CAMBRIDGE
Judge Business School

University of Cambridge
Centre for the Management of Societal & Economic Risk

Science and Catastrophe Risk

Dr. Andrew Coburn

Risk Management Solutions, Inc.

Understanding Risk : Lunchtime Seminar Series

Agenda

- The Catastrophe Risk Industry
- Why Don't We Expect Extremes?
- Disruptive Societal Events
  - And trends that influence them
- The Cambridge Risk Centre
  - Defining the research agenda

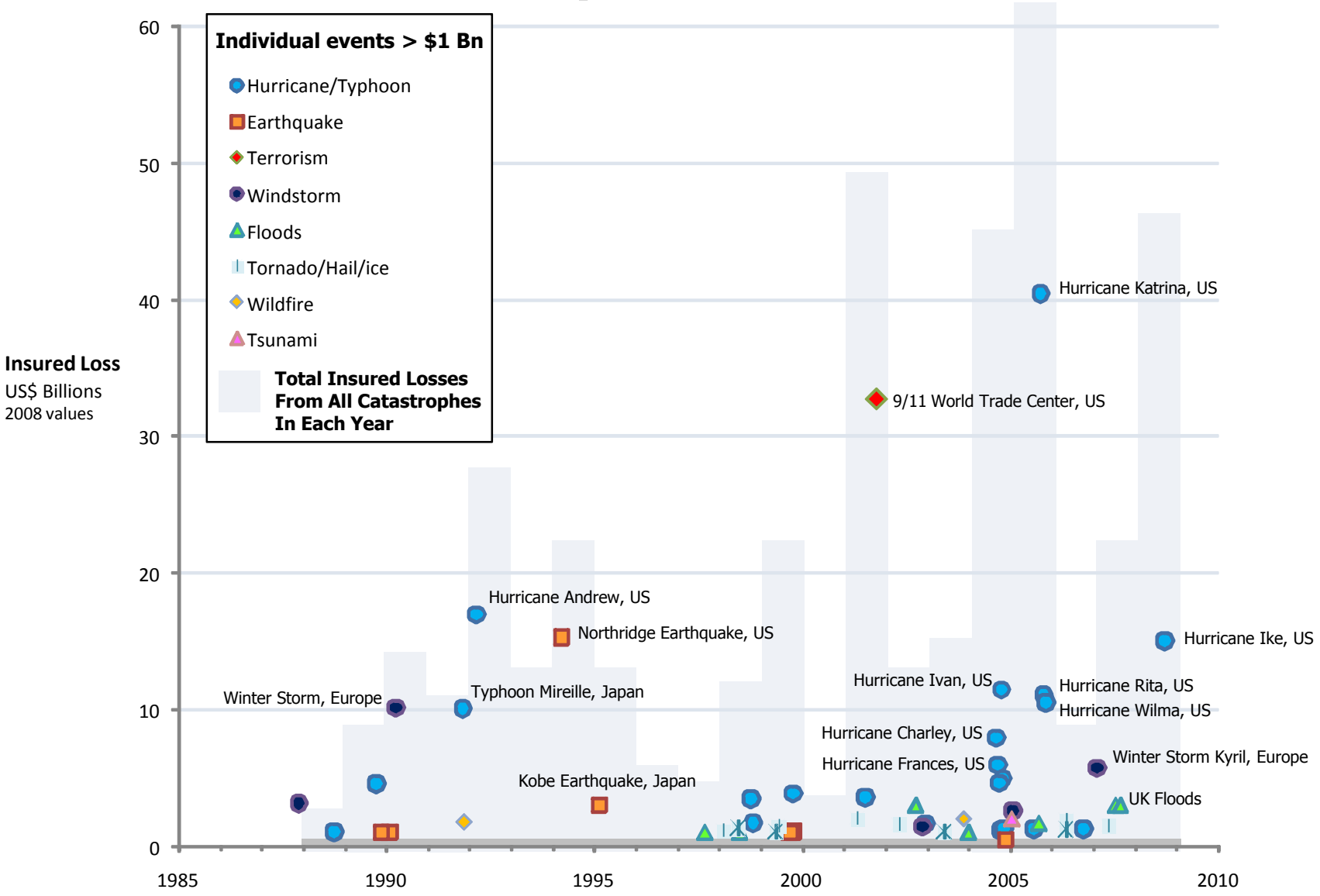
The Catastrophe Risk Industry

Insurance Payouts

$34 Bn WTC Attack Sept 11, 2001

$45 Bn Hurricane Katrina, Aug 2005

Insurance Catastrophe Losses



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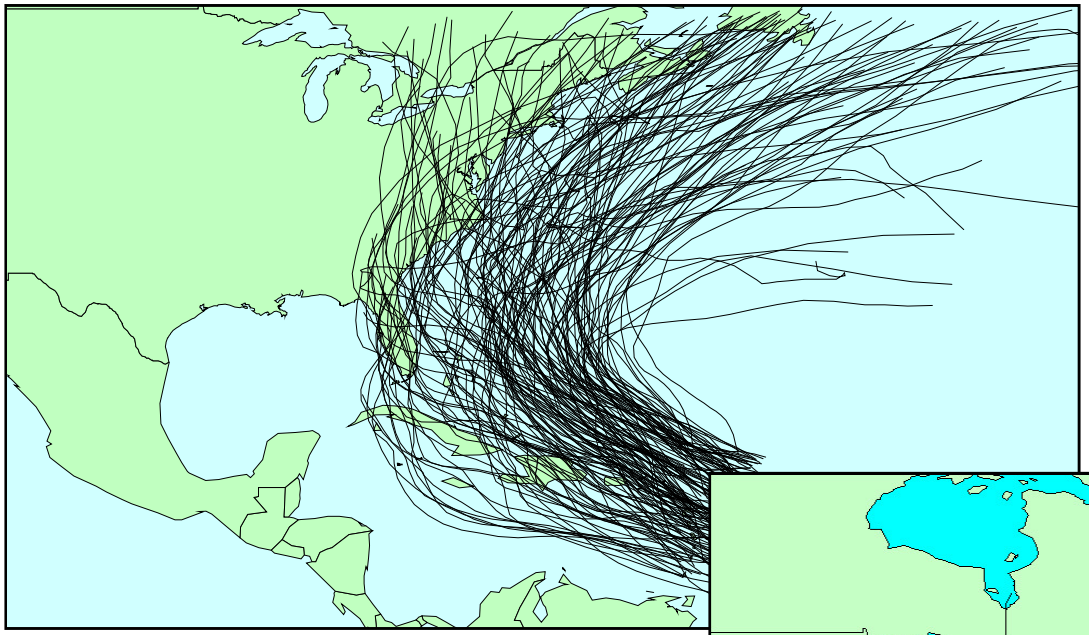
Catastrophe Models

- The management of risk from rare, extreme events is aided by the use of phenomenological representations of the processes that cause them:
  - Hurricanes; Floods; Temperate Windstorms; Earthquakes; Tornados; Extreme Weather; Pandemics; Terrorism
  - These models draw from a body of scientific expertise: meteorology; seismology; engineering; social sciences
  - They create a stochastic event set, representing the universe of potential loss events
  - Insurers use the model to analyze the frequency and severity of losses to their portfolio of insured assets

Hurricane Andrew, 1992: **$15 Bn loss: 23 insurance companies failed**
Hurricane Katrina, 2005: **$42 Bn loss: No insurers failed (8 downgraded)**

