Modeling and Simulation of Disaster Dynamics

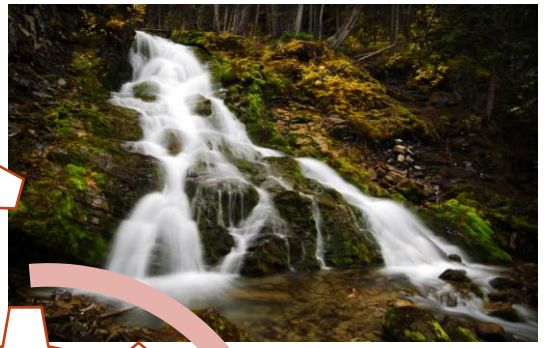
Saini Yang

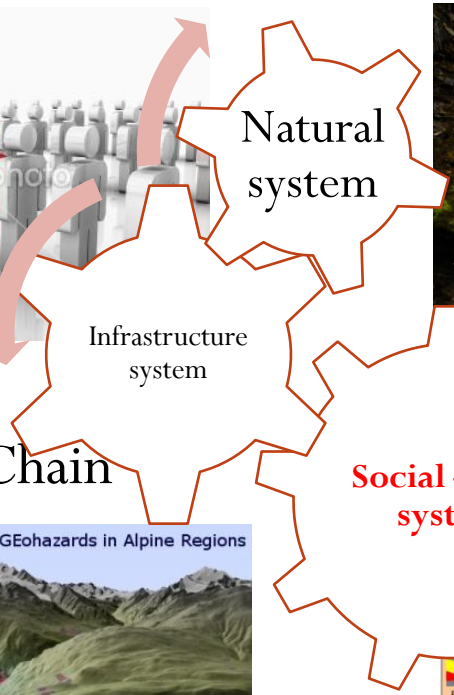
yangsaini@bnu.edu.cn

Introduction

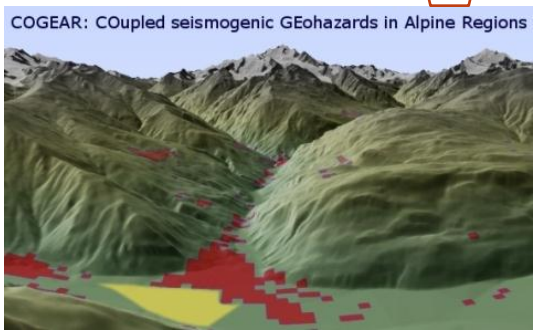
- Domino effect

- Cascading effect

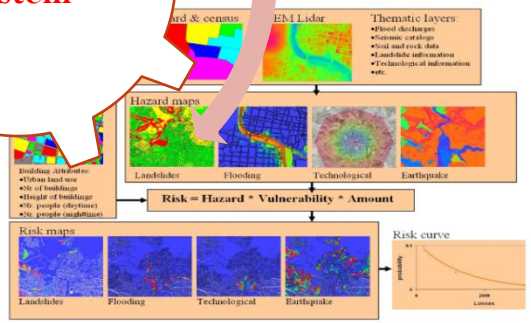




- Hazard Chain



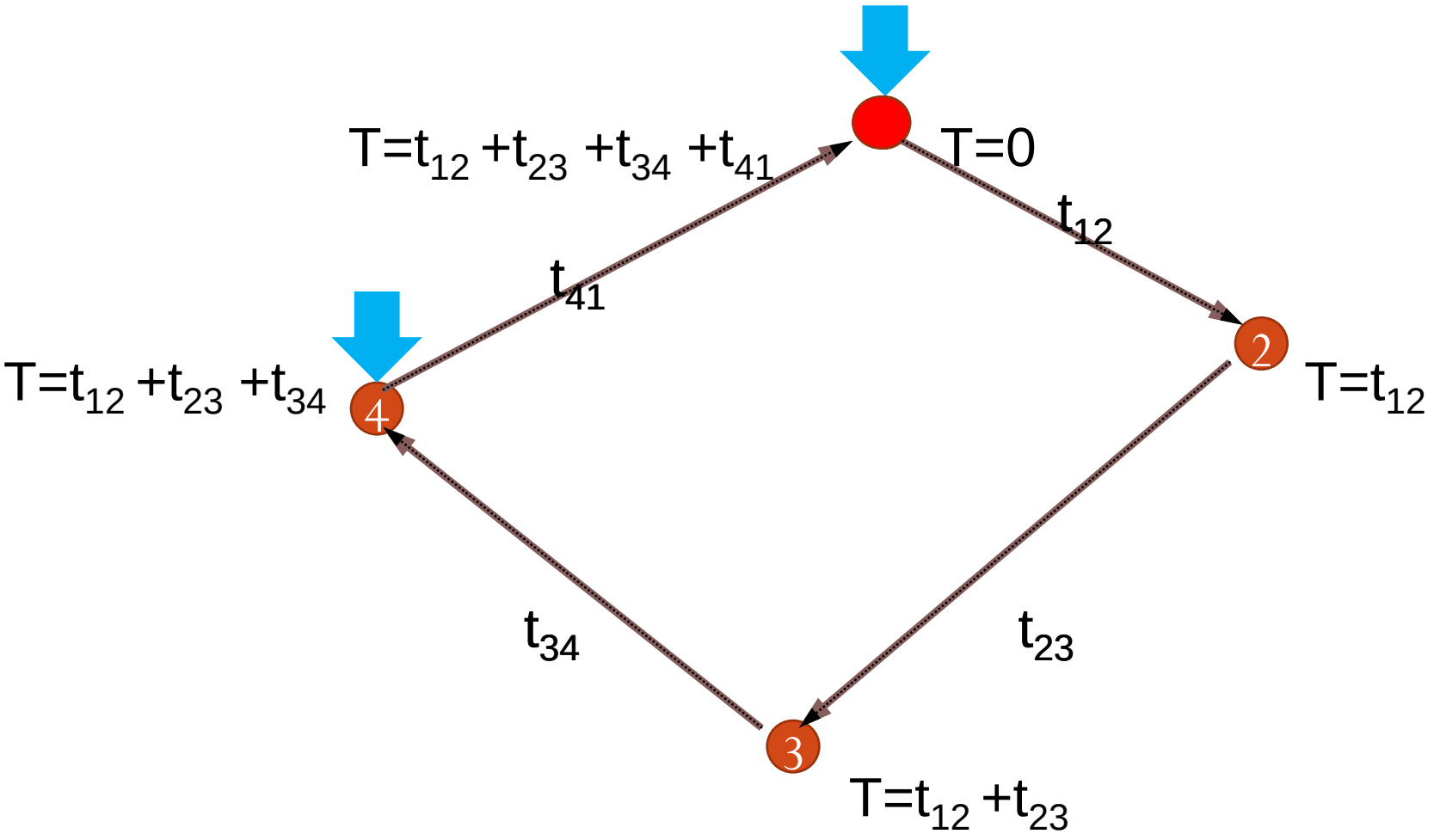
- azard



How to model disaster spreading effect?

- "Add-up" is not enough
- Direct impact & Indirect impact
- Impact transfer & Amplification
- Dynamic vulnerability/resilience

Spreading Process



