COASTAL RESILIENCE SCHOOL

Sustainable Coastal Growth and Resilience

Natural Catastrophe Modelling: Strategies for Resilience and Sustainable Risk Management

Cecilia Bittoni, DCC-CR Program Manager

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UN Decade Collaborative Centre for COASTAL RESILIENCE

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Coastal Resilience Webinar Series

Natural Catastrophe Modelling: Strategies for Resilience and Sustainable Risk Management

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February 4th, 2025 - 14:00 CEST
The recordings will be available on YouTube

Speaker:
Cecilia Bittoni, Economist - DCC-CR Program Manager

Take-aways

What are probabilistic natural catastrophe models?

What is financial resilience to natural catastrophe?

What is the role of the insurance industry?

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What is a “Natural CATASTROPHE”?

What is a ”Return Period”?

The **Return Period (T)** is the average time interval between occurrences of a specific natural catastrophe (e.g., floods, earthquakes, hurricanes).

$$T=1/\lambda$$

Where λ is the average frequency of occurrence (events per year).

Example Calculation:
Suppose a region experiences a major earthquake on average **once every 200 years**.

- **Frequency**: $\lambda=1/200$ (events per year)
- **Return Period**: $T = 1/(\frac{1}{200})$ = $200\ years$

This means that in any given year, the probability of such an earthquake occurring is **1/200 = 0.5%**.

Even if a **200-year flood** happened last year, it **can still** happen again next year because events are random in nature.

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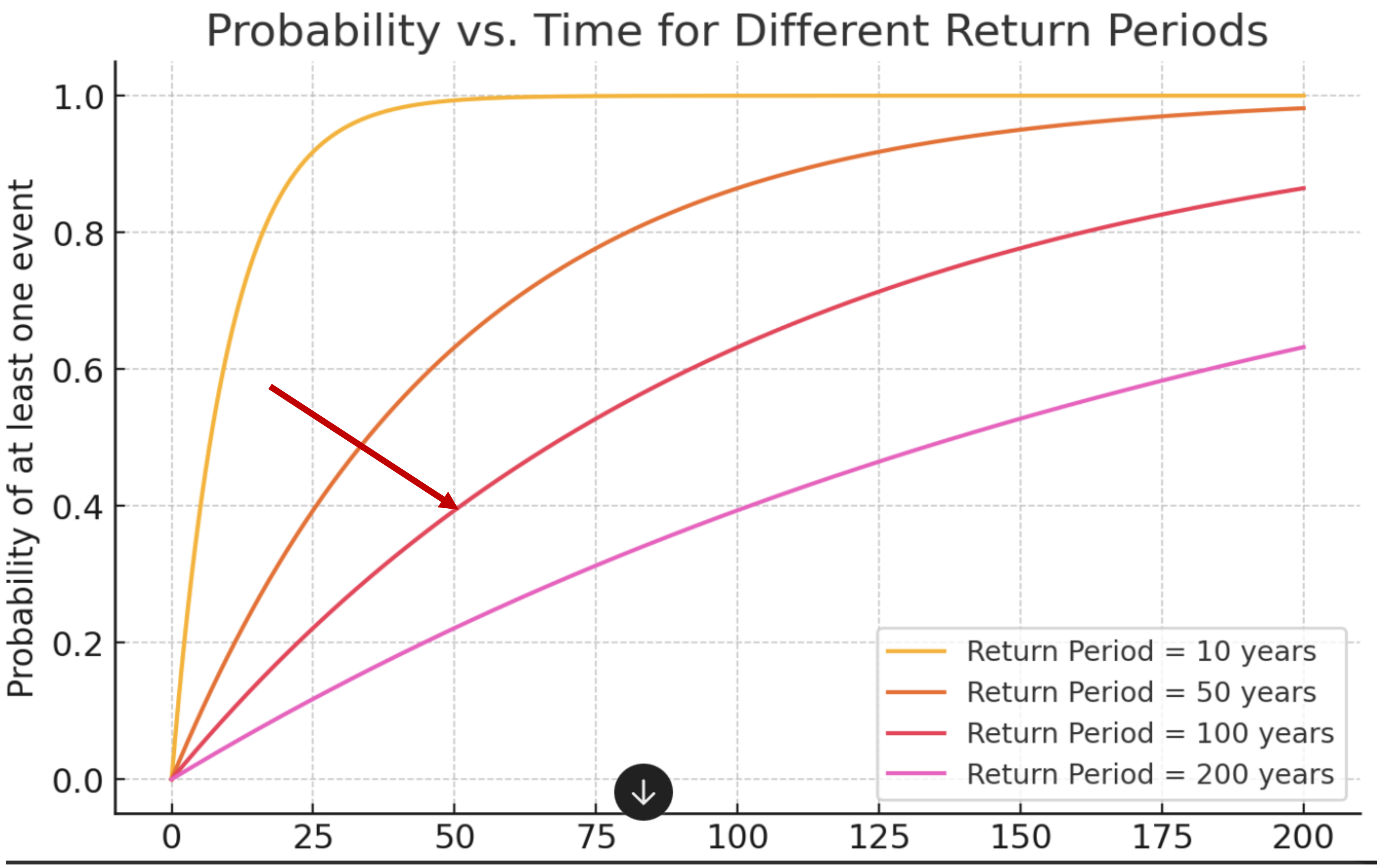
What is a "Return Period"?

This graph shows the probability of at least one event occurring over time for different return periods (10, 50, 100, and 200 years).



Probability of occurrence increases with time

Key Takeaways from the Graph:

Shorter return periods (e.g., 10 years) quickly approach a near 100% probability.

Longer return periods (e.g., 200 years) take much longer to reach high probabilities.

Even for a **100-year return period**, there's a **~40% chance** of the event occurring within 50 years.

