An Introduction to Spatial Hazard Vulnerability Indices

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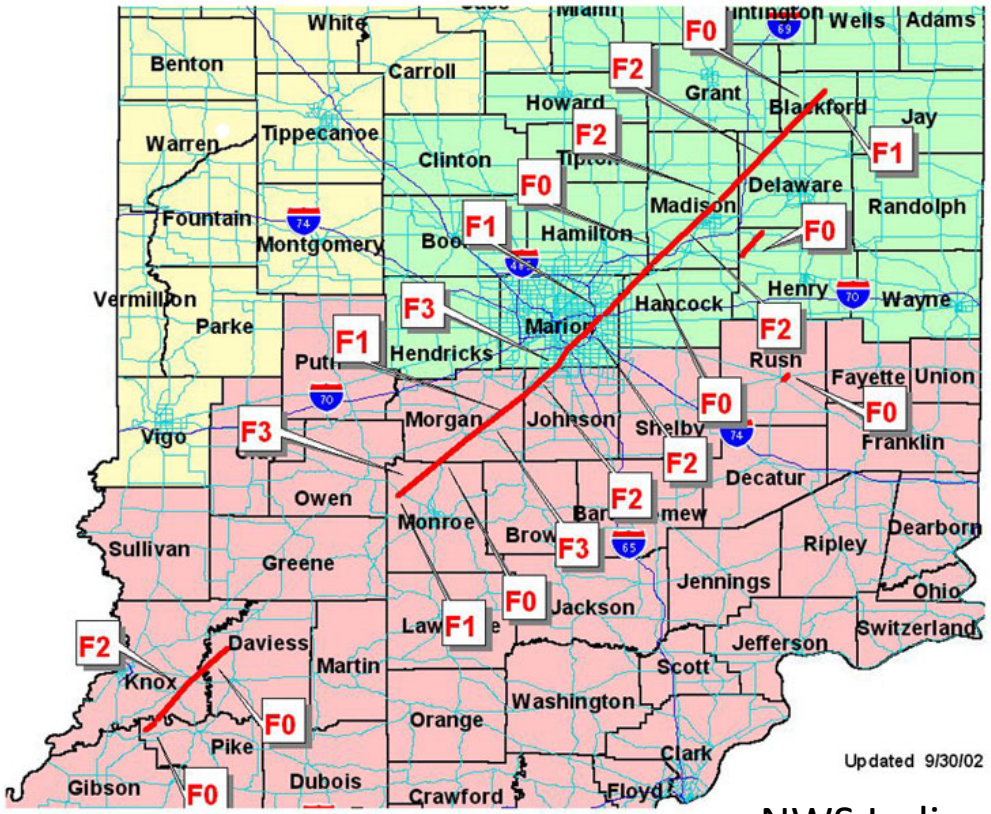
Indiana GIS Day

September 20, 2016

Indiana State Department of Health

September 20, 2002 Tornado

- F3 on Fujita scale
- 112 mile track – 2nd longest recorded in Indiana
- $156 million in damage
- No deaths, 130 injuries
- Damage still visible years later

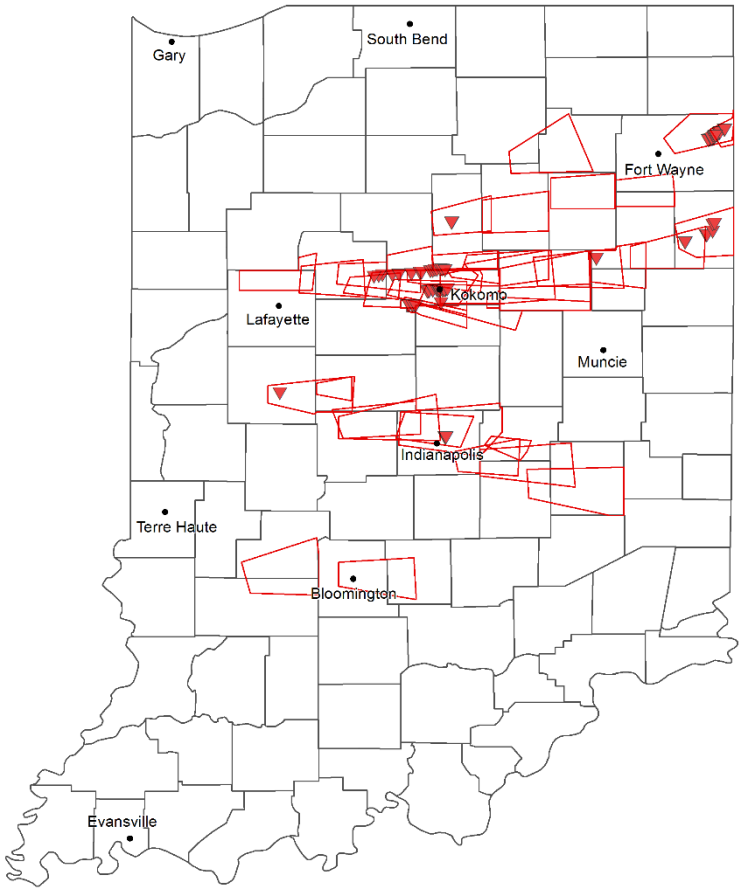


NWS Indianapolis

NWS Indianapolis

August 24, 2016 Tornado Outbreak

- 11 tornadoes reported in Indiana
- 48 tornado warnings
- EF-3 tornado in Kokomo
- No deaths, 20 injuries



What is Social Vulnerability?

- Many different definitions
- Community's susceptibility to harm from natural hazards (e.g. flood, tornado, extreme heat)
- Vulnerability is affected by community's characteristics
  - Socioeconomic factors (e.g. poverty, age, education)
  - Availability of preparedness resources
  - Institutional capabilities and barriers
- Risk = Hazard Exposure x Vulnerability

Vulnerability Varies Spatially

- Socioeconomic conditions are different in different communities
- Natural hazards are different in different parts of the country
- Both factors can be quantified
- Can compare relative vulnerability of different places
- Different components of vulnerability may be more important in different areas
- Differences in vulnerability can contribute to differences in impacts
- Great opportunity to use GIS

Benefits of Vulnerability Indices

- Can combine a lot of information of different types to create a simpler set of numerical scores
- Can use GIS to calculate and map those scores to see which communities are more vulnerable and may need more resources and attention in preparedness, emergency response, and recovery
- Helps promote disaster preparedness and mitigation and identify vulnerable areas **BEFORE** disaster strikes
- Officials and decision makers can use indices to inform decision making

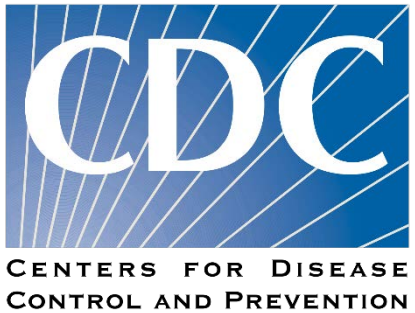
Creating Vulnerability Indices

- Census/American Community Survey data is most common
- This can be combined with hazard, health, infrastructure, and environment information
- Some indices are applicable for all hazards, some are designed for a specific hazard
- Some indices could be specific to a particular sector

American Community Survey (ACS)

- Census surveys every person in U.S. every 10 years (most familiar)
- Starting in 2005, the Census Bureau moved many questions from the decadal Census to ACS
- ACS surveys approx. 250,000 people each month
- Results are used to create 1, 3, and 5 year estimates
- Only the 5 year ACS has estimates for all areas
- Data is updated more frequently, but it’s a sample rather than a full count

Social Vulnerability Index (SVI)



- Created by Centers for Disease Control (Flanagan et al. 2011)
- Census tract level for entire U.S.
- 15 Census/ACS variables
- Groups variables into four categories and adds category scores together
  - Socioeconomic Status
  - Household Composition
  - Race/Ethnicity/Language
  - Housing/Transportation
- Scores based on percentiles
- Also flags tracts that are in the 90th percentile in each variable
- All data is freely available
- http://svi.cdc.gov/

SVI Calculation

Socioeconomic Status	Household Composition	Race/ Ethnicity/Language	Housing/Transportation
In Poverty	Age 65 or Older	Minority	Multi-Unit Structures
Unemployed	Age 17 or Younger	Speak English Less than Well	Mobile Home
Income	Older than Age 5 with disability		Crowding
No High School Diploma	Single Parent Household		No Vehicle
			Group Quarters