Conceptual Model

- X_i: state of component i

$$\dot{x_i}(t) = \omega(p) \cdot x_i(t) - \frac{x_i(t) - 1}{\tau_i} + \Theta\left(\sum_{i \neq j} \frac{M_{ji}\left[x_j(t - t_{ji}) - 1\right]}{f(O_j)} e^{\beta t_{ji}}\right)$$

$$\Theta(y) = \frac{1 - exp(-\alpha y)}{1 + exp\left[-\alpha(y - \theta_i)\right]}, \quad f(O_j) = (aO_j)/(1 + bO_j)$$

Direct hazard impact

Recovery process

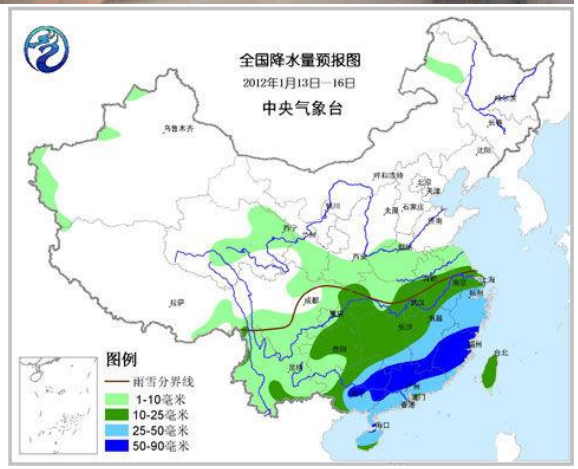
Spreading impact

(Indirect impact)

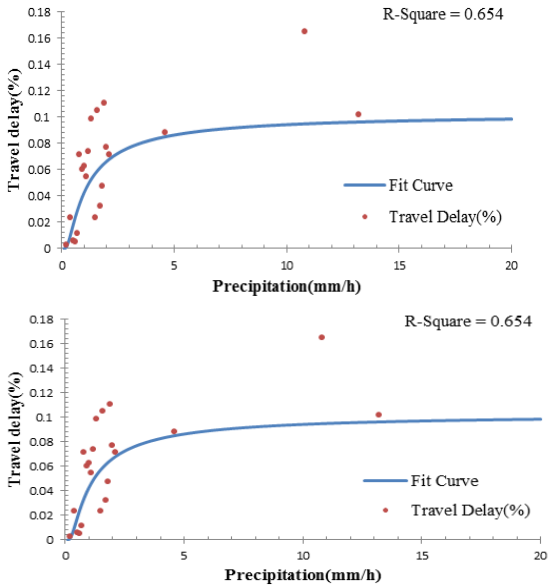
Modified from Lubos Buzna et al.(2006)