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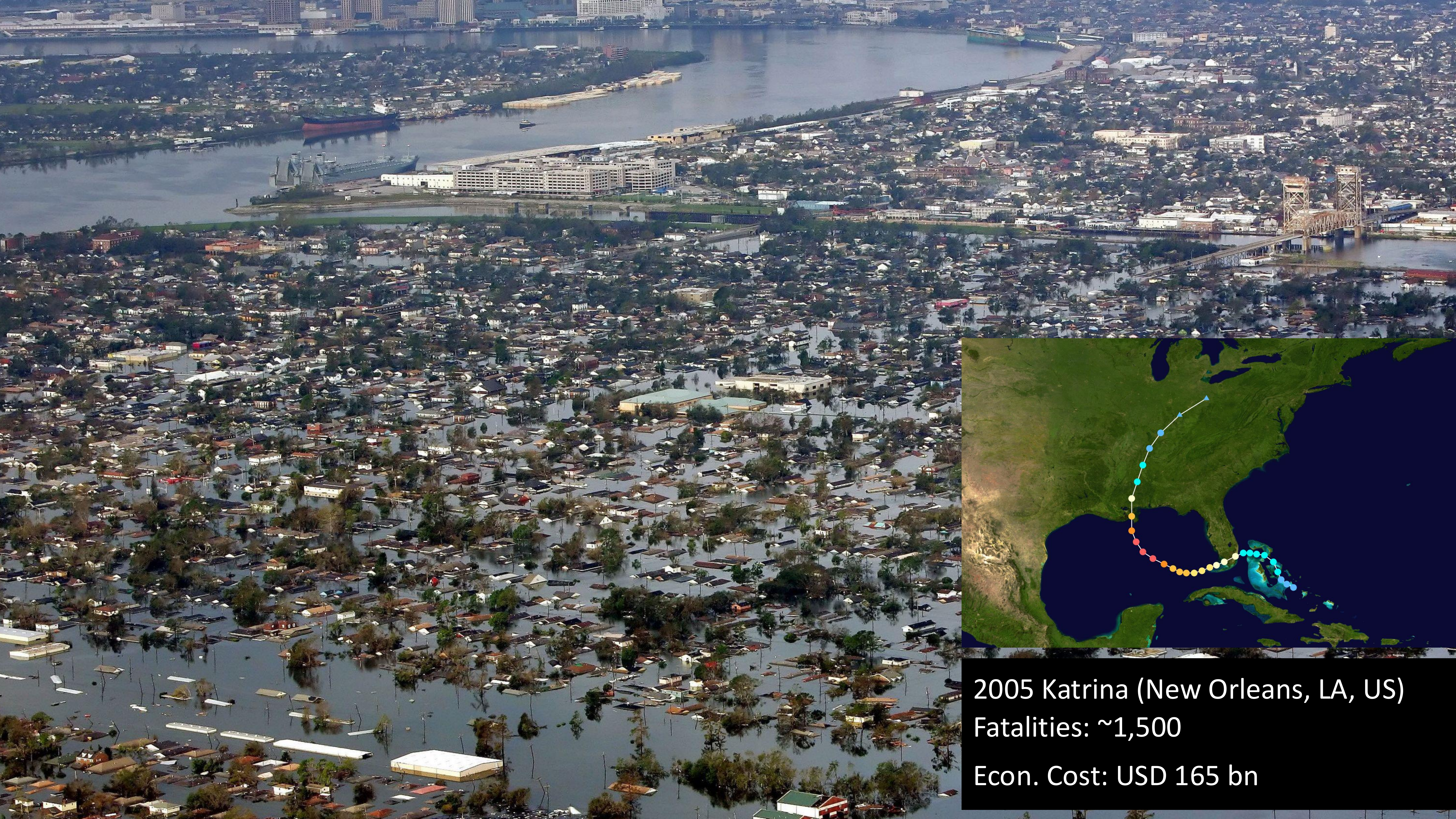
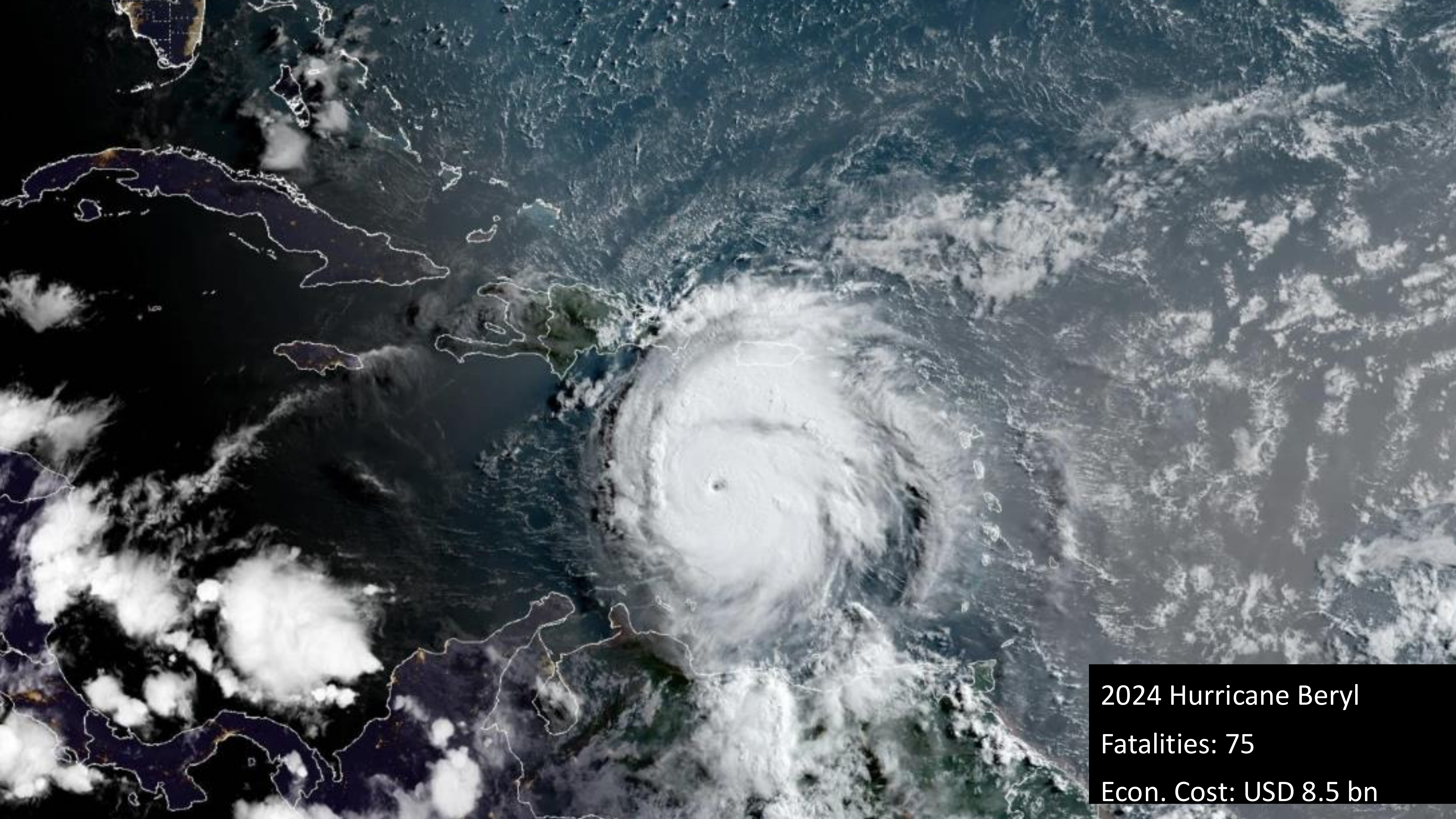
2011 EQ Tohuku (Japan)
Fatalities: 19,759
Econ. Cost: USD 411bn



