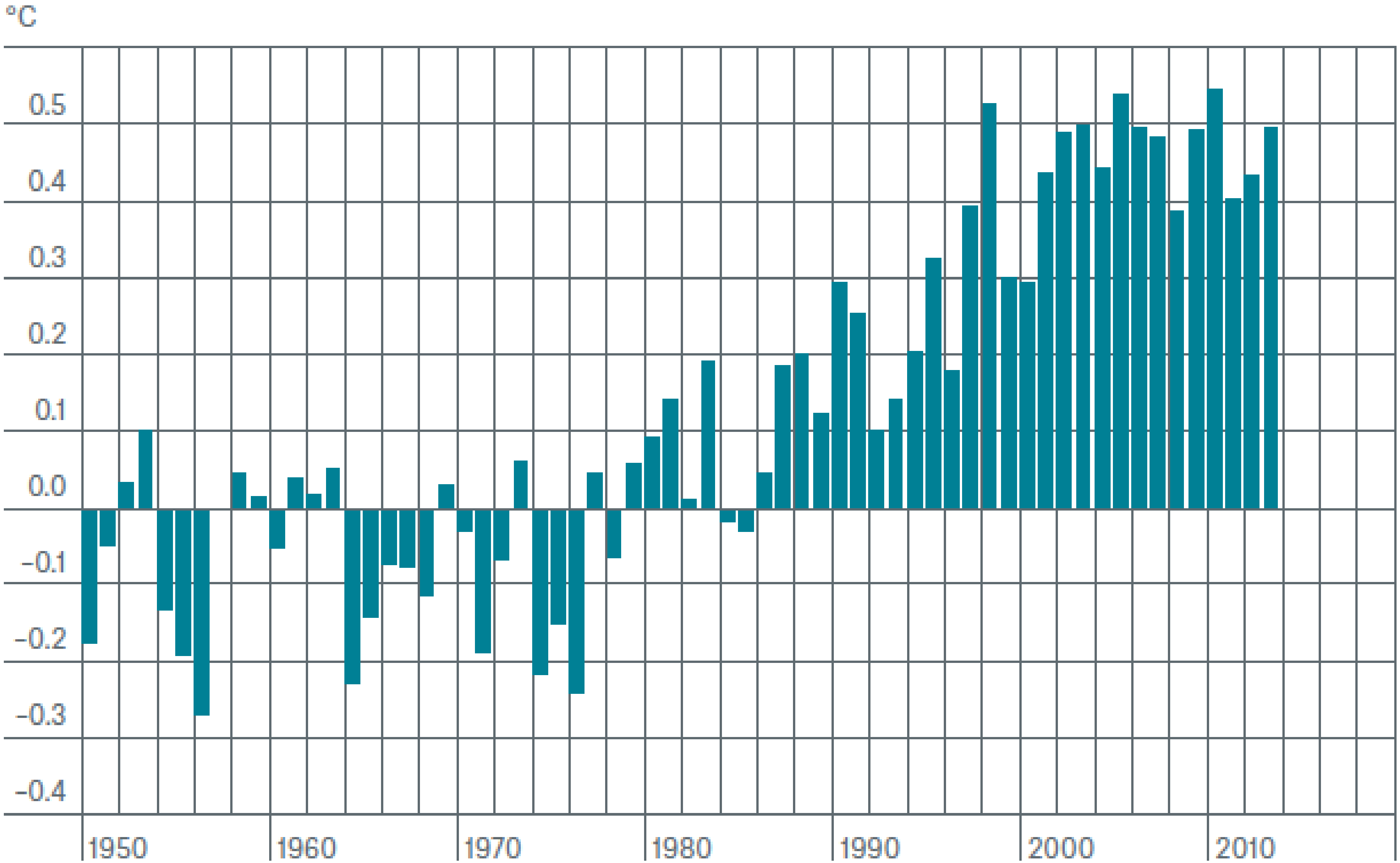



North Pole
Summer Arctic Sea
Ice Boundary 1979
photo: NASA

This has consequences:

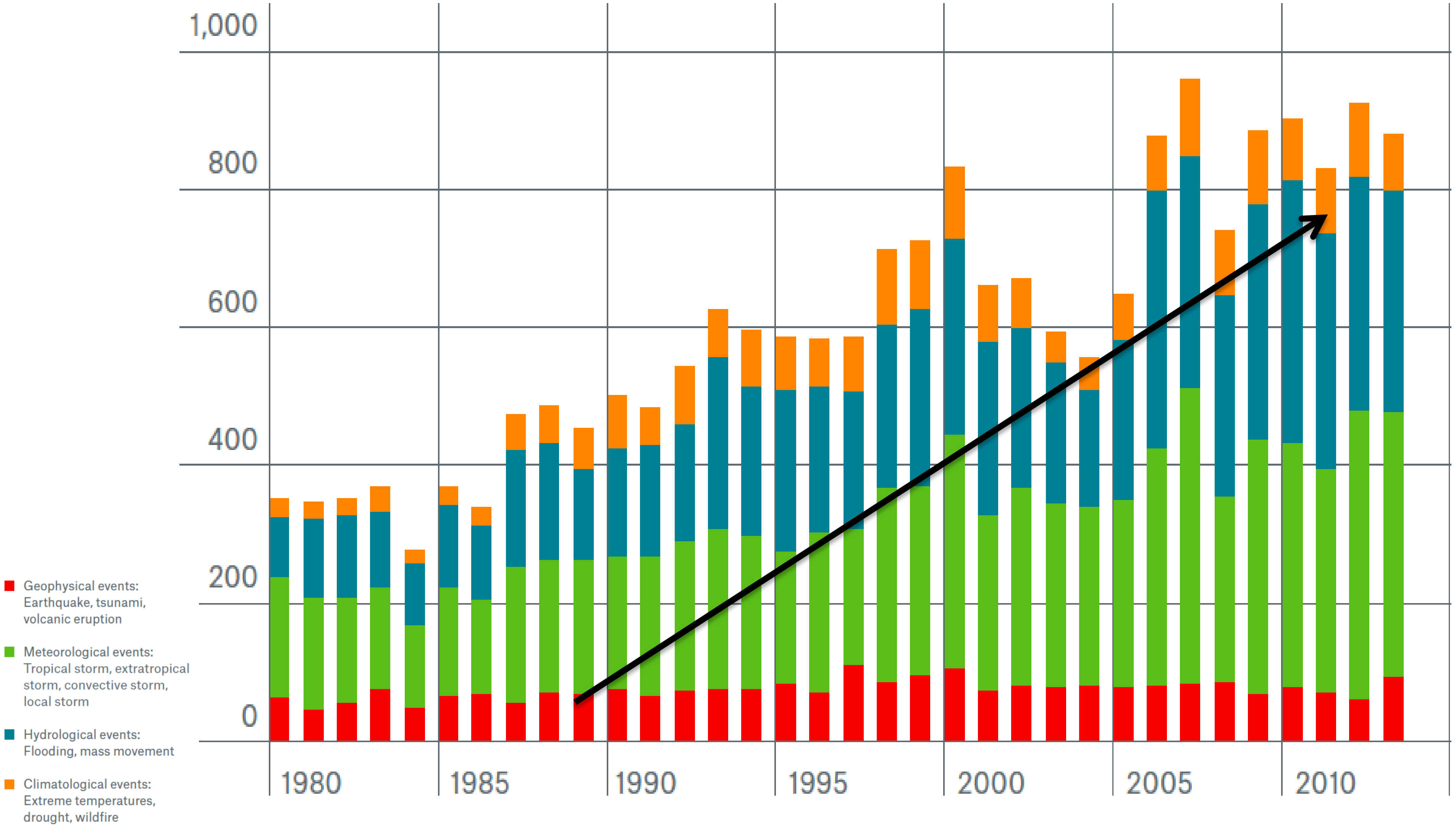
The 10 warmest years over the period 1850 to 2013 were *ALL* after 1998 ….

