Future Property Damage from Flooding: Sensitivities to Climate and Economy

Presented by Jing Liu

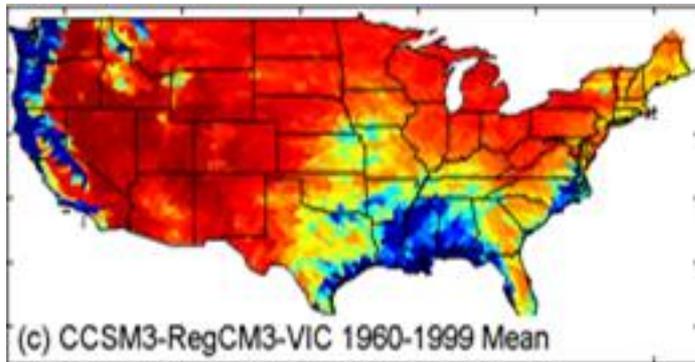Based on a joint work with Thomas Hertel, Michael Delgado, Moetasim Ashfaq and Noah Diffenbaugh

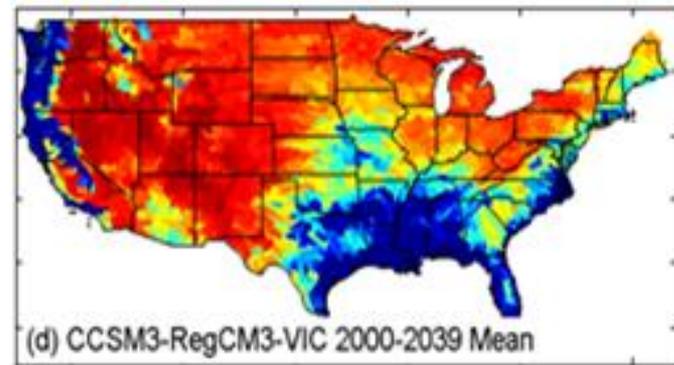PIAMDDI meeting, December, 2013

Stanford University, CA

Background

- Flooding caused tremendous damage. 17 >1$US billion events since 1980, total damage > 60$US billion.

- Increasing damage in light of climate change?

Increasing flood hazard due to climate change

Simulated Historical

Simulated Future

(c) CCSM3-RegCM3-VIC 1960-1999 Mean

(d) CCSM3-RegCM3-VIC 2000-2039 Mean

0   15   HUC08 40Y Daily High Runoff (mm/day)   45   60

Background

- Flooding caused tremendous damage. 17 >1$US billion events since 1980, total damage > 60$US billion.
- Concerns over increasing damage in light of climate change
- Debates on attribution
  - Climate, especially the role of extreme weather events
  - Accumulated wealth
  - Ineffective adaptation

Background

- Flooding caused tremendous damage. 17 >1$US billion events since 1980, total damage > 60$US billion.

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  - Climate, especially the role of extreme weather events

  - Accumulated wealth

  - Ineffective adaptation

- Objectives of this study

  - Use historical data to investigate marginal effects of risk factors on flood damage

  - Compare projected flood damages under various combinations of future conditions

Method

- Conceptual Model

$$Damage = Hazard * Exposure * Vulnerability$$

  - Hazard: probability that a potentially damaging phenomenon occurs
  - Exposure: values at risk
  - Vulnerability: degree of loss resulting from a damaging event

- Empirical Strategy
  - Panel data of property damage from flooding at Indiana counties, during 1995-2012
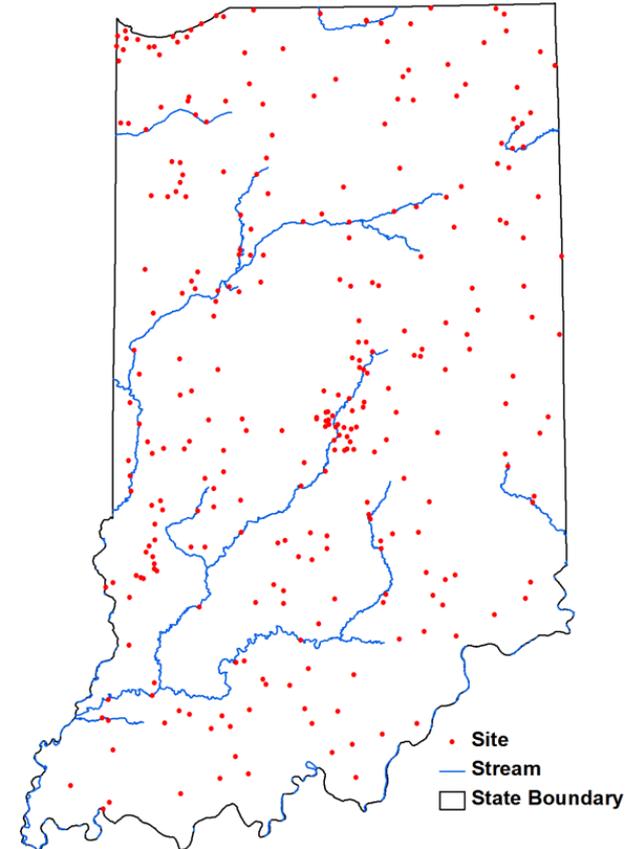 - Tobit model with county fixed effects

