What do we need to understand about populations and places to prepare communities for future environmental changes?

Deborah Balk

Remarks prepared for

Integrating the Human Sciences to Scale Societal Responses to Environmental Change: A Workshop

National Academy of Sciences, Board on Environmental Change and Society

4 May 2023

THE GRADUATE CENTER
CITY UNIVERSITY OF NEW YORK

Baruch COLLEGE
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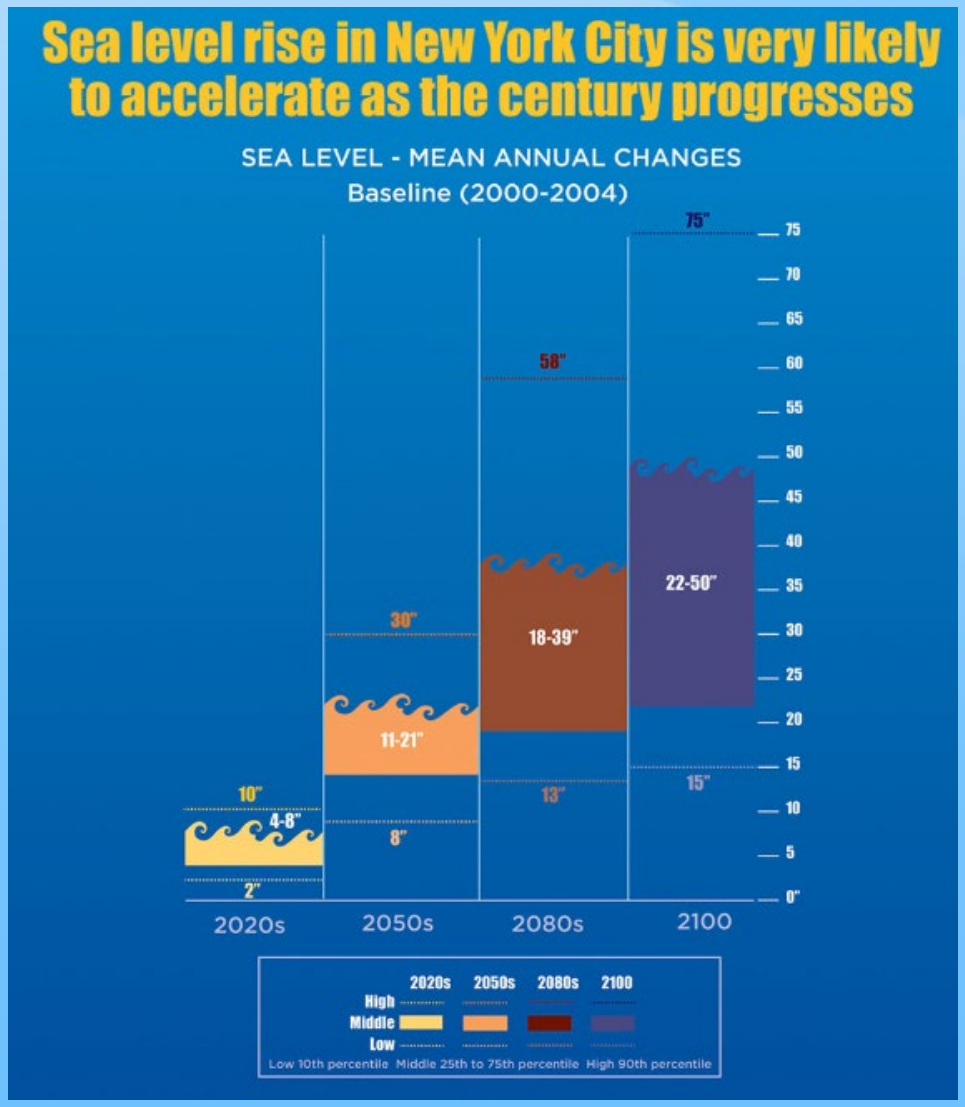
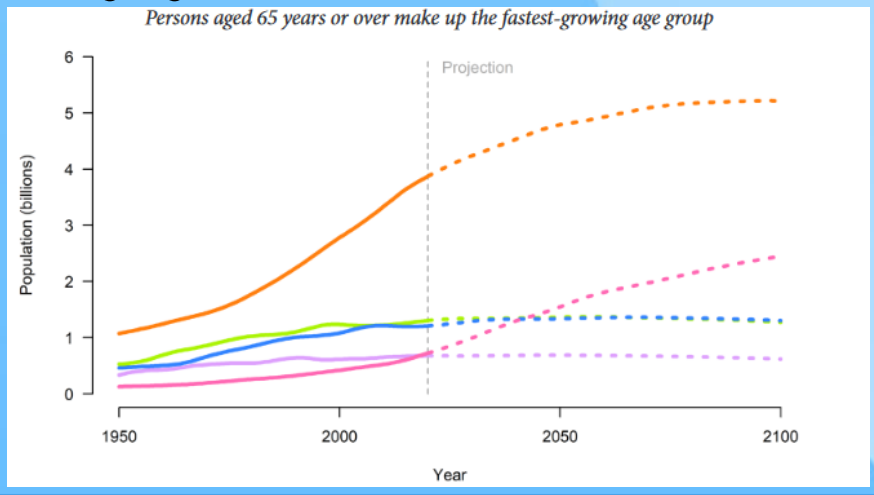
Certainties in an Uncertain Century



NPCC2 (2015)

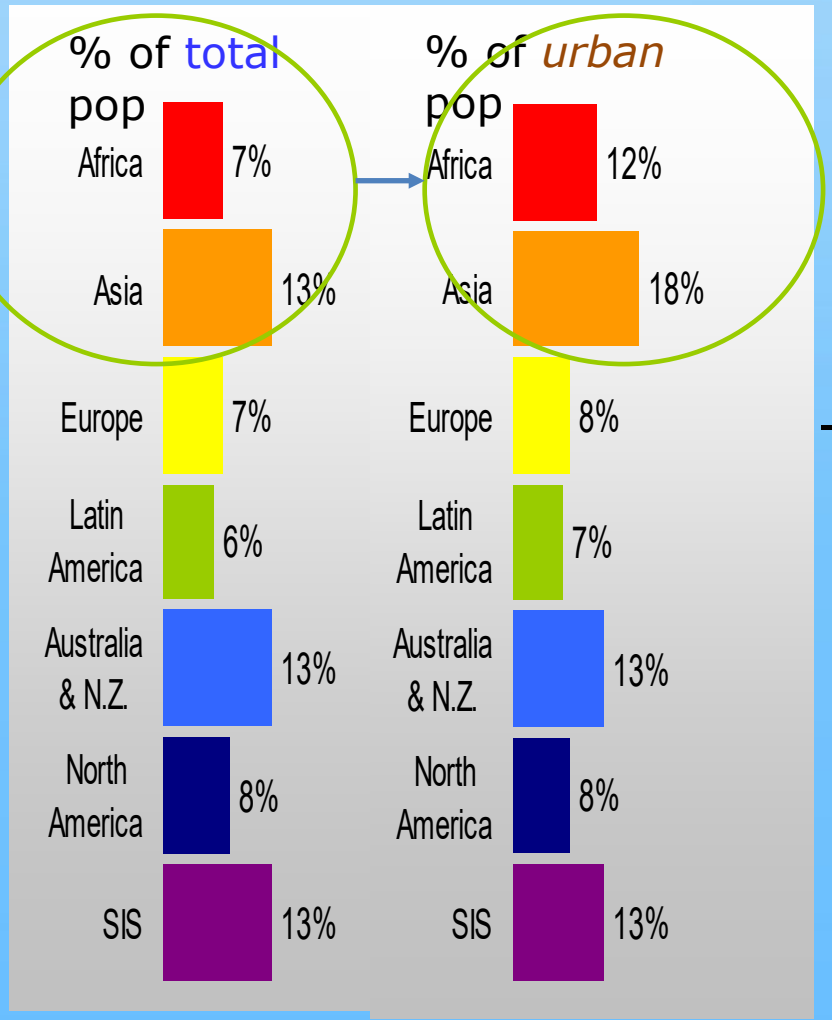
- Climate Change
  - Hotter (in most places)
  - More variability in weather
  - Sea levels will rise
  - More flood prone
  - Stormier
  - Drier
- Demographically
  - Urbanization
  - Aging



