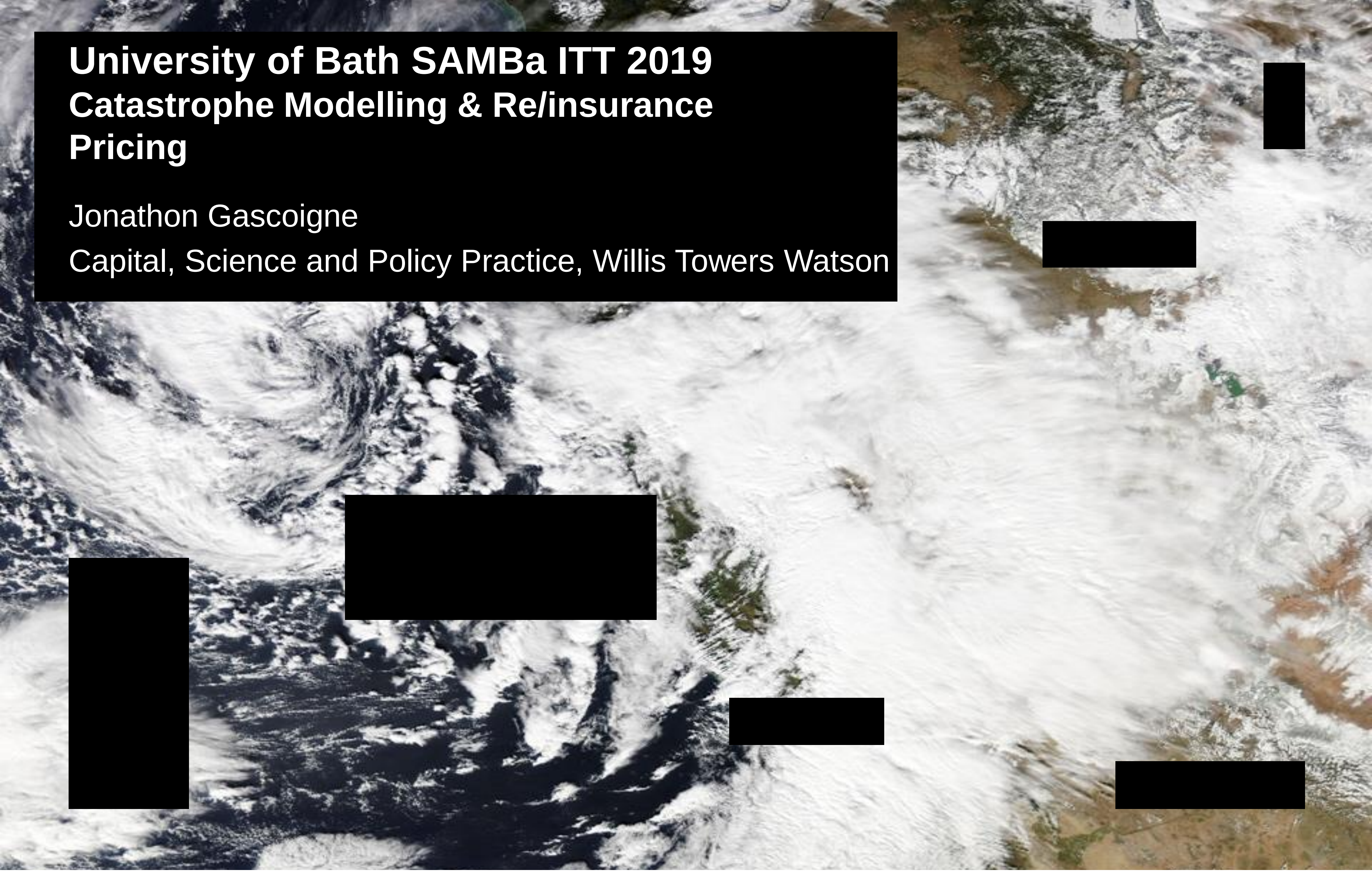


University of Bath SAMBa ITT 2019

Catastrophe Modelling & Re/insurance Pricing

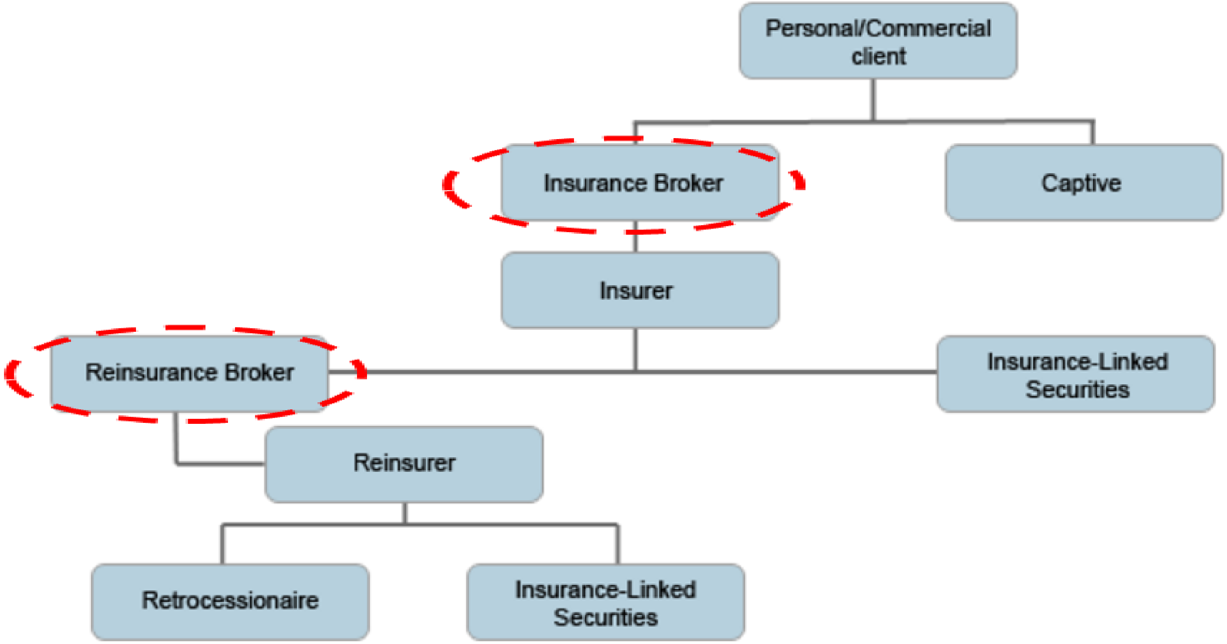
Jonathon Gascoigne

Capital, Science and Policy Practice, Willis Towers Watson

Willis Towers Watson

What does the company actually do?

- Leading global advisory, broking and solutions company
  - Helps clients around the world turn risk into a path for growth