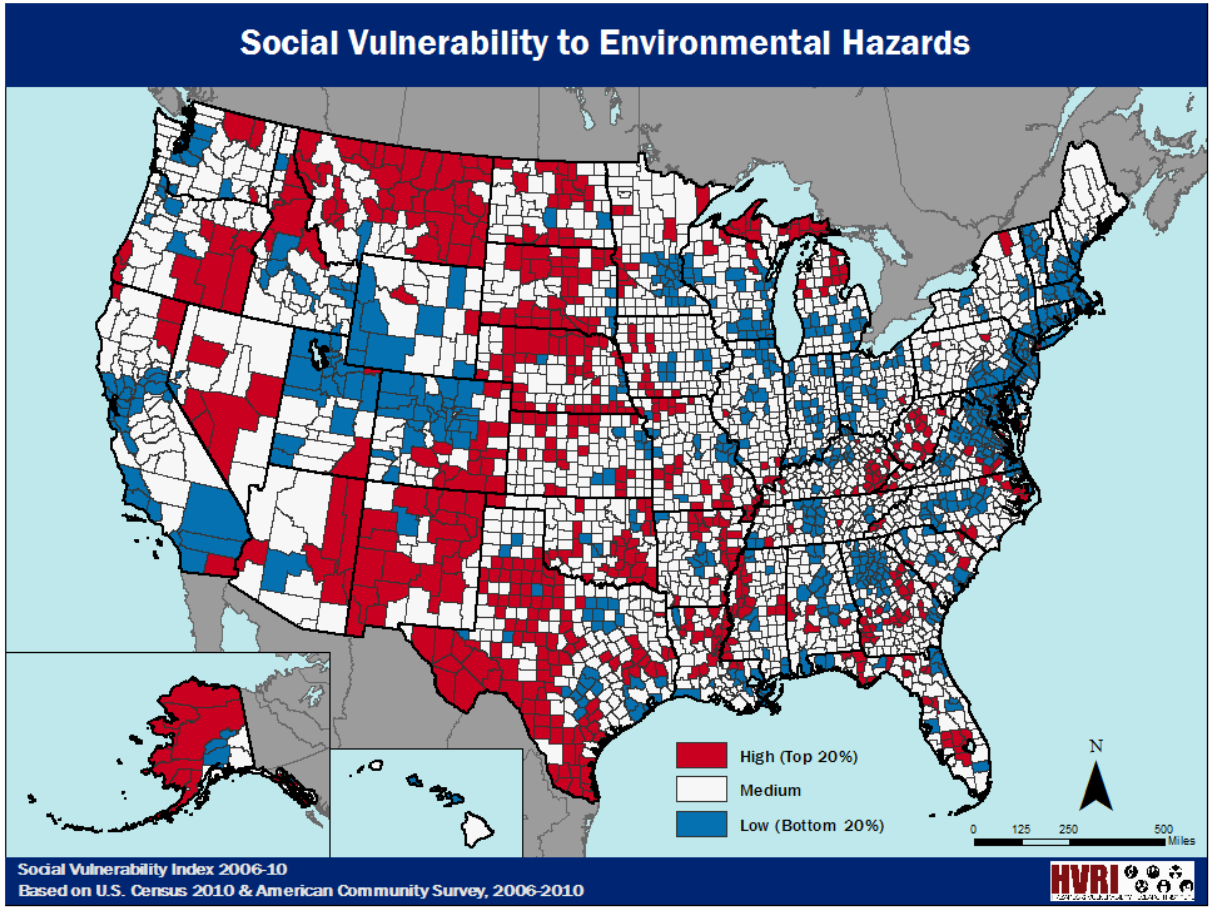
Each tract is ranked by percentile (0-1) for each of the 15 variables, the 4 components, and overall.
A tract can have a flag for each of the 15 variables, 4 components, and overall.
40 total values for each tract.

Social Vulnerability Index (SoVI)

- Created by University of South Carolina's Hazards and Vulnerability Research Institute (HVRI) (Cutter et al. 2000, 2003)
- County and Census tract level for entire U.S.
- 29 Census/ACS variables
- Uses principal component analysis to group variables differently for each analysis, and adds component scores together
- Results change depending on area and scale selected
- Final scores available in ArcGIS Online and ArcGIS Pro
- http://webra.cas.sc.edu/hvri/products/sovi.aspx

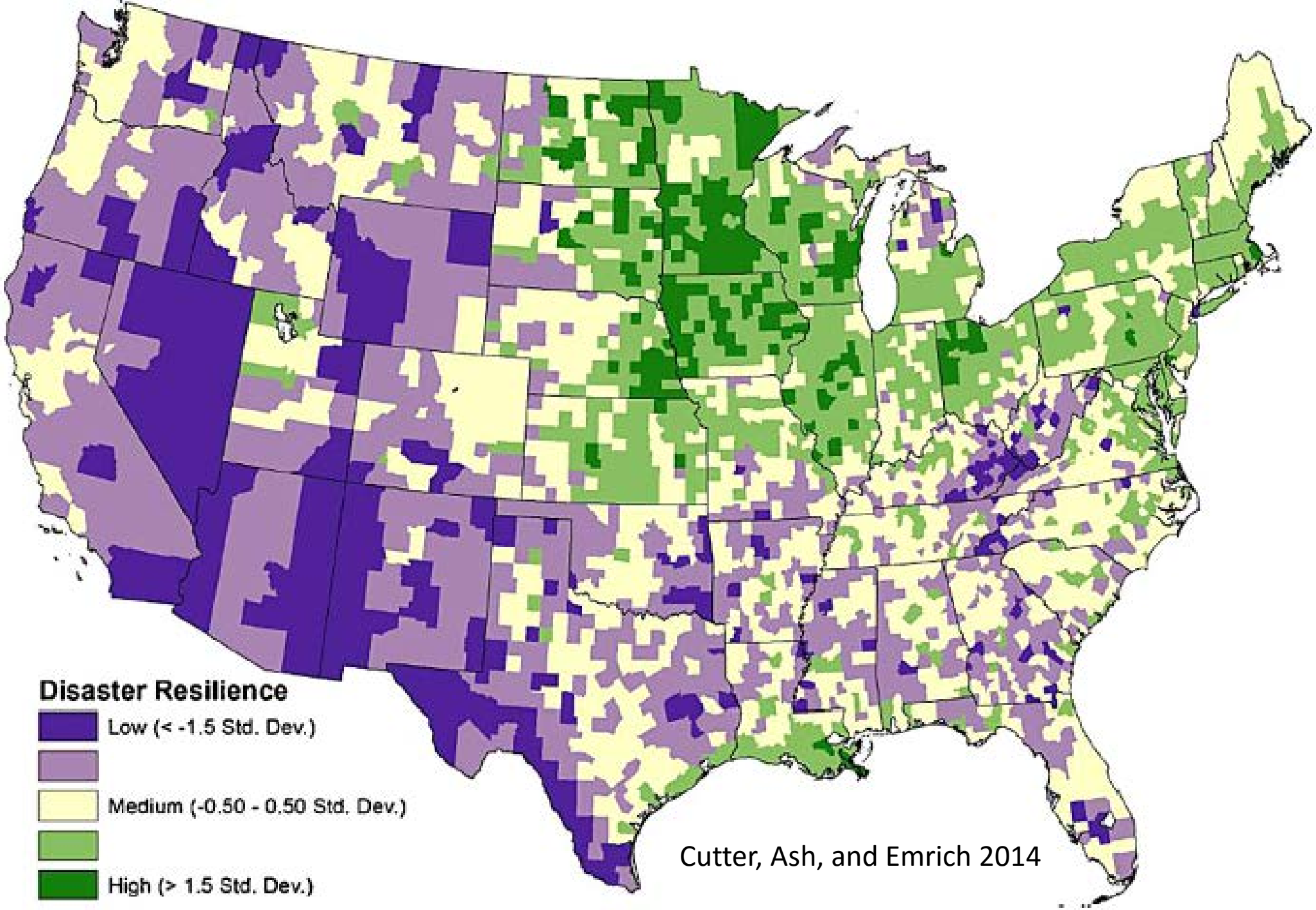
Vulnerability Components

- Race (black) and class (poverty)
- Wealth
- Age (old)
- Ethnicity (Hispanic)
- Nursing home residents
- Ethnicity (Native American)
- Employment in service industries



Baseline Resilience Indicators for Communities (BRIC)

- Created by HVRI (Cutter et al. 2010)
- Resilience is ability to withstand harm from hazards, not exact opposite of vulnerability
- 49 variables grouped into six categories ahead of time
  - Social
  - Economic
  - Community capital
  - Institutional
  - Housing/Infrastructural
  - Environmental
- Large number of data sources