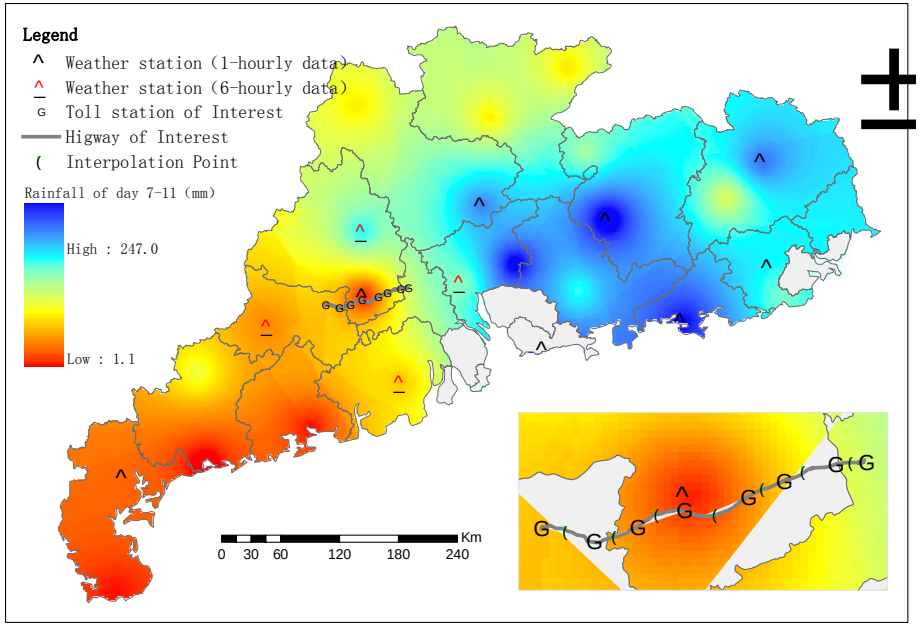
A Real World Case Study

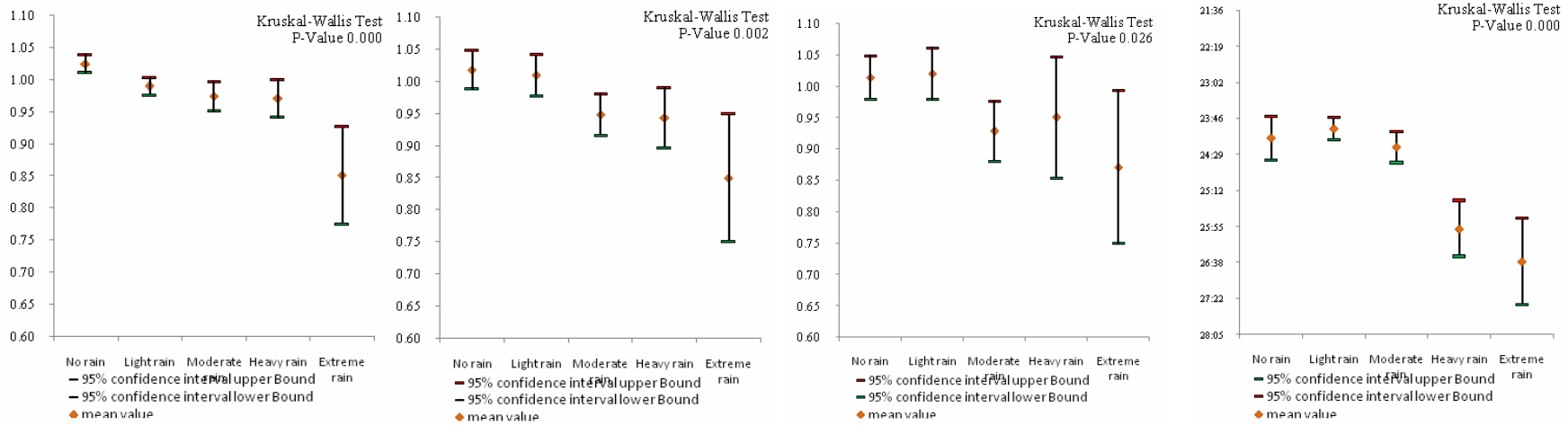
- Why transportation?
  - Critical Infrastructure
  - Crucial for daily operation and emergency response
  - Direct and indirect losses due to disasters
- Why rainfall?
  - Typical hazard in Southeast China



