Development and Applications of a Typhoon Catastrophe Model: OpenCyclone

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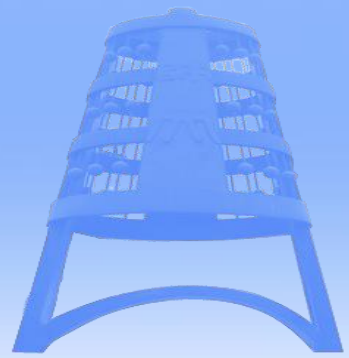
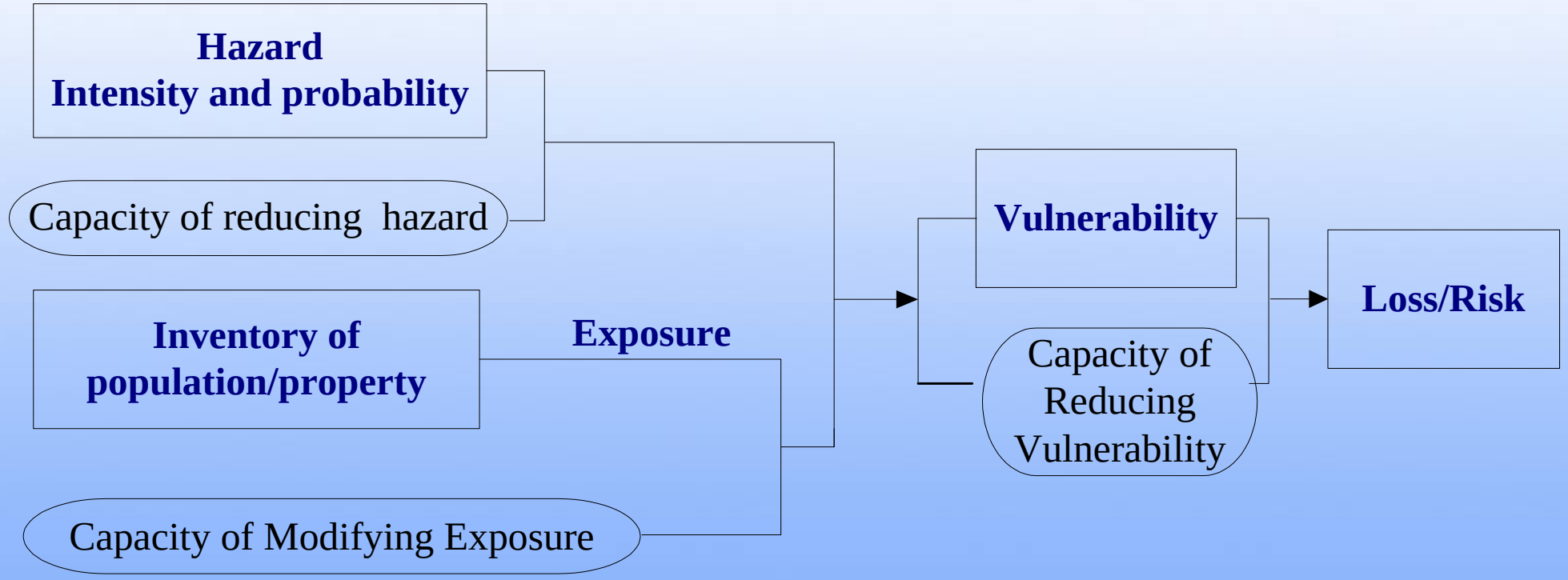
Contents



1. Background

- **What is Risk?**
- **Spatial and Temporal Heterogeneity**
  - Where? When? How often? How Strong?
- **Policy-Making**
  - Target Users: *National/Province/County Govs.*
  - What-if scenario:
    - Casualty
    - Building Damage
    - Economic Lose
    - Evacuation Population
- **Other DRR Practice**
  - Risk transfer
  - Education
  - ……

1. Background: Framework



- **Risk Quantification**
  - Quantitative
  - Semi-quantitative
  - Categories

1. Background: Database

Hazards

- Earthquake
- Flood
- Typhoon
- Drought
- Snow Storm
- Sand Storm
- Storm Surge
- Landslide
- Hail
- Frost
- Forest Fire
- Grassland Fire
- Chemical incidents
- ……

Auxiliary Dataset

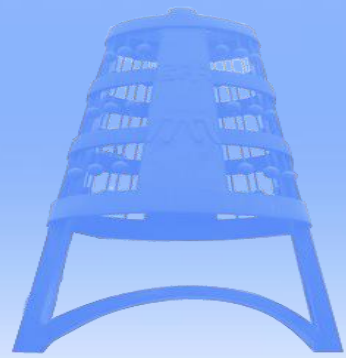
- GIS, social-economic
- Coping capacity……

Exposure Data

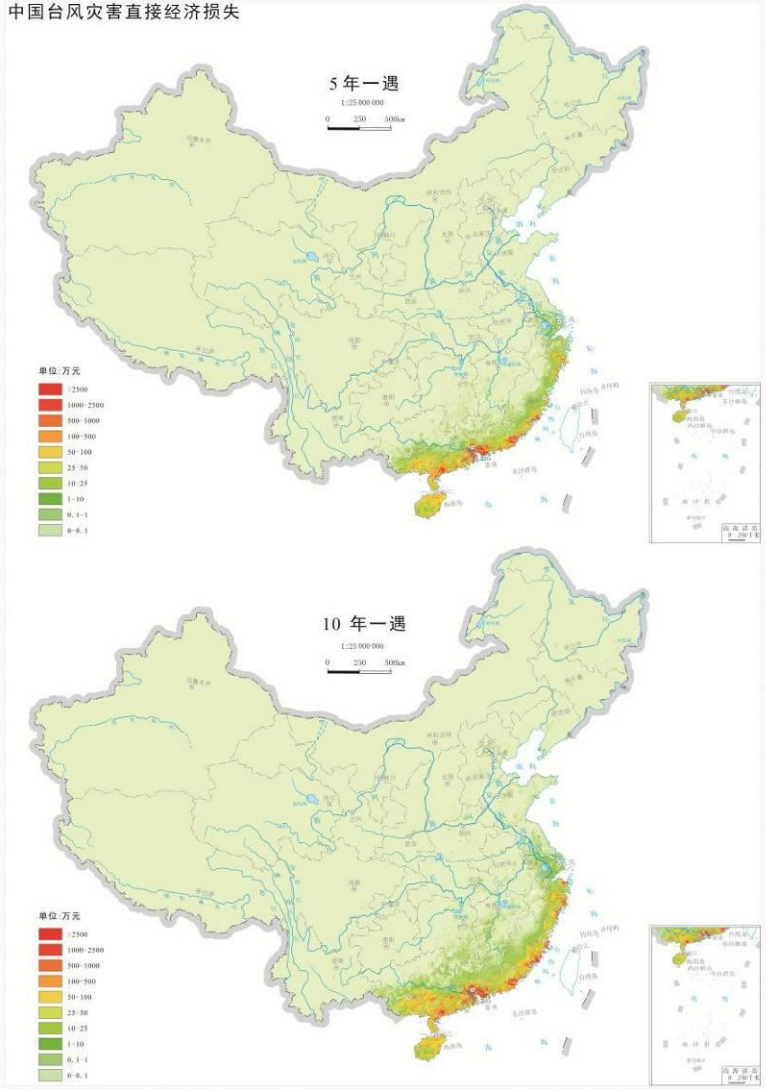
- **Population**
  - County/township/zip-code
  - 1km*1km
- **GDP**
  - County/township/zip-code
  - 1km*1km
- **Building**
  - Year
  - Story
  - Type
  - Occupancy
  - …
- **Infrastructure**
  - Transportation
  - Utility
  - Evacuation site
  - Hospital
- **Crops**
  - Wheat, Corn
  - Rice…..

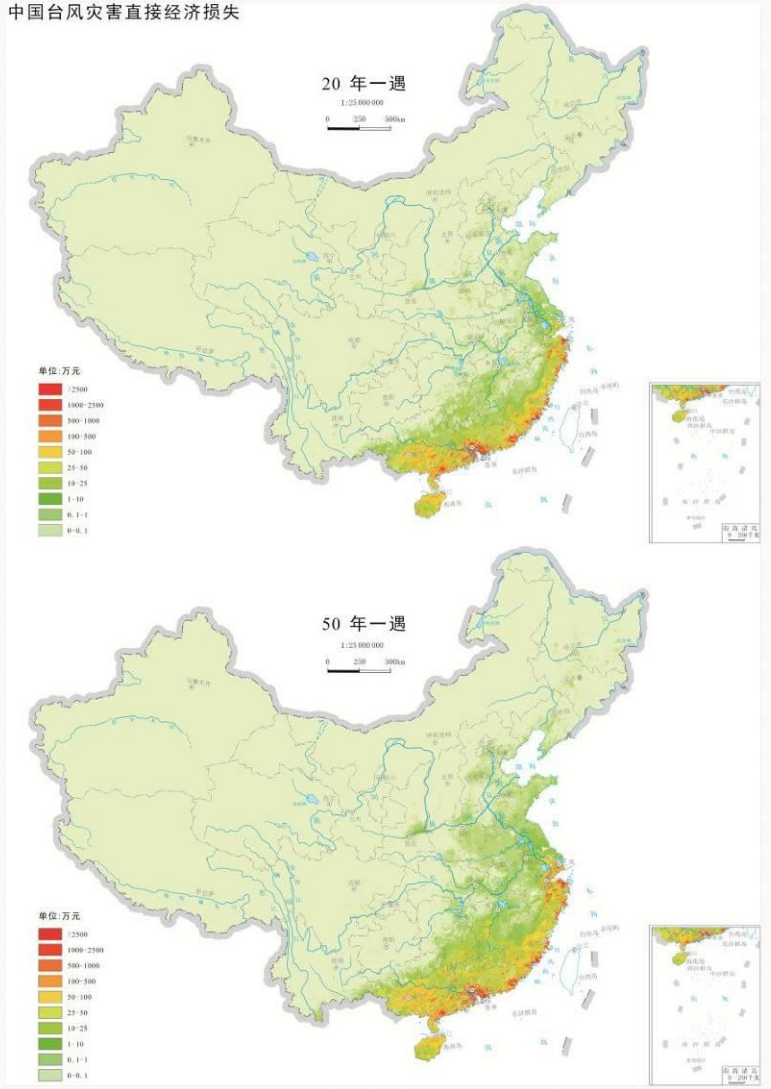
Loss Data

- **MoCA Statistics**
  - 1949-2009
  - County-level
  - Province level
  - Hazard-specific
- **Insurance Data**
  - Policy
  - Claim
- **Case Study Data**
  - Earthquakes
  - Flood
  - Typhoon
  - Drought
  - Wildfire
  - ……
- **Satellite-based**
  - Wildfire
  - Drought
  - Earthquake
  - Flood……

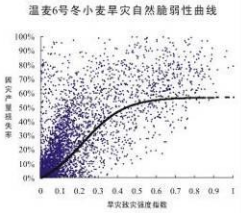


1. Background: Typhoon Risk

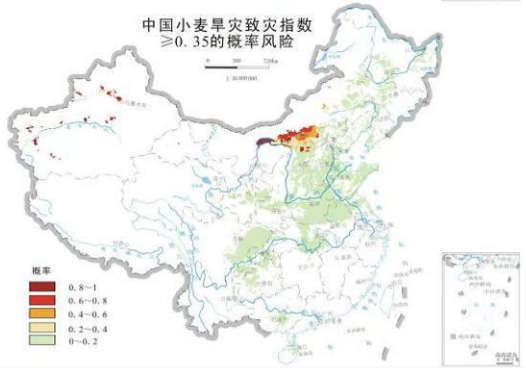




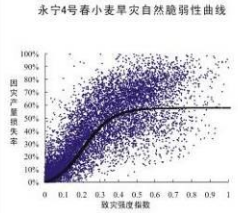
1. Background: Drought Risk



干旱造成地面龟裂



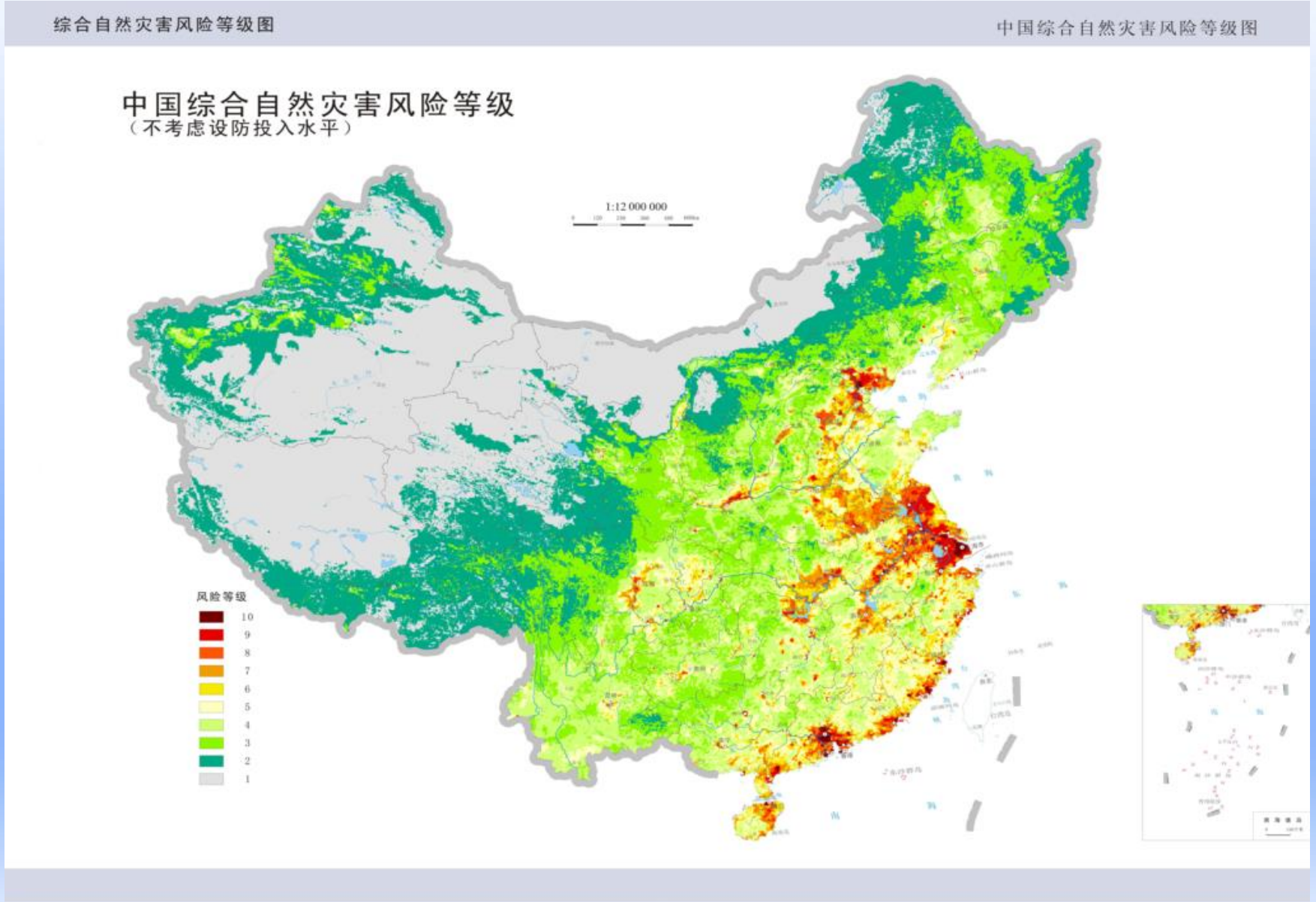
干旱造成居民饮水困难



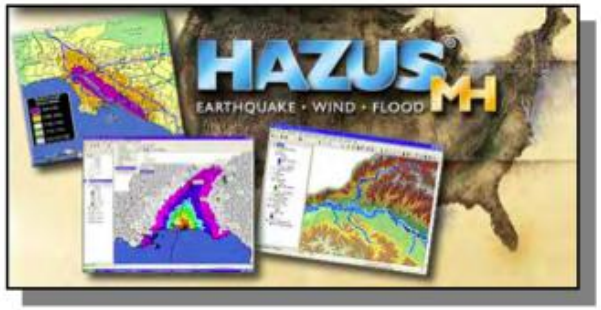
干旱造成水库干涸

工作人员在装填增雨火箭弹

1. Background: Multi-hazard Integration



2. Cat Model: Introduction



EXTREMUM

QUAKELOSS

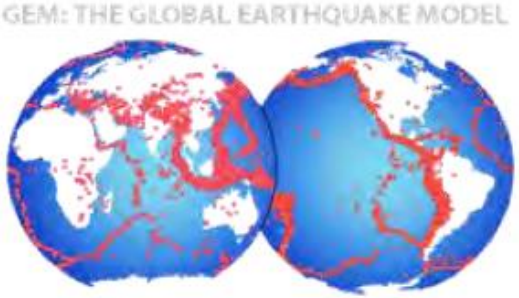
A COMPUTER TOOL TO ESTIMATE BUILDING DAMAGE AND HUMAN LOSSES DUE TO EARTHQUAKES ANYWHERE IN THE WORLD

AIR

EQECAT

RMS

GEM: The Global Earthquake Model



Central American Probabilistic Risk Assessment (CAPRA)

CATS

CATS is a powerful disaster analysis system for Natural and Technological Hazards.

BEFORE disaster strikes

- Create realistic scenarios for training and planning.
- Create contingency plans with CATS comprehensive population and infrastructure data.