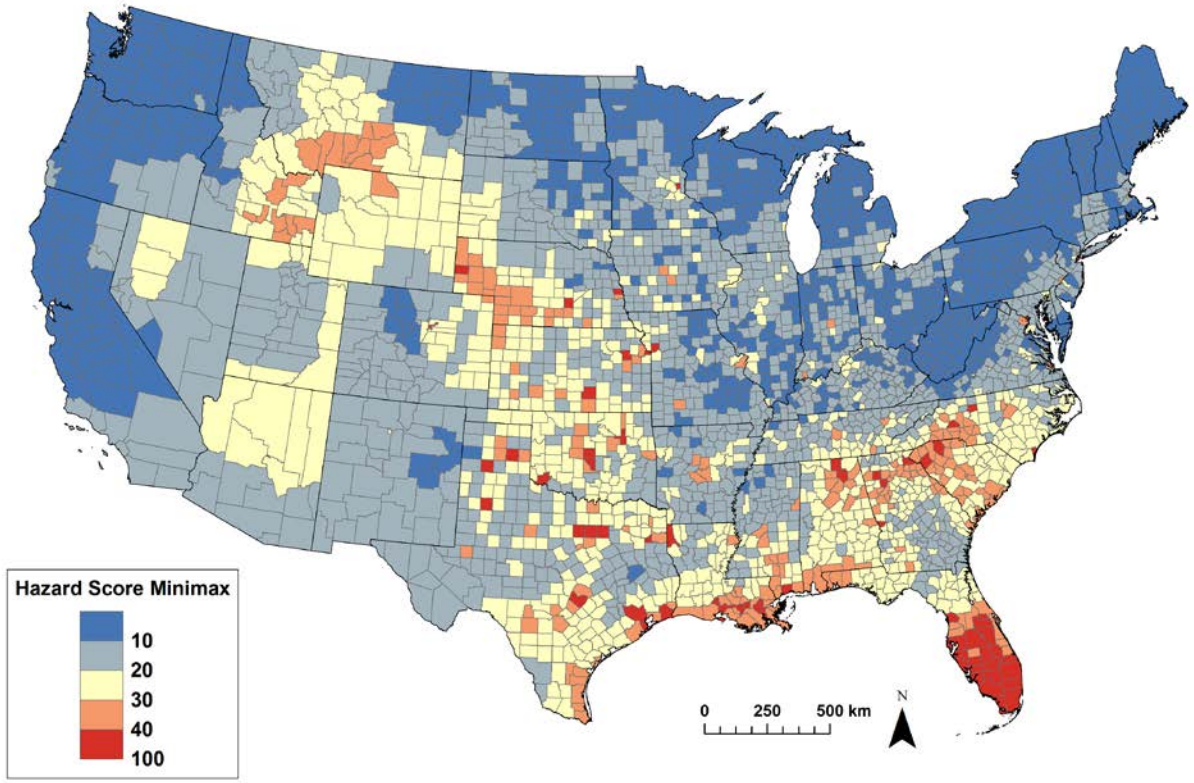


Cutter, Ash, and Emrich 2014

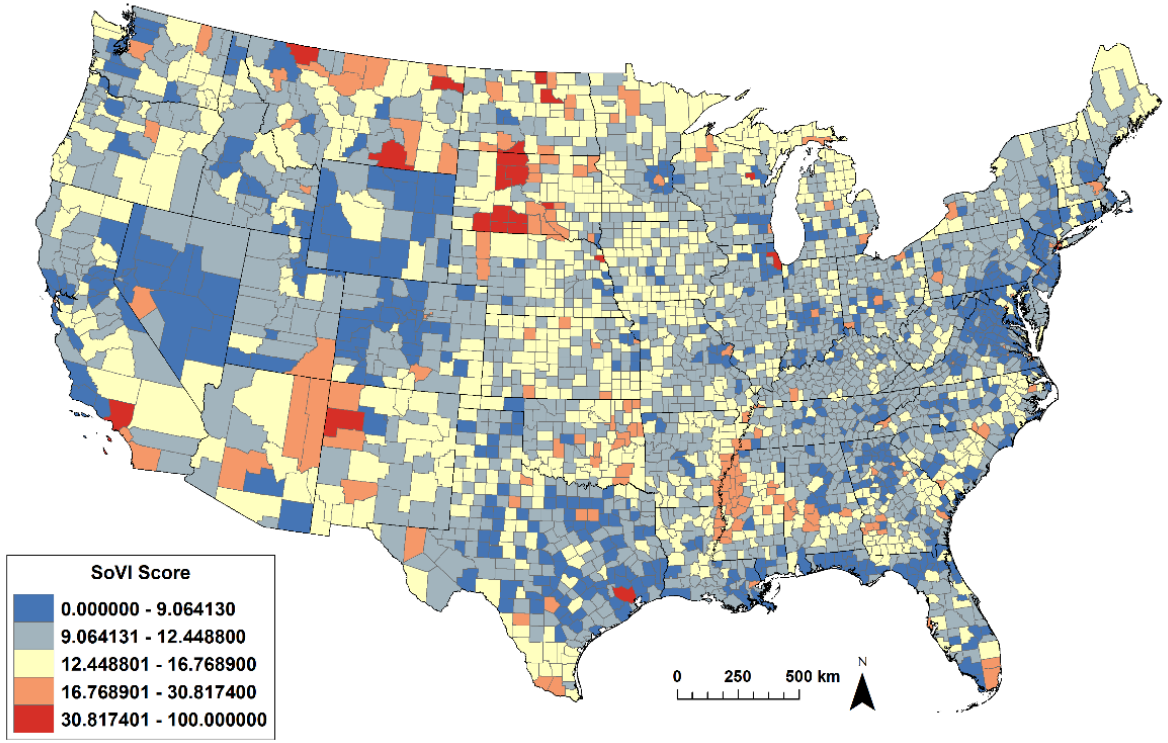
My Hazard Vulnerability Index

- Developed for my Master's thesis at University of Oklahoma (2011)
- County level for contiguous U.S.
- Combined SoVI with historical data for seven natural hazards
  - Tornado
  - Severe thunderstorm winds
  - Hail
  - Hurricane winds
  - Storm surge
  - Drought
  - Wildfires
- Multiply SoVI and hazard score together

