

Climate Change Impacts on the Built Environment in the U.S. and Implications for Sustainability

Climate Change Impacts on the Built Environment in the United States and Implications for Sustainability

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Climate Change Impacts on the Built Environment in the U.S. and Implications for Sustainability

Outline of the Talk

- What is the built environment and why is it important to assess how it will respond to climate change impacts?
- What are some key impacts of climate change on the built environment?
- Why we need to develop indicators of climate change for sustainable development and adaptation planning in response to impacts on the built environment?
- What are some examples of adaptation strategies for resiliency and sustainability of the built environment under climate change?



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Background

- As an integral part of the National Climate Assessment (NCA), technical assessment reports for 13 regions in the U.S. that describe the scientific rationale to support climate change impacts within the purview of these regions, and provide adaptation or mitigation measures in response to these impacts.
- These technical assessments focus on climate change impacts on sectors that are important environmental, biophysical, and social and economic aspects of sustainability within the U.S.:

Climate change science

Water resources

Energy supply and use

Transportation

Agriculture

Forestry

**Rural communities development
biodiversity**

Ecosystems and biodiversity

Human health

Water/energy/land use

Urban/infrastructure/vulnerability

Impacts of climate change on tribal/indigenous and native lands and resources

Land use/land cover change

Impacts on biogeochemical cycles, with implications for ecosystems and



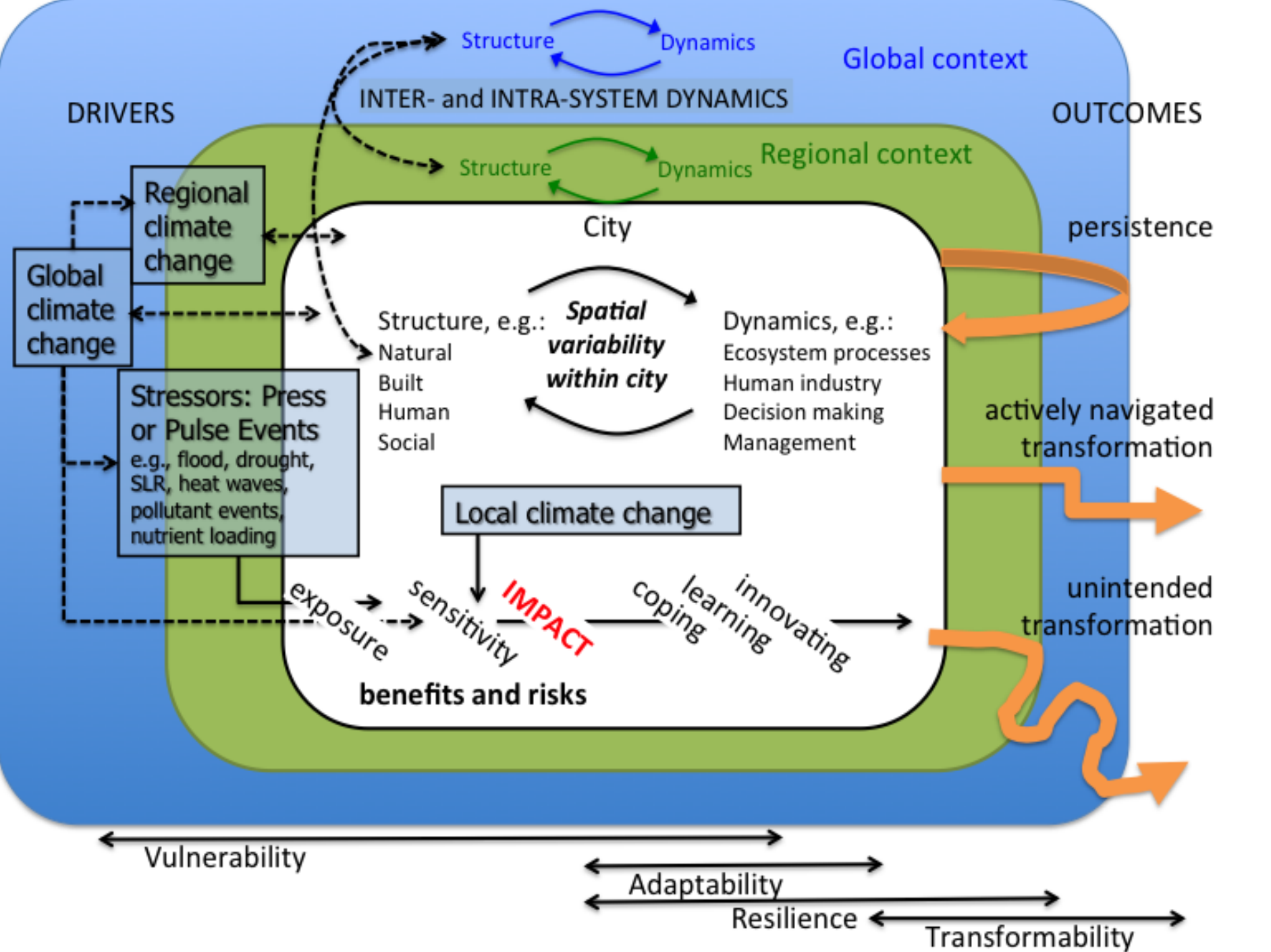
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What is the Built Environment?

The 'Built Environment' is a key component of the National Climate Assessment's (NCA) Urban infrastructure/vulnerability sector

- The Built Environment consists of components that have been made by humans at a range of scales from small (e.g., offices, houses, schools) to large (e.g., transportation networks and communities) to highly modified landscapes such as cities.
- Climate change will have significant impacts on the physical and biophysical interactions that occur between the land-atmosphere interface that presides over the Built Environment.
- It will also have consequences for social/human scale aspects of the Built Environment, such as energy, poverty, economic development, and urban migration. such as the exchanges between the land and atmosphere.





DRIVERS

Global context

OUTCOMES

INTER- and INTRA-SYSTEM DYNAMICS

Structure

Dynamics

Structure

Dynamics

Regional context

City

persistence

Global climate change

Regional climate change

Stressors: Press or Pulse Events
e.g., flood, drought, SLR, heat waves, pollutant events, nutrient loading

Structure, e.g.:
Natural
Built
Human
Social

Spatial variability within city

Dynamics, e.g.:
Ecosystem processes
Human industry
Decision making
Management

Local climate change

actively navigated transformation

exposure

sensitivity

IMPACT

coping

learning

innovating

benefits and risks

unintended transformation

Vulnerability

Adaptability

Resilience

Transformability

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Key Impacts of Climate Change on the Built Environment

Although certainly not all-inclusive, perhaps the most important impacts of climate change will be related to:

- Air Quality
- Urban Heat Island Effect
- Effects on Precipitation
- Urban Flooding
- Coastal Environment
- Human Health



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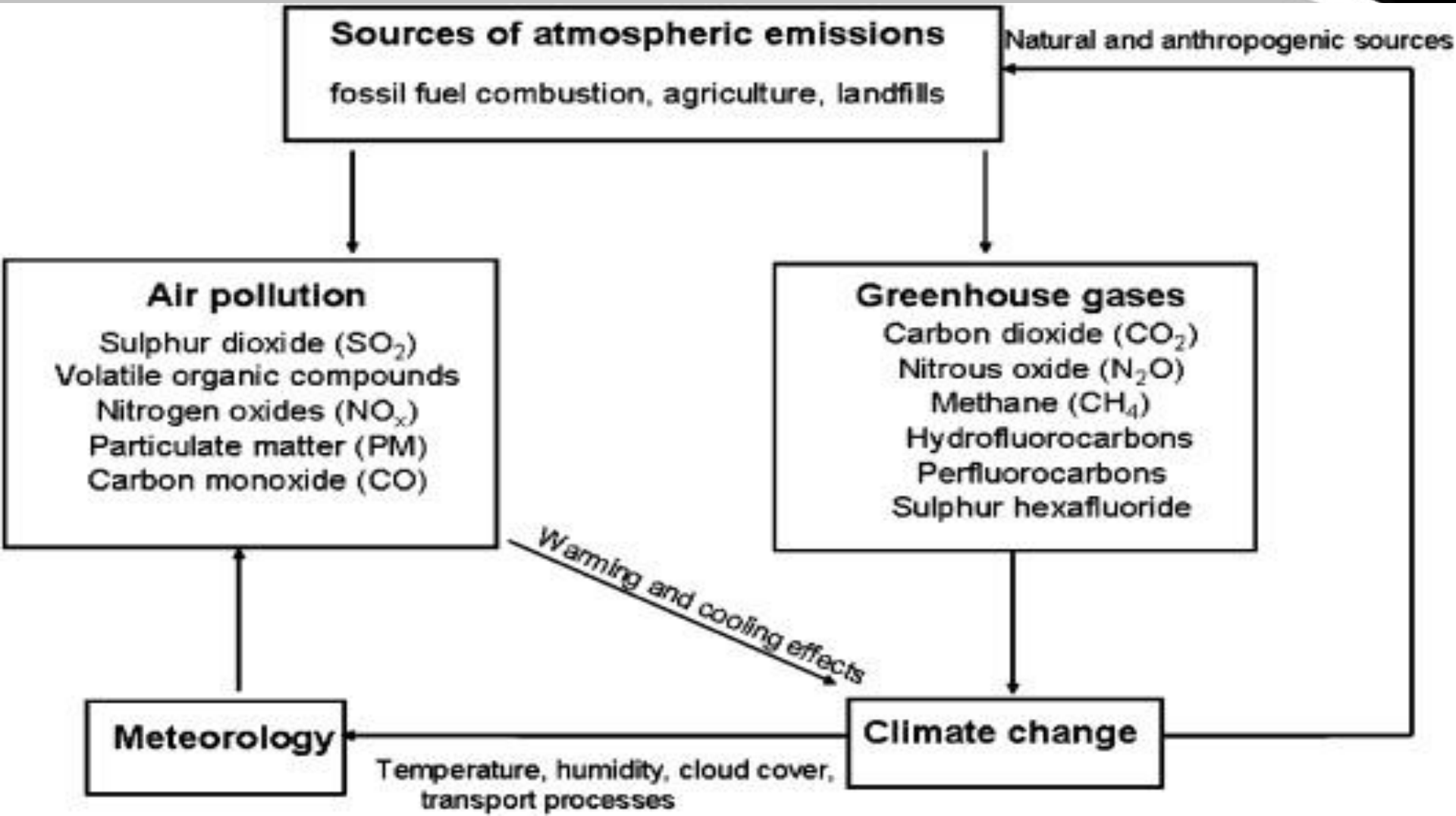
Air Quality

