Asian Actuarial Conference 2025 Bangkok

Enhancing Population Health Resilience to Climate Risks

12 Nov | 15:20-16:00

R. Dale Hall

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Enhancing Population Health Resilience to Climate Risks

Improving Disaster Resilience in ASEAN

An Open Statistical Toolkit to Modeling Natural Catastrophe Risk

R. Dale Hall, FSA, MAAA, CERA, CFA

NOV | 2025

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Climate Change and Health

- WHO has been working on climate change and health for over 25 years
- Advocating, collecting evidence and providing comprehensive support to countries in dealing with health effects of climate change.
- SOA Research Institute
  - Catastrophe and Climate Research Program
  - Health Care Cost Trends Research Program

World Health Organization

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Climate Change and Health

- Research on the health impacts of hurricanes
- Immediate risks: drowning and injury
- Long-term effects:
  - Lack of access to healthcare
  - Contaminated water
  - Stress
  - Carbon Monoxide
  - Mold
- Increased hospitalizations for cardiovascular issues, higher emergency room visits for conditions like diabetes, and adverse health outcomes in the weeks and months following a hurricane

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Climate Change and Health

- R

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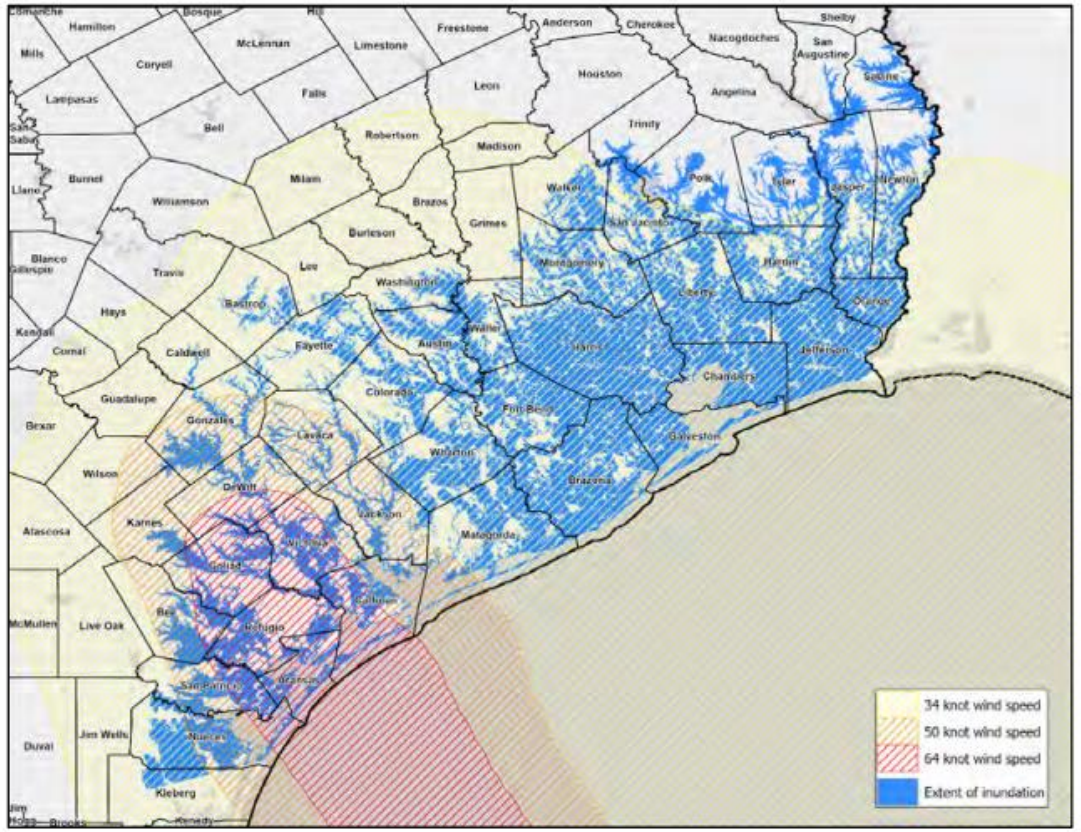
Health and Hurricanes

Diversity, Equity and Inclusion

Catastrophe and Climate

Studying Disparate Health Impact of Extreme Climate Events, 2017-2020

COMPARISON BETWEEN WIND SWATH LAYERS AND FEMA INUNDATION LAYERS (FIGURE 3)



https://www.soa.org/48f109/globalassets/assets/files/resources/research-report/2022/health-hurricanes-studying-impact.pdf

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Climate Change and Health

- Climate-transformative leadership and governance
- Climate-smart health workforce
- Assessment of climate and health risks and GHG emissions
- Integrated risks monitoring, early warning, and GHG emissions tracking
- Health and climate research
- Climate-resilient and low carbon infrastructures, technologies, and supply chain
- Management of environmental determinants of health
- Climate-informed health programmes
- Climate-related emergency preparedness and management
- Sustainable climate and health financing

World Health Organization

Presentation Outline

- Background and motivation
- Data
- Exploratory analysis
- Proposed modeling framework
- Ongoing work

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Background of the Project

- An SOA-funded research project
- Led by a team of academic researchers
- Advised by a Project Oversight Group of experienced practitioners
- A strong example of academia–industry collaboration

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Background of the Research

- ASEAN countries sit in a disaster-prone region:
  - 2011 Thailand floods (Thailand; **US$10 billion**)
  - 2013 Typhoon Haiyan (Philippines; **US$2.99 billion**)
  - 2020 Central Vietnam floods (Vietnam; **US$1.57 billion)**
  - 2024 Typhoon Yagi (Philippines, Thailand, Vietnam, etc; **US$3.3 billion**)
  - 2025 Myanmar Earthquake (Myanmar; **US$11 billion**)

- Factors intensifying impacts:
  - Climate change
  - Dense populations
  - Rapid urbanization
  - Varying levels of infrastructure resilience

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Motivation

NAT CAT models support decision-making:	Commercial platforms:	Common limitations:
• Insurance industry • Regulatory authorities • Public sector agencies	• Moody's RMS • AIR Worldwide • Aon Impact Forecasting • KatRisk, etc.	• Limited transparency for trust building • Difficult to incorporate with local data • High financial costs and specialized expertise requirements for small insurers or policy-making agencies

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Goals

- Building an open statistical framework for modeling NAT CAT risk in ASEAN countries.

- Emergency Events Database (EM-DAT):
  - A **publicly available multi-peril** disaster database
  - Since 1900 and systematically since 1988
  - Meeting at least one criterion:
    - ≥ 10 fatalities
    - ≥ 100 people affected
    - state of emergency

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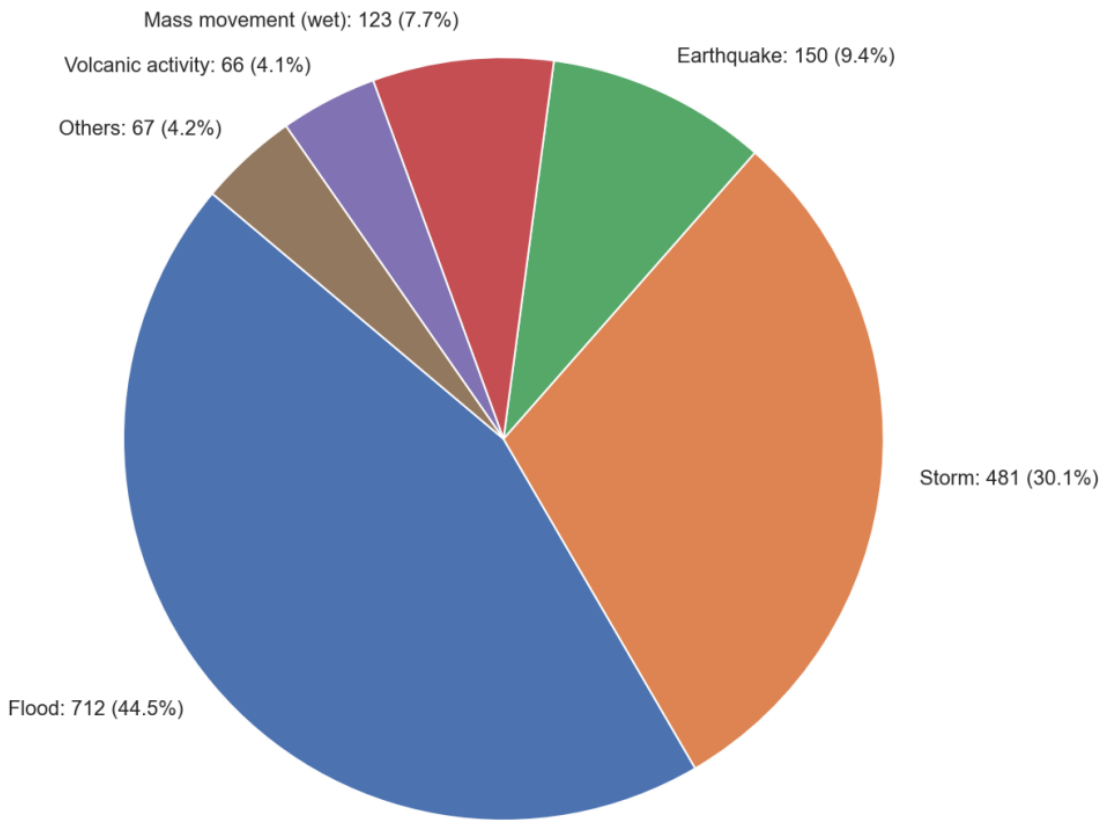
Frequency of Disaster Types