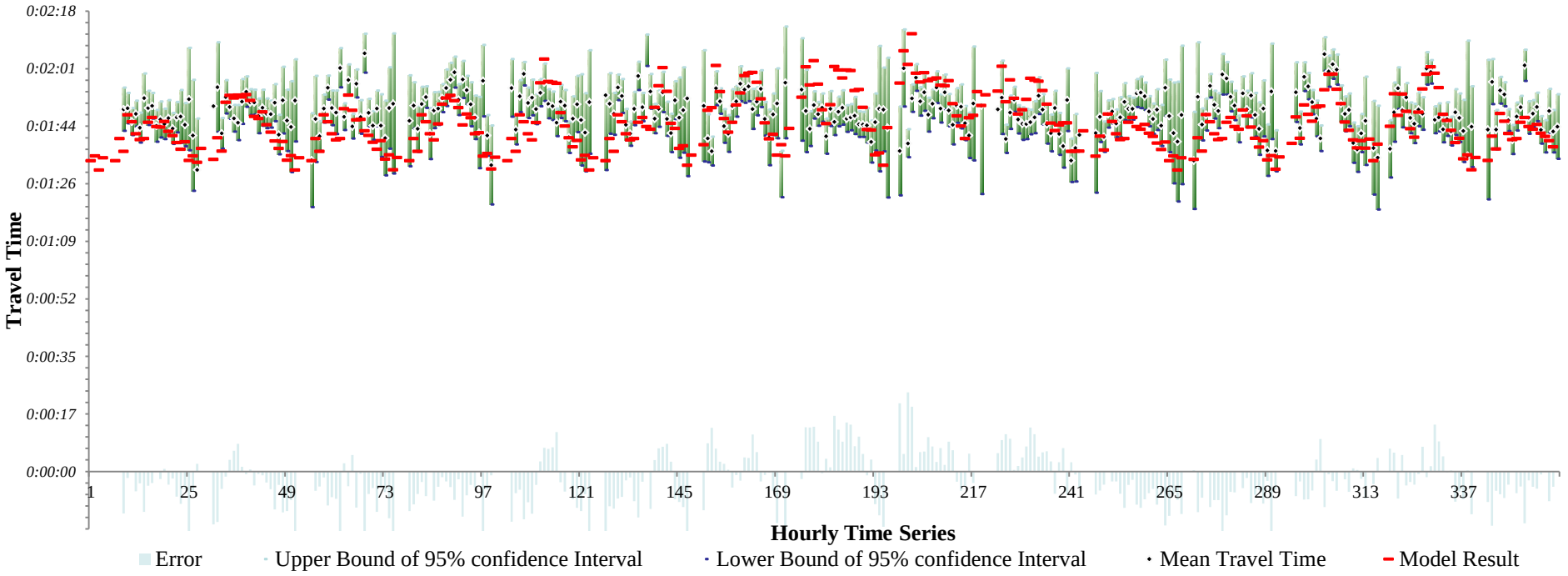
Precipitation and Freeway Traffic





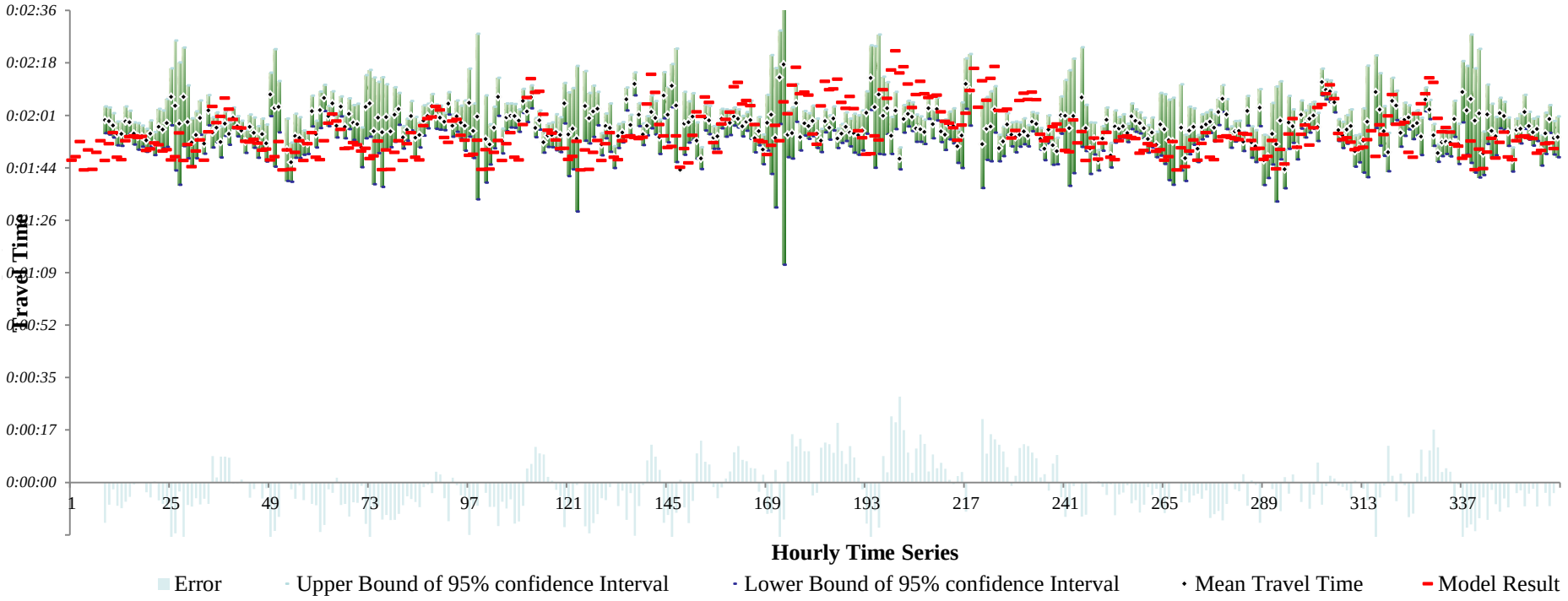


- Passenger Cars' Travel Times



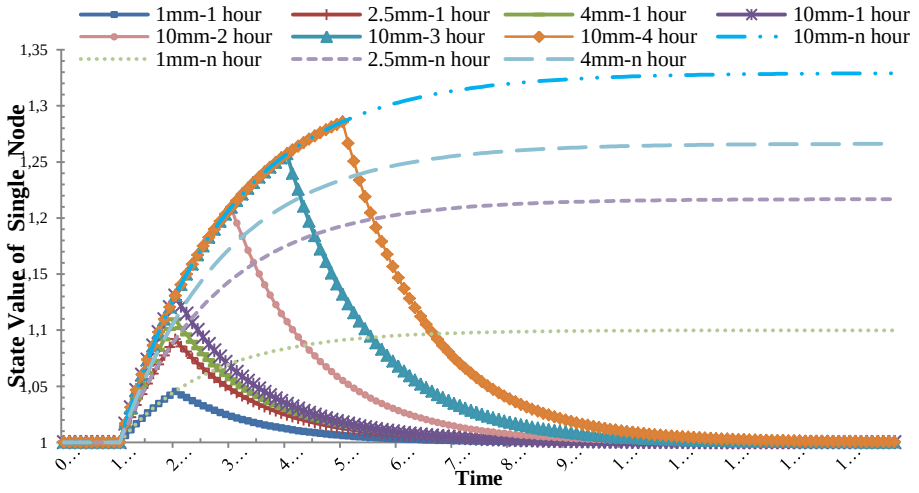
- 68.46% estimated travel time of records are in the range of 95% confidence interval/