- Coupled global climate model (GCM) and chemical transport model (CTM) studies show that climate change alone will increase summertime surface ozone in polluted regions by 1-10 ppb over the coming decade, with the largest effects in urban areas and during pollution episodes (Jacob and Winner, 2009).
- Climate change has the potential to push ground level O₃ concentrations beyond (EPA, 2009).
- In addition, it has the potential to lengthen the ground level O₃ season (EPA, 2009).
- Preliminary simulation results suggest that PM (particularly PM_{2.5}) response to climate change, depending upon the region, will potentially increase (EPA, 2009).



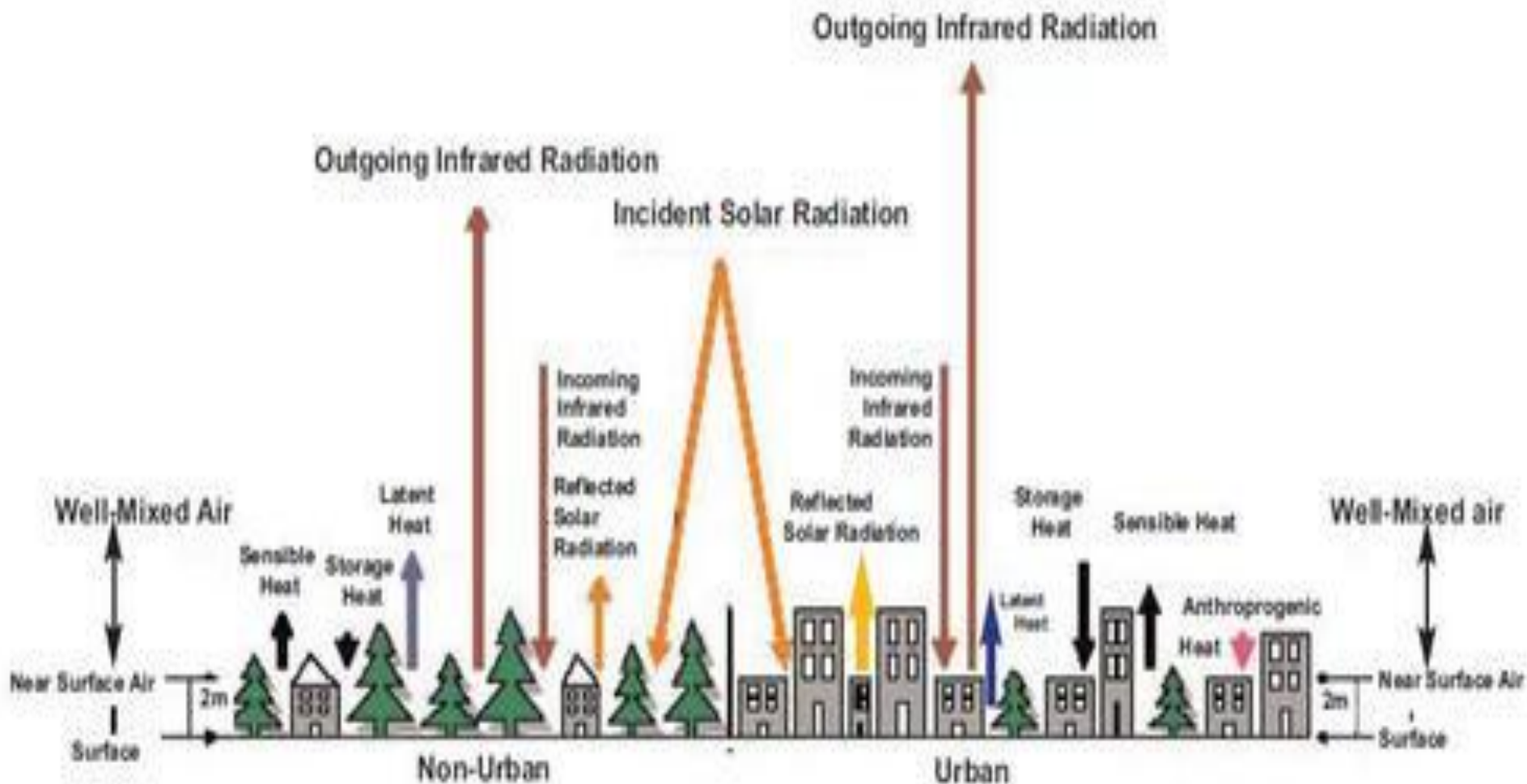
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Air Quality and the Built Environment



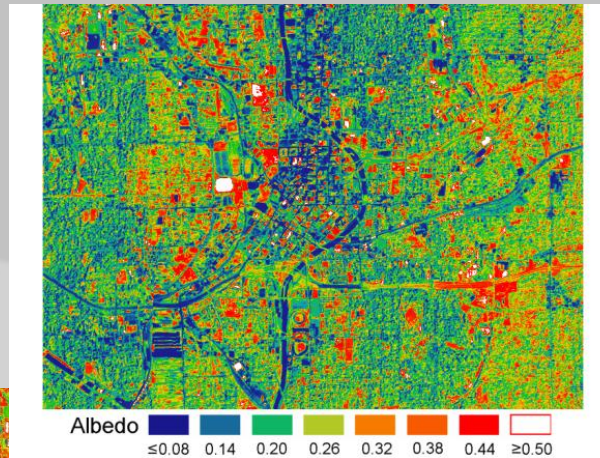
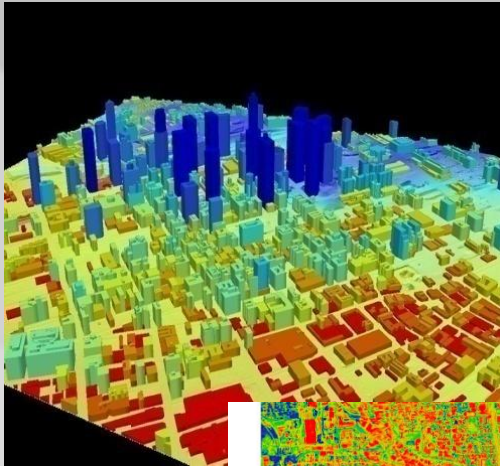
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Urban Heat Island Effect