- Most frequent disasters:
  - Floods
  - Storms
  - Earthquakes

- Together: Above 83% of total events



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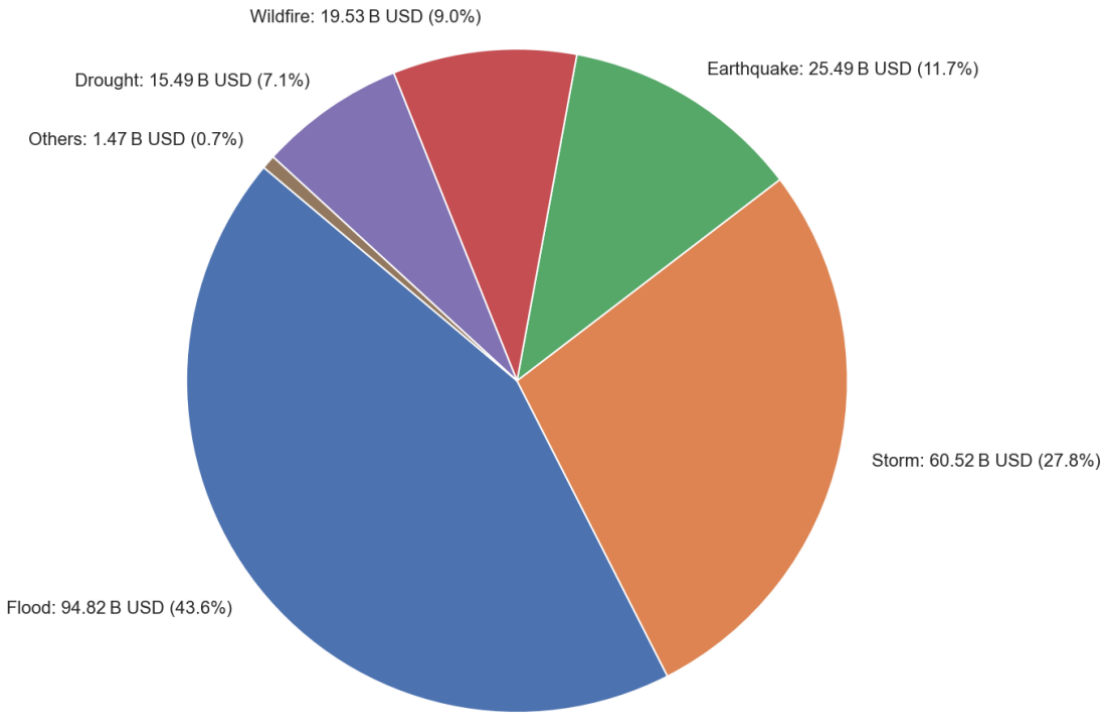
Total Damages of Disaster Types (CPI Adjusted)

- Most severe disasters:
  - Floods
  - Storms
  - Earthquakes

- Together: About 86% of total events

- The top 3 most frequent disaster types cause the greatest financial damage



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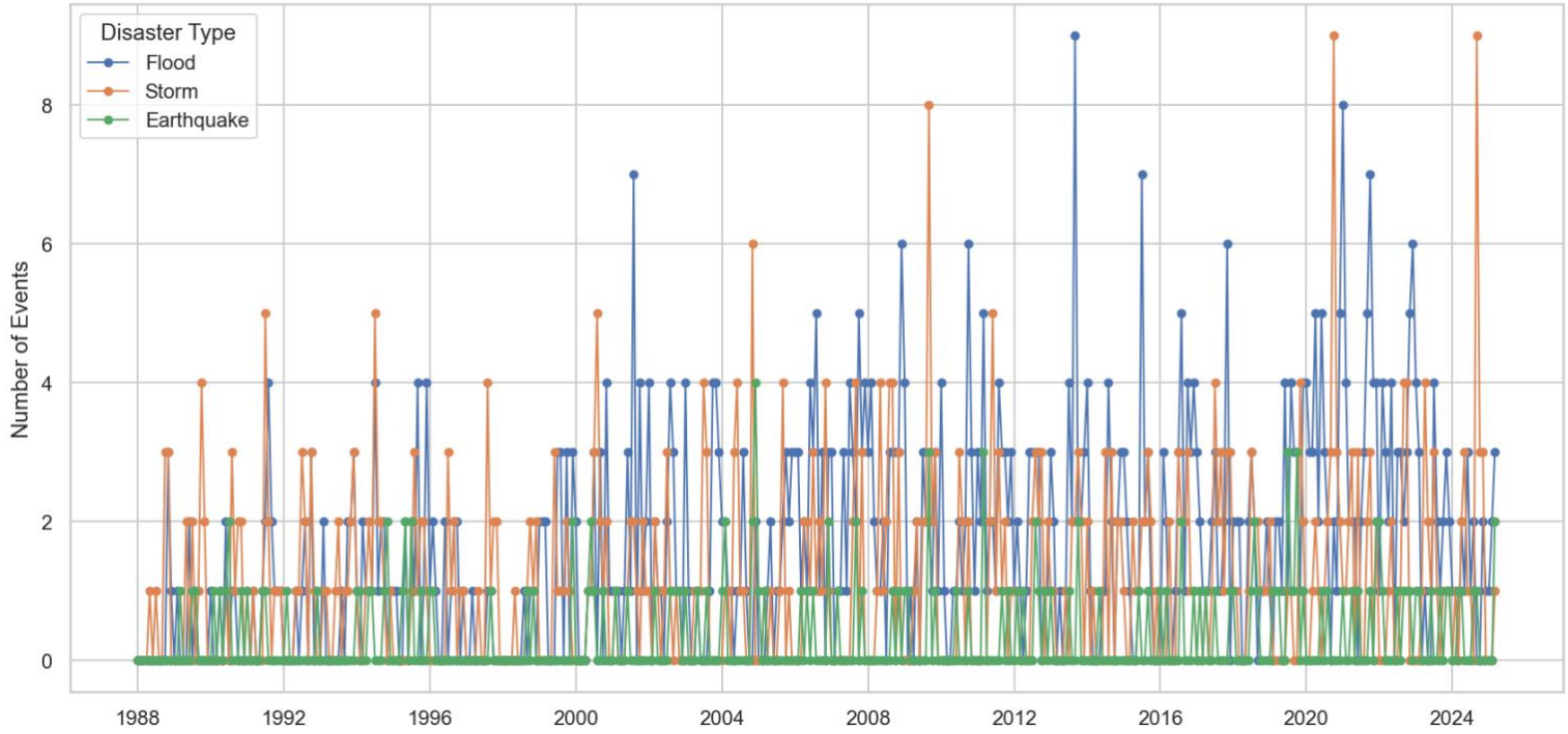
Trends in Disaster Frequency (Monthly)

Floods and storms appear to be becoming more frequent

Earthquakes have shown a consistent frequency overtime



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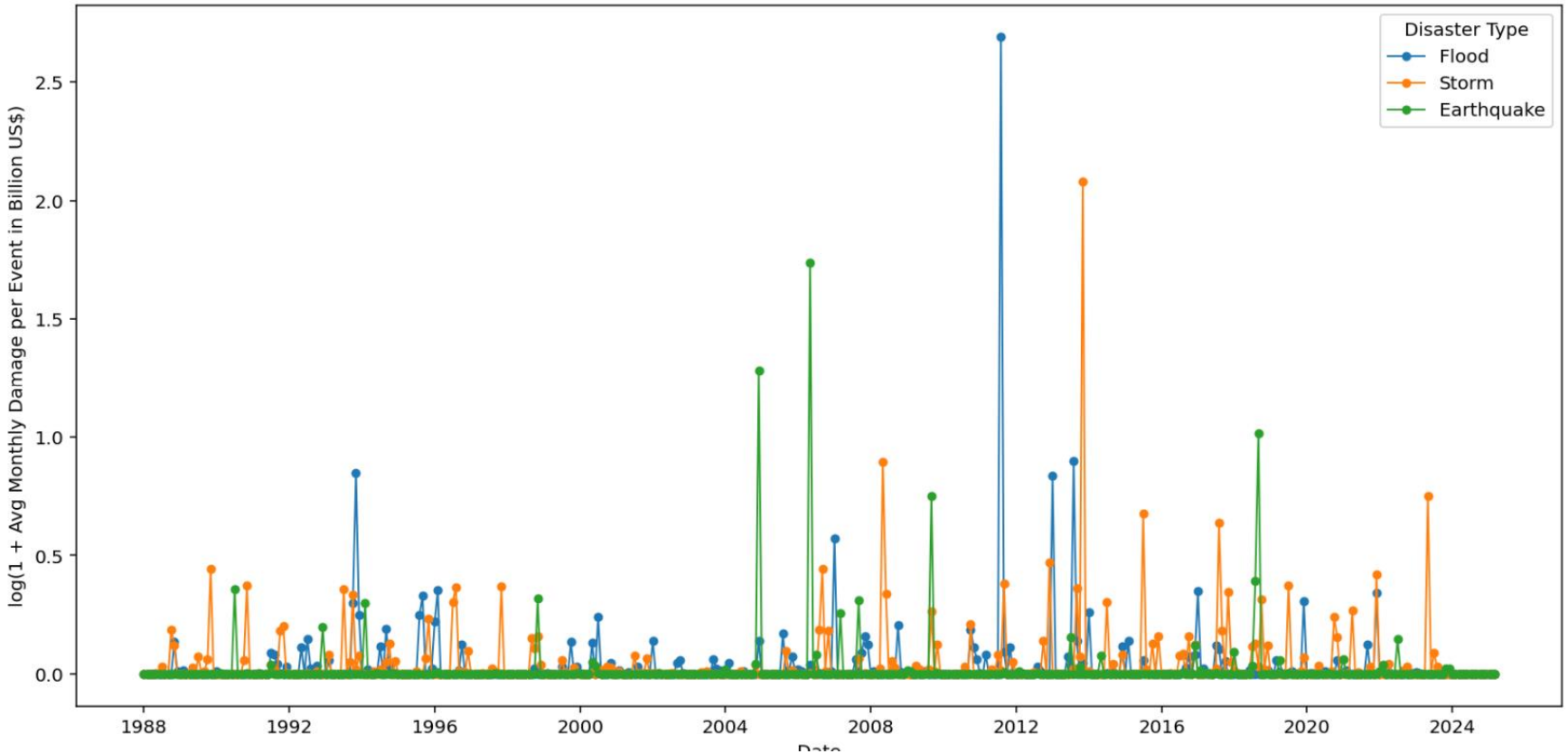
Trends in Disaster Severity per Event

Extreme disasters are occurring more often and with greater severity.