Annual variations in the global annual mean temperatures in the period 1950-2013 (compared with the 1961-1990 mean)

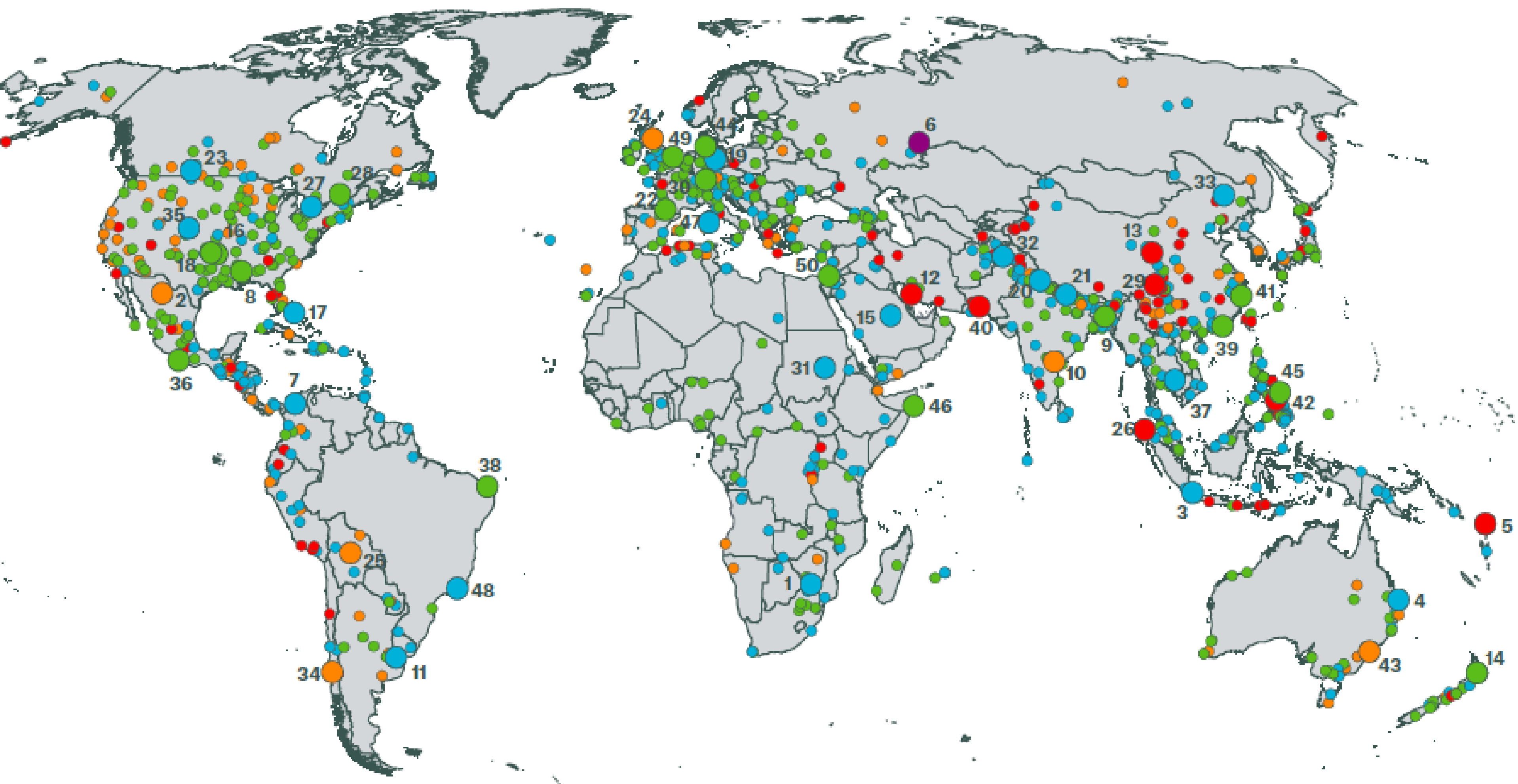


Sources: British Met Office

Number of major weather events is rising fast



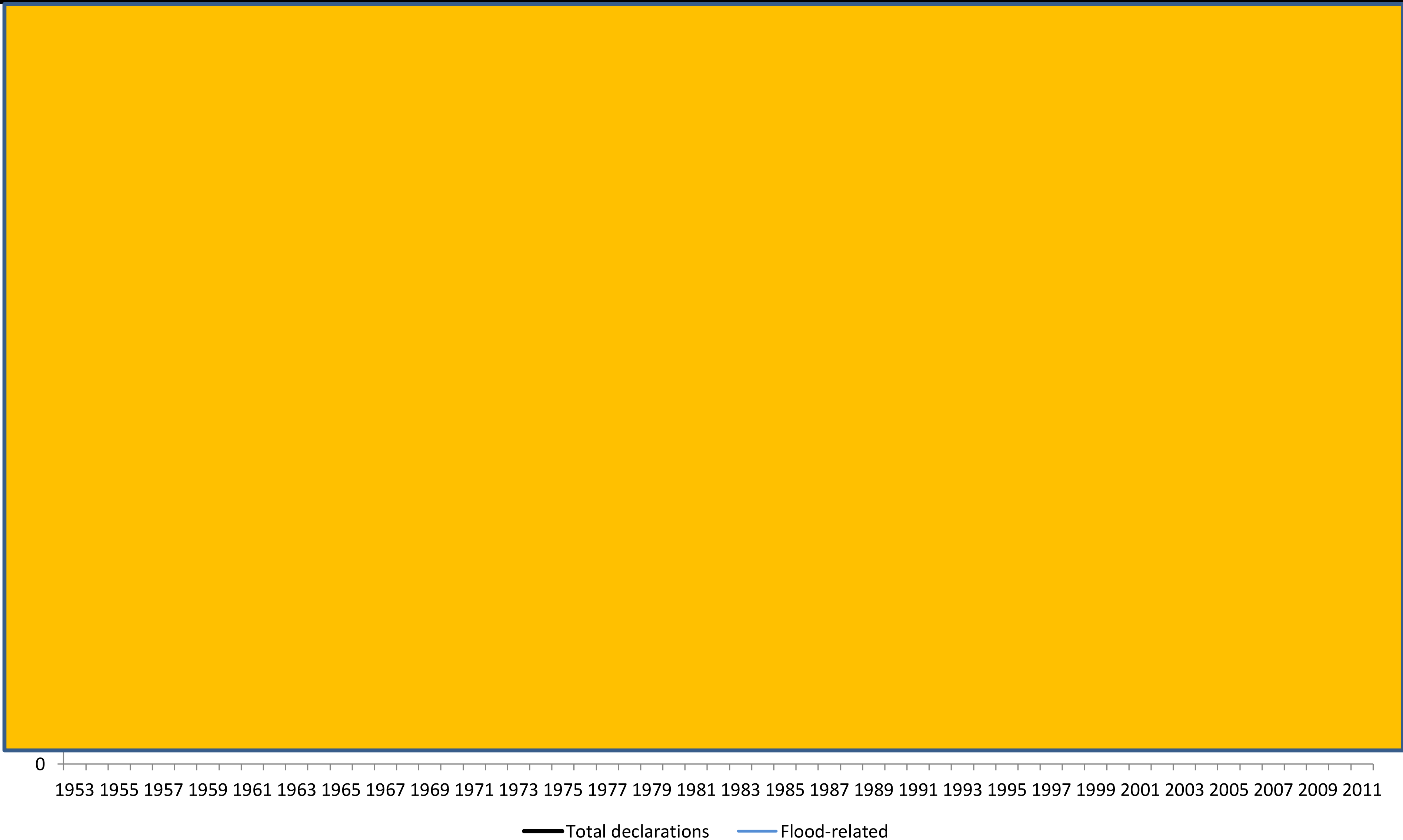
Disaster World Map in 2013: 890 events!



12 of the 15 Most Costly Insured Catastrophes Worldwide between 1970–2012 (in 2012 prices), occurred since 2000

$ BILLION	EVENT	VICTIMS (dead and missing)	YEAR	AREA OF PRIMARY DAMAGE
78	Hurricane Katrina; floods	1,836	**2005**	USA, Gulf of Mexico
41	9/11 Attacks	3,025	**2001**	USA
37	Earthquake (M 9.0) and tsunami	19,135	**2011**	Japan
35	Hurricane Sandy; floods	237	**2012**	USA
26	Hurricane Andrew	43	1992	USA, Bahamas
22	Northridge Earthquake (M 6.6)	61	1994	USA
22	Hurricane Ike; floods	136	**2008**	USA, Caribbean
16	Hurricane Ivan	124	**2004**	USA, Caribbean
15	Floods; heavy monsoon rains	815	**2011**	Thailand
15	Earthquake (M 6.3); aftershocks	181	**2011**	New Zealand
15	Hurricane Wilma; floods	35	**2005**	USA, Gulf of Mexico
12	Hurricane Rita	34	**2005**	USA, Gulf of Mexico, et al.
11	Drought in the Corn Belt	123	**2012**	USA
10	Hurricane Charley	24	**2004**	USA, Caribbean, et al.
10	Typhoon Mireille	51	1991	Japan

At the same time, U.S. Federal Disaster Relief Has Been Increasing Dangerously Over Time



Number of U.S. Presidential Disaster Declarations – 1953-2011

Now that you got the point you are going to do something about it

Right?