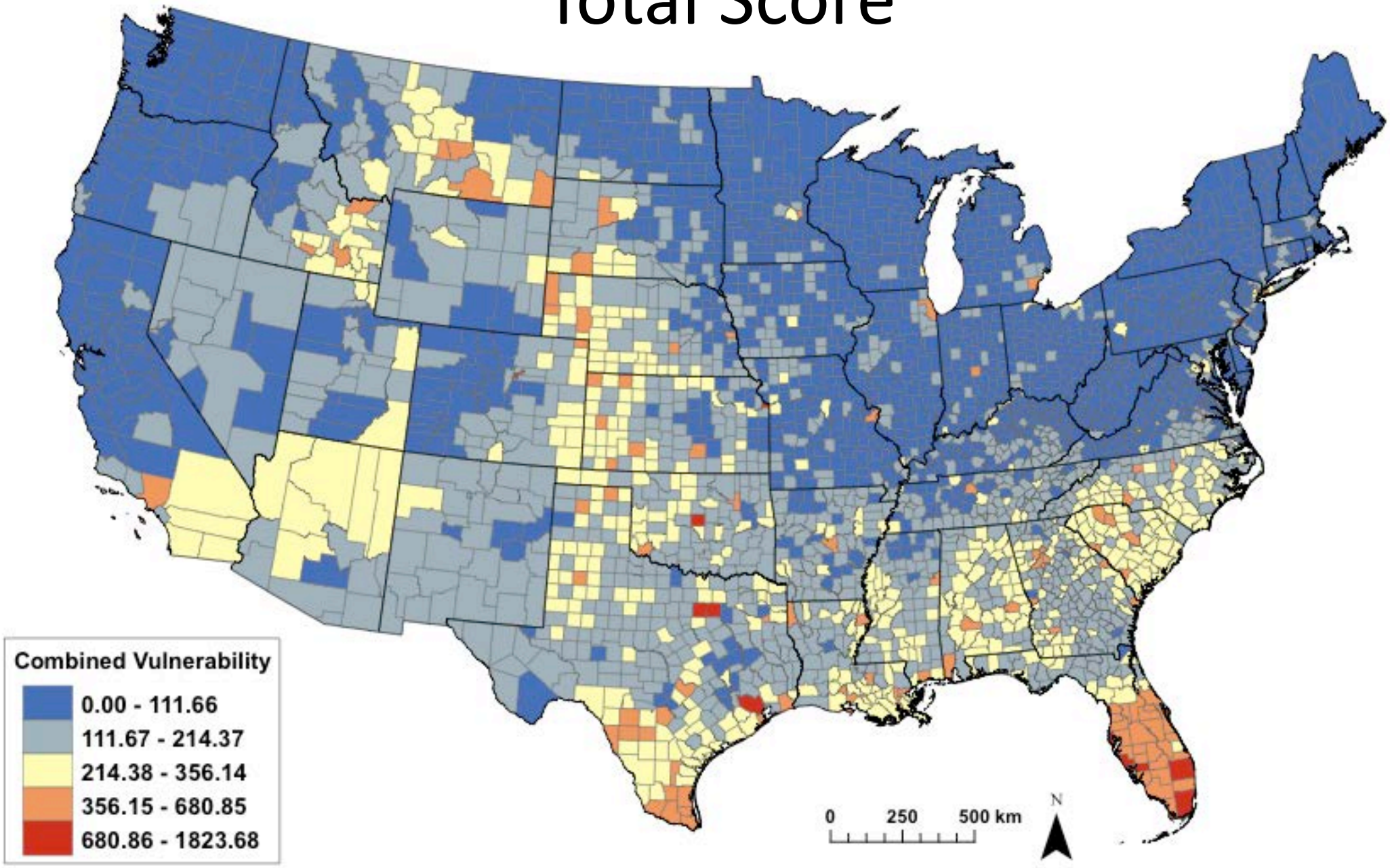
Hazard Score



Vulnerability Score



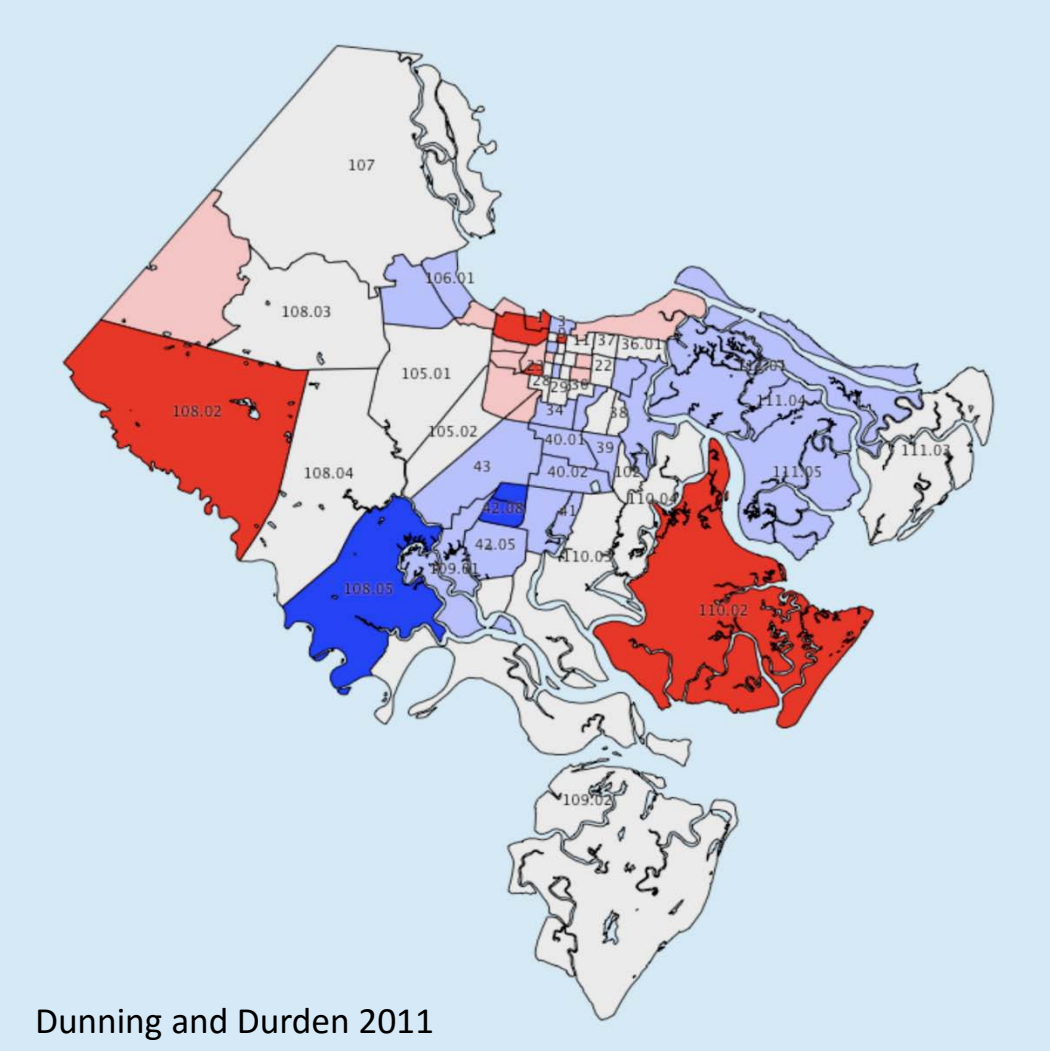
Total Score


Combined Vulnerability
0.00 - 111.66
111.67 - 214.37
214.38 - 356.14
356.15 - 680.85
680.86 - 1823.68
0
250
500 km
N

Army Corps of Engineers Flood Risk Management

- Uses SoVI at the tract level (Dunning and Durden 2011)
- Also made own Social Vulnerability Profiling – 7 variables
- Can be difficult to compare the results of different indices
- Either index can be used to identify and locate vulnerable populations to increase outreach with them and incorporate their needs in a risk assessment and hazard mitigation strategies

Chatham County, GA SoVI



Dunning and Durden 2011

Table 8. Full SoVI showing drivers of vulnerability for Chatham County study area census tracts.

Census tract	Popula-tion	Race and class	Elderly	Housing tenure	Gender	Urban/ rural	Unemployed-female- headed households	Hospitals	Extractive industry	SoVI score
1	1215					X	X	X	X	X
6.01	4034	X	X			X			X	X
32	1111	X	X	X			X			X
33.01	1995	X	X	X	X	X				X
33.02	1851	X	X	X	X					X
36.01	3000	X		X		X				
40.02	3891							X	X	
41	2066			X						
42.02	8312					X			X	
42.05	9888			X				X		
42.06	1693			X	X					
101.01	2084	X		X			X			X
101.02	3738							X		
105.01	4720	X				X			X	
106.01	5685									
106.03	1848									
107	4484	X	X	X		X				
108.04	8331			X		X			X	
108.05	9241									
109.01	3652									
109.02	1170				X					
110.02	6958		X	X			X			X
110.03	6161			X	X				X	
110.04	3767		X	X	X					
111.01	7952									
111.03	3696		X							
111.05	9325			X	X					
TOTAL	123756									

Note: An X in a cell indicates that the SoVI score was at least ≥0.5, indicating higher levels of social vulnerability for the dimension or total SoVI score.

Dunning and Durden (2011)

Heat Vulnerability Index

- Used by San Francisco and Wisconsin health departments
- 9 Socioeconomic variables – e.g. poverty, age, education
- 6 Environmental variables – e.g. temperature, air quality, land cover
- 8 Health variables – e.g. diabetes, asthma, hypertension prevalence
- Scores created by calculating the z-scores of each variable, adding those z-scores, and calculating a percentile of the sum

