

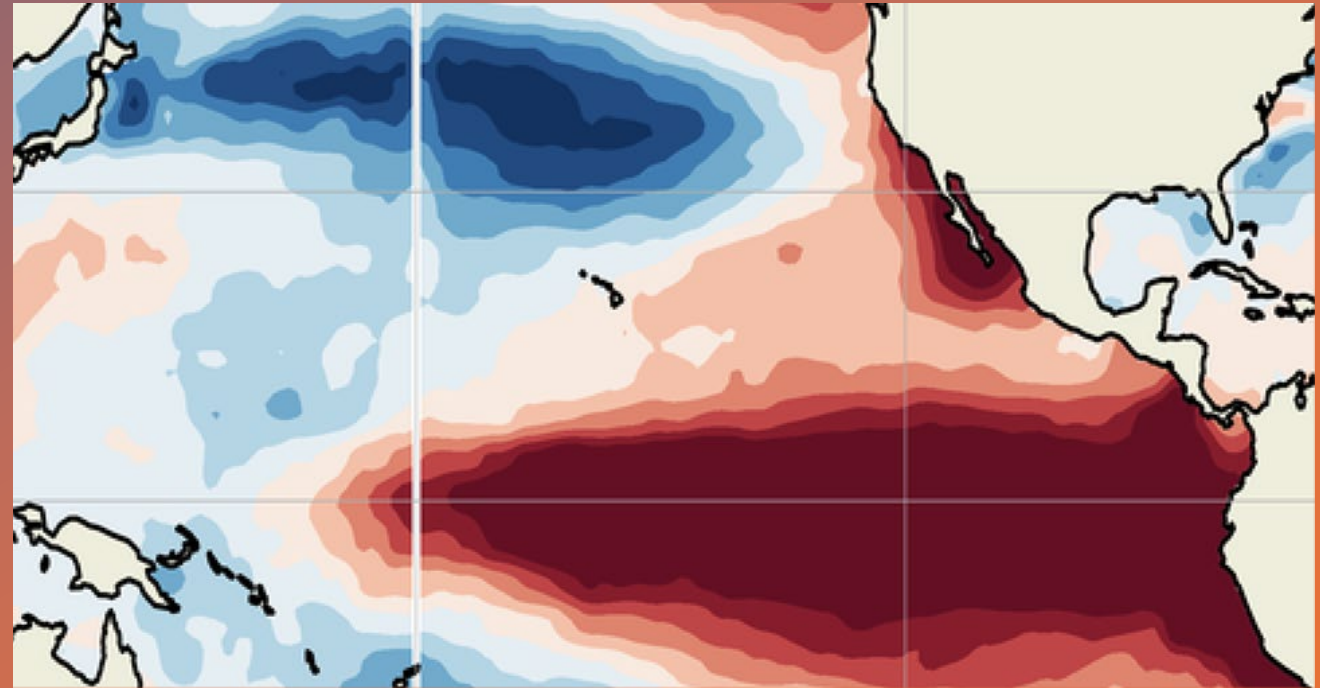
Futures in AI for Climate Risk

Spatiotemporal Planning
for an Evolving Climate

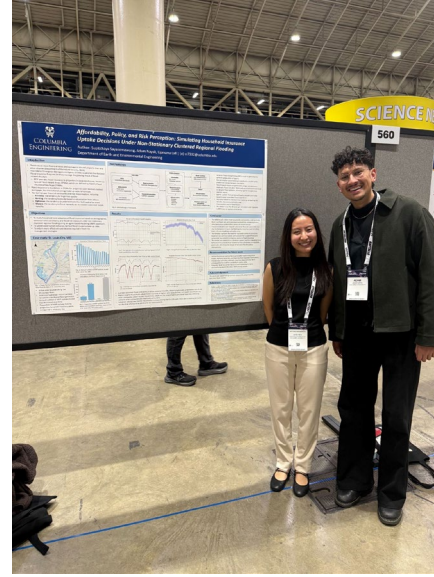
Adam Nayak

PhD Candidate

*Dept. Earth & Environmental Engineering,
Columbia University*



Introduction



- **NSF Graduate Fellow, Columbia Engineering**
 - Focus on ML/AI applications in hydroclimate risk
- **Experience in engineering, policy, and climate science**
 - EPA, Jacobs, NOAA, NASA, White House Climate Policy Office



Climate-driven disasters & insurance failures

 The New York Times

How the Climate Crisis Became an Insurance Crisis

Home insurers are raising premiums and ending coverage. The upheaval could push down home values and reverberate through the economy.

 Fast Company

Hurricane Helene is exposing the broken flood insurance system

Very few homeowners have flood insurance, and the National Flood Insurance Program is \$20 billion in debt. As disasters increase, what is the solution?

 NPR

Why the government's flood insurance program is underwater

 Reuters

Breakingviews - Flood insurance swamps US government

The U.S. government's flood coverage could soon find itself financially underwater. The National Flood Insurance Program, which covers...