Not necessarily …

Illustration with Sandy flooding NY & NJ:

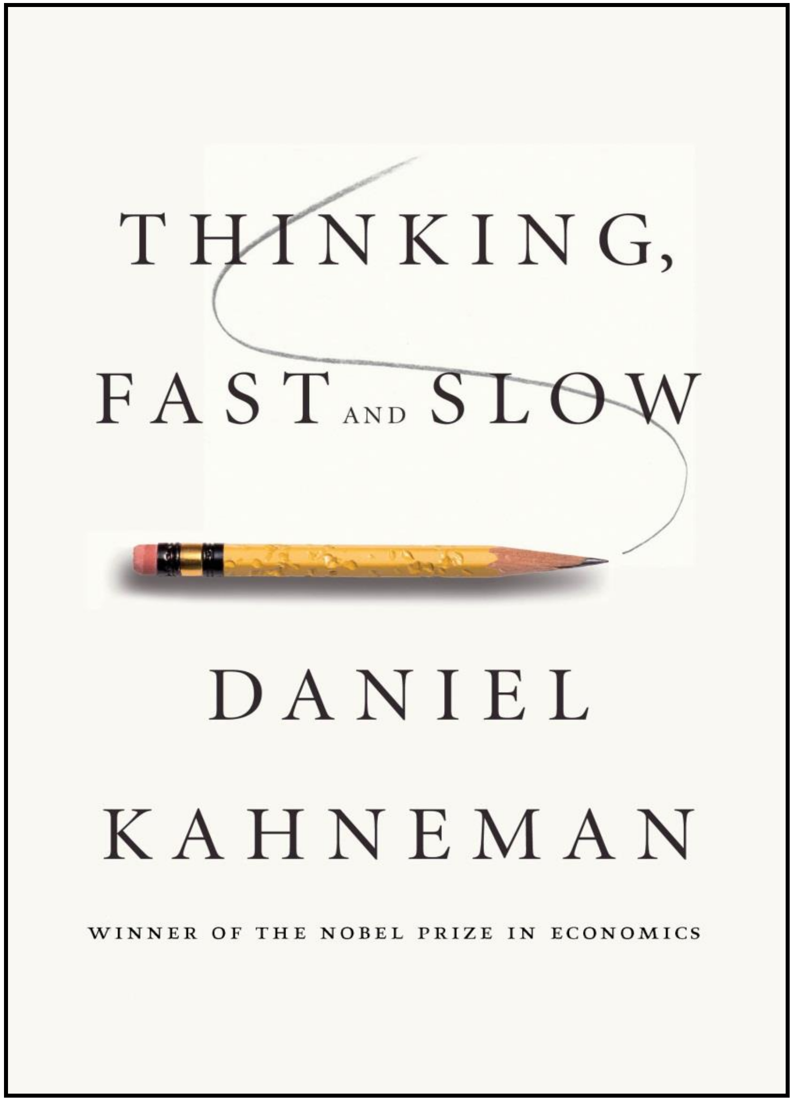
- **80%** of people living in the inundated areas did **not** have flood insurance
- **92%** of small businesses did **not** either…

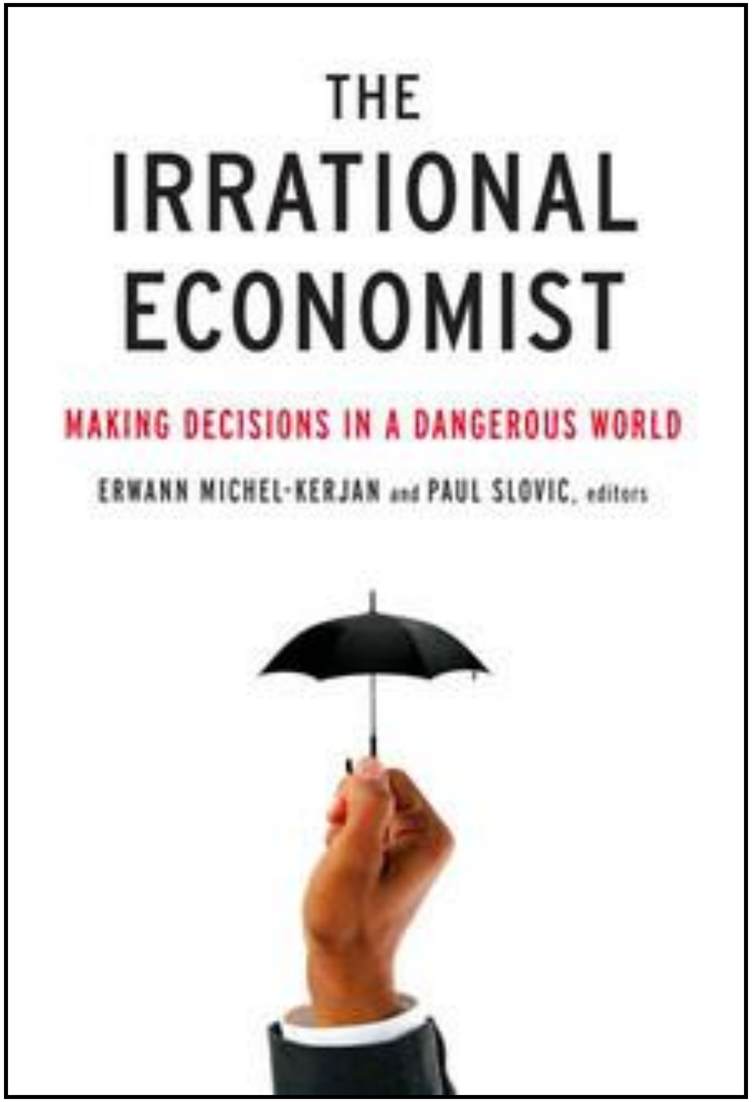
Our analysis of the entire portfolio of the 5 million policies in the US *National Flood Insurance Program* revealed that the majority of the people cancel their flood policy after only … 3 years

Be Aware of Psychological Biases

Tool # 2:

Five Well-Known Mistakes to Avoid


THINKING,
FAST AND SLOW
DANIEL
KAHNEMAN
WINNER OF THE NOBEL PRIZE IN ECONOMICS


THE
IRRATIONAL
ECONOMIST
MAKING DECISIONS IN A DANGEROUS WORLD
ERWANN MICHEL-KERJAN and PAUL SLOVIC, editors

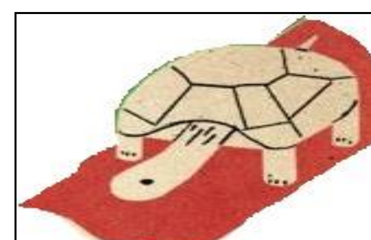
Intuitive Thinking (“System 1”) versus Deliberative Thinking (“System 2”)

System 1 operates automatically and quickly with little or no effort

- Individuals use simple associations including emotional reactions; follow others without questions
- Focus on past experience
- Basis for systematic judgmental biases and simplified decision rules

System 2 allocates attention to effortful and intentional mental activities

- Individuals undertake trade-offs implicit in benefit-cost analysis and quantitative analysis
- Recognizes relevant interconnectedness and need for coordination
- Focuses on long-term strategies for coping with risks



1. The "Last Crisis" Bias– Always fighting the last war

2. Myopia– Focus on short-time horizons in comparing upfront costs of risk management investment with expected benefits in the long-term; "it might not pay out this quarter"

3. Ignore the Issue. NIMTOF– Failure to significantly embrace strategic risk management that leads to value creation if actions of competitors, regulators, consumers are not perceived as being that pressing; overconfidence.

4. Lack of Valid Information– We don't know where to start; this is such a big topic. We put together a nice risk management report, but it is not clear it is creating any measurable value.

5. Procrastination– We think we know what to do and we have big ideas that we should probably start implementing next year, then the year after, etc. As a result, we have not done anything in years; rather, we should start and build up.

How Do We Move to Action and Create Value?

Making More Informed Decisions to Measure Return on Investment

Tool # 3:

Learning from New York City

Why the New York Area?

- One of the largest coastal mega-cities
- Important economic hub for the U.S. and international community (tourism, trade, financial markets)
- High urban exposure to flooding
- Just experienced $80 billion flood-related losses from Hurricane Sandy
- Sandy revealed massive impediments to flood resilience (8 out of 10 residents and 9 out of 10 small businesses were uninsured against flood losses).
- Costly delays in restoring and upgrading damaged infrastructure
- Interest by both community leaders (2013 NYC's Mayor report) and business leaders in making this community more resilient to flood

Key Questions

What are current and future flood risk levels in NYC? Can we quantify these in a transparent manner?