Synthetic Hurricane Catalog

Type 1 (of 5) Hurricanes: Recurving Atlantic Storms

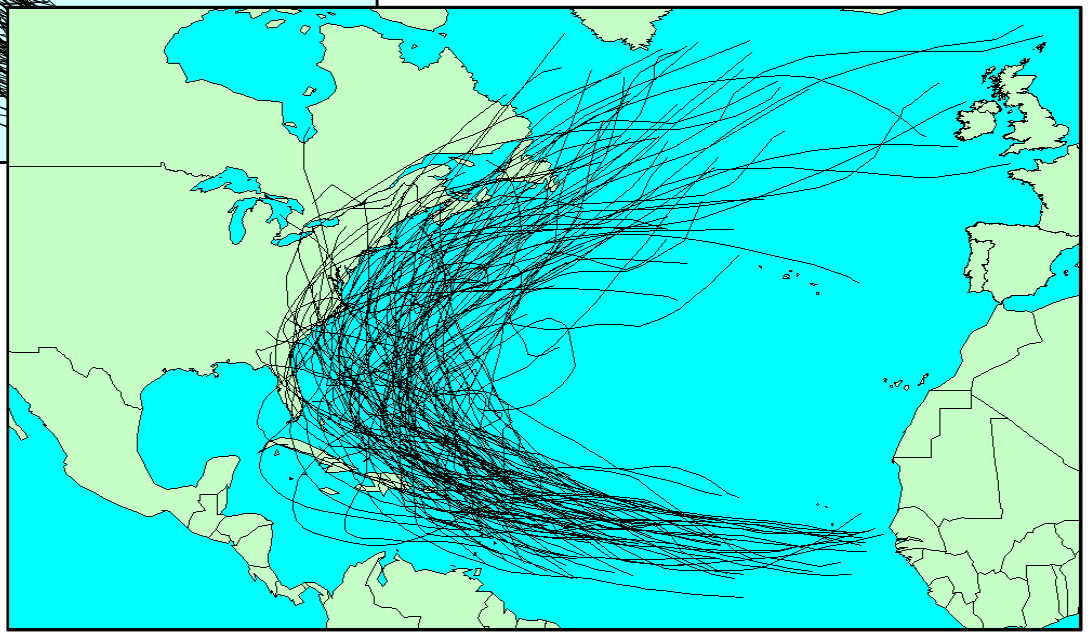


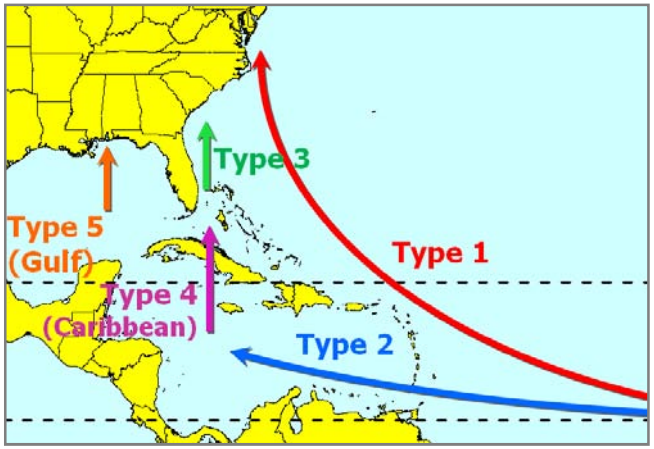
Stochastic

50,000 years simulated
79,000 events; 10,000 Cat 4 & 5 hurricanes

History

110 year catalogue
178 events; 22 Cat 4 & 5 hurricanes





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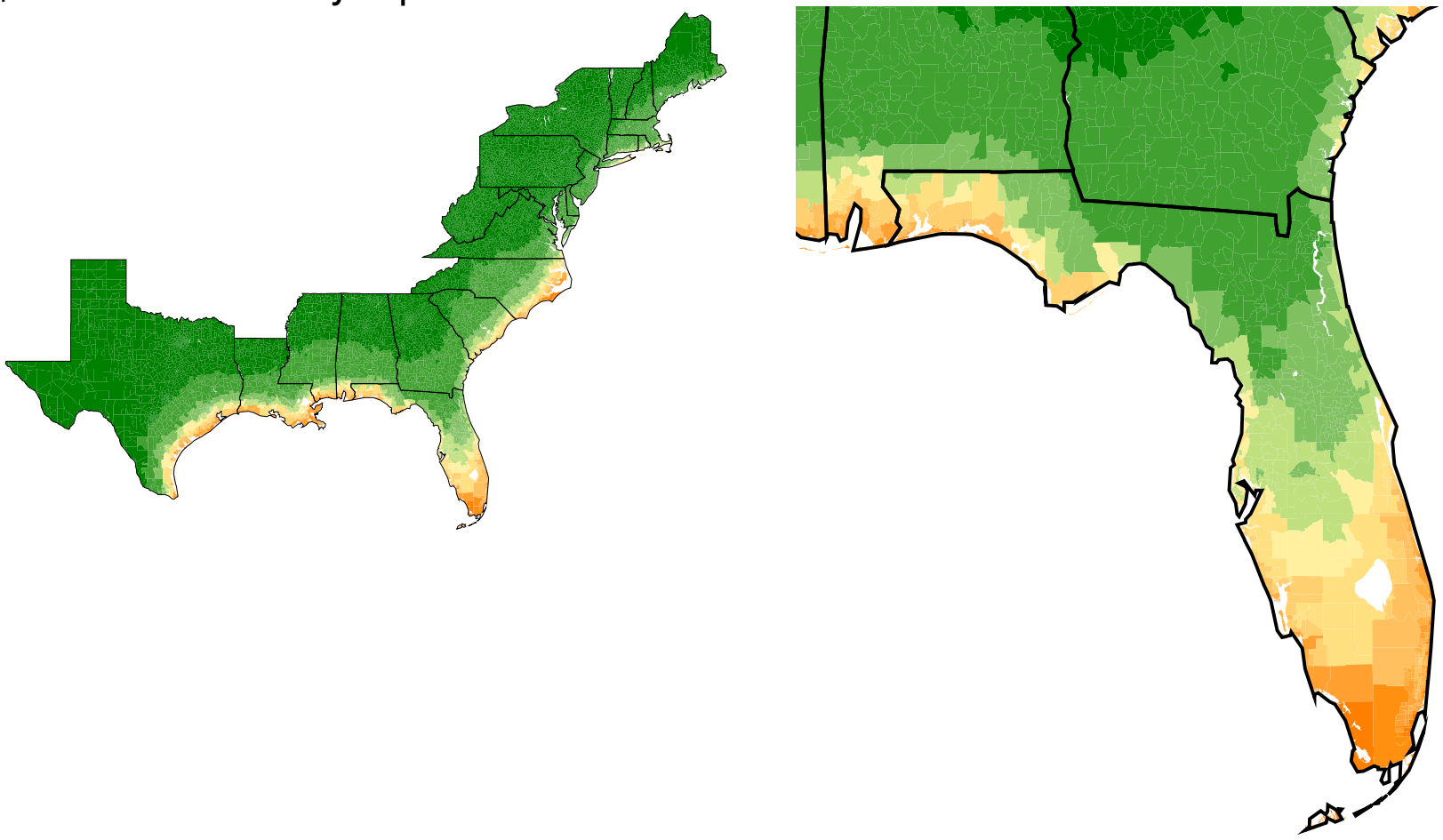
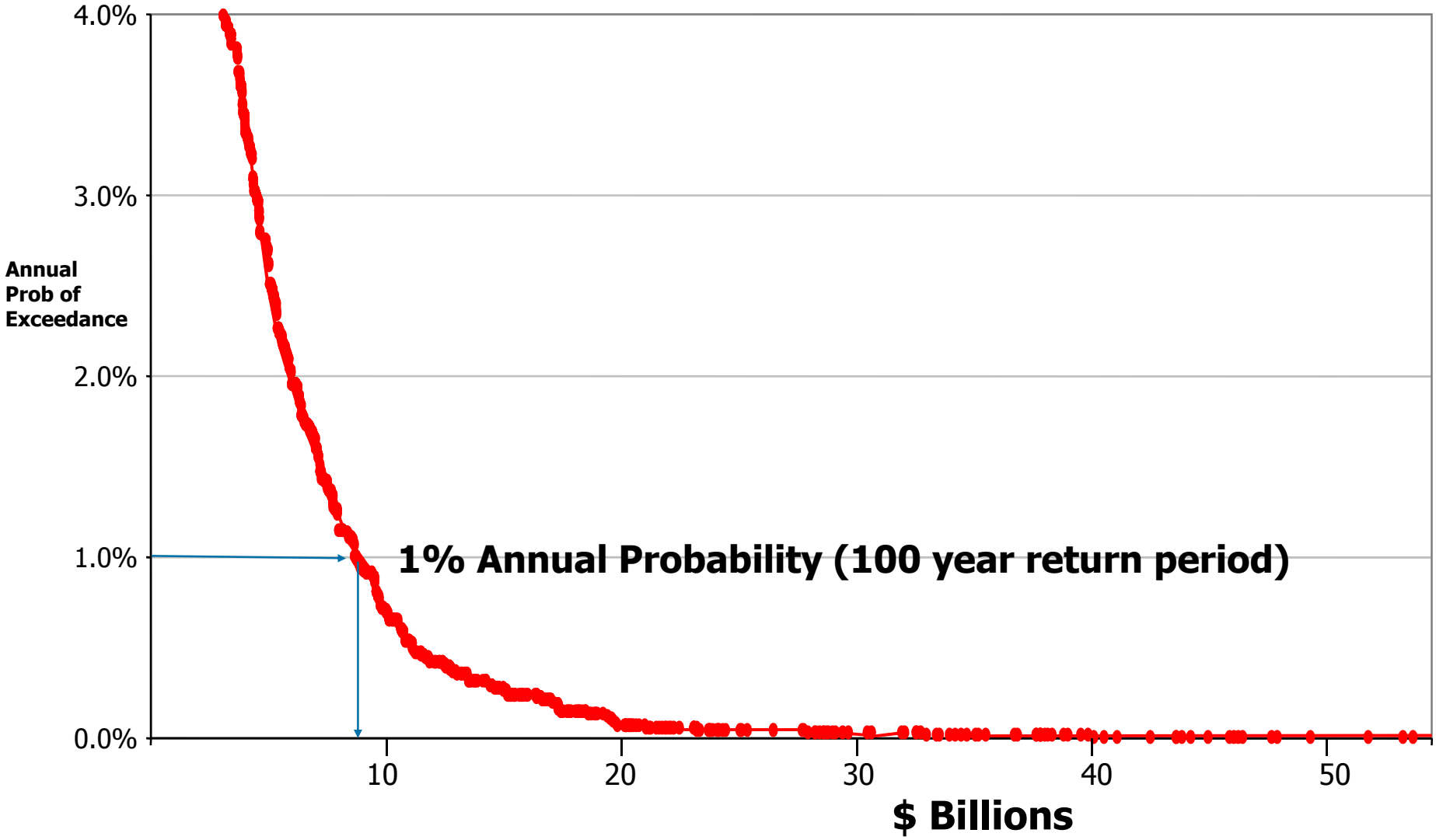
‘Landscape of Hurricane Risk’