 The Guardian

Insurance is failing hurricane survivors: 'People thought they were covered'

Flooding is separate from typical US home insurance and many homeowners are not adequately covered.

 The New York Times

Insurer's Retreat in Florida Signals Crisis With No Easy Fix

 Los Angeles Times
<https://www.latimes.com › business › story › california-...>

California exodus of home insurance companies continues

Apr 19, 2024 — Two more insurers are pulling out of California's troubled homeowners insurance market, straining a marketplace that already has seen the pullback of several ...

Two parallel timescales for adaptive planning

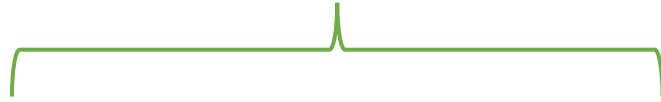
Insurance Systems



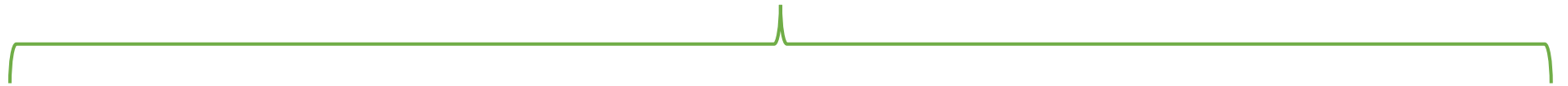
1 year
Insurance Policy



30 years
Home Mortgage



100 years
Large scale infrastructure



Hydroclimatic

100+ years
Climate Change



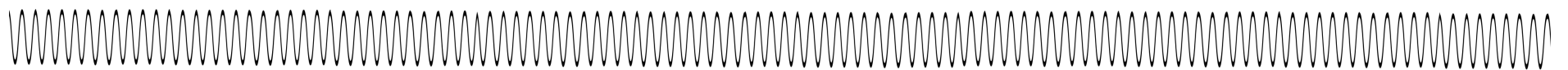
20-40 years
AMO, PDO



<10 years
ENSO

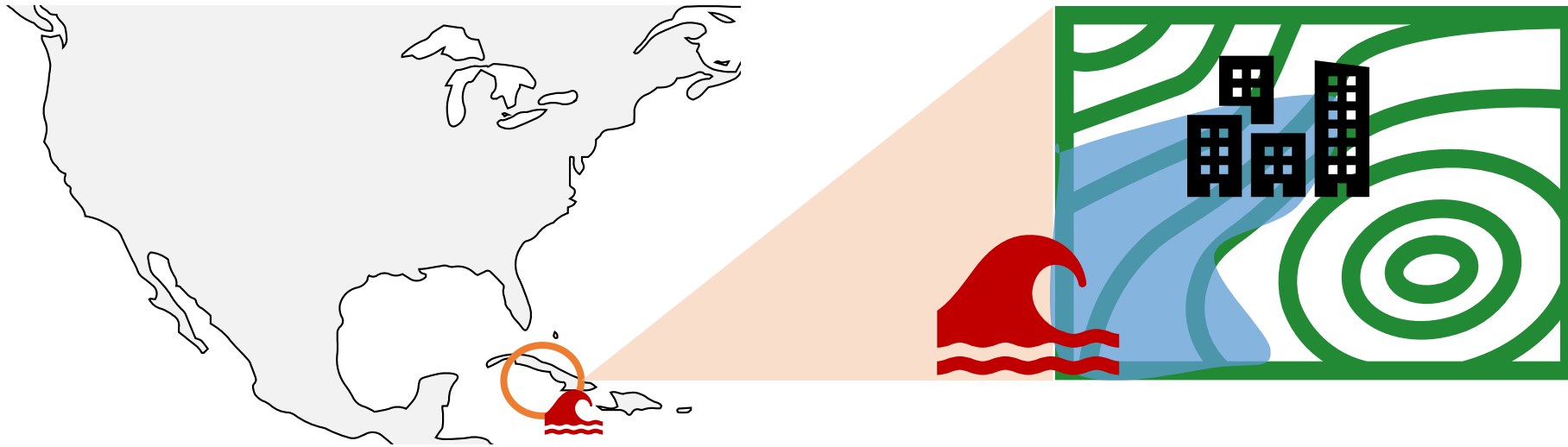


<1 year
MJO, PNA, Seasonality



How do we quantify hazard risk?