Which strategies should be implemented to **reduce the costs of future floods and save lives**?

- What are the costs and benefits of these strategies?
- Is it economically efficient for NYC to invest in making buildings flood resilient, or in flood-protection infrastructure?
- Who should pay for such investments?

Aerts, Botzen, Emanuel, Lin, de Moel, and Michel-Kerjan (2014).
Evaluating Flood Resilience Strategies for Costal Megacities, Science, *Vol. 344, pp. 473-475. (plus supplemental material online)*

CLIMATE ADAPTATION

Evaluating Flood Resilience Strategies for Coastal Megacities

Integration of models for storms and floods, damages and protections, should aid resilience planning and investments.

Jeroen C. J. H. Aerts,[1*] W. J. Wouter Botzen,[1] Kerry Emanuel,[2] Ning Lin,[3] Hans de Moel,[1] Erwann O. Michel-Kerjan[4*]

Recent flood disasters in the United States (2005, 2008, 2012); the Philippines (2012, 2013); and Britain (2014) illustrate how vulnerable coastal cities are to storm surge flooding (*1*). Floods caused the largest portion of insured losses among all catastrophes around the world in 2013 (*2*). Population density in flood-prone coastal zones and megacities is expected to grow by 25% by 2050; projected climate change and sea level rise may further increase the frequency and/or severity of large-scale floods (*3–7*).

Despite trillions of dollars of assets located in coastal flood-prone areas, investments in protection have often been inadequate (*8*), postponed for short-term economic reasons, for lack of consensus on how to properly evaluate the return on investment, or from the fear of making irreversible choices that become suboptimal over time. To help inform policy decisions, we have developed a multidisciplinary scientific approach to evaluate flood management strategies. It combines probabilistic risk assessment of hurricanes and storm surge with vulnerability determination of exposed assets at a census level, accounting for sources of uncertainty and the timing of investments in storm-surge flood-risk protection. We applied this methodology to New York City (NYC)—one of the most exposed coastal megacities—working with local policy-makers.

Barriers and Building Codes

A wealth of ideas about protecting NYC from floods has been proposed (*9*, *10*), including barriers, levees, wetland restoration and beach strengthening that are effective in reducing flood occurrence in large parts of the city. However, as in other cities, some of these large-scale engineering options have been criticized because they are costly or may harm the environment. Other measures, such as reducing exposure and vulnerability (e.g., by enacting zoning regulations and enhancing building codes), may considerably reduce flood damage and entail lower investment costs, but they do not prevent flood waters from entering the city.

We present three main classes of strategies that focus on reducing vulnerability or avoiding flooding or a combination of both [see the figure and supplementary material (SM)]. The Resilient Open City strategy (S1) is a cluster of measures to enhance building-code strategies in NYC (*11*) by elevating, or dry or wet flood-proofing, both existing and new buildings. Storm surge barrier strategies (S2, a, b, and c) aim to lower flood probabilities in NYC and parts of New Jersey (NJ), with barriers, levees, and beach nourishments. "Environmental dynamics" (S2a) consists of three barriers to close off parts of NYC and NJ that preserve wetland dynamics of Jamaica Bay. "Bay closed" (S2b) expands on S2a by adding a fourth barrier that closes off Jamaica Bay. "NJ-NY connect" (S2c) replaces three barriers from S2b with one large barrier in the outer harbor to protect a larger area (see the figure). The barrier systems are designed to withstand an extreme surge of 8 to 10 m (25 to 30 feet).

The "hybrid solution" (S3) (see the figure), reflecting many measures in (*9*), combines building code measures of S1 that turned out to be cost-effective according to our analysis (SM) only in high-risk 100-year return flood zones (defined by the U.S. Federal Emergency Management Agency), with protection of critical infrastructure to reduce economic loss due to business interruption. S3 includes moderate local flood protection measures, such as levees and beach nourishment that are also part of S2c. The local protection measures and building codes for new structures are adjustable to future climate change, as they can be upgraded if flood risk increases in the coming decades.

Modeling Flood Risks, Estimating Costs

The heart of the method is a probabilistic flood-risk model developed for the city (*12–14*) (SM §1). We simulated 549 storm-surge simulations, varying from extremely low probability events to more frequent storms, using a new coupled hurricane–hydrodynamic–inundation model (*15*) (SM). Then we applied flood depth–damage curves to calculate potential damage to buildings and vehicles at the census block level. In addition to flood risk to buildings, the risk to other categories (like infrastructure), the risk to parts of NJ, and indirect economic effects were added, based on observed consequences of Hurricane Sandy in 2012 (*13*).

We estimate the average annual expected flood loss for NYC alone at $174 million/year, if no flood management measures are implemented. Flood losses with a 100- and 1000-year return period are $2.2 billion and $25.4 billion, respectively. Our loss estimates for an extreme event of return period similar to Sandy are very close to the actual damages it triggered (SM §1.11).

The future risk in 2040 and 2080 is also calculated, accounting for estimated changes in surge probabilities (*15*) and projected sea-level rise under future climate change scenarios, as well as the increase in urban exposure due to new construction in flood zones (SM §1.3). Flood defenses in the storm surge barrier strategies (S2, a, b, and c) are assumed not to fail. A benefit-cost analysis (BCA) of flood risk–management strategies was conducted for NYC over a 100-year period to evaluate the benefit (avoided risk) of each strategy and its cost (*13*), under future scenarios (SM §2). We tested the robustness of the

[1]Institute for Environmental Studies, VU University, 1081HV, Amsterdam, Netherlands. [2]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA. [3]Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ 08544, USA. [4]Center for Risk Management and Operations and Information Management Department, The Wharton School of the University of Pennsylvania, Philadelphia, PA 19104, USA. *Corresponding authors. E-mail: jeroen.aerts@vu.nl (J.C.J.H.A.) and erwannmk@wharton.upenn.edu (E.M.-K.).

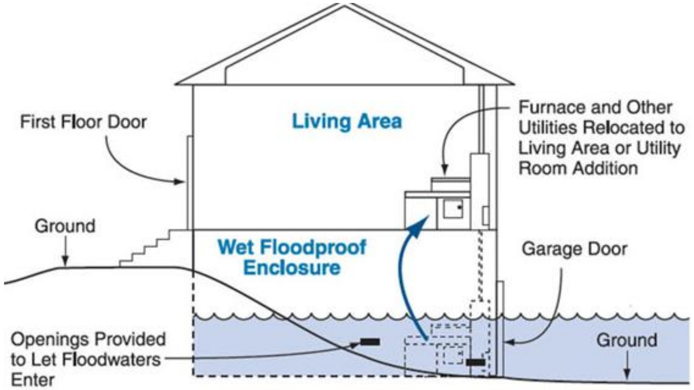
First one needs to assess flood risk

Flood Risk Management Strategies

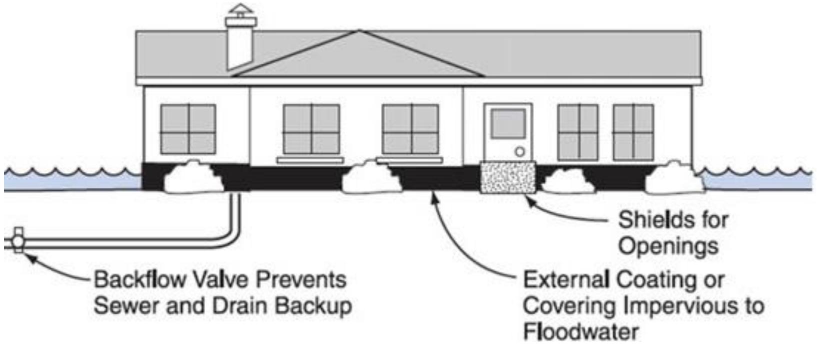
S1: Flood-proof buildings

- New, or existing buildings
- +2ft, +4ft, or +6ft above the current ground level
- Applied to the 1/100 or 1/500 year flood zone

