Modeling Long-Term Human Dynamics in Response to Natural Hazard

Analyzing the Impact of Hurricane Katrina on Louisiana Cities

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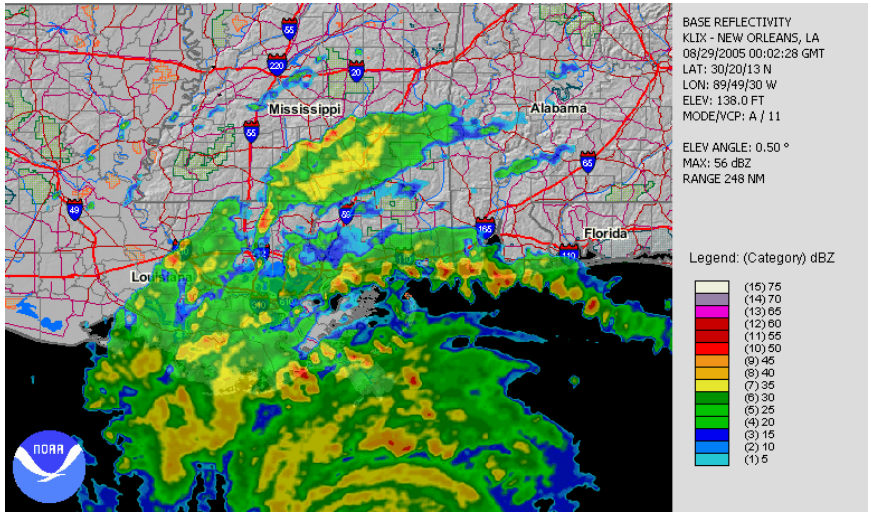
Hurricane Katrina in 2005

Downtown New Orleans

- Most destructive and costliest hurricane in the U.S. history (3rd most intensive)
- Passed just east of New Orleans, a metropolitan area with > 1,3m population (40th of the USA)
- Caused ~14 feet storm surge and >80% of New Orleans is in flood
- > 1,800 death; > $150 billion economic loss