WHEN disaster strikes

- Assess the affected population quickly and accurately
- Track hurricane damage

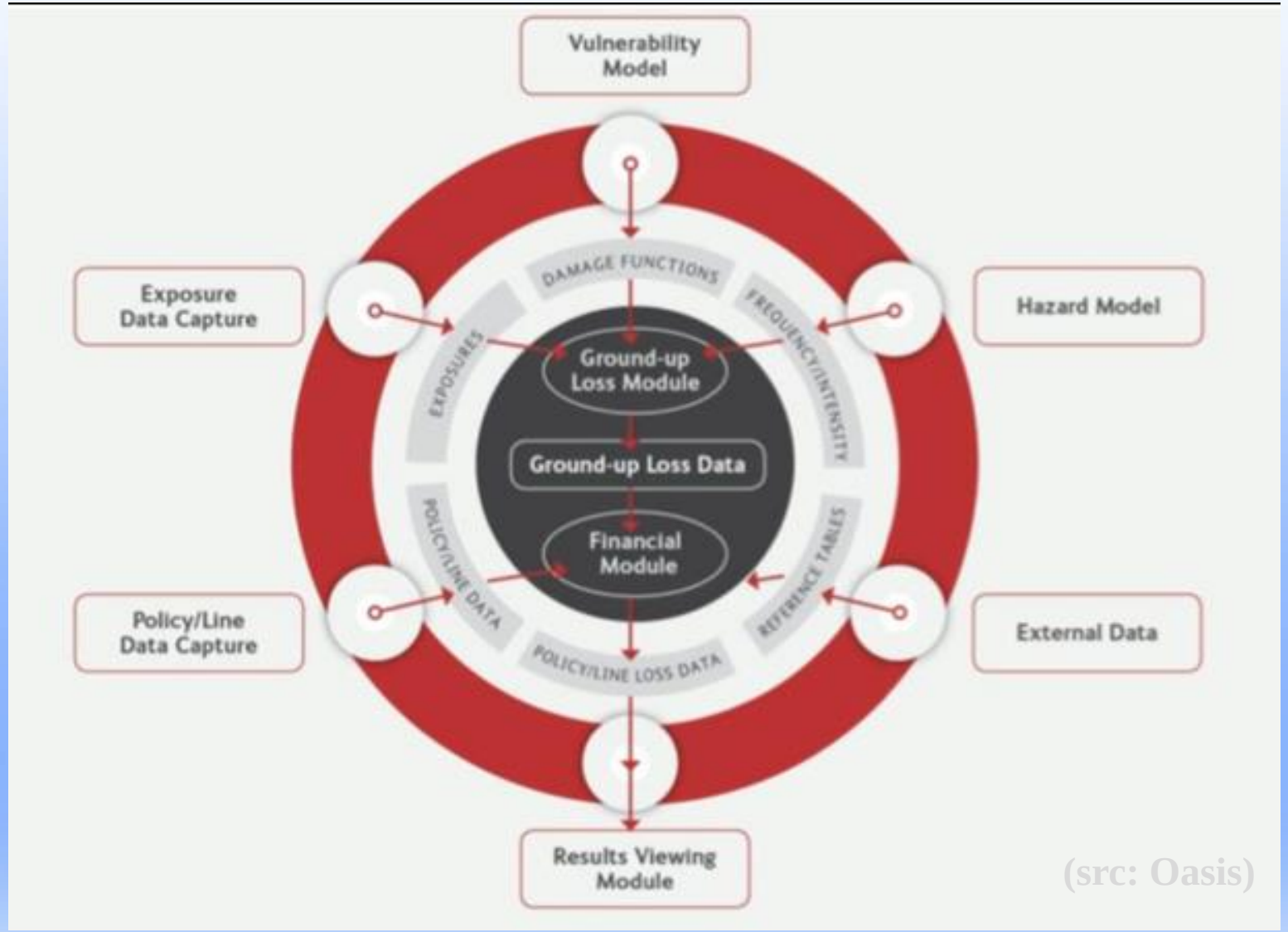
LESSLOSS

Florida Public Hurricane Loss Model

2. Cat Model: Components

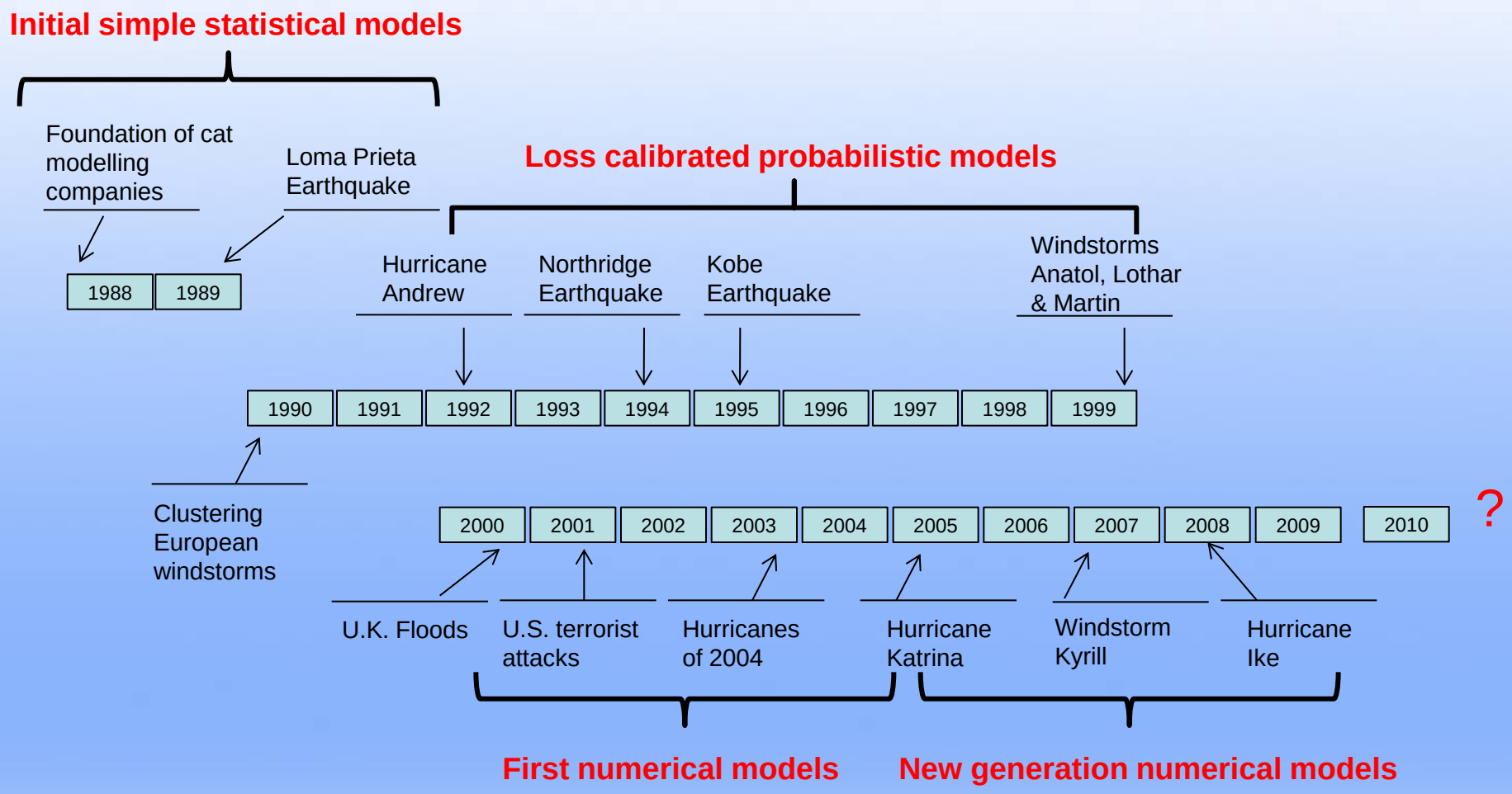
- **Stochastic Event Module:** Track and Intensity Modeling
- **Hazard Module**: Wind and Rainfall Modeling
- **Vulnerability Module**: Linking Hazard and Loss
- **Risk Module: Statistics, Actuary, Cost-Benefit Analysis**

2. Cat Model: Components



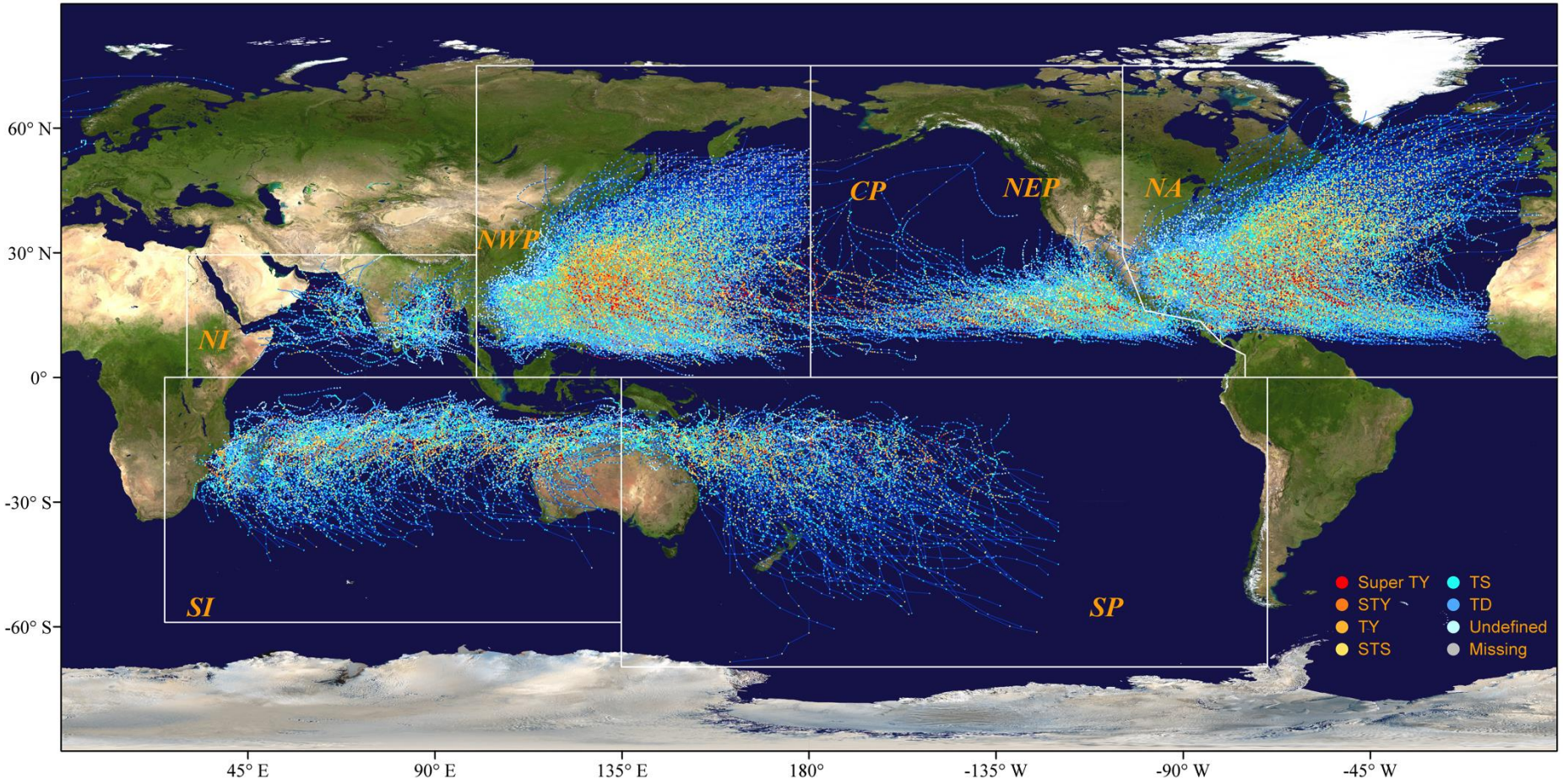
General Framework of Catastrophe Model for Insurance Industry

2. Cat Model: Components



(src: WillisRe)

2. Cat Model: Event Generation



Historical tropical cyclone best track dataset

2. Cat Model: Incentives

SPECIAL HURRICANE EDITION

The Miami Herald

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THE BIG ONE

Hurricane of our nightmares is knocking at the front door

Deadly Andrew kills 4 in Bahamas

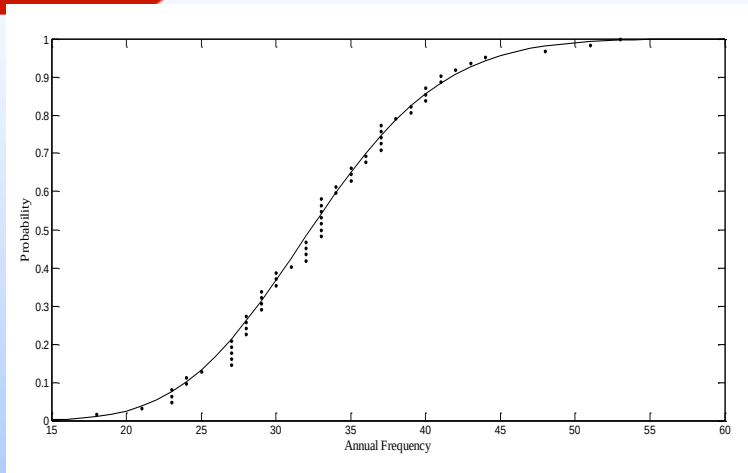
Floridians flee today's landfall

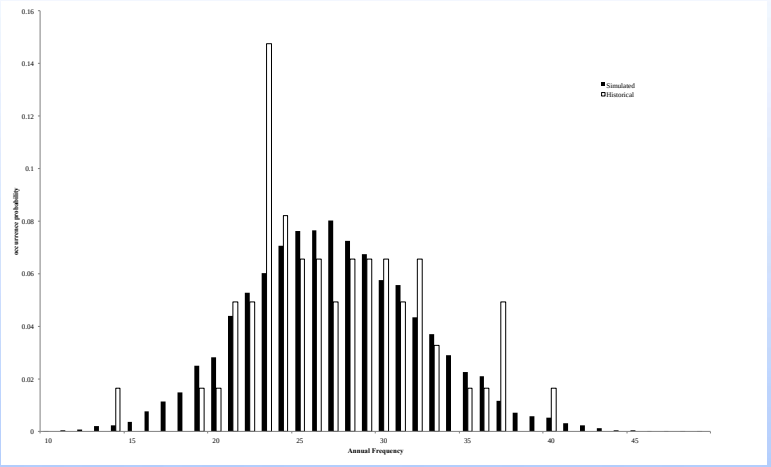
By MARTIN MERZER
Herald Senior Writer

Every Floridian's most persis-
tent fear mushroomed into terri-

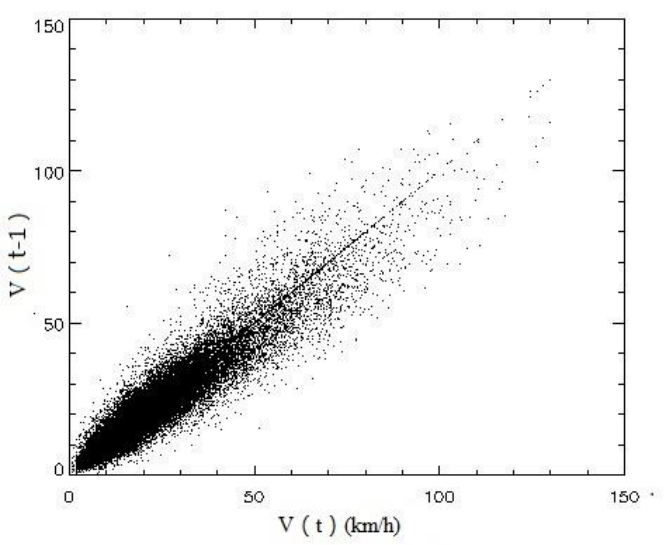
Hurricane Andrew (1992): $16 billion in insured losses and $26.5 billions in total losses expressed in 1992 dollars

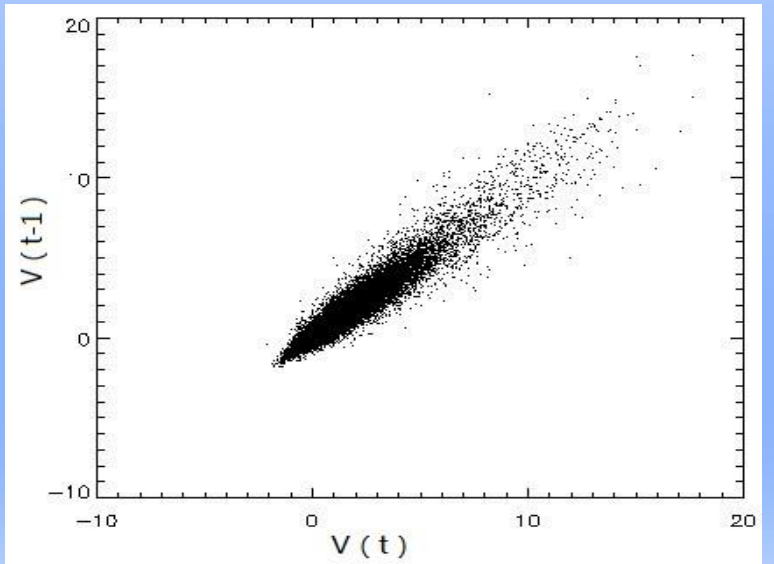
2. Cat Model: Event Generation





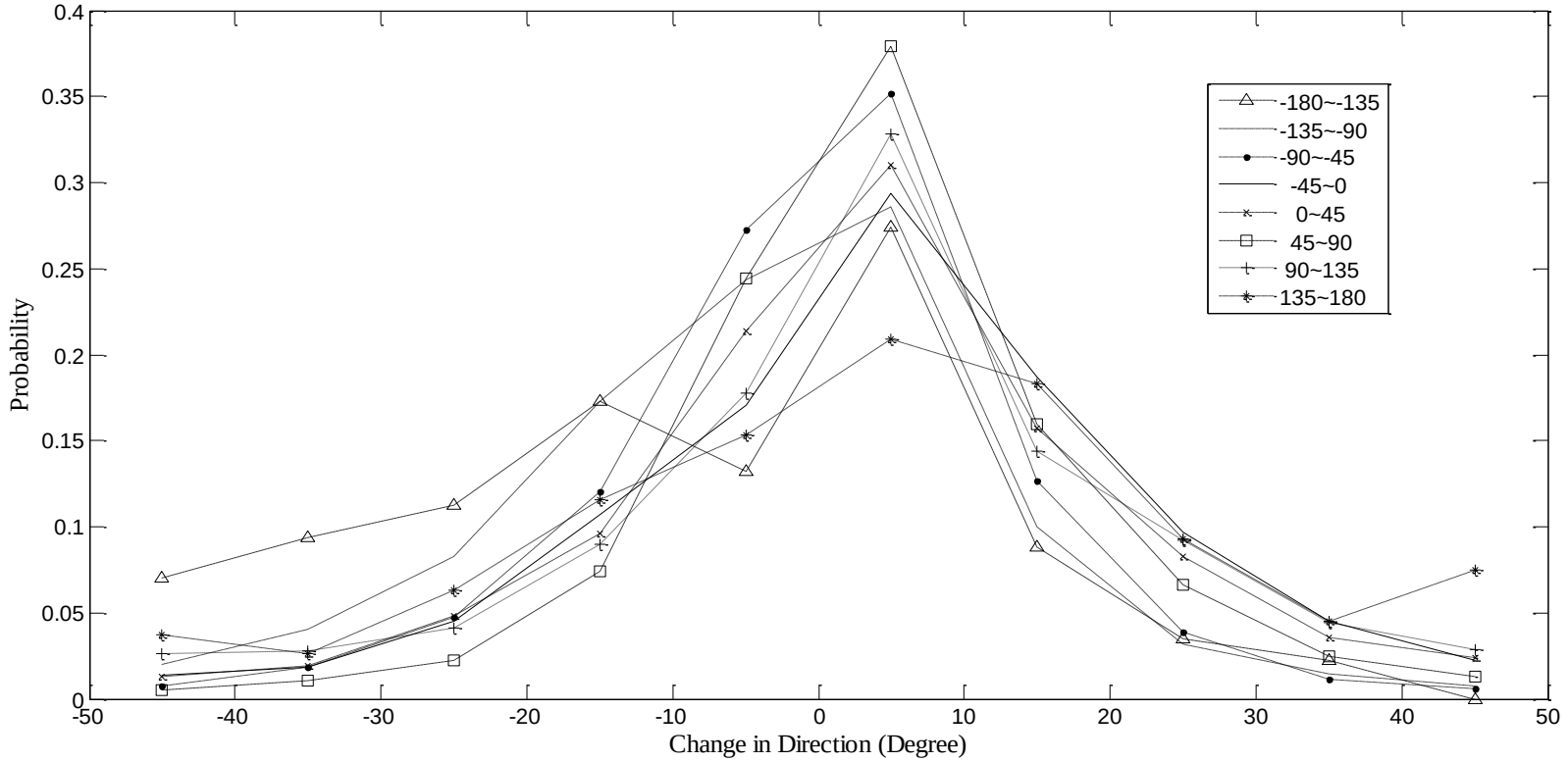
Annual Typhoon Occurrence Probability: Fitting and Event Gen.