Average Annual Insured Property Loss

$ Rate Per Mille by Zip Code



Loss Exceedance Probability (EP) Curve



The Catastrophe Risk Management Industry

- Predominantly private sector industry: insurance, financial investors, commerce and banks
- Over $1 billion spent in licensing models and staffing cat modeling analysis and decision-support units
- 4,000 catastrophe risk management professionals (underwriters, computer specialists, mathematicians, actuaries, economists, business managers)
- No clear career path or recruiting source for these professionals
- Growing applications of analytics in public sector: Government and policy units, international aid, development banking

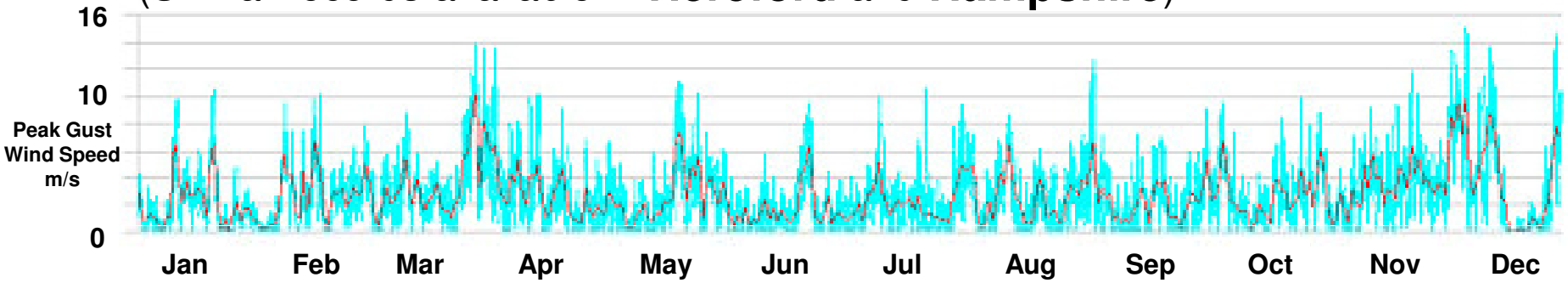
Improving Catastrophe Analytics

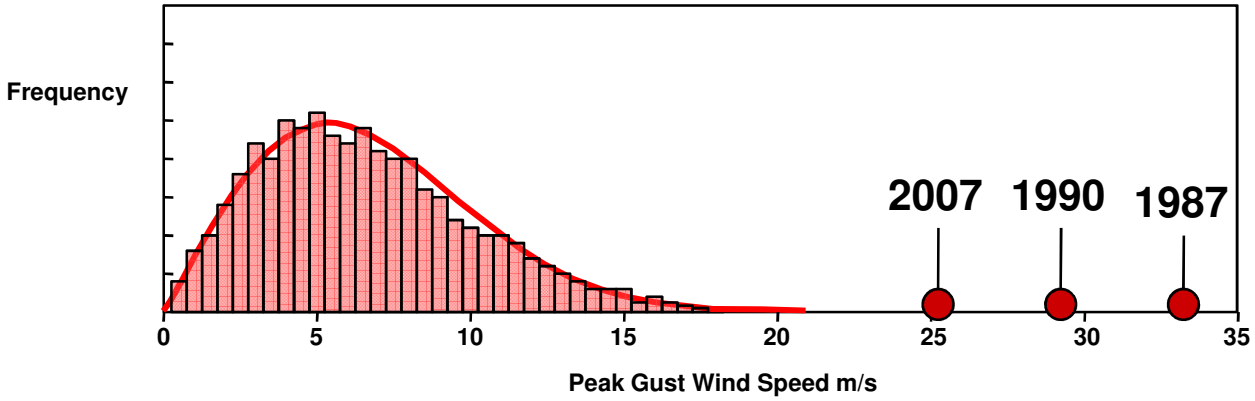
- Academic basis for catastrophe analysis is still based on 1990s theoretical foundations
- Major need for next generation theoretical advances:
  - Mathematical advances
  - Computational techniques and exploiting growth in computer processing power
  - Understanding uncertainty
  - Expanding range of perils that can be modelled
  - Understanding ‘exposure’: changes in population, demography, behaviour, risk decisions and choice

Why Don't We Expect Extremes?