- Total average error of travel time is 4.6%.

Trucks' Travel Time

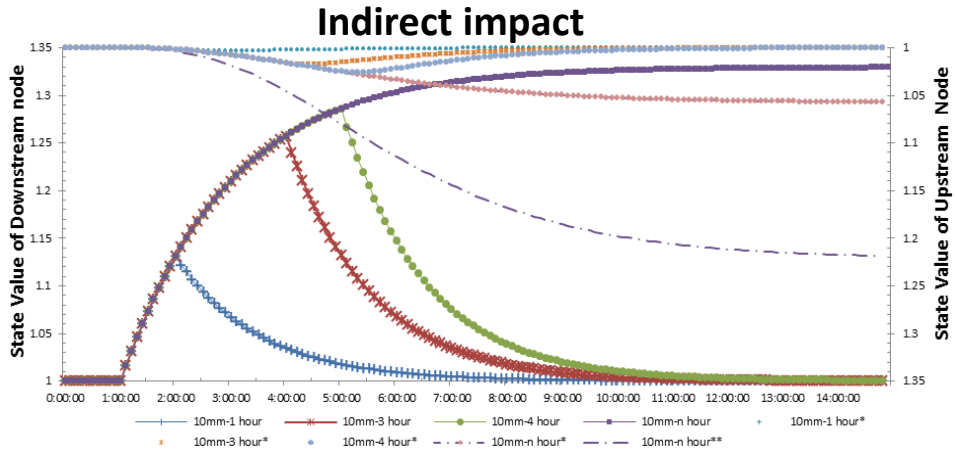


- 59.61% estimated travel time of records are in the range of 95% confidence interval
- Total average error is 4.7%.