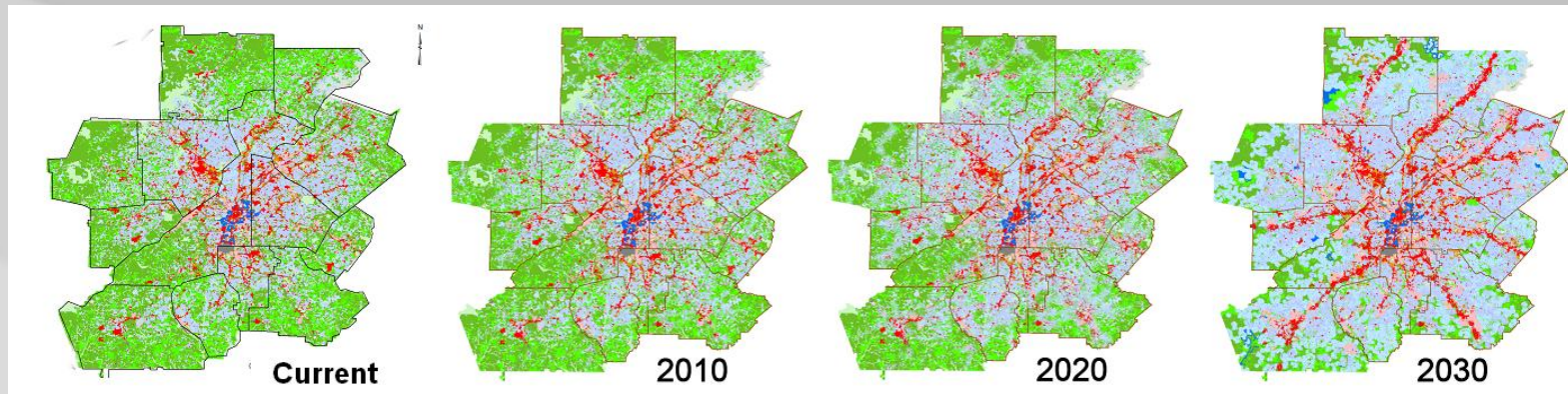
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- Development of the UHI is forced by a number of causes related to the land and atmosphere interactions that occur over cities
- These include: surface geometry, surface thermal properties, surface conditions, anthropogenic heat, and the urban greenhouse effect (Voogt, 2003)
























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- Urban warming carries the potential to not only enhance the magnitude of future warming trends, but to amplify the intensity of heat waves.
- Recent studies have found the UHI effect to be contributing to a rising number of extreme heat events in southeastern cities (Stone, Hess & Frumkin, 2010), as well as to an amplification of heat wave events in large cities such as Atlanta, Georgia (Zhou & Shepherd, 2010).



Legend

	COMMERCIAL		LTD_ACCESS		RES_MOBILE
	FOREST		PARKS		RES_MULTI
	IND/COM		RESERVOIRS		RIVERS
	AG_CONFINED		RES_HIGH		TCU
	AG_CROPS		RES_LOW		TRANSITIONAL
	AG_ORCHARD		INST_EXTENSIVE		RES_MED
			INST_INTENSIVE		URBAN_OTHER



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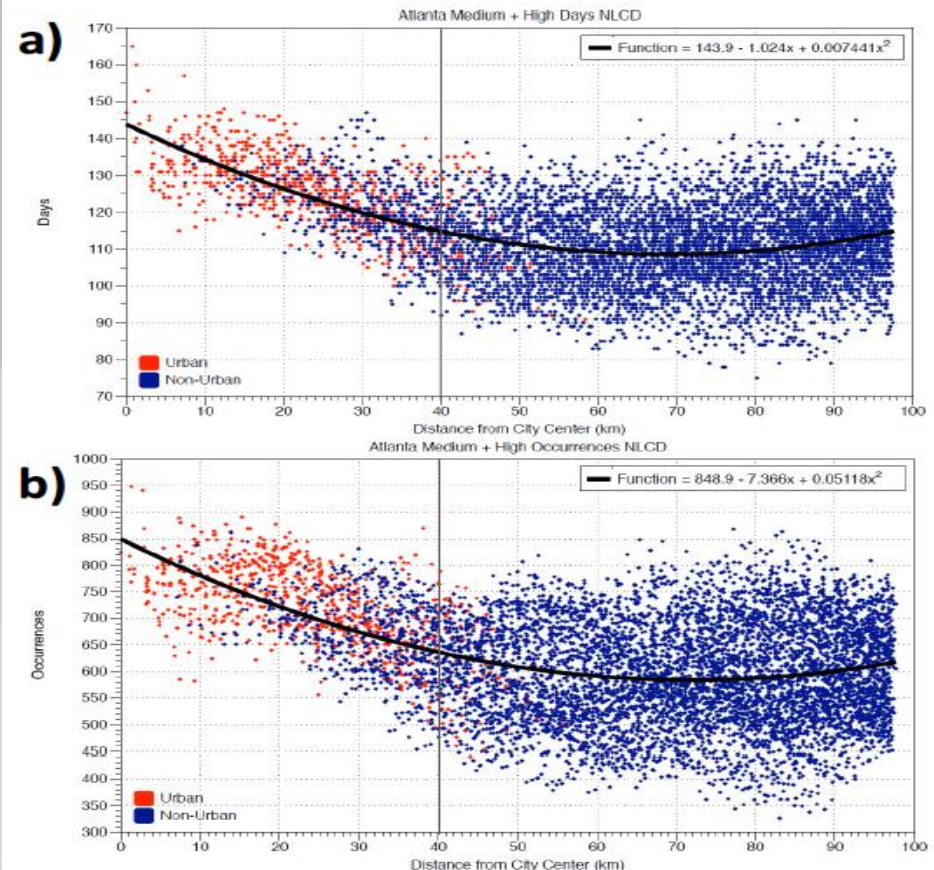
Effects on Precipitation

- While urban heat islands and urban air pollution are fairly common in the public and scientific vernacular, the “urban rainfall effect” is not as common (Shepherd et al. 2010).
- Potential of increased frequency and intensity of lightning due to thunderstorms.

Composite radar analysis for Atlanta, Georgia

a. The total number of day ≥ 40 dBZ

b. The Total number of 5-minute occurrences ≥ 40 dBZ for each 2-km grid cell versus distance from city center in the Atlanta domain for the 10-year, June-August period of record. NLCD urban delineated cells are colored red, whereas non-urban cells are blue. (Figure and caption following Ashley et al. 2011).

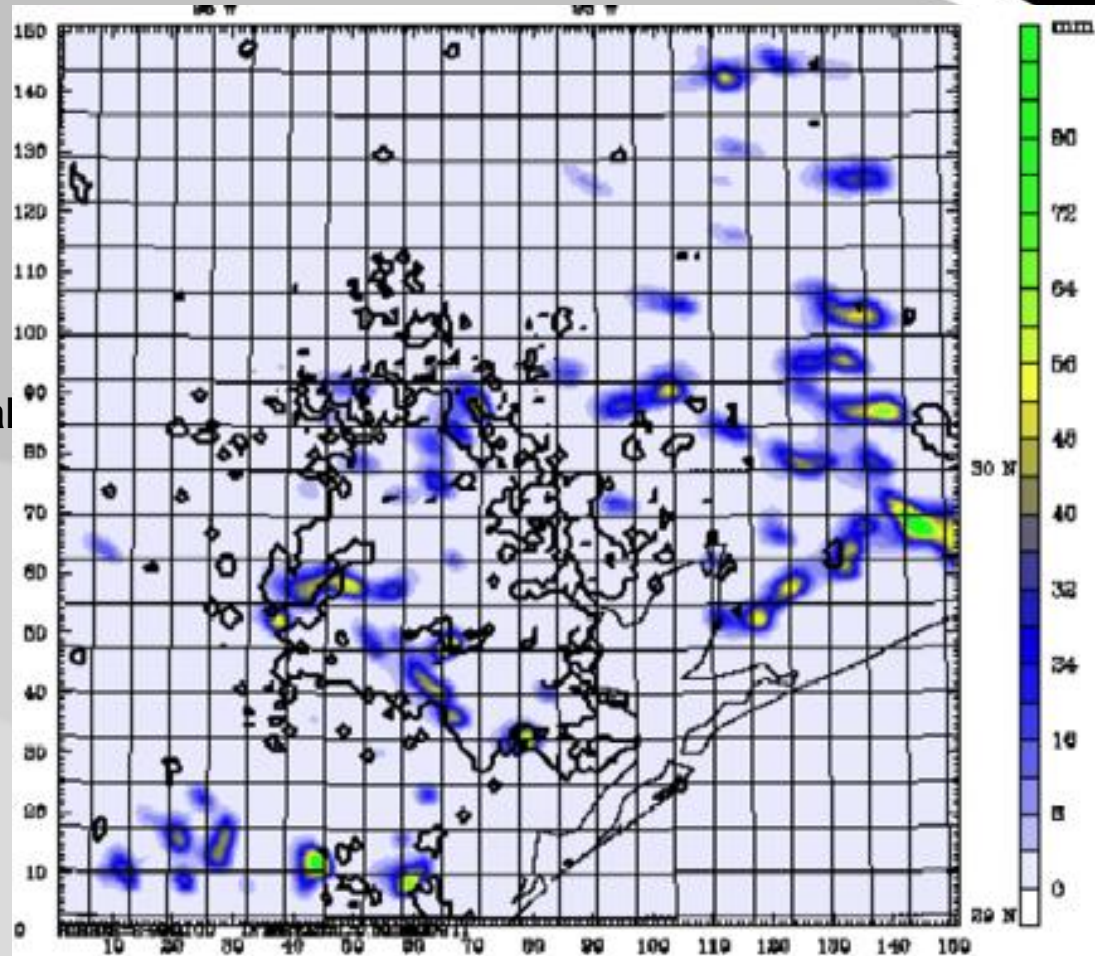


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- Amplification of thunderstorms – both in frequency and intensity.