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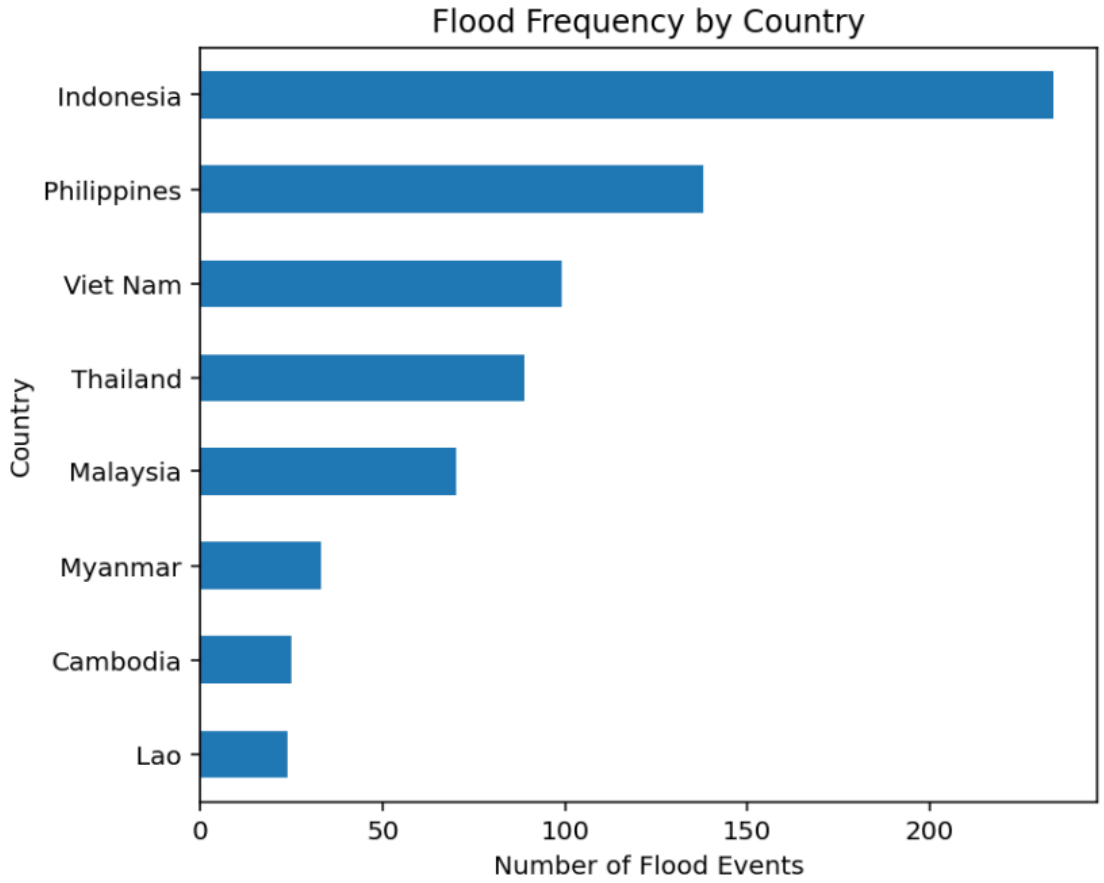
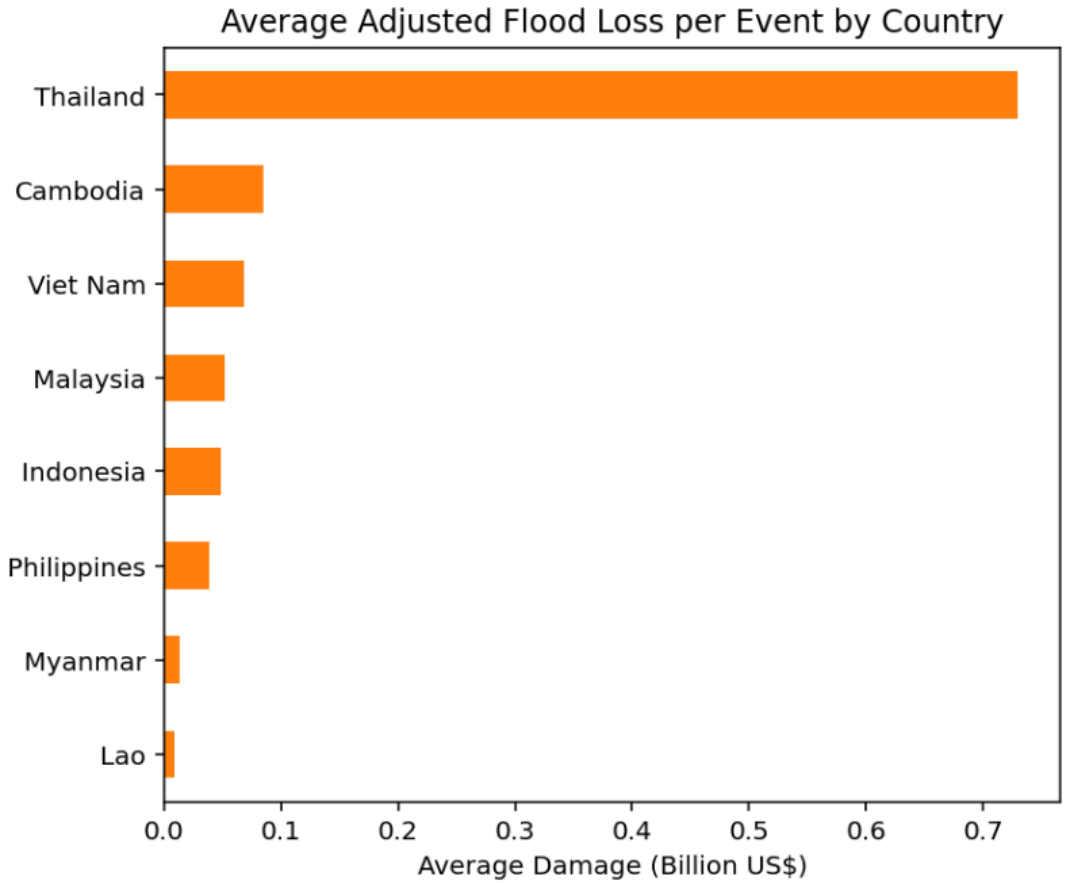
Country-Level Breakdown: Flood Events