- Indirect impact will be amplified on nodes with high connectivity.
  - under long continuous precipitation, the direct impact and indirect impact are at the same level
- Model expandable and adaptable
- With known weather trend, this model can be extended to evaluate the potential economic loss caused by adverse weather (ongoing research)



Direct impact under different precipitation scenarios



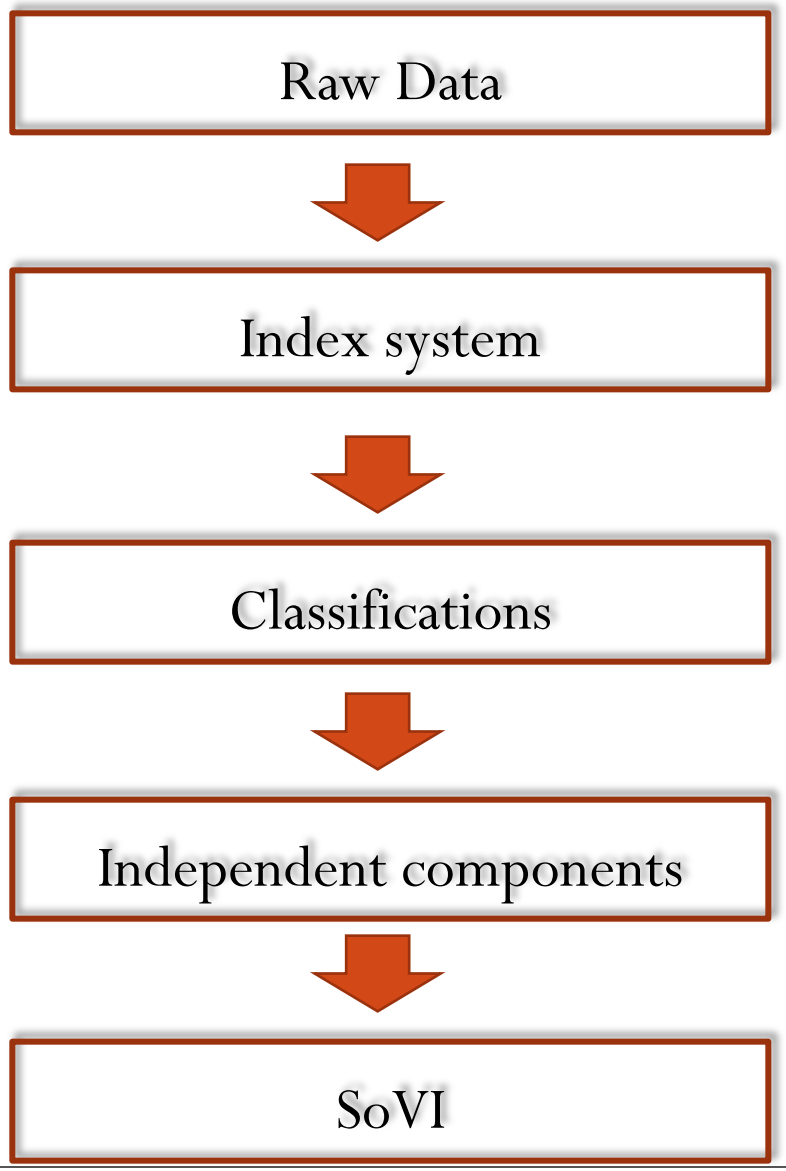
Direct impact

Social Fabrics of China to Natural Disaster

Social Fabrics of China to Natural Disaster: why special?

- Multi-hazard
- Rapid Economic Growth
- High Population Density
- Quick Urbanization
- Little is known about social vulnerability in China.