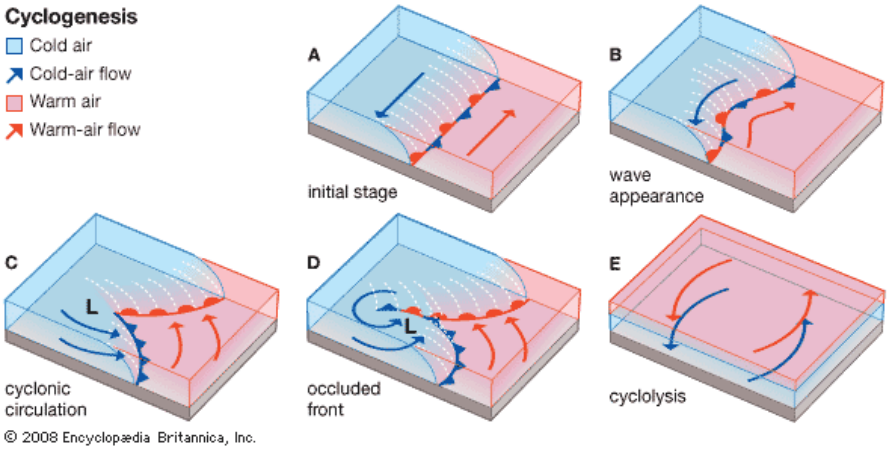
Wind Speed Measurements in Hartford

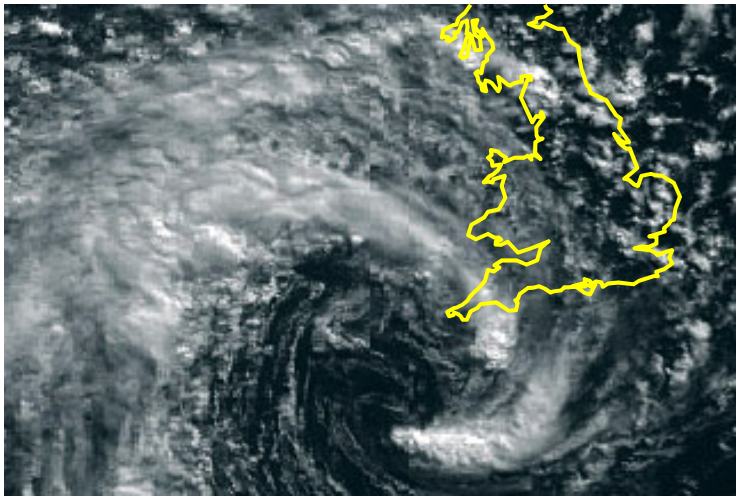
(Similar records available in **Hereford** and **Hampshire**)





The Extra-Tropical Cyclone





"Earlier on today, apparently, a woman rang the BBC and said she heard there was a hurricane on the way... well, if you're watching, don't worry, there isn't!"

Catastrophes are Phase Changes

- Many shocks and catastrophic events are qualitatively different processes that occur, rather than extremes of existing, observable regimes:
  - Cyclones – sudden formation of a different meteorological system
  - Earthquakes – tectonic stress is suddenly released in geomorphological event
  - Mutation of a new virus causes an epidemic
  - Engineering failures: Industrial accidents, component & systems breakdowns
- Human nature expects continuity – planning mainly projects existing regimes forward and doesn't anticipate shocks
- Complex systems experience phase changes and face catastrophic collapse
- Studies of Complex Systems and Catastrophe Science have interesting commonalities

Seminar

CAMBRIDGE Judge Business School

Celebrating Twenty 20 Years

- **Managing the Risk of Catastrophic Failure in Complex Systems**
- Thursday 10 December 2009
- Speakers include:
  - Prof. **Jon Crowcroft**, Marconi Professor of Communication Systems, Cambridge
  - **Sid Dalal**, Scientific Advisor to the President, RAND Corporation
  - **Rowan Douglas**, Chairman of the Willis Research Network
  - Prof. **Sanjeev Goyal**, Professor of Economics, Cambridge University
  - Prof. **Nick Kingsbury**, Signal Processing, Cambridge University
  - **Trevor Maynard**, Emerging Risks Manager, Lloyd's
  - Prof. **Jim Norton**, UK Parliament's Office of Science & Technology
  - Prof. **Steve Oliver**, Professor of Systems Biology, Cambridge University
  - Prof. **Stefan Scholtes**, Management Science, Judge Business School
  - **Hemant Shah**, CEO, Risk Management Solutions Inc.
  - Prof. **David Spiegelhalter**, Winton Professor of Public Understanding of Risk, Cambridge University

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Centre for the Management of Societal & Economic Risk

Unexpected Disruptive Events to UK Society

Chernobyl
1986
Russian nuclear reactor meltdown causes radioactive cloud over northern Europe, polluting agriculture and causing health scares

Great wind storms
1987, 1990, 2007
Southern England suffered destruction, deaths and wide spread loss of trees and environment

AIDS epidemic
1989-1999
A previously unknown virus kills thousands and changes the sexual practices of a generation

BSE Scare 1990
Foot & Mouth 2001
Consumer confidence in food industry undermined by disease outbreaks; hundreds of thousand of animals destroyed

Kobe Earthquake
1995
Earthquake hits semi-conductor plants and port facilities in Japan, leading to sudden unavailability of semi-conductors and worldwide computer price hike

River floods
2000, '03, '05, '07
Thousands of people homeless and £billions of cost

Energy Crisis
2000
Petrol shortages recall the crises of 1973 and 1979 as price hikes prompt protests and strikes

9/11 Terrorist Attack
2001
Hijacked aircraft flown into US targets kills 3,000 and prompts global security crackdown, stock market slump and military campaigns in Afghanistan and Iraq

Northeast Blackout
2003
Power distribution failure across major cities in US causes internet failure cascade across the world

Terrorist Bombing
2005
London paralyzed by multiple bombings – impact on UK GDP and company stock valuations

Credit Crunch
2008
Sudden collapse of banks in US, UK and elsewhere leads to worst recession for at least 80 years

Swine Flu Pandemic
2009
Influenza pandemic closes schools and instigates national vaccination programme

A Holistic Approach to the Resilience Revolution

- Can we be holistic in our approach to designing a more resilient society?
- Why should we be continually surprised at extreme events?
- Can we identify the large majority of the threats to our way of life and develop approaches to managing them?
  - Management will entail:
    - Mitigation of causes
    - Early warning that events are imminent
    - Rapid response measures to contain and prevent escalation
    - Building resilience into our economic and social infrastructure to cope better with extremes and shocks

In the 19th and 20th century, the scourge of disease in our society was finally overcome by the 'Sanitary Revolution' – a combination of medical science, social education, attitude change, and investment in systems and infrastructure.

Can we bring about a 'Resilience Revolution' to overcome the threat to society of disruptive events?