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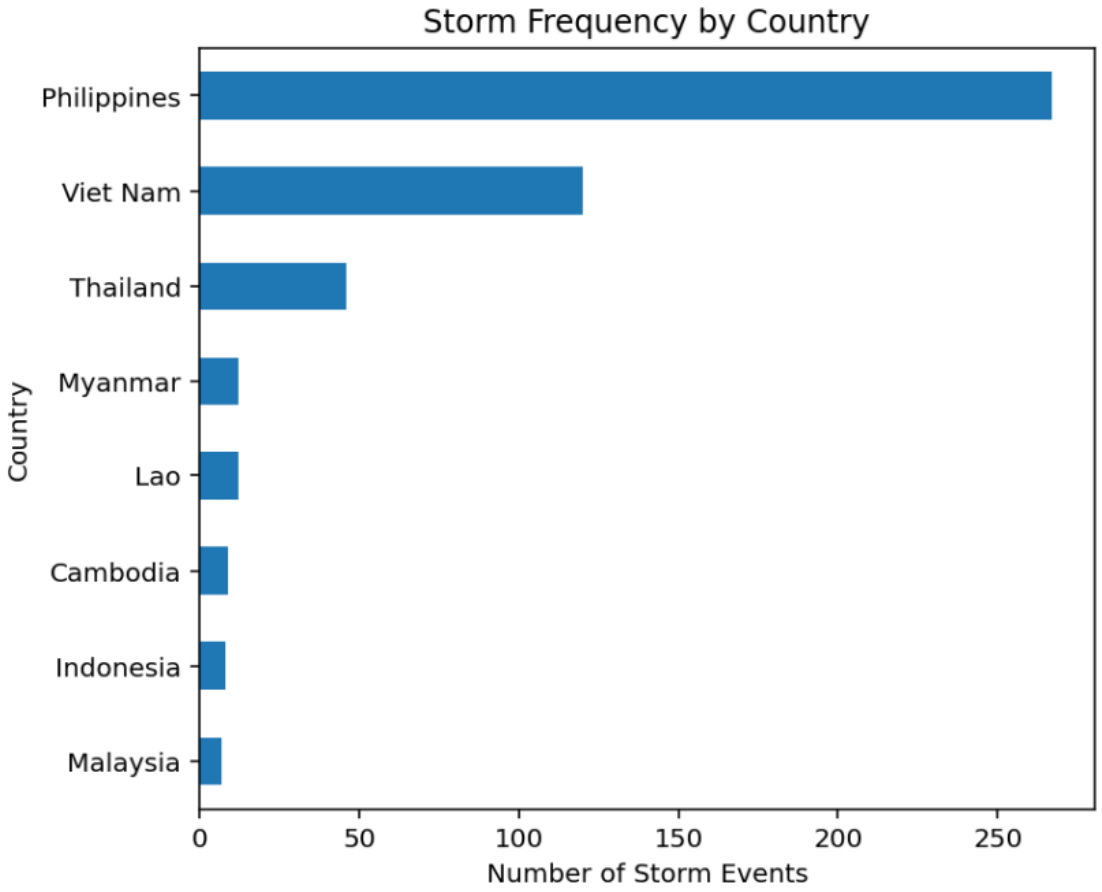
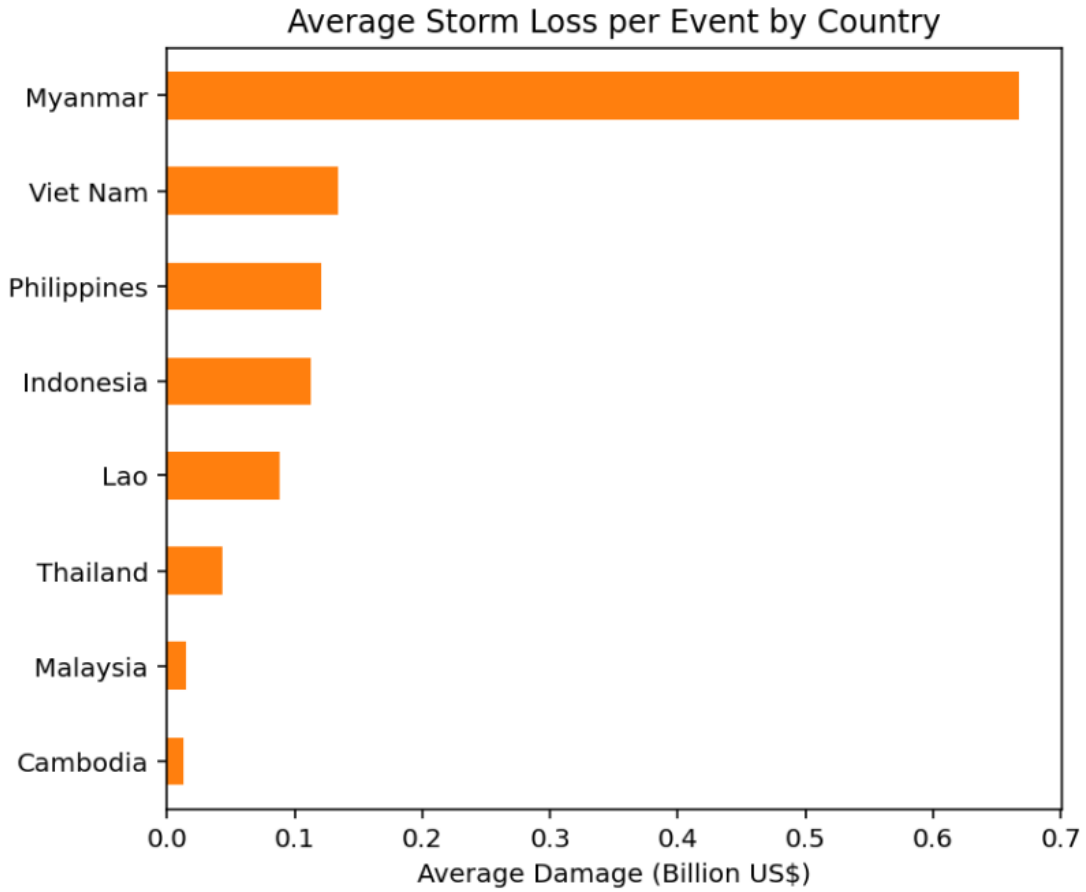
Country-Level Breakdown: Storm Events





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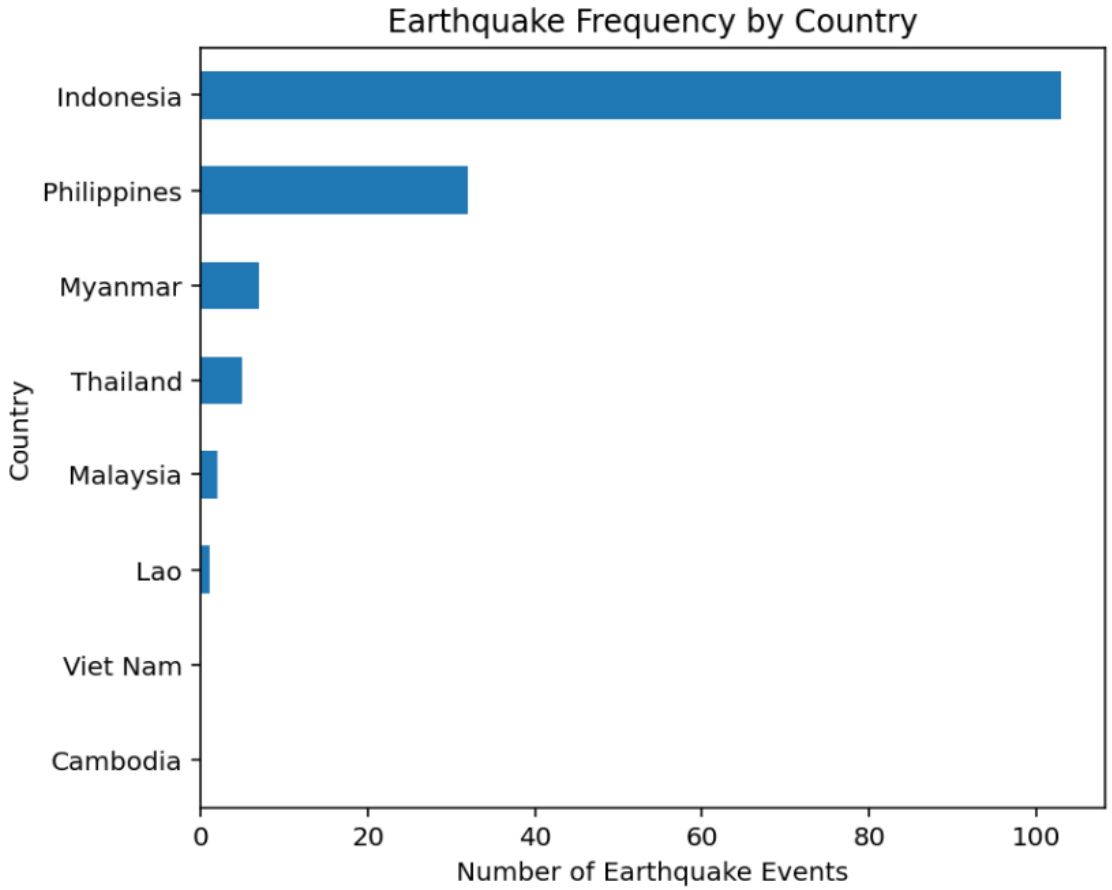
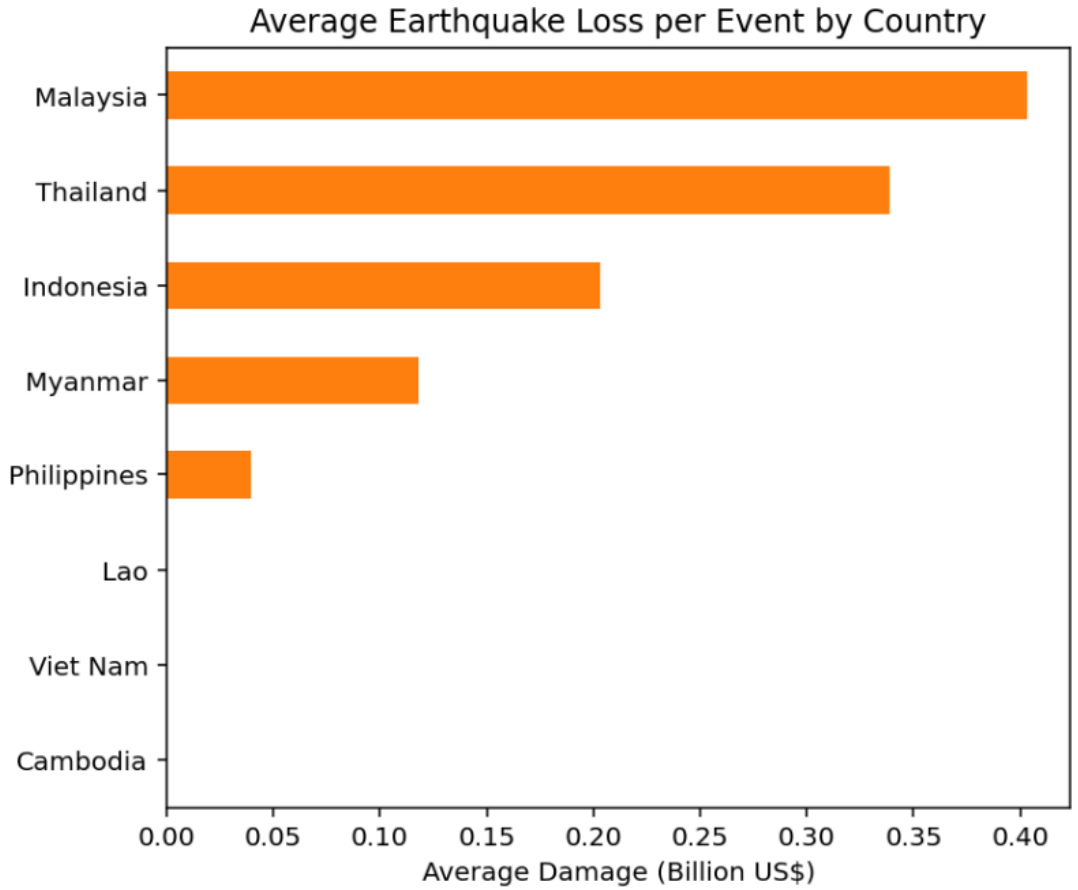
Country-Level Breakdown: Earthquake Events