ArcGIS San Francisco Heat Vulnerability Index

Modify Map Sign In

Details | Basemap | Share Print | Measure Find address or place

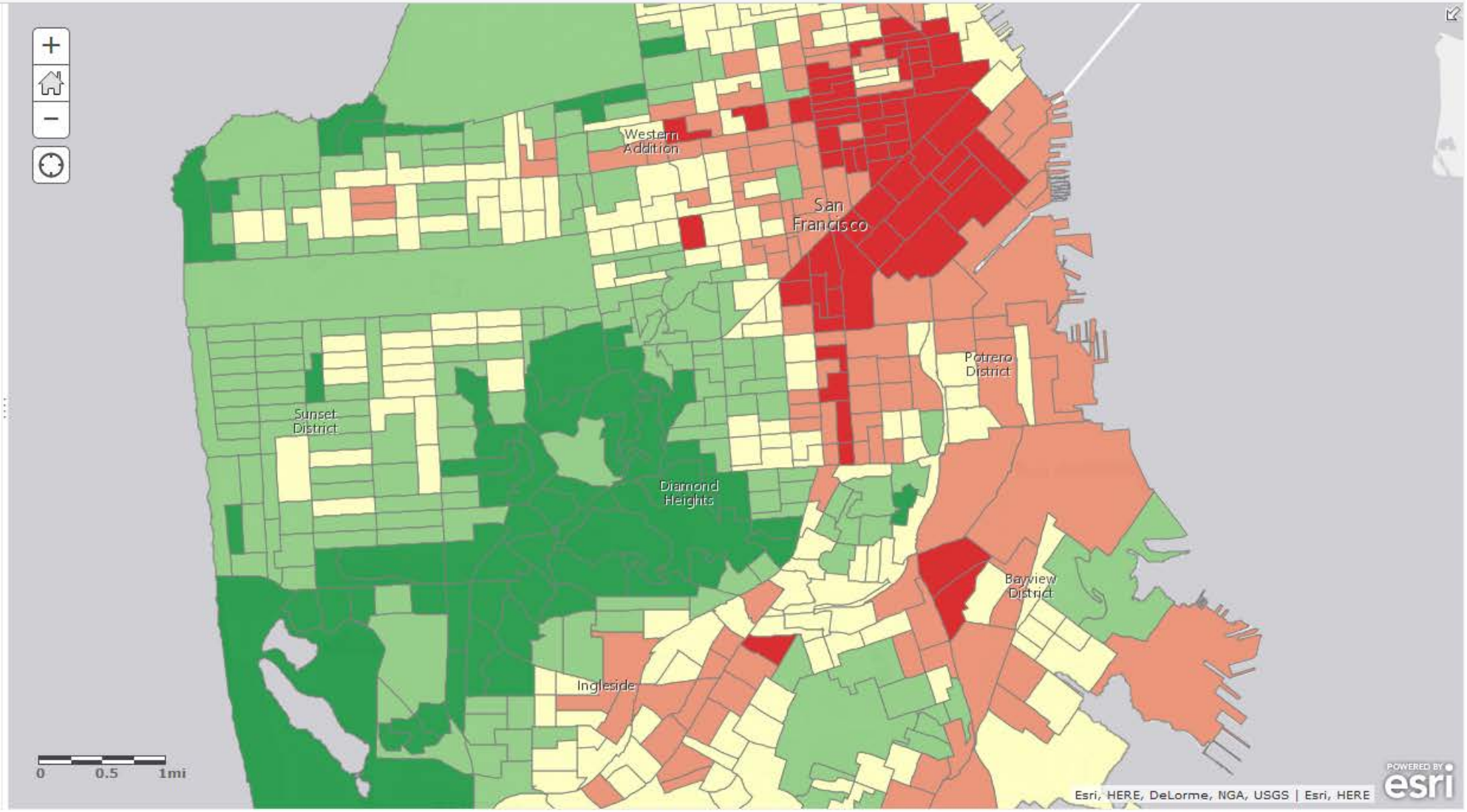
About Content Legend

Legend

Heat Vulnerability

Heat Vulnerability Score

- High
- Medium-High
- Medium
- Low-Medium
- Low



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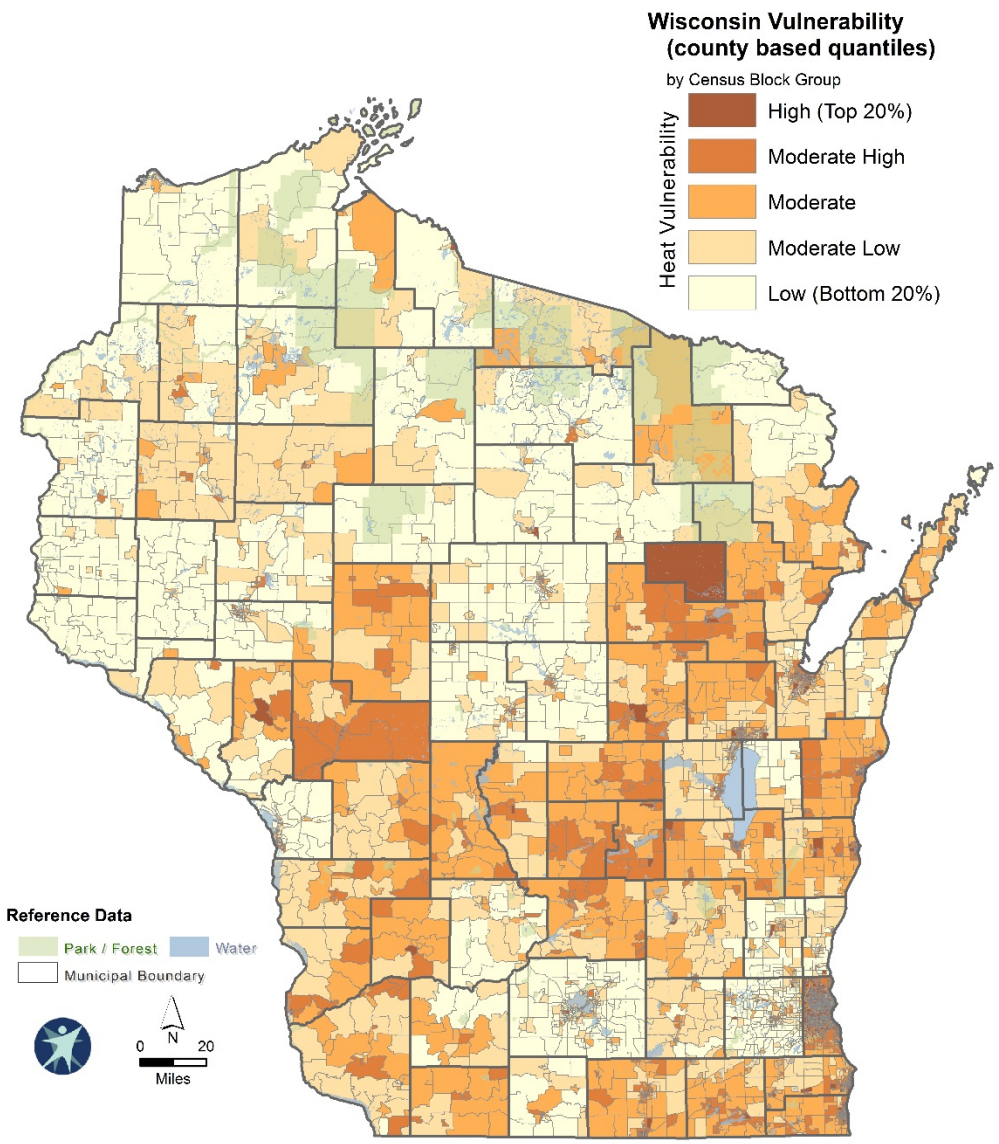
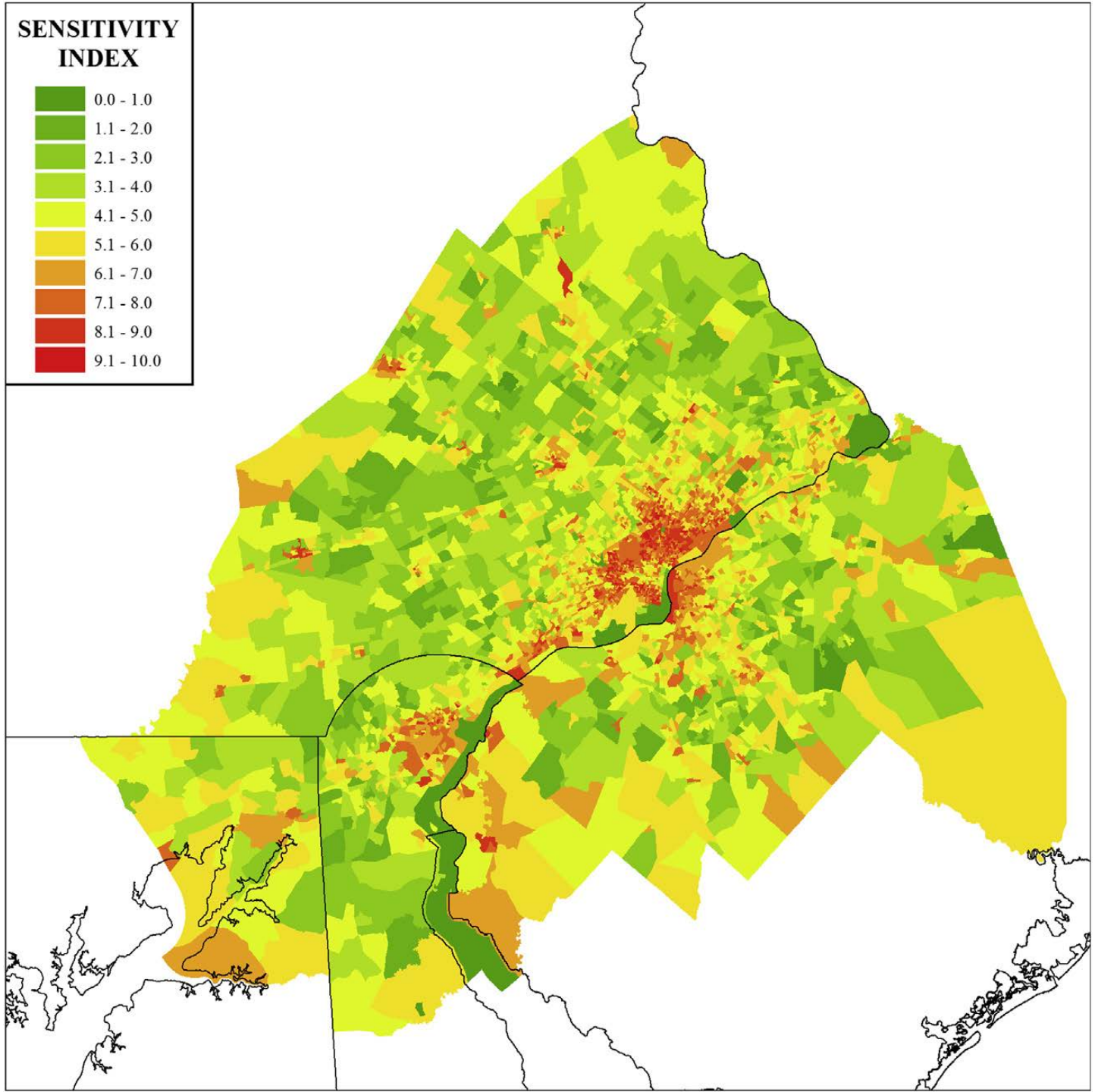
Wisconsin Heat Vulnerability Index (HVI)