Disruptive Events – the Catastrophe Perils

- Natural Hazards
  - Wind storm
  - Floods
  - Earthquake
  - Extreme weather
- Malicious Man-Made Threats
  - Terrorism and political violence
  - Crime and vandalism
  - Civil disturbance
- Accidents
  - Industrial accidents
  - Network Failures
  - Transportation accidents
- Health and Disease
  - Infectious disease epidemics
  - Overloads of healthcare systems
- Environmental
  - Pollution
  - Ecological change
- Resource Constraints
  - Energy
  - Water
- Economic and Financial
  - Bubbles and crashes
  - Price escalations
  - Failures in supply & distribution chain

Disruption to Our Society

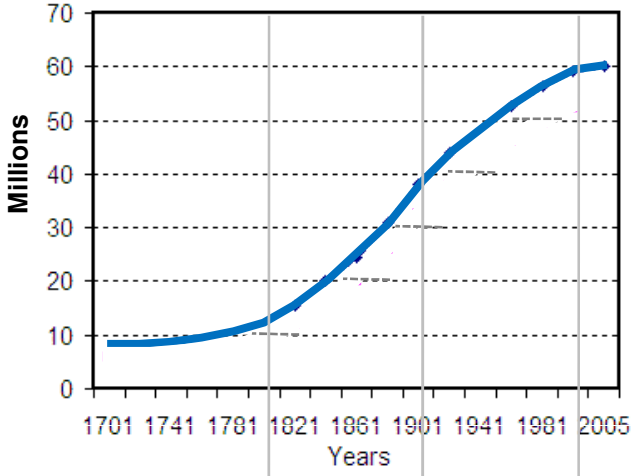
- Can we measure and categorize ‘disruption’ and ‘loss’?
  - Life loss
  - Injury
  - Repair cost
  - Economic productivity loss
  - Opportunity cost
  - Social well-being
- How often should we expect ‘disruption’ to occur?
  - Each event is deemed ‘rare’ by specialists in these types of peril occurrences:
    - Probabilities are often assessed as e.g.: ‘once a century’
      - 1% annual probabilities
  - But a dozen events in 24 years suggests that events occur at a frequency of at least 1 in every two years
    - Does this mean there are at least 50 perils we need to worry about?
- How severe can they get?
  - What is the likelihood-severity distribution?
- What measures are best taken for risk management?

Trends that Influence Extreme Event Impacts

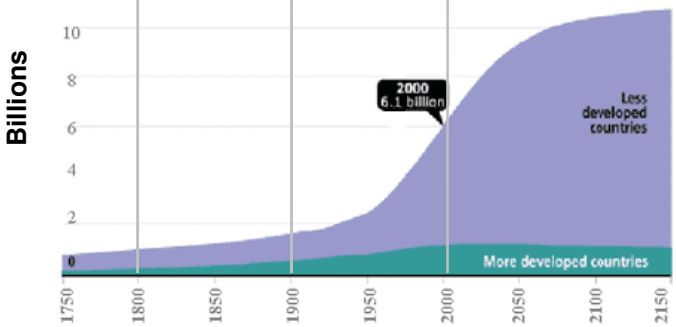
- Growing populations
- Resource uncertainty
- Globalization
- Aging and demographic change
- Climate change

Growing Populations Increase Disruptive Event Impacts

UK Population Growth

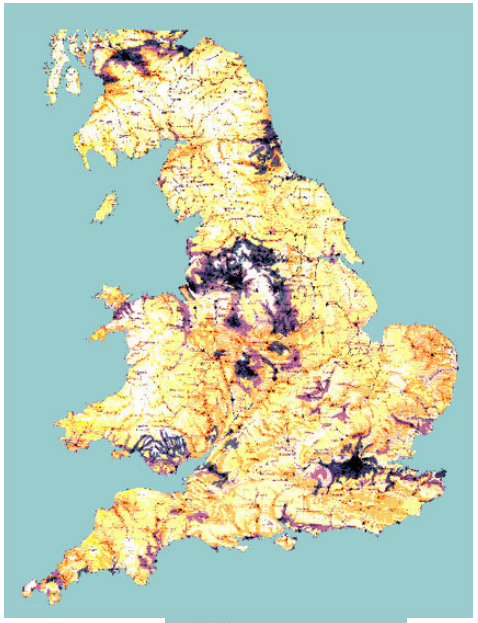


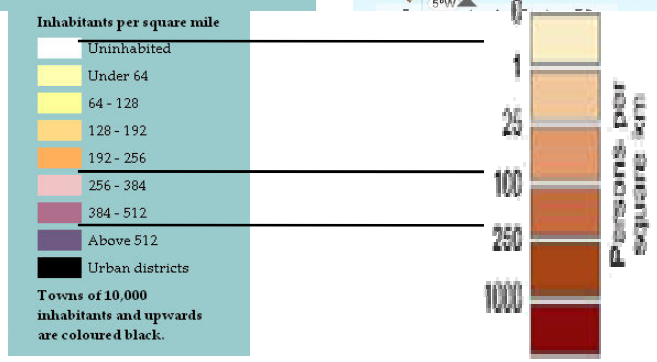
World Population Growth



Source: United Nations, *World Population Prospects, The 1998 Revision*; and estimates by the Population Reference Bureau

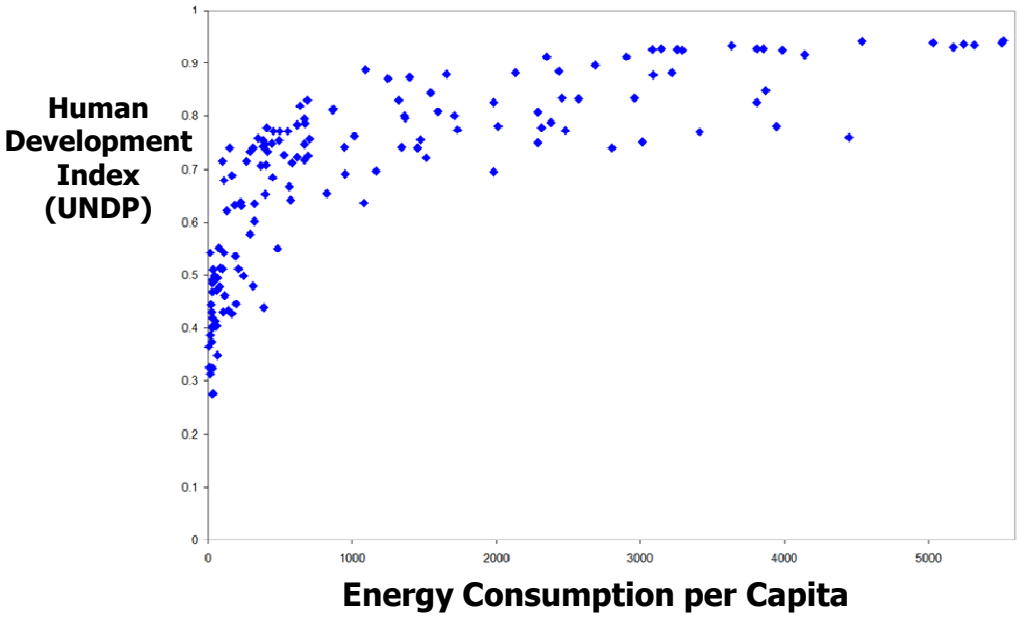
1891
Population Density

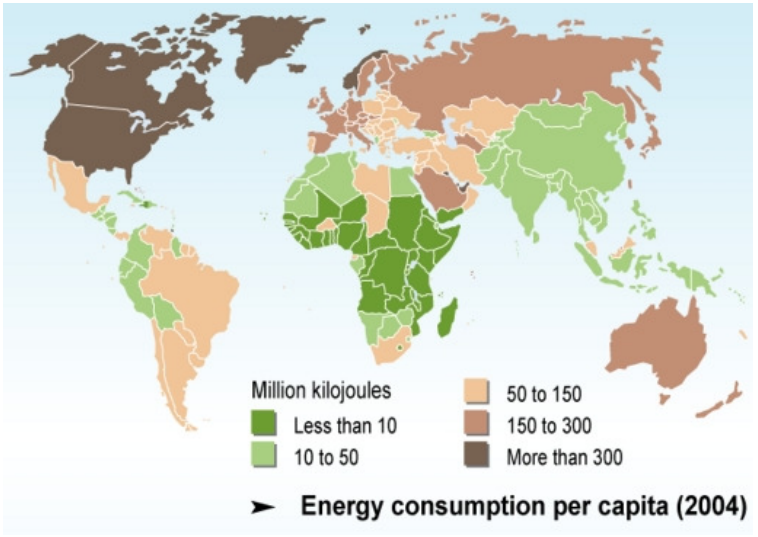




2001
Population Density

Energy Security is Crucial to Economic Continuity





- Economic growth depends on increasing resource consumption

  e.g. (Industrialized world):