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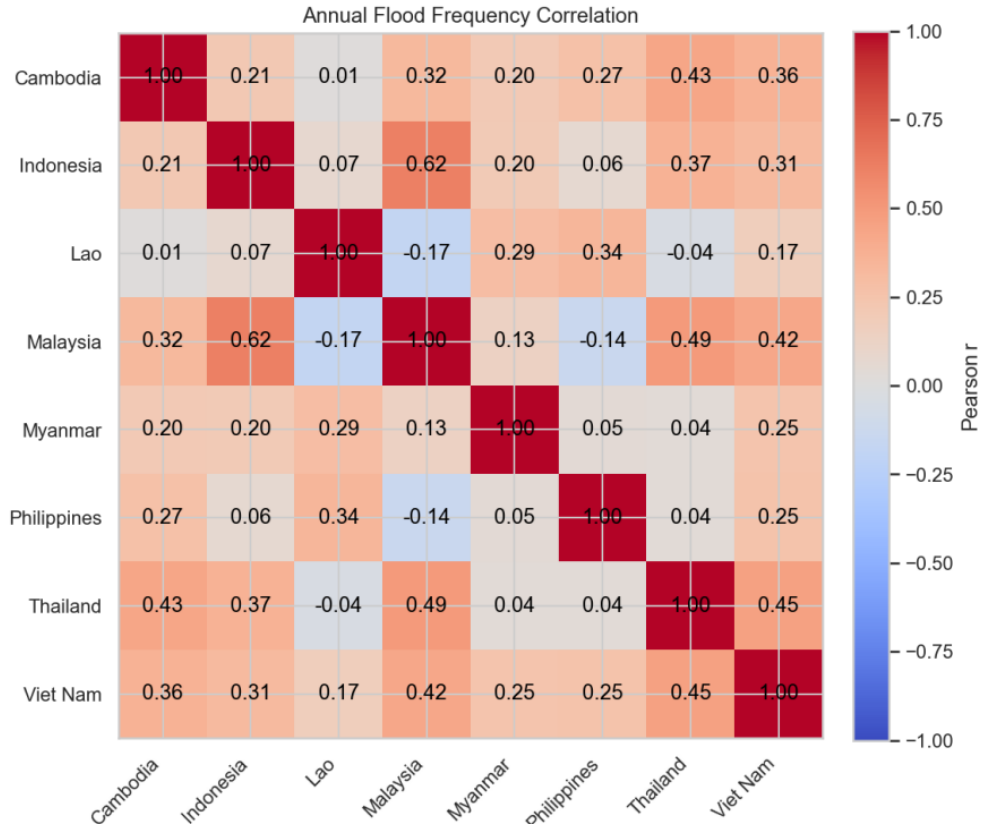
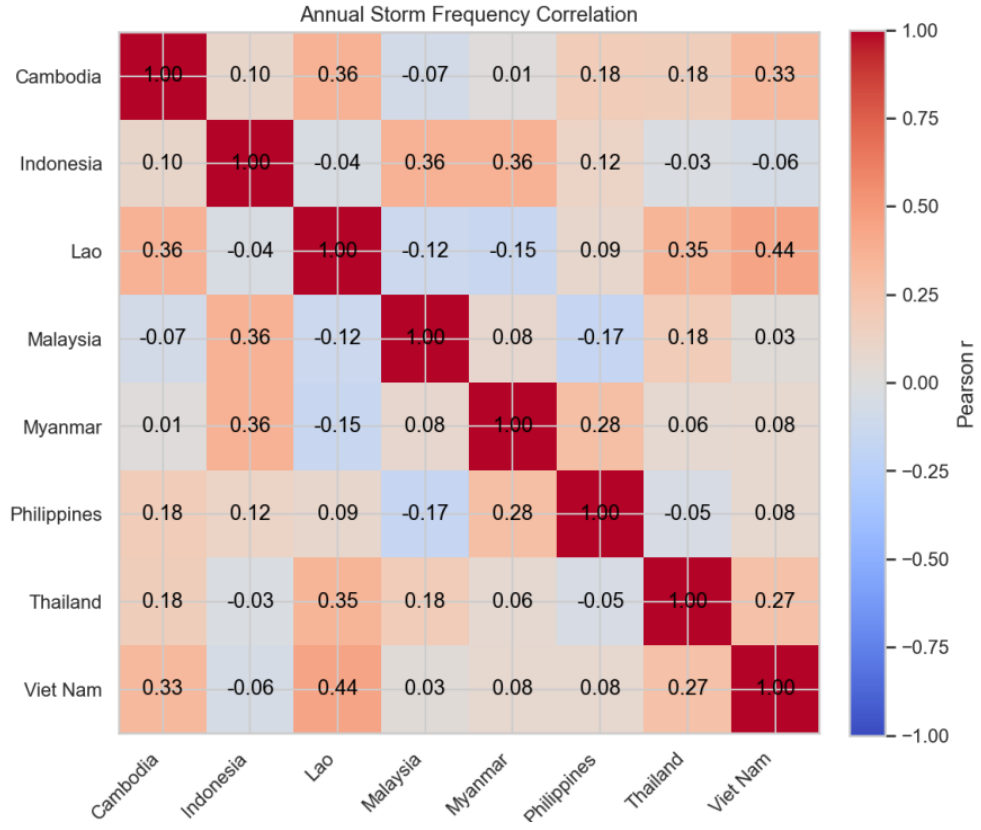
Spatial Dependencies





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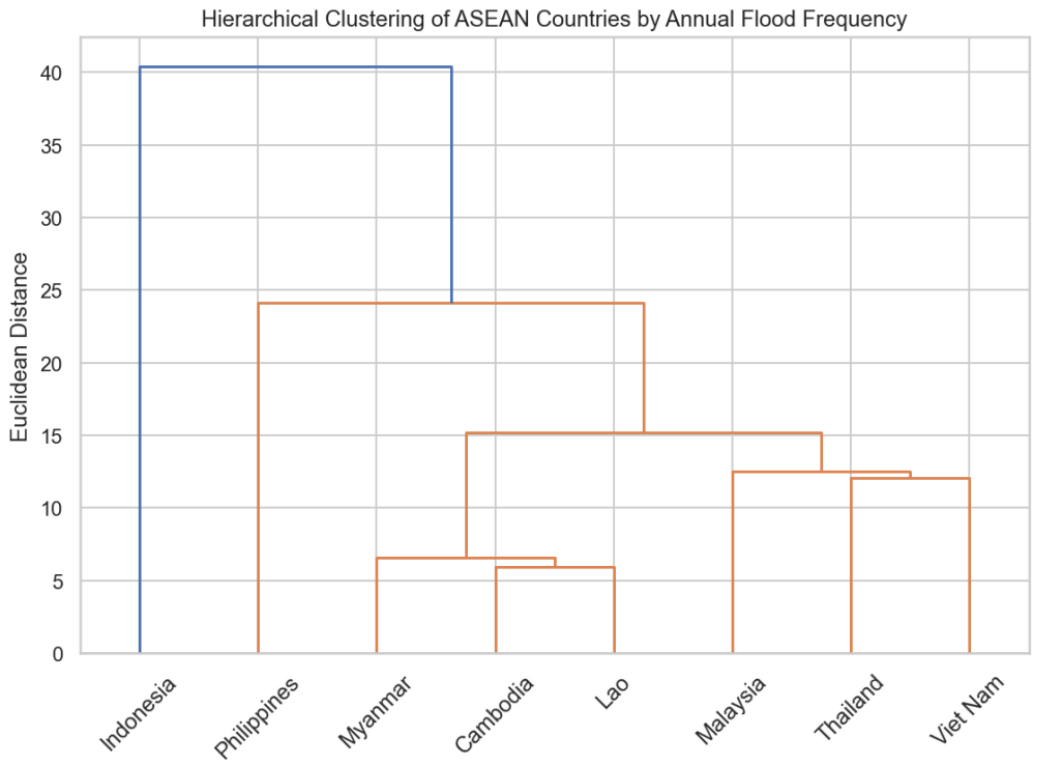
Spatial Clusters: Flood Frequency