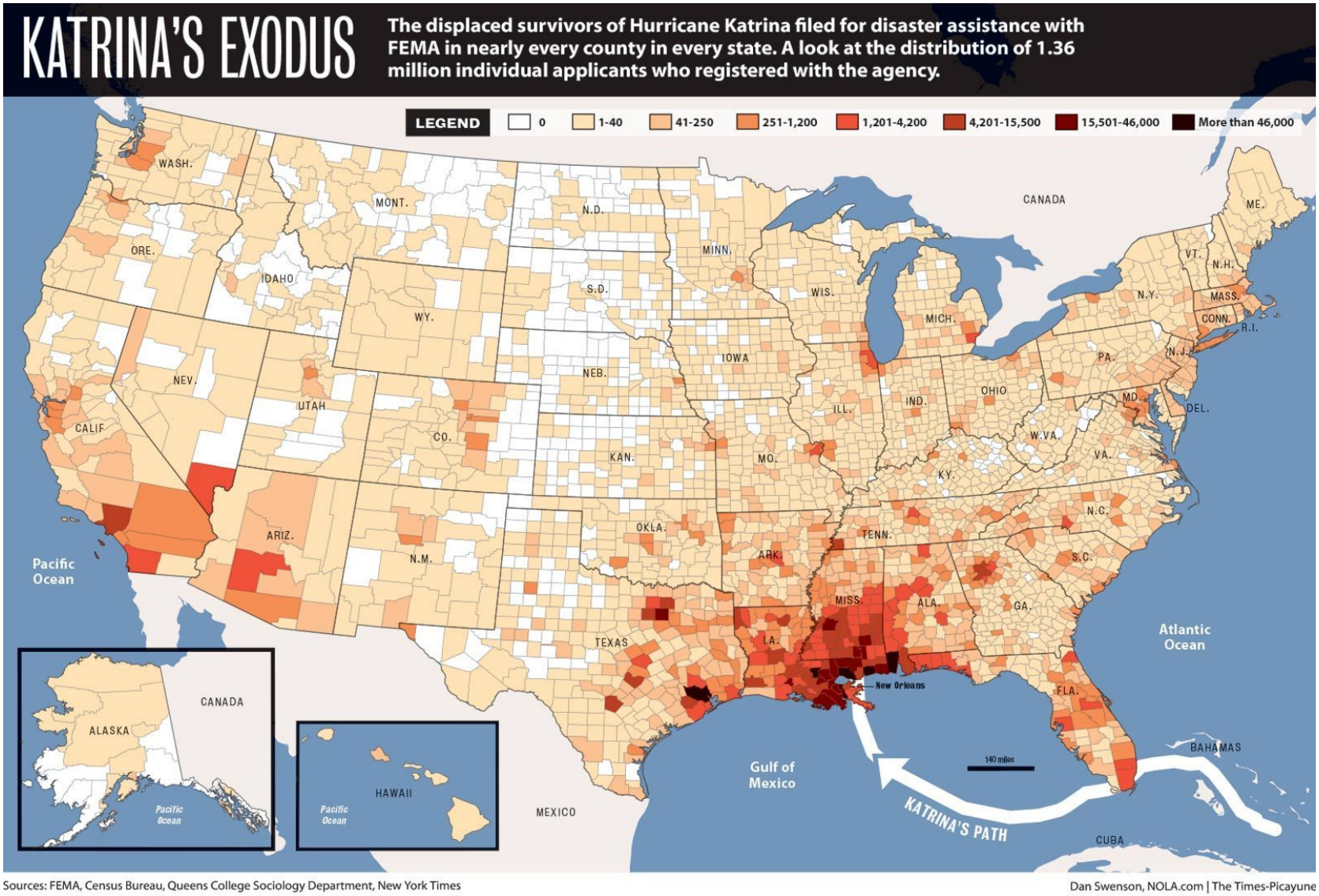
Radar loop of Hurricane Katrina

Snapshots of the city before and after the landfall

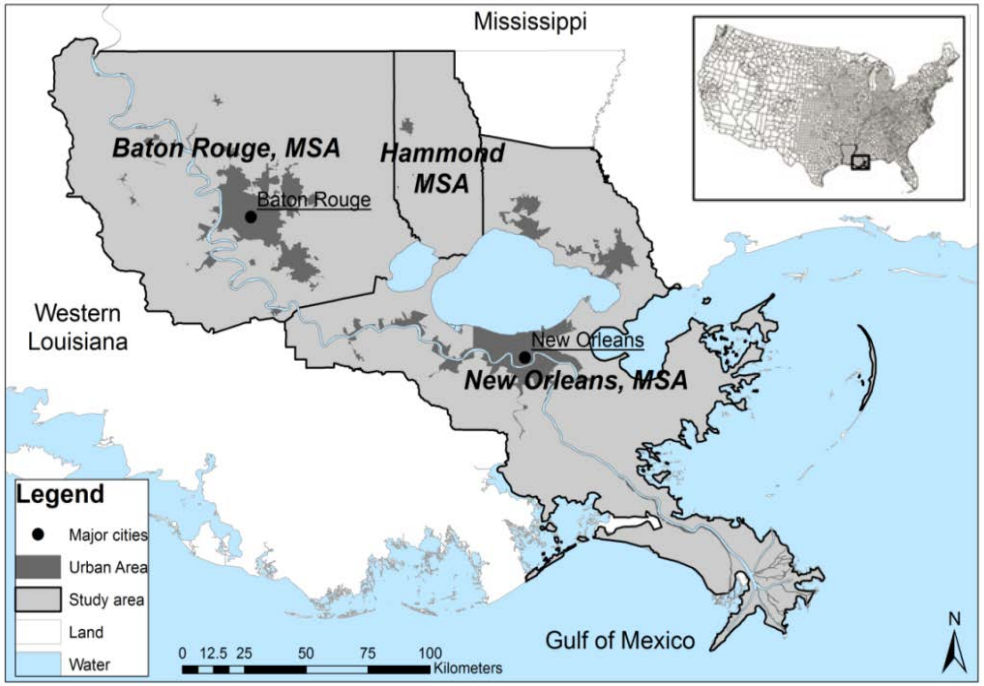
Impact of Hurricane Katrina on coastal Louisiana

Hurricane Katrina has changed demographic and socio-economic landscape in coastal Louisiana