Data

- Damage - SHELDUS property loss from flooding ($US 2011), coastal flooding excluded
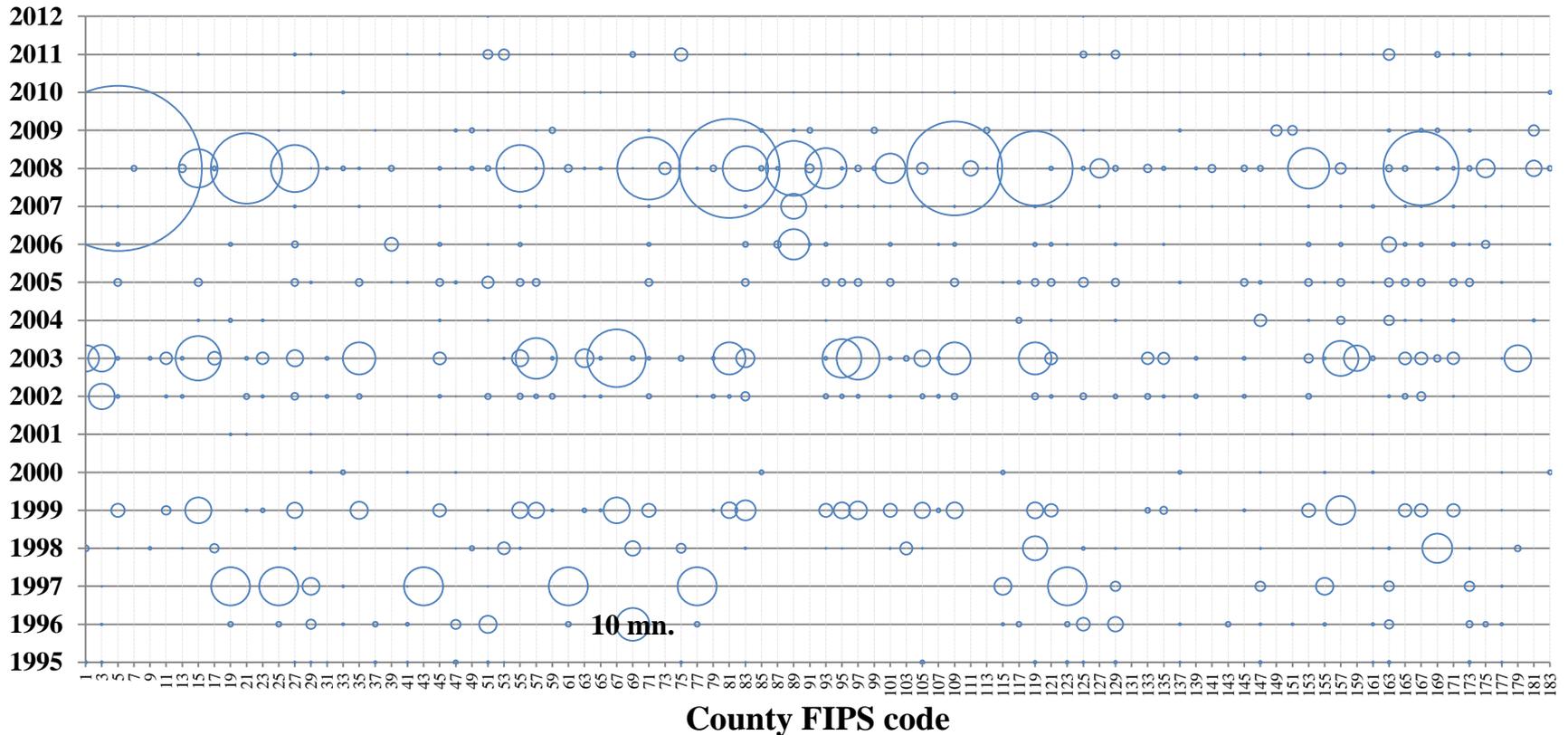
Data

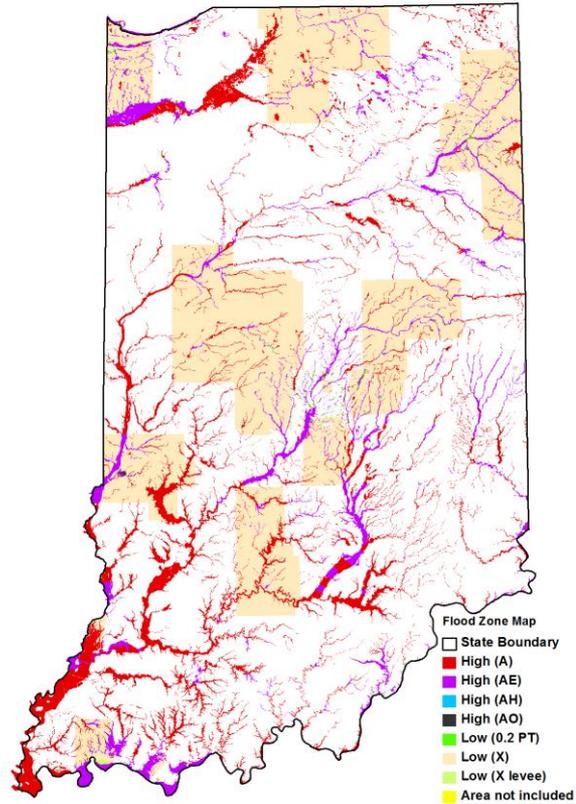- Hazard – counts of extreme days and aggregated flow from these days, USGS data