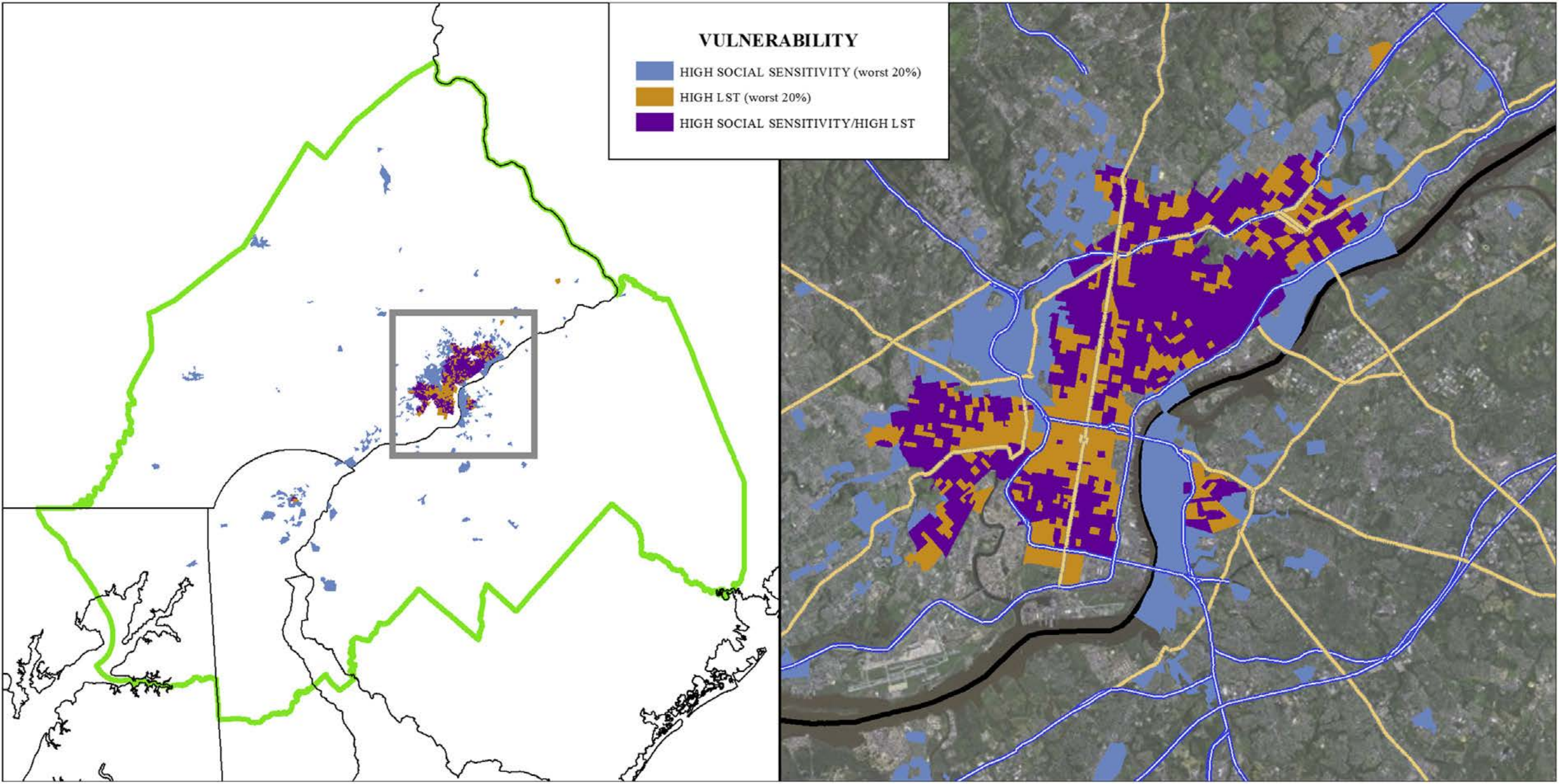


Philadelphia Heat Wave Index

- Weber et al. (2015) involved decision makers from the beginning in construction of this index. Indicators are specifically intended to be actionable.
- Advisory group of academia, private sector, and city officials created the index
- Four socioeconomic variables combined with satellite-based temperatures at block group level
- Informs decisions on where to put cooling stations and increase vegetation
- 10 years worth of temperature and vegetation data, could see the effects of new buildings on temperature



Weber et al. (2015)



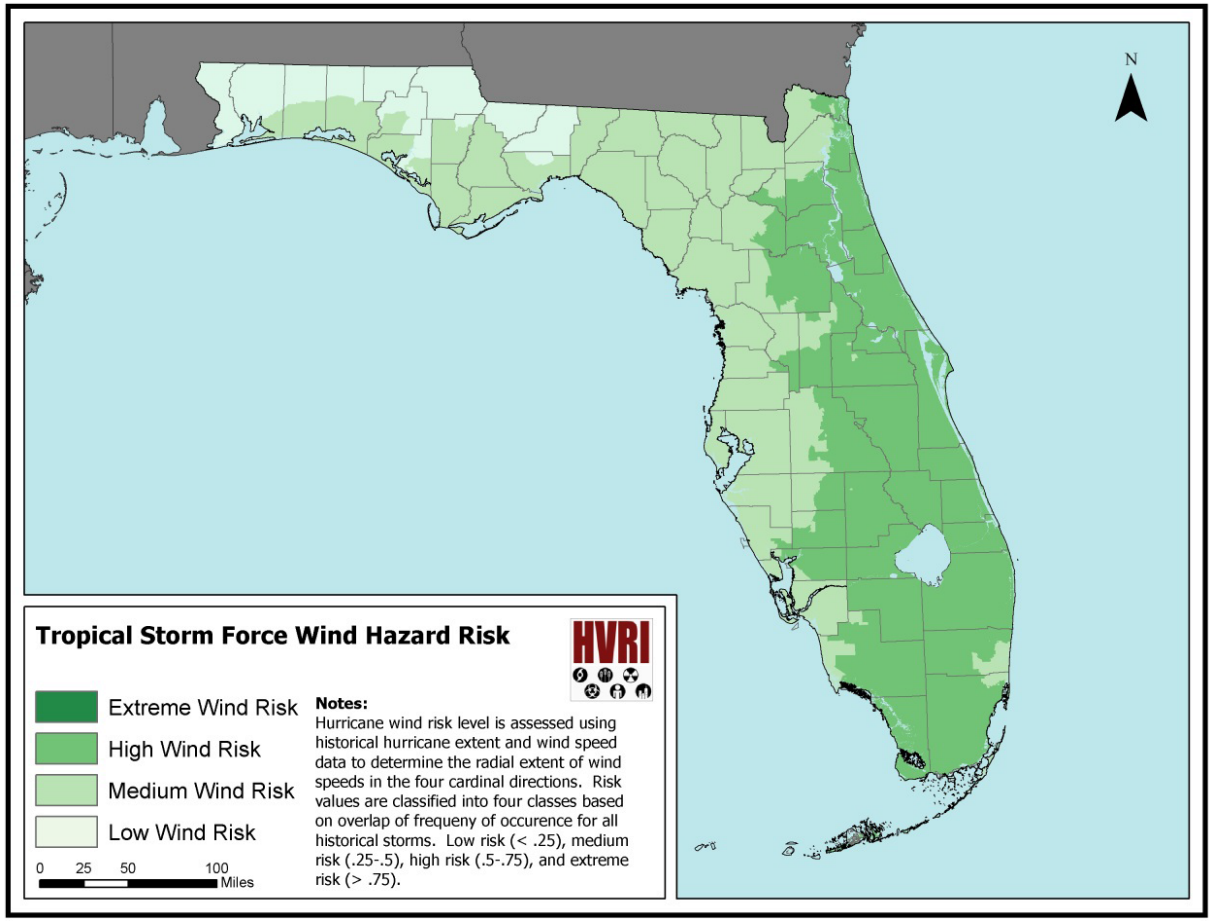
Weber et al. (2015)

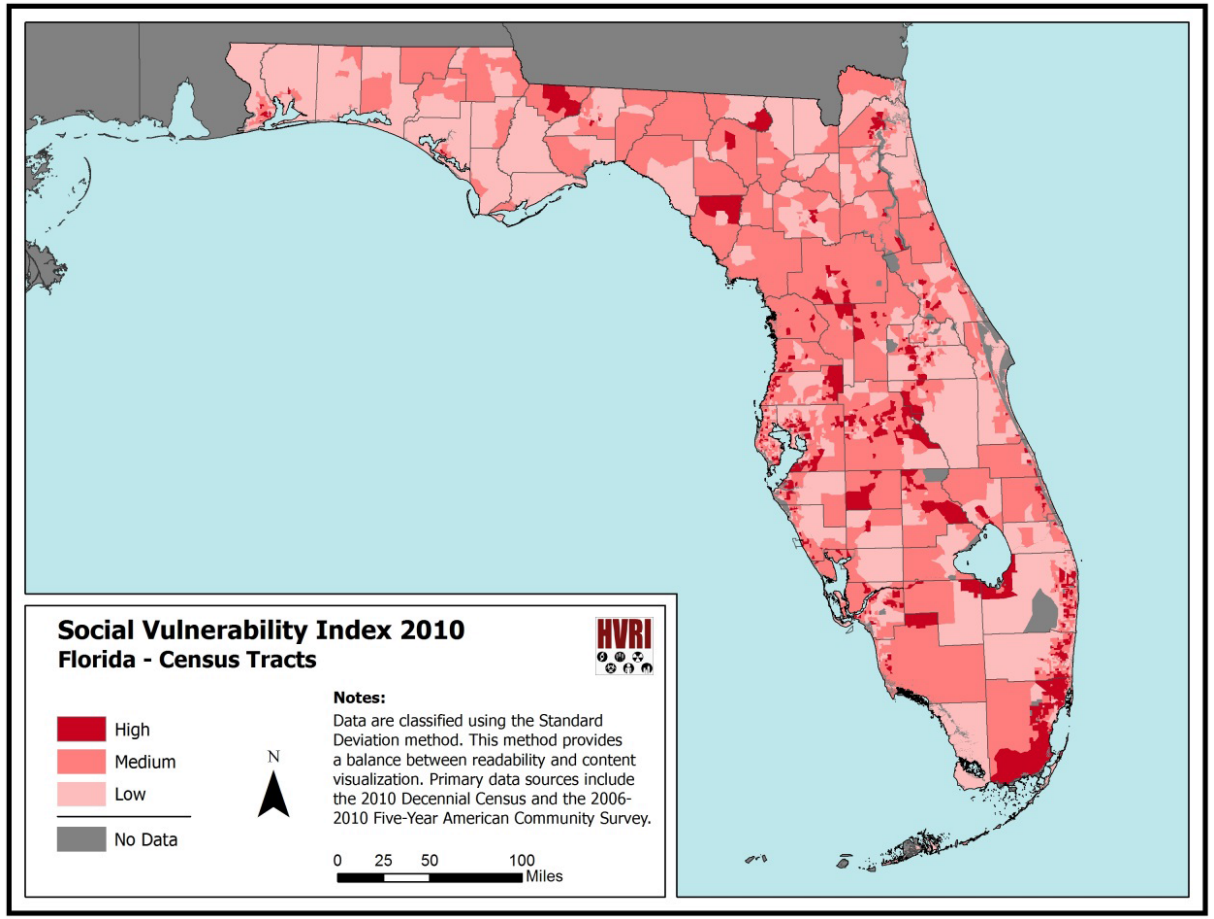
Philadelphia Heat Wave Index (cont.)