- Region and hazard specific



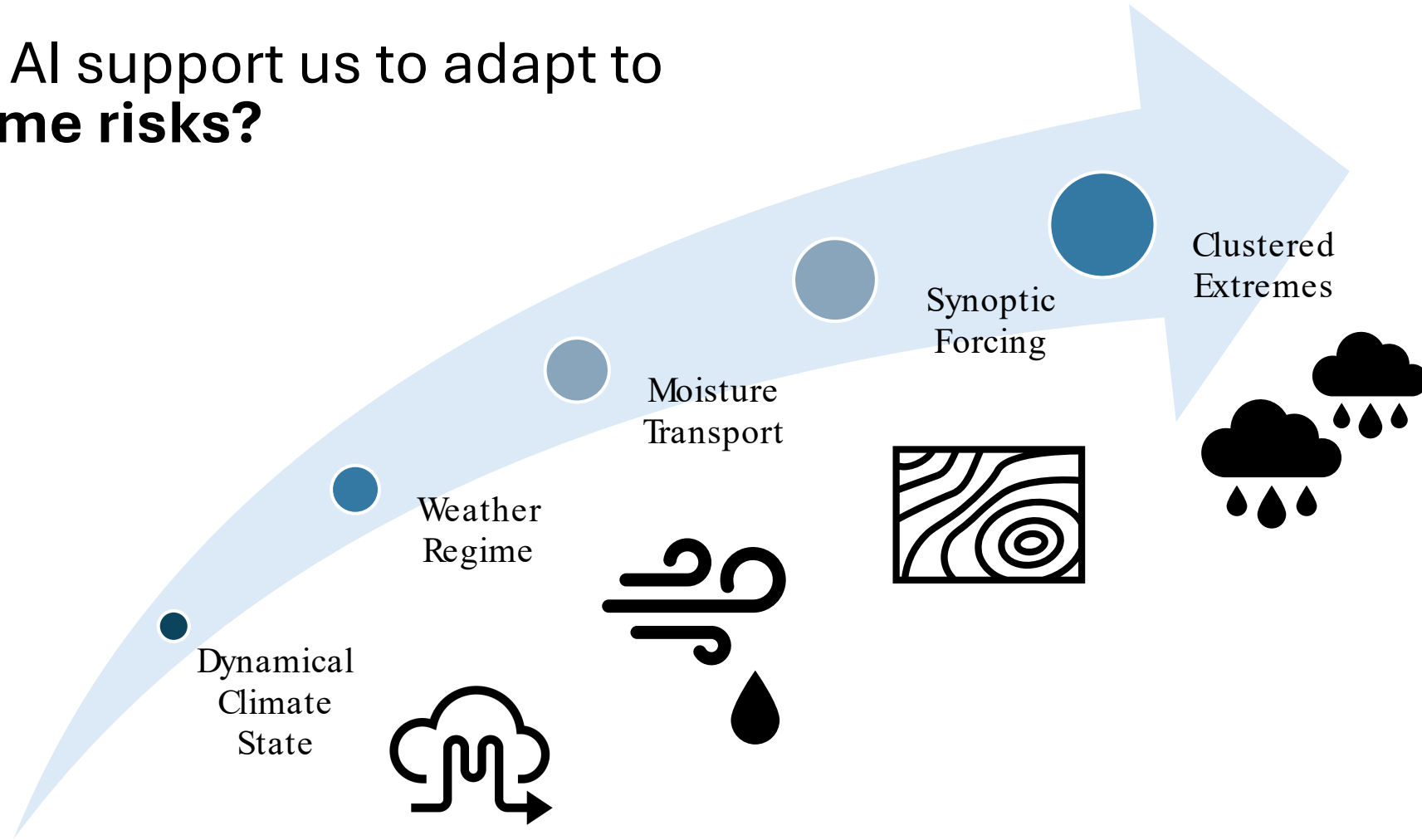
$$Loss = Exposure * Vulnerability(Hazard)$$