Difference (2025 – Current Land Cover) in simulated rainfall amount for a typical case day in Houston, Texas. Black outline represents 2025 urban land cover.

(Courtesy of Marshall Shepherd – Univ. of Georgia)



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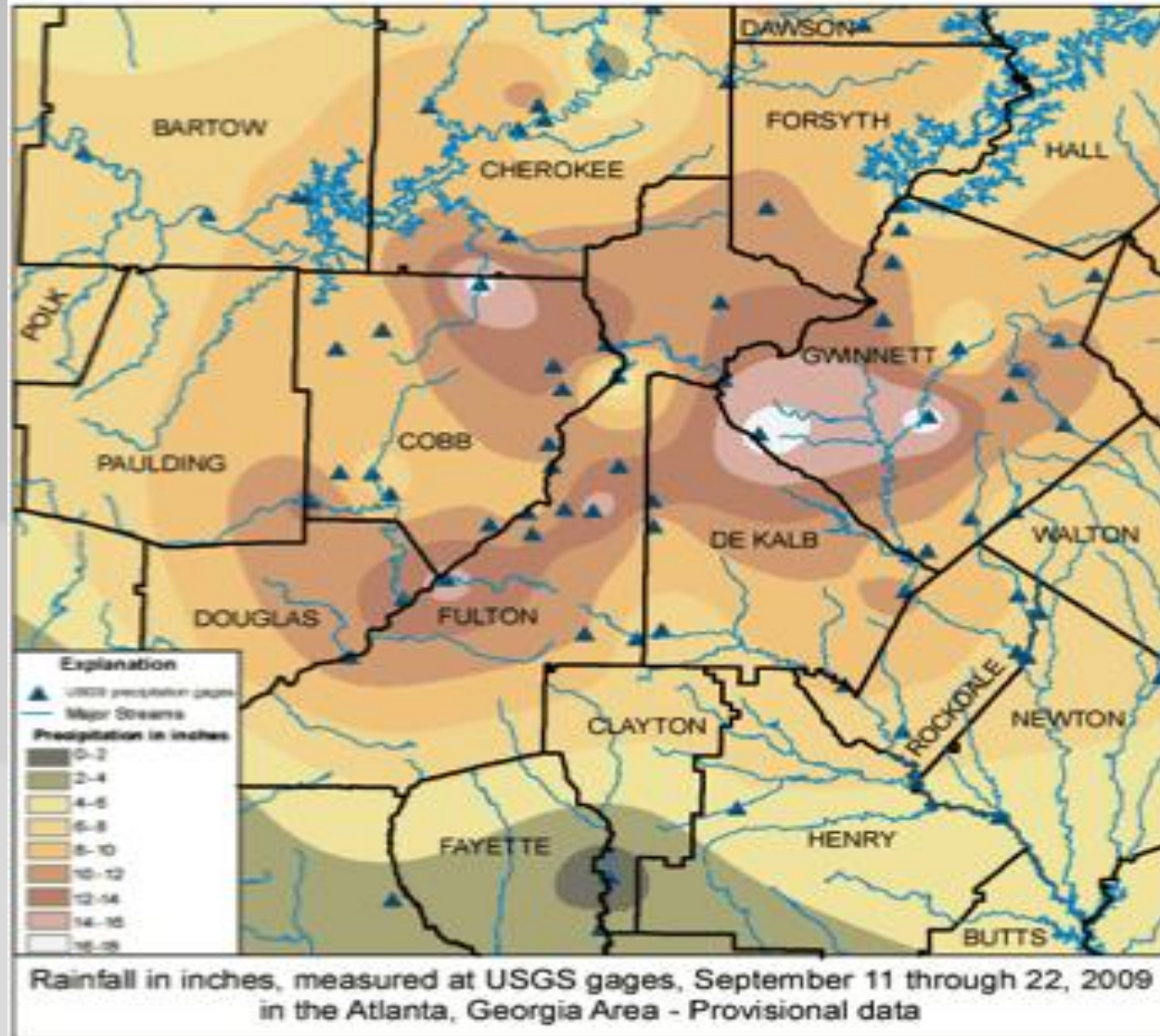
Effects on Urban Flooding

- Hydrological extremes such as flooding and drought occurrence have increased markedly in the last three decades with more intense and longer episodes (Trenberth et al. 2007)..
- Analysis by the NOAA NCDC suggests that in the southeastern United States, an increasing trend is detectable in the extreme precipitation record.
- The southeastern United States has experienced some of the most extreme urban flooding in recent years (e.g. Atlanta, Nashville).
- While many urban-related floods are explained by large scale meteorological and hydrological forcing, it is also clear that the urban environment may modify or increase the likelihood of flooding (Shepherd, 2011).



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It is speculated that the urban landscape, through urban-enhanced precipitation, could have explained various regions of enhanced flooding around Atlanta during the historic North Georgia floods of 2009, even as large scale hydro-meteorological processes governed the main flooding event (Shepherd, 2009).

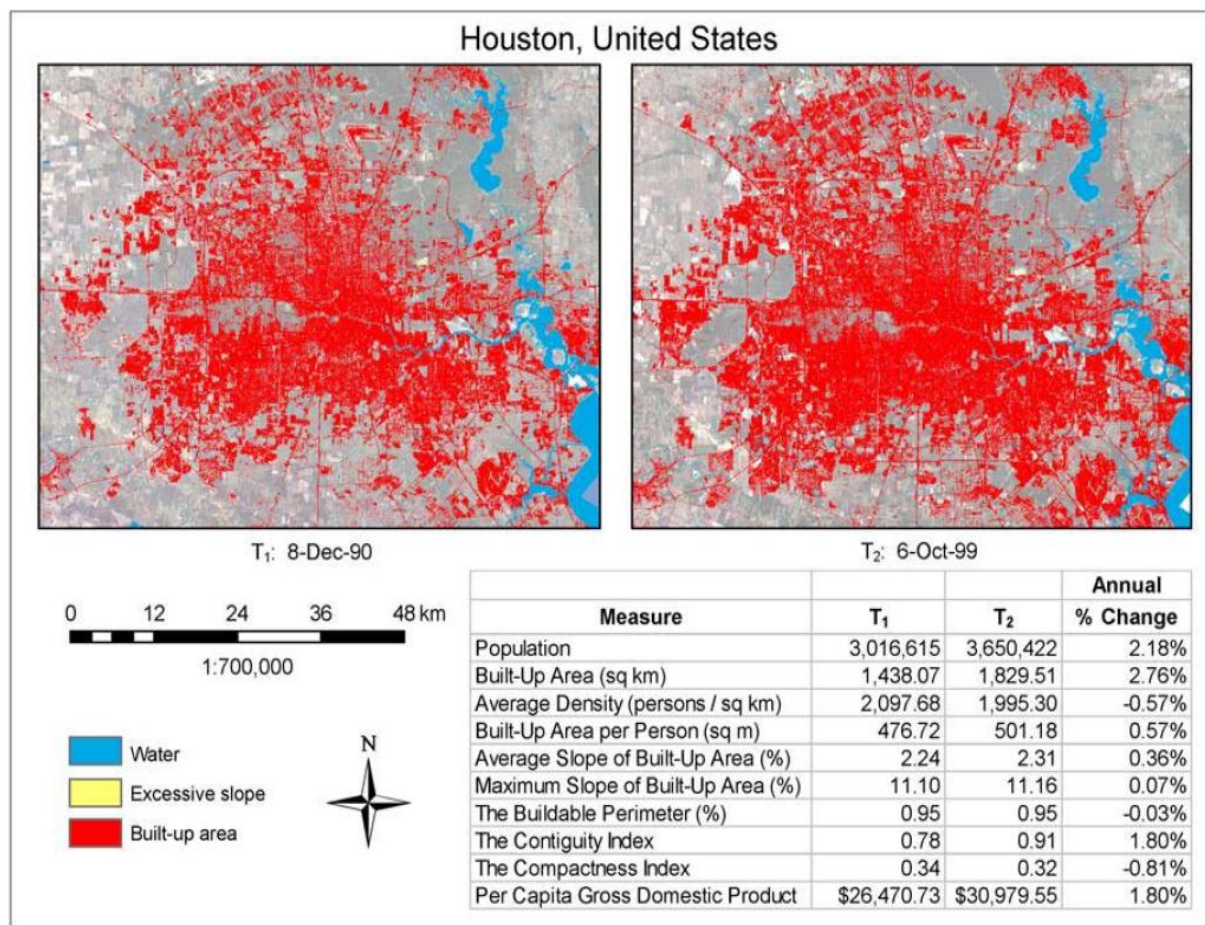


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Shepherd et al., (2011) projected the growth of Houston, Texas urban land cover to the year 2025,.