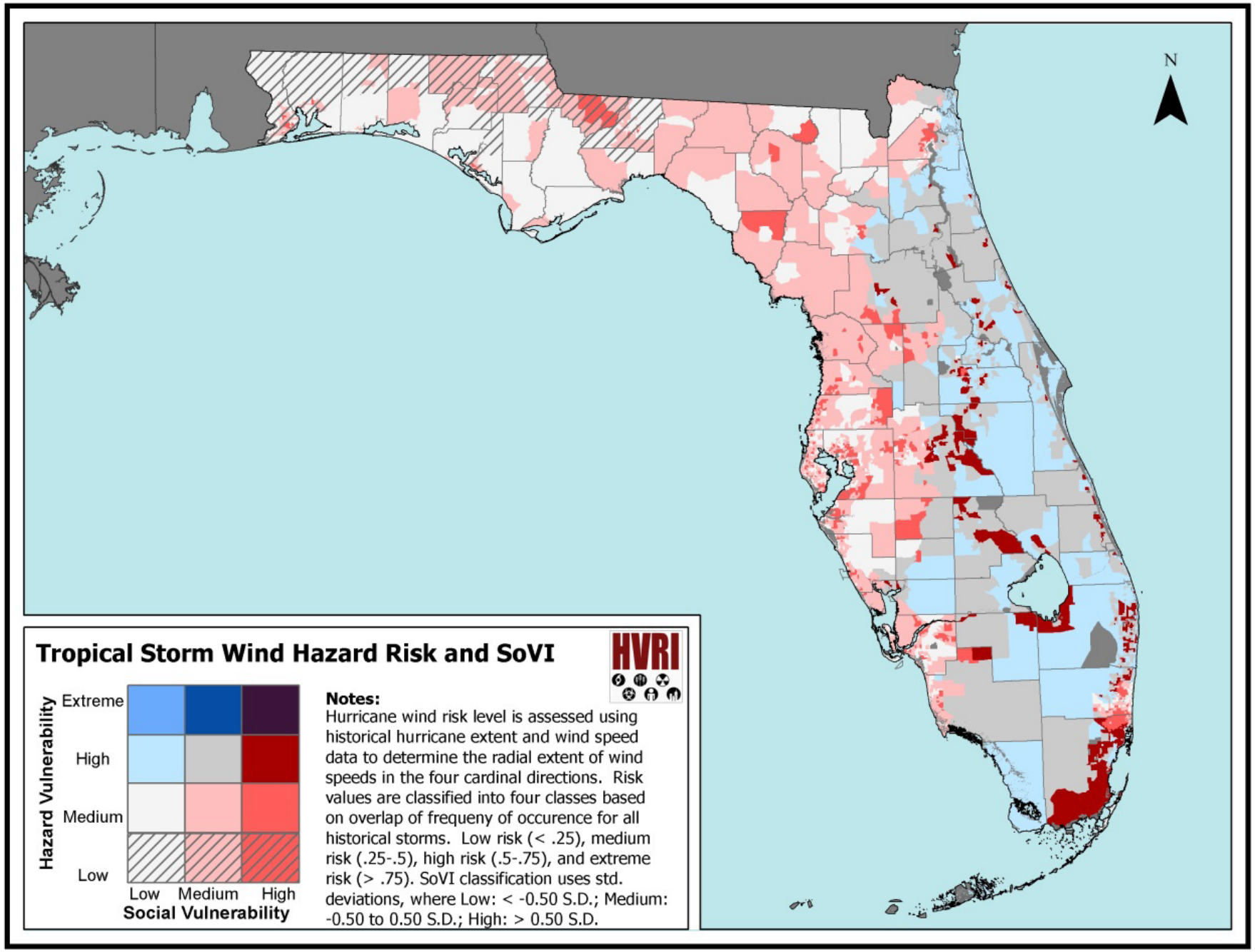
- Helped Mayor’s Office of Sustainability implement and evaluate sustainability plan
- Philadelphia Department of Public Health and City Planning Commission interested in updating District Plans
- Philadelphia Electric Company interested in peak energy demand
- Want to bring this into more mapping applications
- Data availability issues with heat mortality and morbidity data
- Testing using the index in New York City

Index Use By Decision Makers

- Florida Department of Health combined SoVI with exposure to seven individual hazards at tract level. Also predicted future risk for injuries and carbon monoxide poisonings from hurricanes using hospital records.
- North Carolina Vulnerable and At-Risk Populations (VARP) Guide (varpguide.com) – developed at UNC, uses SVI
- Other potential uses – locating evacuation assistance (Evans et al. 2014), emergency and tornado shelters, estimating need of emergency supplies, identifying structures vulnerable to flooding
- Need more progress turning vulnerability assessments into policy (e.g. Wolf et al. 2015)


N
Tropical Storm Force Wind Hazard Risk
HVRI
Extreme Wind Risk
High Wind Risk
Medium Wind Risk
Low Wind Risk
0 25 50 100
Miles
Notes:
Hurricane wind risk level is assessed using historical hurricane extent and wind speed data to determine the radial extent of wind speeds in the four cardinal directions. Risk values are classified into four classes based on overlap of frequeny of occurence for all historical storms. Low risk (< .25), medium risk (.25-.5), high risk (.5-.75), and extreme risk (> .75).


Social Vulnerability Index 2010
Florida - Census Tracts
HVRI
High
Medium
Low
No Data
N
Notes:
Data are classified using the Standard Deviation method. This method provides a balance between readability and content visualization. Primary data sources include the 2010 Decennial Census and the 2006-2010 Five-Year American Community Survey.
0 25 50 100
Miles


N
Tropical Storm Wind Hazard Risk and SoVI
HVRI
Hazard Vulnerability
Extreme
High
Medium
Low
Low
Medium
High
Social Vulnerability
Notes:
Hurricane wind risk level is assessed using historical hurricane extent and wind speed data to determine the radial extent of wind speeds in the four cardinal directions. Risk values are classified into four classes based on overlap of frequeny of occurence for all historical storms. Low risk (< .25), medium risk (.25-.5), high risk (.5-.75), and extreme risk (> .75). SoVI classification uses std. deviations, where Low: < -0.50 S.D.; Medium: -0.50 to 0.50 S.D.; High: > 0.50 S.D.

Vulnerable and At-Risk Populations Resource Guide (VARP)

