Institute and Faculty of Actuaries

Chatham House
4 November 2014

An Actuarial Approach to Climate Change Risk: Risk of Ruin

Oliver Bettis, Institute and Faculty of Actuaries' Resource and Environment Board

Institute and Faculty of Actuaries

Risk of Ruin

If climate change is primarily a risk management problem, then:

One of the most important goals of climate change policy is to *Limit the probability of very bad outcome (ruin) to acceptably small value.*

Risk of Ruin

In other words, probability “tail risk” should be a major factor in climate policy.

Martin Weitzman, Professor of Economics at Harvard, has written on this subject:

1. 2011 Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change
2. 2012 Journal of Public Economic Theory, 14 (2), 2012, pp. 221–244.
3. 2013 A Precautionary Tale of Uncertain Tail Fattening

Risk of Ruin

1. **Capital modelling for insurance companies**
2. Capital modelling as a logical framework for climate change
3. A sketch of a climate ruin model
4. Areas for further work

Capital Protects Policyholders in case of Extreme Events

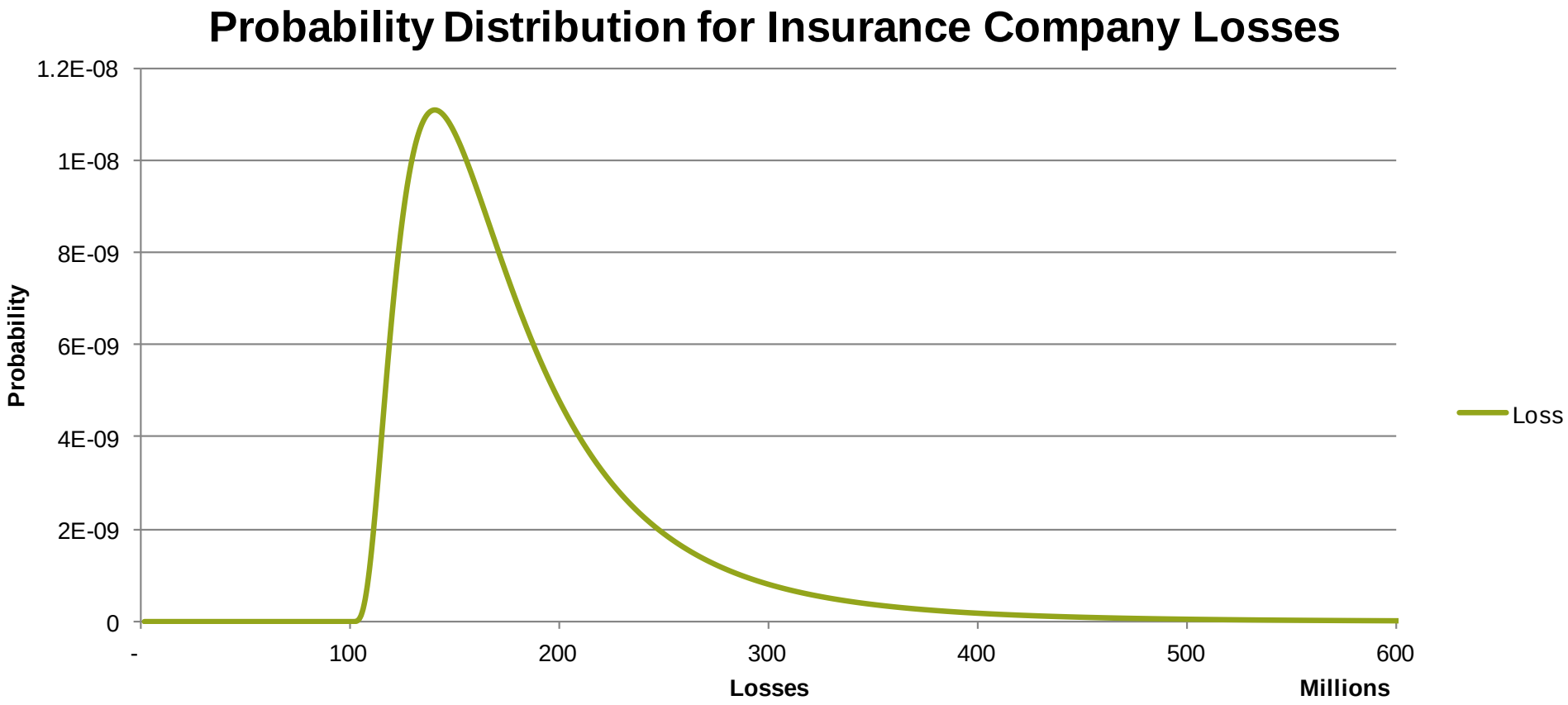
World Trade Center 9th Sept 2001

Hurricane Katrina, August 2005

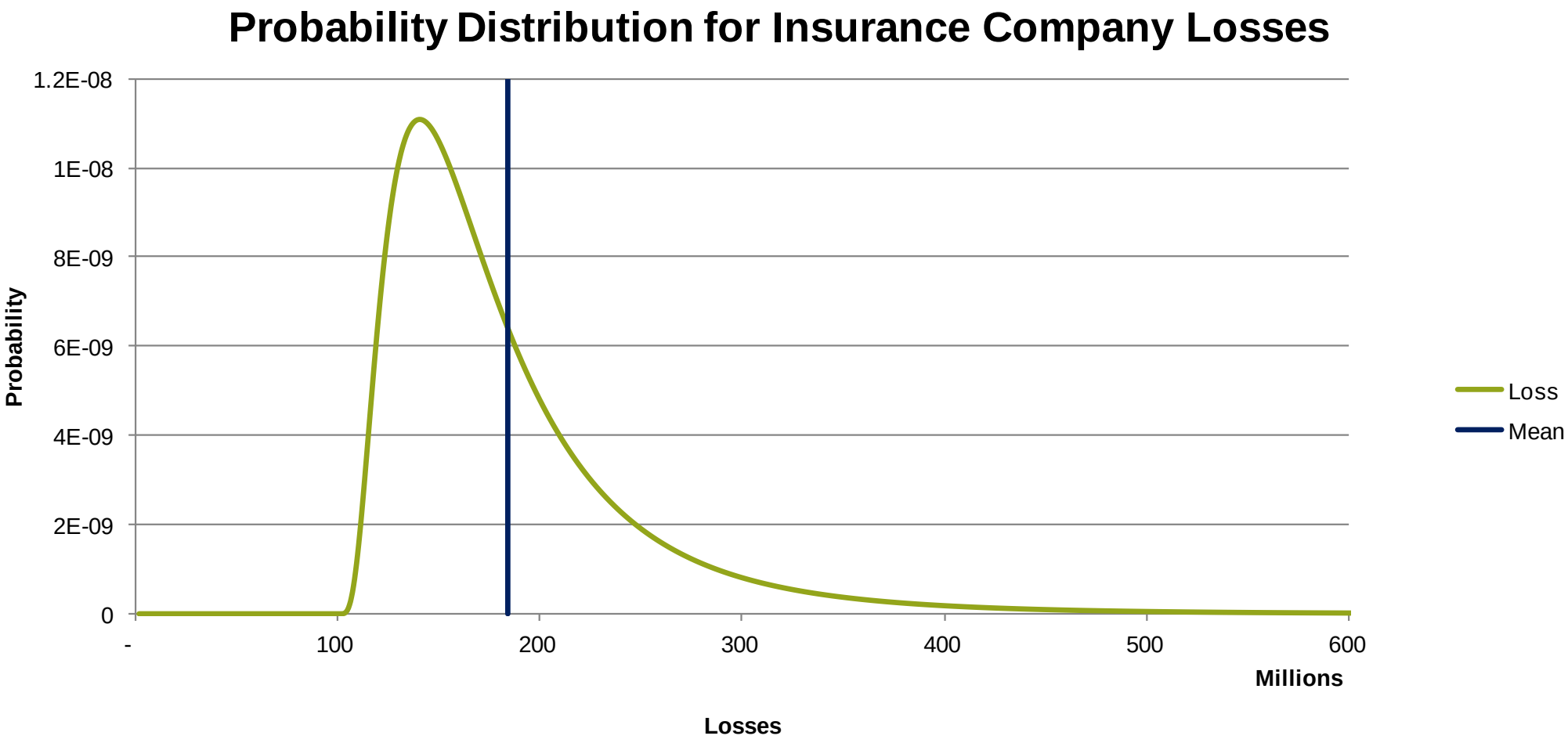
Capital Modelling for Insurance Companies (under Solvency II)

- Insurance companies must hold capital so that they are protected from insolvency from any amount of claims, up to the size that would occur 1 in 200 years.
- Time horizon is one year.
- Insolvency is defined as excess of liabilities over assets i.e. the company is ruined.

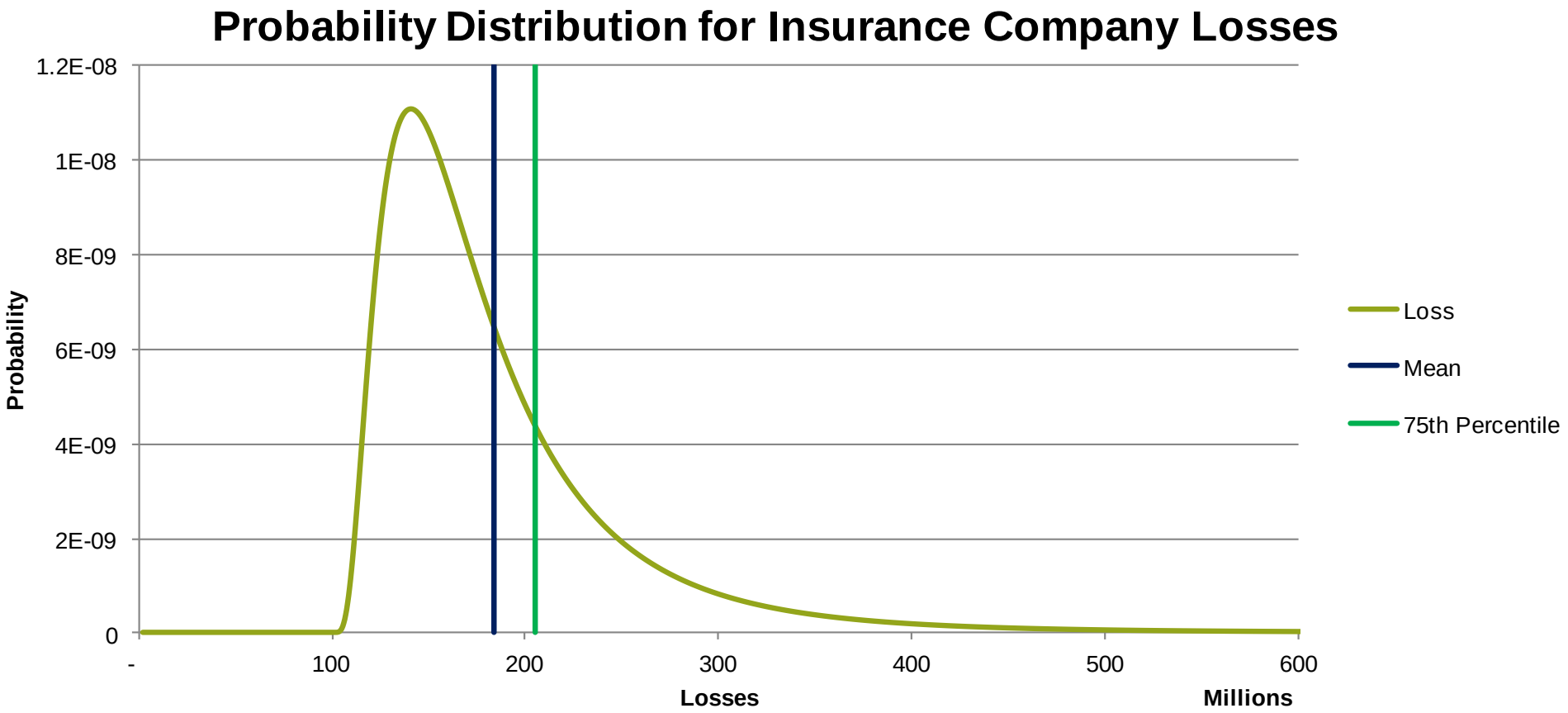
Hypothetical Example – Insurance Company Claims