  - Average person consumed 0.13 megawatt-hour in 1800
  - Average person consumed 4.70 megawatt-hours in 1950

- Dependency on energy resources causes societal fragility and increases geo-political uncertainty

- Shocks elsewhere are compounded
  - e.g. Oil price hike of 30% following Hurricane Ivan in 2004

Jan 2009 - Russia gas war with Ukraine cuts off supplies to 12 European countries

Energy issues underpin the two Gulf wars

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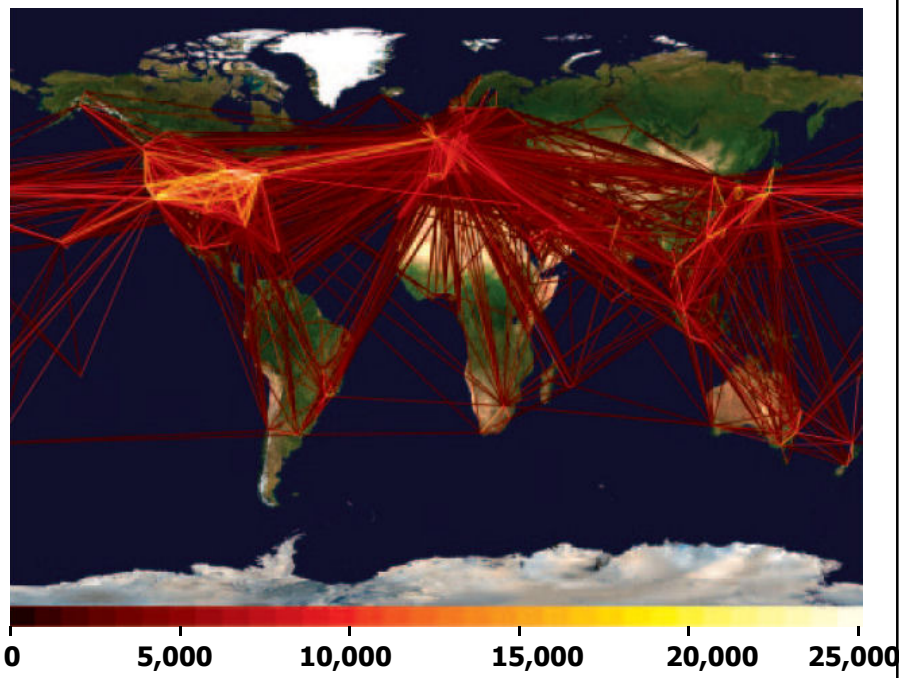
Globalization

- **Interdependancy** – trading links, 'just-in-time' stock delivery, transportation reliance
- **Complexity** – specialization; outsourcing; international diversification
- **Efficiency** – drive for profitability rewards lean operations and optimization to minimize extra capacity in systems (safety factors)

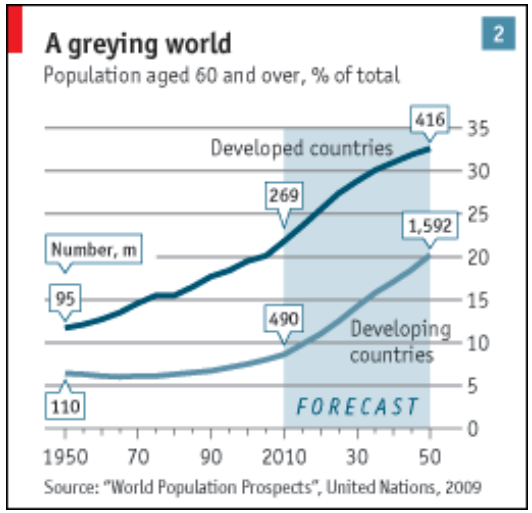


International travellers **per day**

The fragility of social and economic systems to external shocks is growing with increasing complexity and optimization towards efficiency

20% of **British** shellfish consumed in Britain is processed in China

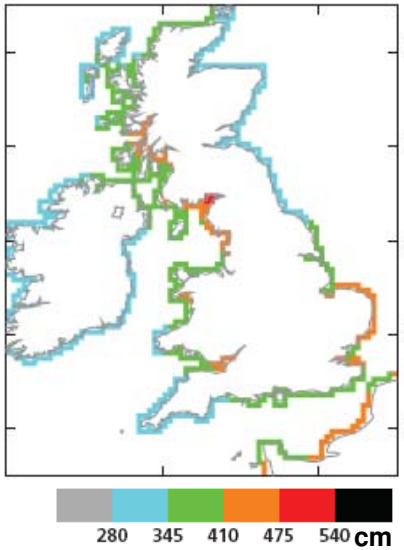
Aging and Demographic Change



Equitable Life

- Increasing wealth, healthier life styles and medical science is increasing life expectancy in most countries and societies
- The result is a much higher proportion of older people than has ever been previously seen in human societies
- This is creating a radical new balance between economically active populations and non-economically active, with implications for
  - Healthcare resourcing, pensions and savings, social welfare, and consumer economics
- Systemic unsustainability will eventually cause non-linear economic change

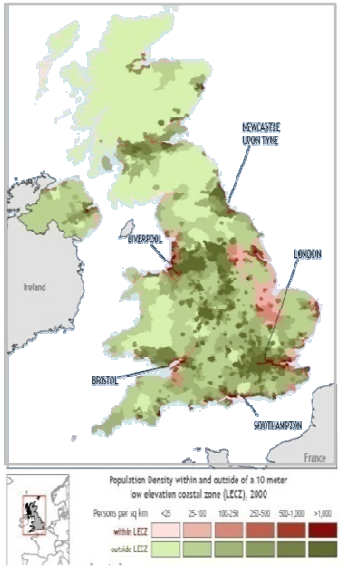
Climate Change



50-yr return period

UK Climate Impact Programme, 2009

Forecast Sea Level Rise



Coastal Population

- Climate change will increase the frequency and severity of weather extremes
- Rising sea levels will increase flood risk and threaten coastal populations
- Much of the debate about climate change has focused on gradual, linear change, but climate change is likely to cause catastrophic phase changes and switches to new environmental regimes
  - Catastrophic ice shield collapses
  - Jet stream and gulf stream instability
  - Threshold transitions to new ecologies
  - Small changes in 'average' weather conditions cause major increases in extremes
  - Agricultural productivity changes

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Centre for the Management of Societal and Economic Risk

- Judge Business School 'Initiative' (Academic Year 2009/10)
  - Acting Director: Professor Daniel Ralph
  - Acting Executive Director: Michelle Tuveson

Objectives:

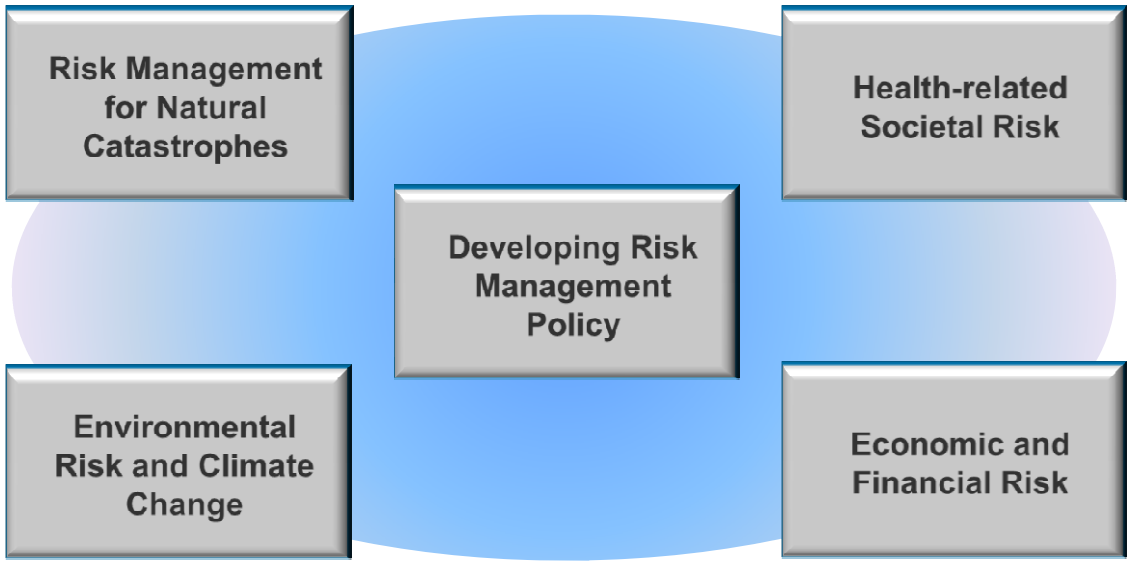
  - To explore interest among the Cambridge academic community
  - To generate research proposals and raise funding

- Multi-disciplinary Centre to coordinate a research agenda in societal and economic risk
- Create an influential body of published output
- Focus on policy-making and decision support for managing the risk
  - Create an evidence base for decisions
  - Develop an understanding of the processes that cause societal disruption
  - Establish an academic framework for systematic study
- Holistic focus on societal risk distinguishes the Centre from other academic institutions that focus on natural hazards or other individual threats

Cambridge Risk Centre Research Threads

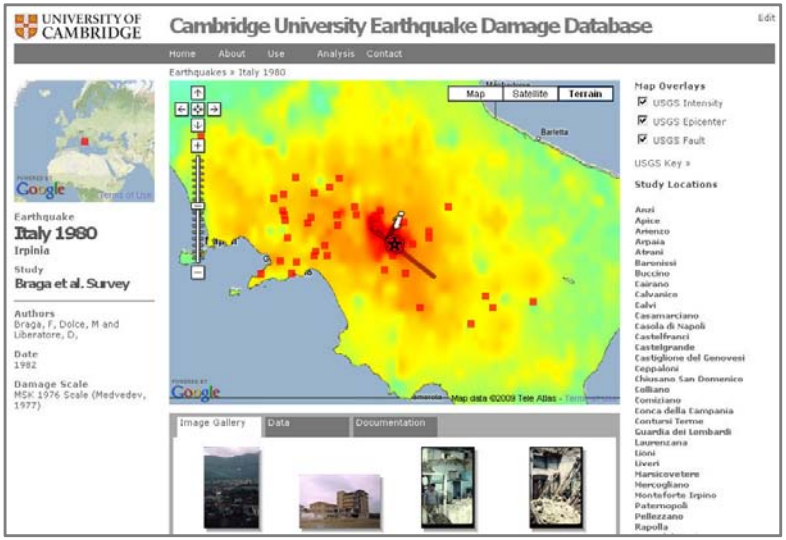
Cambridge Centre for the Management of Societal and Economic Risk

- Multi-disciplinary research programme areas:
  1. Risk Management for Natural Catastrophes
  2. Environmental Risk and Climate Change
  3. Health-Related Societal Risk
  4. Economic and Financial Risk
  5. Developing Risk Management Policy



Risk Management for Natural Catastrophes

- The next generation of catastrophe modeling
- Building a rigorous evidence-base for decisions
- Application of new developments in seismology and other research on catastrophe processes
- Mitigation and capacitation building to create more resilient societies
- Recovery and reconstruction after disaster
- Disasters and Development



Collaboration with
Cambridge Centre for Mathematical Sciences (CMS)
Cambridge University Centre for Risk in the Built Environment
Cambridge University Department of Earth Sciences
Cambridge Coastal Research Unit

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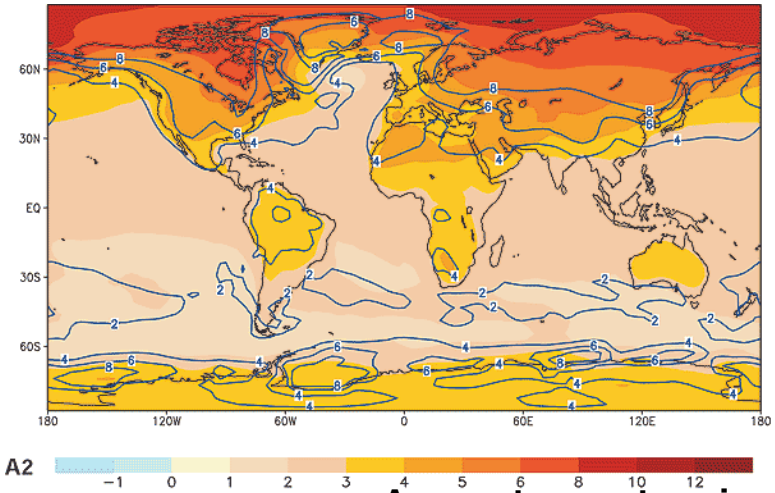
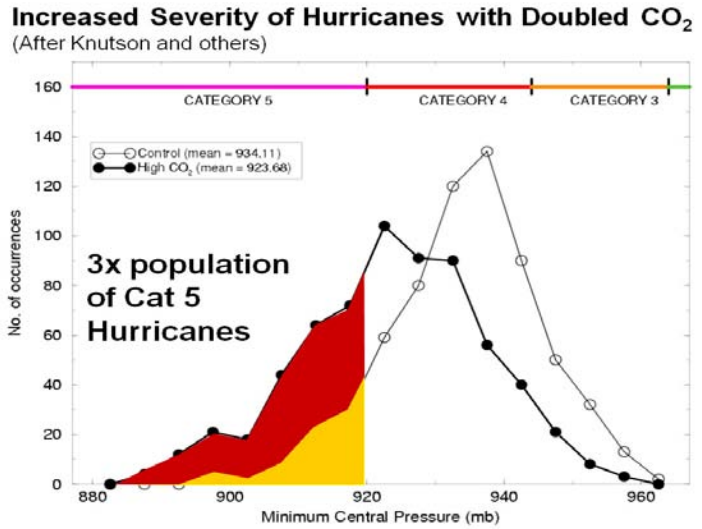
Environmental Risk and Climate Change

- Interpreting science on climate change into understanding potential for catastrophic disruption events, costs and impacts
  - Flood risk and threats to coastal populations
  - Meteorological extreme events
    - Hurricanes and windstorms
    - Freeze
    - Droughts
- Understanding implications for potential phase-changes and systemic changes
- Provide inputs into debates on mitigation and adaptation in dealing with climate change



Average temperature rise
Emissions Scenario A2, IPCC, 2001



Collaboration with
Cambridge Centre for Climate Change Mitigation Research (4CMR)
Energy and Environment Research Group
Cambridge Centre for Energy Studies (CCES)