Elevated building



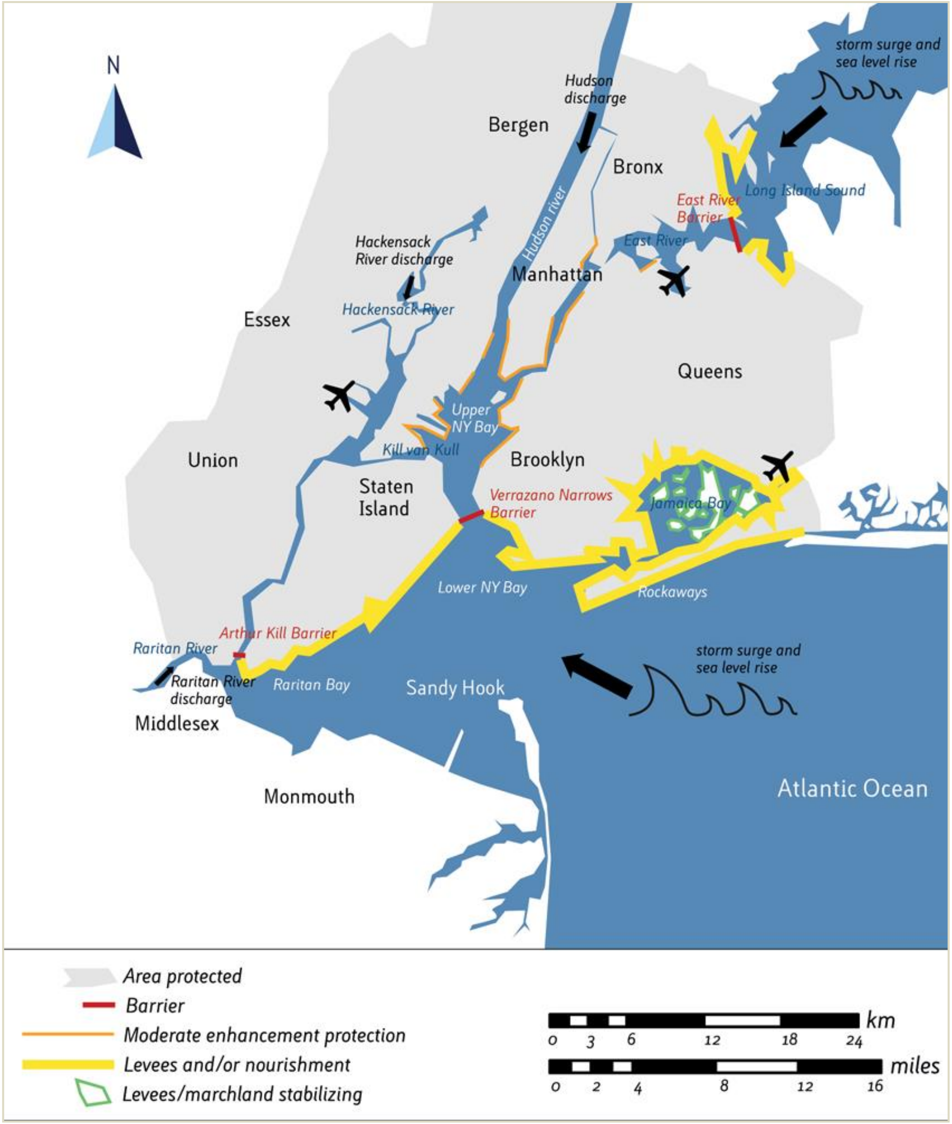
Wet-flood proofing



Dry-flood proofing

Source: Aerts et al, 2013, *ANYAS*

S2a: Flood Protection 'Environmental Dynamics'