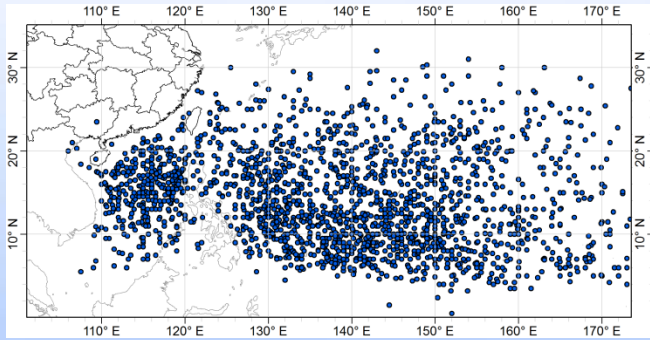
Moving Velocity: Auto-relation

2. Cat Model: Event Generation

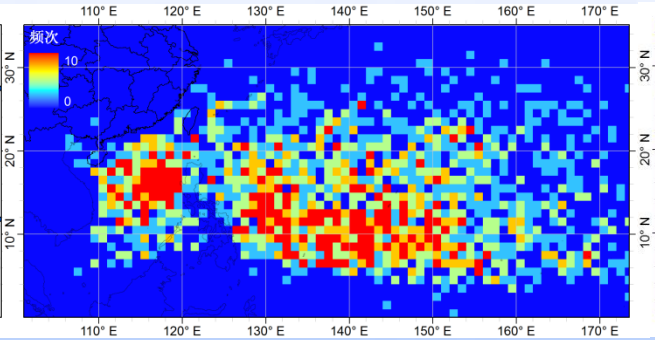


Moving Direction: Markov chain with optimal sampling

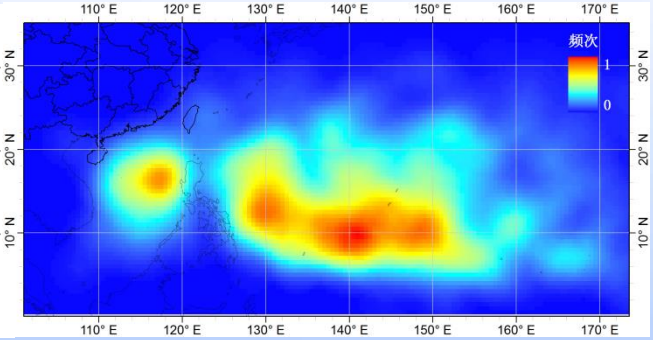
2. Cat Model: Event Generation



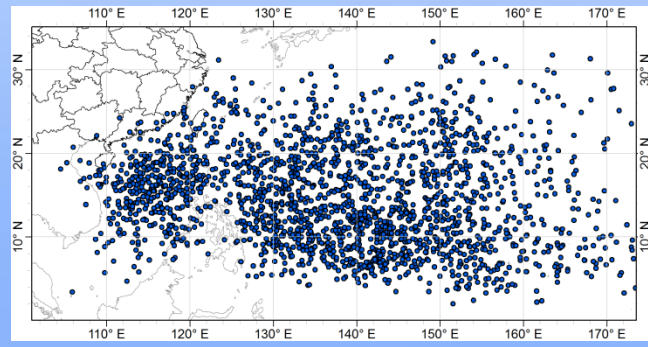
Historical Genesis (1949~2010)



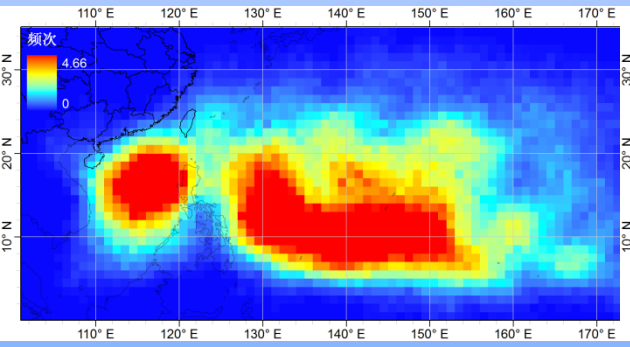
Historical Frequency by grid



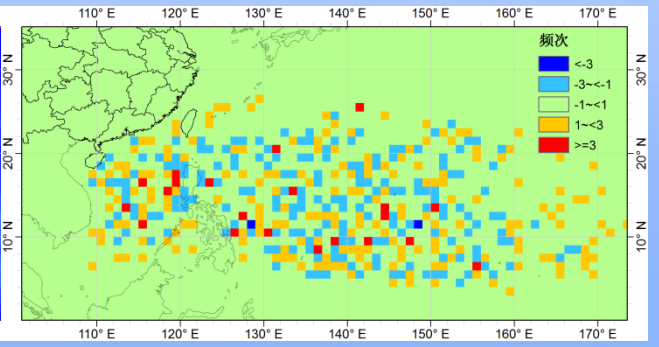
Kernel Density of Genesis



Simulated Genesis (62 yrs)



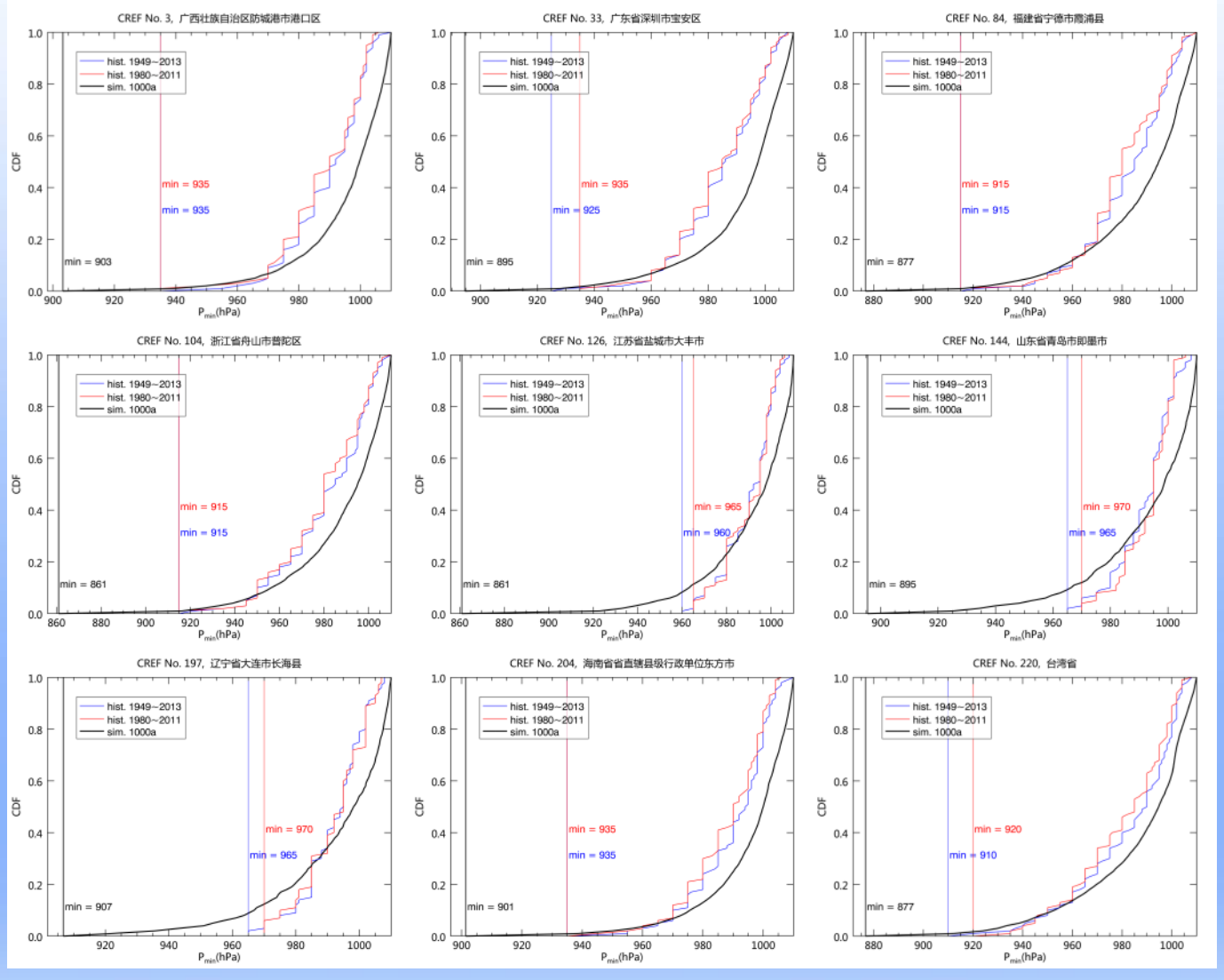
Simulated Genesis (10,000 yrs)



Difference Analysis

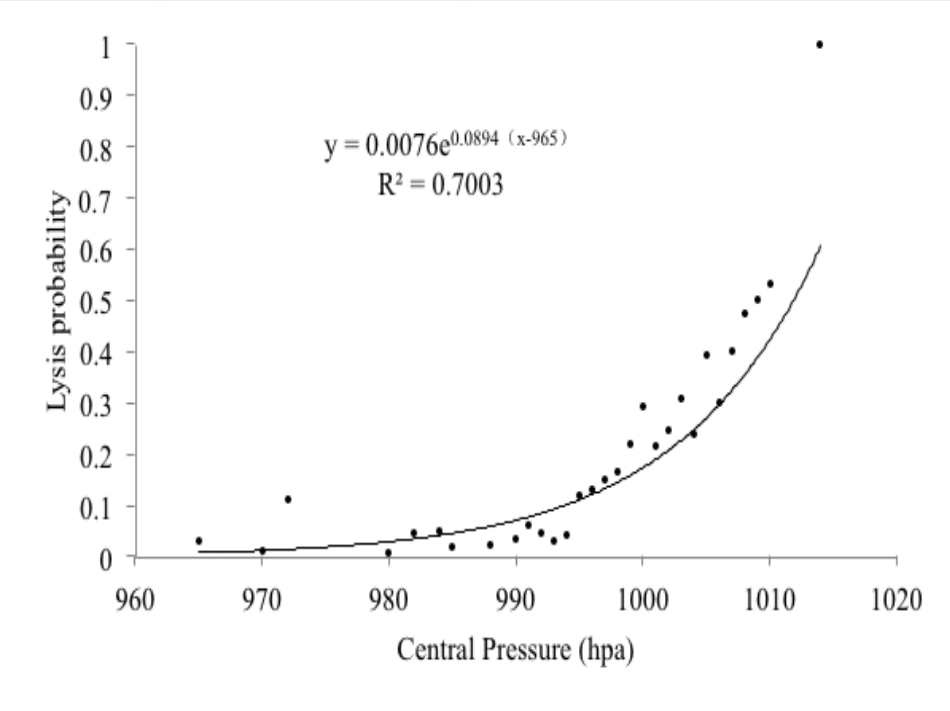
Empirical Typhoon Genesis Probability: Kernel Density

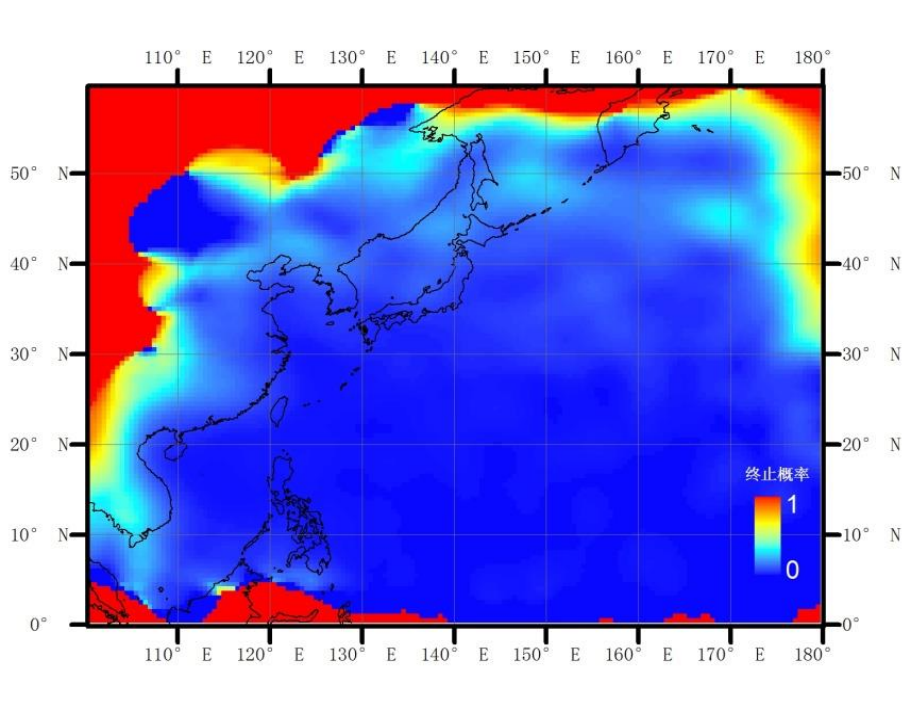
2. Cat Model: Event Generation



Landing intensity at county level by modeling potential intensity over the sea considering SST, outflow temperature, wind shear, etc.

2. Cat Model: Event Generation

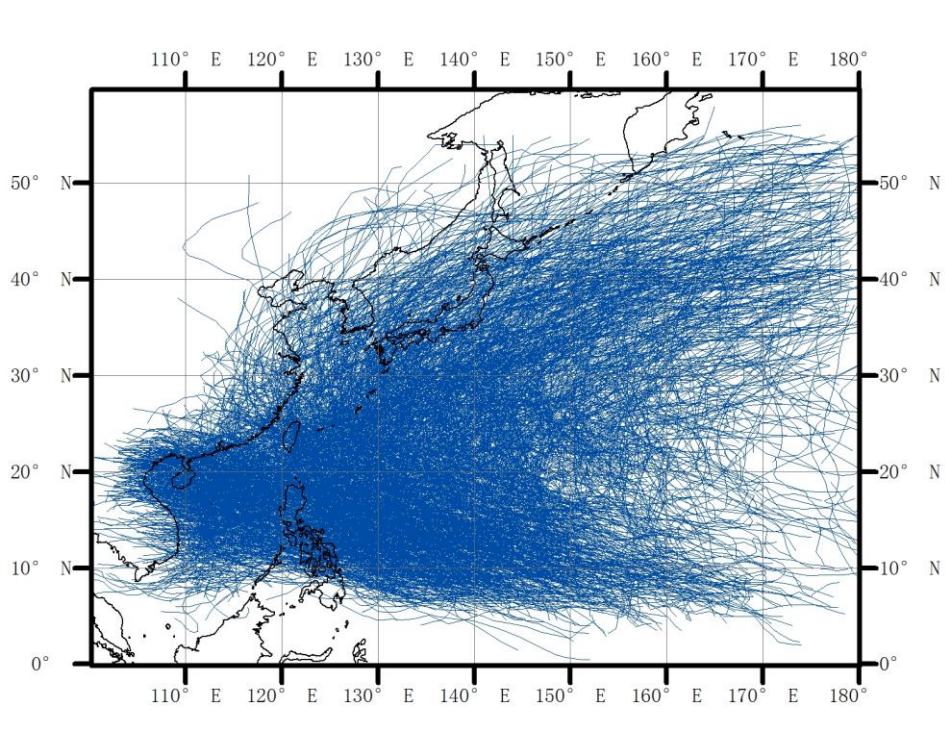


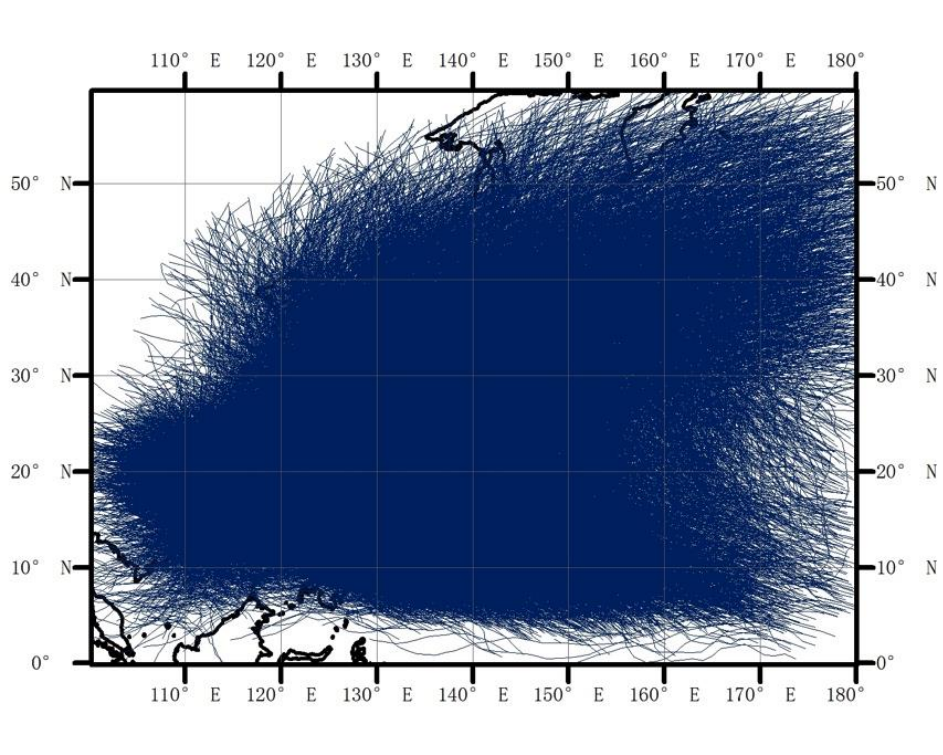


Decay Probability and Lysis Probability (Spatial Kernel Density)