2005 Katrina (New Orleans, LA, US)
Fatalities: ~1,500
Econ. Cost: USD 165 bn



2024 Hurricane Beryl

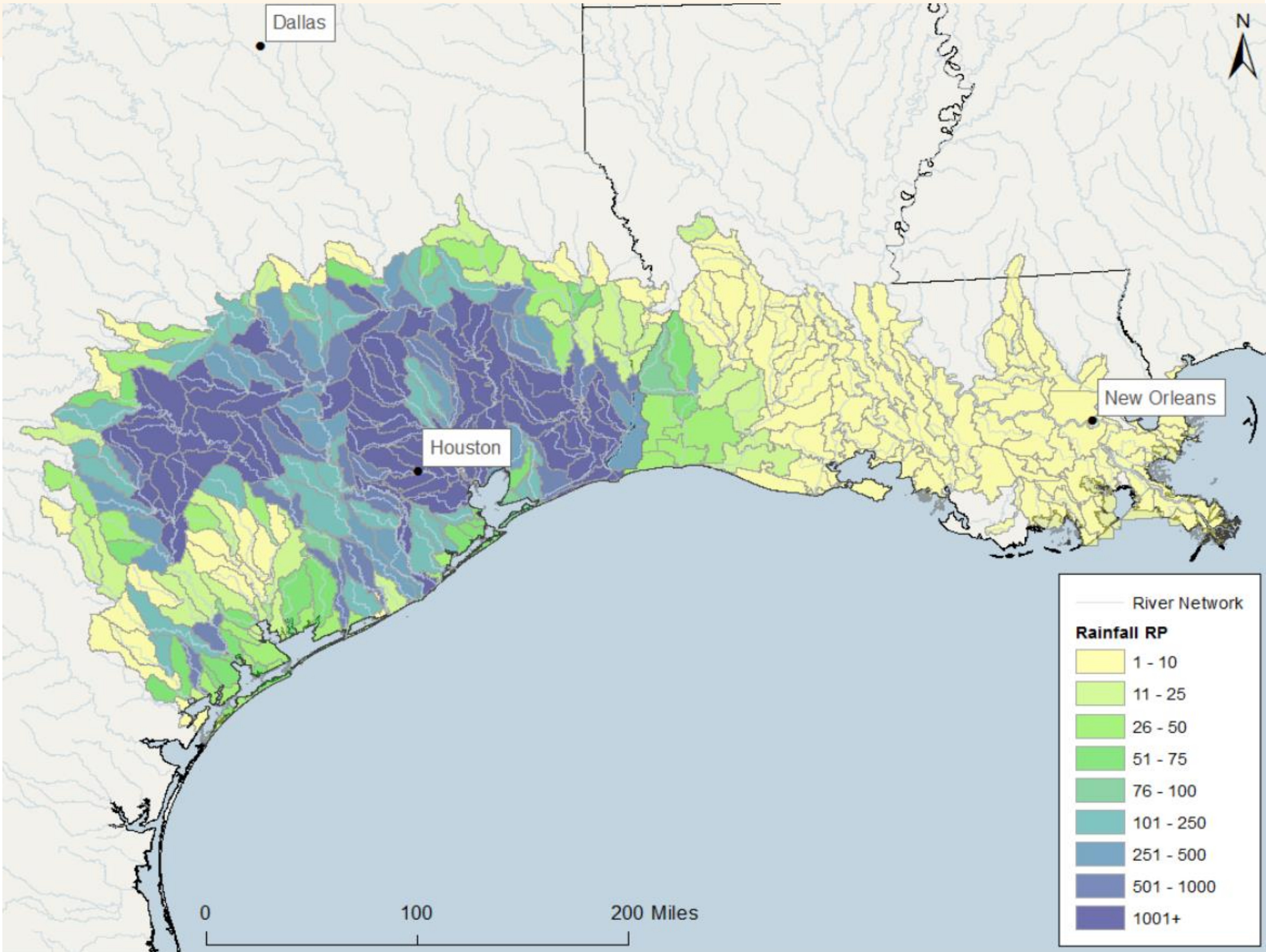
Fatalities: 75

Econ. Cost: USD 8.5 bn

2017 Harvey (Houston, TX, US)
Fatalities: 107
Econ. Cost: USD 130 bn

Return Period of rainfall by catchment

- Several catchments had rainfall exceeding 1,000 year RP (return period)
- Houston, max total observed rainfall = 52’’ (1.32m)
- It is a lot? Yes if recorded in ~48h, as average annual rainfall in Houston is 50’’
- Record-breaking for a single tropical storm



What is a “Probabilistic Natural Catastrophe Model”?

LOSS = HAZARD x VULNERABILITY x EXPOSURE

- **Hazard**: How frequently and severely can a location be flooded?

- **Vulnerability**: For a given flood depth, what is the expected damage to a specific property?
  - Stucture
  - Content
  - Business Interruption
- **Exposure**: The cost of repairing or replacing the damaged parts.

Correlation: What is the probability that when Building A is flooded, Buildings B and C are also flooded?
Correlation significantly influences total losses.