Hypothetical Insurance Company Claims
The mean is the “best estimate”

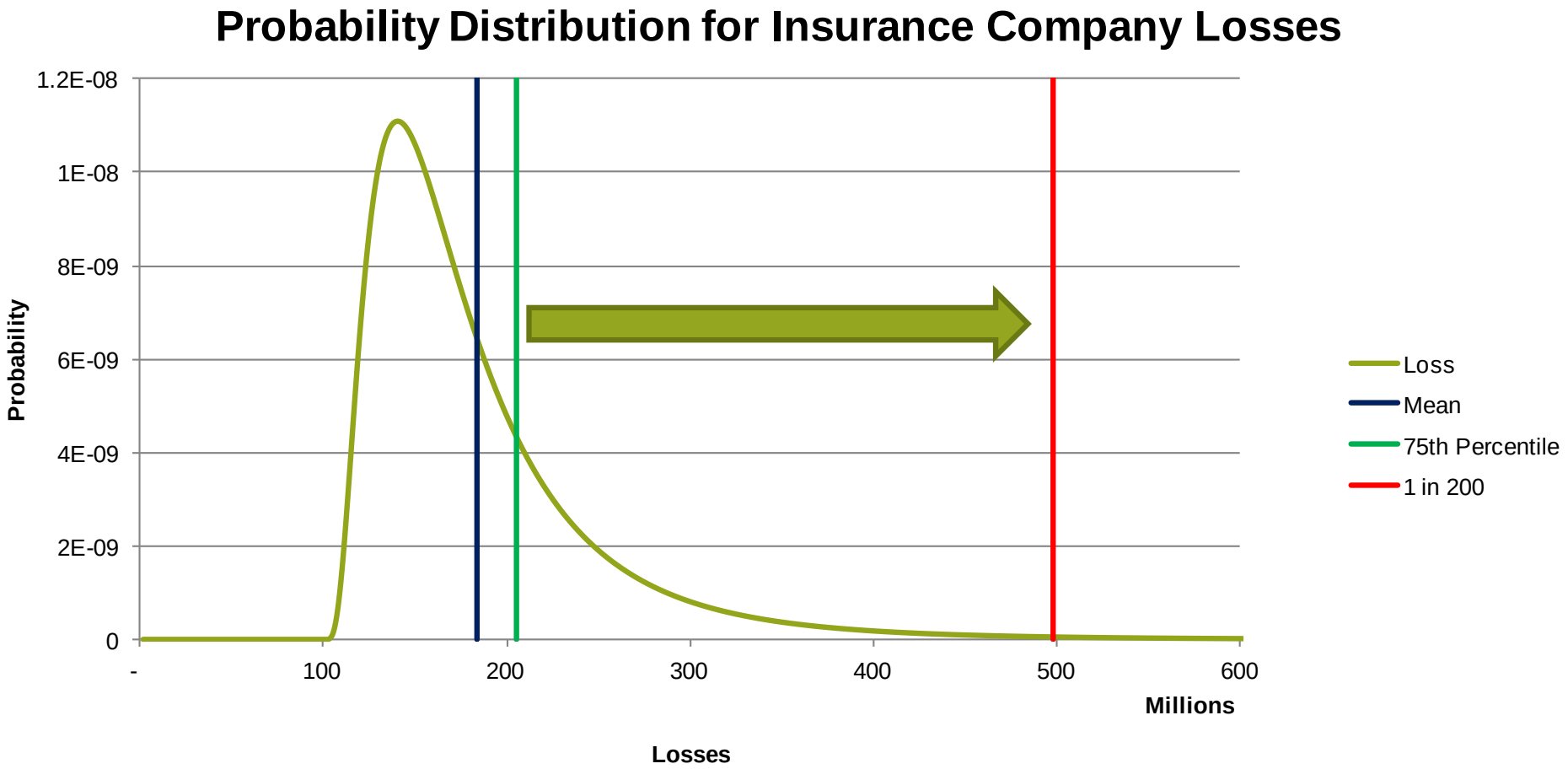


Hypothetical Insurance Company Claims
Claims are usually reserved conservatively*



*In insurance and risk management, use of the word “conservative” denotes a high estimate.

Hypothetical Insurance Company Claims
What does the 1 in 200 level look like?



These values are to scale for this probability distribution.

Capital Modelling for Insurance Companies under Solvency II

- The 1 in 200 one year ruin probability is a minimum benchmark, set by the regulator.
- Insurance companies hold capital to far exceed this benchmark. (i.e. they have a lower than 0.5% one year ruin probability)
- Insurers and reinsurers are generally well-regulated and secure e.g. Munich Re founded 1880, Swiss Re founded 1863.