- Displaced over one million people from the central Gulf coast to elsewhere across the U.S.
- Significant population decline in the metropolitan area of New Orleans,
  - Declined from1.386 million in 2005 before Katrina to 1.04 million (declined by 25%) in 2006 after Katrina, and recovered to 1.252 million (declined by 10%) in 2014
- Changed the racial and ethnic make-up
  - Growth of white and Hispanic communities, but contraction of black communities.
- Changed the economic composition
  - Seriously hit the transportation, tourism, and service sectors, but boomed the construction sector


KATRINA'S EXODUS
The displaced survivors of Hurricane Katrina filed for disaster assistance with FEMA in nearly every county in every state. A look at the distribution of 1.36 million individual applicants who registered with the agency.
LEGEND
0
1-40
41-250
251-1,200
1,201-4,200
4,201-15,500
15,501-46,000
More than 46,000
WASH.
ORE.
CALIF
NEV.
IDAHO
MONT.
WY.
UTAH
ARIZ.
COLO.
N.M.
N.D.
S.D.
NEB.
KAN.
OKLA.
TEXAS
MINN.
IOWA
MO.
ARK.
LA.
WIS.
ILL.
MICH.
IND.
OHIO
KY.
TENN.
MISS.
ALA.
GA.
FLA.
S.C.
N.C.
VA.
W.VA.
PA.
N.Y.
MD.
DEL.
N.J.
CONN.
R.I.
MASS.
VT.
N.H.
ME.
CANADA
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
MEXICO
CUBA
BAHAMAS
New Orleans
KATRINA'S PATH
140 miles
ALASKA
HAWAII
Sources: FEMA, Census Bureau, Queens College Sociology Department, New York Times
Dan Swenson, NOLA.com | The Times-Picayune

The Study Area



- Including three Metropolitan Statistical Areas in coastal Louisiana (MSA)
- The most populated area in Louisiana (47% LA population in 15% land area)
- Two largest cities in Louisiana, with different environmental and socio-economic conditions
- Different impacts from Hurricane Katrina

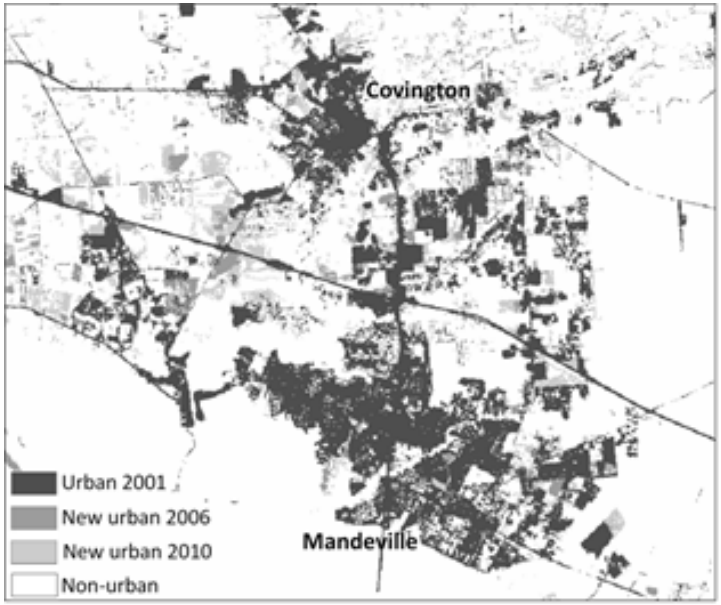
Metropolitan Statistical Area	2001 Population	2010 Population	Population change (2001-2010)	Avg. elevation (meter)
New Orleans-Metairie, LA	1,311,062	1,173,572	-10.5%	3.11
Baton Rouge, LA	709,897	804,568	13.3%	22.82
Hammond, LA	101,541	121,460	19.6%	34.89