$$Risk \sim P(Losses)$$

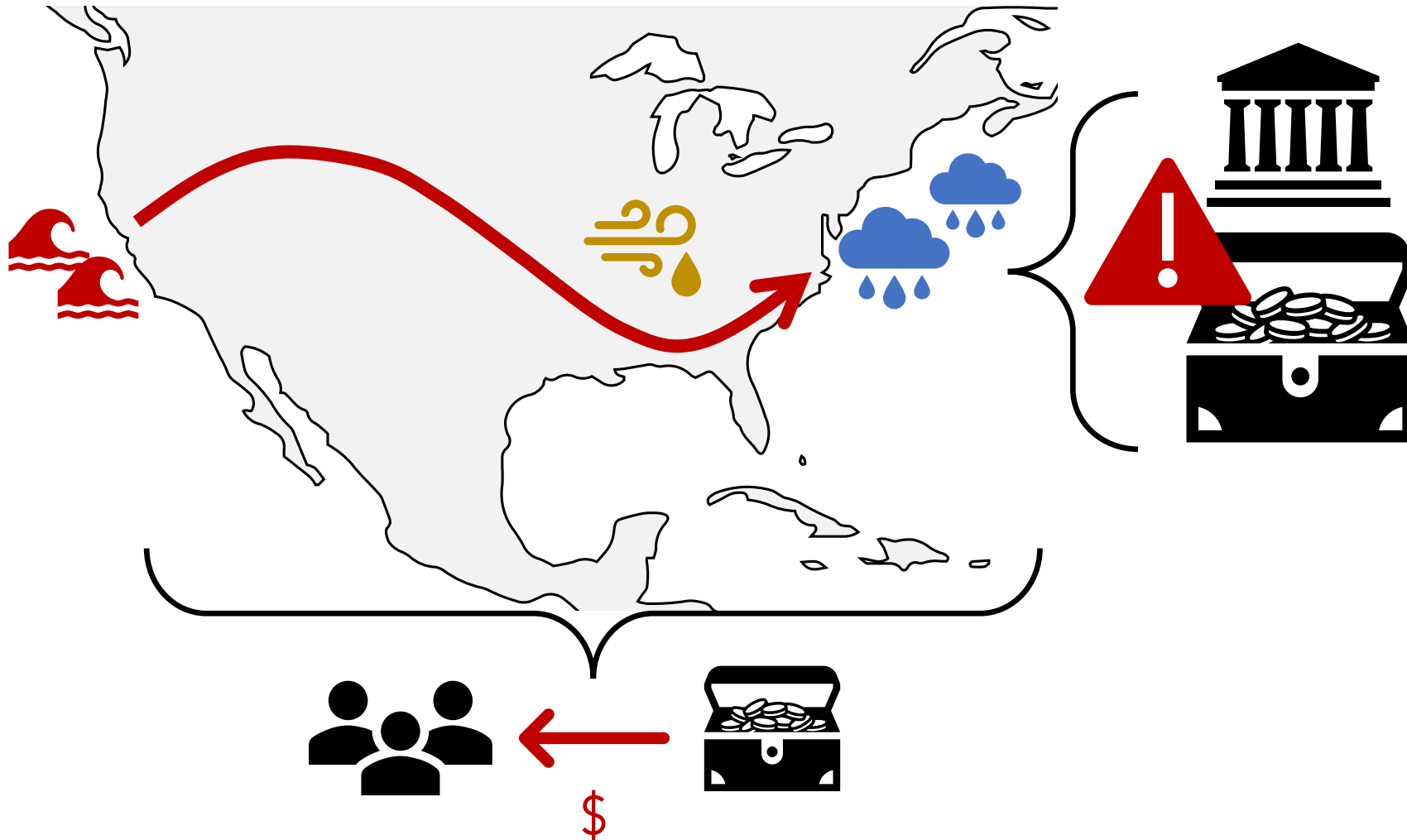
- Priced by the return probability of the hazard plus uncertainty
- Modeled with catastrophe models

Floods are extreme realizations of dynamical systems

How can AI support us to adapt to **space-time risks**?