Populations at-risk estimation

- We estimated for the first time that…
  - **1:10** person lives in the **Low Elevation Coastal Zone (LECZ)**
    - Most countries with any land area in the LECZ, have their largest city in it
    - Small Island States and deltaic countries (and their cities) at much higher risk
  - **1:8** ***urban*** **person** lives in the LECZ
    - City dwellers in **Africa** and **Asia** disproportionately at risk
      - Most future population growth to take place in the cities and towns of Asia, Africa and LAC

Persons living in the LECZ (millions), by continent (2000)



Source: McGranahan, Balk and Anderson (2007)

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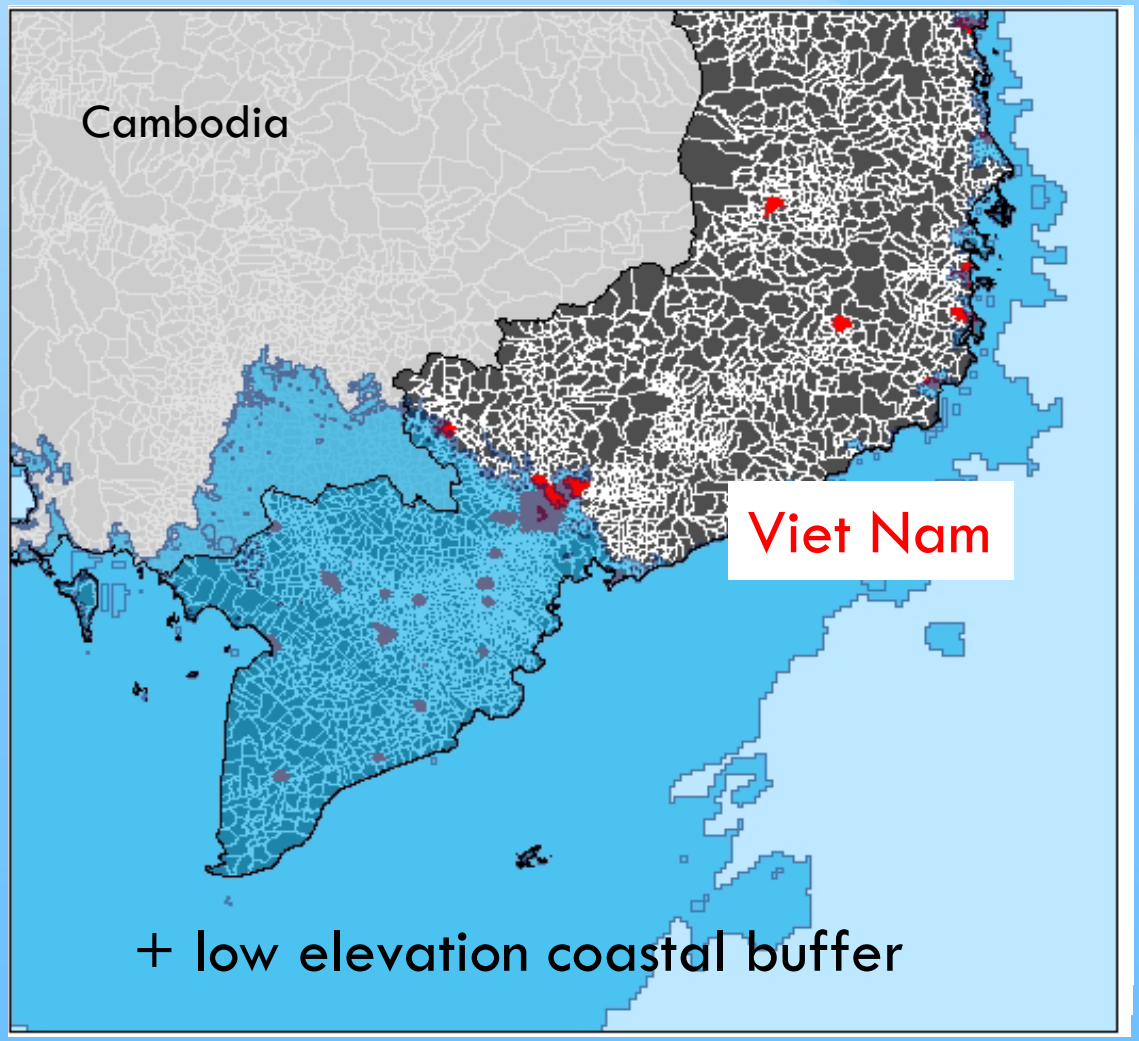
Simple method, but depends on the quality of the data: demographic + satellite data



- Population (census) data is reported in irregular administrative units
  - Underlying spatial resolution varies by country and year
  - Transform to a quadrilateral grid (not shown)
  - Reallocation to grid ranges from lightly to heavily modelled
- Method is applicable to most hazard
  - Accuracy and themes depend on underlying census (or survey unit)

Source: McGranahan, Balk and Anderson, 2007
Updated in MacManus et al., 2021

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Conclusions (c. 2007)

- The LECZ covers 2 per cent of the world's land area but contains 10 per cent of the world's population and 13 per cent of the world's urban population.
- A disproportionate number of the countries with a large share of their population in this zone are small island countries, but most of the countries with large populations in the zone are large countries with heavily populated delta regions.
- On average, the low-income countries have a higher share of their population living in the zone (14 per cent) than do OECD countries (10 per cent), with even greater disparities in the urban shares (21 per cent compared to 11 per cent).
- Almost two-thirds of urban settlements with populations greater than 5 million are situated, at least partly, in the zone.
- In some countries (most notably China), urbanization is driving a movement in population towards the coast.
- Reducing the risk of disasters related to climate change in coastal settlements will require a combination of mitigation, migration and settlement modification.

The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones

Gordon McGranahan, Deborah Balk, Bridget Anderson

First Published April 1, 2007 | Research Article

https://doi.org/10.1177/0956247807076960

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Update! Why? Improvement in underlying data & models

LECZ data and models

- Improvements in the spatial (horizontal and vertical) dimensions of Digital Elevation Model (DEM) data and modelling of its imperfections since 2000
- Allows for distinguishing two zones: 0-5m and 5-10m contiguous to coast

Population data and models

- Improvements in resolution of underlying census data
- Many new models of population distribution; some with time-series
- Allows for range of spatial population estimates, and change over time*

Urban-proxy data and models

- Big improvements and time-series since GRUMP; much progress in remote-sensing community since mid-2000
  - Opening up of Landsat archive, higher resolution satellites (sentinel) → settlement models
  - New class of lights data, and inter-comparisons over time
- Allow for distinguishing urban areas along a continuum:
  - Characterize the built-up and population density of locations;
  - and Comparison of different urban classification schema, and change over time*