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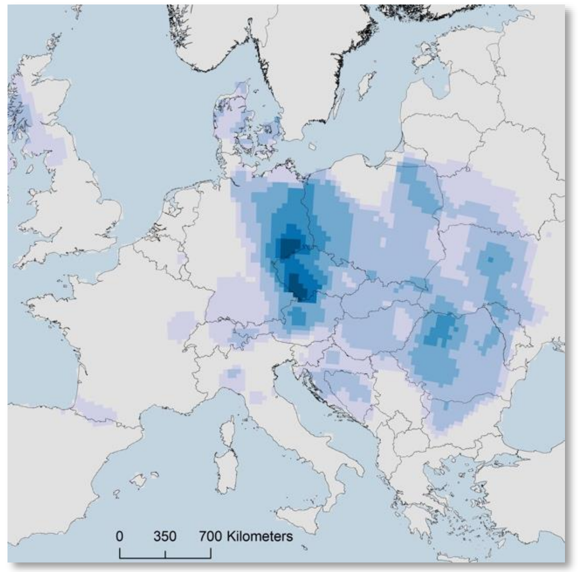
CATASTROPHE MODELING FRAMEWORK



Stochastic Event Module

Define precipitation /streamflow discharge

Hazard Module

Assess local severity (water depth)

Vulnerability Module

Calculate Damage

Exposure Module

Apply Exposure

Financial Analysis Module

Quantify Financial Loss

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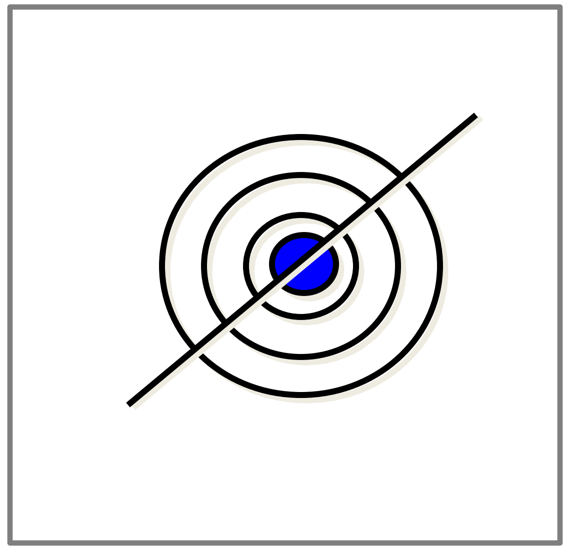
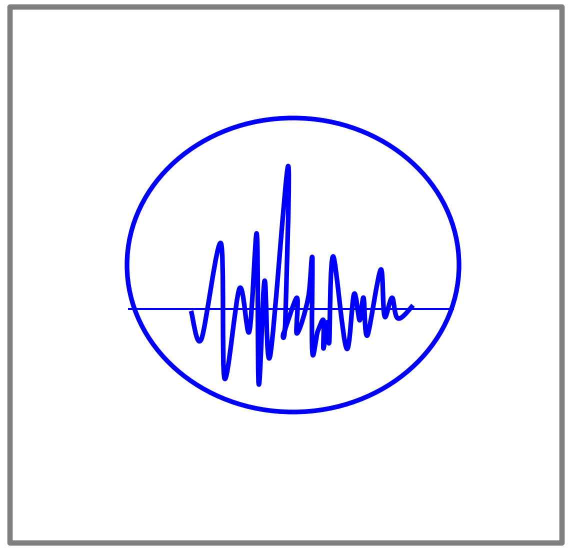
AND HOW THIS WOULD LOOK LIKE FOR QUAKE RISK?



Stochastic Event Module

Define source location, magnitude, depth



Hazard Module

Assess local severity: Spectral or peak ground acceleration

Vulnerability Module

Calculate Damage

Exposure Module

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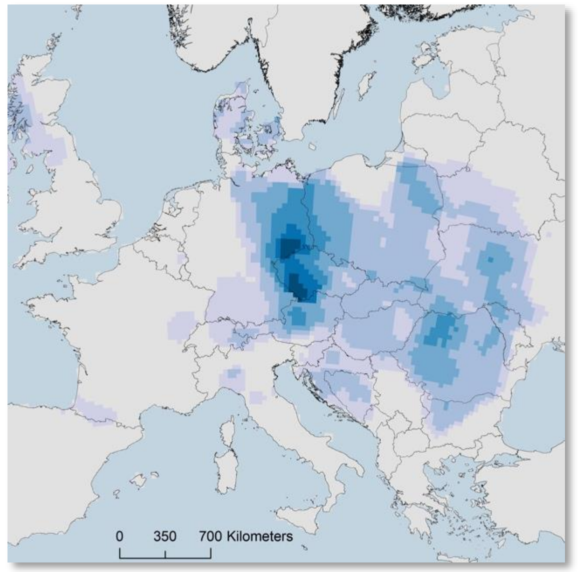
STOCHASTIC AND HAZARD MODULES (FLOOD)



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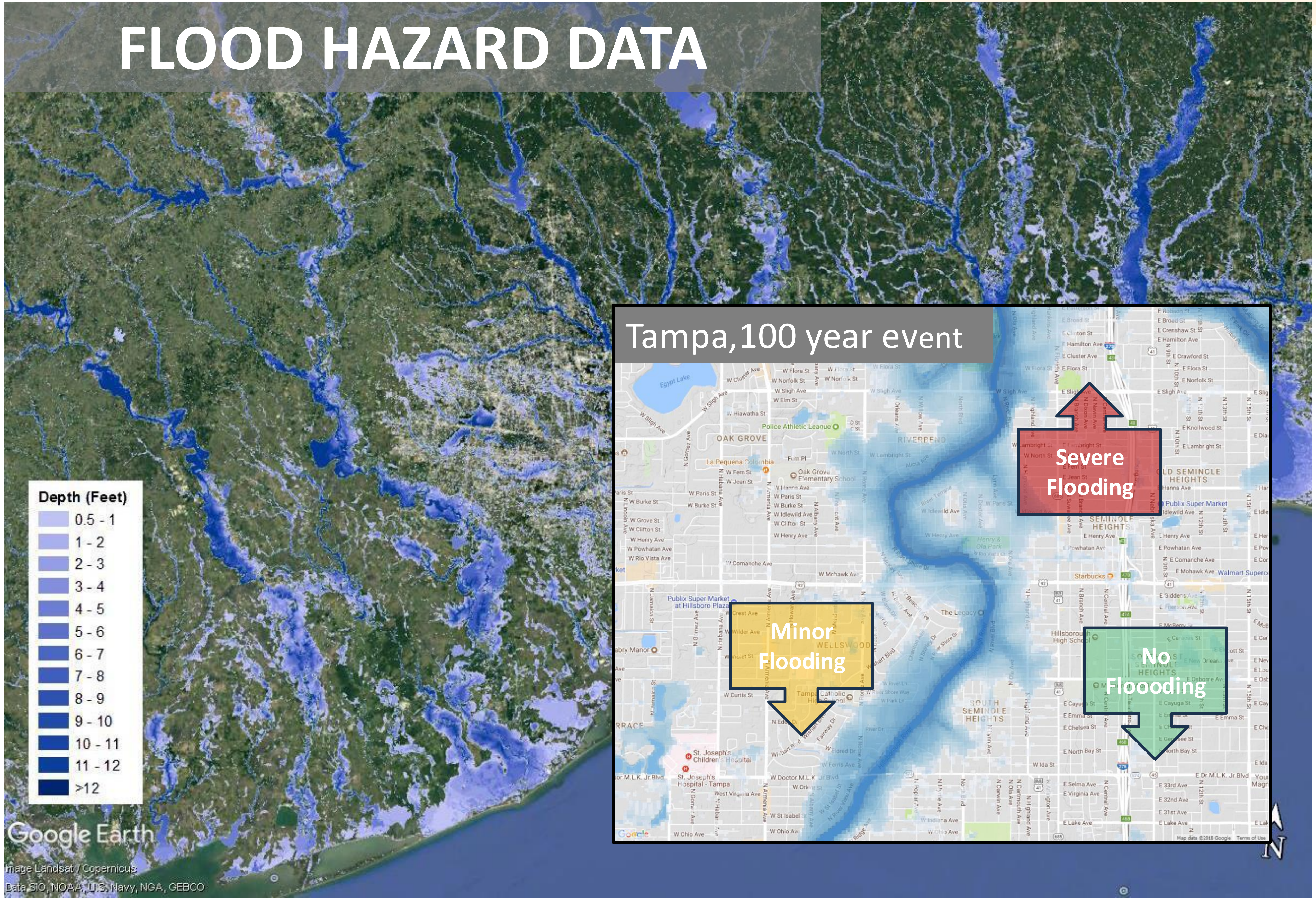
HAZARD MODULE - FLOOD