Risk of Ruin

1. Capital modelling for insurance companies
2. **Capital modelling as a logical framework for climate change**
3. A sketch of a climate ruin model
4. Areas for further work

Capital modelling as a logical framework
Analogy 1: The regulatory regime

Use the regulatory regime for insurance as an analogy to efforts to protect citizens from climate change:

- Capital modelling for insurance companies is part of regulatory regime to protect policyholders.
- Climate change is a danger to citizens, so the regulatory regime for climate change should be designed to protect citizens.

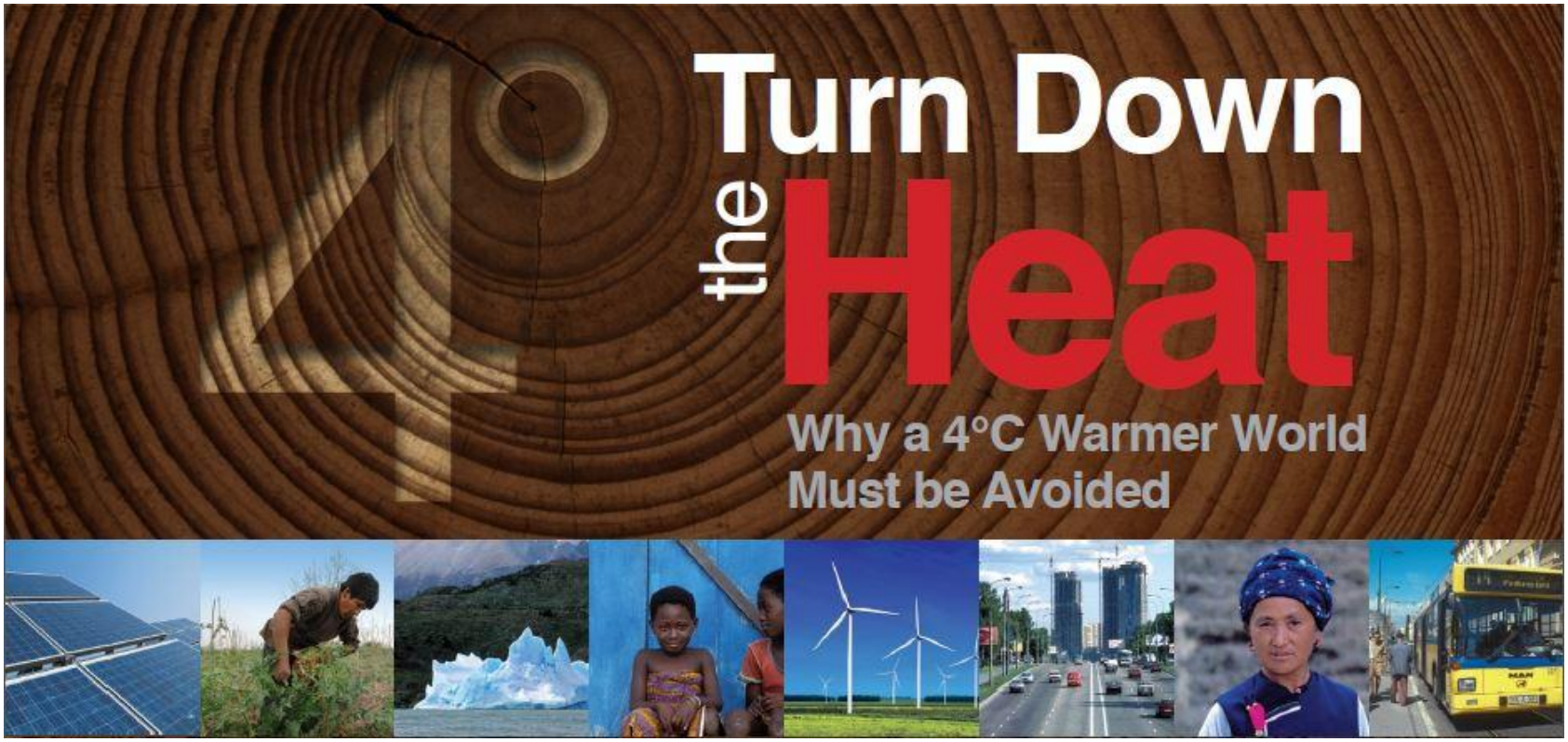
Capital modelling as a logical framework
Analogy 2: The regulated entity

- In insurance capital modelling, the regulated entity is the insurance company.
- In this analogy, the regulated entity is the global economy.

Capital modelling as a logical framework
Analogy 3: Definition of “Ruin”

- In insurance capital modelling, the ruin scenario is insolvency of the insurance company i.e. insolvency = ruin.
- Definition of climate “ruin” is a value judgement.

Selection of Climate Ruin Scenario



Choice of “ruin” scenario is a value judgement.

Source:
http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf

Why Select 4°C Temperature Rise as Ruin Scenario?

4°C warmer world would mean:

- Possible large-scale displacement of populations.
- Risk of crossing thresholds of nonlinear tipping elements in the Earth system e.g. disintegration of West Antarctic ice sheet.
- Possible nonlinear responses within particular economic sectors e.g. reduced crop yields.
- Given uncertainty about the full nature and scale of impacts, there is no certainty that adaptation to a 4°C world is possible.

Source:
http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf

Can we apply the logical framework of insurance company capital modelling to climate change?

- We have two elements for a ruin model for climate change:
  - Regulated entity; The Earth
  - Ruin scenario; 4°C global average temperature rise

Can we use this model to decide on an upper bound for an acceptable atmospheric CO_2 stabilisation target?