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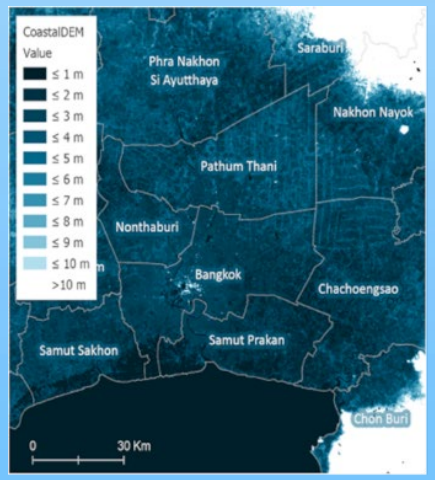
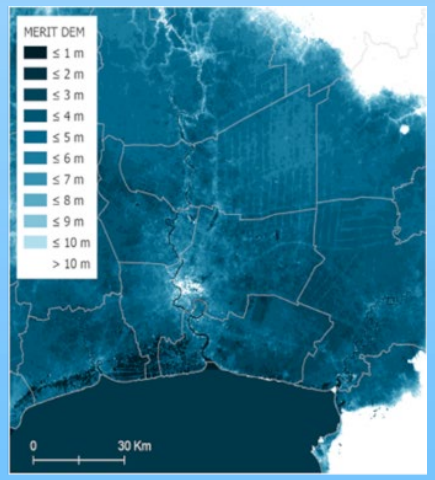
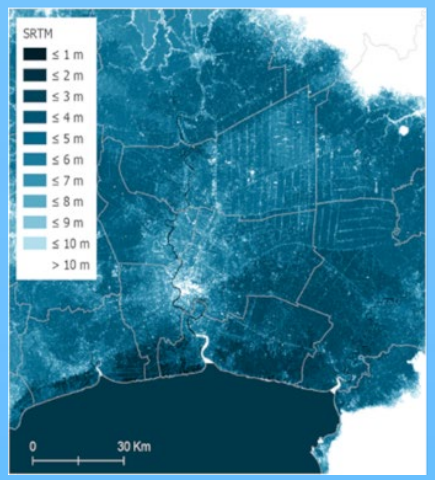
* Temporal data can inform future projections

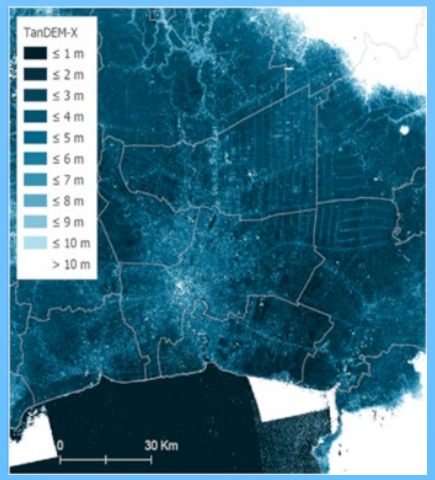
Many data choices

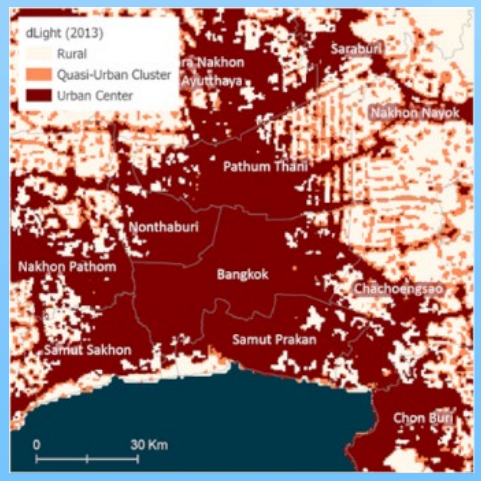
- Elevation → LECZ
  - Coastal DEM, MERIT, SRTM, TanDEM-X
- Urban Construct
  - Night Lights-based, Settlement, Degree of Urbanization, GRUMP