  - Roots dating from 1828 - over 40,000 employees serving >140 countries
- Designs and delivers solutions that manage risk, optimize benefits, cultivate talents, and expand the power of the capital to protect and strengthen institutions and individuals
- On the legacy Willis side…



University of Bath SAMBa ITT 2019

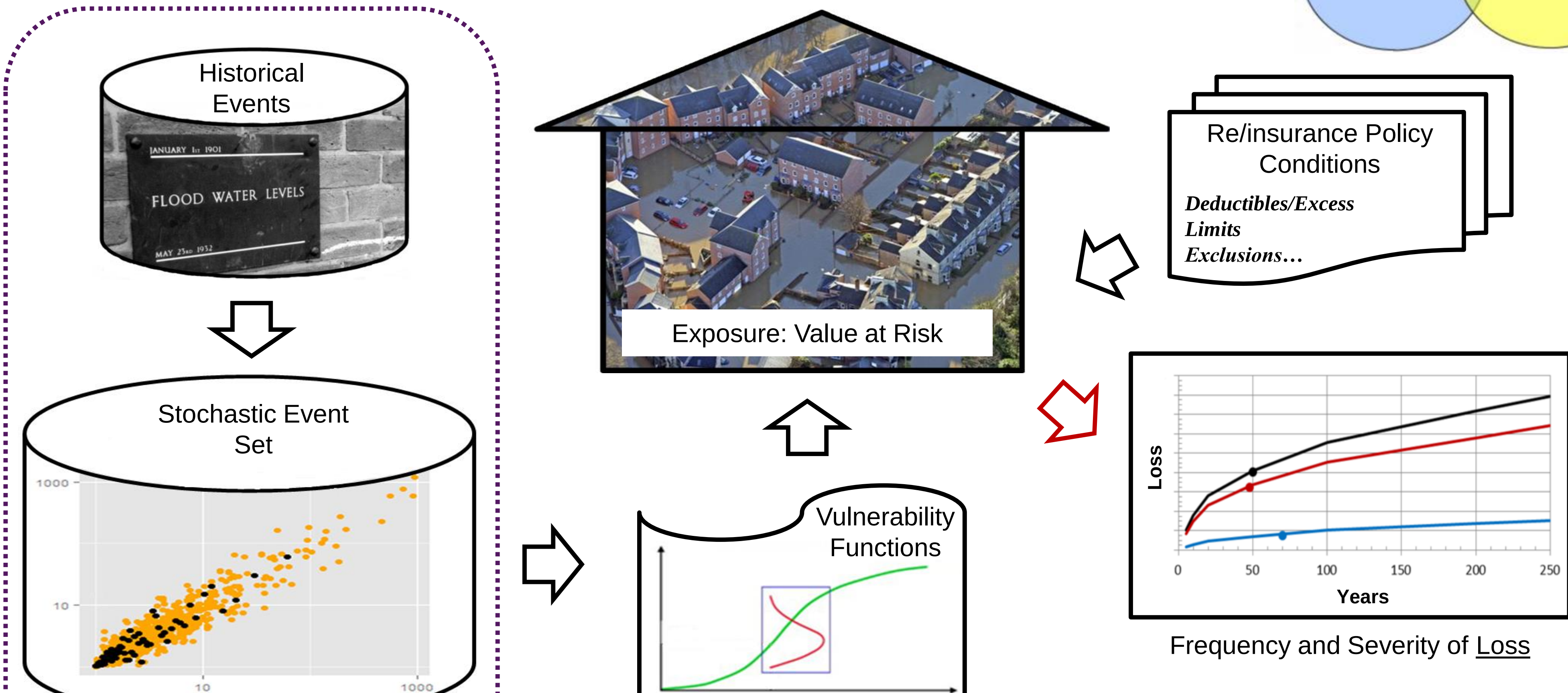
Centre for Doctoral Training (CDT) in Statistical Applied Mathematics