2. Cat Model: Event Generation

Genesis, Moving, Landing, Decay (filling) and Lysis

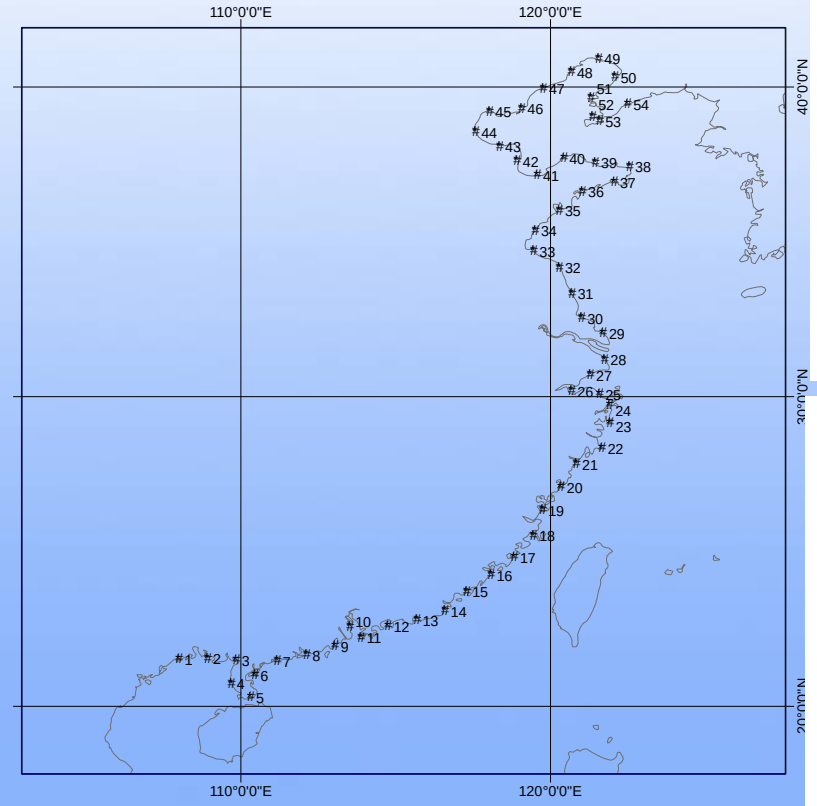


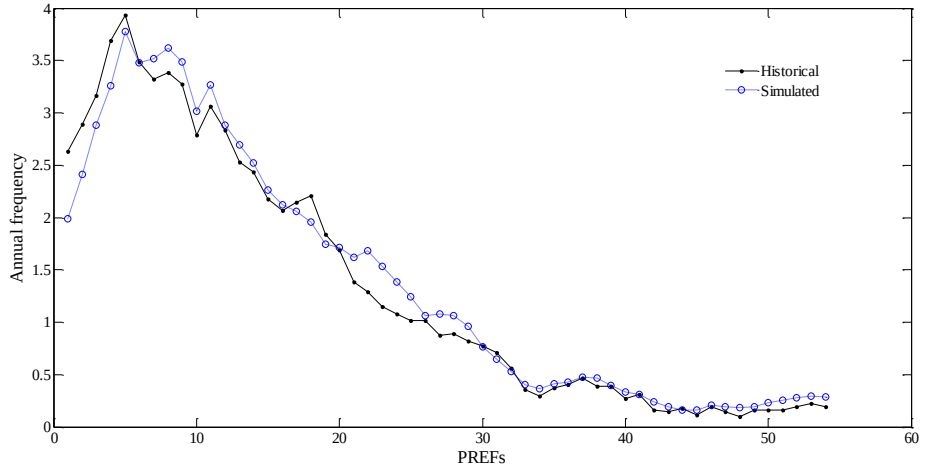


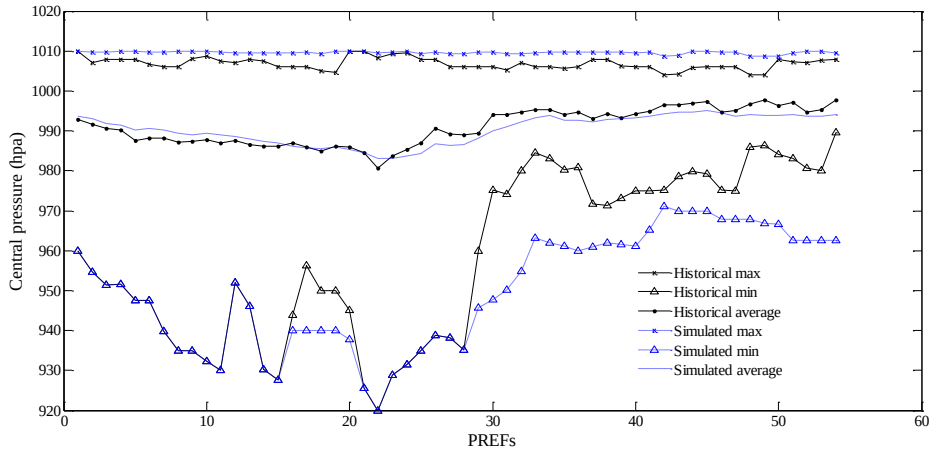
Historical tracks (62 yrs) and stochastic event set (620 yrs)

(Key parameters: Time, location, P0, RMW, MWS)

2. Cat Model: Event Generation

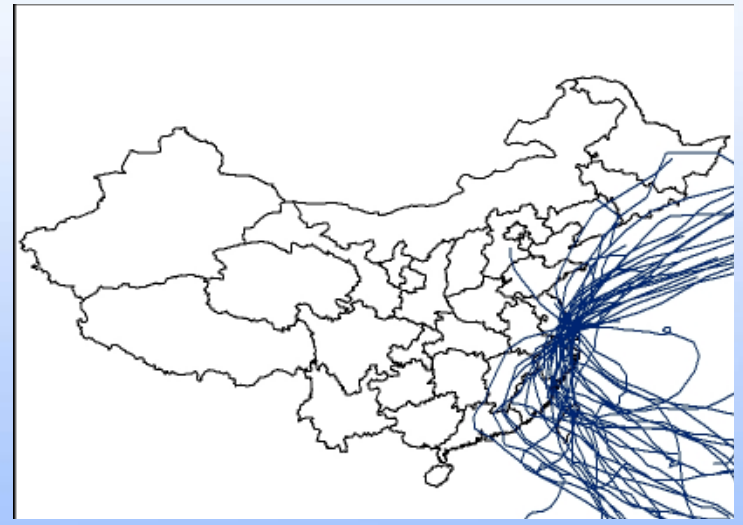


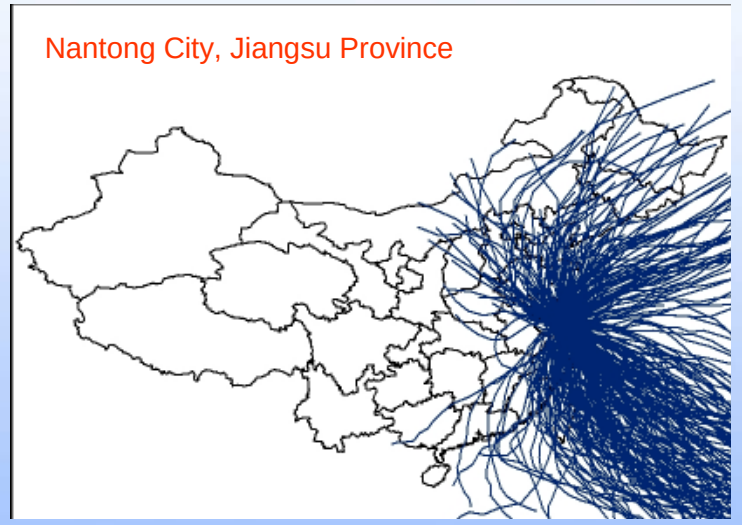


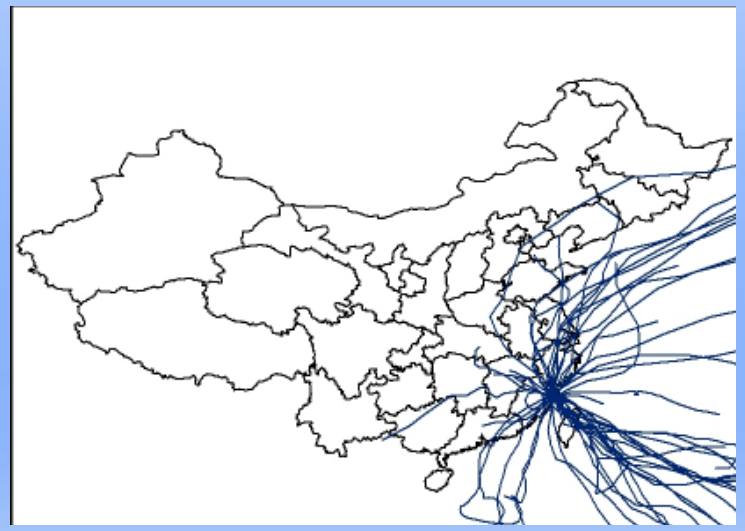


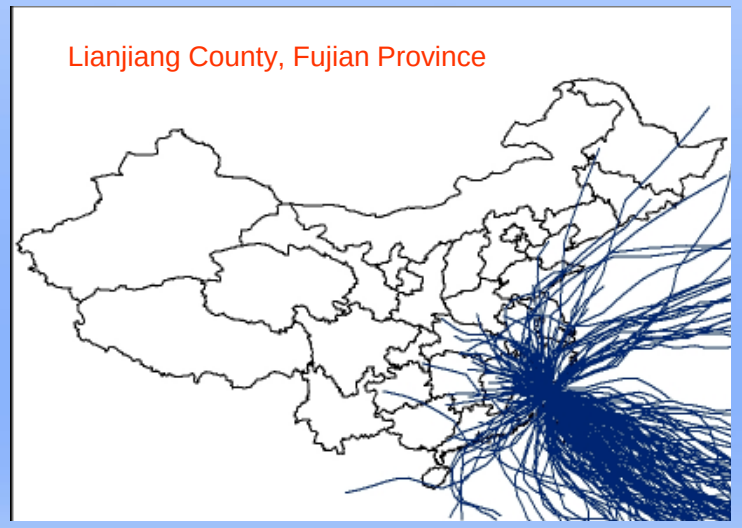
Comparison of historical and simulated parameters:
frequency, P0, RMW, MWS, moving direction and velocity, etc.

2. Cat Model: Event Generation



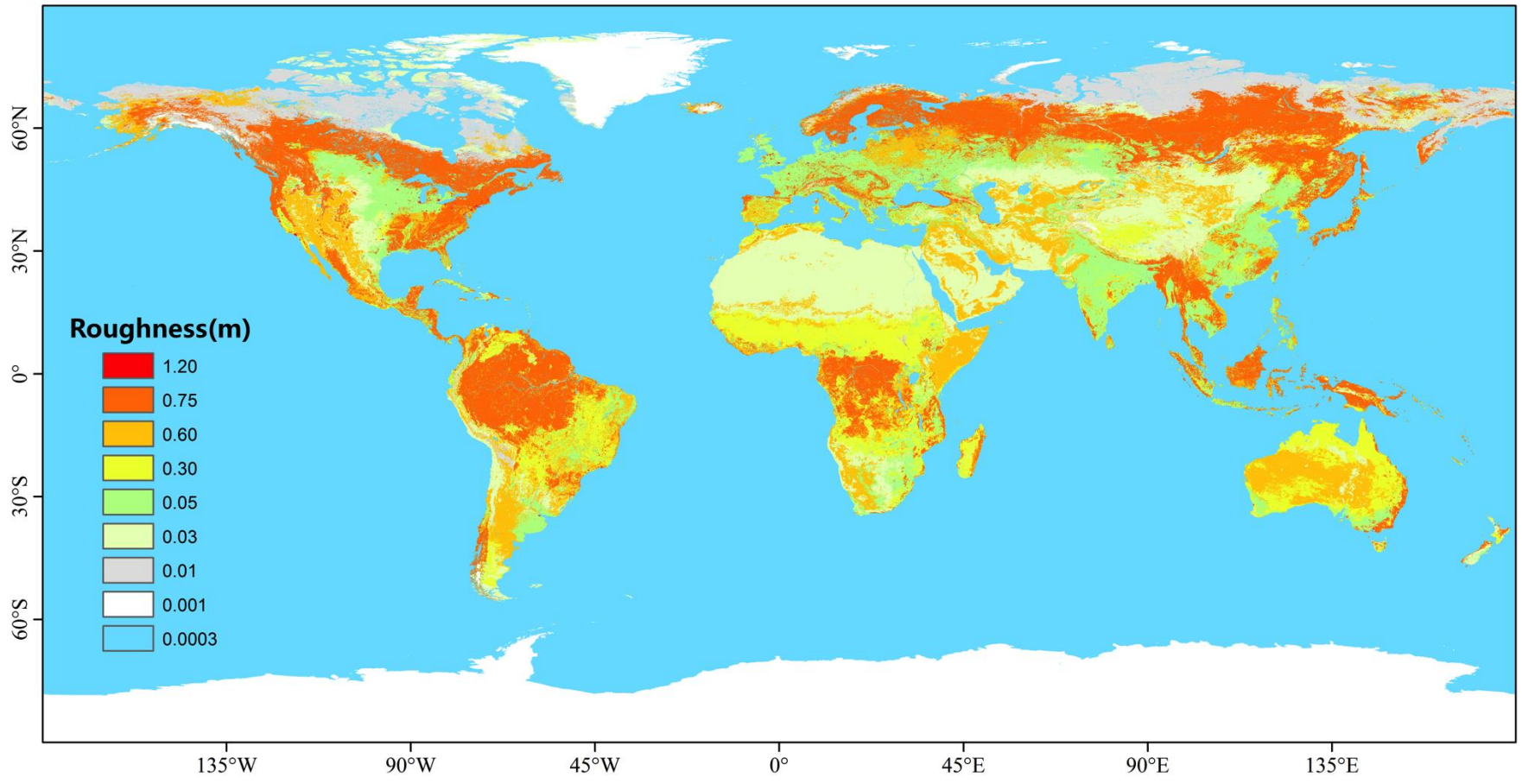






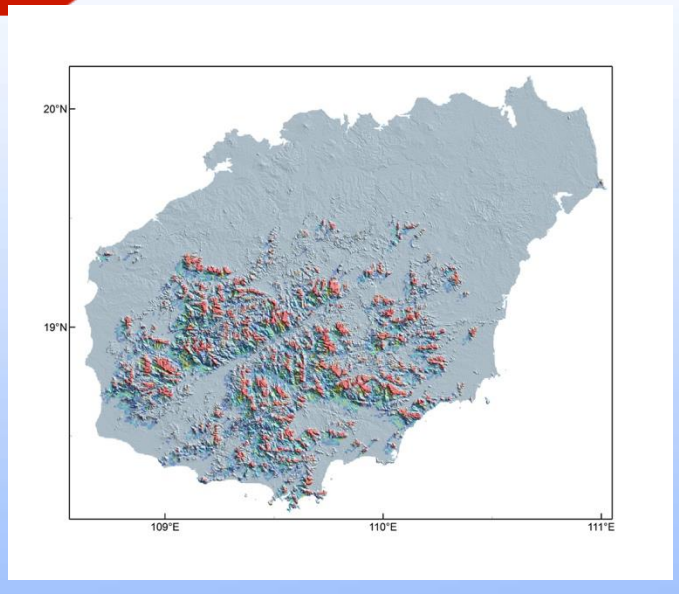
Historical tracks (62 yrs) and stochastic event set (620 yrs)

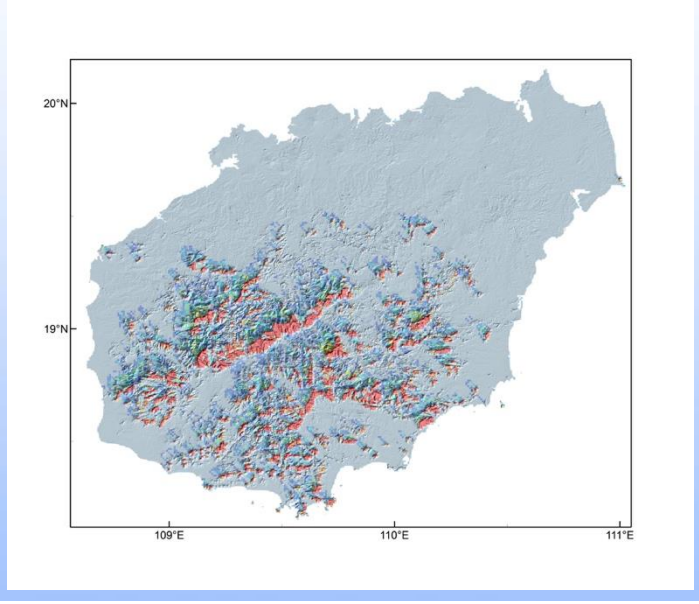
2. Cat Model: Wind Hazard

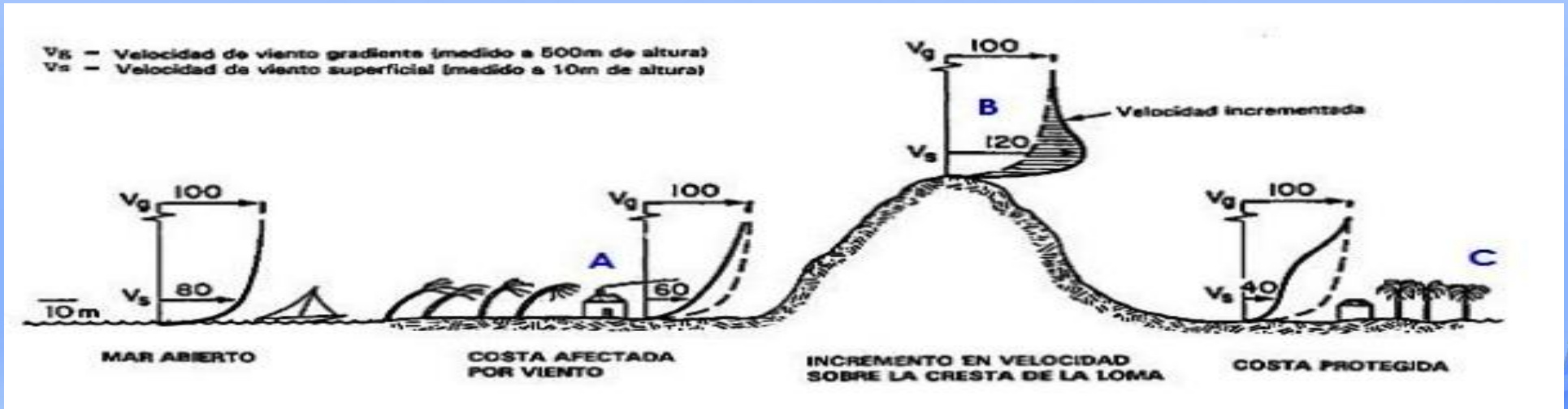


Local roughness effects due to landuse are modeled (24 types)