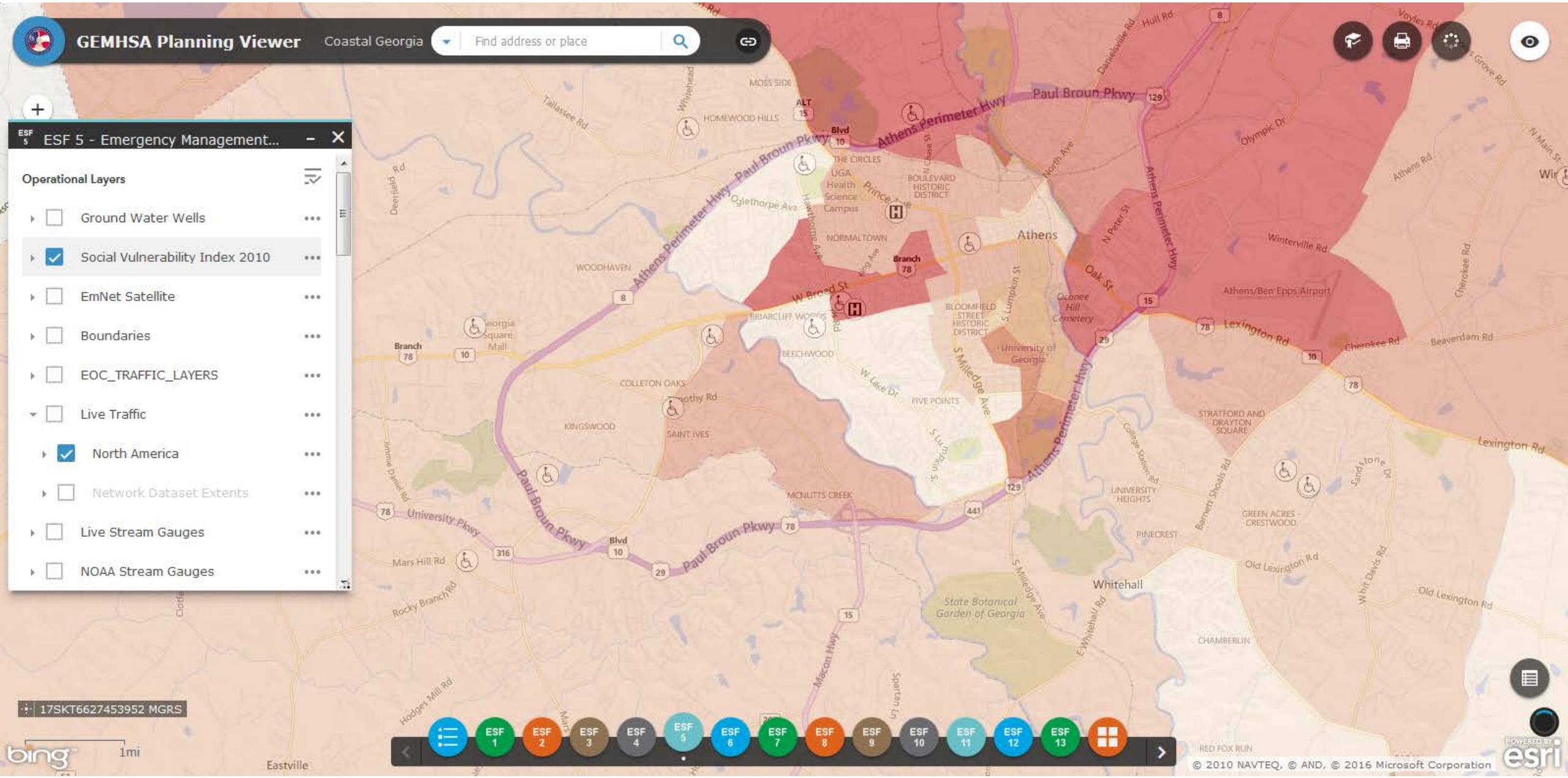
- Developed by North Carolina Preparedness and Emergency Response Research Center (NCPERRC) at University of North Carolina – Chapel Hill
- Combines SVI for different regions with resource guides about communicating with vulnerable populations
- Helped build Georgia Online Disaster Awareness Geospatial System (GODAWGS) for the State of Georgia

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Vulnerable & At-Risk Populations Resource Guide

GODAWGS

- Developed by Georgia Department of Public Health, Georgia Emergency Management Agency, and UNC.
- Mapped SVI by regions for Emergency Management, hospitals, and public health.
- SVI is a layer in their online maps and apps (http://gema-soc.maps.arcgis.com/home/index.html)
- Held a training session to show practitioners how to use online SVI tool


GEMHSA Planning Viewer
Coastal Georgia
Find address or place
ESF 5 - Emergency Management...
Operational Layers
Ground Water Wells
Social Vulnerability Index 2010
EmNet Satellite
Boundaries
EOC_TRAFFIC_LAYERS
Live Traffic
North America
Network Dataset Extents
Live Stream Gauges
NOAA Stream Gauges
17SKT6627453952 MGRS
1mi
ESF 1
ESF 2
ESF 3
ESF 4
ESF 5
ESF 6
ESF 7
ESF 8
ESF 9
ESF 10
ESF 11
ESF 12
ESF 13
Athens
Paul Broun Pkwy
Athens Perimeter Hwy
Lexington Rd
University Pkwy
Whitehall
© 2010 NAVTEQ, © AND, © 2016 Microsoft Corporation

Georgia Emergency Management

- Georgia Hazard Mitigation Strategy (2014) combines SoVI and hazard scores for 5 hazards
  - Storm surge, wind, flood, earthquake, wildfire
- Increase training – HAZUS, risk and vulnerability workshops
- Build risk scores into wildfire sections of county hazard mitigation plans.

How to Use Vulnerability Metrics

- Get an understanding of vulnerability **BEFORE** disaster
  - Can identify communities that may require more attention, outreach, and investigation of more detailed processes
  - Help these communities raise awareness, access resources, supplement efforts of local organizations
  - Interviews, focus groups, workshops, studies, and plans with local organizations, leaders, and subject matter experts, can provide more insight on the needs of vulnerable areas.
  - Building trust and collaboration takes time
- Examining individual component scores, not just the overall score, can provide additional insight
- They are one of many tools – no one tool tells you everything
- Indices can be starting point of larger risk and vulnerability assessments
- Often can’t change the index variables directly
- They do not describe processes that create vulnerability

Best Practices for Creating Indices

- Use data that are up to date and available for relatively similar times
- Support use of variables with documented evidence
- Express variables as a percentage and standardize
- A simpler process will be easy to understand, but also want index to be comprehensive
- GIS can help combine data available at different scales, but need to be careful about how that is done – finer scale is preferable
- Weighting variables not encouraged – how to do it?
- Building indices with input from more diverse stakeholders throughout process can incorporate more perspectives and promote buy-in, but it can be more difficult to build consensus

Limitations and Other Notes

- Scores in study area are relative, not absolute
- Not all people in a geographic unit are equally vulnerable
- Do not ignore areas with a low vulnerability score
- Consider uncertainty in data (e.g. ACS)
- Verifying vulnerability is very difficult - impacts affected by hazard severity and many other factors
  - Can examine health outcomes and recovery time after hazard event, but unlikely to be able to show causation – too many variables
  - Can’t control how people will respond
  - Other types of assessments and incident reports will be more useful at this stage
- Local knowledge and qualitative information are also very important

Conclusion

- Hazard vulnerability indices can help identify communities that are more susceptible to harm from natural hazards
- They can use GIS incorporate different data types to create a composite view of vulnerability
- Examining indices can inform decisions on where to target outreach, assistance, policy measures, etc.

Thank you!

Questions?

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References

- Cutter, S.L., J.T. Mitchell, M.S. Scott, 2000. Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina, Annals of the Association of American Geographers, 90(4): 713-737.
- Cutter, S.L., B.J. Boruff, W.L. Shirley, 2003. Social Vulnerability to Environmental Hazards, *Social Science Quarterly*, 84(1): 242-261.
- Cutter, S.L., C.G. Burton, C.T. Emrich, 2010. Disaster Resilience Indicators for Benchmarking Baseline Conditions, *Journal of Homeland Security and Emergency Management*, 7(1), Article 51.
- Cutter, S. L., K.D. Ash, C.T. Emrich, 2014. The Geographies of Community Disaster Resilience, *Global Environmental Change* 29:65-77.
- Dunning, C.M., S. Durden. 2011. Social Vulnerability Analysis Methods for Corps Planning. U.S. Army Corps of Engineers Campaign Plan: Goal 2. 92 pp. http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/2011-R-07.pdf
- Emrich, C.T., D.P. Morath, G.C. Bowser, R. Reeves. 2014. Climate-Sensitive Hazards in Florida. Identifying and Prioritizing Threats to Build Resilience against Climate Effects. http://www.floridahealth.gov/environmental-health/climate-and-health/_documents/climate-sensitive-hazards-in-florida-final-report.pdf
- Evans, J.M., M. Hauer, R.D. Hardy, J.S. Pippin. 2014. Social Vulnerability and Local Hazard Mitigation Planning: Application and Evaluation of a “SoVI-Lite” Approach for Glynn County, Georgia. https://www.researchgate.net/publication/263194584. 21 pp.
- Flanagan, B., E. Gregory, E. HalliseyFlanagan, B., E. Gregory, E. Hallisey, J. Heitgerd, and B. Lewis, 2011. A Social Vulnerability Index for Disaster Management. Journal of Homeland Security and Emergency Management 8(1)., J. Heitgerd, and B. Lewis, 2011. A Social Vulnerability Index for Disaster Management. Journal of Homeland Security and Emergency Management 8(1).
- Georgia Emergency Management Agency. 2014. 2014 State of Georgia Hazard Mitigation Strategy. http://www.gema.ga.gov/Mitigation/Documents/Planning/2014%20GHMS.pdf. 199 pp.
- Gottlieb, R. 2011. Using GIS to Assess Vulnerability to Meteorological and Climatological Hazards in the Contiguous United States. Master’s Thesis. University of Oklahoma. 116 pp.
- National Weather Service Indianapolis. 2002. September 20, 2002 Indiana Tornados. https://www.weather.gov/ind/sept20_2002tor
- National Weather Service Indianapolis. 2016. Tornadoes of August 24. http://www.weather.gov/ind/august242016severe
- National Weather Service Northern Indiana. Tornado Outbreak August 24, 2016. http://www.weather.gov/iwx/20160824_TornadoOutbreak
- Weber, S. Sadoff, N., Zell, E., de Sherbinin, A. 2015. Policy-relevant indicators for mapping the vulnerability of urban populations to extreme heat events: A case study of Philadelphia. *Applied Geography*. 63(9): 231-243.
- Wisconsin Department of Health Services. 2014. Wisconsin Heat Vulnerability Index. P-00882. 14 pp. https://www.dhs.wisconsin.gov/publications/p0/p00882.pdf
- Wolf, T., W. Chuang, G. McGregor. 2015. On the Science-Policy Bridge: Do Spatial Heat Vulnerability Assessment Studies Influence Policy? *International Journal of Environmental Research and Public Health.* 12(10): 13321-13349.