- Challenge leaders:
  - Jon Gascoigne — Catastrophe Modelling & Re/insurance Pricing
  - Chris Au — Forecast-Based Financing for Natural Hazards
  - Jacqueline Wharton — Parametric Insurance and Volcanic Risk
  - Sam Phibbs — Assessing the Risk of Hypothetical Windstorms

  - Additional support during the week from:
  - Geoff Saville — Willis Research Network
  - Nick Moody — WTW consultant for Insurance Development Forum
  - Matt Stoughton-Harris — Capital, Science and Policy Team

The 'Gearbox': Catastrophe Modelling

The common currency of nat cat risk communication



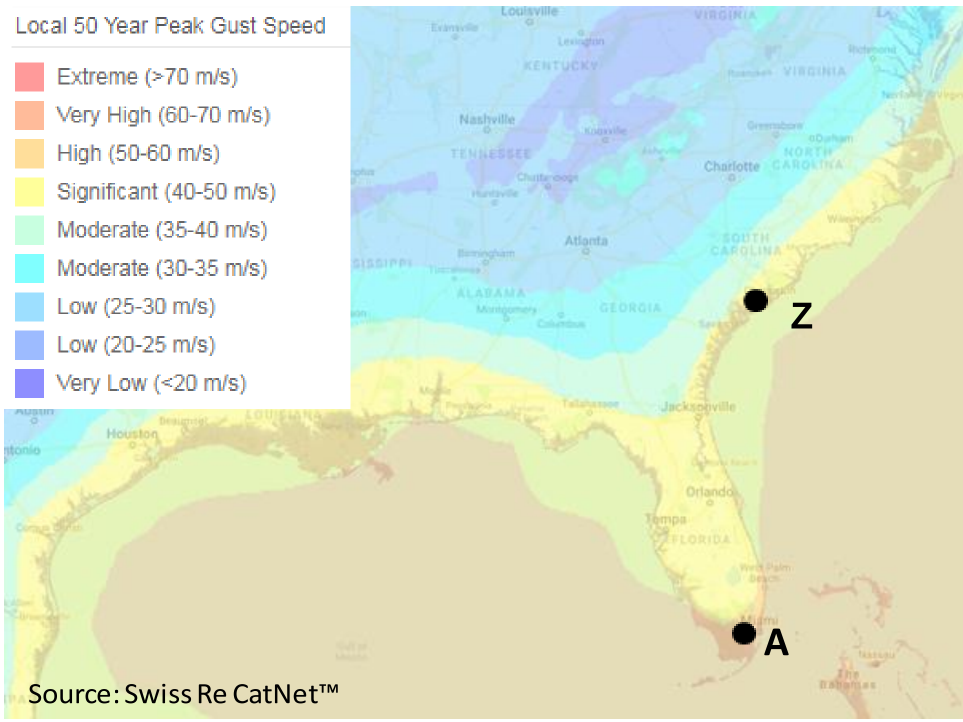
AAL: Annual Average Loss (£)
PML: Probable Maximum Loss (£)
e.g. 1 in 20, 1 in 100 year loss