Population changes and elevation of the three MSAs in the study area

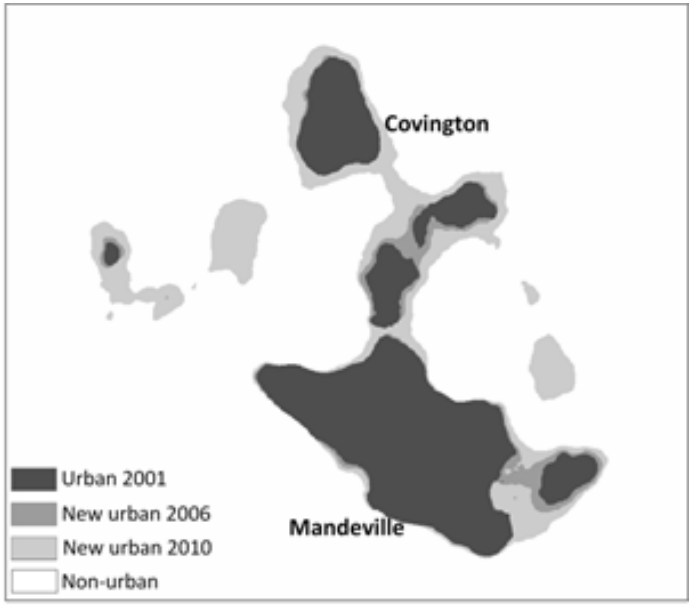
Urban area and growth

Focal filter is applied to convert scattered urban pixels into continuous urban areas

- Circle moving window with a 33-cell (990m) radius
- If counts of urban pixels >50%, the center pixel is classified as urban
- More intuitive urban extent and expansion
- Eliminate noise and focus on general trend
- Urban growth pattern is compared between pre-Katrina (2001-2006) and post-Katrina period (2006-2010)



Original urban pixels



Continuous urban area

Distance decay of city attractiveness

Urban growth probability decreases with increasing distance (travel time) to the city centers:

$$P(x) = a \cdot {x_t}^{b}$$

Central attractiveness

Rate of distance decay

Equations	Time period	a	b
New Orleans	2001-2006	2.946	-1.948
	2006-2010	2.024	-1.903
Baton Rouge	2001-2006	0.1466	-0.8735
	2006-2010	2.554	-1.657

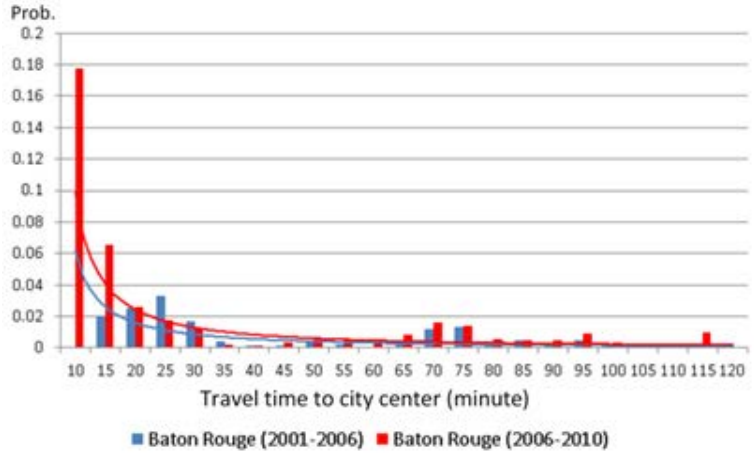
Equation coefficients

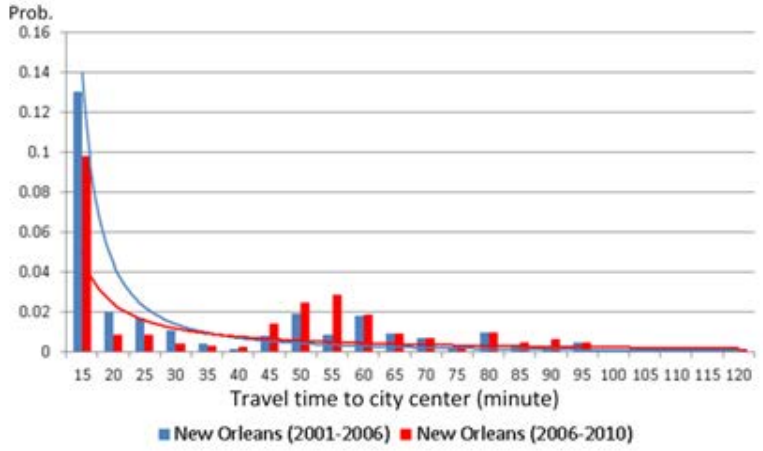
Central attractiveness:

Baton Rouge ↑, New Orleans ↓

Rate of distance decay:

Baton Rouge ↓, New Orleans ↑





Urban growth probability with traveling time to city center.