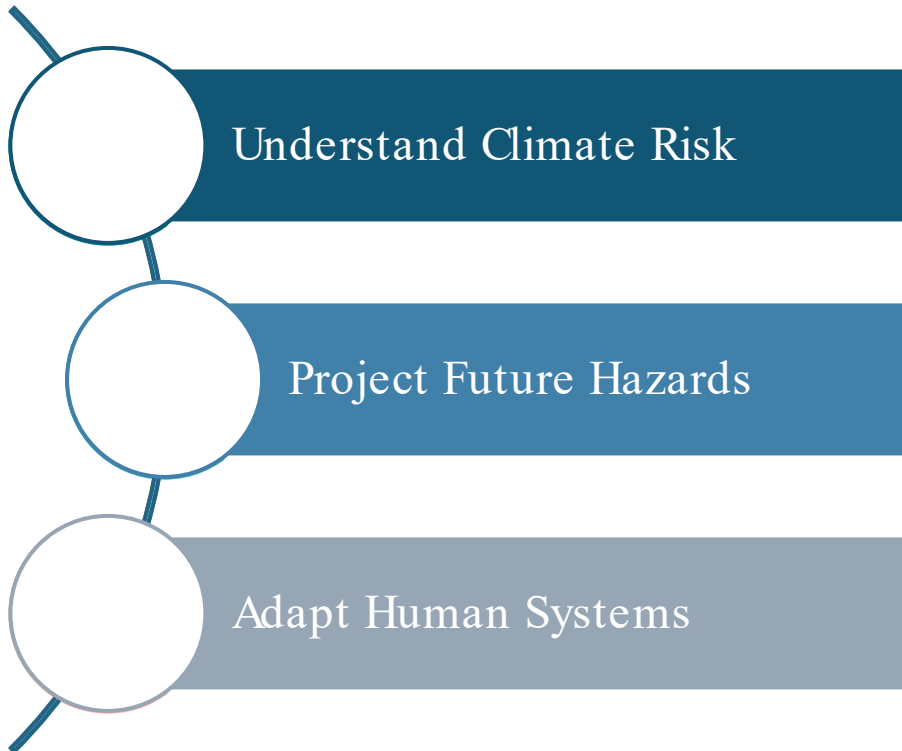


Space-time risks jeopardize diverse risk portfolios

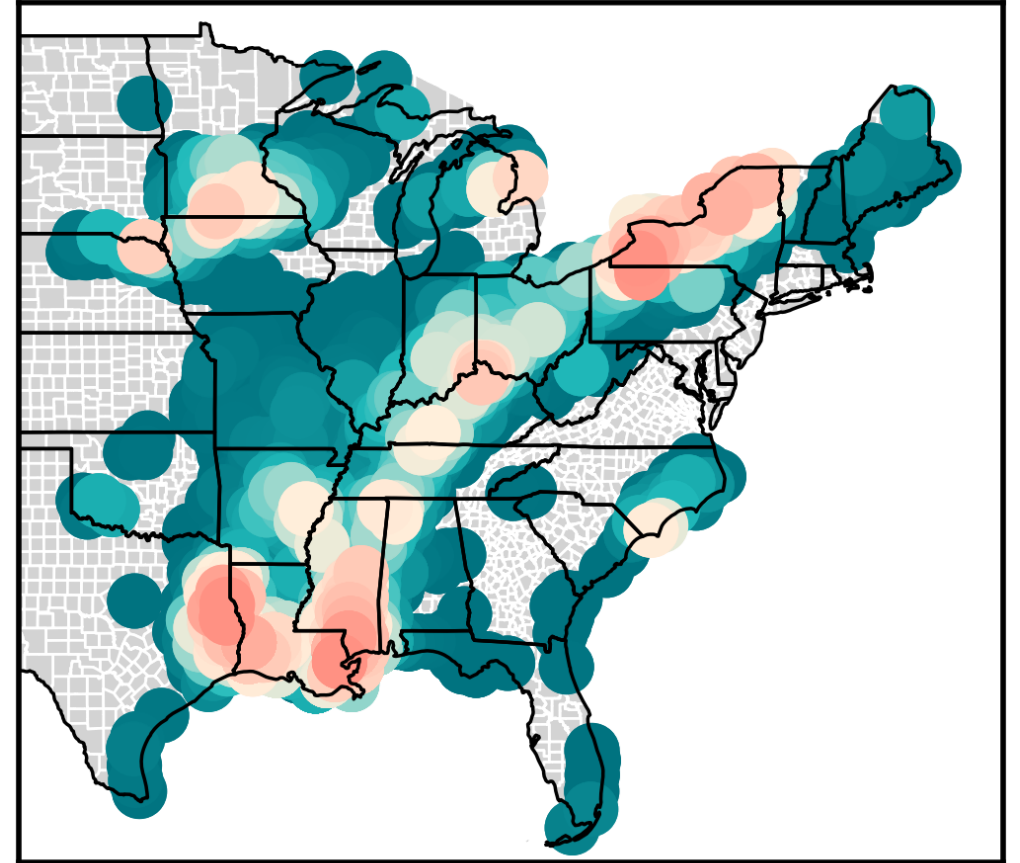


Spatiotemporal risk

The space-time organization of clustered extremes are climatologically driven



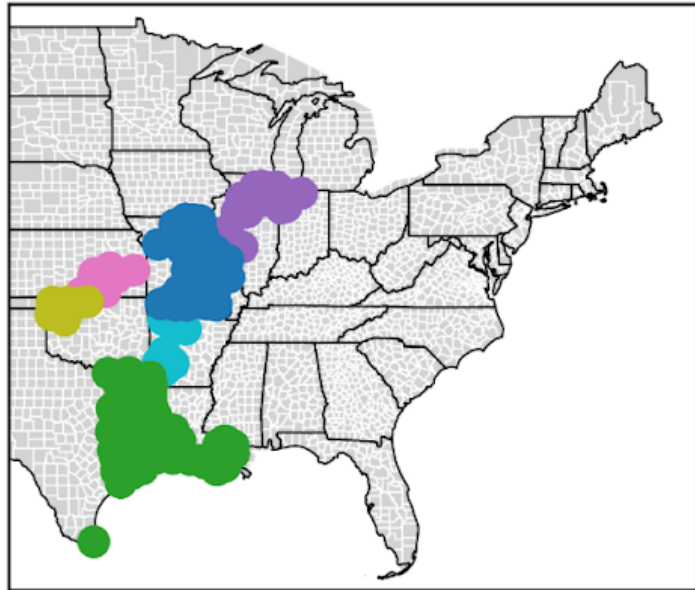
Hurricane Katrina Space-Time Precipitation