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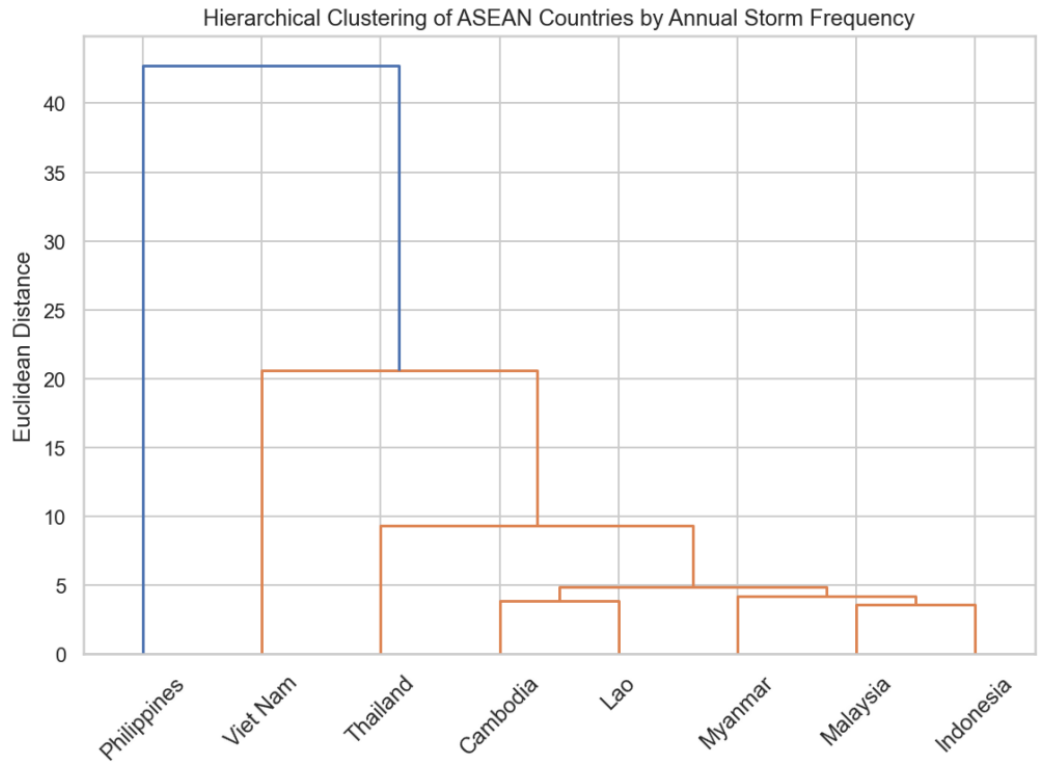
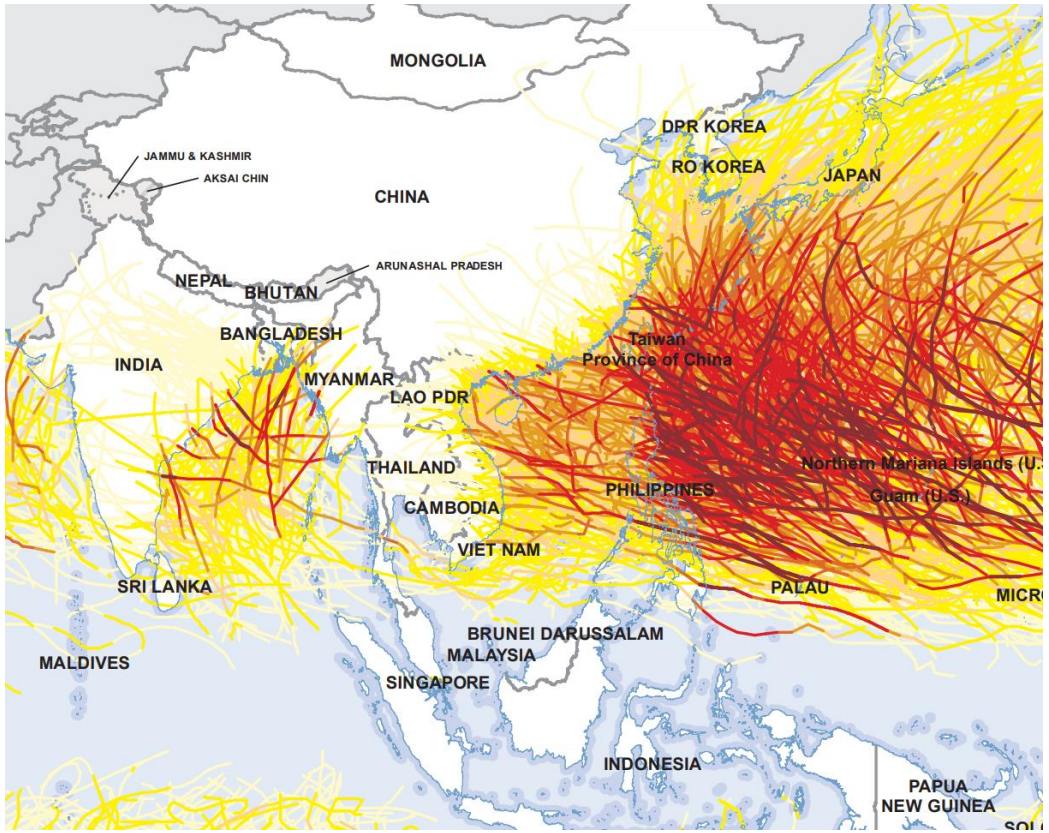
Spatial Clusters: Storm Frequency





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Takeaways for Model Building

Risk profiles vary significantly across countries.
Each country requires models tailored to its own data characteristics.

Country-specific calibration is essential.
Localized models better capture unique hazard patterns and vulnerabilities.

Joint modeling can enable spatial data sharing.
Estimating models jointly allows for borrowing strength across countries where appropriate.

Frequency and severity rankings may differ.
The most frequent disasters are not always the most severe.

Model frequency and severity components separately.
Treat them as distinct processes to improve accuracy and interpretability.

Core Statistics Ingredients

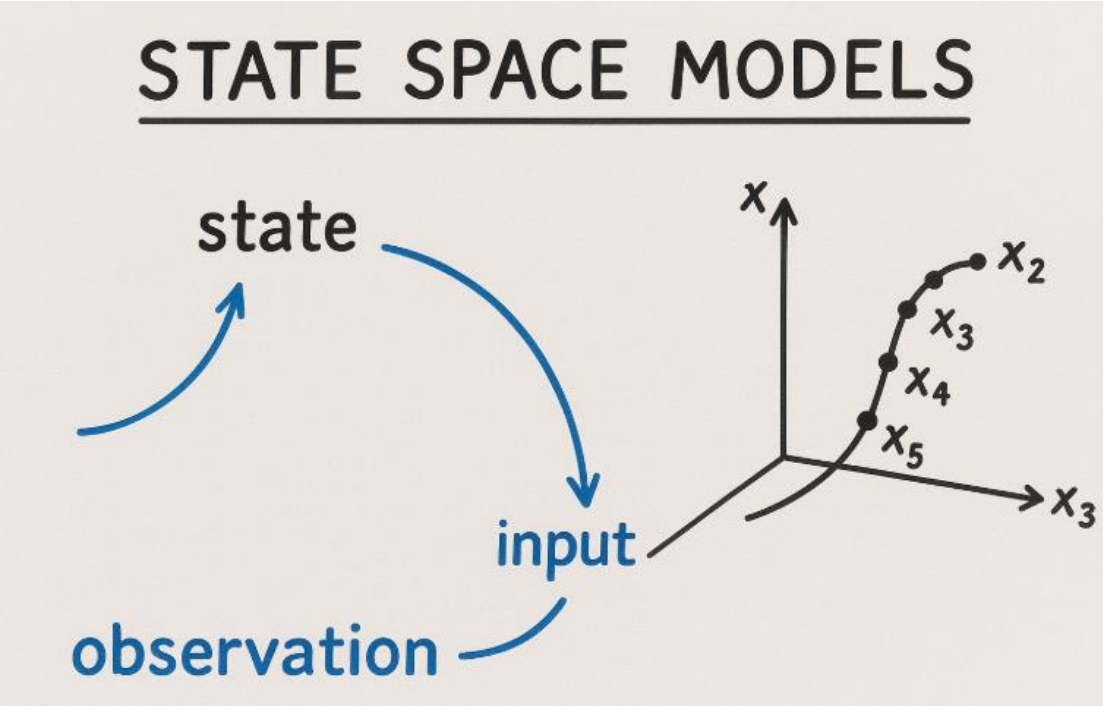
- State Space Models:
  - Time series
  - Exogenous drivers
  - Irregular patterns

- An observation equation:

$$g(y_t) \sim \theta_t + X_t + \epsilon_t^O,$$

- A state evolution equation:

$$\theta_t \sim \theta_{t-1} + \epsilon_t^S.$$



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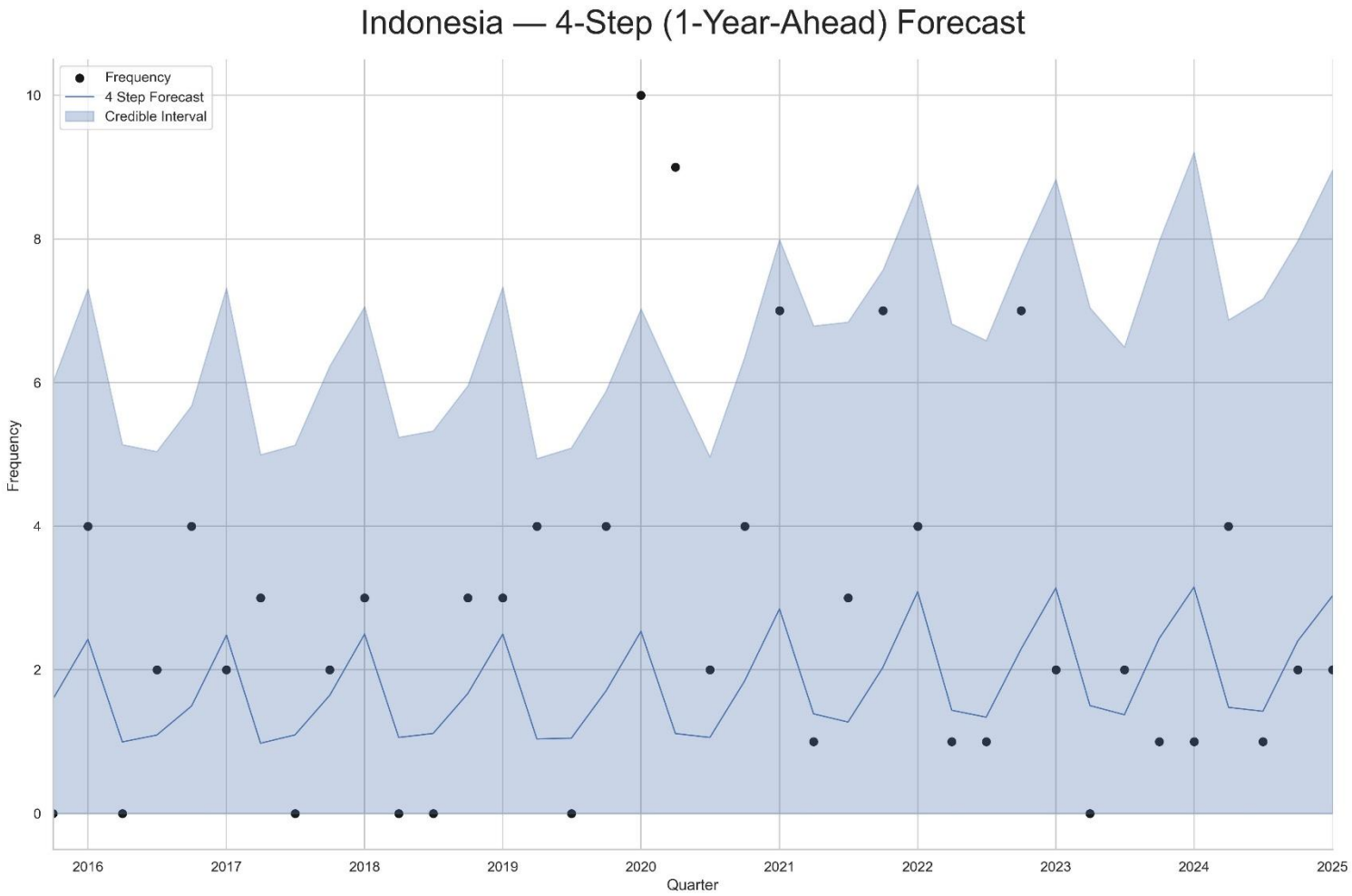
Mean and 99% Credible Interval Forecast: High Frequency Country (Flood)



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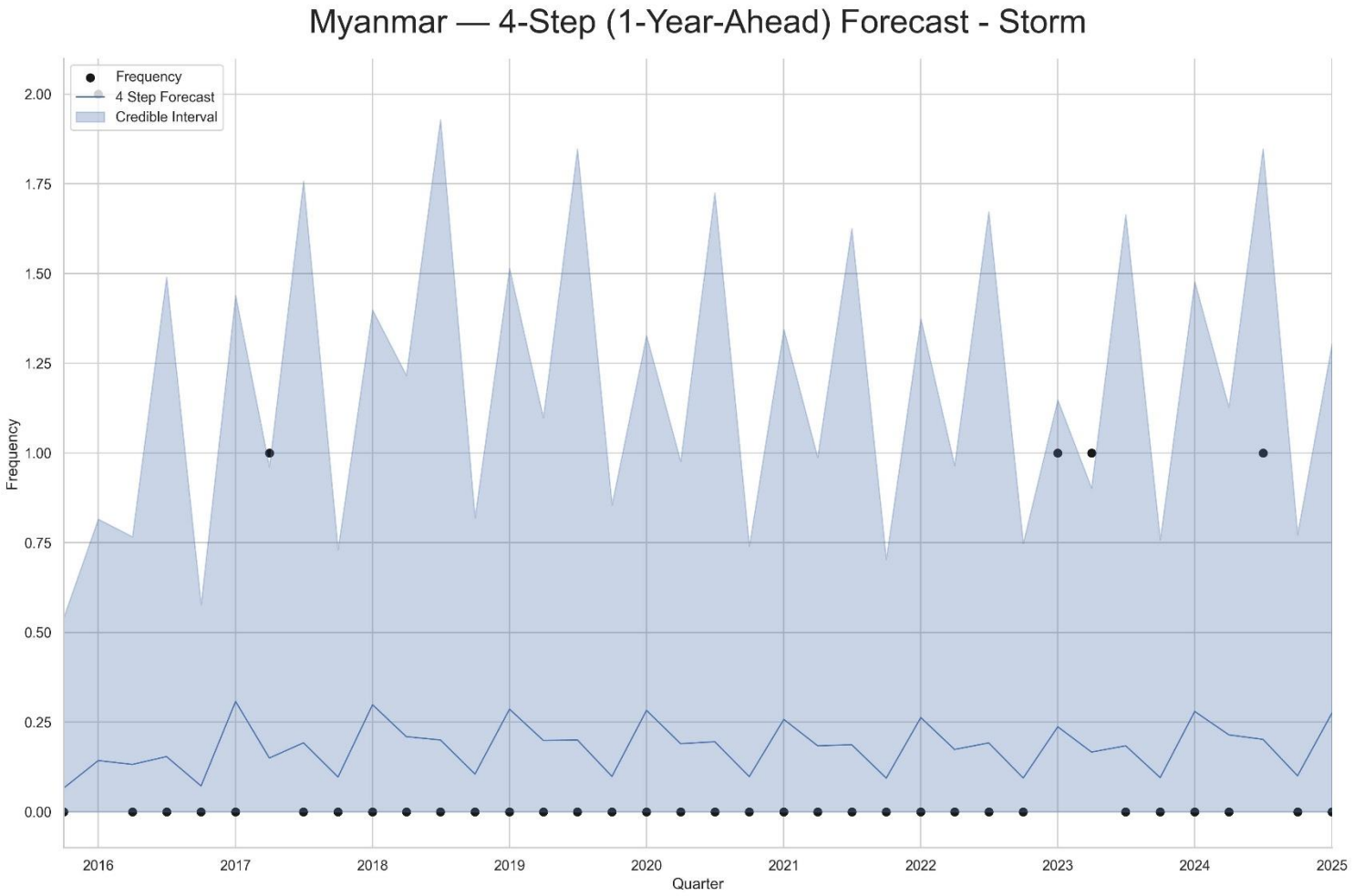
Mean and 99% Credible Interval Forecast : Low Frequency Country (Storm)



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Severity Modeling

$$\log(damage) = \beta_0 + \beta_1 \log(population\ density) + \varepsilon$$

- Damage of each event
  - Country-specific
  - Measured in USD at 2025 price level

- Predicted by population density
  - Of the same country
  - In the year when the event occurred