Site
Stream
State Boundary

Data

- Hazard – counts of extreme days and aggregated flow from these days, USGS data

- Vulnerability - county level dependent population and counts of vulnerable houses, Census data

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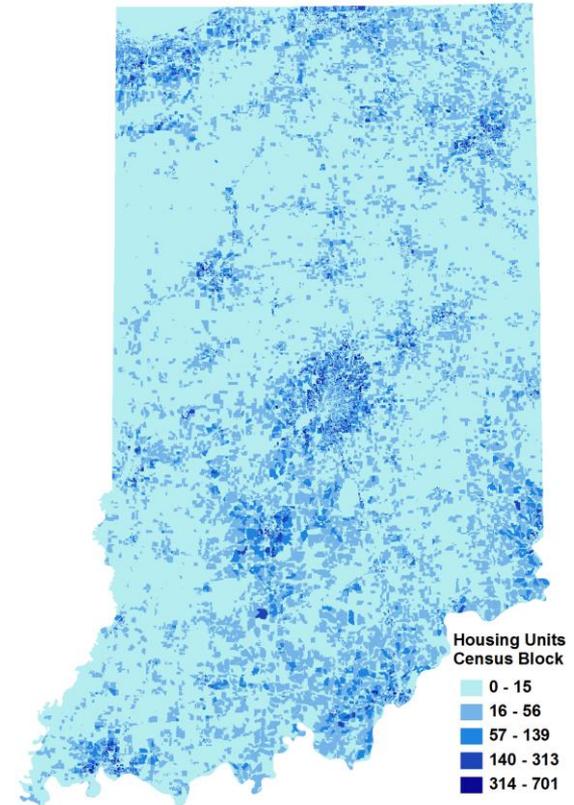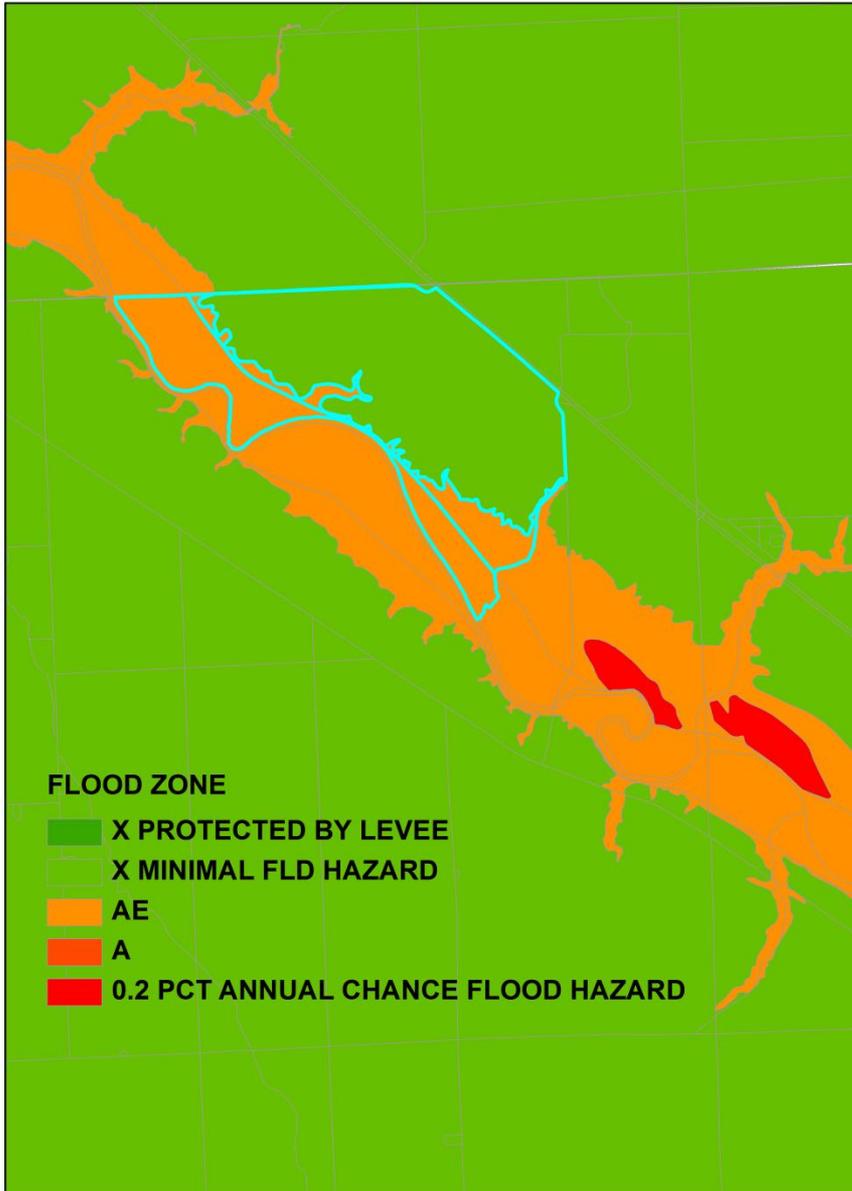- Exposure – county level house units in high flood risk zones, FEMA flood plain map and Census data
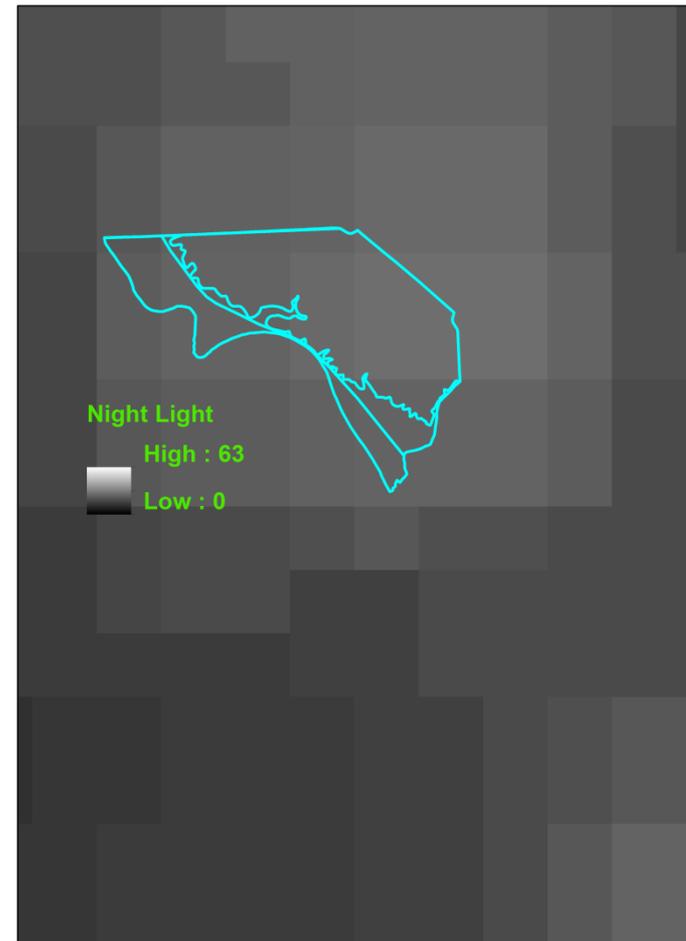
FEMA flood plain layer