Is a property at risk of flooding?

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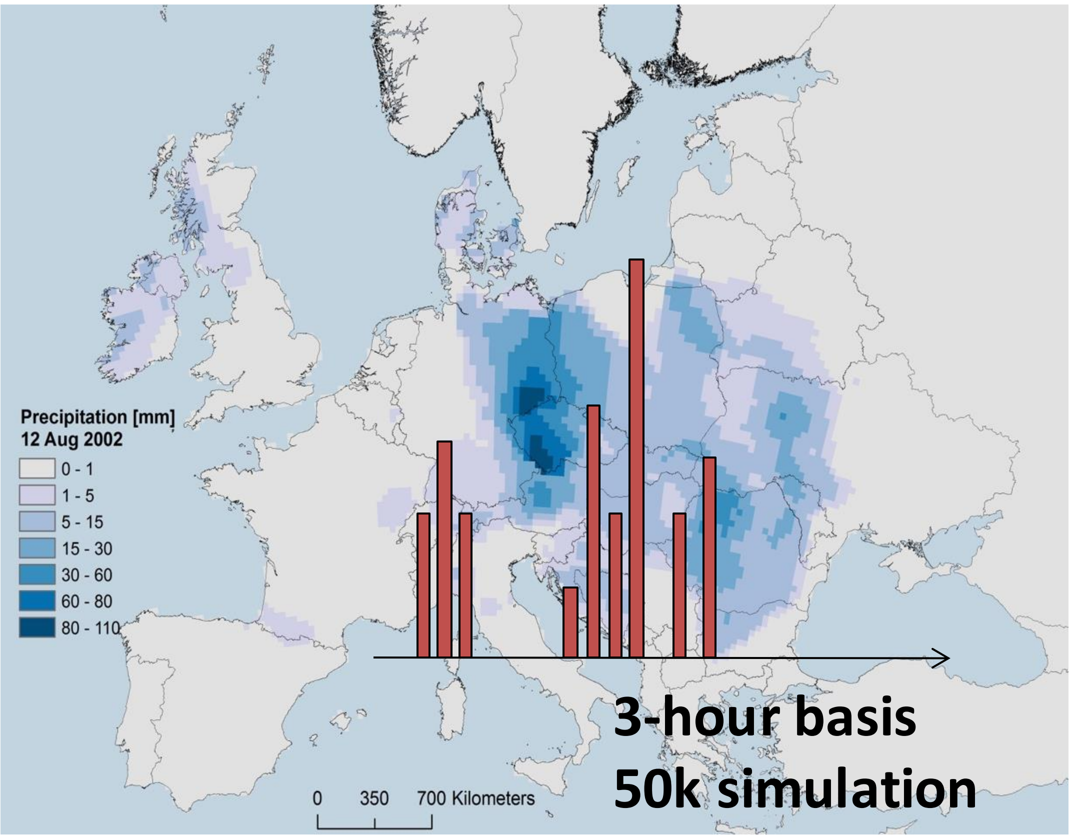
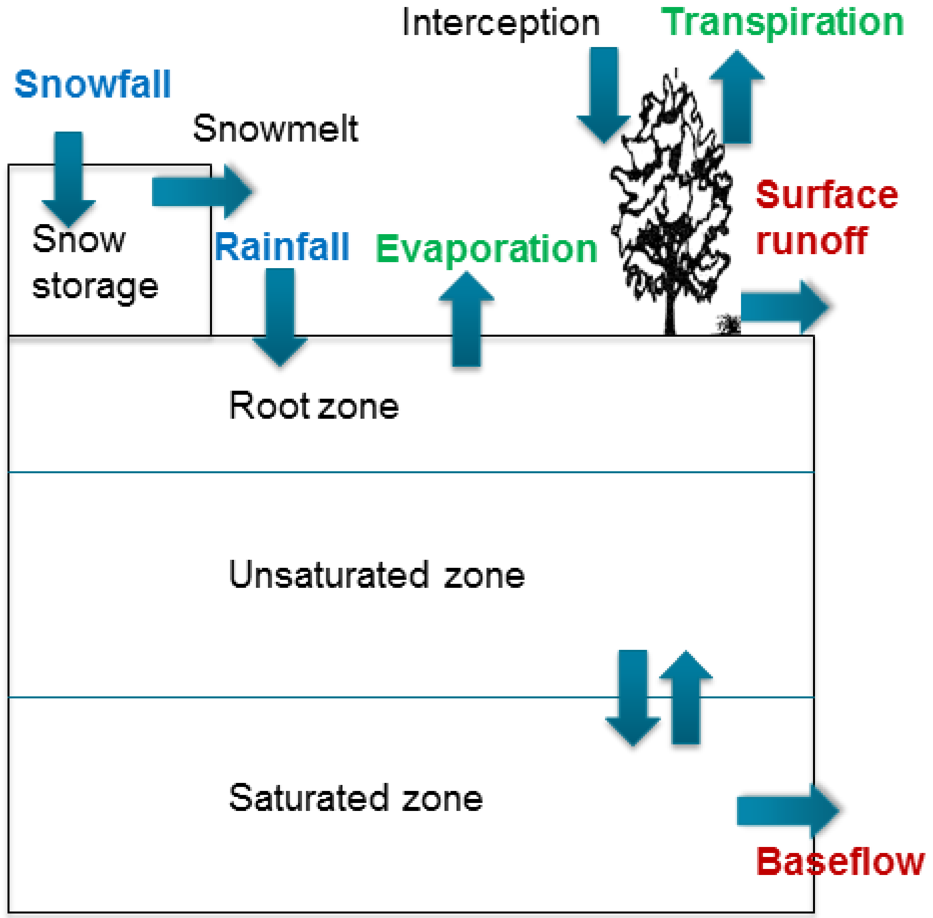
A COMPLETE MODELLING OF FLOOD RISK PROCESSES