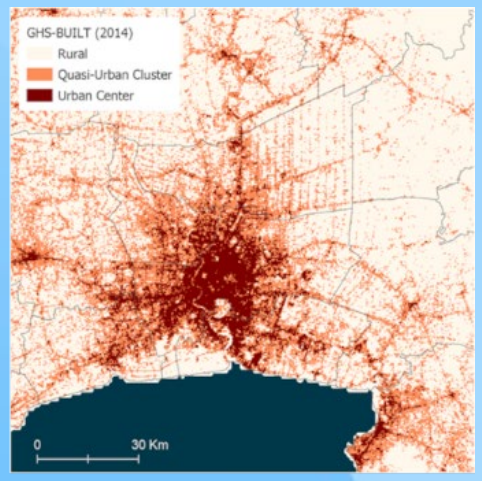


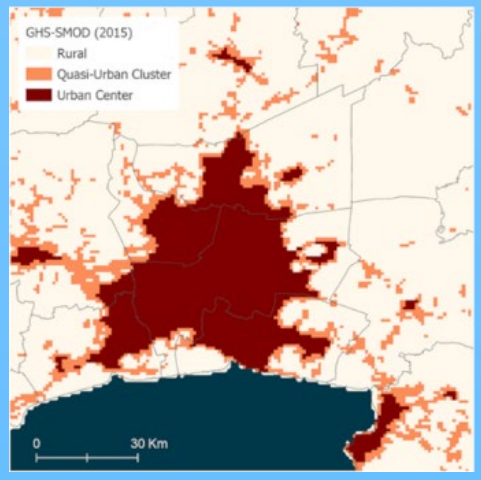


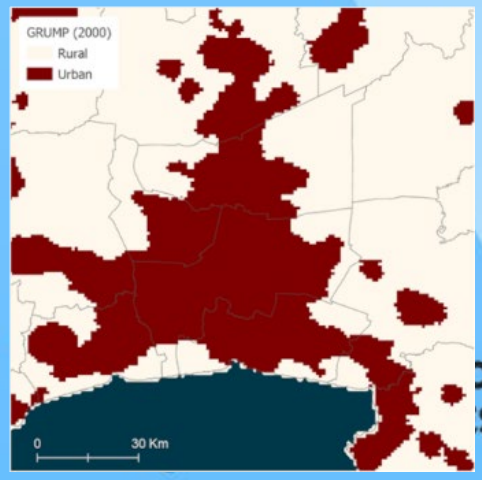








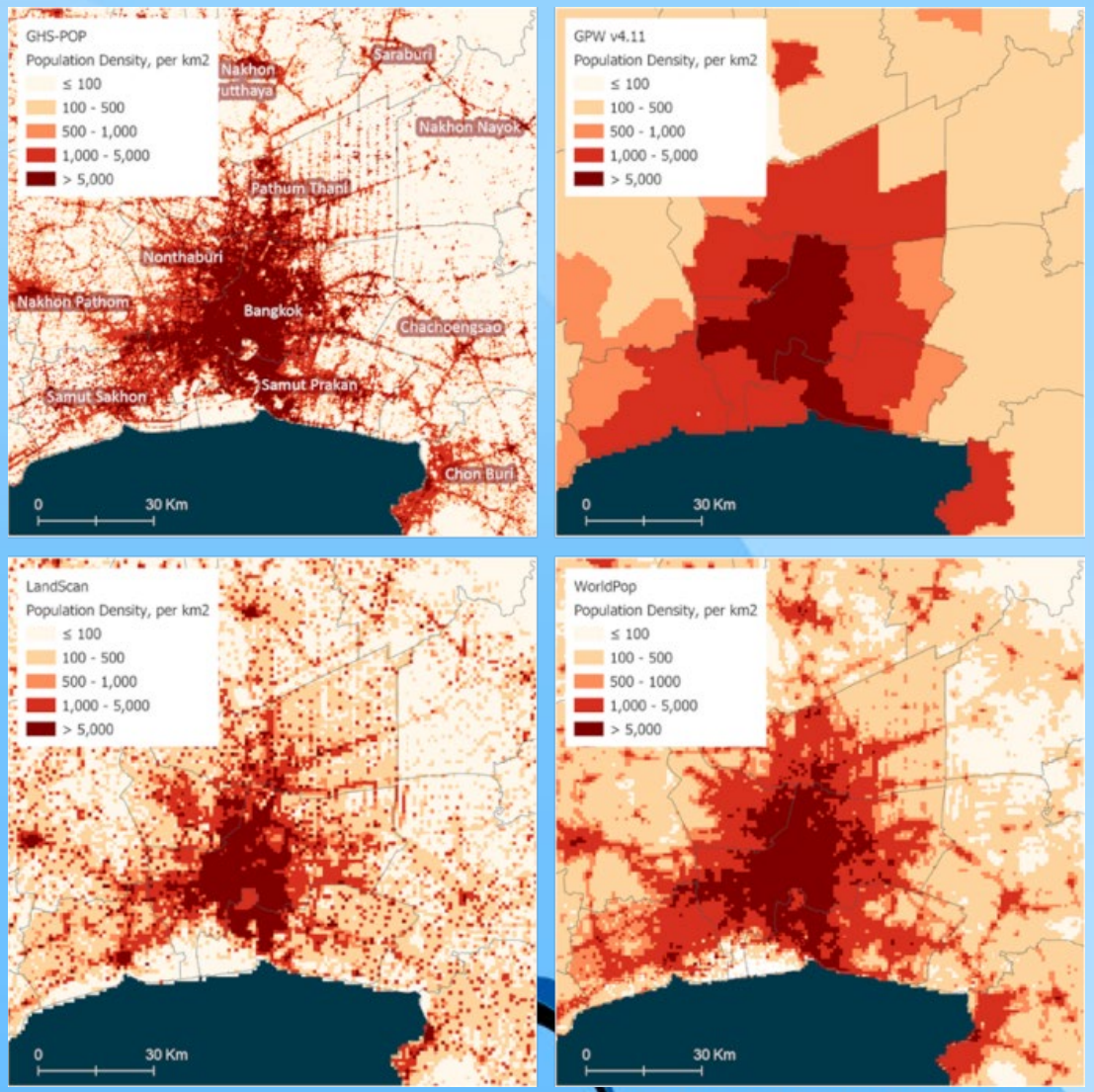




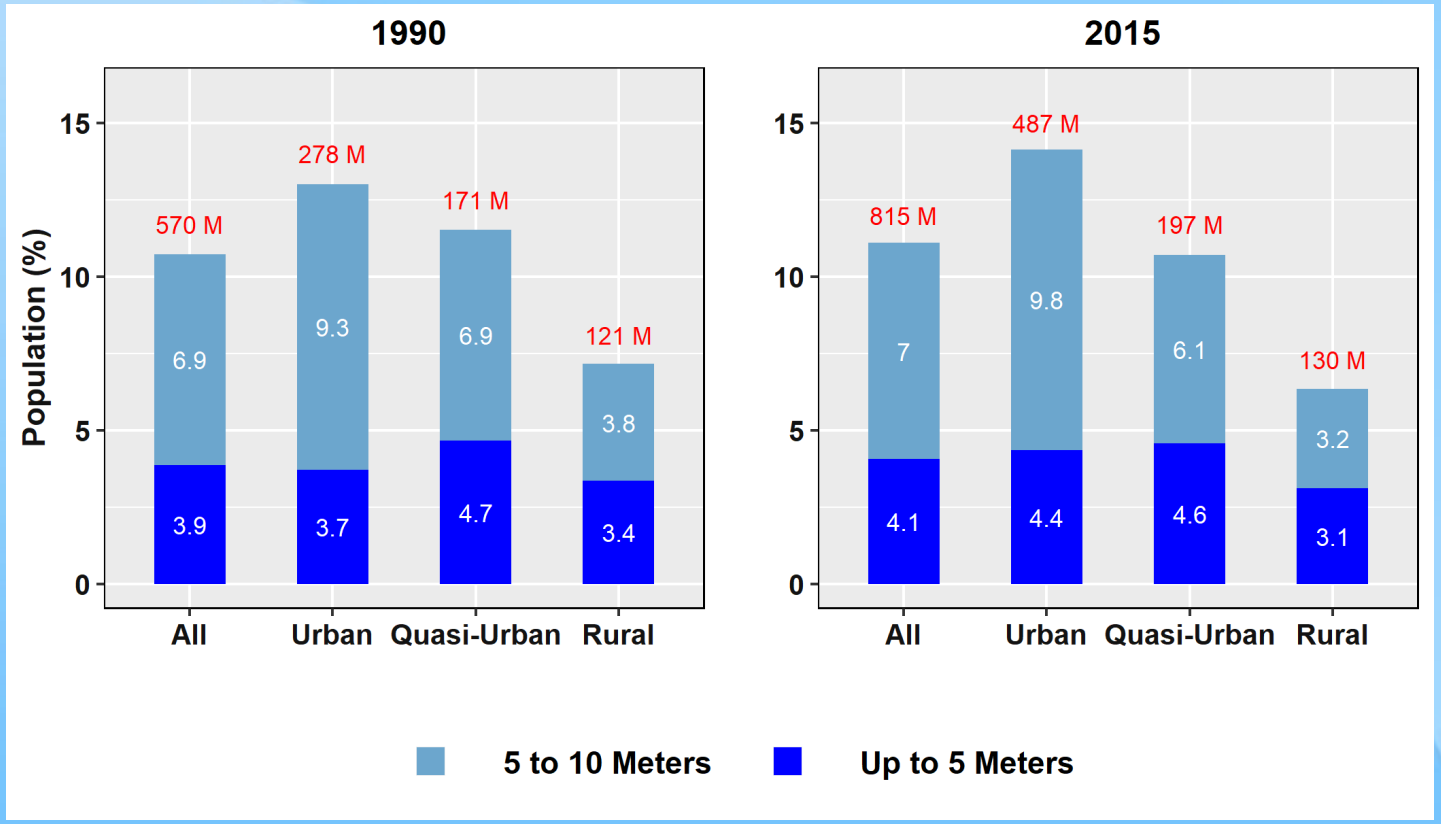
Many data choices

- Gridded Population Models
  - GHS-POP
    - 1990-2015
  - GPW
    - 1990-2015
  - LandScan
    - 2000-2015
    - Restricted use
  - WorldPop
- Differ in:
  - Underlying data
  - Modelling inputs
  - Modelling methods

See Leyk et al. 2019



Changes over Time



Data shown for
Population: GHS-Pop
Urban: GHS-SMOD
LECZ: MERIT-DEM

- Urban areas have experienced the greatest increase in population, from 1990-2015 but
- Urban areas within the LECZ have grown even faster than outside the LECZ
  - 75% increase in urban center pop in LECZ vs. 59% in urban centers outside of LECZ
  - Urban Center population in the 0-5m LECZ growth been fastest of all
  - Global averages driven by change in Asian cities (next)

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Sensitivity Analysis: Data choices matter!

Data choices can lead to differences in estimates

- Large differences in estimates of potential SLR and coastal hazards
- While high agreement for urban centers and rural areas, but less so for the harder-to-classify areas (towns, peri-urban, sub-urban, etc

Consistency in estimation

- Despite important differences, every source we evaluated shows that LECZs
  - are disproportionately urban
  - urban population in the LECZ is growing at a rate faster than we see outside of the LECZ

Fitness for use matters

- Depends on respective use cases
- Change over time?
- Better local data?

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"Top ten" countries at risk

- Deltas at risk, particularly in Asia!
- Small Island States (SIS), too.

Total population (000s) living in Urban Centres and Quasi-Urban Clusters in the LECZ: Ranked by Population in Urban Centers

	in Urban Centers		in Urban Centers + Quasi-urban Clusters	
Country (Rank)	Count	(%)	Count	(%)
China (1)	129,507	(23)	181,635	(17)
India (2)	55,216	(8)	70,827	(7)
Bangladesh (3)	40,912	(47)	62,875	(44)
Indonesia (4)	34,805	(24)	47,402	(23)
Japan (5)	26,593	(32)	33,446	(29)
Viet Nam (6)	23,871	(62)	44,556	(60)
United States of America (7)	17,607	(11)	23,027	(10)
Thailand (8)	16,811	(81)	21,460	(54)
Egypt (9)	14,200	(24)	25,579	(30)
Philippines (10)	12,998	(33)	19,038	(32)

Note: Countries with a total population of under 100,000 people, or smaller than 1,000 square kilometres were excluded from this list.