Methodology

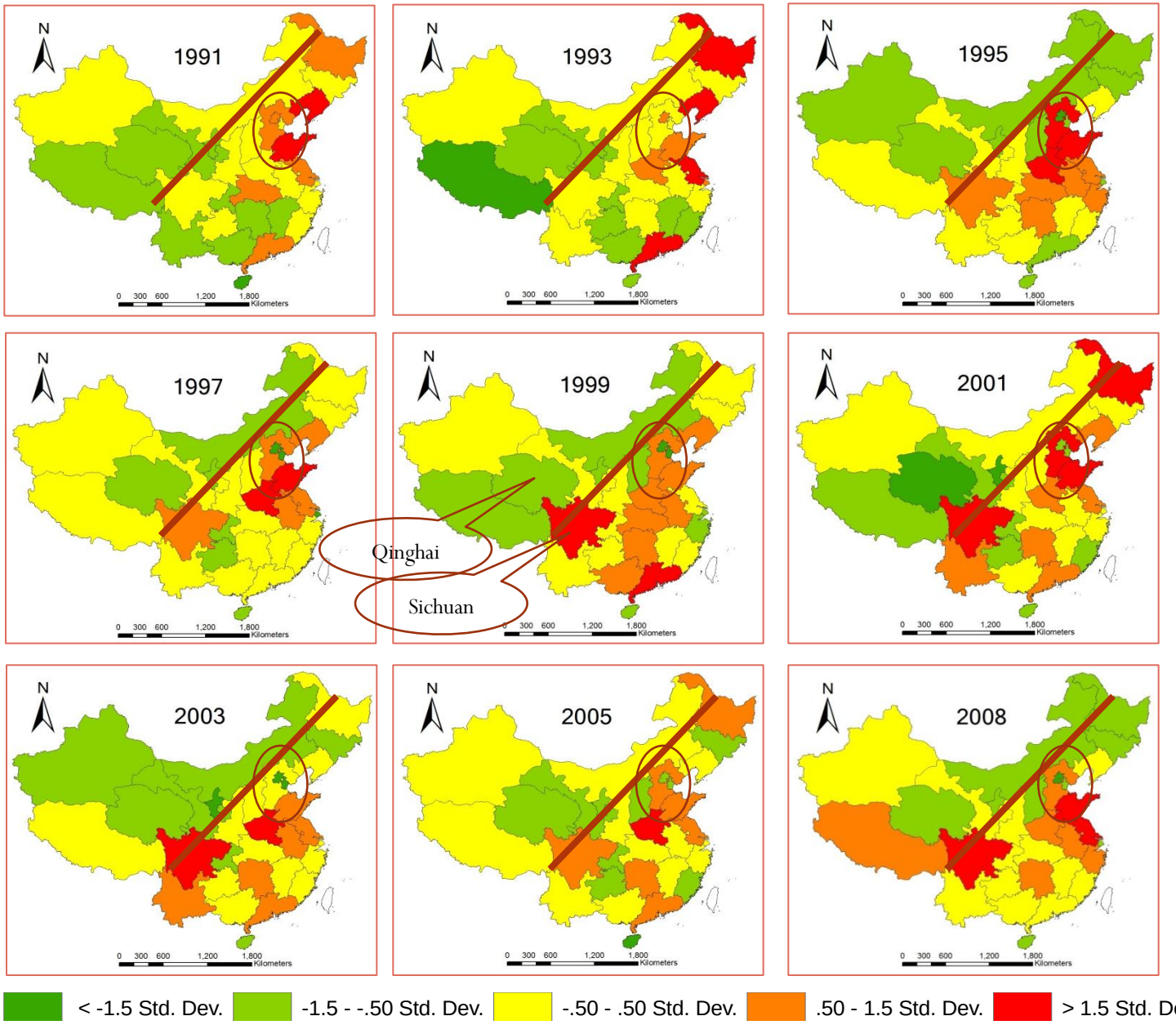


- Provincial socioeconomic and demographic data of 31 provinces in China (except Taiwan, Hong Kong and Macao) (1991~2010)
- The selection of social vulnerability index system :
  - The principle of index construction
  - The hazards-of-place(HOP) conceptual model (Cutter, 1996))
- Divide the index system into 10 groups:
  - Population
  - Employment and Unemployment
  - Social Security
  - Construction Industry
  - Economy
  - Health, Culture & Education
  - ……
- Principal component analysis (PCA)
  - The rule of "potential loss" and "ability to adapt"
  - Transform a set of correlation response variables into a small set of uncorrelated variables
  - A few principal components can contain almost all the information
  - An effective method to deal with the problem : Fewer experimental units than response variables
- More than 250 indexes

The Social Vulnerability Index (SoVI) (Cutter. 2003, 2008)

$$Z = W_1 Z_1 + W_2 Z_2 + \ldots + W_p Z_p$$

Results



The social fabrics index of southeastern China is higher than that of northwestern China.