Models vs. Maps

Factoring in exposure and vulnerability to physical hazard

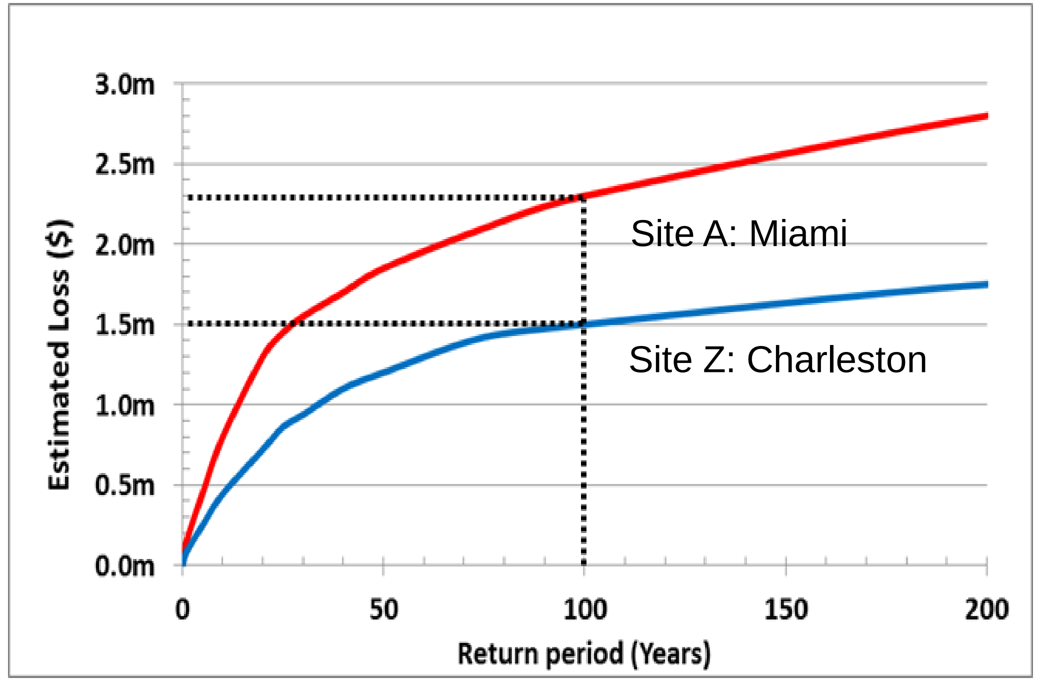
	Site A	Site Z	A > Z
Location	Miami	Charleston	
Hazard: Tropical Cyclone (50-year peak gust)	53 m/s	43 m/s	23%
Loss: (1-in-100 year)	$ 2.3m	$ 1.5m	53%