Precipitation simulation
(seasonality, clustering)



Hydrological modelling
(antecedent conditions)



Flood modelling

Precipitation ❯ Rainfall Runoff ❯ Routing ❯ Defense ❯ Inundation

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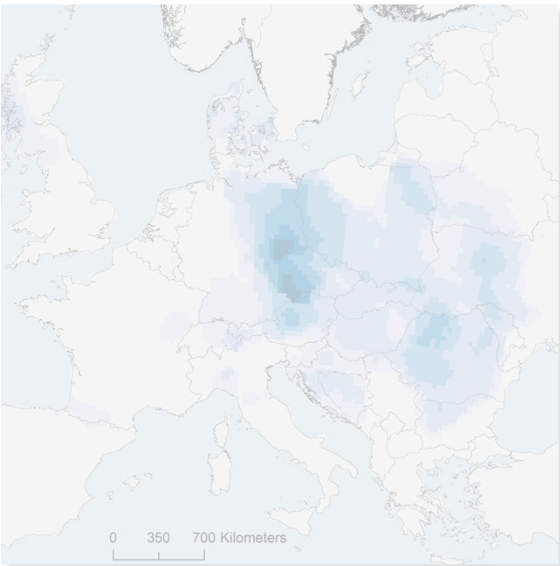
VULNERABILITY MODULE (FLOOD)



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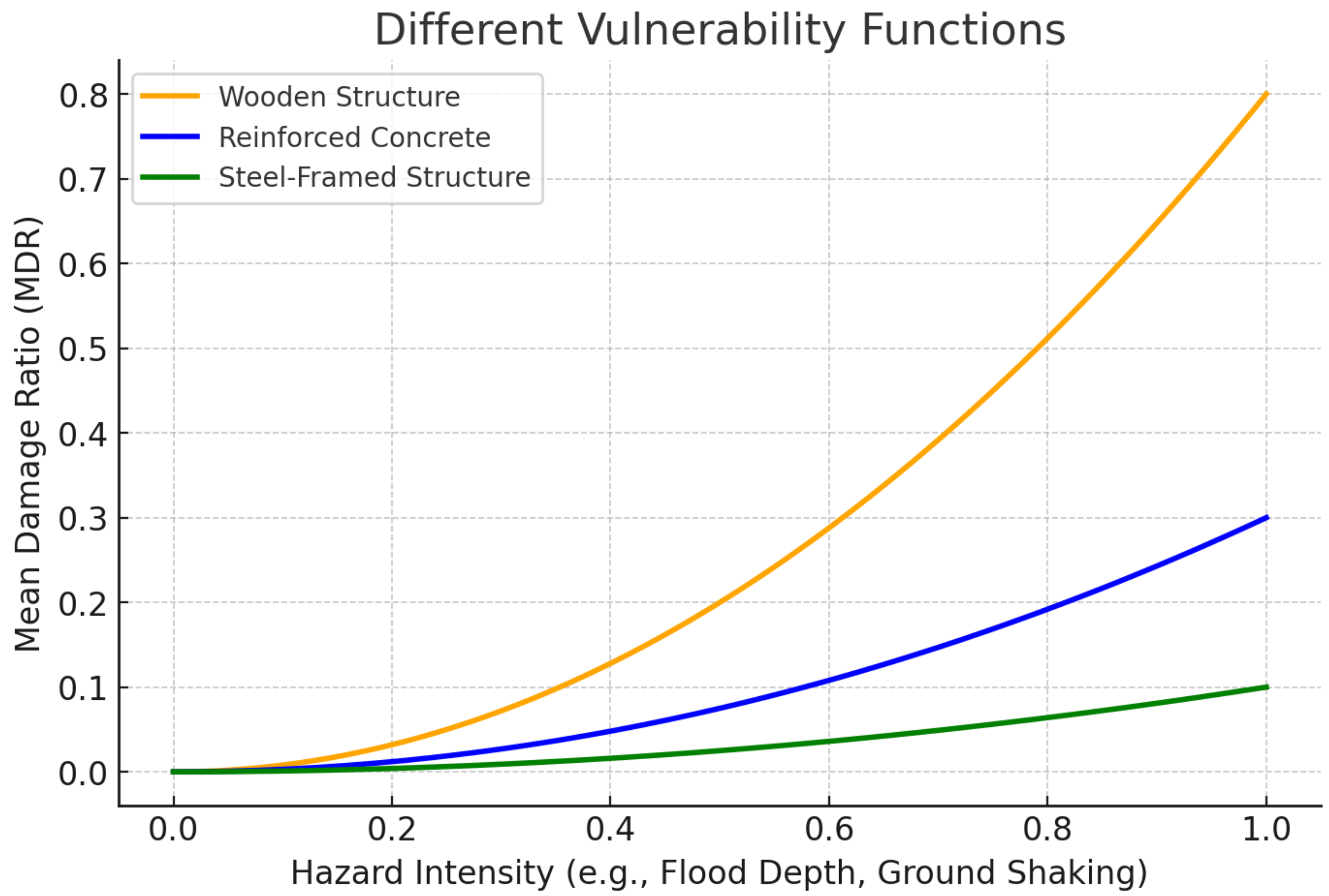
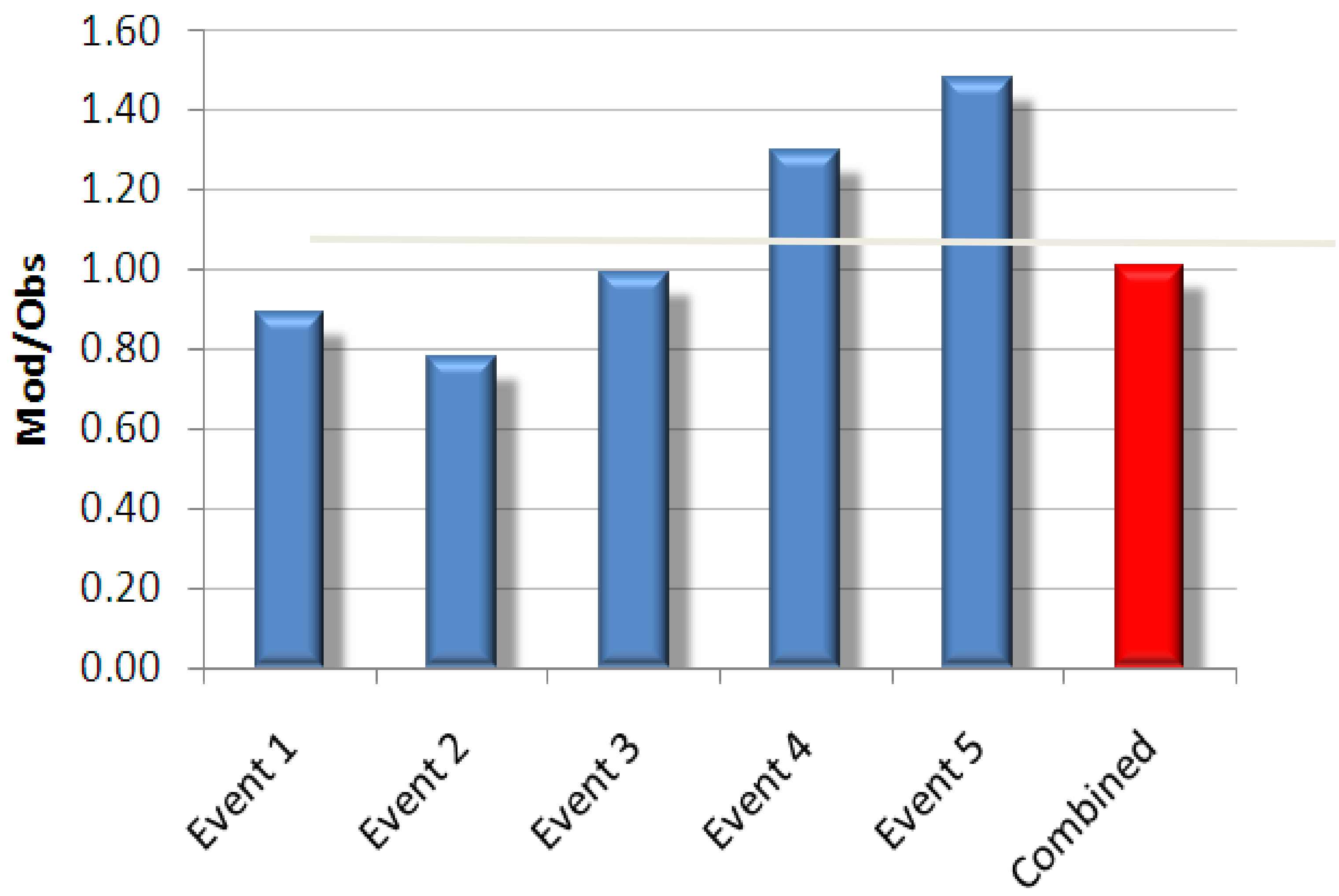
VULNERABILITY CURVES AND EMPIRICAL CALIBRATION