- Need to know:
  - Sensitivity of the climate to CO_2
  - Time horizon
  - Maximum acceptable ruin probability over this time horizon

Selection of time horizon for climate ruin model

- Climate change operates over long timescale, many delays
- Selection of time horizon is a value judgement.
- Often, future damages from climate change are discounted to present value using a discount rate.
- However, for a global issue such as climate change, should use low discount rates. See discussion paper by Nicholas Stern.
- With low discount rates, the far future matters.

Reference: http://www.cccep.ac.uk/Publications/Working-papers/Papers/90-99/WP97-ethics-equity-economics-of-climate-change.pdf

Risk of Ruin

1. Capital modelling for insurance companies
2. Capital modelling as a logical framework for climate change
3. **A sketch of a climate ruin model**
4. Areas for further work

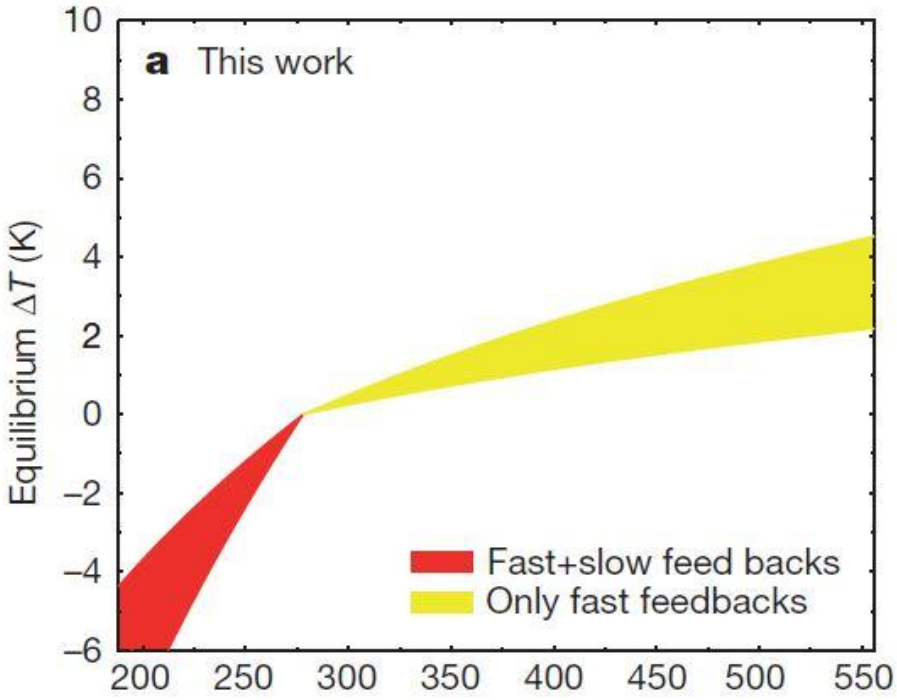
What is the sensitivity of the climate to CO_2?

“Equilibrium Climate Sensitivity”

- The amount of warming expected at “equilibrium” of the climate system, for a given amount of greenhouse gas forcing.
- Normally calibrated to double carbon dioxide i.e. double CO_2 from the pre-industrial 280ppm to 560ppm.
- The 2013 Intergovernmental Panel on Climate Change 5th assessment report, advised that “equilibrium” climate sensitivity to doubled CO_2 was between 1.5 - 4.5 °C, with a probability of 2/3rds.

Making Sense of Paleoclimate Sensitivity Nature 2012

- But, the yellow area is the 68% confidence interval for climate sensitivity
- This gives an unacceptably high 16% tail probability
- For a risk of ruin calculation, need a much wider confidence interval.