US tropical cyclone windspeed intensity map



Source: Swiss Re CatNet™

Frequency & severity in exceedance probability (EP) curve

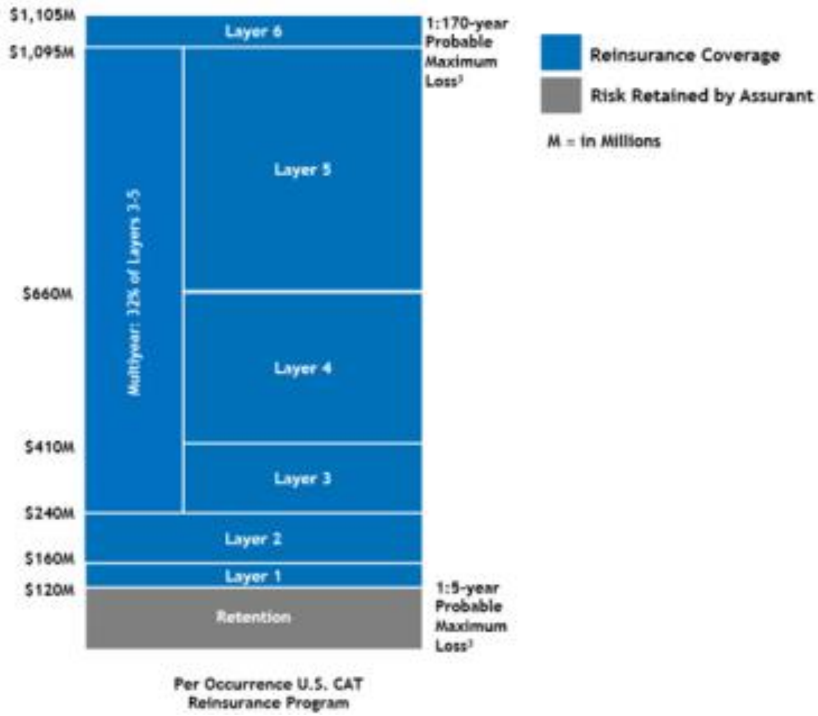


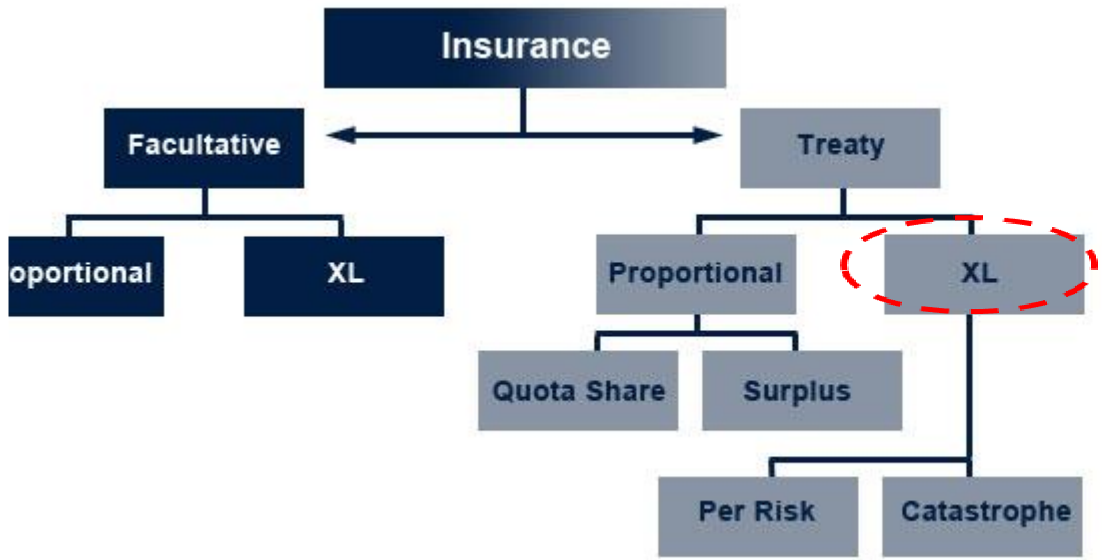
- US Tropical Cyclone Wind Speed Intensity Map

Re/insurance Pricing

Passing the parcel - diversifying risk

- Reinsurance occurs when multiple insurance companies share risk by purchasing insurance policies from other (re)insurers
  - to limit the total loss the original insurer would experience in case of disaster
  - Premium paid by the insured is *typically shared by all of the insurance companies involved*
    - E.g. 'Excess of Loss' (XL) reinsurance





Re/insurance Pricing

How should it be done – ‘risk-based’ underwriting?

- Insurance is a unique industry
  - Companies don’t know the actual cost of the goods sold as the product is being sold.
  - ‘There’s no such thing as a *bad* risk - it’s just got to be priced accordingly
  - Motor, health or fire claims make these lines of business easier to price that infrequent & severe events
- Other social and market issues
  - Regulation, market conditions, distribution channels, insurer IT systems
  - Political dimensions of insurance affordability and social equity

- A simplified pricing model may include:
  - Modelled average losses
  - Expenses
  - Profit
    - Often expressed as cost of capital

Re/insurance Pricing

In praise of Rodney Kreps

- In 1990, actuary Rodney Kreps defined a marginal capital pricing model
  - Tenured professor at University of Toronto (Ph.D. from Princeton, theoretical physics)
  - 1970s: quit for nature, construction work and then actuarial programme
  - Now pursuing Sufi mentoring

- Rule-of-thumb calculation for pricing a layer of property cat reinsurance
  - "Expected loss plus one-third the standard deviation"

Finally, combining the above and taking σ as the measure of risk, say that r, the risk load, is equal to reluctance times risk:

$$r = \mathfrak{R}\sigma, \tag{1.9}$$

where $\mathfrak{R}$, the reinsurer's reluctance to take on risk, is defined by

$$\mathfrak{R} = [yz/(1 + y)](2SC + \sigma)/(S' + S). \tag{1.10}$$

REINSURER RISK LOADS FROM MARGINAL SURPLUS REQUIREMENTS

RODNEY KREPS

Abstract

The return on the marginal surplus committed to support the variability of a proposed reinsurance contract is used to derive an appropriate risk load for reinsurers. The risk load is a linear combination of the standard deviation and variance of the return on the contract, and depends upon the covariance of the contract with the existing book, the standard deviation of …contract, the standard deviation of the existing book, …ptable probability of "ruin" of the company, and the …uired on marginal surplus (the additional surplus …or this contract). A new term is defined, the reluct…ite risk, and relatively simple formulas result for it …mium, which satisfy intuitive reasonableness cri…ions to include expenses and an existing "bank" … and application is made to the interesting case …r pricing. Empirical comparison suggests that …ing is consistent with this approach.

- *(In the near future, will actuaries, lawyers and accountants save us from climate risk…)*

Re/insurance Pricing

Beyond Kreps?

- Kreps' reluctance factor – a.k.a. Standard deviation load - in theory is calculated based on 3 elements:
  - Required return on capital of the company
  - The return period level at which a company sets its capital (in Kreps paper 1 in 1000)
  - The degree to which the risk is correlated with the existing portfolio

- Assumption that insurance recoveries are normally distributed
- Difficulty of assessing how correlated particular new risk is to the existing portfolio
  - Catastrophe models did not exist at this time
  - In practice standard benchmark loads have gained broad acceptance
    - higher for risks in territories where (re)insurers had most risk (e.g. Florida hurricane)
    - lower for risks which clearly were diversifying
      - straddling a range of 5% to 50% though dependent upon the state of the market

- Additionally, what is the existing portfolio?
  - What is currently is on the books (I.e. confirmed renewals only)?
  - Based on the current portfolio renewing 'as is'?
  - What is planned to be written (e.g. allowing from expected new business/business losses/ portfolio adjustment)?