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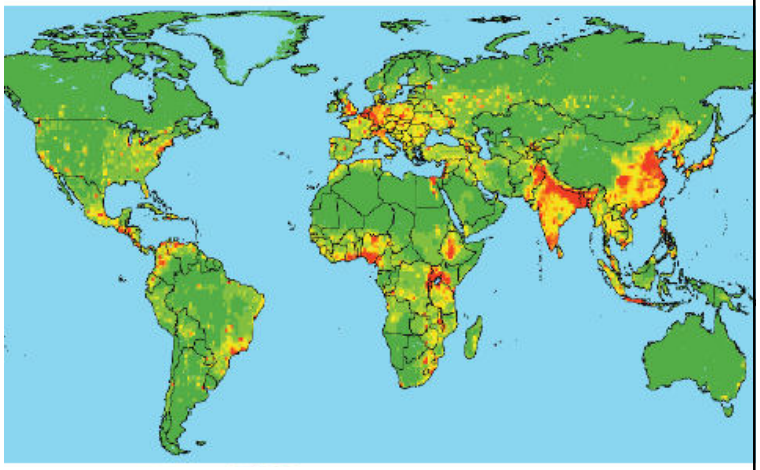
Health-Related Societal Risk

- Emerging infectious diseases
  - Identification of potential candidates of EID
  - Understanding the frequency and severity of future potential epidemics
  - Optimizing response plans and healthcare investment
- Healthcare resource planning
  - Understanding healthcare demand and extreme loads
  - Aging and implications for future healthcare provision
  - Changing patterns of disease and treatment



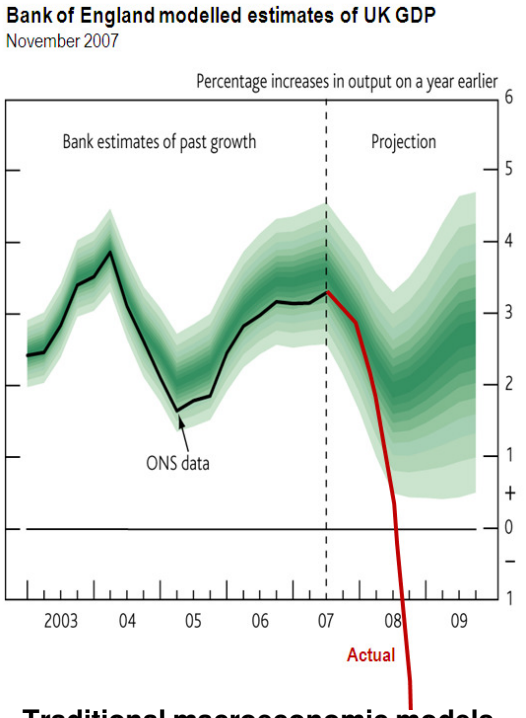
Emerging Infectious Diseases
Zoonotic pathogens from wildlife, 1940-2004

Public Health Programmes
Mass vaccinations to combat pandemics

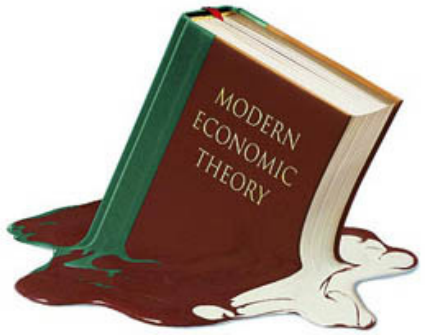
Collaboration with
Cambridge International Health Leadership Programme
Cambridge Infectious Diseases Consortium (CIDC)

Economic and Financial Risk

- Understand the threats to modern economies from exogenous shocks
- Explore new approaches, such as behavioural economics and complexity economics, to model the frequency and severity of catastrophic shocks in economy
- Understand how external events trigger behavioural responses, feedback and tipping points
- Develop holistic approaches to identifying potential exogenous triggers for future economic catastrophes, and approaches to understanding, monitoring and preparing for such threats



Traditional macroeconomic models, such as the Bank of England 'Fan Chart', failed to anticipate the impact of the credit crunch recession



Collaboration with
The Cambridge Finance Initiative
Cambridge Centre for International Macroeconomics and Finance
Mathematics of Systems at the Centre for Mathematical Sciences

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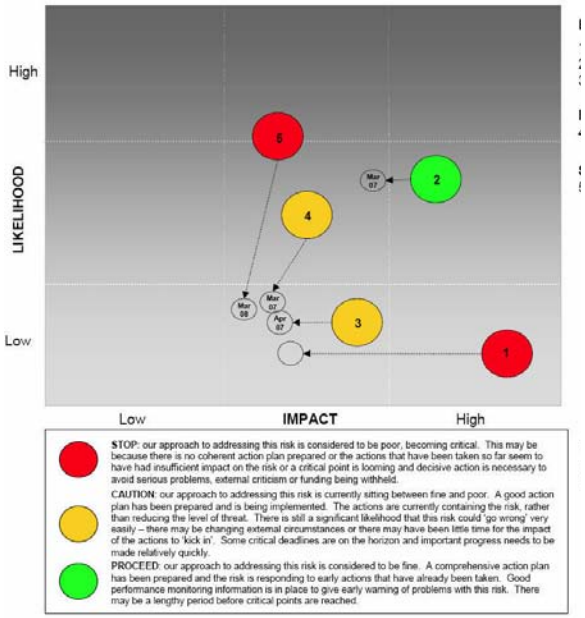
Developing Risk Management Policy

- 'Risk-based government' and 'risk-based decisions' are common aspirations for policy-makers
- Turn outputs of risk science into policy decisions that will improve resilience against a wide range of future extreme threats.
- Frameworks and tools for risk decision policy-making: threat analysis; systemic vulnerability assessment; deterministic scenario stress tests; probabilistic event sets
- Understanding and incorporating uncertainty in risk management decisions: robustness of strategies under deep uncertainty
- Sources of uncertainty analytics and decisions



Threat assessment chart: Strategy for risk management by a UK Government Department

Collaboration with
The Cambridge Centre for Science and Policy
The Winton Professorship for the Public Communication of Risk
Cambridge Centre for Centre for Research in the Arts, Social Sciences and Humanities (CRASSH)

Understanding Risk – Lunchtime Seminars

Forthcoming attractions:

22 Oct Prof. **David Spiegelhalter**, Winton Professor of Public Understanding of Risk
Representations of Risk and Uncertainty

5 Nov Prof. **Robin Spence,** Cambridge University Centre for Risk in the Built Environment
Reducing Casualties in Natural Disasters

19 Nov Prof. **Hashem Pesaran,** Faculty of Economics
Modelling Volatilities and Conditional Correlations in Futures Markets

3 Dec Prof. **Chris Gilligan**, Cambridge Environmental Initiative, Dept. of Plant Sciences
Computational Ecology: An Emerging Discipline (title to be confirmed)

Action Plan

- Over the next year we intend to clarify and focus this research agenda
  - We are looking for inputs and direction for our focused efforts
- We will be submitting research proposals
  - Ideas and participants in research proposals are welcome
- We will be pursuing funding
  - Identifying potential funders with interests in these topics

Science and Catastrophe Risk

- Management of catastrophe and creating a more resilient society from the threats it faces is a vital area of study
  - Some of the threats we face have the ability to destroy our way of life and our economic livelihoods
  - It is arguably the most important challenge we face as a community
- Scientific study is the only method of identifying and understanding these threats
- There is a real need to develop a coherent theoretical basis for the management, investment and actions necessary to achieve the 'Resilience Revolution'
- Cambridge University has the leading intellectual resources in many of the critical disciplines
- This is an opportunity to lead the development of catastrophe science