Nayak, Gentine, & Lall 2025, Nature Water

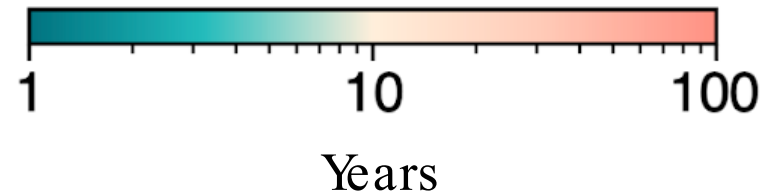
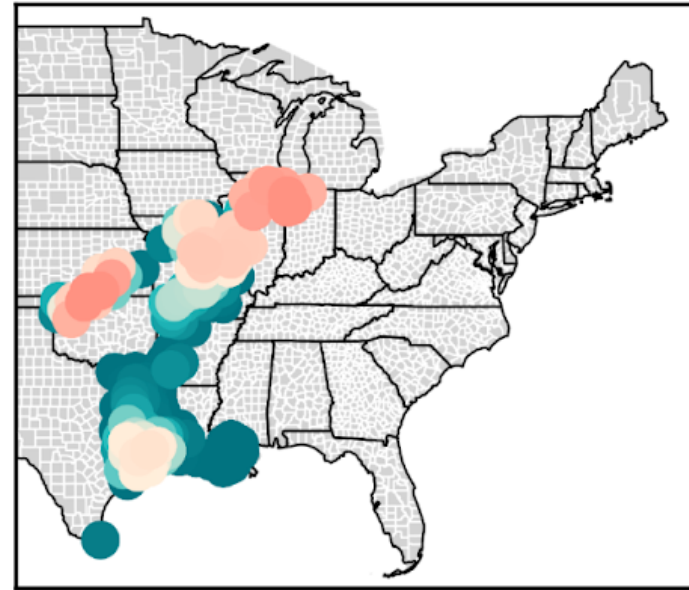
Unsupervised learning for understanding

a) Disaster Declaration

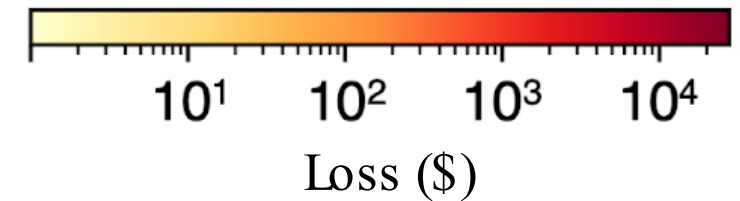
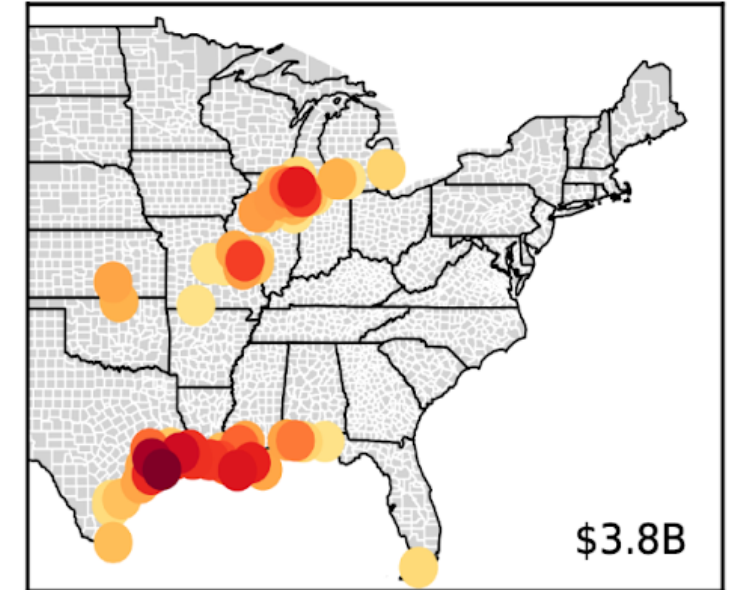


- SEVERE STORMS, FLOODING, AND A TORNADO
- HURRICANE IKE
- SEVERE STORMS AND FLOODING
- SEVERE STORMS, FLOODING, AND TORNADOES
- SEVERE STORMS, TORNADOES, AND FLOODING
- TROPICAL STORM IKE