Re/insurance Pricing

A sequencing complication

- Much reinsurance business has set renewal dates
  - A large proportion of re/ins business renews on 1st Jan
    - At 31st Oct, there is huge uncertainty what the ultimate book will look like on 2nd Jan

- Consider two identical risks within a region being presented:
  - Risk A on15th Nov
  - Risk Z on 5th Dec

  - Risk A risk may not trigger a significant increase in capital requirement
    - being one of the first risks for that region to renew contract

  - Risk Z risk may cause the cumulative effect with Risks B-to-Y to drive the capital requirement
    - Additional capital of Risk Z is much higher that Risk A
      - Thus Risk Z attracts a higher price despite being an <u>identical risk</u>

- Example: CCRIF policies renew on 1st June…

Re/insurance Pricing

A sequencing complication - illustration

	Site A	Site Z	A > Z
Location	Miami	Charleston	
Hazard: Tropical Cyclone (50-year peak gust)	53 m/s	43 m/s	23%
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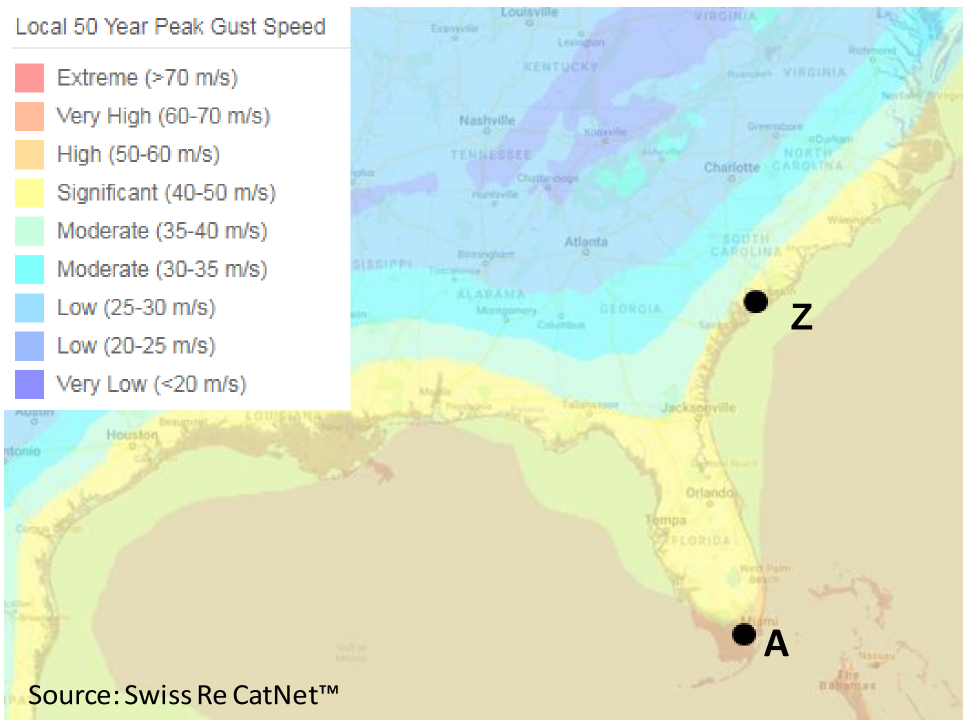

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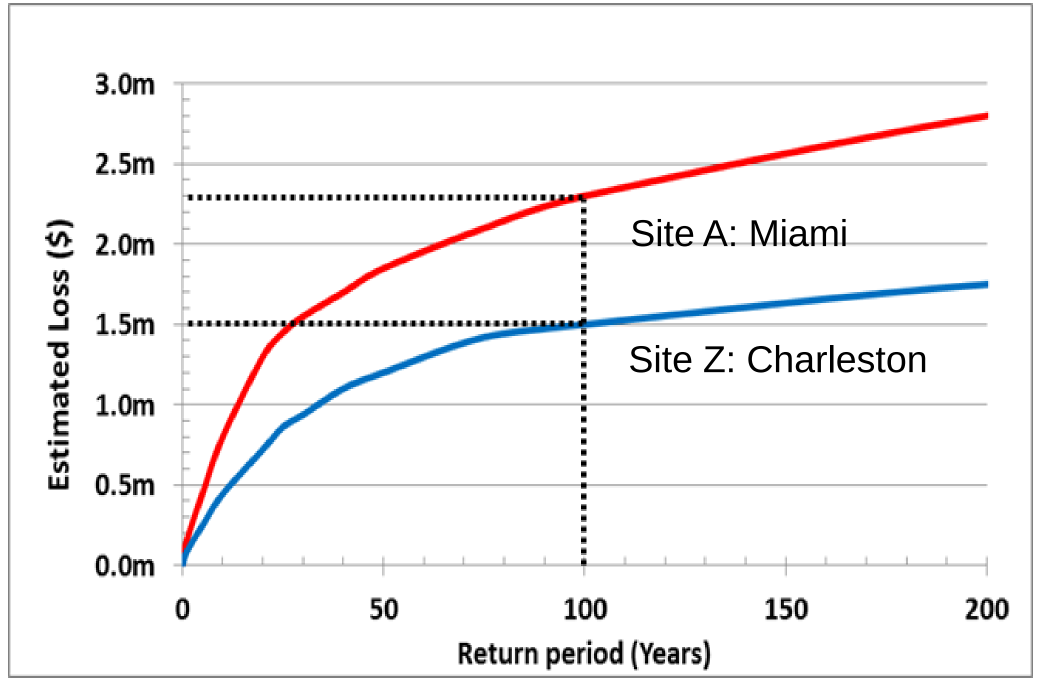