Flood Zone Map
- ☐ State Boundary
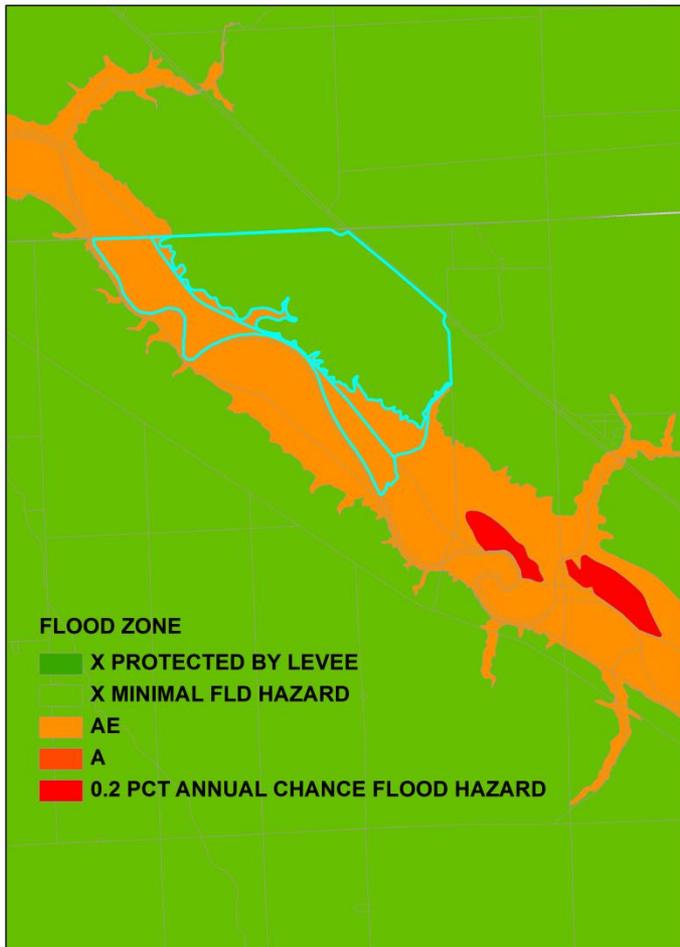- High (A)
- High (AE)
- High (AH)
- High (AO)
- Low (0.2 PT)
- Low (X)
- Low (X levee)
- Area not included

Housing units at census block

Housing Units
Census Block
- 0 - 15
- 16 - 56
- 57 - 139
- 140 - 313
- 314 - 701

High risk flood zone

Low risk flood zone

One census block

One census block runs across multiple flood zones.