They used the new land cover as a boundary condition for a set of regional modeling studies using current meteorological conditions.

Results illustrated that the regional precipitation climatology of southeastern Texas could be significantly altered, irrespective of greenhouse-gas driven climate changes, by changing the urban land cover and the interactions between the urban areas and sea-breeze circulations.



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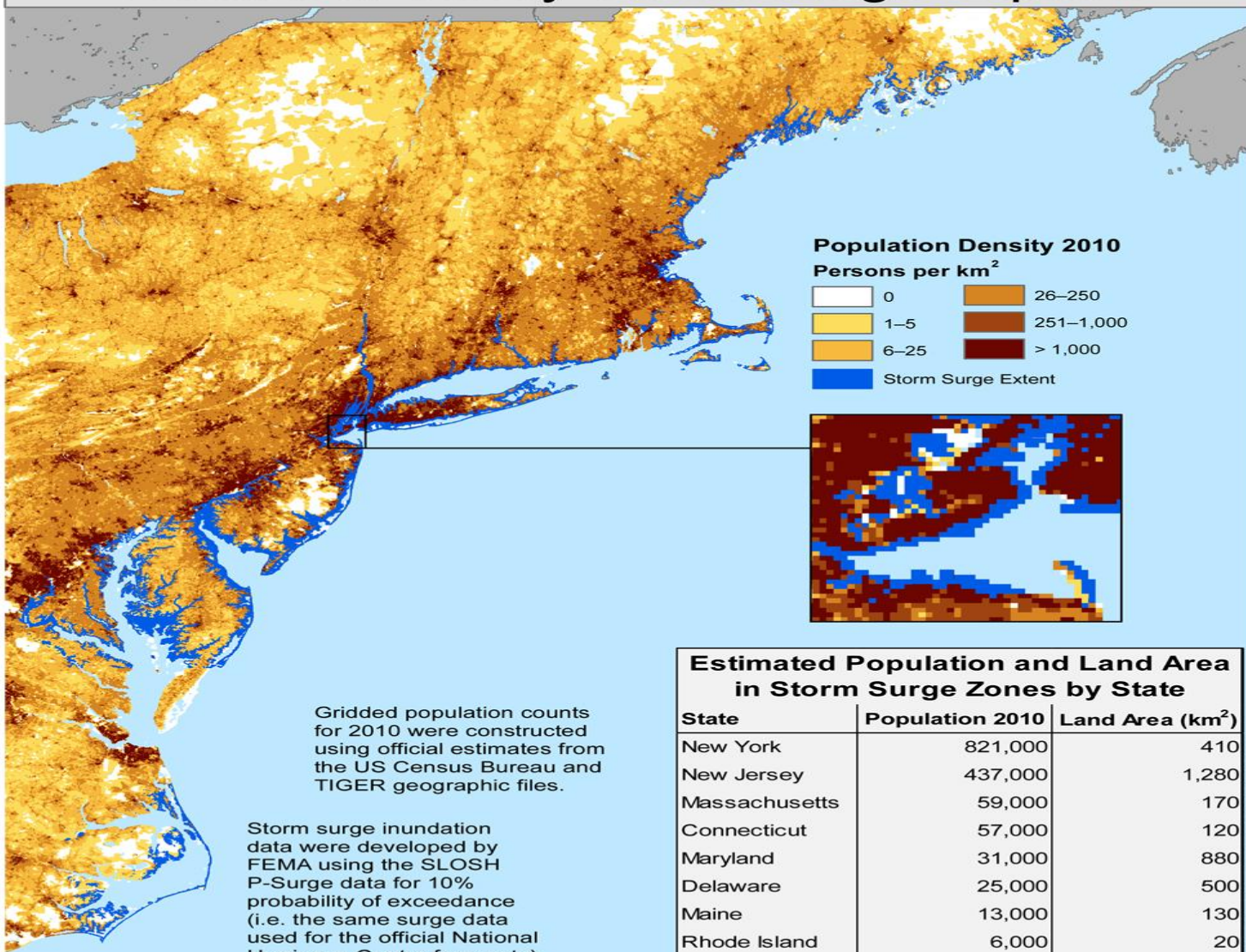
Coastal Environment

- Perhaps the most vulnerable Built Environments to climate change impacts are cities located in coastal areas.
- Impacts are far-ranging and include:
 1. Sea level rise
 2. Storm surge
 3. Heavy precipitation events
- Potentially severe Impacts on urban infrastructure, social structure, and human health.



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Hurricane Sandy Storm Surge Impacts

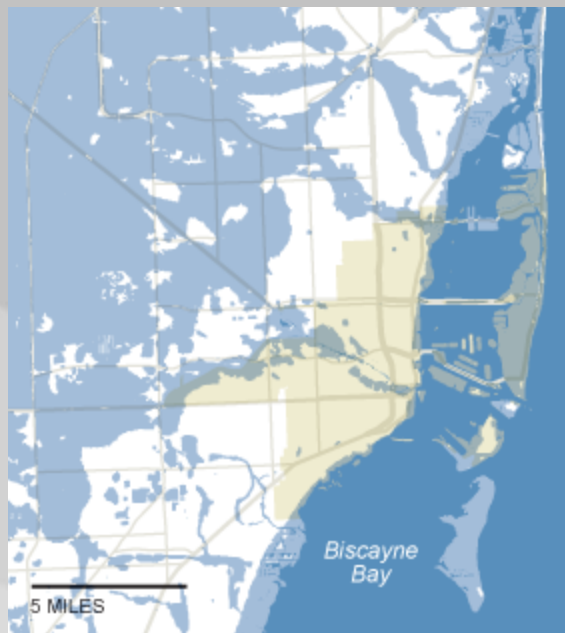


State	Population 2010	Land Area (km ²)
New York	821,000	410
New Jersey	437,000	1,280
Massachusetts	59,000	170
Connecticut	57,000	120
Maryland	31,000	880
Delaware	25,000	500
Maine	13,000	130
Rhode Island	6,000	20
North Carolina	5,000	270
Virginia	5,000	70
New Hampshire	1,000	10

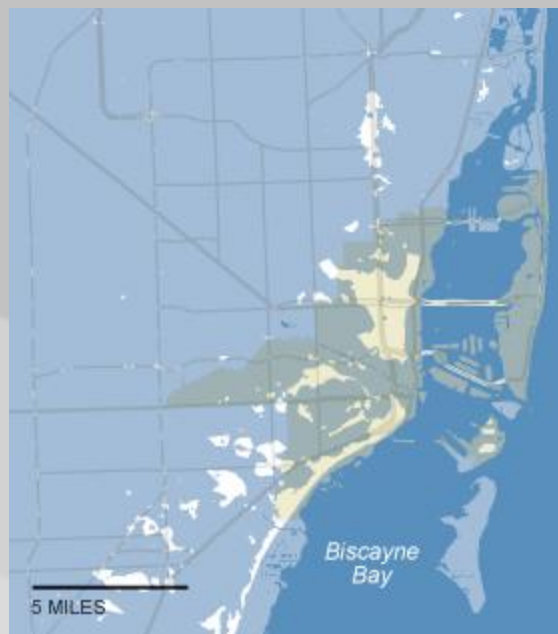


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Projected Sea Level Rise Scenarios Miami, FL



Projected 5 foot sea level rise



Projected 12 foot sea level rise



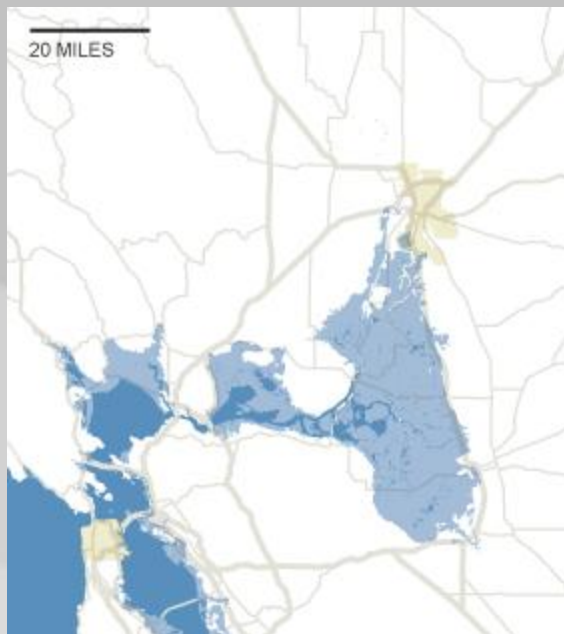
Projected 25 foot sea level rise

Source: *New York Times* – 11/2412
(based on USGS, NOAA, and
Science data)