Modelled / Observed by Client / Event



Mean Damage Ratio (MDR)

$$MDR = \frac{\textit{Expected Cost of Damage}}{\textit{Replacement Value of Asset}}$$

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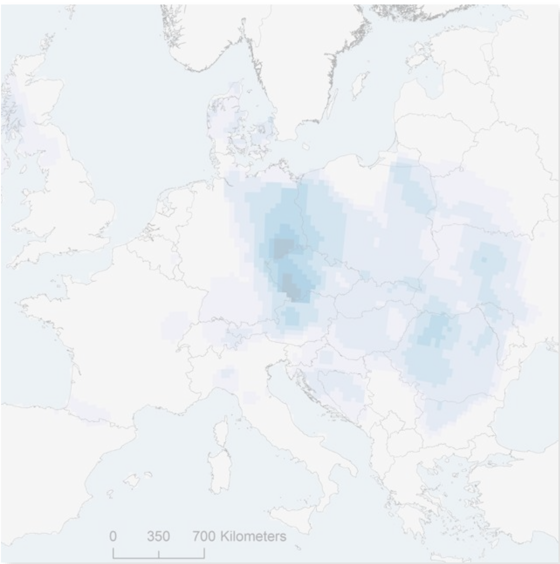
EXPOSURE MODULE



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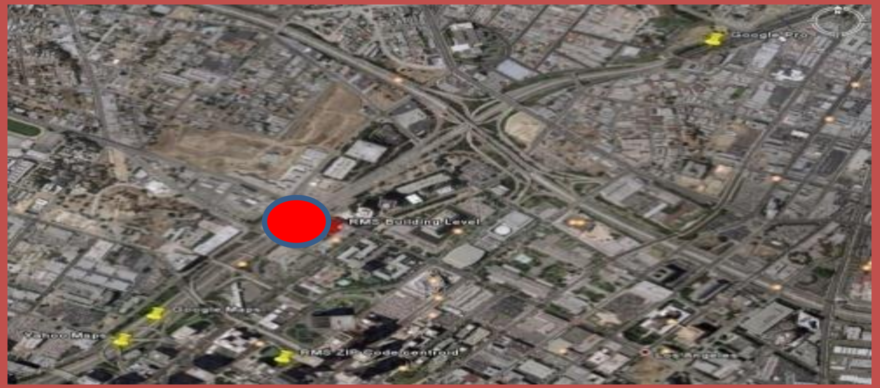
EXPOSURE: WHAT DOES A MODEL NEED?



Location / Address

Replacement Value and Insurance Information

+ other information, e.g., number of stories, age of the building, ...