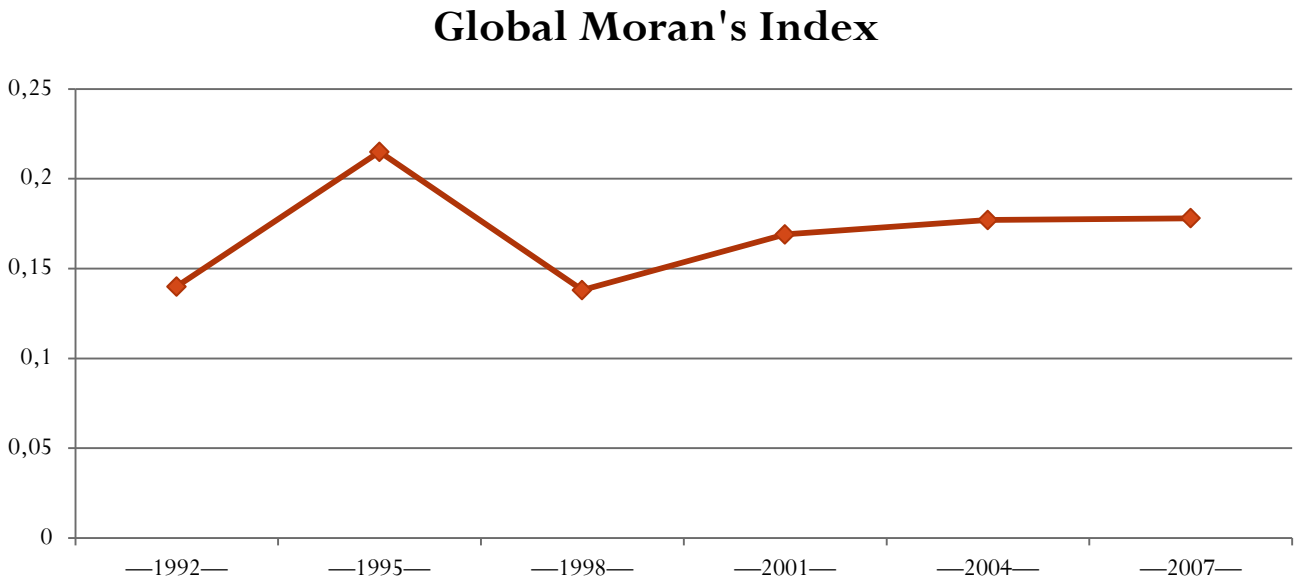
Moran's Indexes

	1991		1993		1995		1997		1999	
Global Moran's I	0. 22		0. 13		0. 22		0. 15		0. 10	
Local Moran's I	Count	% of total	Count	% of total	Count	% of total	Count	% of total	Count	% of total
High–high	2	6. 67		0. 00	4	13. 33	3	9. 68	1	3. 23
Low–Low		0. 00		0. 00		0. 00		0. 00		0. 00
Low–high		0. 00		0. 00	1	3. 33	1	3. 23		0. 00
High–low		0. 00		0. 00		0. 00		0. 00	1	3. 23
Counties	28	93. 33	30	100. 00	25	83. 33	27	87. 10	29	93. 55
Total	30	100. 00	30	100. 00	30	100. 00	31	100. 00	31	100. 00
	2001		2003		2005		2007		2008	
Global Moran's I	0. 06		0. 19		0. 12		0. 12		0. 26	
Local Moran's I	Count	% of total	Count	% of total	Count	% of total	Count	% of total	Count	% of total
high–high	2	6. 45	2	6. 45	2	6. 45	3	9. 68	4	12. 90
low–low		0. 00	1	3. 23		0. 00		0. 00		0. 00
Low–high		0. 00		0. 00		0. 00		0. 00	1	3. 23
High–low	1	3. 23		0. 00		0. 00		0. 00		0. 00
Counties	28	90. 32	28	90. 32	29	93. 55	28	90. 32	26	83. 87
Total	31	100. 00	31	100. 00	31	100. 00	31	100. 00	31	100. 00

Generally, Moran's Index value close to +1.0 indicates clustering, and the value near -1.0 indicates dispersion.

Spatial Autocorrelation Analysis

- The clustering effect was significant in mid 90's
  - Deng's Talk during inspect of south in 1992.



Global Moran Index: 3-year average

Major Indexes

	1991 year	1992 year	1993 year	1994 year	2000 year	2001 year	2006 year	2007 year	2008 year	2009 year
Population	6.46%	5.44%	7.14%	5.72%	6.88%	8.38%	14.65%	11.97%	15.90%	14.99%
Employment and Unemployment	8.41%	10.56%	10.21%	10.77%	10.72%	10.87%	9.59%	9.11%	5.23%	11.68%
Social Security	3.82%	5.52%	3.60%	2.19%	9.16%	7.02%	5.26%	4.97%	2.99%	4.17%
Construction Industry	10.87%	6.77%	13.62%	12.07%	11.33%	9.59%	8.99%	11.88%	12.38%	10.87%
Health, Culture & Education	9.59%	13.43%	12.18%	11.65%	9.49%	8.53%	9.24%	7.38%	5.81%	6.47%
Economy	23.41%	25.37%	22.44%	24.39%	21.51%	20.10%	17.60%	16.24%	18.90%	16.43%
GDP	8.99%	7.74%	11.06%	8.46%	9.67%	10.96%	10.30%	11.80%	10.99%	7.40%
People's Livelihood	6.16%	4.64%	2.96%	4.05%	3.53%	1.86%	3.51%	2.06%	5.10%	1.38%
Infrastructure	11.11%	10.79%	9.27%	11.24%	8.87%	11.77%	13.81%	13.57%	14.52%	15.77%
Agriculture	11.19%	9.75%	7.51%	9.48%	8.85%	10.92%	7.05%	11.02%	8.18%	10.85%