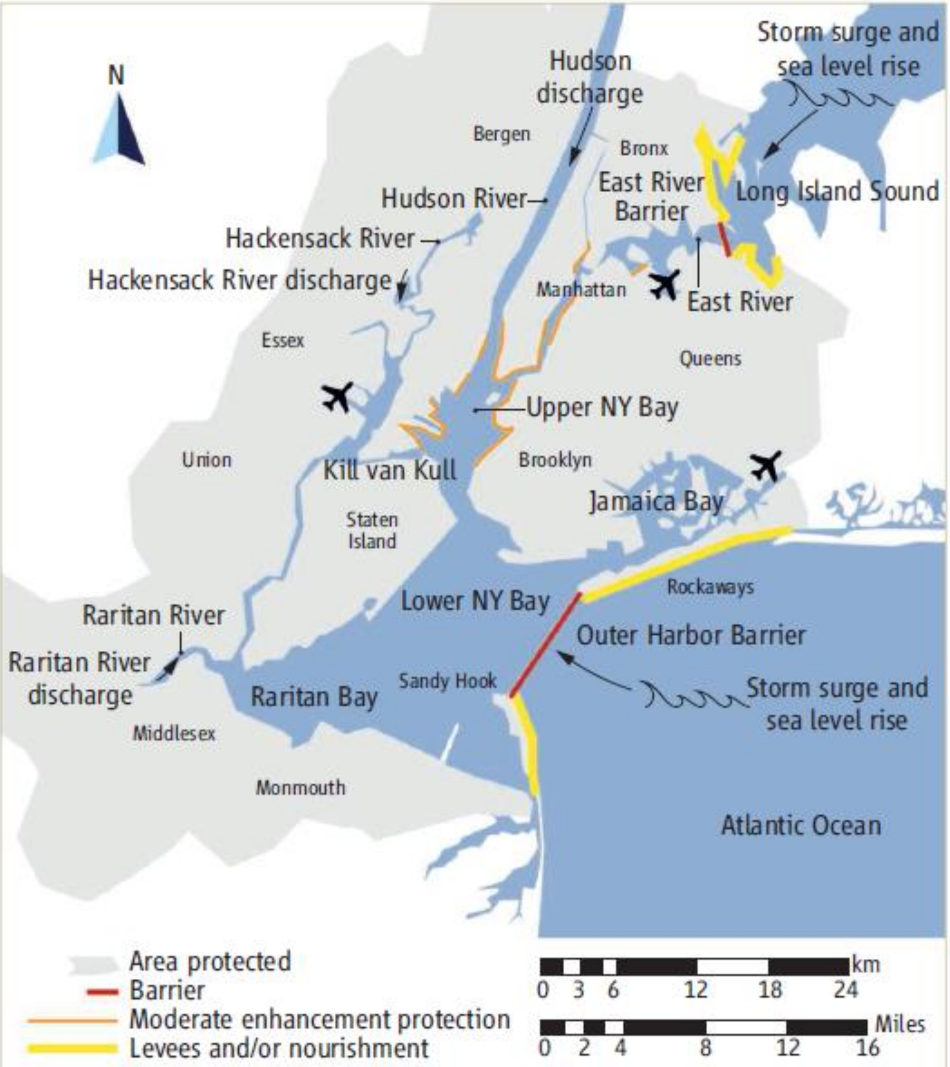


Three storm surge barriers

- Arthur Kill
- Verrazano Narrows
- East River

Coastal protection near barriers

Open system to preserve ecosystem dynamics



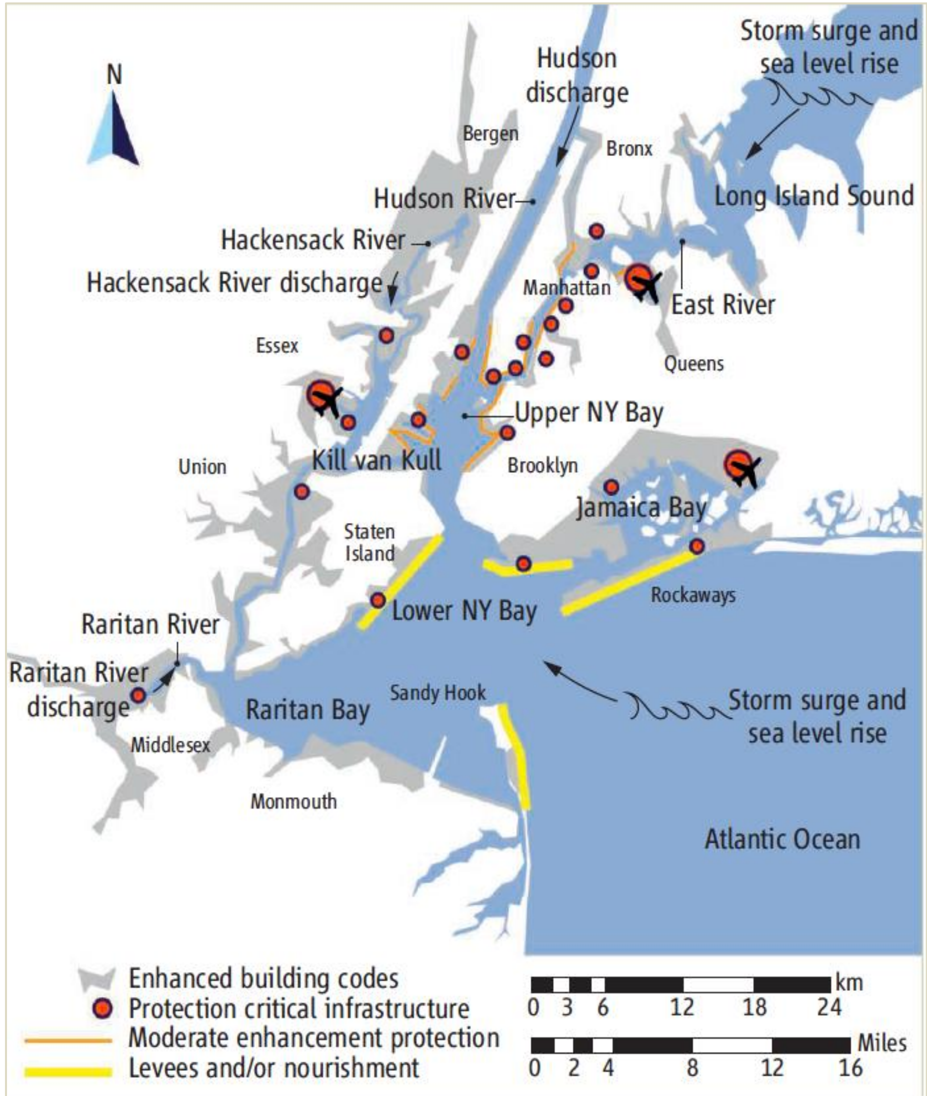
Large outer harbor barrier

Large reduction coastline

Protects larger area in NJ

May disrupt water flows

S3: Hybrid Solution of Local Protection



Sources: Aerts, Botzen, Emanuel, Lin, de Moel, and Michel-Kerjan (2014). *Science*, *Vol. 344.*

Results (communicated to NYC Mayor's Office and other decision makers)

	Where/ how much	Environ.dyn. S2a	Bay closed S2b	NJ-JY connect S2c	Hybrid solution S3
Costs					
Total investment	NYC	$16.9–21.1 billion	$15.9–21.8 billion	$11.0–14.7 billion	$6.4–7.6 billion
Total investment	NJ	$2 billion	$2 billion	n/a	$4 billion
Total investment	NYC+NJ	$18.9–23.1 billion	$17.9–23.8 billion	$11.0–14.7 billion	$10.4–11.6 billion
Maintenance	NYC+NJ	$98.5 million	$126 million	$117.5 million	$13.5 million
BCR for current climate					
BCR	4% discount	0.21 (0.11; 0.35)	0.21 (0.11; 0.34)	0.36 (0.18; 0.59)	0.45 (0.23; 0.73)
	7% discount	0.13 (0.07; 0.21)	0.12 (0.07; 0.20)	0.23 (0.12; 0.37)	0.26 (0.13; 0.43)
BCR for middle climate change scenario					
BCR	4% discount	1.32 (0.67; 2.16)	1.29 (0.65; 2.11)	2.24 (1.14; 3.67)	2.45 (1.24; 4.00)
	7% discount	0.60 (0.30; 0.98)	0.60 (0.30; 0.97)	1.06 (0.54; 1.74)	1.09 (0.55; 1.78)

Sources: Aerts, Botzen, Emanuel, Lin, de Moel, and Michel-Kerjan (2014). *Science*, *Vol. 344.*

Who Should Pay for NYC's Resilience Investments?

- NYC generates significant positive externalities to the rest of the U.S. (trade, tourism, port) and the world (financial market)
- If cost is shared, then the benefit-cost ratio will make these resilience investments much more appealing financially for the City of New York

Possible Solutions:

1) NYC issues a **Resiliency Bond** to cover their share (to spread upfront cost)

2) Establish a **NYC Resiliency Fee** to be paid by all tourists who visit the city (similar to the current 9/11 security fee on each airplane ticket)

$10 * 50 million tourists/year = $500 million/year = $5bn in the next 10 years

Davos, Switzerland

For Executives to Approach Risk Management More Strategically

Tool # 4:

Joint work with the World Economic Forum (2005-present)

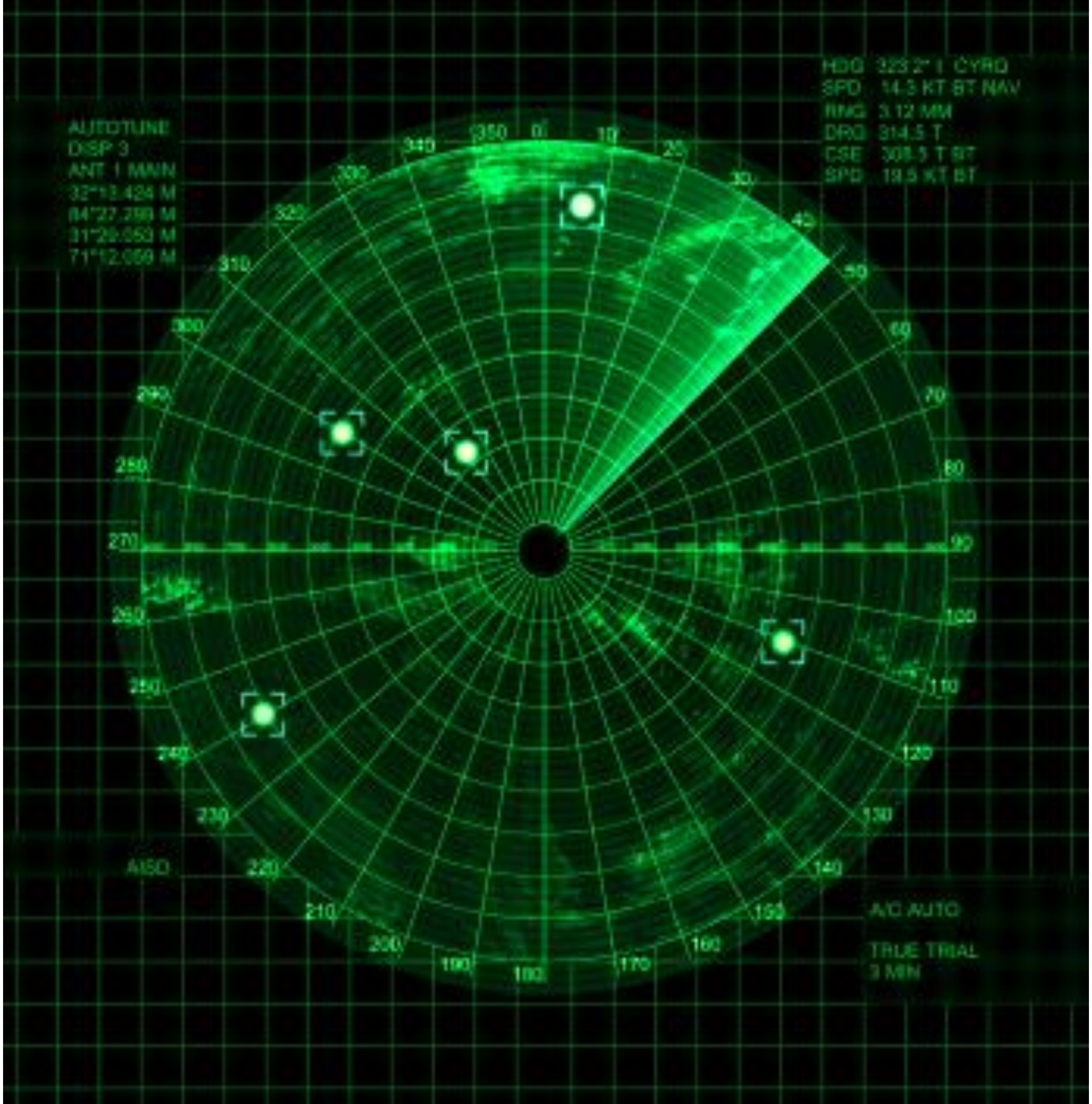
WEF-Wharton Risk Center on Global Risks

(along with Marsh and Zurich)

A New 5-Step Methodology Was Developed

1. Do not focus only on the one or two risks you know best (expert bias).
2. Look at 20, 30, 50 risks & cluster them in categories to be presented to the C-suite and also (most likely these days) to the Board.
3. Do **not** try to predict what will happen **tomorrow or next quarter**; Rather take a **longer view** to avoid myopia: 3-5 years.
4. Think of domino effects, how these risks interact with each other. Map a number of interdependencies, even second or third level.
5. Compare the (dynamic) likelihood and severity across all risks and the resilience capacity of your organization or country.