2. Cat Model: Wind Hazard

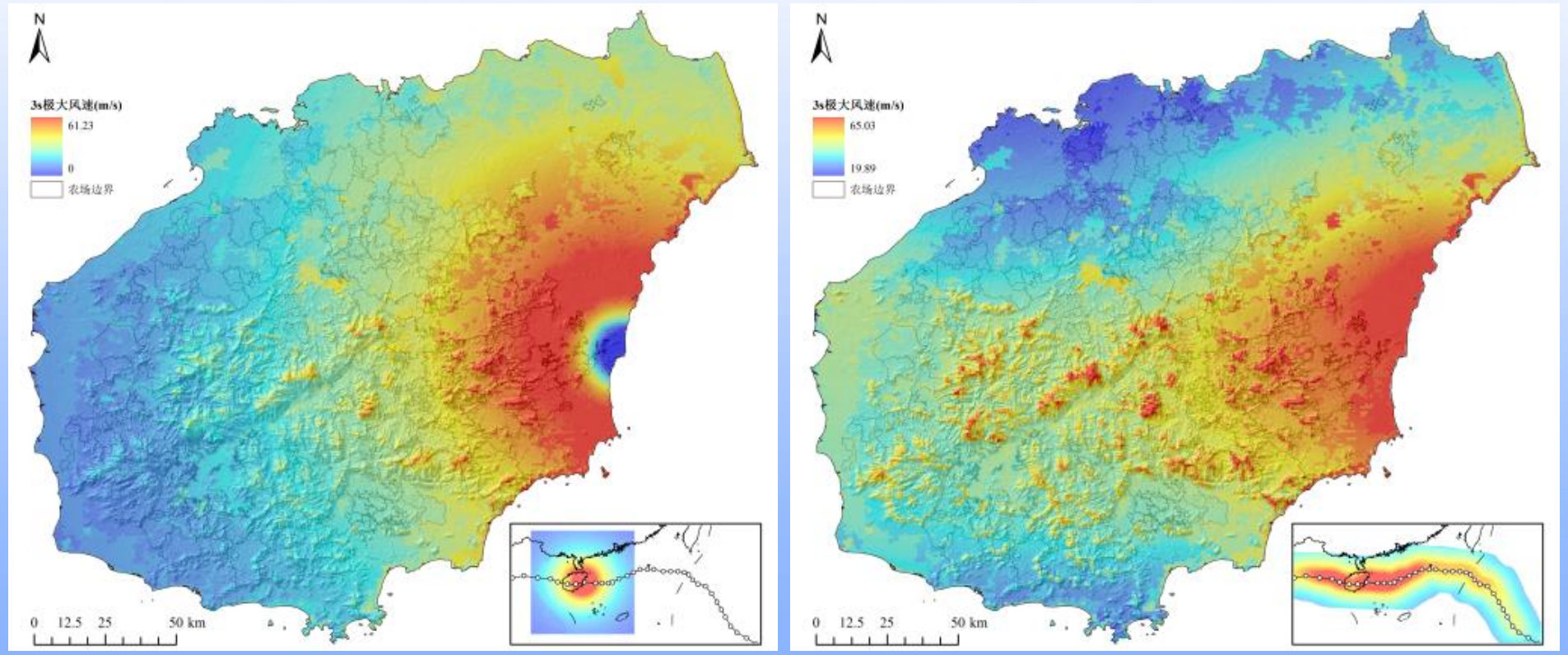






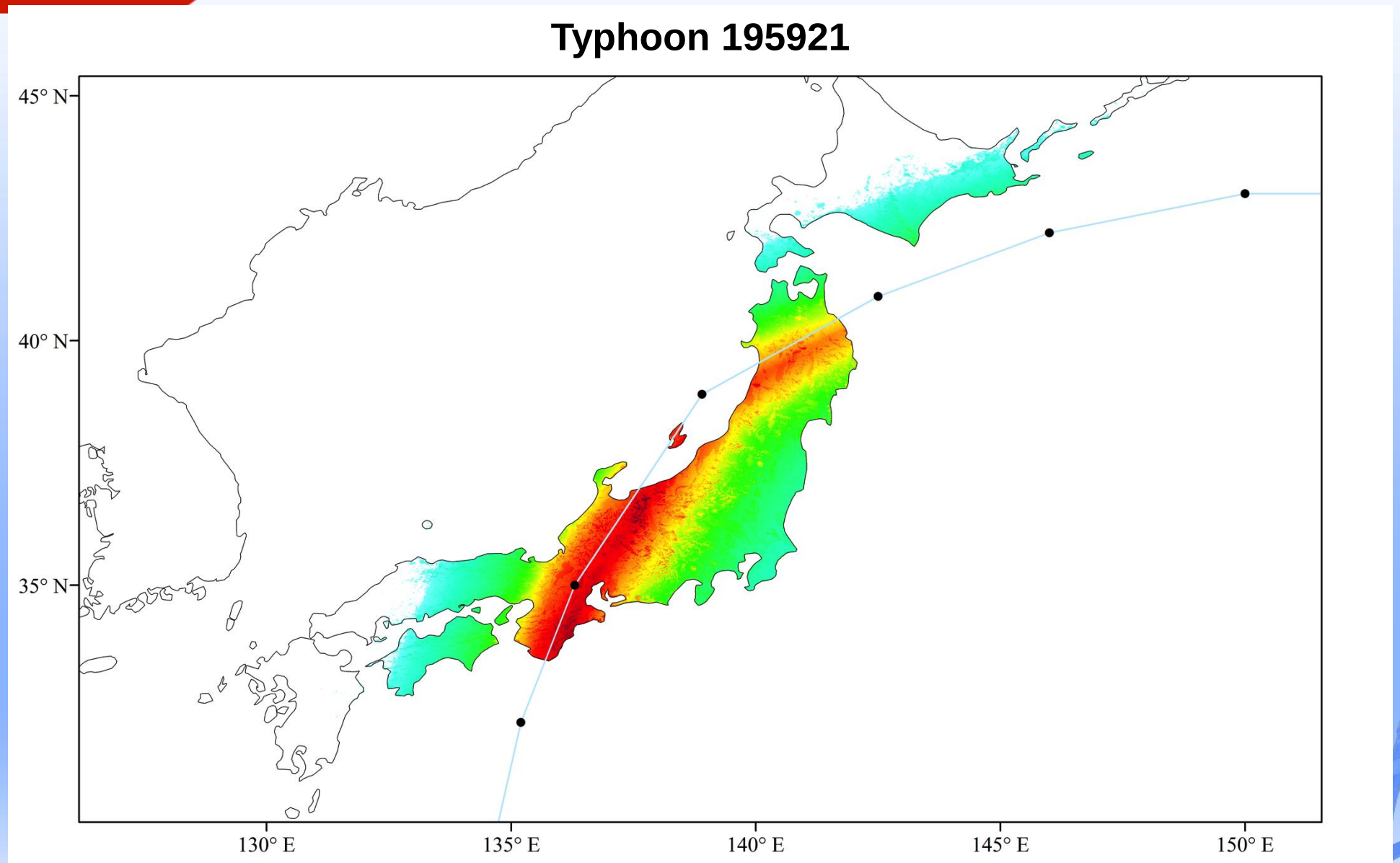
Directional topographic effects of elevation are modeled (8 directions)

2. Cat Model: Wind Hazard



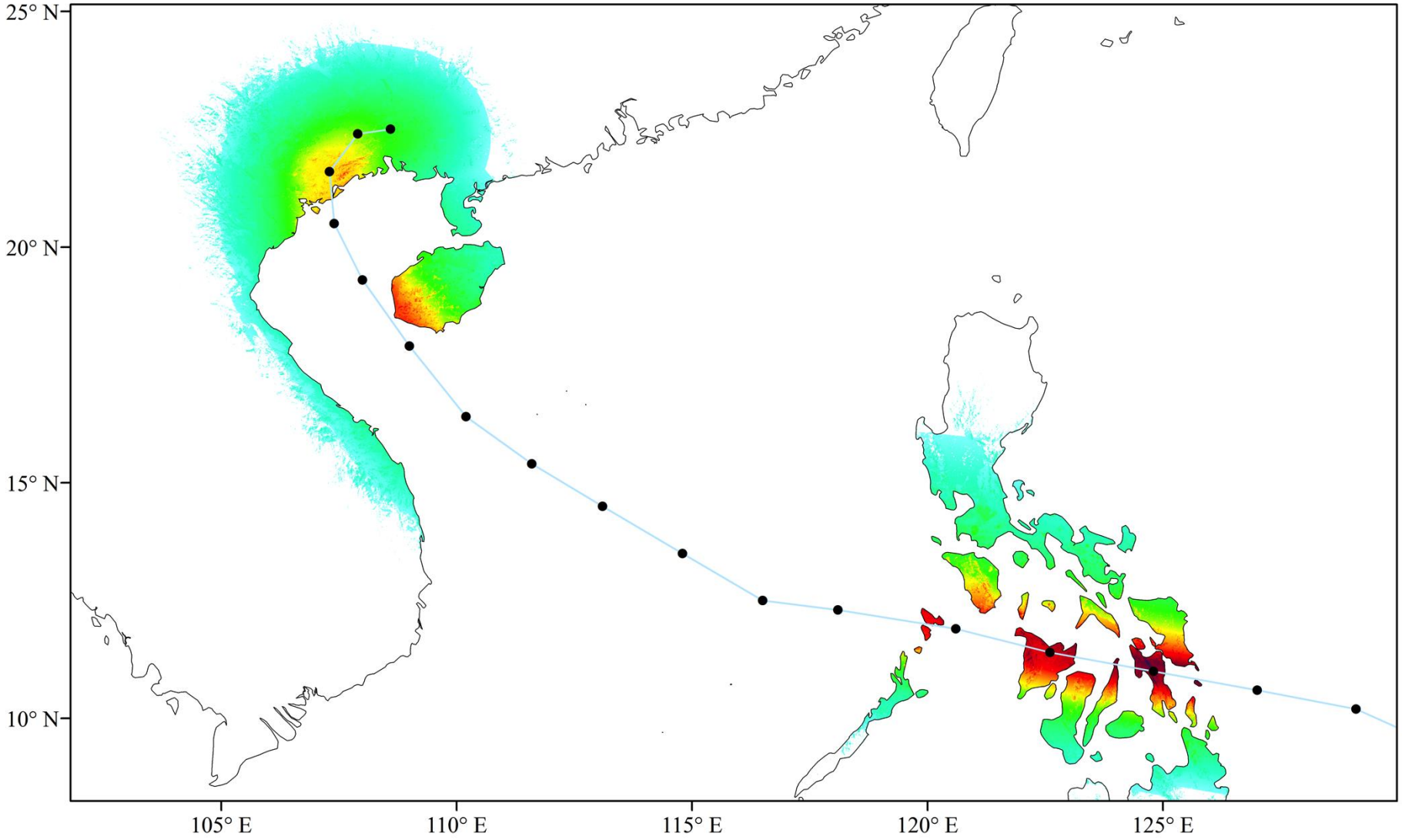
Snapshot and Footprint of surface peak gust (V_{3s}) wind of Typhoon Damrey

2. Cat Model: Wind Hazard

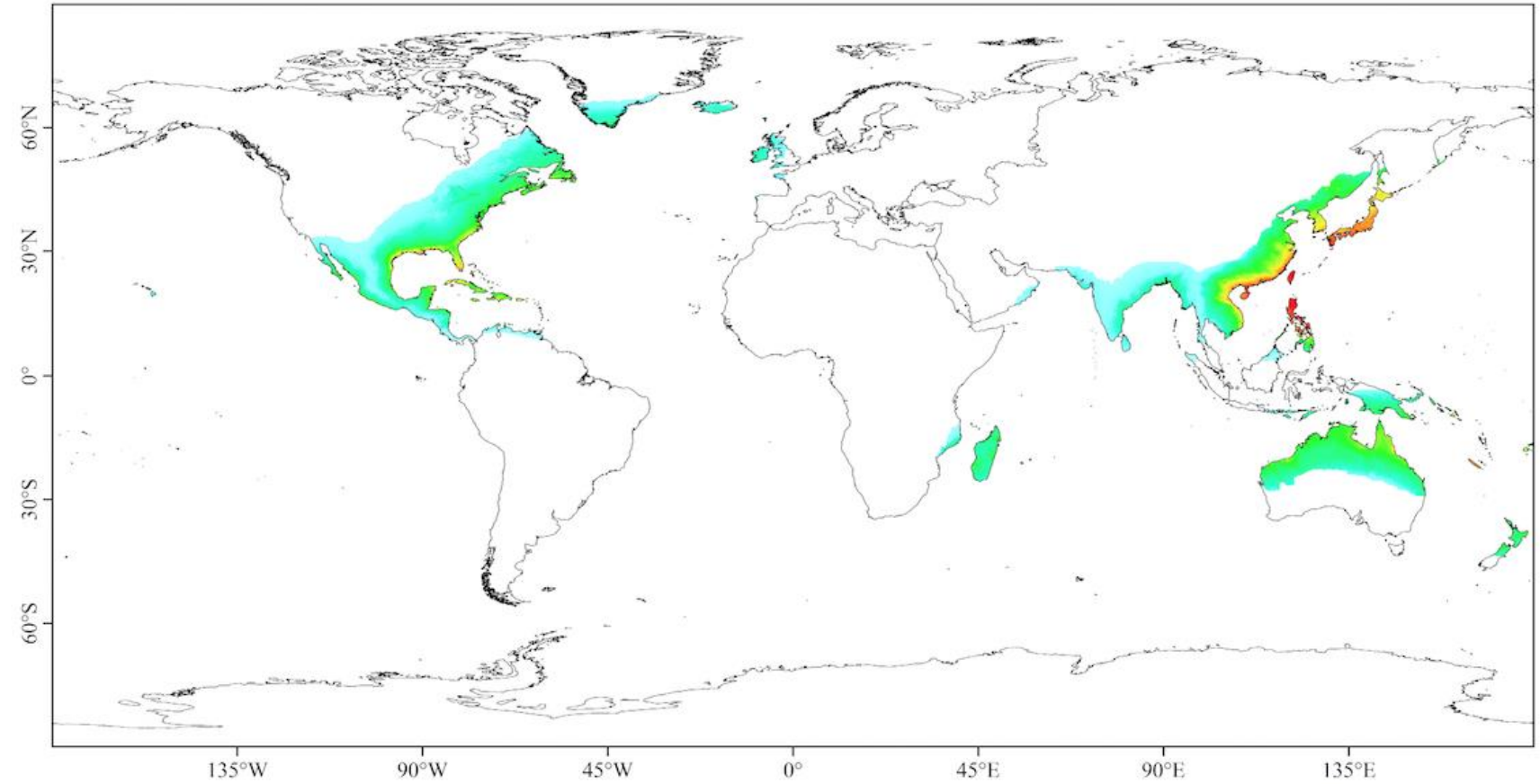


2. Cat Model: Wind Hazard

Typhoon 201334 (Haiyan)



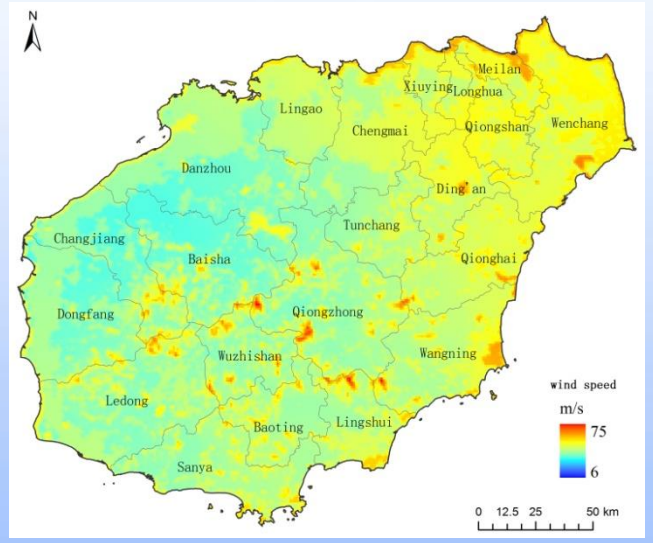
2. Cat Model: Wind Hazard



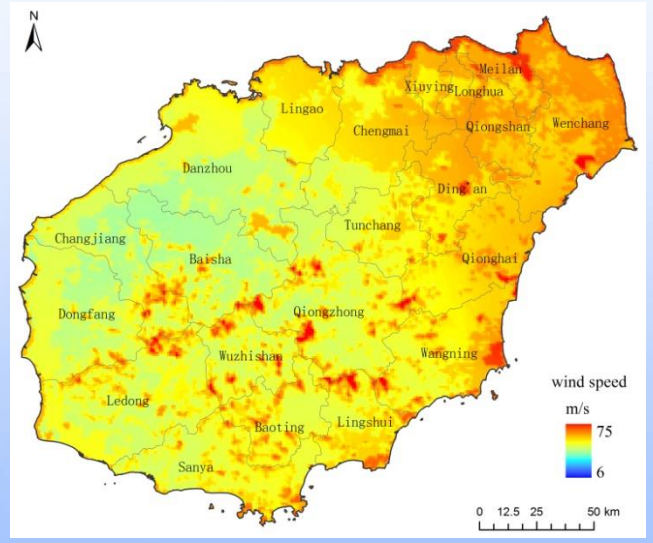
Wind hazard assessment with simulated historical windfields (rp: 20a)