Ranked by share of population living in urban centres in the low elevation coastal zone

	in Urban Centers		in Urban Centers + Quasi-urban Clusters	
Country (Rank)	Count	(%)	Count	(%)
Guyana (1)	226	100	447	95
Suriname (2)	201	100	356	97
Thailand (3)	16,811	81	21,460	54
Bahamas (4)	169	80	259	83
Netherlands (5)	6,027	77	9,731	70
Mauritania (6)	1,175	76		
Djibouti (7)	474	69	508	63
Liberia (8)	1,053	64		
Viet Nam (9)	23,871	62	44,556	60
United Arab Emirates (10)	3,875	57	4,407	53
French Guiana			141	69
Belize			152	58

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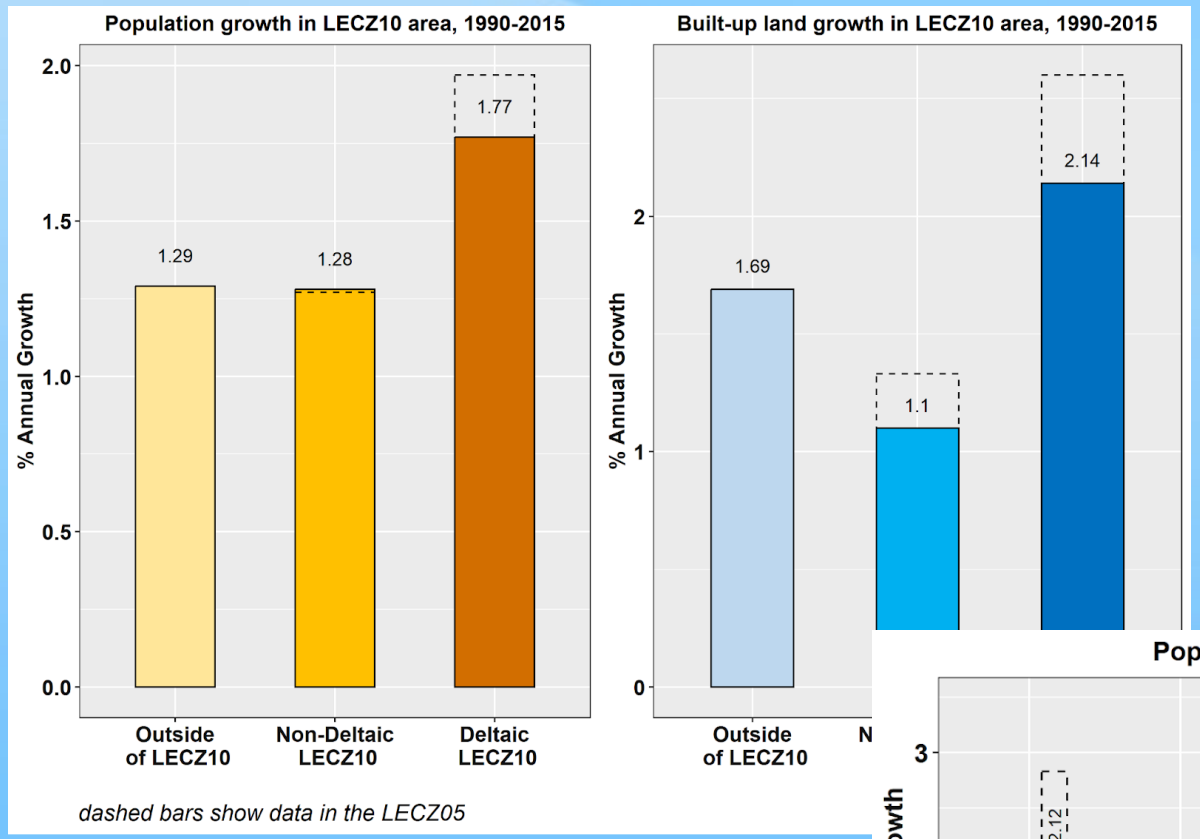
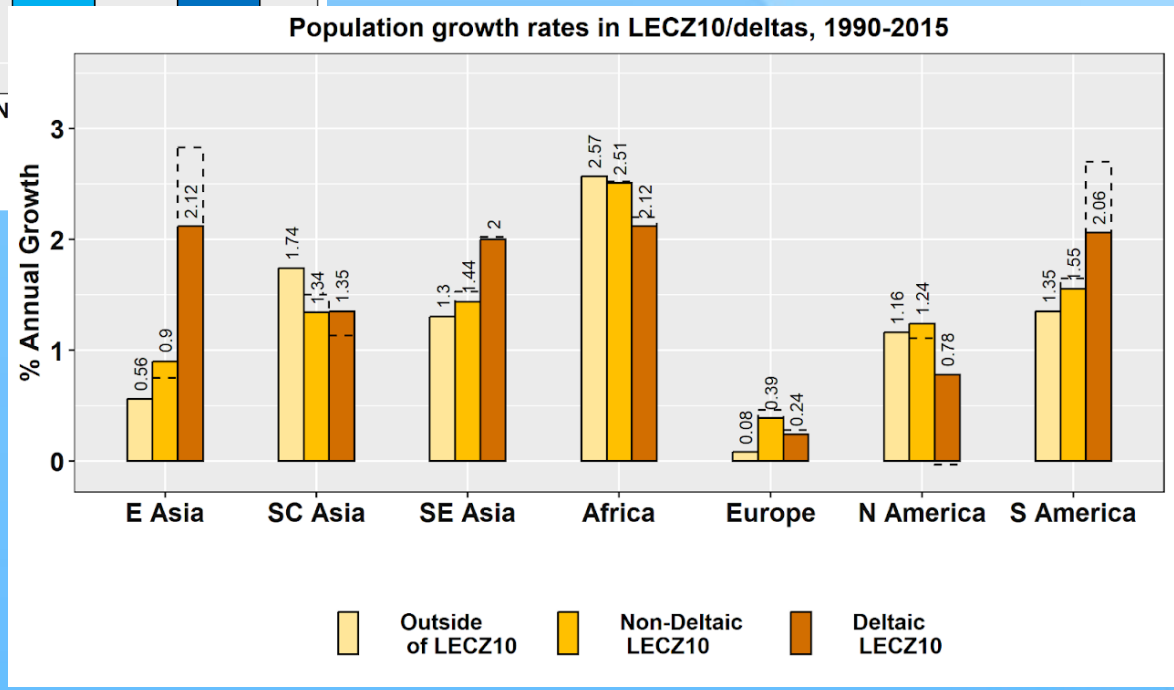
Growth, 1990-2015



- Growth highest in the deltaic LECZ
  - Everywhere, but especially in the in the level of built-up in the LECZ05 in Asia (not shown)



  - Growth higher in deltaic regions of E and SE Asia, both in population and built-up (not shown)

FROM REGIONAL → US → LOCAL

Source: Tagtachian and Balk (in review), Uneven Vulnerability: Characterizing population composition and change in the Low Elevation Coastal Zone in the United States with a climate justice lens, 1990-2020

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US LECZ Study, 1990-2020

Differs from global study in that we use 4 decades of census data, with a richer set of variables

- Pop and land exposures, urban vs. rural
  +
- Age distribution, Race/Ethnicity, Housing Tenure

Differs from prior studies in the US (e.g., NOAA, Hauer) in that the finest spatial unit available in the census is used

- Coastal counties here defined as having any land area in the LECZ
- But census blocks (rather than tracts or counties) with any land area in the LECZ are then summarized to the county