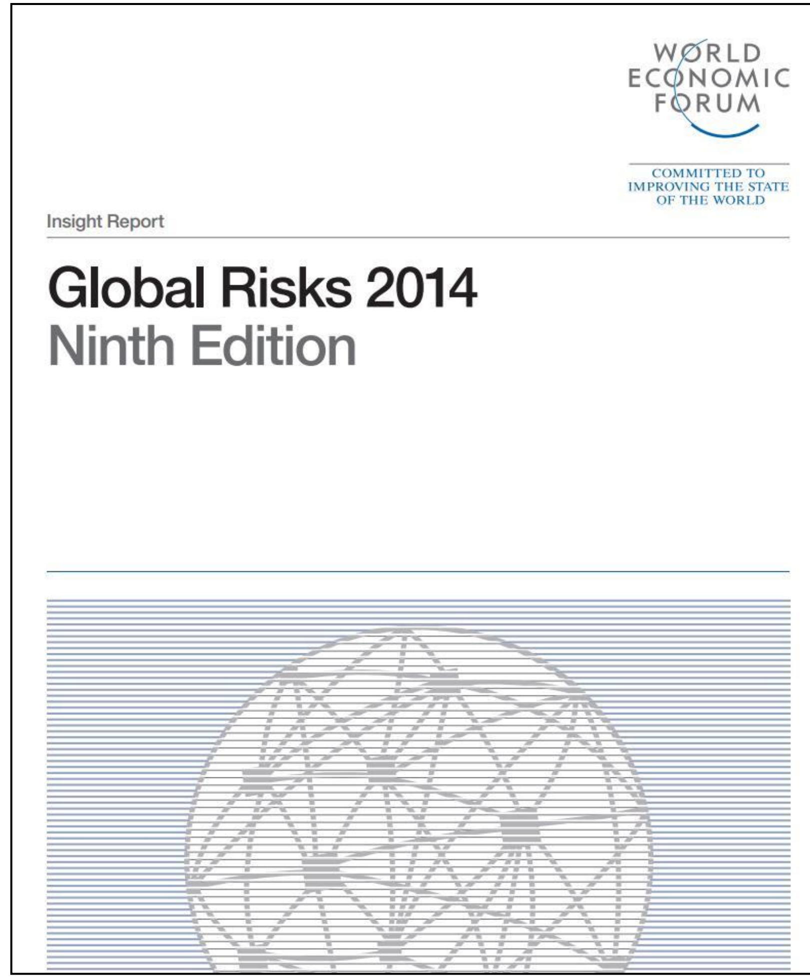
Monitor over time; it is not just a one-time exercise



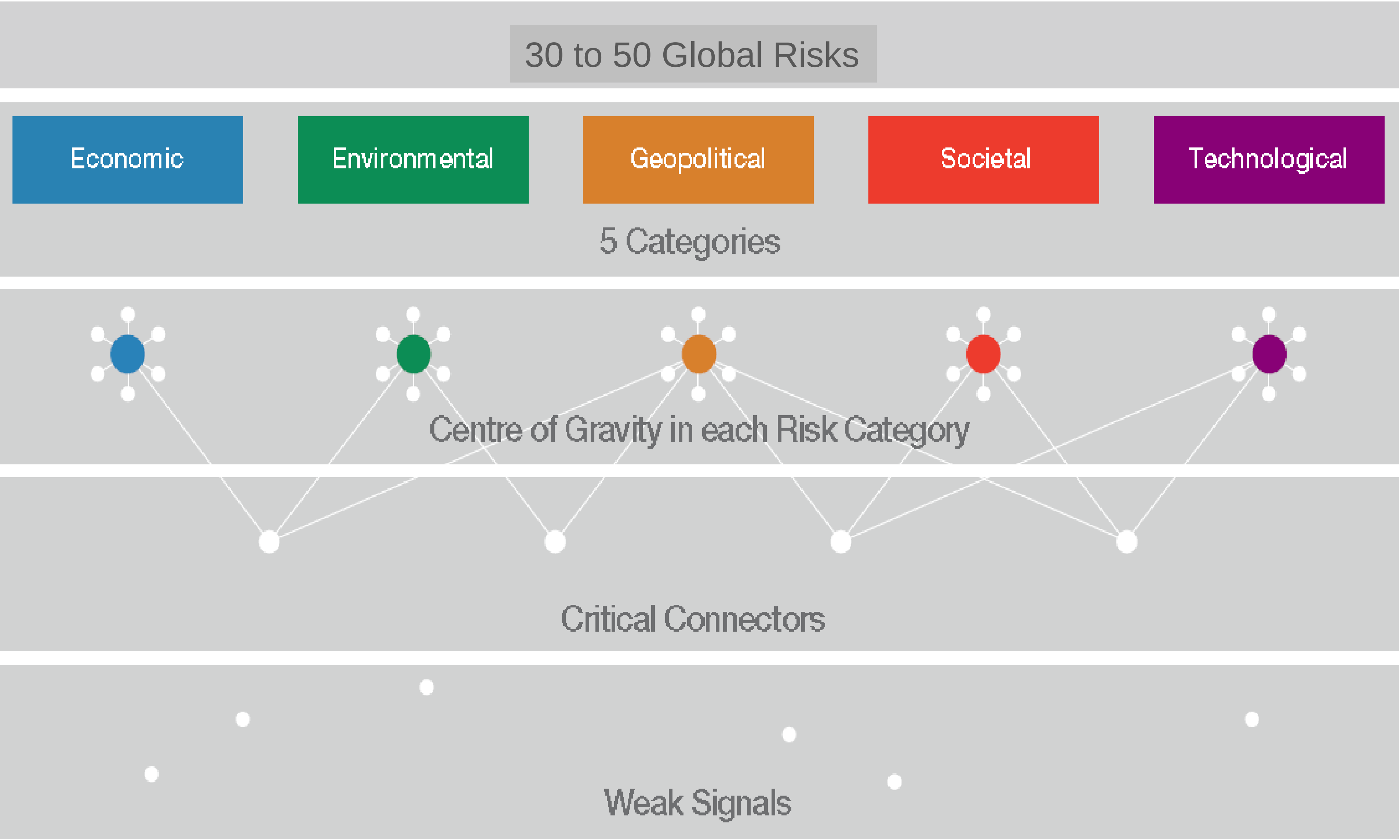
AUTOTUNE
DISP 3
ANT 1 MAIN
A/C AUTO
TRUE TRIAL
3 MIN

Taking Concrete Actions

- Selection of 32 core risks
- Ongoing consultations with experts and world leaders
- Creation of the "Global Risks Barometer"
- Annual presentations in Davos