2. Cat Model: Wind Hazard

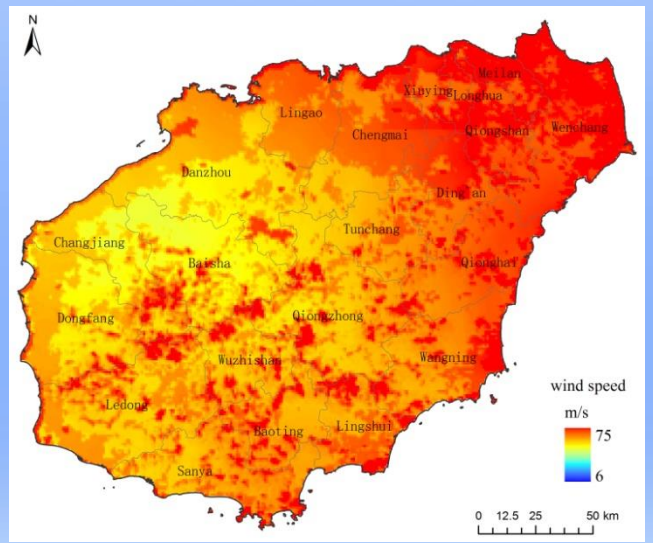
Rp: 10a



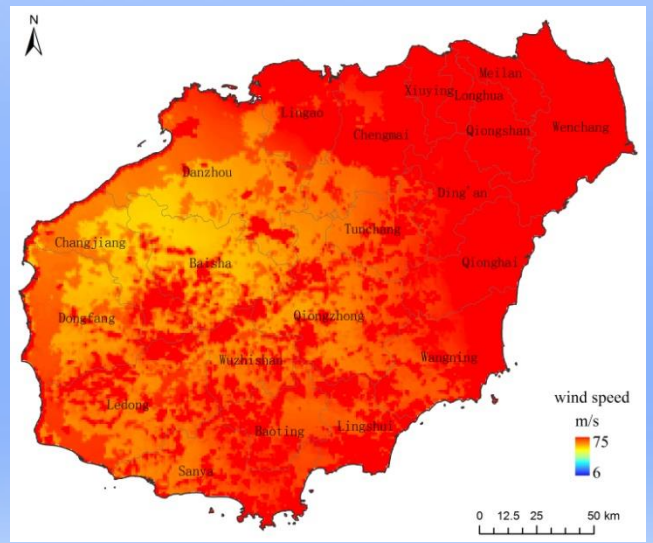
Rp: 20a



Rp: 50a



Rp: 100a



Wind hazard assessment with 1000 yrs of stochastical windfields

2. Cat Model: Rainfall Hazard

1) Rain rate & radius

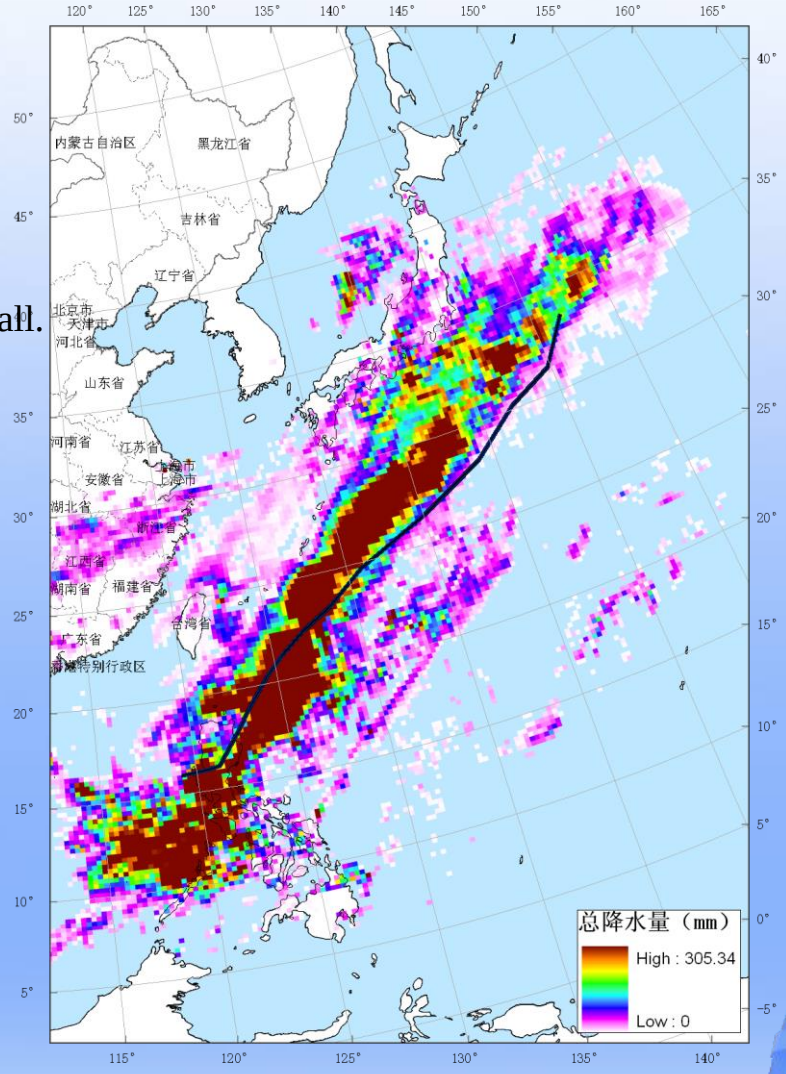
$$R(r)=\begin{cases} R_0+(R_m-R_0)\cdot(r/r_m) & r\le r_m \\ R_m\cdot\exp(-(r-r_m)/r_e) & r>r_m \end{cases}$$

where r_m is the radius of maximum rainfall and r_e is the surrounding rainfall. the R_0,and R_m are the mean rainfall rates at r_e and r_m, respectively.

2) Rain rate & wind speed

$$R_0 = a_1 + b_1 U$$
$$R_m = a_2 + b_2 U$$
$$r_m = a_3 + b_3 U$$
$$r_e = a_4 + b_4 U$$
$$U = (V_m - 10)/12$$

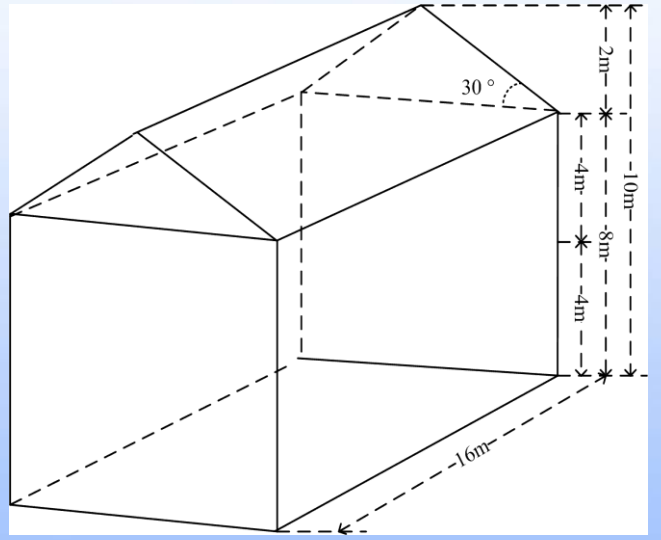
where U is the standardized MWS. a_i and bi are the coefficient by linear fitting.

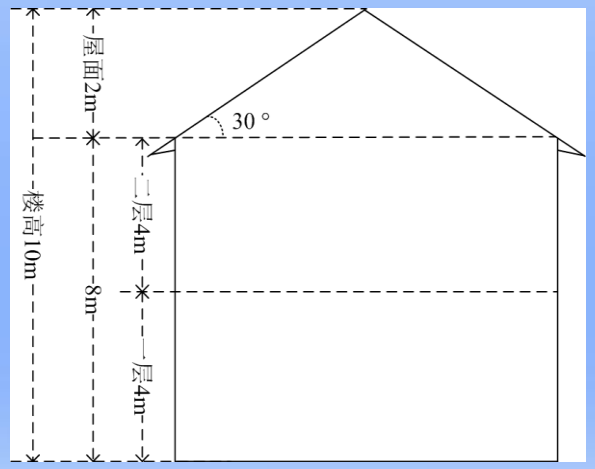


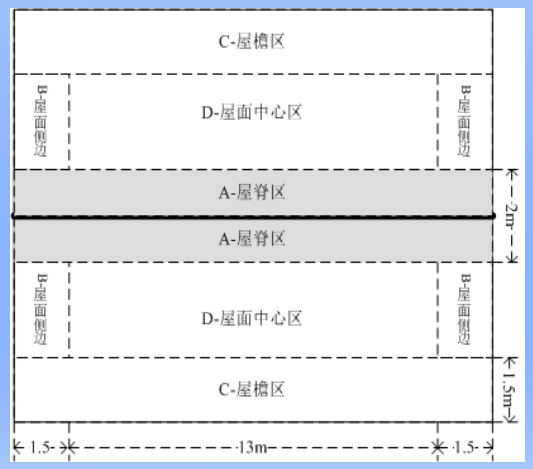
Linking Rainfall Rate with Other Typhoon Parameters

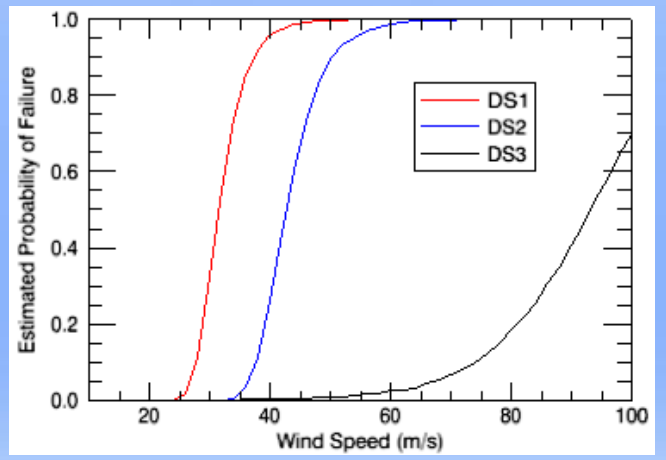
(Similar to R-Cliper Model)

2. Cat Model: Vulnerability



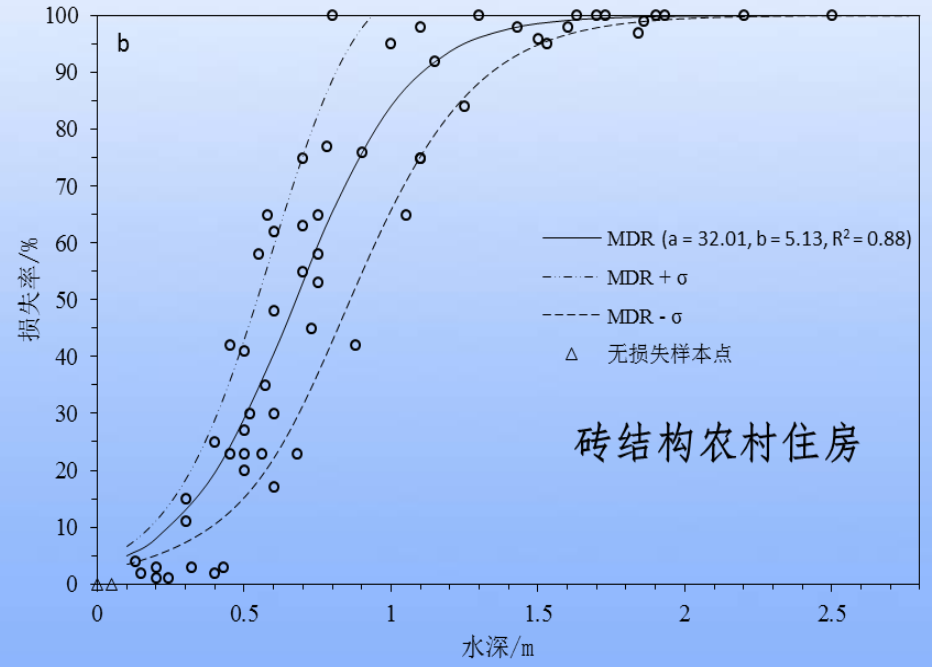


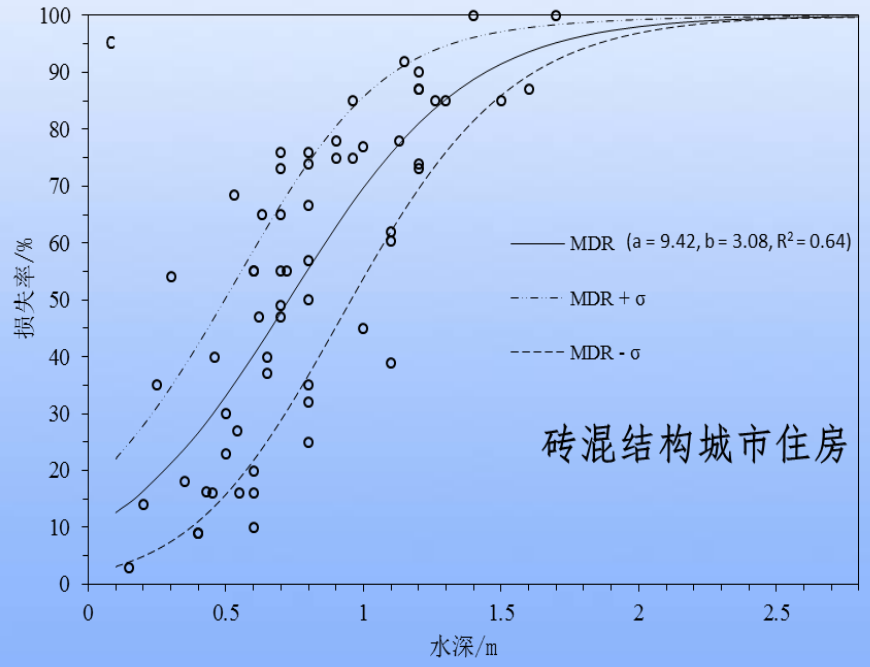




Fragility curves developed by component-based Monte Carlo simulation transform wind load & structure resistance to damage status (none, slight, medium, extensive, collapse)

2. Cat Model: Vulnerability

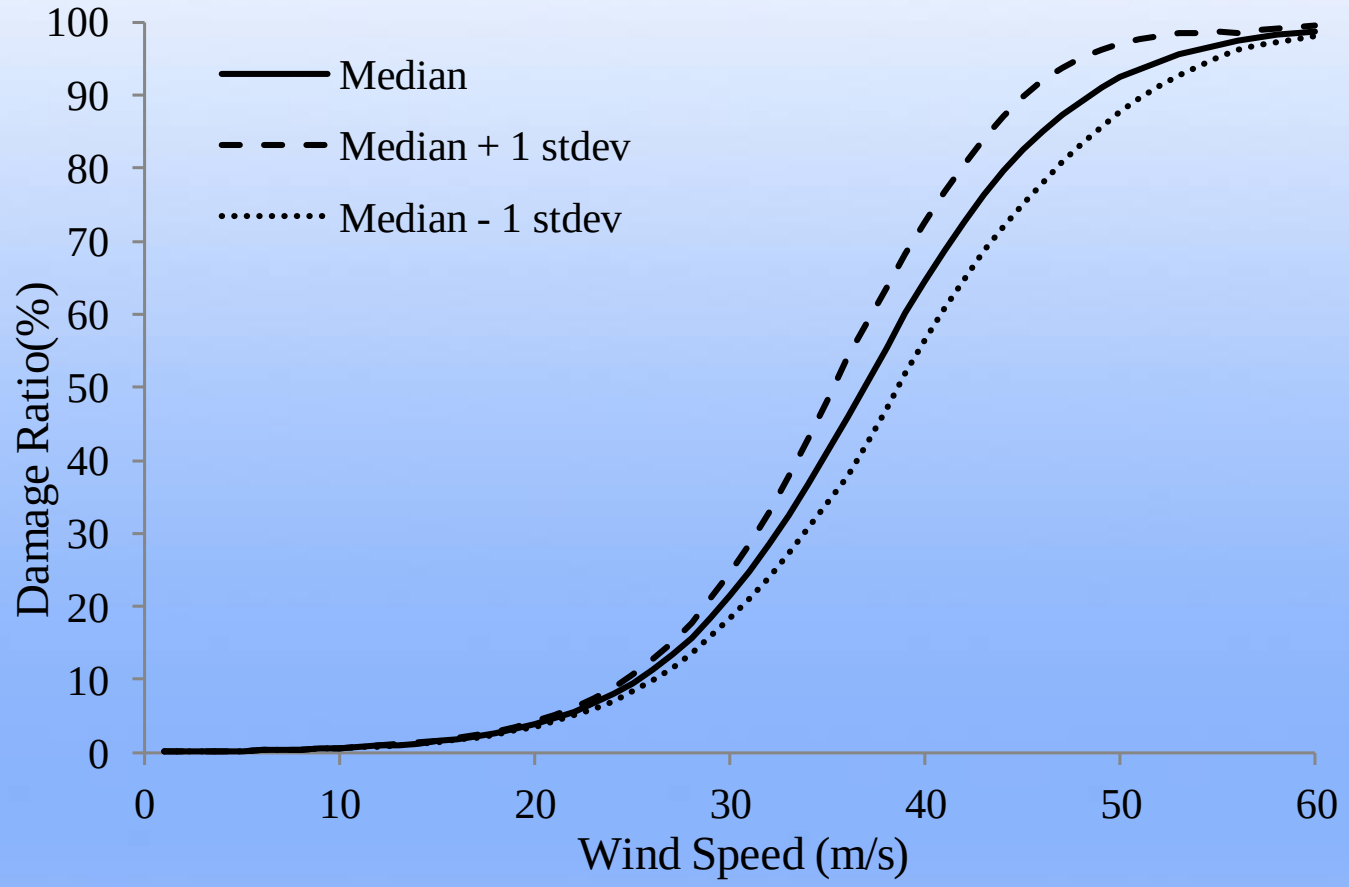




Empirical vulnerability curves of building contents to flood:

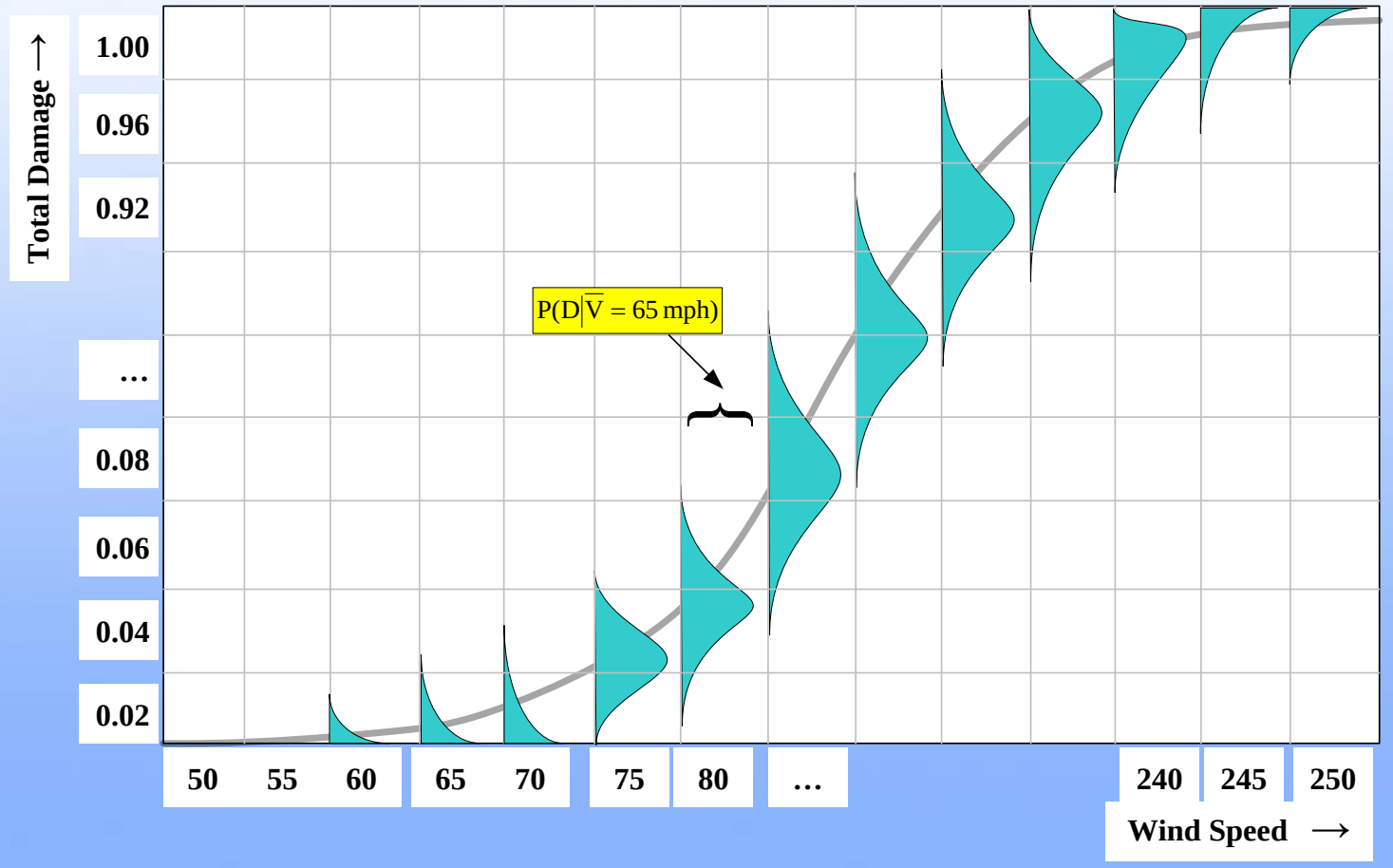
Case study of Typhoon-induced flood (Fitow, 201323)

2. Cat Model: Vulnerability



An example of vulnerability curve to wind hazard

2. Cat Model: Vulnerability



Quantification of the secondary uncertainty:
(uncertainty of damage ratio to identical hazard intensity)

2. Cat Model: Vulnerability

Empirical Vulnerability Curves Developed:

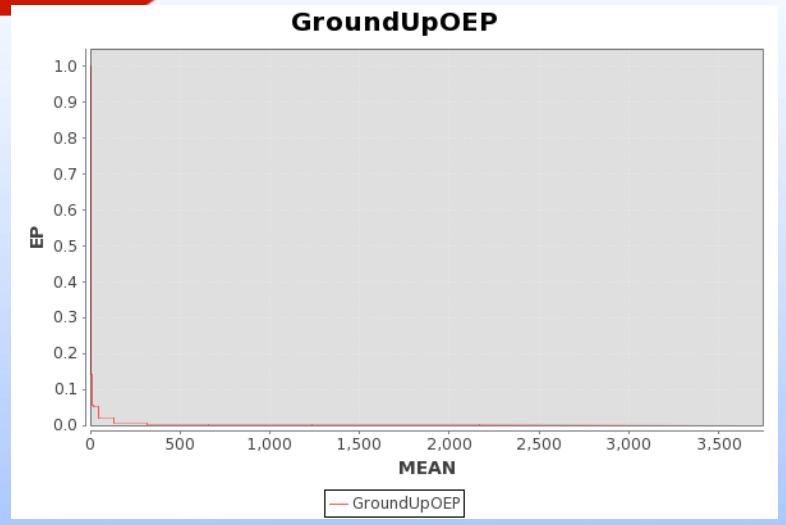
- **Residential**
- **Commercial**
- **Industrial**

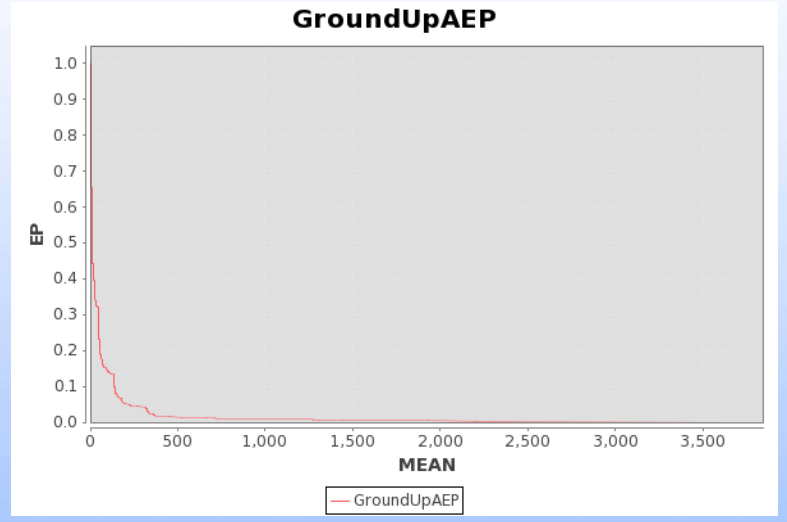
- **Buildings**
- **Contents**

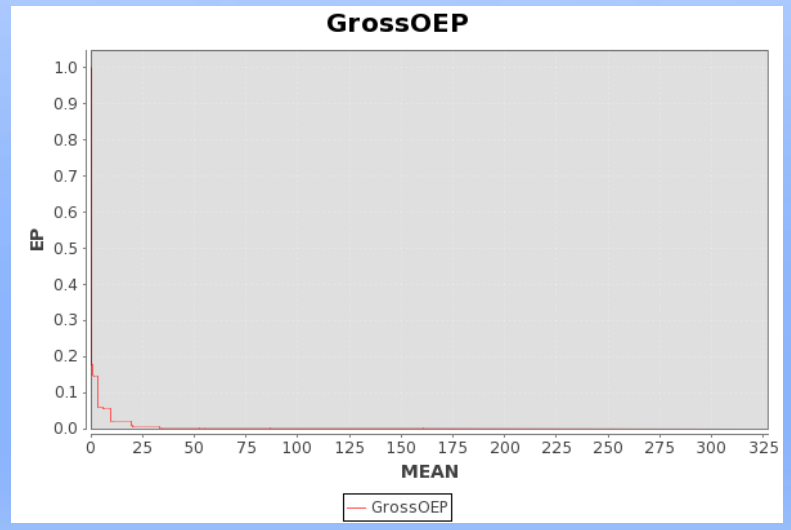
- **More than 100 curves**

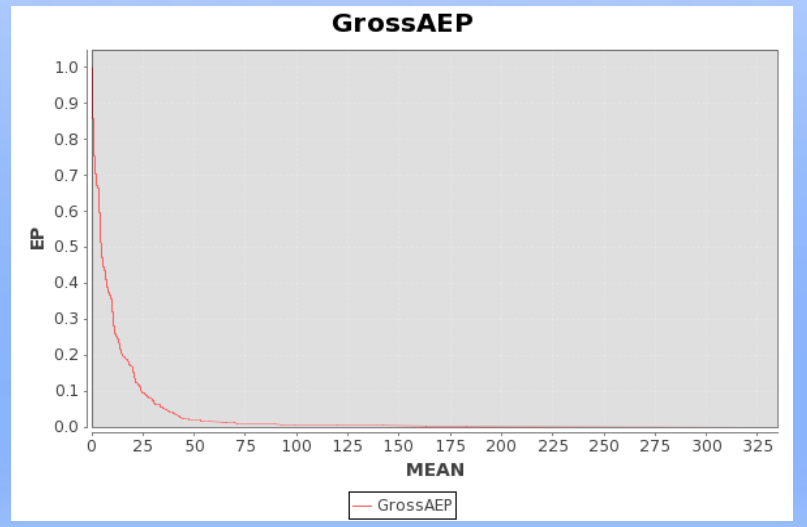
- **With actual insurance policy/claim data, government statistics, and field survey**

2. Cat Model: Risk Metrics



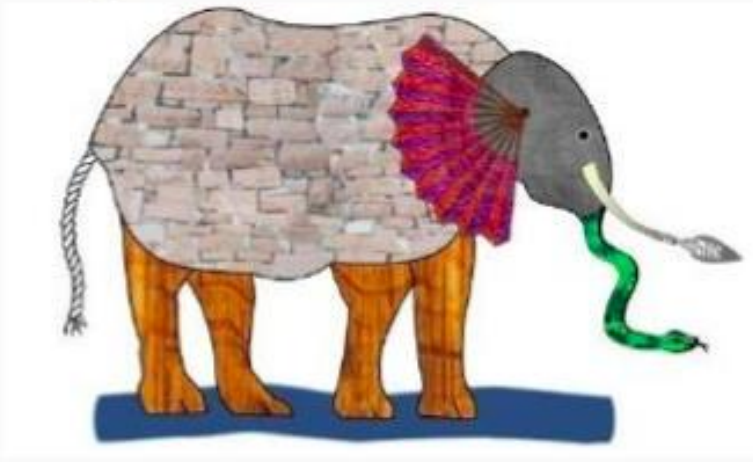






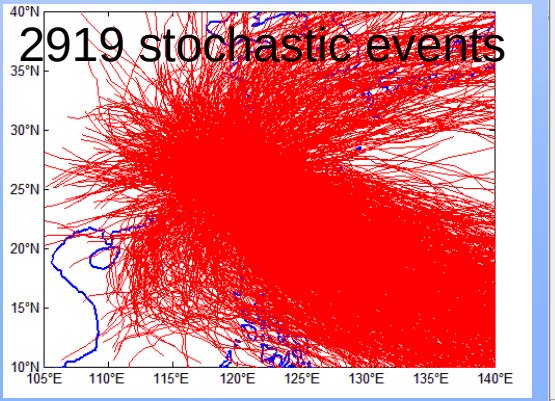
AAL, AEP, and OEP, etc. for any policy portfolio

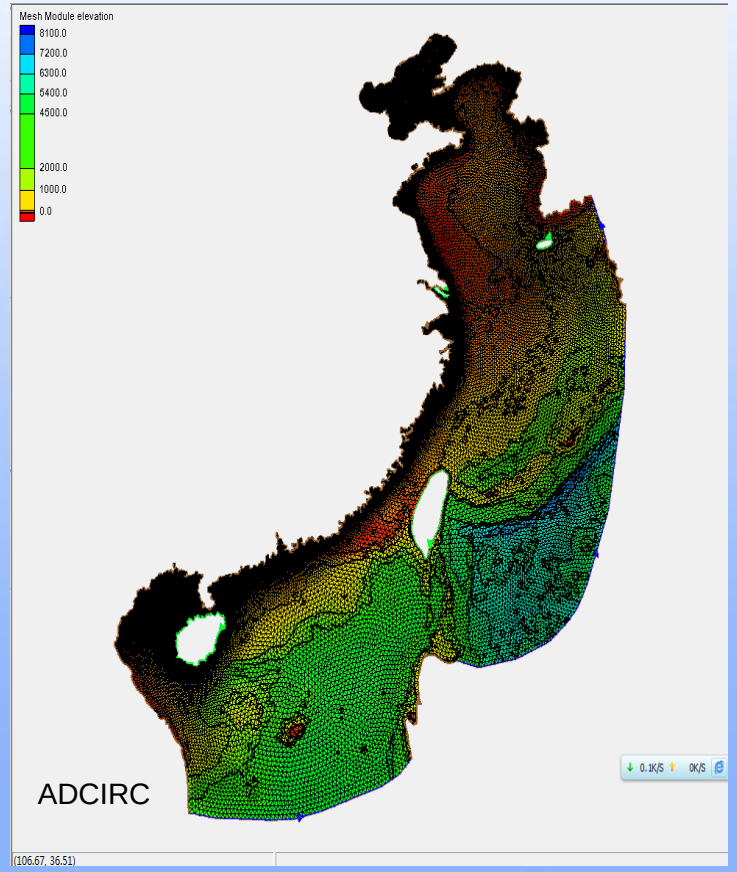
2. Cat Model: Hazard

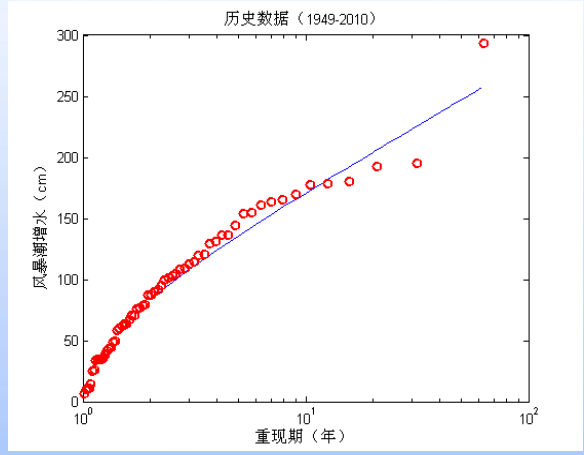


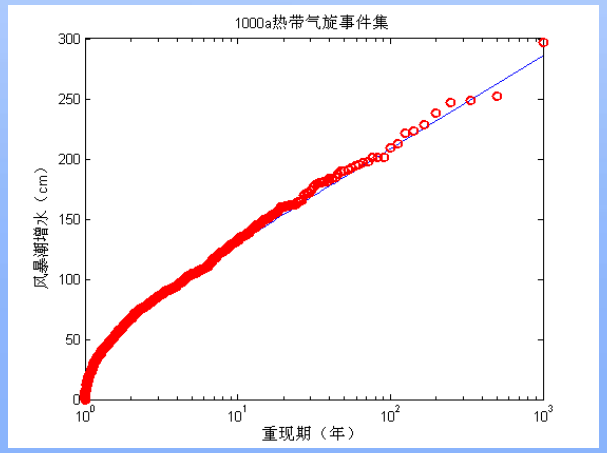
Communicate model uncertainty to users is critical

3. Application Example: Storm Surge Hazard Assessment







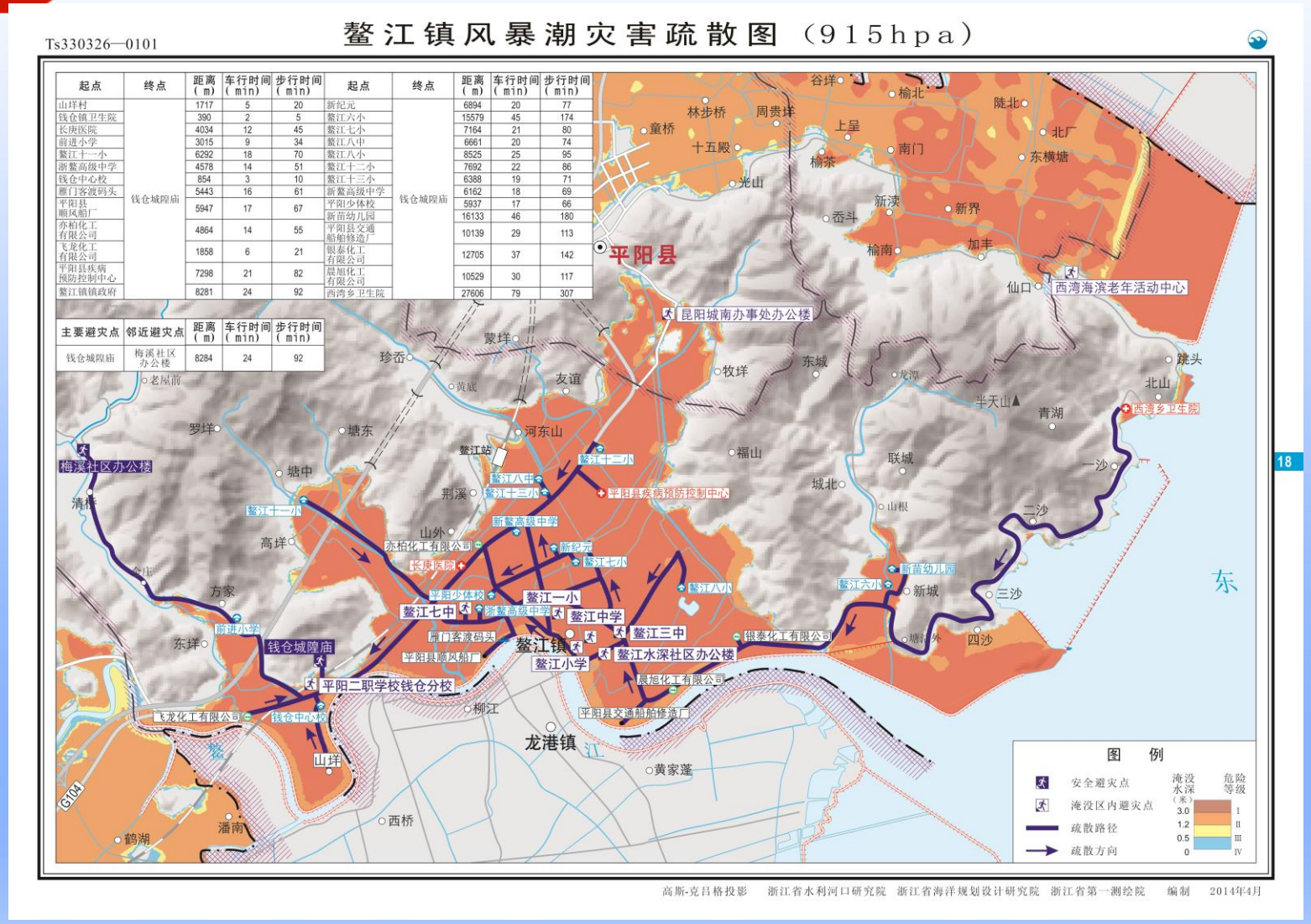


Storm surge modeling with historical typhoon events and stochastic events

(1) Probable Maximum Storm Surge Inundation Maps by Typhoon Intensity Scale

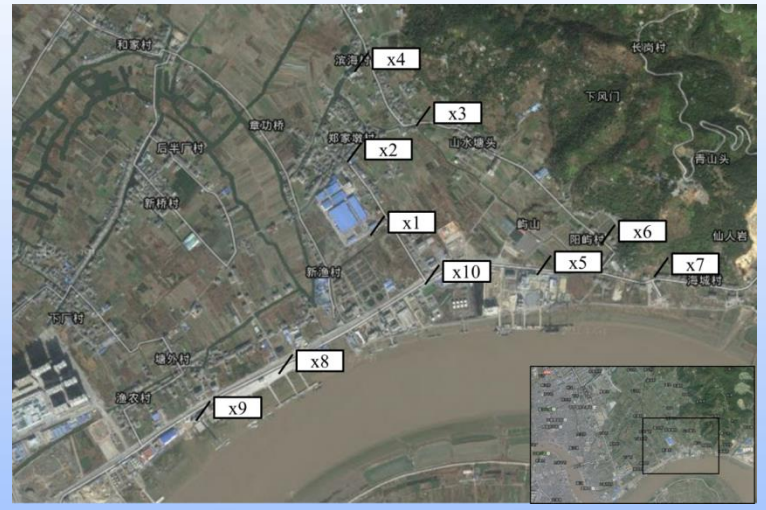
(2) Storm Surge Inundation Maps by Return Period