Urban Growth Prob. at Different Elevation

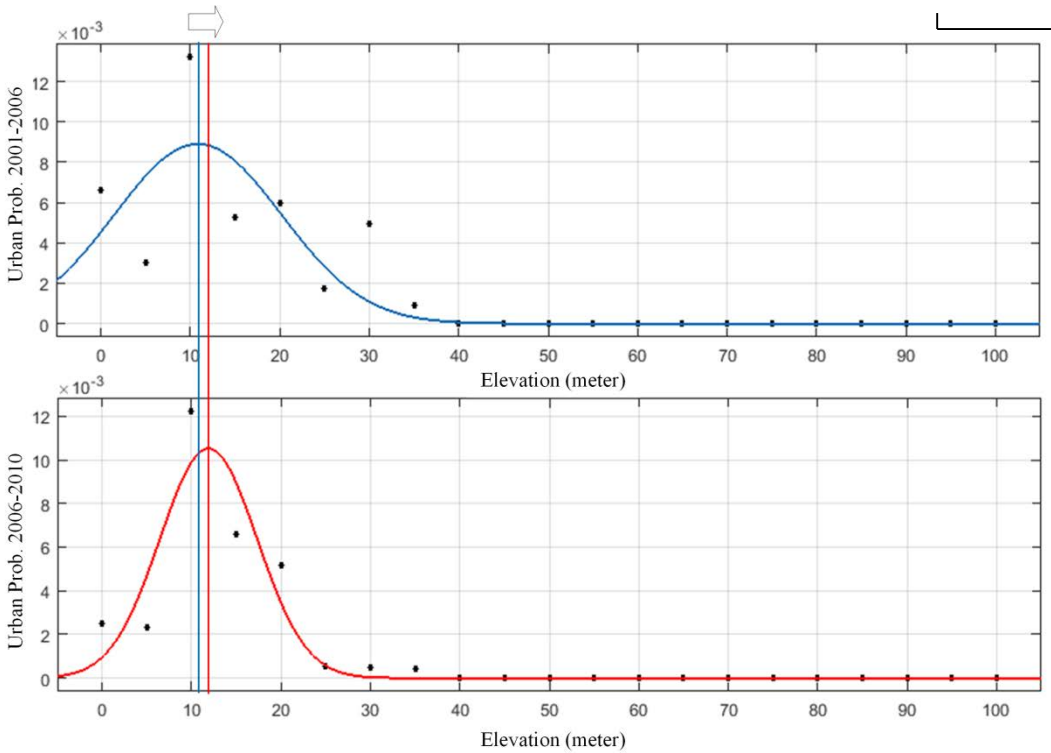
Urban growth probability at different elevation can be fit into a Gaussian Function

The height of the peak

$$P(x_h) = a \cdot exp\left(-\frac{(x_h - b)^2}{c}\right)$$

Elevation most probable for urban growth

The width of the curve



Urban growth probability at different elevations.

Equations	Time period	a	b	c
Elevation	2001-2006	0.008903	10.84	13.22
	2006-2010	0.01052	11.9	7.681

Equation coefficients

- The elevation most probable for urban growth (coefficient *b*) has increased from 10.84 to 11.90 meter after Katrina.
- Urban growth is more concentrated around the central lines (i.e. increased coefficient *c*)

Calibration of the Integrated Transition Function

- Integrated transition function consists of city attractiveness, elevation and road proximity

$$P(x) = \alpha_1 \cdot exp\left(-\frac{(x_e - \beta_1)^2}{\gamma_1}\right) + \alpha_2 \cdot {x_{tb}}^{\beta_2} + r \cdot \alpha_2 \cdot {x_{tn}}^{\beta_2} + \alpha_3 \cdot {x_d}^{\beta_3}$$

- Calibrating the coefficients using a genetic algorithm
- Two sets of coefficients are calibrated with urban growth before and after Hurricane Katrina, representing pre- and post-Katrina transition rules.
- Implemented in a cellular automata model to simulate the urban expansion
- Validation : correctly captured ~40% of urban growth (0.5% by random model)