- US Tropical Cyclone Wind Speed Intensity Map

Caribbean Catastrophe Risk Insurance Facility

CCRIF
The Caribbean Catastrophe Risk Insurance Facility

Case study: CCRIF

- **Established in 2007**
  - First regional risk pool limiting the impacts of hurricanes, earthquakes and excess rainfall events
  - Initially English Speaking Caribbean (CARICOM) plus Haiti; 16 countries, then extended to include Central America in 2015
- **Allows Caribbean governments to receive immediate post-catastrophe funding**
  - Parametric insurance for immediate post-event liquidity covering earthquake, cyclones and excess rainfall
  - CCRIF delivers funds within two weeks of a triggering event
- **Initial Scheme Development by WTW, backed by the World Bank**
  - Capitalized through contributions to a Multi-Donor Trust Fund
- **Coverage intended to cover:**
  - Loss to government buildings/infrastructure
  - Emergency Costs
  - Loss of tax/tourist income
  - Originally against perils of tropical cyclone (wind) and earthquake - later adding excess rainfall
- **WTW operates as the sole reinsurance broker in 2016**

- **2017 hurricanes Irma and Maria led to 12 pay-outs**
  - CCRIF's reinsurance triggered, allowing full pay-outs to its clients

Case Study: SIDS

Absolute magnitude of loss vs. dispersion of modelled loss distribution

- Ideally the price of premiums each country pays should be driven by how much it affects the need for reinsurance
  - And hence should pay for the cost of that reinsurance

- CCRIF introduced a pricing methodology along the lines of Kreps:
  - Price a country pays for its cover is the higher of:
    - 1) Expected recoveries times a multiplier
      - multiplier fixed at a level to cover expenses and allow for fund growth, so reducing future reinsurance needs
    - 2) Expected recoveries plus (Standard Deviation x SD Load)
      - where the SD load is broadly the SD load applied by reinsurers for the reinsurance contract

- The aim of the second term is to give volatile countries a higher premium
  - I.e. countries more likely to cause/contribute towards a reinsurance loss - but crude:
  - It penalises a small island, buying little cover - so on its own unlikely to impact reinsurance requirements - but with highly volatile modelled recoveries
  - Against a larger island/country which buys so much cover that on its own it can trigger a reinsurance recovery and, as it is larger, has a less volatile result.
- **Challenge: How can a better/fairer reinsurance pricing algorithm than Kreps be designed and implemented?**

Country	Net Premium	Attachment Point	Exhaustion Point
Island A	$ 357,000	$ 1,705,000	$ 34,650,000
Island B	$ 392,000	$ 2,760,000	$ 155,250,000
Island C	$ 609,000	$ 15,250,000	$ 176,250,000
Island D	$ 836,000	$ 837,000	$ 124,875,000
Island E	$ 1,388,000	$ 777,000	$ 42,616,000
Island F	$ 1,459,000	$ 888,000	$ 70,800,000
Island G	$ 1,604,000	$ 7,150,000	$ 163,150,000
Island H	…	…	…