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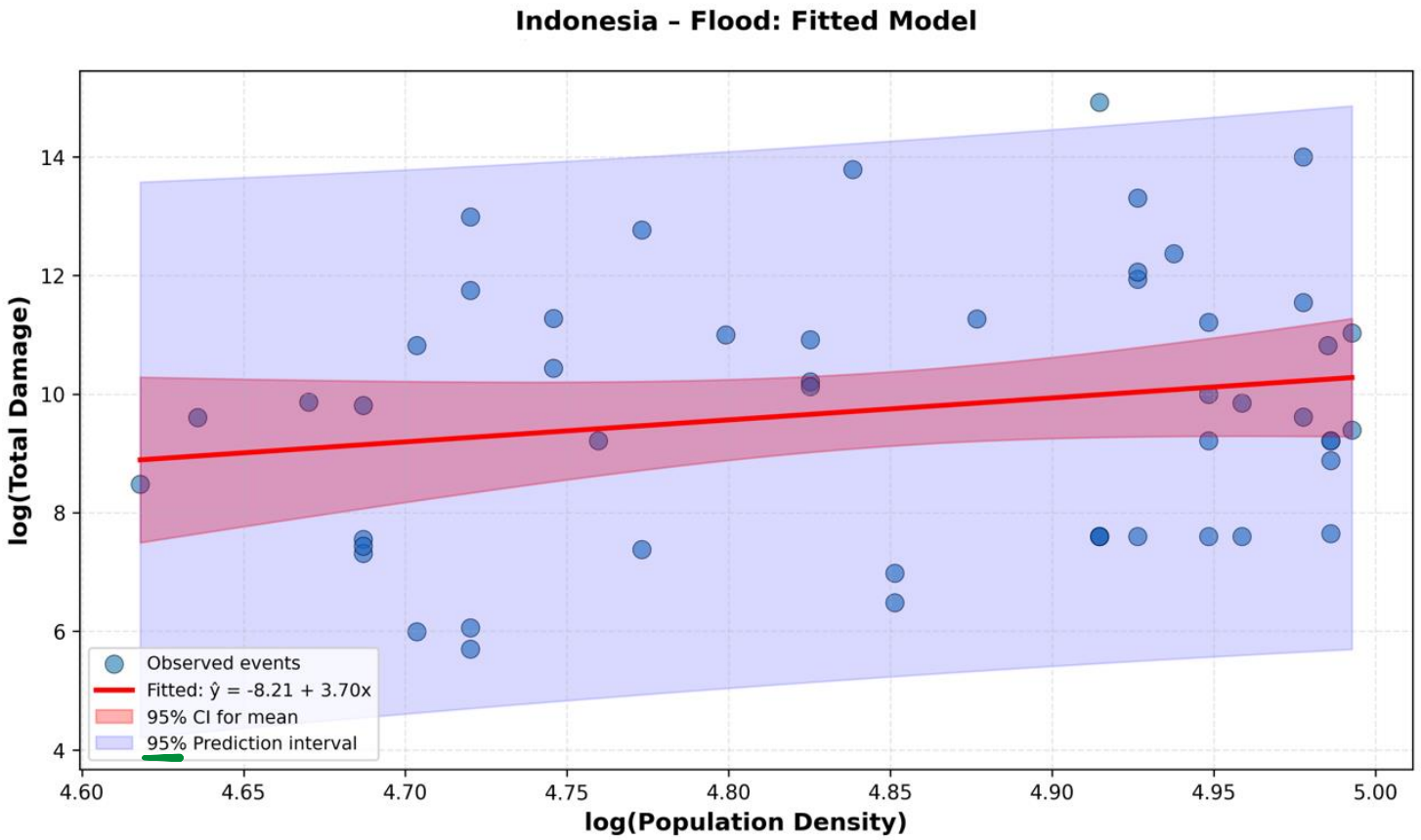
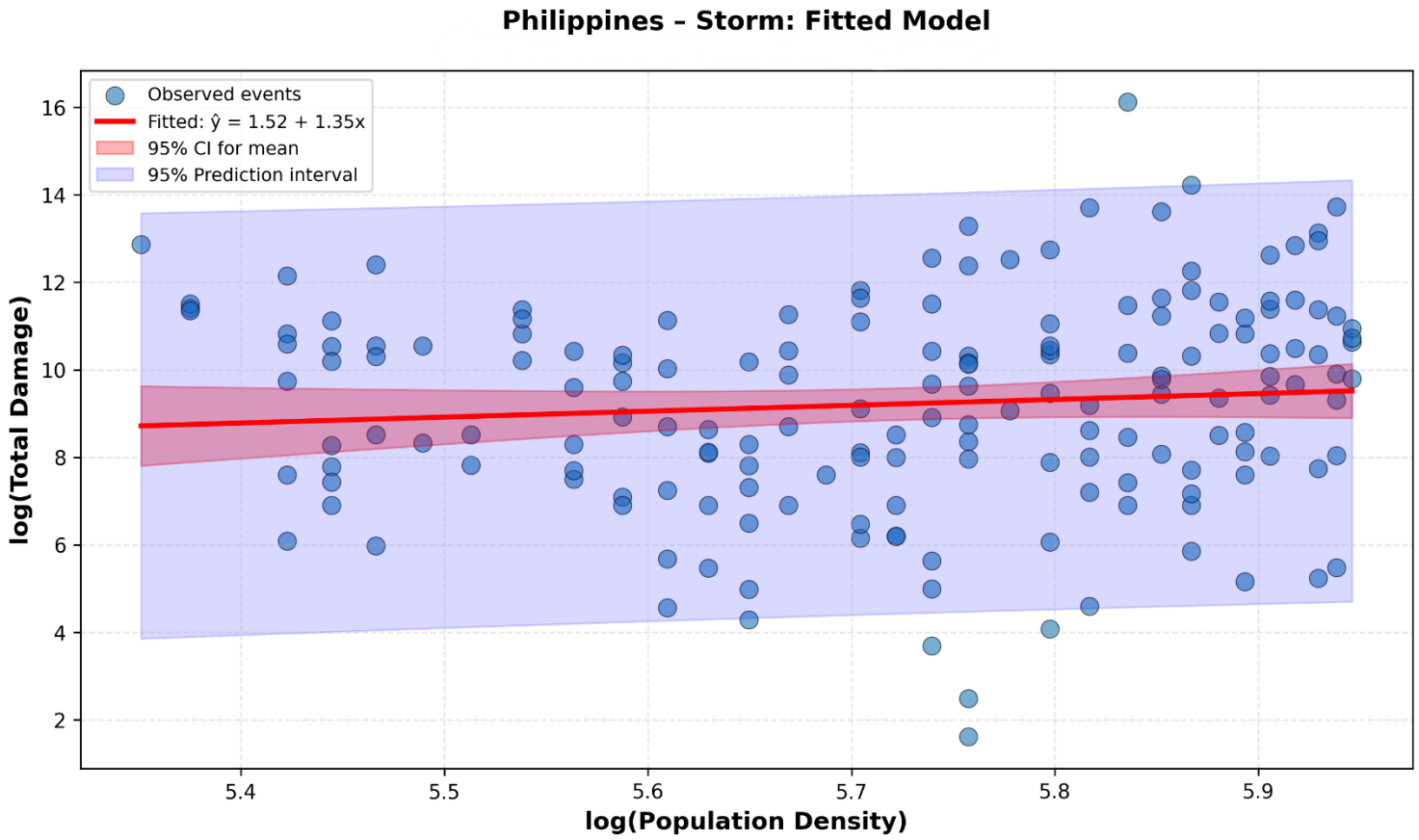
An Illustration of Severity Model Performance (Flood)



An Illustration of Severity Model Performance (Storm)



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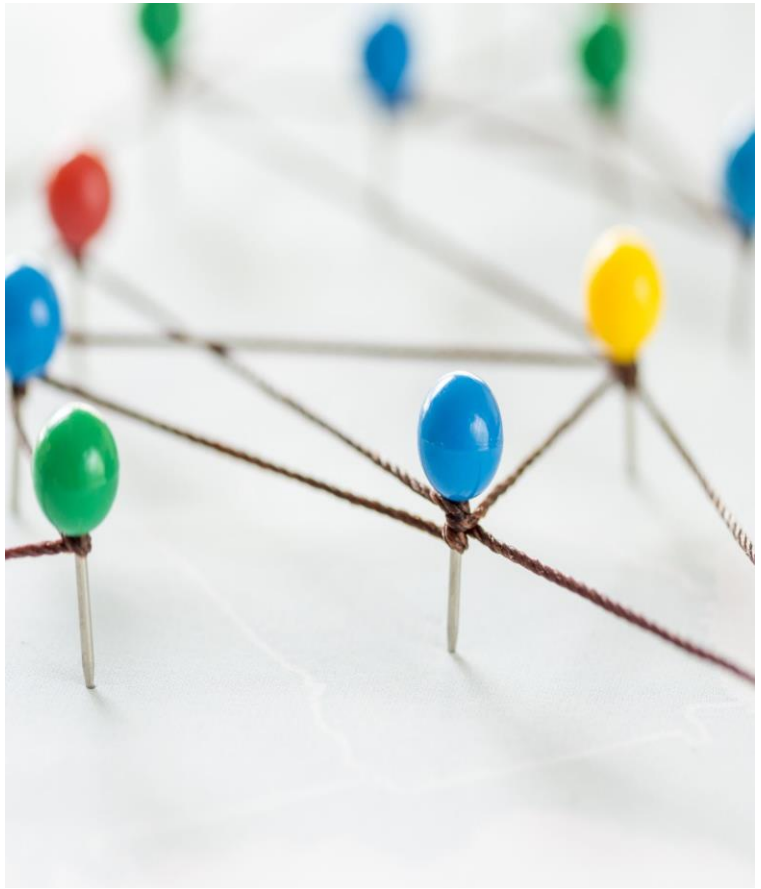
Cross-region Risk Sharing



- Potential and significance:
  - Diversification of catastrophe risk exposure
  - Enhanced financial resilience
  - Efficient capital utilization
  - Equitable and transparent participation

- A hypothetic coverage structure:
  - Notional amount: F
  - Attachment point: b_1
  - Exhaustion point: b_2
  - Actual loss or parametric trigger: L
  - Coverage function:

$$f(L) = F \times \frac{\max\{0, \min\{L - b_1, b_2 - b_1\}\}}{b_2 - b_1}$$

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Proposed premium principle

- Each country contributes a risk-based premium proportional to its expected coverage:

$$p = (1 + \theta) \times E[f(L)].$$

- The parameter θ represents a safety loading to ensure the financial sustainability of the risk sharing fund pool.
- The risk-based contribution framework provides a built-in incentive for risk reduction, as countries with lower expected losses benefit from lower premiums.
- The premiums collected from individual countries/regions will be pooled into a shared fund.

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Management of the share fund

- The shared fund is established to cover losses over a given period (e.g., a quarter).
- If the fund is sufficient, any remaining balance after payouts will be refunded or rolled over to the next period.
- In the event of insufficient fund where multiple regions need radiation, then payouts are allocated proportionally to each country's realized risk exposure:

$$q_i = \frac{f(l_i)}{\sum_j^d f(l_j)},$$

where $f(l_i)$ denotes country/region i's realized loss within the period.

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Goal and approach of the application study

- Assess the model's potential to enhance regional financial resilience and reduce post-disaster funding gaps.
- Simulate quarterly loss realizations across countries with varying disaster frequencies.
- Evaluate fund sufficiency under different correlation and loading θ scenarios.
- Compare outcomes with and without risk sharing to measure diversification benefits and capital efficiency.

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Ongoing Research

- Continuous model development
- Robust model validation
- Applications to NAT CAT financing studies
- Spreadsheets for prediction outcomes

Significance for ASEAN Countries

- Vulnerable Region: ASEAN countries are disproportionately affected by natural catastrophes (Nat Cats) including floods, typhoons, earthquakes, and droughts.

- High Economic Exposure: Increasing losses from disasters highlight the urgent need for robust and scalable disaster financing solutions.

- Limited Risk Transfer Mechanisms: Many countries rely heavily on ad hoc government aid, leaving them vulnerable to tail risks and financial volatility.

- Promoting an openly accessible Nat Cat modeling framework for supporting Nat Cat risk management in ASEAN countries

Key Contributions

Application 1: Disaster Financing Innovation

- Evaluate the effectiveness of reinsurance vs. CAT bonds using predictive analytics.
- Guide optimal CAT bond designs tailored for ASEAN:
  - Multi-peril & multi-location
  - Indemnity-based & index-based
- Enable data-driven, risk-sensitive investment decisions to enhance financial resilience.

Application 2: Cross-Country Risk Sharing

- Propose Country-to-Country (C2C) disaster risk pooling mechanisms to promote regional solidarity.
- Compare financial outcomes of local vs. shared risk approaches.
- Support integration of C2C pooling with existing instruments (reinsurance, CAT bonds) for hybrid resilience models.


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