Occupancy Type

Construction Type

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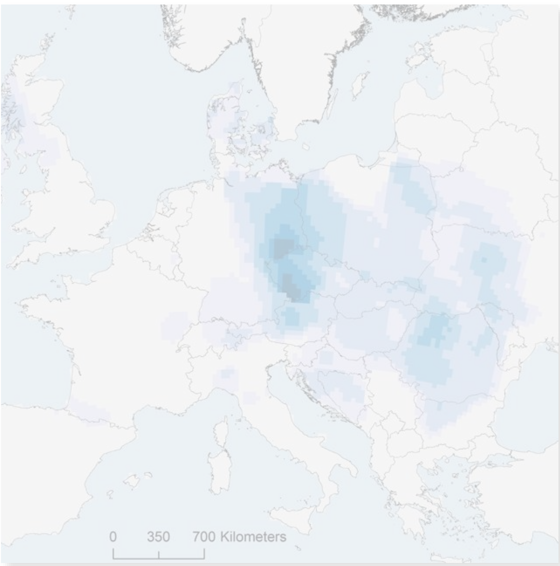
FINANCIAL ANALYSIS MODULE



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FINANCIAL ANALYSIS MODULE

Once we have calculated the Mean Damage Ratio (MDR), we evaluate the mean Ground Up (GU) loss using:

Mean Loss = MDR * Total_Replacement_Value

Ground Up Loss (GU): loss before any financial structure applies

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Physical Vs Financial Resilience

CAT MODEL DESIGN FOR TOTAL RESILIENCE MANAGEMENT

Total Resilience = Physical Resilience (Defenses) + Financial Resilience (Insurance)

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PHYSICAL RESILIENCE

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PHYSICAL RESILIENCE

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PHYSICAL RESILIENCE

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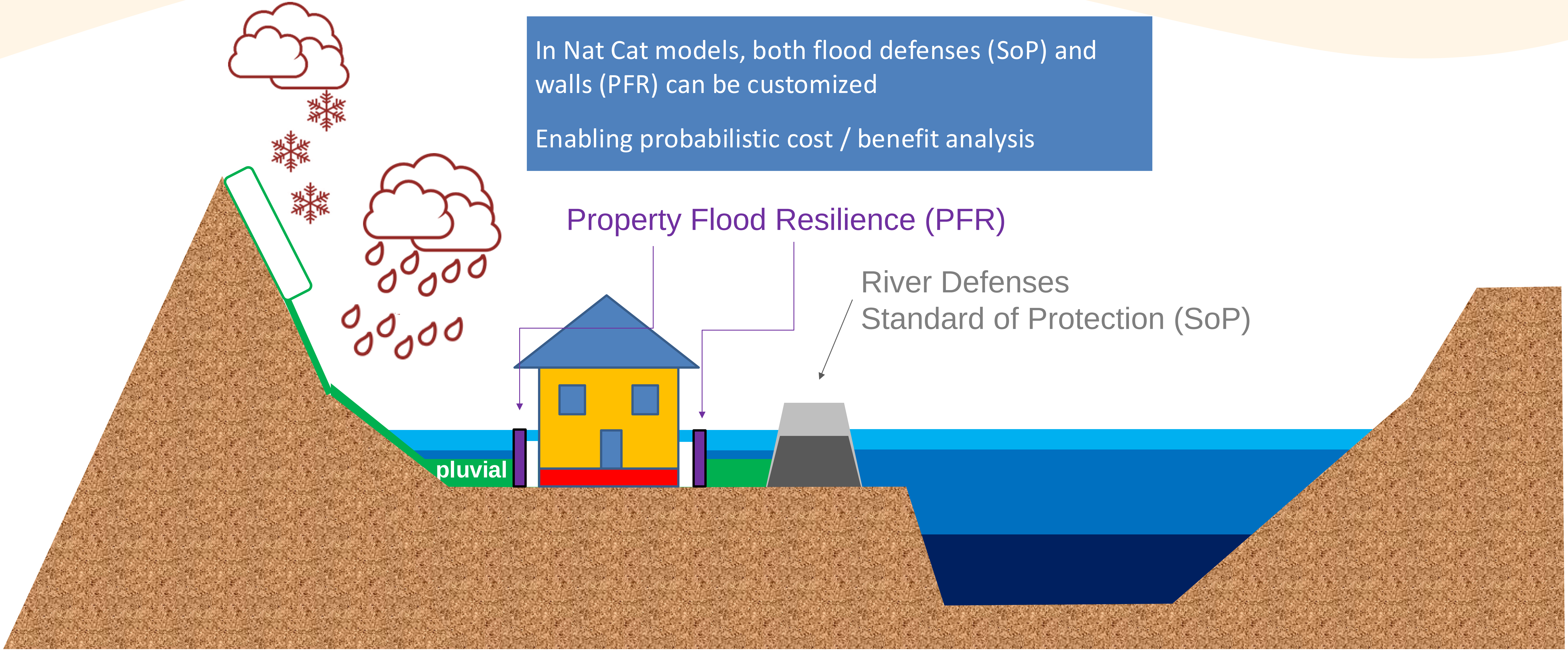
UNDERSTANDING FLOOD PROTECTION PERFORMANCE

In Nat Cat models, both flood defenses (SoP) and walls (PFR) can be customized

Enabling probabilistic cost / benefit analysis



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FINANCIAL RESILIANCE - Insurance Industry & Risk Transfer

Policy holders

Buy protection, i.e. transfer risk to insurers

UnipolSai ASSICURAZIONI

ZURICH INSURANCE

GENERALI

Insurers

Keep part of the risk, cede the rest to reinsurers

Munich RE

Swiss Re

ASPEN RE

Reinsurers

Keep part of the risk, transfer the rest to financial market

CREDIT SUISSE

UBS

Financial market

Investors buy part of the risk (uncorrelated risk = diversification)

GUY CARPENTER

AON BENFIELD

Willis Towers Watson

Reinsurance Brokers

Facilitate risk transfer

Independent models to quantify risk, used as currency along risk chain

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Strengthening Financial Resilience to Natural Catastrophes

Challenges:

- **Developed countries** have established systems to manage catastrophe risks.
- **Developing countries** face limited resources, leading to greater losses and slower recovery.

Solutions:

- Adoption of **Probabilistic Cat Models** and **consistent risk auditing methods** can help design cost-effective policies to enhance resilience.
- International institutions, like the UN, are driving global collaboration to address these challenges.

Strengthening Financial Resilience to Natural Catastrophes

Key Global Frameworks:

- **The Sendai Framework for Disaster Risk Reduction (2015):**

  Signed by 180 countries, this voluntary, non-binding agreement emphasizes shared responsibility for disaster risk reduction between governments, businesses, and communities.

  Focus: Substantial reduction in disaster risks and losses in lives, livelihoods, and critical assets.

- **Agenda 2030 for Sustainable Development (2015):**

  Integrates disaster resilience into its global development goals.

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Conclusion

Take-aways

What are probabilistic natural catastrophe models?

They provide a more comprehensive understanding of risk by extending analysis beyond historical records

What is financial resilience to natural catastrophe?

It is the ability to build more sustainable societies and economies

What is the role of the insurance industry?

It provides financial resilience enhancing the capacity to recover from catastrophic events

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THANK YOU!

CONTACTS:

ADDITIONAL LINKS:

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