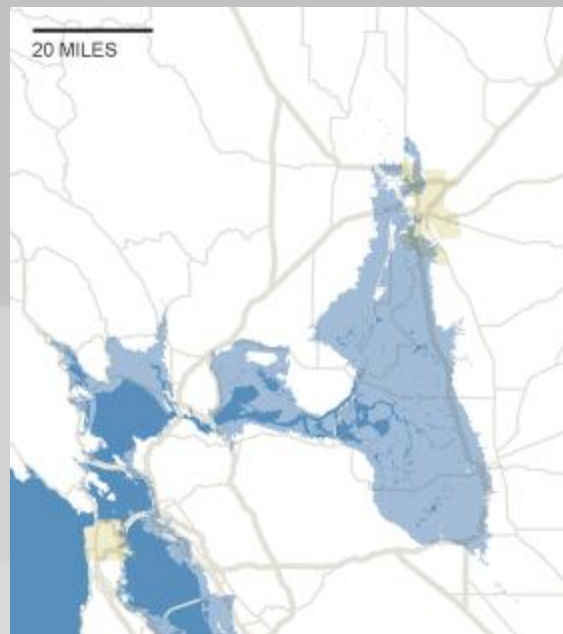


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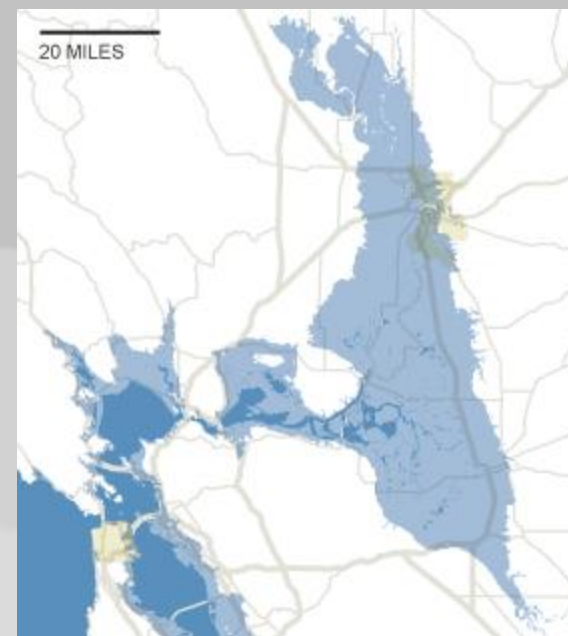
Projected Sea Level Rise Scenarios San Francisco, CA



Projected 5 foot sea level rise



Projected 12 foot sea level rise



Projected 25 foot sea level rise

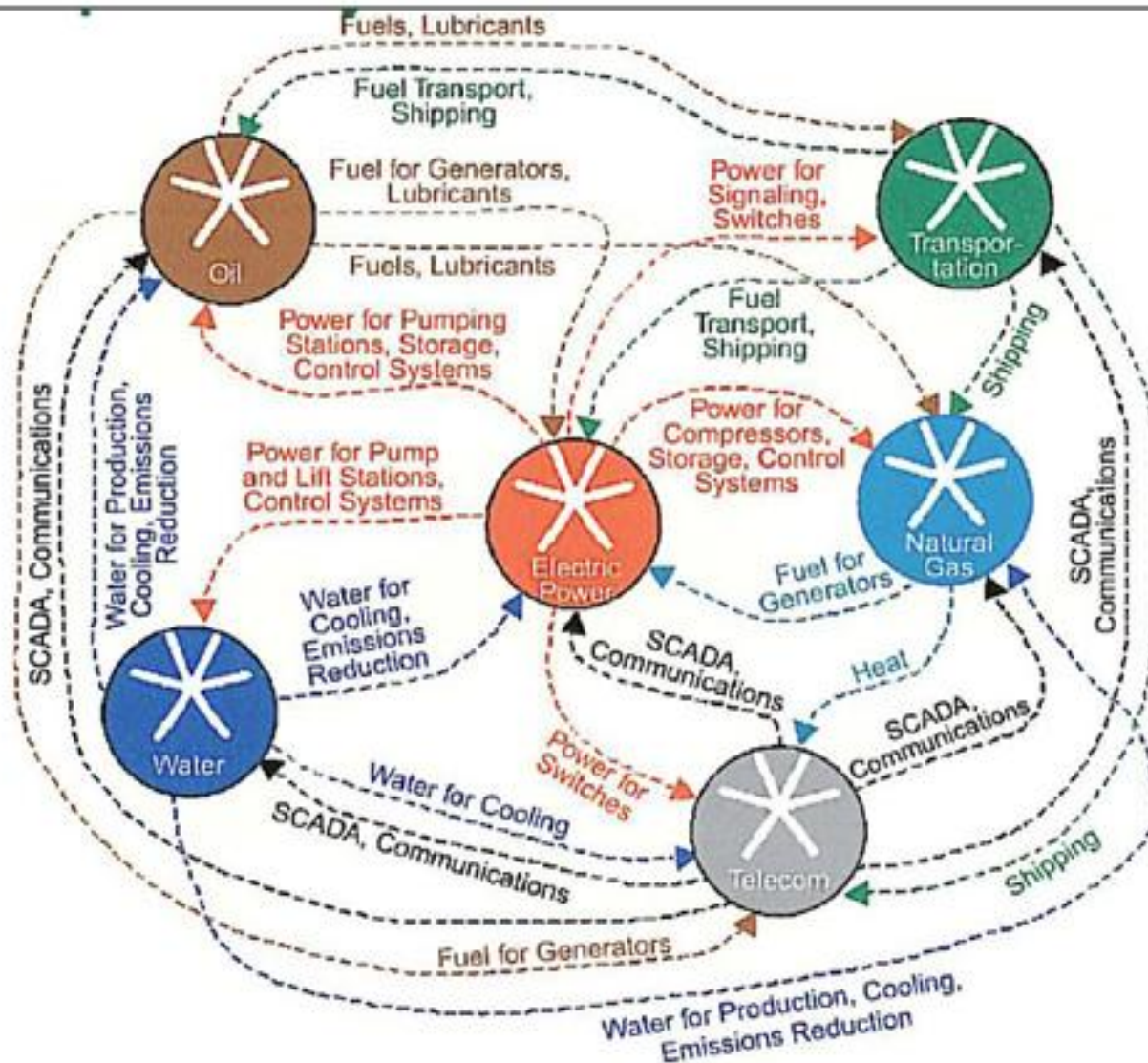
Source: *New York Times* – 11/2412
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Inter-linkage of urban infrastructure sectors as impacted by climate drivers.

(NCA Infrastructure Technical Report, 2012)