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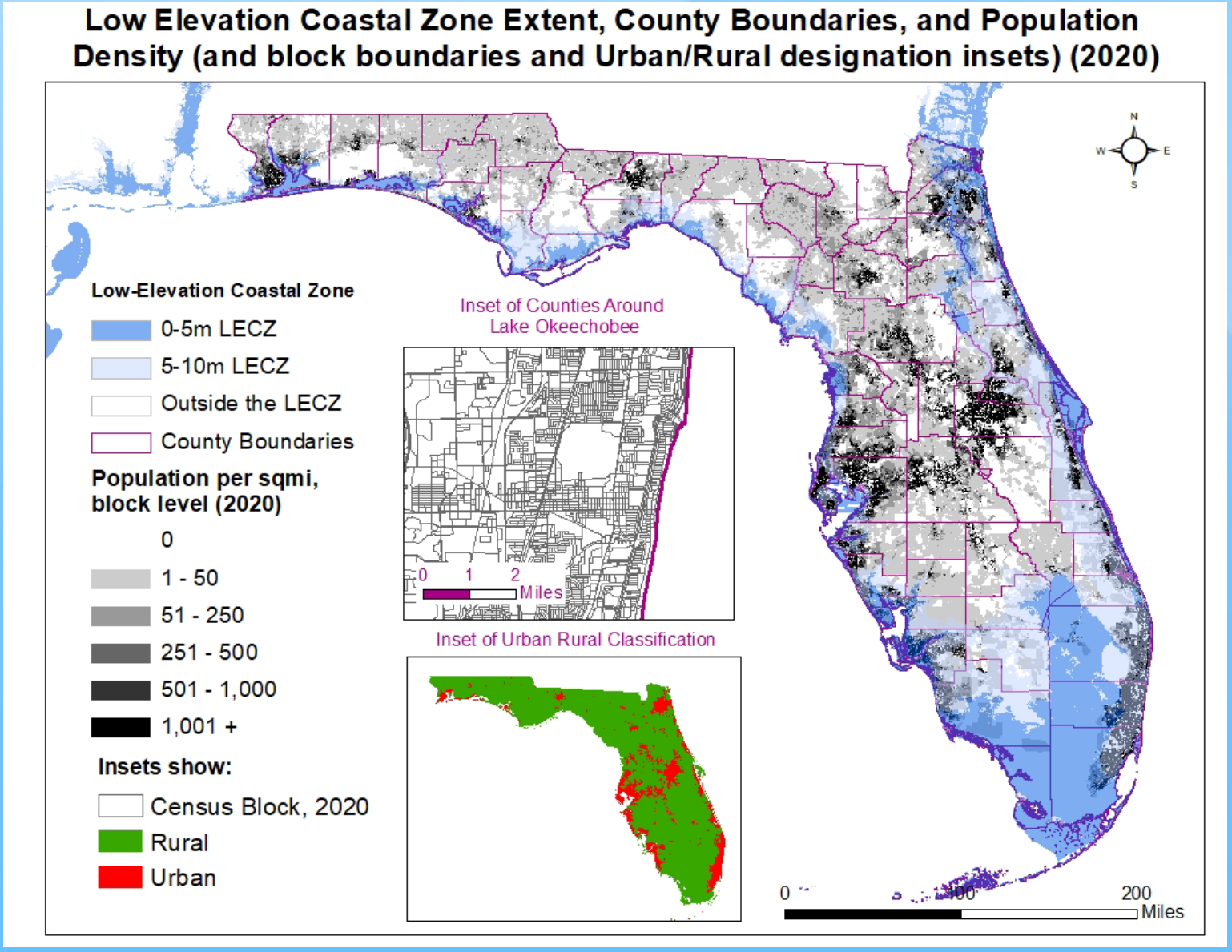
Visualizing the data inputs



- Variables available at the block-level are limited
  - Change in measures over time limit them further
  - 2020 block data is limited to PL release

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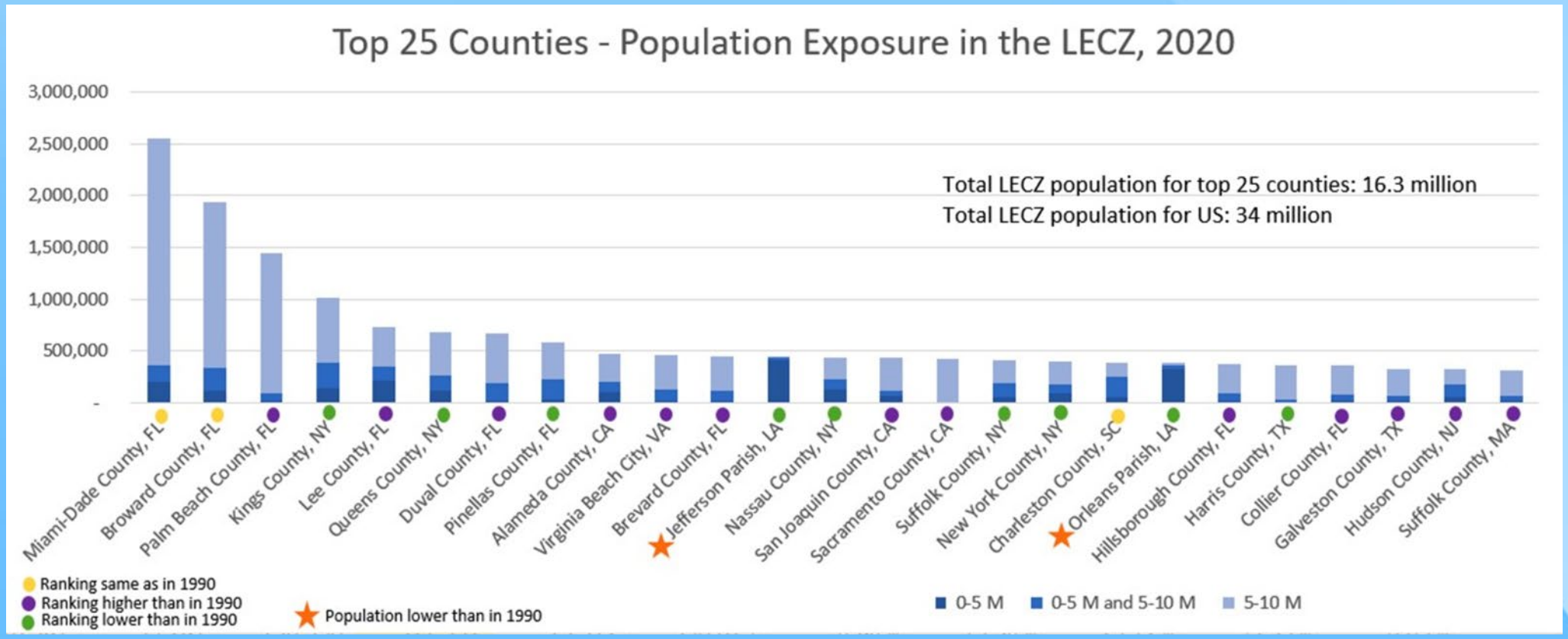
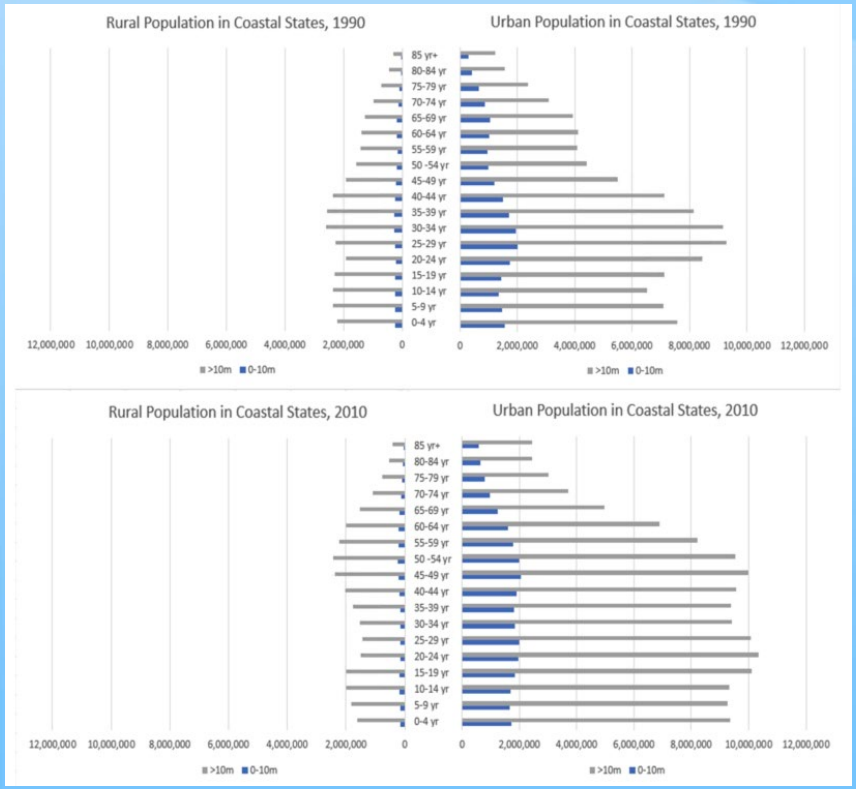
States and Counties at Risk