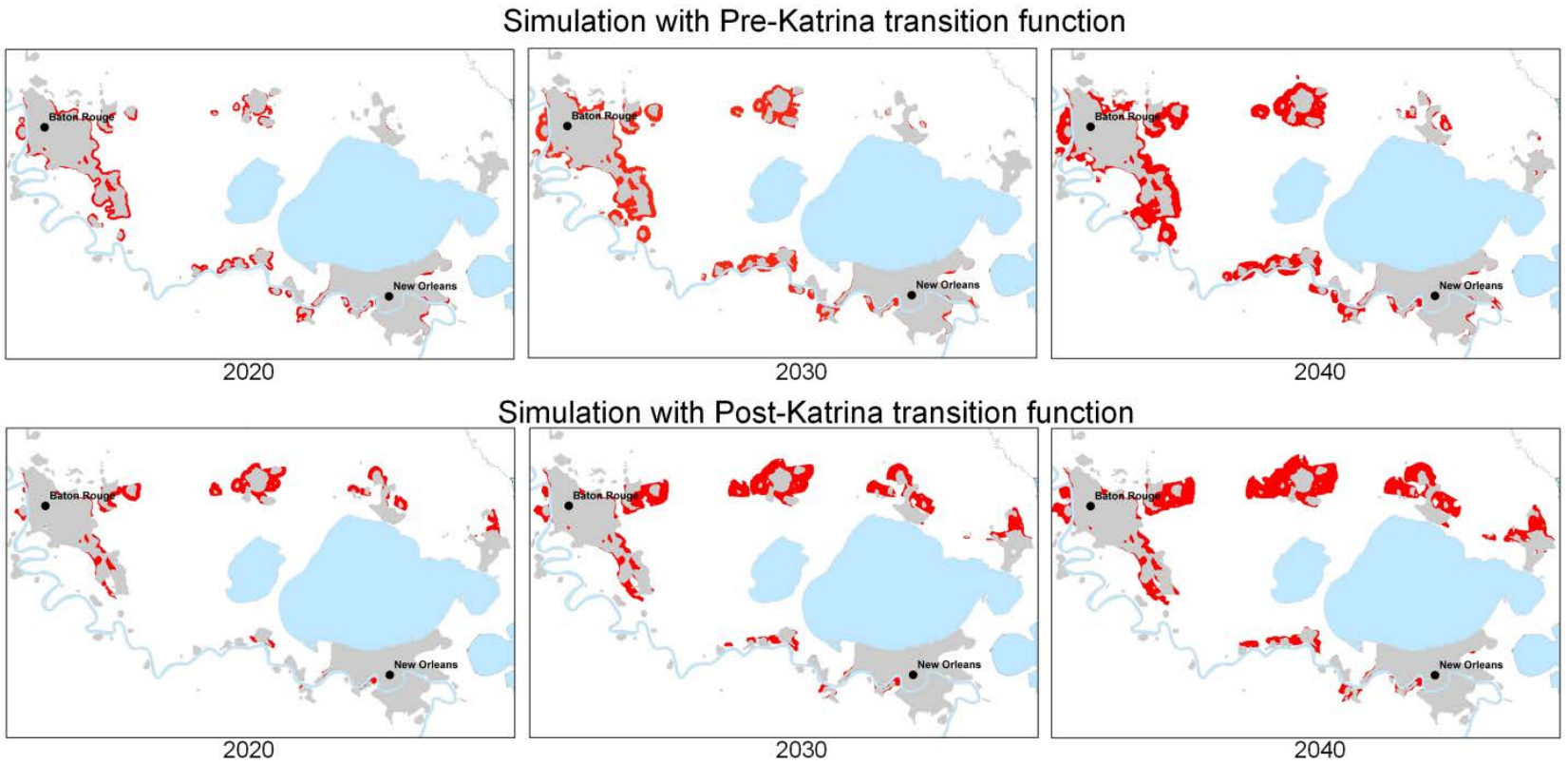
	Elevation			City attractiveness		Dist. to highway		Accuracy		
Parameters	α_1	β_1	γ_1	α_2	β_2	α_3	β_3	Total pixels	Error predictions	Error rate
2001 - 2006	1.140464	0.425875	0.042891	2.097344	-1.90265	2.311349	-0.57261	221994	64890	0.292305
2006 - 2010	3.503202	0.425912	0.131243	1.13776	-2.48992	1.719949	-0.44794	182295	47113	0.258444
Parameter changes	↑	↑	↑	↓	↓	↓	↑			