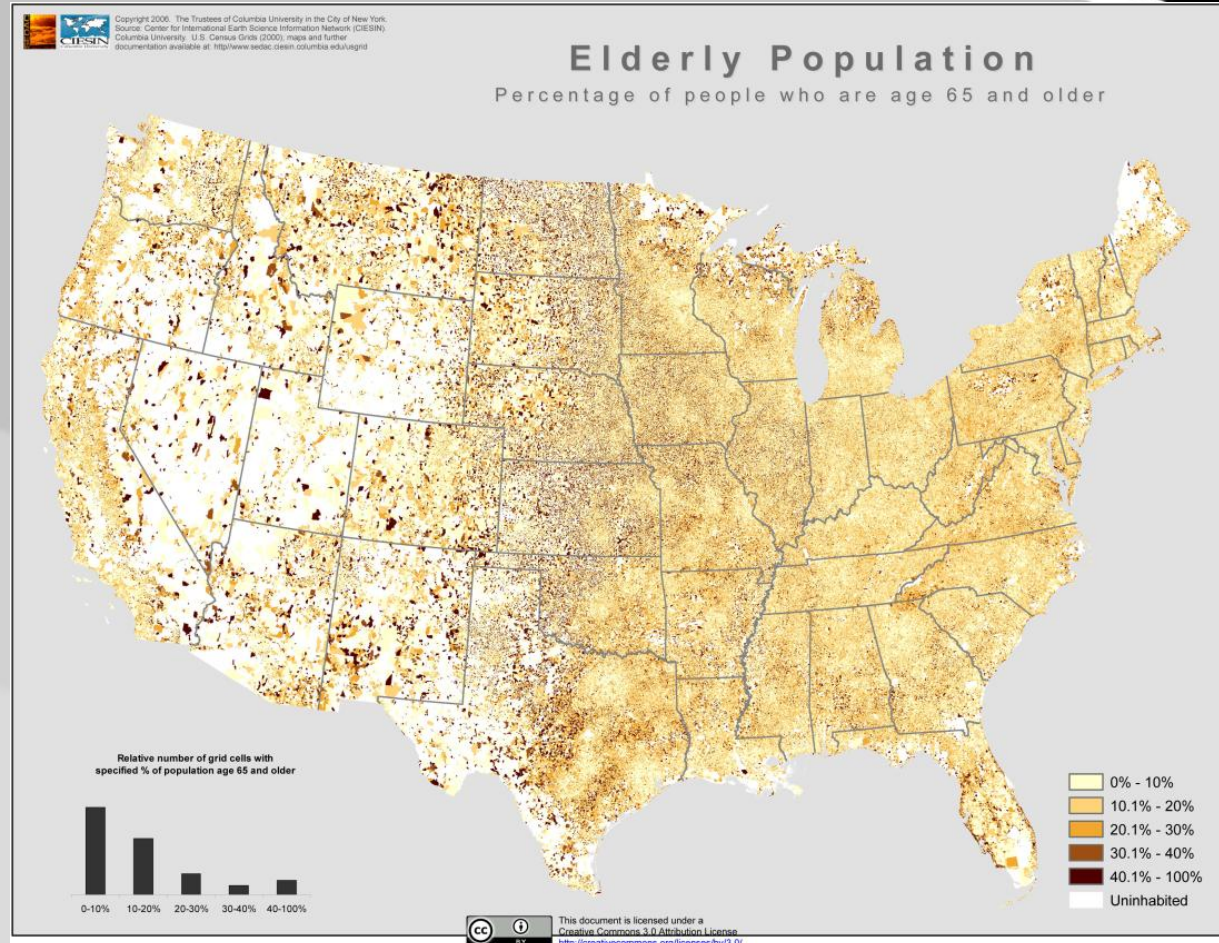


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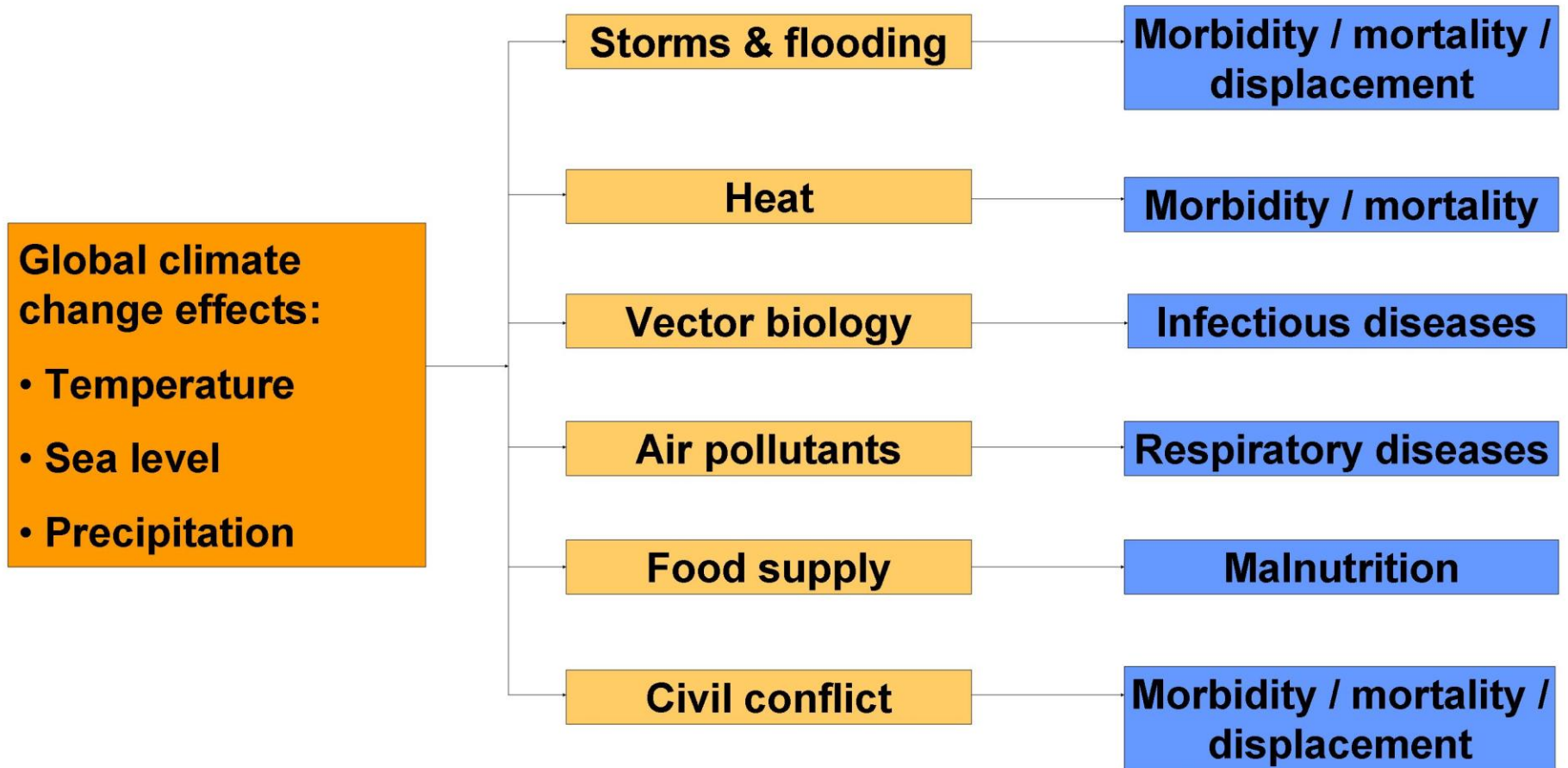
Social Structure Impacts

The “Climate Change Diaspora”

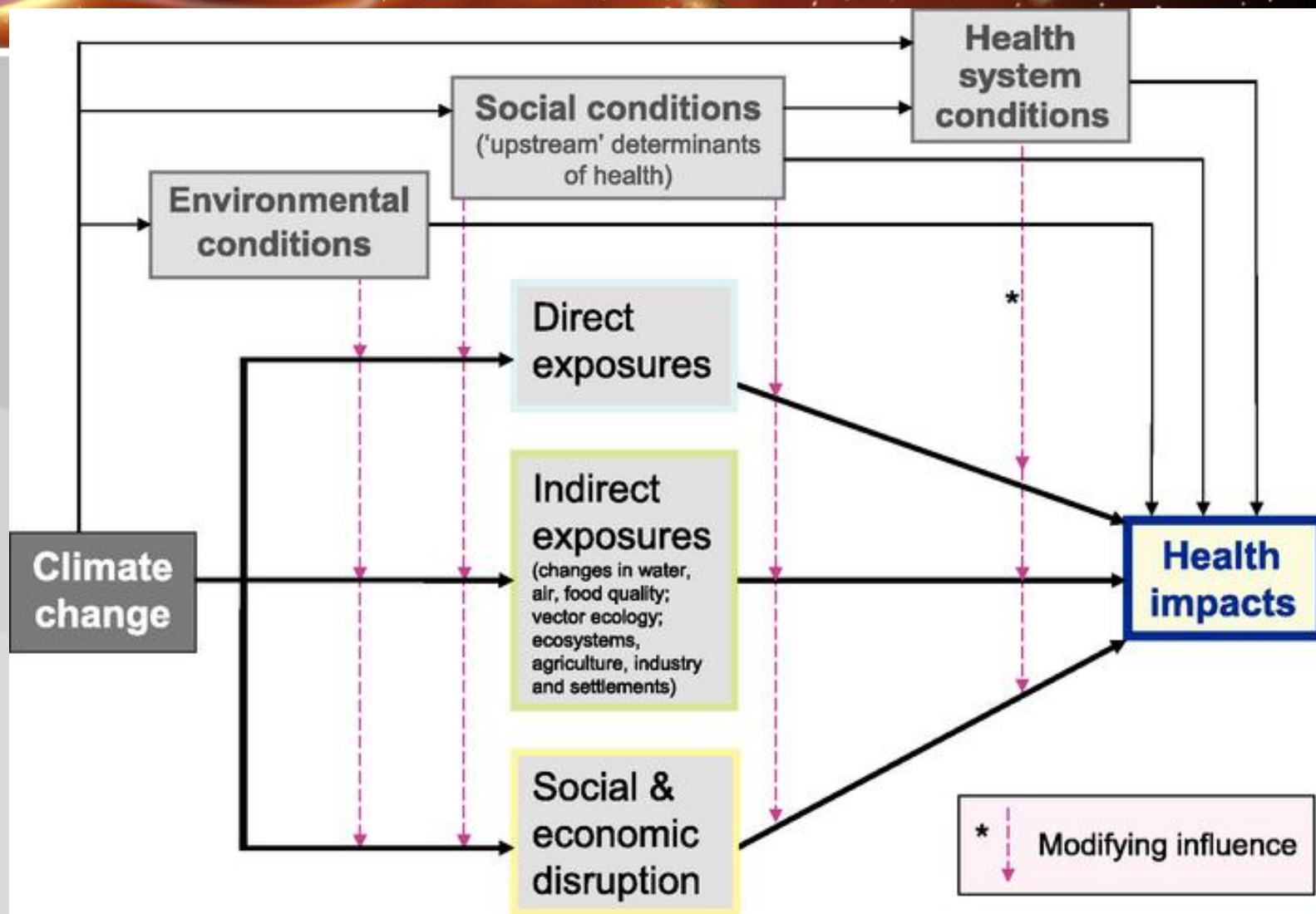
- Extensive or mass migration away from affected areas due to environmental impacts and circumstances (e.g., Hurricane Katrina)
- Severe impacts on non-mobile populations:
 - Economically disadvantaged
 - Elderly
 - Infirm/assisted living/nursing homes
 - Persons unable to migrate because of family/cultural situations