- Of the ~3,000 counties in the lower 48 states
  - 390 (~13%) have any land area in the LECZ, with more 34 million persons at risk (1:6 person).
  - Population exposure is even more concentrated with only 55% of the population exposure found in the top 25 counties.

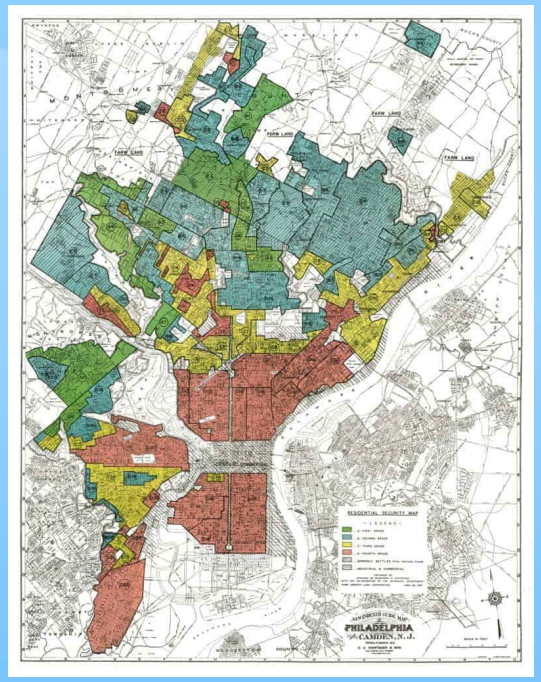


Exposures differ by vulnerability

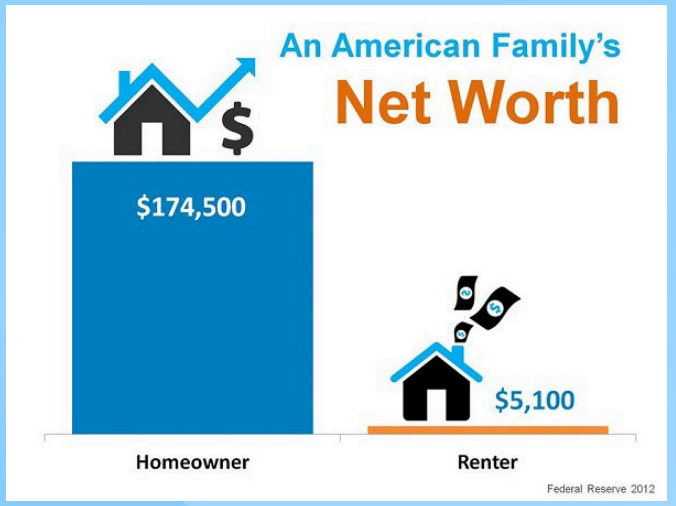
Age & Urban/Rural



Race & Ethnicity



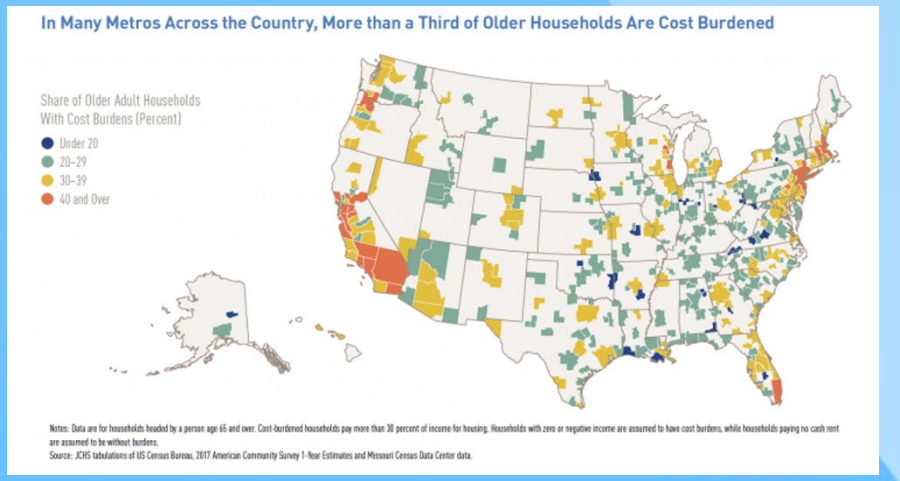
Housing Tenure



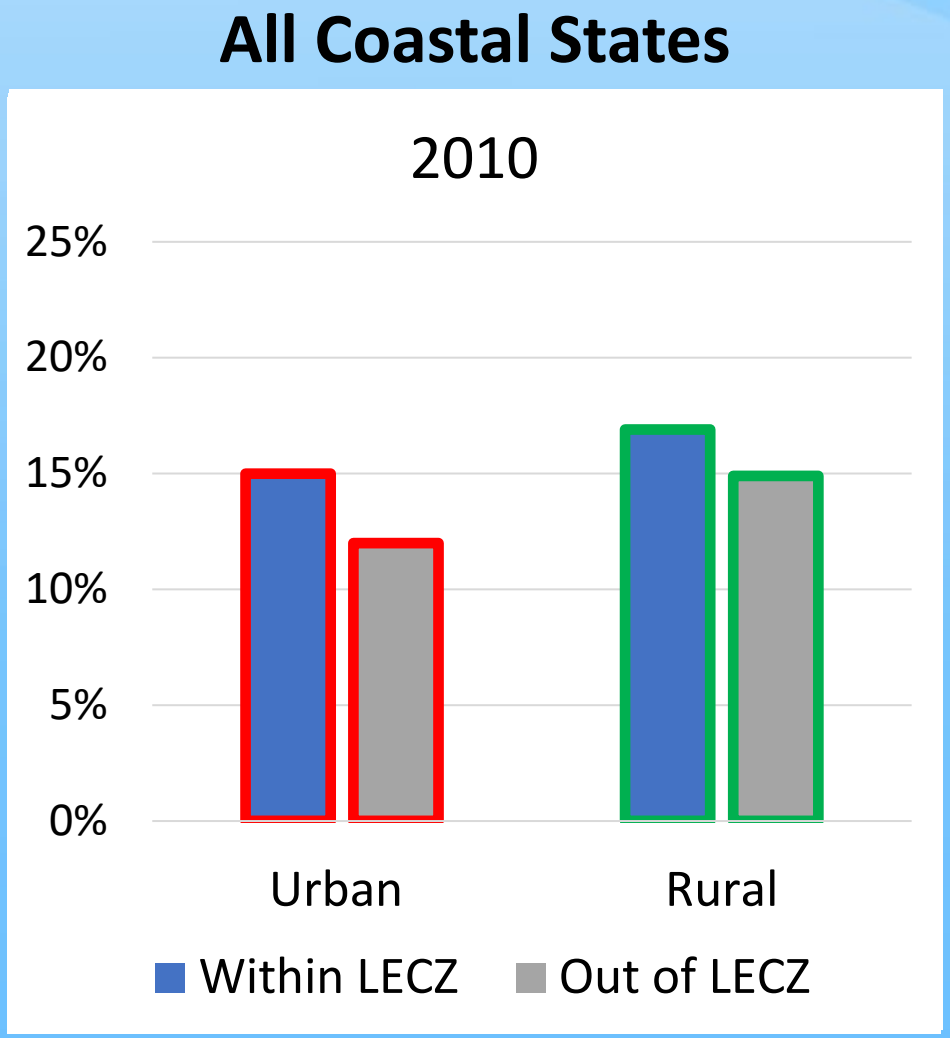
Vulnerabilities interact!