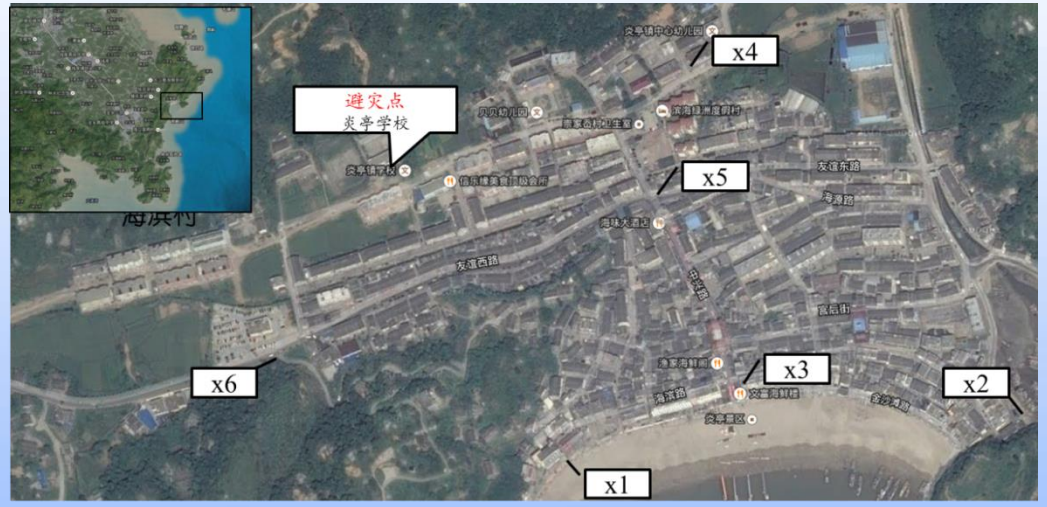
3. Application Example: Storm Surge Hazard Assessment

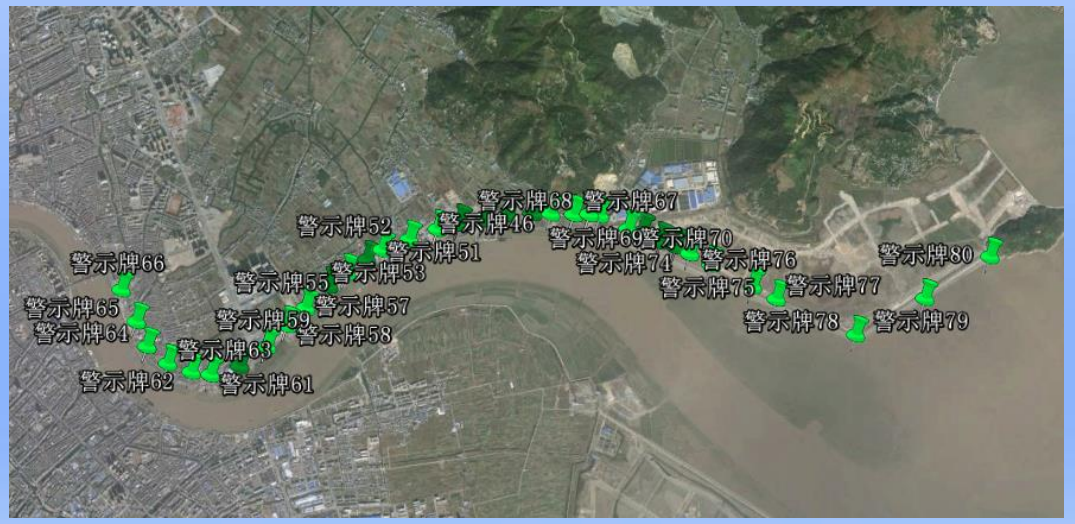


Evacuation Map for Storm Surge Disaster

3. Application Example: Storm Surge Hazard Assessment







Evacuation maps at high-risk coastal areas (Pingyang County)

3. Application Example: Weather index-based Insurance

Rubber tree damage caused by strong winds (2009, Hainan)

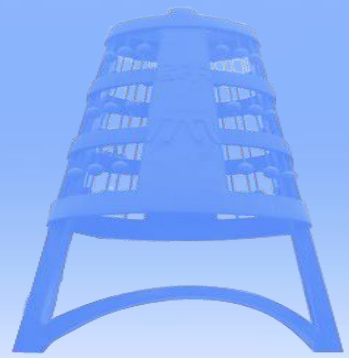
Traditional insurance v.s. index-based insurance?

Benefits:

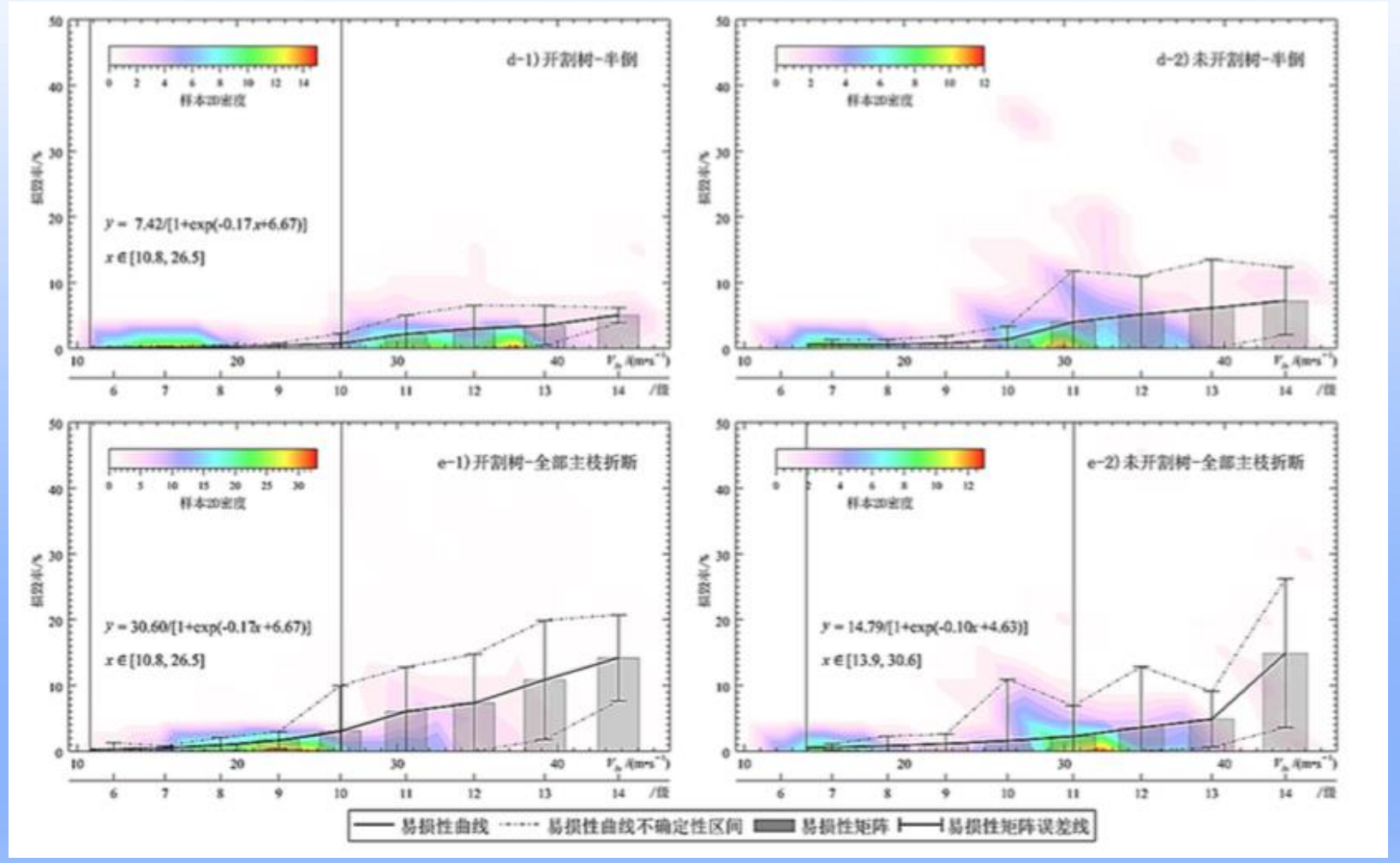
- No moral hazard
- No adverse selection
- Lower operating costs
- Transparency.
- No cross-subsidization
- Immediate disbursement

Challenges:

- Basis Risk
- Model Bias
- Technical limitations of insurable hazards
- Market limitations of insurable hazards
- Education.



3. Application Example: Weather index-based Insurance

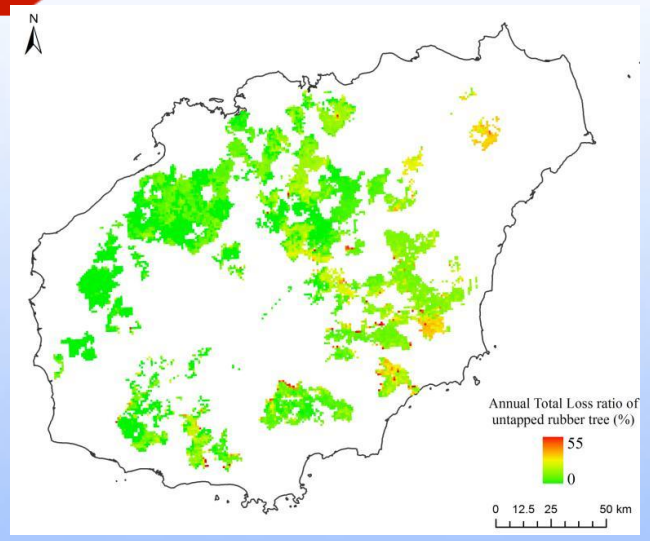


Vulnerability curves of rubber trees in Hainan Island ->

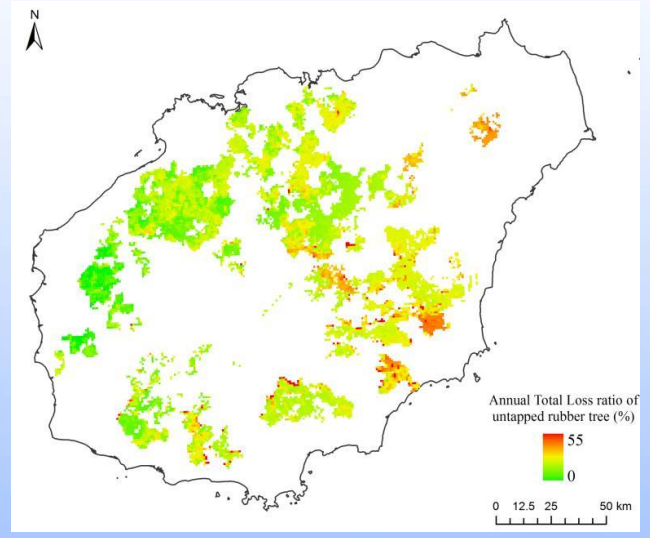
How much to pay by insurance company after disaster is decided by wind speed

3. Application Example: Weather index-based Insurance

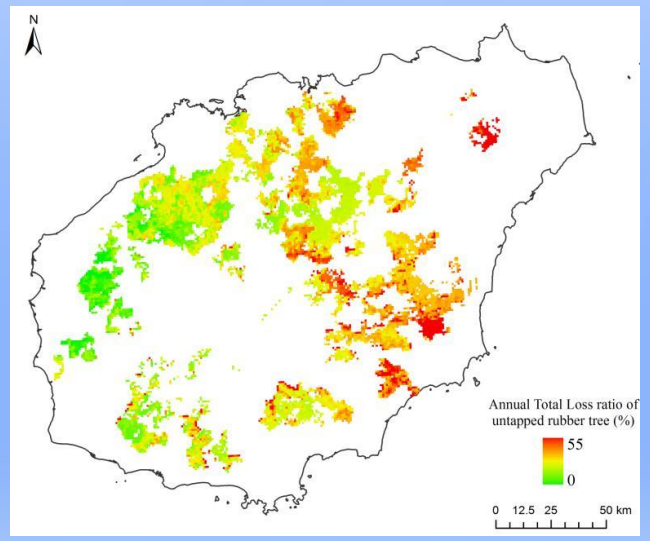
Loss (rp: 10a)



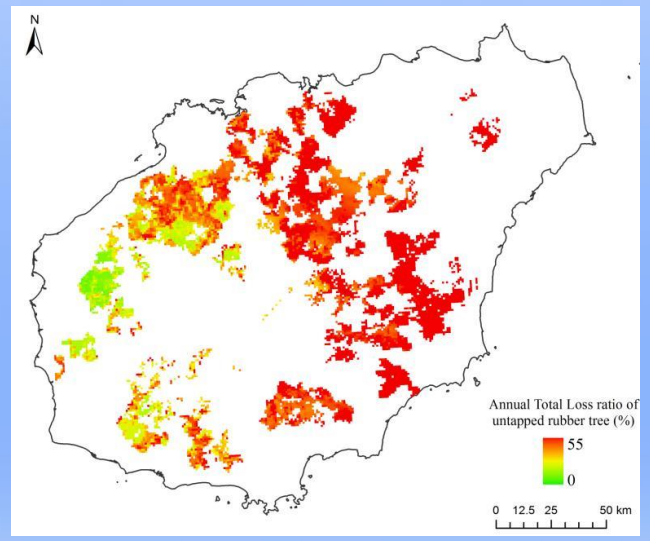
Loss (rp: 20a)



Loss (rp: 50a)



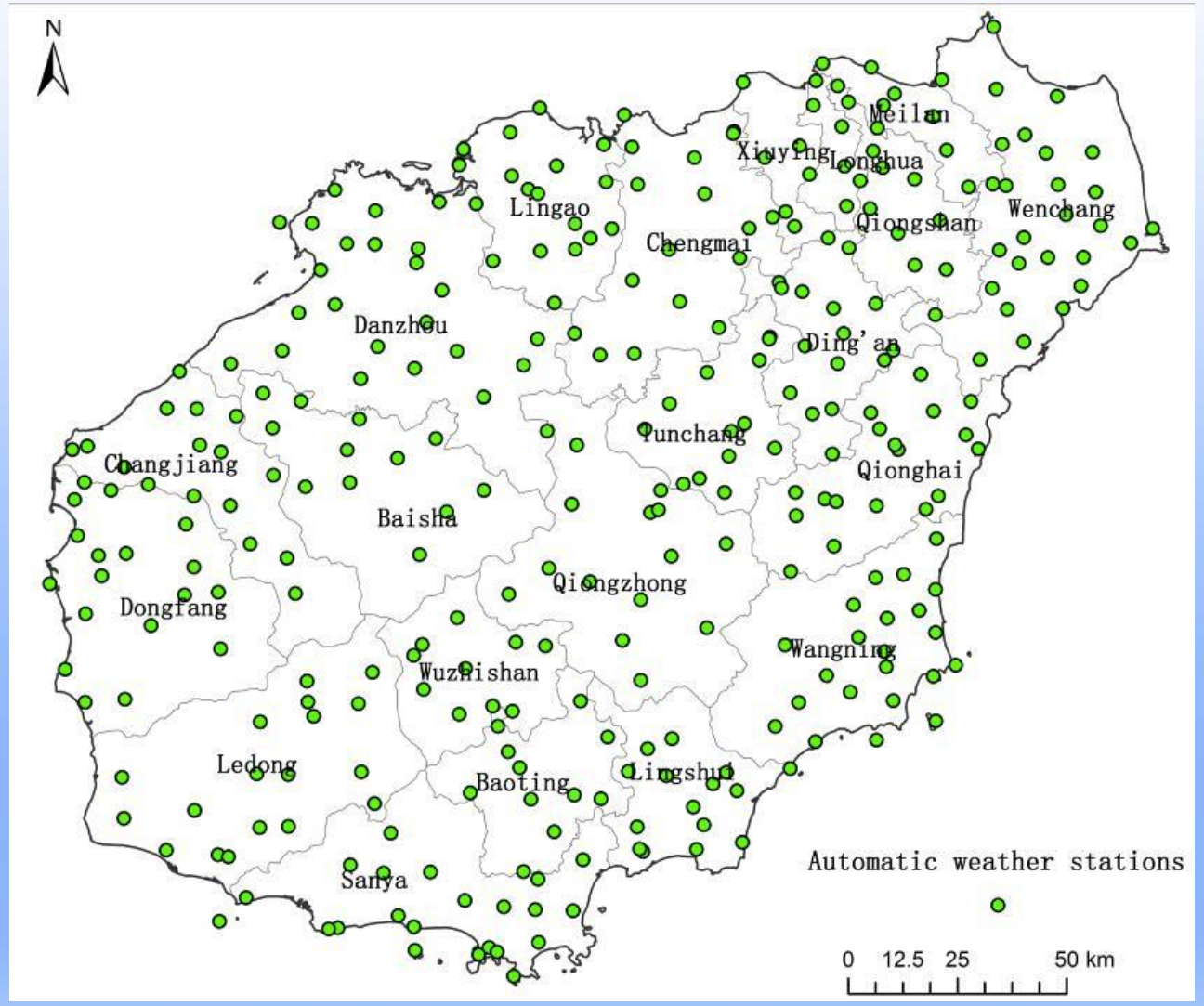
Loss (rp: 100a)



Expected Loss by Return Periods ->

The premium is decided by the modeling result

3. Application Example: Weather Index-based insurance



Rapid weather index-based payout after typhoon disaster ->

Based on third-party independent observation from metro-department

Thank you.