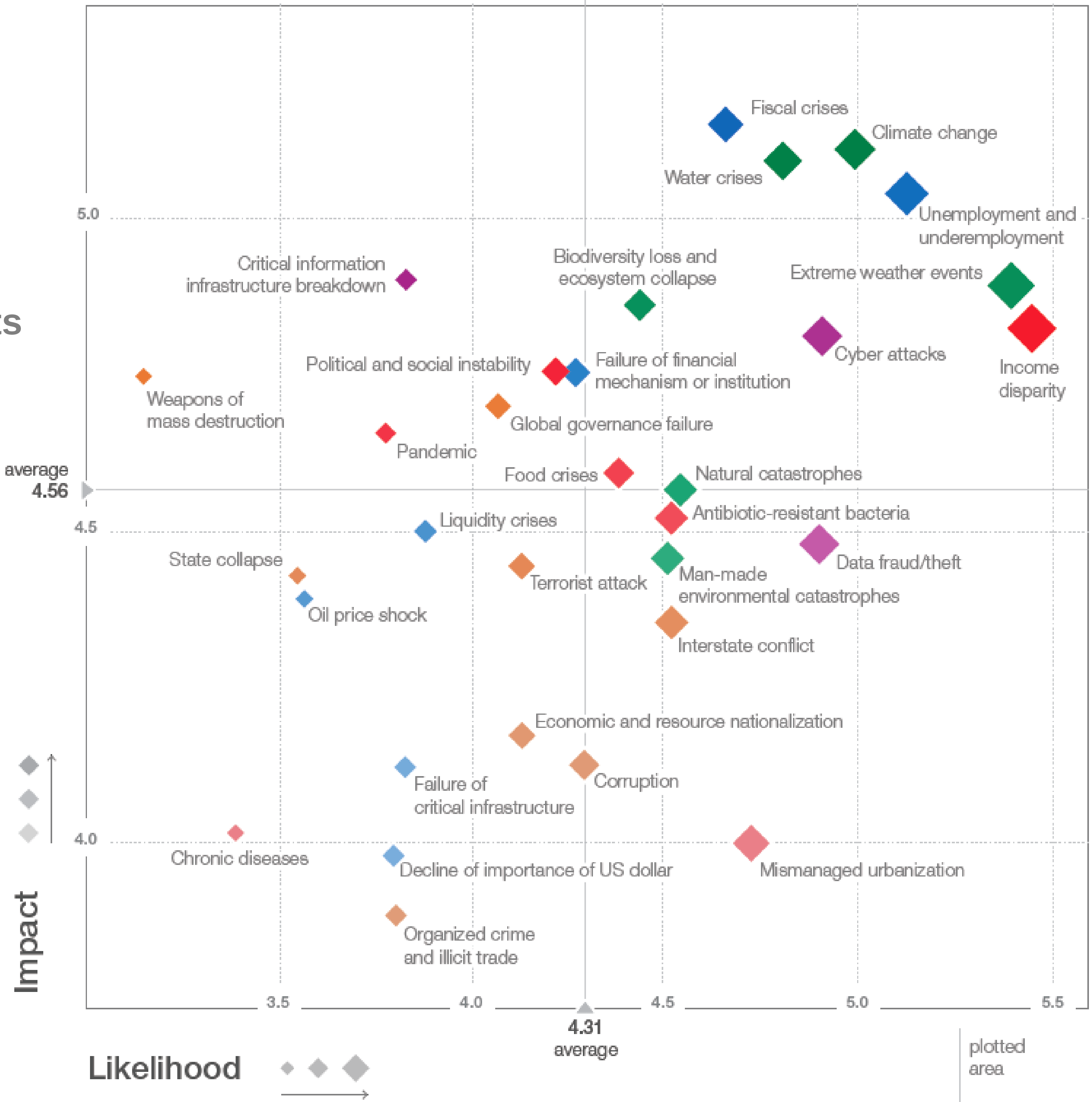


Typology of Global Risks



Source: World Economic Forum

2014 results



Top 5 Global Risks in Terms of Impact (2007-2014)

	2007	2008	2009	2010	2011	2012	2013	2014
1st	Asset price collapse	Asset price collapse	Asset price collapse	Asset price collapse	Fiscal crises	Major systemic financial failure	Major systemic financial failure	Fiscal crises
2nd	Retrenchment from globalization	Retrenchment from globalization	Retrenchment from globalization	Retrenchment from globalization	Climate change	Water supply crises	Water supply crises	Climate change
3rd	Interstate and civil wars	Slowing Chinese economy (<6%)	Oil and gas price spikes	Oil price spikes	Geopolitical conflict	Food shortage crises	Chronic fiscal imbalances	Water crises
4th	Pandemics	Oil and gas price spike	Chronic disease	Chronic disease	Asset price collapse	Chronic fiscal imbalances	Diffusion of weapons of mass destruction	Unemployment and underemployment
5th	Oil price shock	Pandemics	Fiscal crises	Fiscal crises	Extreme energy price volatility	Extreme volatility in energy and agriculture	Failure of climate change adaptation	Critical information infrastructure breakdown

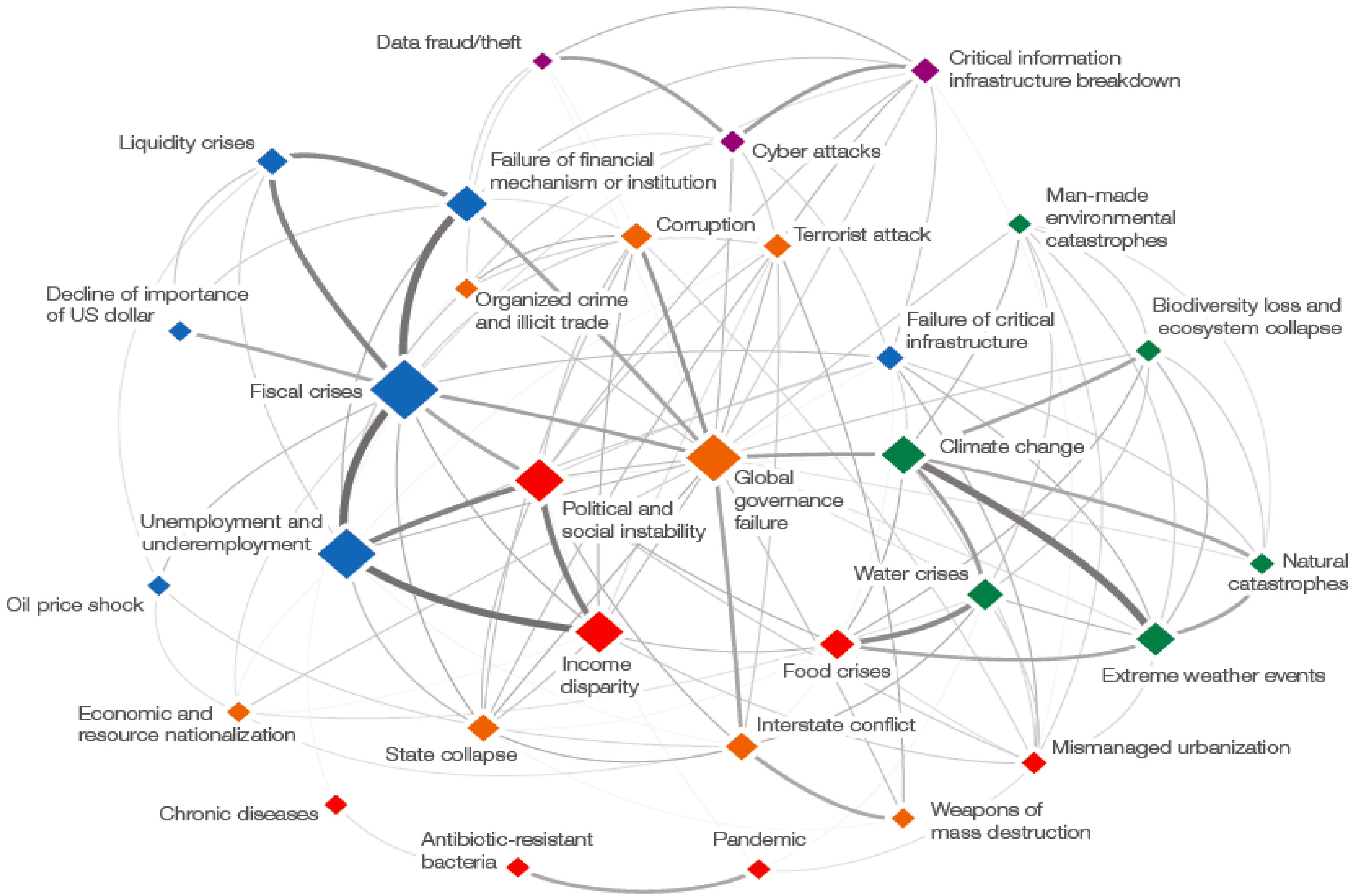
Top 5 Global Risks in Terms of Likelihood (2007-2014)

	2007	2008	2009	2010	2011	2012	2013	2014
1st	Breakdown of critical information Infrastructure	Asset price collapse	Asset price collapse	Asset price collapse	Meteorological catastrophes	Severe income disparity	Severe income disparity	Income disparity
2nd	Chronic disease in developed countries	Middle East instability	Slowing Chinese economy (<6%)	Slowing Chinese economy (<6%)	Hydrological catastrophes	Chronic fiscal imbalances	Chronic fiscal imbalances	Extreme Weather Events
3rd	Oil price shock	Failed and failing states	Chronic disease	Chronic disease	Corruption	Rising greenhouse gas emissions	Rising greenhouse gas emissions	Unemployment and underemployment
4th	China economic hard landing	Oil and gas price spike	Global governance gaps	Fiscal crises	Biodiversity loss	Cyber attacks	Water supply crises	Climate Change
5th	Asset price collapse	Chronic disease in developed world	Retrenchment from globalization (emerging)	Global governance gaps	Climatological catastrophes	Water supply crises	Mismanagement of population ageing	Cyber attacks

"Interdependence is the defining issue of the 21st century."

Tony Blair
UK Prime Minister
(1997-2007)

What Risk Assessment Must Be About: Understanding Interdependencies (2014 Global Risks Interdependencies Map)



Key Take Aways for You

1. The recent disasters are just the beginning of the new era of catastrophes that we have now entered.

2. Unless we start recognizing this as a fact, improve our knowledge and build resilience you might continue to be “surprised” again and again, losing market share and reputation.

3. Ultimately, this might not be so much a war against the weather as it is a war against ourselves; because of behavioral biases and short-termism we might be our worst enemies by not moving to action until the disaster occurs, and then quickly forgetting.

Key Take Aways for You

- Your sector is highly exposed to future weather catastrophes but has an amazing opportunity to get it right given your expertise.

- The next generation of powergrid can be designed to be **smarter**, **greener** and **more disaster resilient** at the same time.

KNOWLEDGE FOR ACTION

Wharton
University *of* Pennsylvania

Thank you!