Other vulnerabilities include:

- Income/wealth, disabilities, English proficiency, certain occupational groups, social isolation/ social networks, medical conditions, where people live/work, and so on…



Percent of Population 65+



- In 1990, one out of every 8 persons, averaging across all residents of coastal states, was over age 65.
  - From 1990-2010, we see an additional 6 million and small increase in the proportion 65+ to 12.9% in coastal states, on average (not shown in graph).
- Residents of the LECZ are older than average (14.6% in 1990, rising to 15.2% in 2010).
- This is true urban and rural areas.
  - 15% of urban residents in the LECZ are over age 65, vs. only about 12% outside it;
  - in 1990, 13.6% of the rural dwellers in the LECZ were over age 65 as compared to 12.1% outside of the LECZ;
    - by 2010 these shares had risen substantially, to 16.9% within the LECZ and nearly 15% outside of it.

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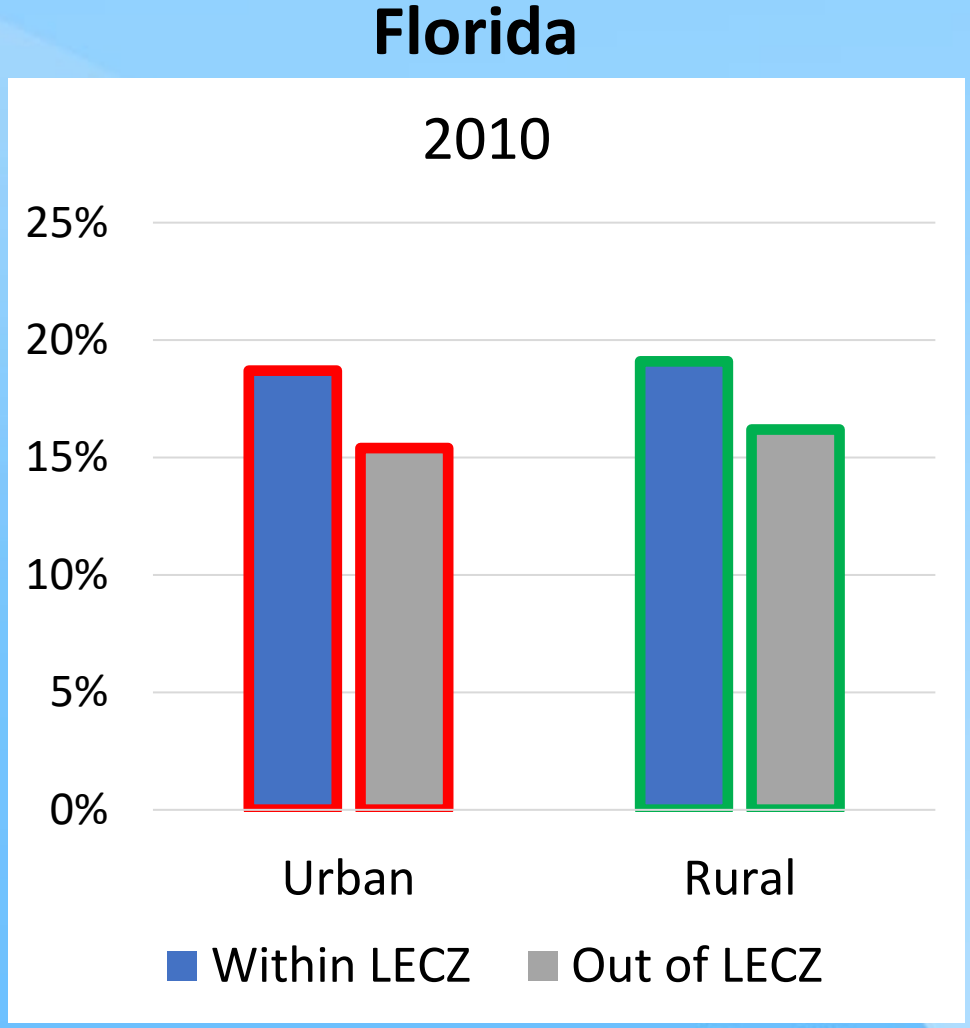
Percent of Population 65+

- Florida has much higher shares of older adults -- over 18% statewide in 1990 – than elsewhere in the US (not shown).
  - While increasing by nearly 1 million older residents, the % of older adults decline to 17.3% of the state population in 2010.
- In 1990, 1:5 residents of the LECZ in Florida was over age 65, with even slightly higher proportions in the urban LECZ.
  - Like the statewide trend, these fractions declined somewhat by 2010 (while the population itself is rising).
- The annual growth rate of older adults (at 1.6% per year) is larger in Florida than elsewhere (1.3% for the coastal states average).



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Race & Housing Tenure (2010)

Homeowners
(Whites overrepresented)

- Almost 70% of White householders owned their home (inside and outside the LECZ),
- In comparison, only a little over 45% of Black and Hispanic households owned their home (inside and outside the LECZ)

Renters
(Blacks/Hispanics overrepresented)

- More than 50% of Black and Hispanics households were in renter-occupied units (inside and outside the LECZ),
- In comparison, only around 30% of Whites were in renter-occupied units (inside and outside the LECZ)

Housing Tenure	Race/Hispanic Origin	2010			
		Urban		Rural	
		0-10 M	> 10 M	0-10 M	> 10 M
Owner Occupied Housing Units	Total	8.93%	40.98%	1.19%	12.11%
	White	9.85%	43.41%	1.42%	14.69%
	Black	7.10%	30.93%	0.81%	6.64%
	Hispanic	7.68%	34.99%	0.26%	3.10%
Renter Occupied Housing Units	Total	5.81%	27.86%	0.27%	2.84%
	White	4.87%	22.37%	0.29%	3.09%
	Black	9.56%	42.10%	0.29%	2.56%
	Hispanic	8.93%	43.11%	0.16%	1.78%

<< Black and Hispanic householders were almost twice as likely than Whites to live in urban renter-occupied housing units within the LECZ.

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Why Housing Tenure Matters

- Climate change is augmenting and accelerating the affordable housing crisis.
  - While low-income residents are particularly vulnerable in areas that are prone to flooding or other coastal hazards,
  - Low-income homeowners and renters are likely to experience flooding, storms, and sea-level rise differently since **homeowners** (particularly middle and lower-income homeowners) **are likely to be less mobile and renters tend to have less equity.**

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Take aways

Use approach with any spatially delineated hazard

- Heat or drought, wildfires, inland (pluvial) flooding, …
- Notably, remote-sensing and environmental data are more and more available and easier to use
  - Measures of vulnerability and demographic change however come from censuses and surveys so we must be prepared to work with interdisciplinary methods and perspectives
- Some hazards are harder to study (storm paths) so think of new ways to capture this information but many significant improvements have taken place in the past two decades so we should work collective to address important new concerns

Embrace publicly available data and engage with it

- National statistical office continue to improve and make available increasingly thematically rich, spatial data
  - They even welcome feedback. This helps to prepare communities.
- Use place-based finding to help improve our understanding of causal processes behind vulnerability and the demographic components of change
- Work with communities to find out what matters most to them
- Work with regions becomes communities are connected!

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