FLOOD ZONE
X PROTECTED BY LEVEE
X MINIMAL FLD HAZARD
AE
A
0.2 PCT ANNUAL CHANCE FLOOD HAZARD

FLOOD ZONE
- 🟩 X PROTECTED BY LEVEE
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- 🟧 AE
- 🟥 A
- 🟥 0.2 PCT ANNUAL CHANCE FLOOD HAZARD

Night Light
High : 63
Low : 0

For example, if low risk area is 10% brighter than the high risk area, assets density is 10% higher

# Indiana's Total Property Damage from Flooding in 2030
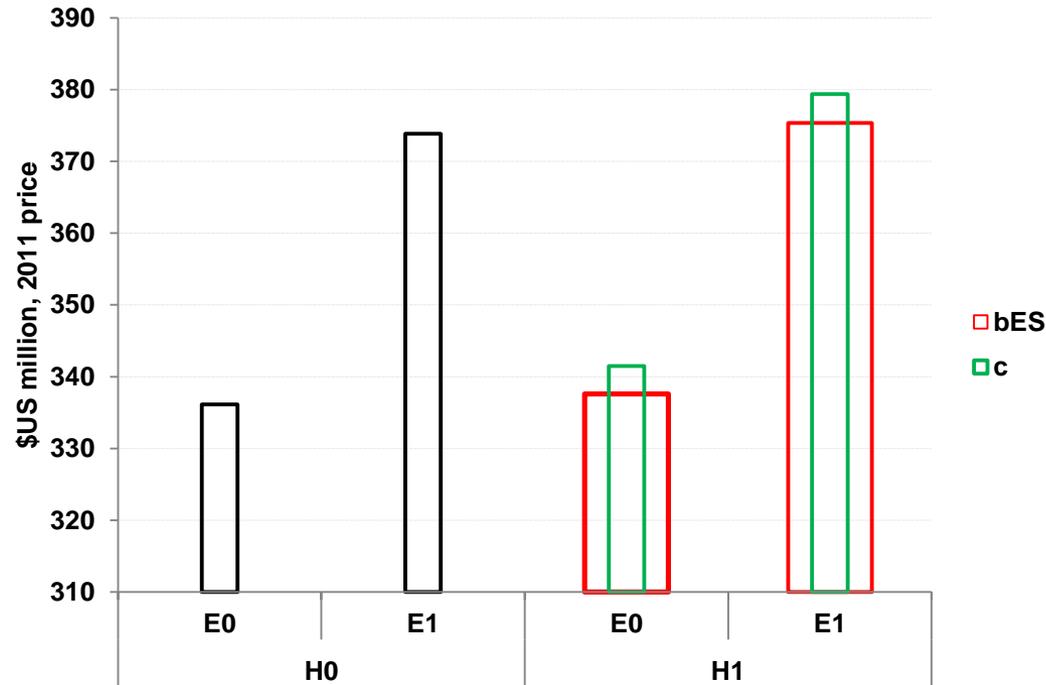
- Hazard (H) and Exposure (E) at current (0) and future (1) level

- Increasing hazard and exposure expect to increase annual property damage in Indiana by $US 43 million, 87% of which is attributed to more houses located in high risk flood zones.

Conclusion

- Hazard severity in 2030 predicted from five CCSM3 ensembles change mildly within Indiana state (except for ensemble c).

- Increasing hazard and exposure in 2030 expect to increase annual property damage in Indiana by $US 43 million, 87% of which is attributed to more houses located in high risk flood zones.

- Results are sensitive to substantial damage events. The assessment depends on whether the focus of concern is the trend of normal average or the likely outcomes caused by abnormally extreme damage events.

Next step

- Extend research scope to regions with completed FEMA flood plain map
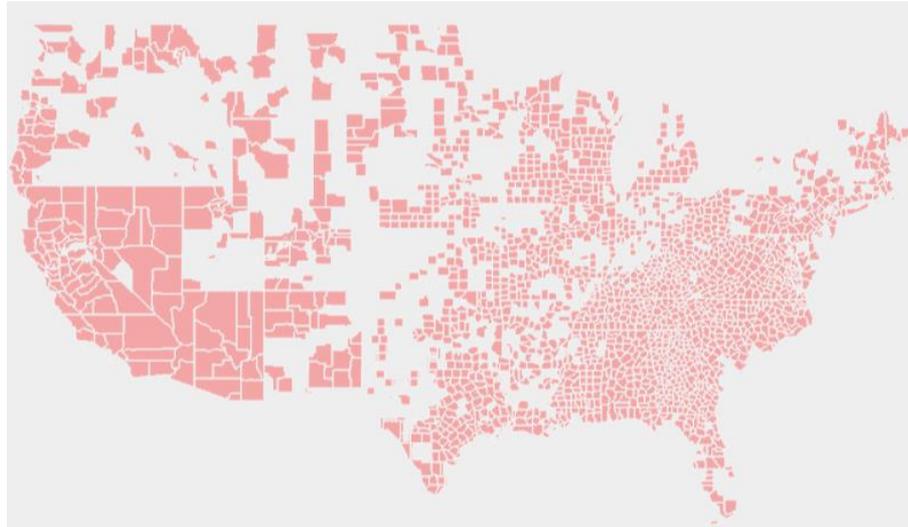

- Incorporate future vulnerability (both physical and social dimensions) into this sensitivity analysis.

- Bootstrap the projected damage to provide confidence intervals.