b) Precipitation Return

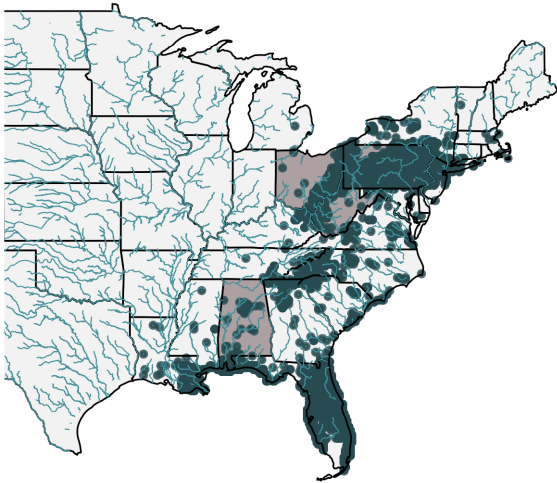


c) Insurance Claims

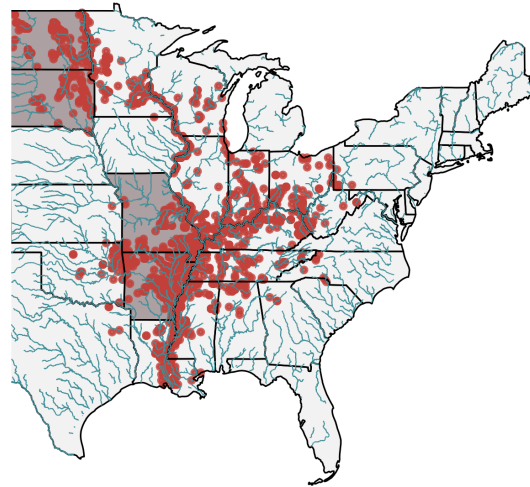


Limited liquid buffer for correlated risks

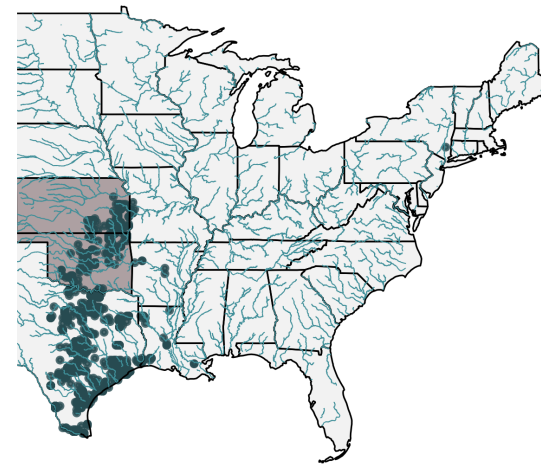
Exposure is driven by heterogeneous interconnected storm patterns shaped by climate regimes



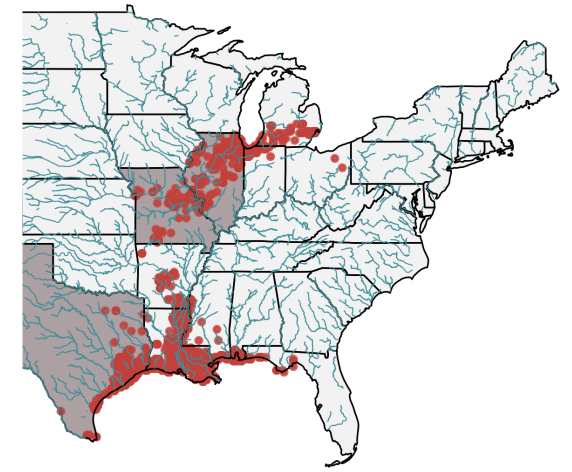
Sequential Tropical Cyclones
Frances/Ivan/Jeanne 2004



Recurrent Riverine Floods
2011 Mississippi River Floods



Severe Convective Storms
2007 Texas Storms & Tornadoes



Inland Storms After Hurricanes
Hurricane Ike

AI-enabled projection and forecasting

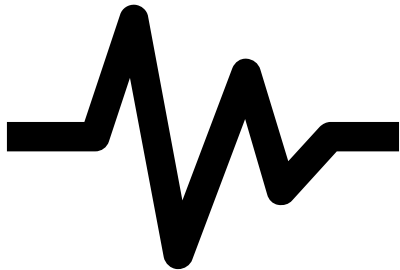
Hydroclimatic Signal Extraction

Signal Forecasting

Climate-Conditional
Flood Clustering

1

Extract a regional signal from historic climate variability.



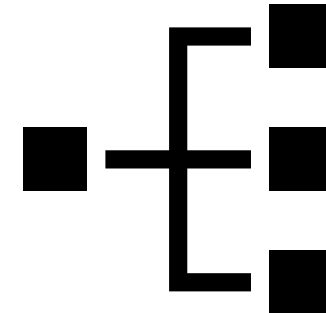
2

Project the signal forward with an ensemble forecast.



3

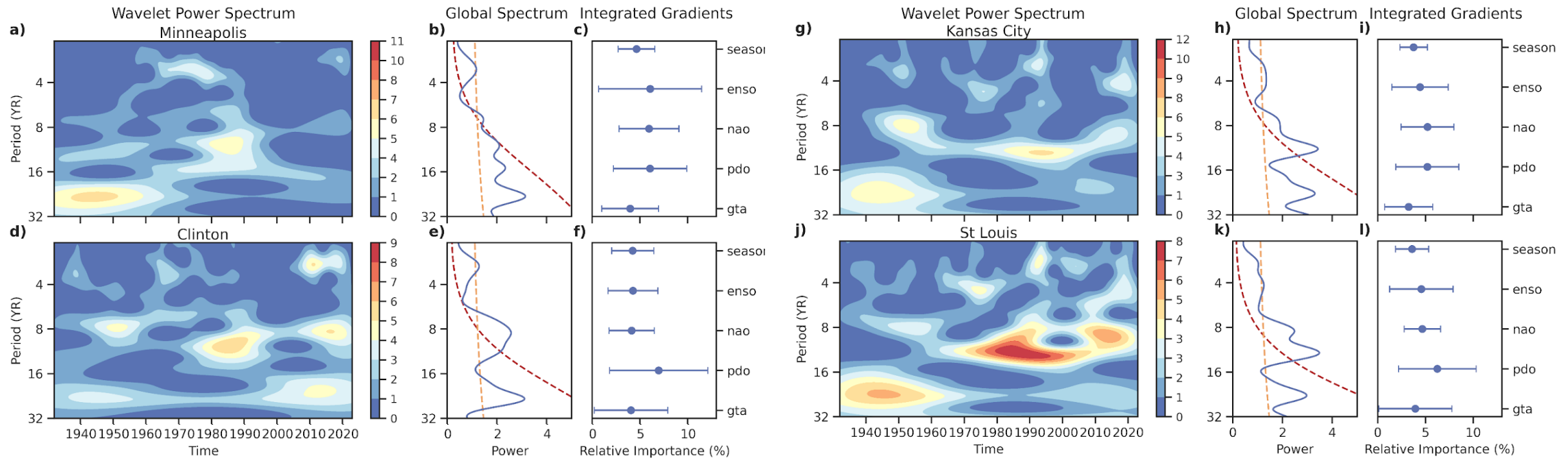
Conditionally parameterize flood clustering on the climate signal.