Source: Nature 2012 doi:10.1038/nature11574
PALEOSENS project members

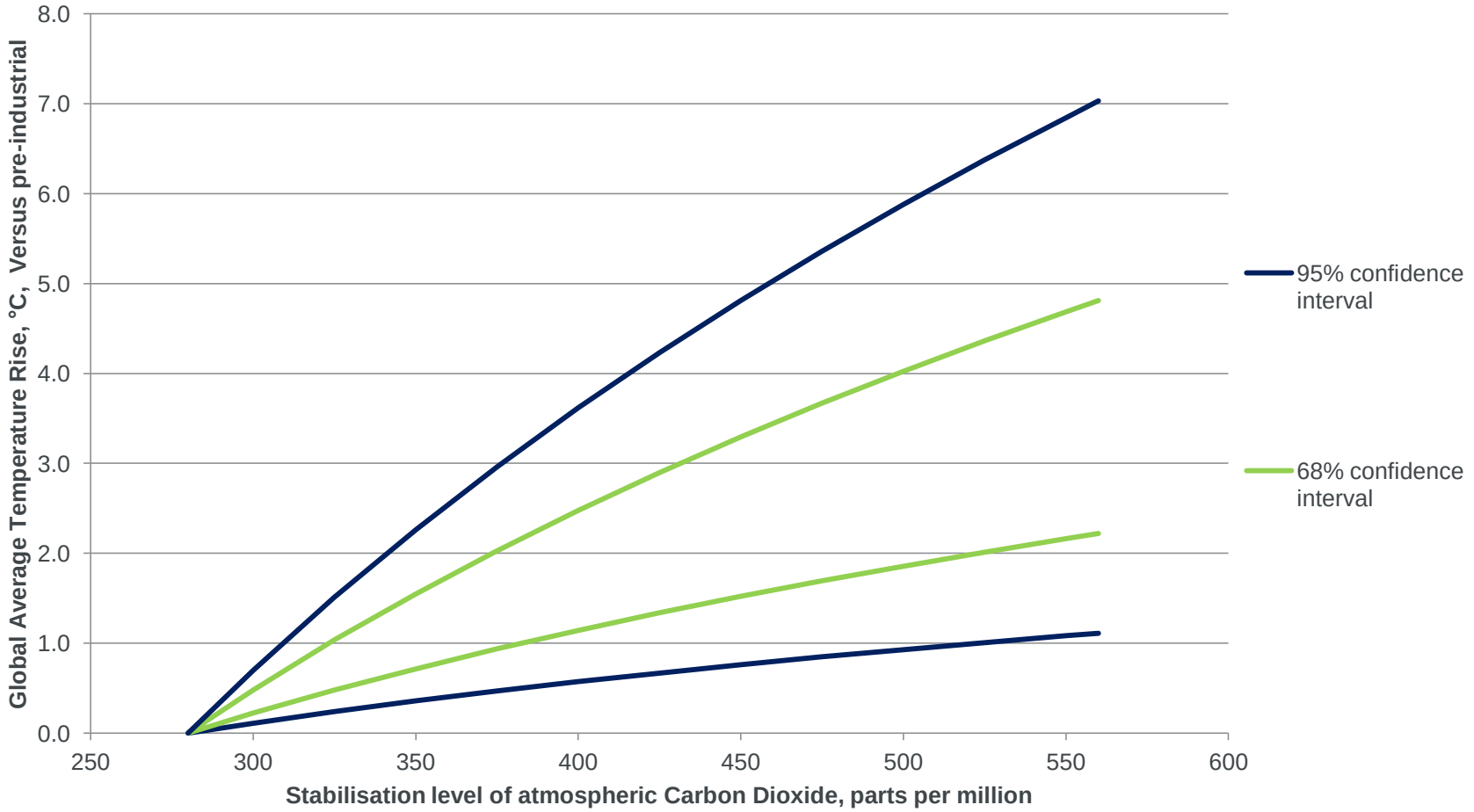
Making Sense of Paleoclimate Sensitivity
Nature 2012

Abstract:

Many palaeoclimate studies have quantified pre-anthropogenic climate change to calculate climate sensitivity (equilibrium temperature change in response to radiative forcing change), but a lack of consistent methodologies produces a wide range of estimates and hinders comparability of results. Here we present a stricter approach, to improve intercomparison of palaeoclimate sensitivity estimates in a manner compatible with equilibrium projections for future climate change. Over the past 65 million years, this reveals a climate sensitivity (in $KW^{-1}m^2$) of 0.3–1.9 or 0.6–1.3 at 95% or 68% probability, respectively. The latter implies a warming of 2.2–4.8K per doubling of atmospheric CO2, which agrees with IPCC estimates.

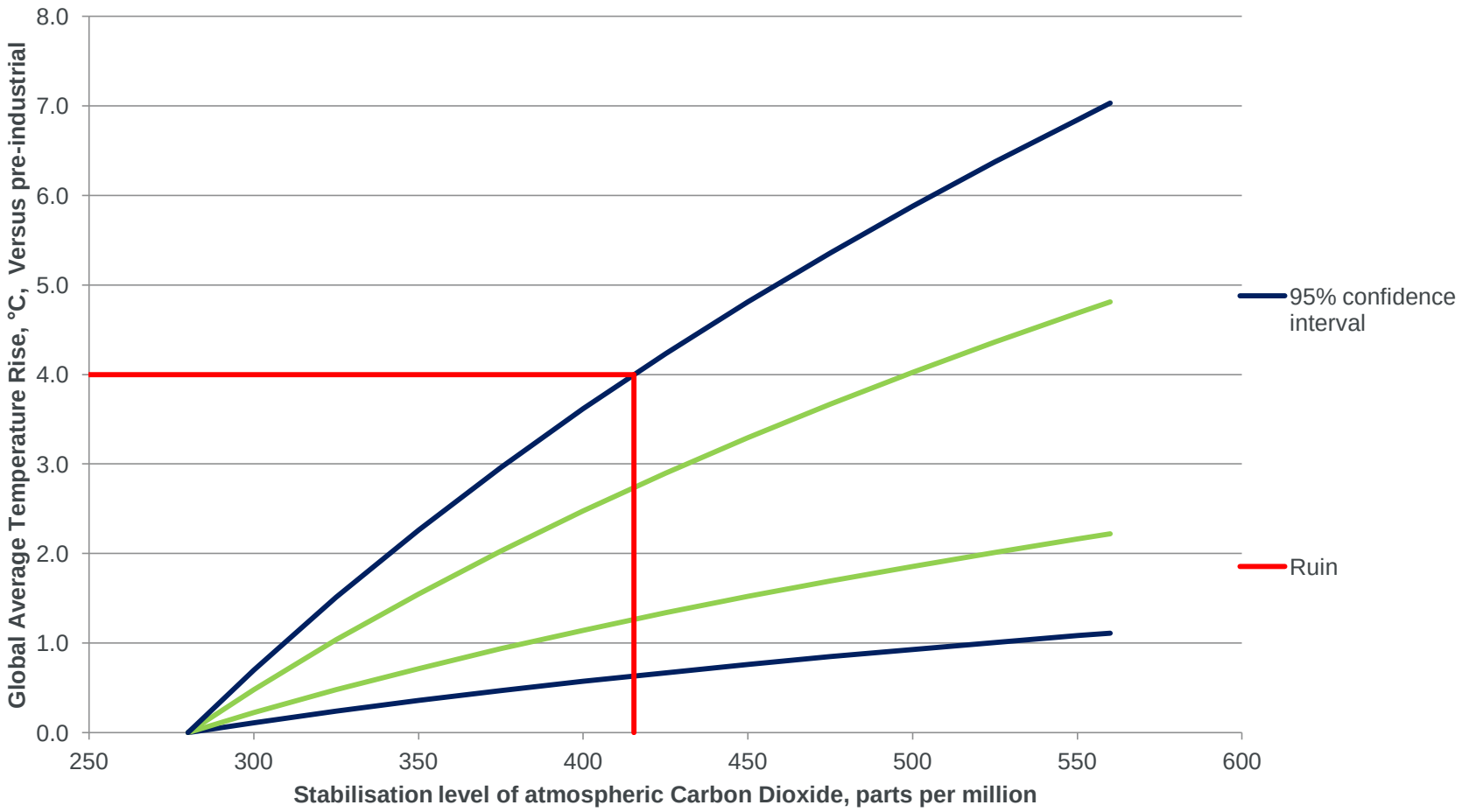
Nature 2012 doi:10.1038/nature11574 PALEOSENS project members