Extra Slides

Water Runoff from CCSM3 simulations

Percentage change of extreme events frequency and aggregated water runoff volume from the extreme events, 2020-2039 mean compared with 1980-1999 mean.
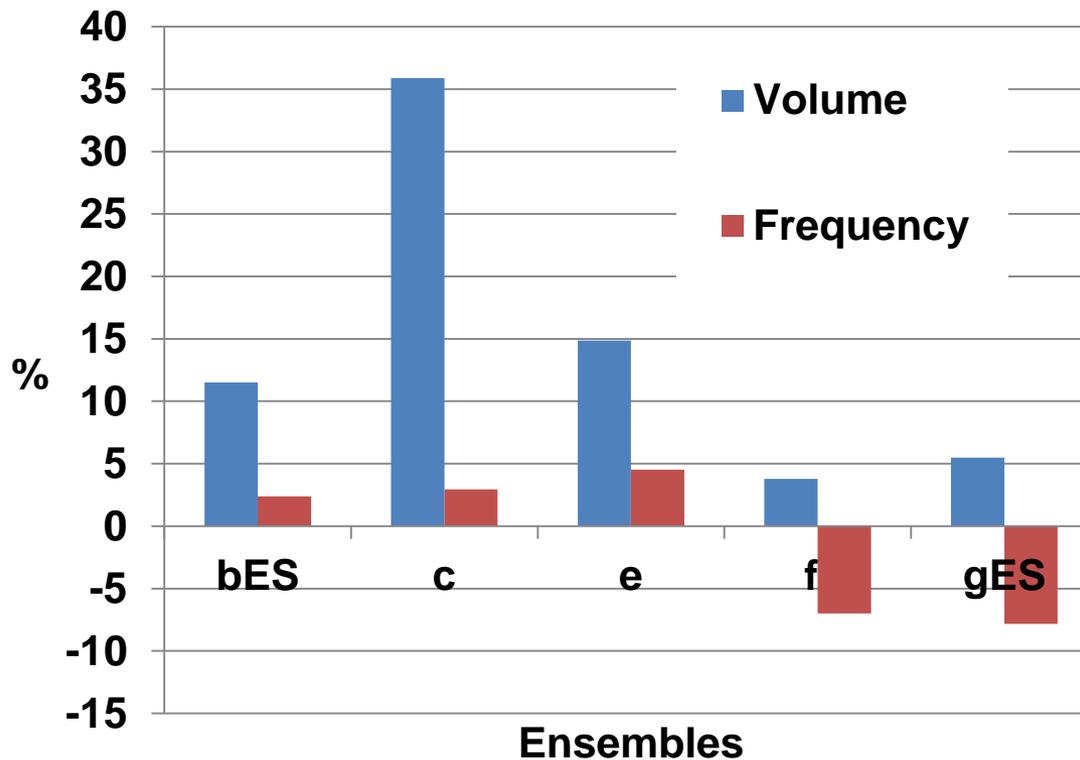
Summary Statistic

Variable	Mean	Std Dev	Min	Max
Property damage, $US (2011 price) per 100 persons	2389.4	17113.2	0.0	344388.8
Flow volume per extreme event, 1,000 ft3/second	13.5	36.8	0.2	388.6
High flood risk zone residential density, houses/100 persons	223.8	31.2	111.1	316.3
Total damaging events recorded during the last 5 years	5.3	6.0	0.0	36.0
Vulnerable houses, 100 units	78.8	98.5	7.5	773.5
Dependent population, 100 persons	313.1	510.2	31.8	3243.2
Supplementary social income, 100 $US (2011 price)	5.0	0.5	3.7	7.1

Variable means at county level, 1995-2012

Tobit model with county fixed effects

Variable	Estimate	Std Err	Pr > |t|	ME
Flow volume per extreme event, 1,000 ft3/second	114.1	28.3	<.0001	41.7
High flood risk zone residential density, persons/100 houses	103.5	95.8	0.28	37.8
Total damaging events during the last 5 years	-685.4	147.1	<.0001	-250.2
Vulnerable houses, 100 units	-317.0	34.3	<.0001	-115.8
Dependent population, 100 persons	18.9	10.6	0.08	6.9
Flow volume per extreme event, 1,000 ft3/second	114.1	28.3	<.0001	41.7
Sigma	27761.0	996.2	<.0001	
Observations	965			