Two sets of parameters representing transition function during the two periods

Comparative simulation using pre- and post-Katrina transition functions

The Impact of Hurricane Katrina to Urban Growth Pattern:

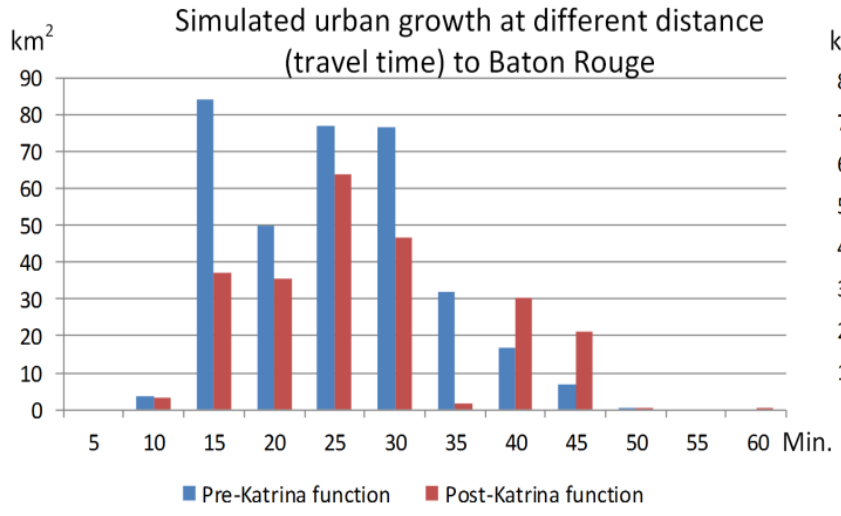
- Less urban growth near New Orleans, which is located in a low elevation region.
- Urban growth in the New Orleans MSA spills over across Lake Pontchartrain to the northern higher-elevation region.

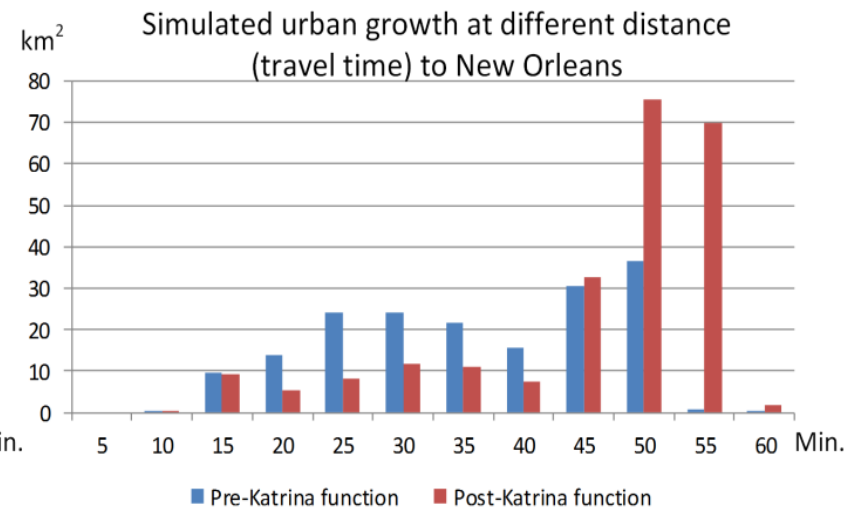


Decentralization of the cities

Both cities show decentralization trend in the long-term simulation

- The trend is more prominent in New Orleans where most urban growth will occur in areas with more than 50 minutes travel time to the city core.
- Implies a decentralized trend of capital, economy, employment, and resources in the urban system.
- The importance of the original city core may gradually decline and new sub-cores may emerge in high elevation regions.





Distance of new urban areas to city centers

Conclusions

- Demonstrated a methodology of using land cover data to detect, model, and simulate urban growth via a set of quantitative approaches.
- Quantitatively analyzed the impact of Katrina on urban growth trend in coastal Louisiana.
- Uncovered individuals' response and adaptation to natural hazards, which can indicate the resiliency and adaptive capacity of the coastal communities.
- The simulation results can serve as a useful planning tool for sustainable development.
- An integration of multiple data sources leads to more comprehensive understanding of human dynamics

Thanks for your attention!

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