Plot the 95% Confidence interval for Climate Sensitivity



Source: Nature 2012 doi:10.1038/nature11574 PALEOSENS project members

Read off the carbon dioxide concentration



CO_2 Stabilization Target

Based on these particular inputs and choices, the approximate model results are:

- To limit probability of exceeding 4°C global average temperature rise to ≤2.5%*
- Upper bound for the CO_2 stabilization target is ≤420ppm

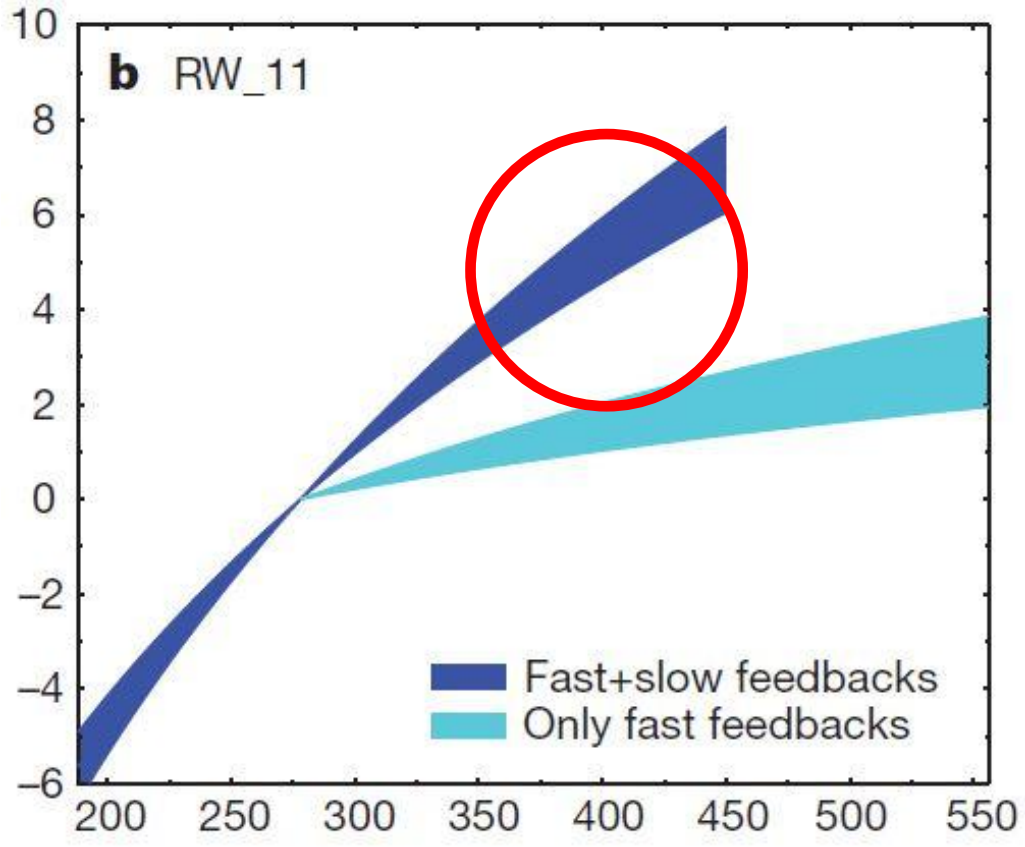
*N.B. The 2.5% tail probability risk of ruin has been selected in this model outline only because data is available. The choice of actual acceptable tail probability is a policy decision.

Institute and Faculty of Actuaries

Risk of Ruin

1. Capital modelling for insurance companies
2. Capital modelling as a logical framework for climate change
3. A sketch of a climate ruin model
4. **Areas for further work**