ME is the marginal effect, indicating change in per capita damage ($) for every unit increase of the corresponding explanatory variable.
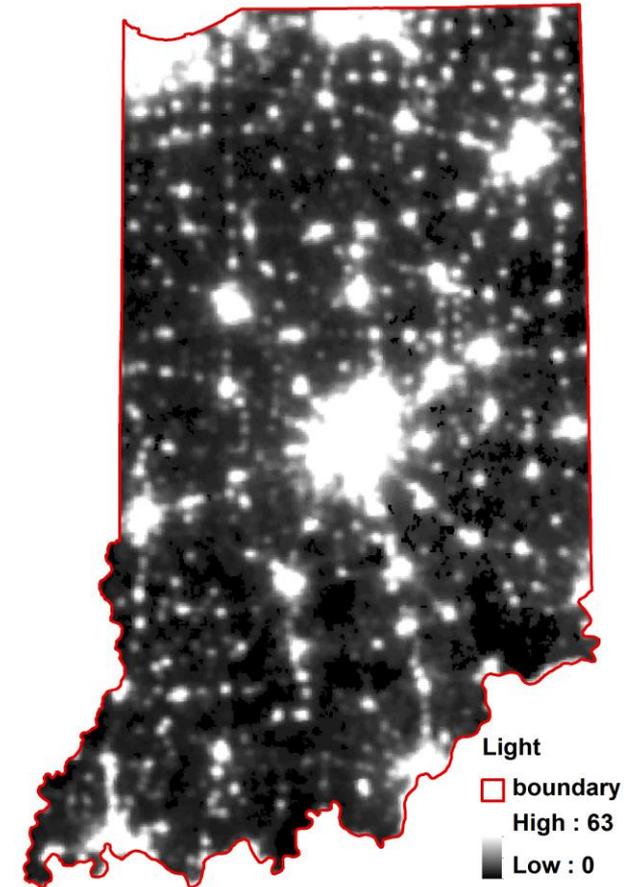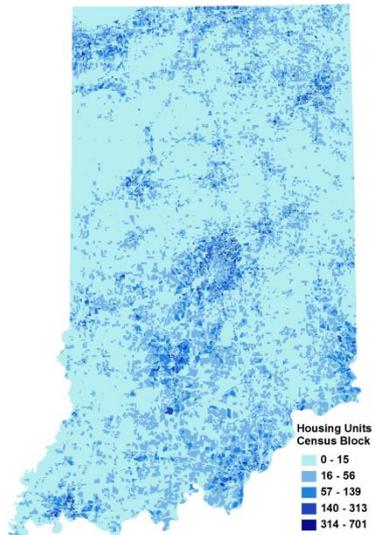
Marginal Effects on Flood Damage

Variable	Increase=10% of the mean	Marginal Effect
Flow volume per extreme event, 1,000 ft3/second	1.4	0.56
High flood risk zone residential density, persons/100 houses	2.3	0.88
Total damaging events during the last 5 years	0.5	-1.32
Vulnerable houses, 100 units	7.9	-9.12
Dependent population, 100 persons	31.3	2.16

Interpretation: If in 2030 aggregate flow per event increases by 10%
(or 1,400 ft3/second), that will increase county flood damage per capita by $US 0.5
For a county with 80,000 people, that will increase total county level damage
by $US 48,000.

Exposure

- County-level data may not reflect the actual value at risk

- Combine three data sources
  - Flood zone map
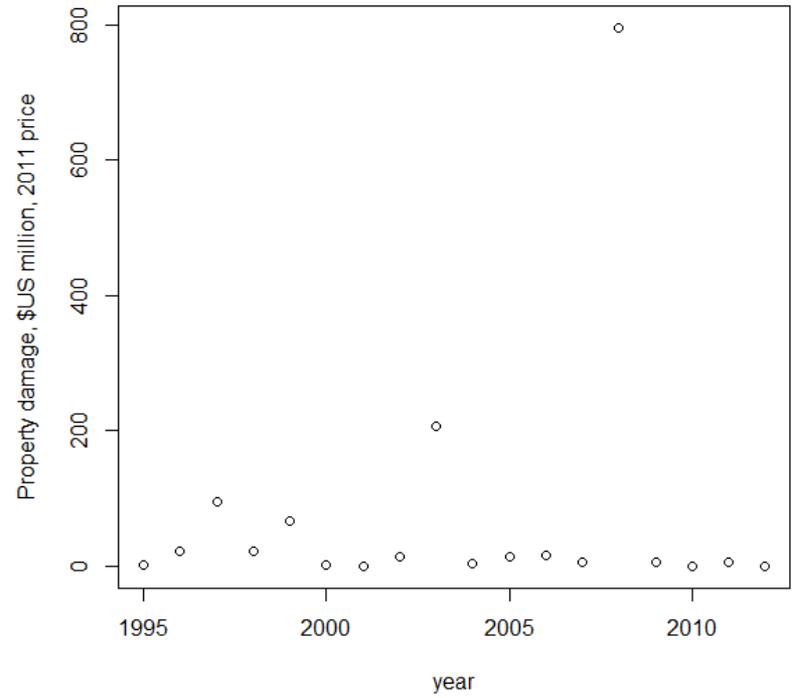 - Census block
  - NASA nighttime light time series

Housing Units
Census Block
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Light
- boundary
- High : 63
- Low : 0