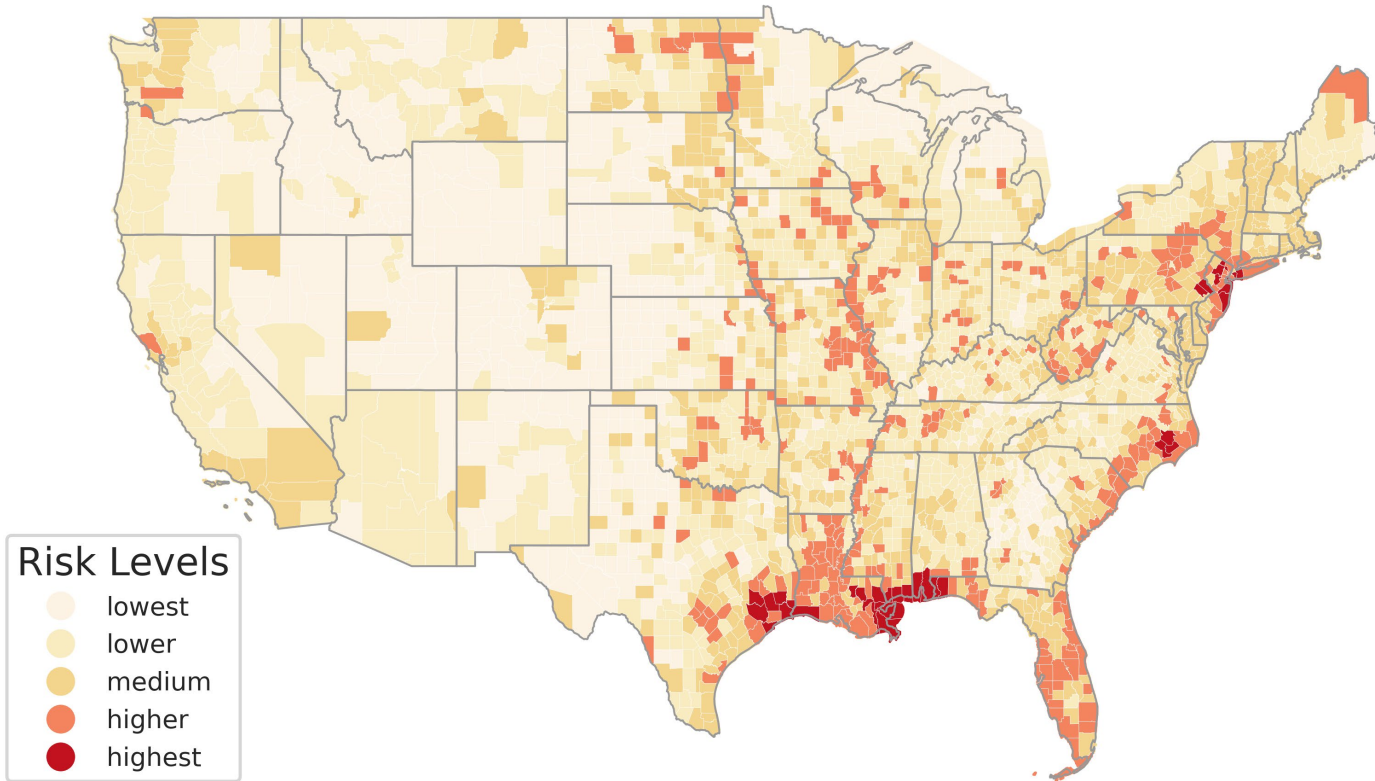
Nayak, Gentine, & Lall 2024, Journal of Hydrology X

Interpretability with explainable AI

Integrated gradients paired with wavelet spectral analysis and coherence provides interpretable attribution to teleconnections with global climate variability



Learning holistic system adaptation



- 1) Risk quantification
- 2) Catastrophe modeling
- 3) Adaptive planning & policy recommendations

Nayak, Zhang, Gentile, & Lall 2025, npj Natural Hazards