Slow climate feedbacks may lead to higher warming, in the long term

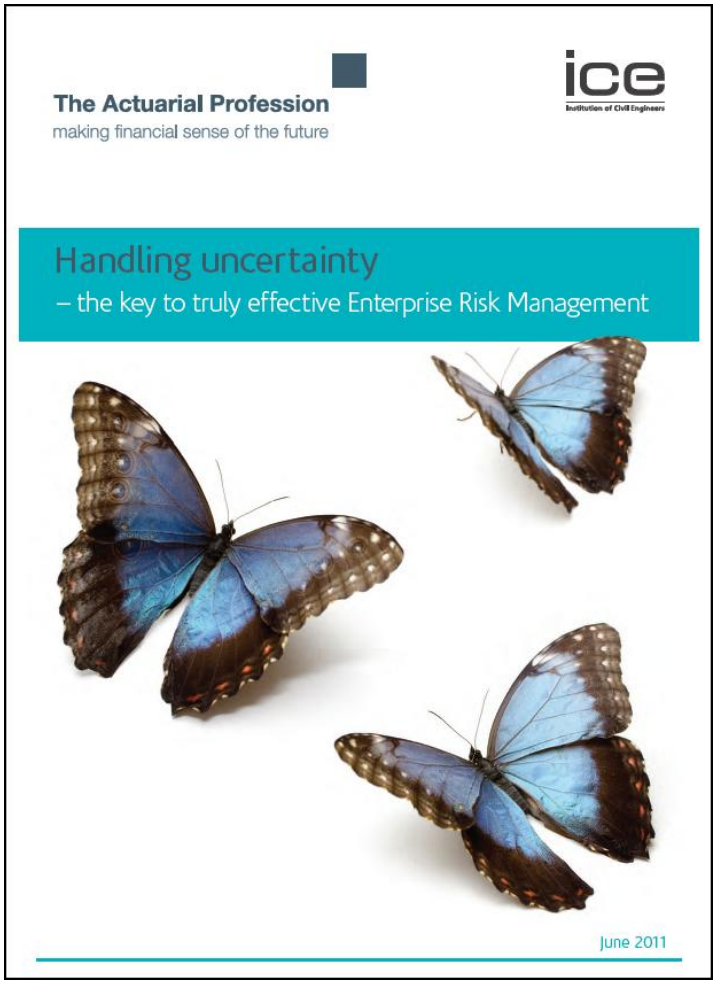


- There is evidence that long term changes e.g. to ice sheets and vegetation, may increase climate sensitivity.
- How can we deal with the risk that slow feedbacks are relevant to us?

Source: Nature 2012 doi:10.1038/nature11574 PALEOSENS project members

Also see http://www.climatenewsnetwork.net/2013/12/earth-may-be-doubly-sensitive-to-co2/

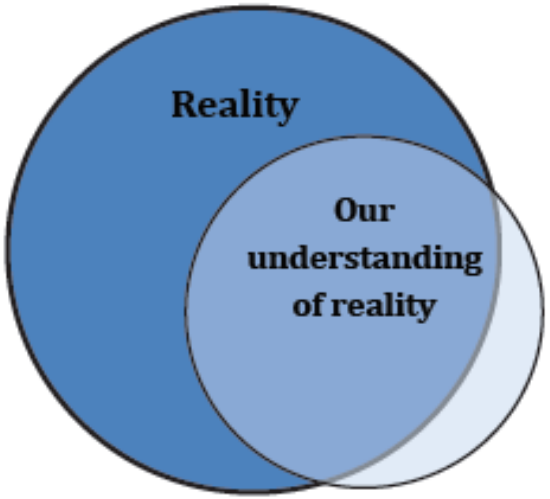
Risk vs Uncertainty

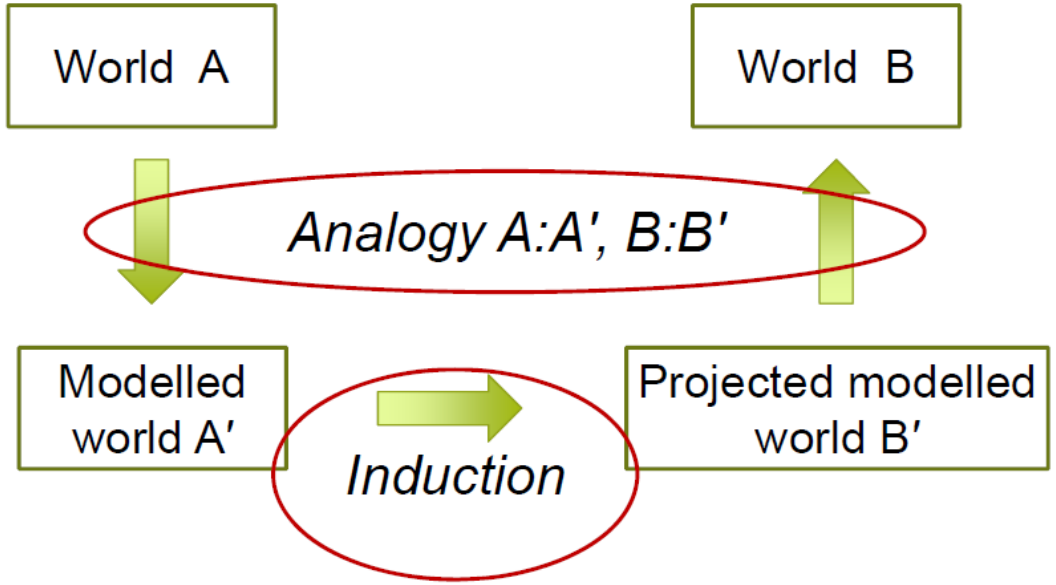


- How can we handle uncertainty, i.e. where the probability distribution is not known?
- Prerequisite is an understanding of model output.

Issues of Risk Modelling

Probability range of model output is the range from the model, not the range of outcomes for the modelled system.





Diagrams from 'The Philosophy of Modelling', by Matthew Edwards and Zaid Hoosain, presented to the Staple Inn Actuarial Society, 26 June 2012
http://www.sias.org.uk/diary/view_meeting?id=SIASMeetingJune2012

Areas for Further Investigation

1. Investigation of uncertainty in modelling the climate system. E.g. clouds and long term feedbacks.
2. Discussion around risk tolerance for tail risk.
3. Risk management – what is the contingency plan if actual climate sensitivity is in the tail of the probability distribution?

Institute and Faculty of Actuaries

Questions or comments?

Expressions of individual views by members of The Institute and Faculty of Actuaries and its staff are encouraged.

The views expressed in this presentation are those of the presenter.

Feel free to contact at:
Twitter at @OliverBettis