NOAA Nighttime Lights Time Series (2010)
Pixel size: 30 arc-second (3k feet or 900 meters)
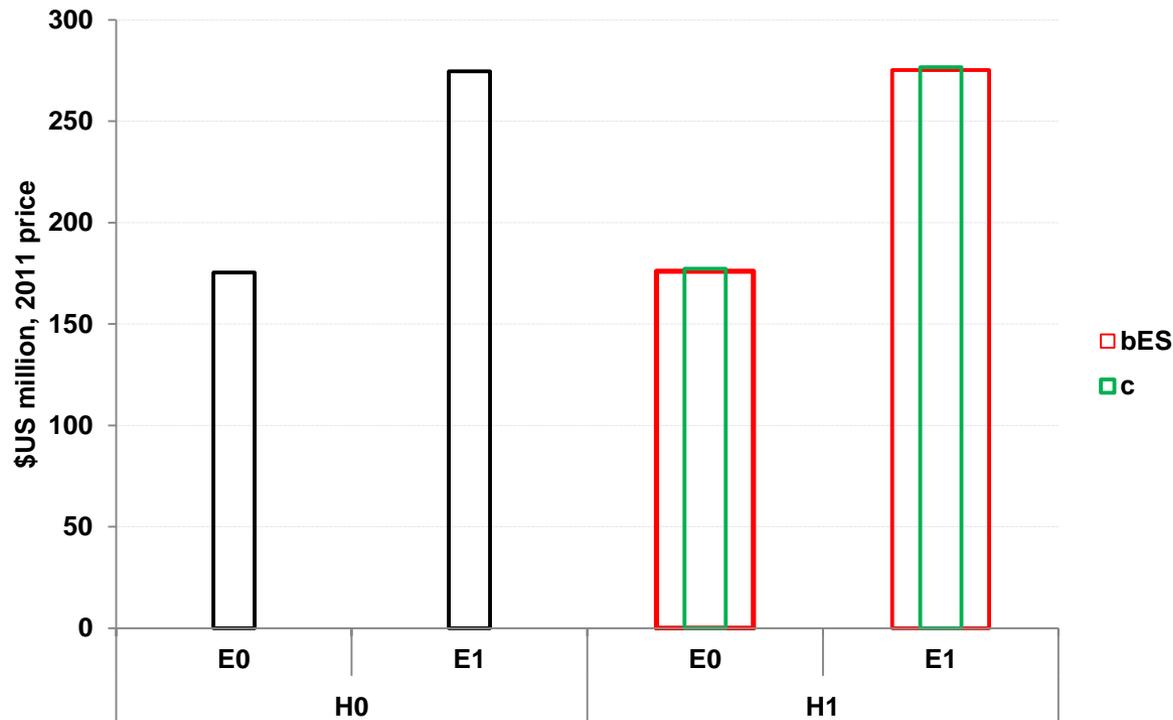**Range of pixel digital value = [0, 63]**

Annual damage, county level 1995-2012
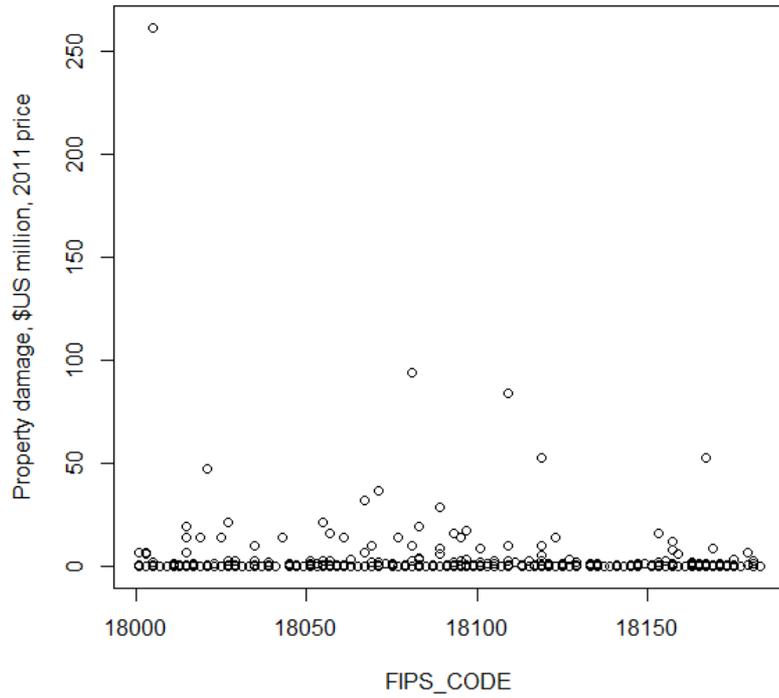
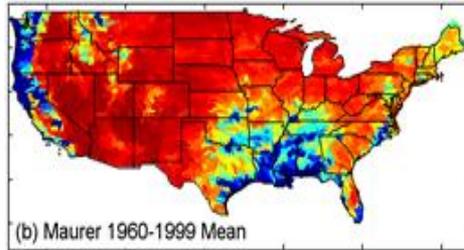**Annual damage, state level 1995-2012**

Indiana's Total Property Damage from Flooding in 2030

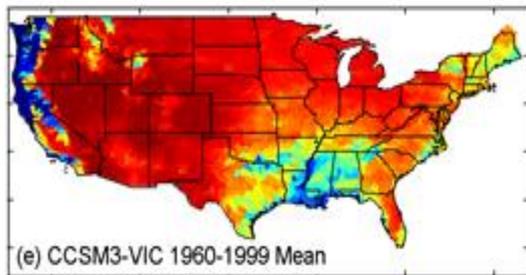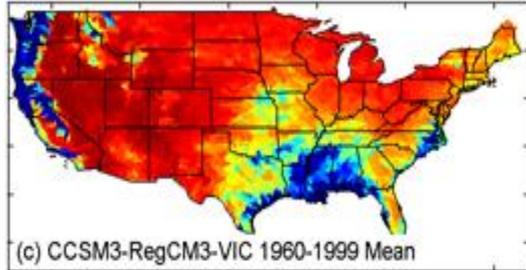Hazard (H) and Exposure (E) at current (0) and future (1) level
Regression is run on a subsample excluding damages>$US 50 million.
Previous figure is based on full sample results.

**Historical
40 year average
daily runoff**

Simulated Historical

Simulated Future

Fine-scale

Large-scale

HUC08 40Y Daily High Runoff (mm/day)