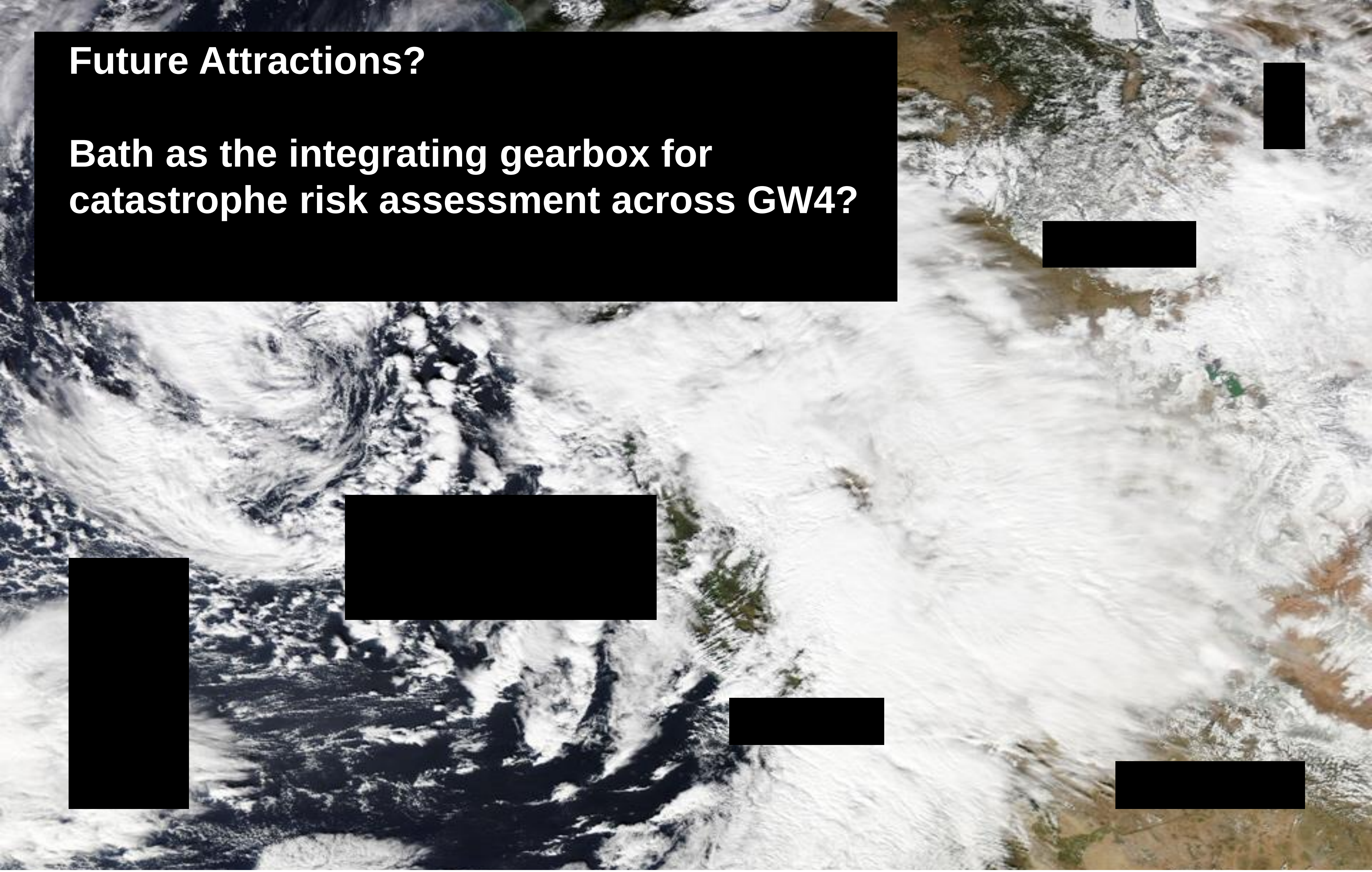
Case Study: SIDS

Sequencing and fairness?

- Theoretical or empirical approaches:
  - Anonymised spreadsheet available
- E.g. possible approach:
  - Compare which countries contribute to modelled losses that trigger reinsurance recoveries
  - Say we are modelling 10,000 as-if years and reinsurance pays for the worst 500 years
    - I.e. pays out on average 1 year in 20)
  - We can look the cumulative sum of losses for any one country for these simulations
    - Allocate reinsurance costs by share of total losses over the portfolio for the same events
- BUT before renewal date, we don't know which countries will buy cover, for which perils and for how much.
  - By using the loss allocation method outlined above, premiums cannot be determined until the entire portfolio is known.
    - But the amount of premium will often dictate how much countries by.
    - A country may have $1m in its budget to buy insurance, it will buy as much cover as $1m buys.
    - **Sub-challenge: How can new portfolio information (i.e. confirmed purchases) be used to inform pricing whilst ensuring fairness between countries, price transparency and clarity?**

Future Attractions?

Bath as the integrating gearbox for catastrophe risk assessment across GW4?



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Simplitium/Modex

Cat modelling sampling convergence?

- Oasis-based catastrophe models work by sampling a loss from underlying 'secondary uncertainty' distributions at location-coverage level
  - The user enters the number of samples as an input before running the models
  - The resultant metrics are a summary of these sample-based losses

- An unresolved question is how many samples are needed to obtain an estimate of a metric to within a certain level of accuracy at a certain confidence level?
- This will likely vary depending on:
  - The metric (AAL, 1 in 200 year loss; at portfolio level, at location level)
  - The model (number of events – high frequency or low frequency model)
  - The input data (number of locations and how they are spread out)
  - The secondary uncertainty correlation structure
- **Challenge: We would like a mathematical model to estimate the required number of samples, given certain inputs**
  - **so that we can provide users with some guidance before they run an analysis**