Potential Impacts of Global Climate Change on Human Health



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The Need for Indicators of Climate Change for Sustainable Development and Adaptation Planning in Response to Impacts on the Built Environment

- 1) Provide meaningful, authoritative climate-relevant measures about the status, rates, and trends of key physical, ecological, and societal variables and values to inform decisions on management, research, and education at regional to national scales.
- 2) Identify climate-related conditions and impacts to help develop effective mitigation and adaptation measures and reduce costs of management.
- 3) Document and communicate the climate-driven dynamic potential and nature of climate impacts on the overall Built Environment.



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Indicators of climate change need to provide solid bases for decision making at all levels and to contribute to the self-regulating sustainability of integrated and development systems

- Sustainability indicators must be more than environmental indicators; they must be about time and/or thresholds
- Development indicators should be more than growth indicators; they should be about efficiency, sufficiency, equity, and quality of life
(D. Meadows, 1998. *Indicators and Information Systems for Sustainable Development*)



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Who are the users sustainable development indicators of climate change impacts on the built environment?

Indicators need to provide information on:

- what impacts will occur
- under what climate change scenarios they will occur
- what the ramifications of these impacts will be



- Federal/State/Local Government (examples of suggestions):
 - Metropolitan, county, and municipal governments, zoning boards, etc.
- Chamber of Commerce
- Interested public
- General public
- Science/technical community
- Managers
- Regulators
- Trade and Professional associations
 - American Medical Association, American Insurance Association, Air Transport Association, Cargo Association, etc.
- Tribal communities
- Private sector
 - Business, industry, energy, transportation, insurance, agriculture, etc.
- Regulators
 - Have needs for indicators that are a little different than other decision makers
- Non-profit and Non-governmental organizations
- Defense/Intelligence community
- People who do mitigation and policy work
- Others not typically included, such as emergency planners and social scientists

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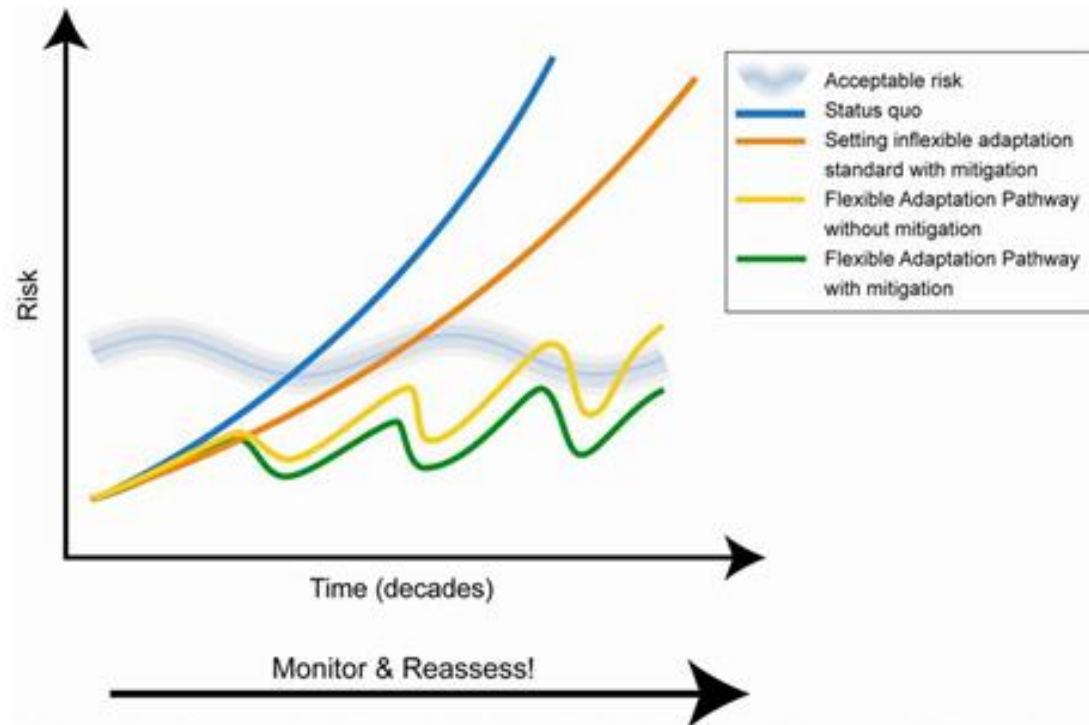
Adaptation Strategies

- Although cities and their supporting human, biophysical, atmospheric, hydrologic, and socioeconomic individual components are subject to climate change impacts, assessing what adaptation measures can be taken to sustain these separate components, will ultimately make the entire ecosystem more resilient and adaptable.
- Because of the complexity of the city and its supporting ecosystems, we must really operate at a component-by-component level to assess what kinds of adaptability measures are needed to make the individual systems sustainable and resilient.
- Here it is both good stewardship of the resources that comprise the subcomponents of these individual ecosystems, and an understanding of what adaptation measures work best from a cost-benefit purview that matter most.



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Adaptive Urbanization - Climate Risk Management in Cities, Flexible Adaptation Pathways and Interactive Mitigation and Adaptation



Graphic adapted from: Lowe, J., T. Reeder, K. Horsburgh, and V. Bell. "Using the new TE2100 science scenarios." UK Environment Agency Source: MPOI, 2009

- Flexible Adaptation Pathways approach that can evolve over time as understanding of climate change improves and that concurrently reflect local, national, and global economic and social conditions.
- Flexible Adaptation Pathways is a concept that encourages building climate change adaptation strategies that can be adjusted and modified over time to reflect the dynamic and ongoing climate change understanding.



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Some Insight into Selected Adaptation Strategies

Transportation:

- Adaptation strategies to address heat, sea level rise and inundation, and storm and precipitation extremes encompass the full spectrum of transportation functions including design, construction, operation and maintenance.

Telecommunications:

- Adaptation strategies appropriate for urban energy systems will vary.
- Some may have a temporal focus (e.g. short vs. long term) and be proactive or reactive.
- Overhead lines can be moved to underground cables where possible and economically feasible
- Trees can be trimmed, where applicable (more often in suburban than urban areas), to avoid or reduce downed lines during wind, snow and ice storms
- Increasing fuel supplies for back-up power generators at cell phone towers, central offices, and radio/TV antennas, can sustain communication options during extended electric grid outages.



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Some Insight into Selected Adaptation Strategies

Energy:

- In general, adaptation responses can be categorized as technological, behavioral, or structural
- Technological responses focus on the hardening of existing system assets to reduce their vulnerability to climate change risks
- Behavioral strategies may involve the relocation of critical energy system assets away from risk-prone areas
- Structural changes promoting adaptive capacity may include changes to fundamental energy market rules to create demand response programs that incentivize power load reductions during heat waves.



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Some Insight into Selected Adaptation Strategies

Public Health:

•Shorter time scales:

- Adaptation efforts include infrastructure planning to reduce impacts, such as unimpaired emergency transportation systems and routes, improved sanitation systems, as well effective communication to the most highly vulnerable populations so they will take necessary actions, (i.e., move to cooling centers, evacuate appropriately, boil water, avoid contaminated water bodies).



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Some Insight into Selected Adaptation Strategies

Public Health:

Longer time scales:

- Involve urban planning, increasing urban green space, access to low carbon footprint food, improved sanitation systems and sewage infrastructure.
- Access to clean water and reliable food supplies, effective and understood evacuation plans, and accessible transportation for evacuation and access to emergency facilities.
- Improvements in surge capacity for hospitals and emergency departments, training of hospital and medical personnel to deal with multiple emergencies and to detect new or emerging diseases and other health risks before an outbreak.



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Some Insight into Selected Adaptation Strategies

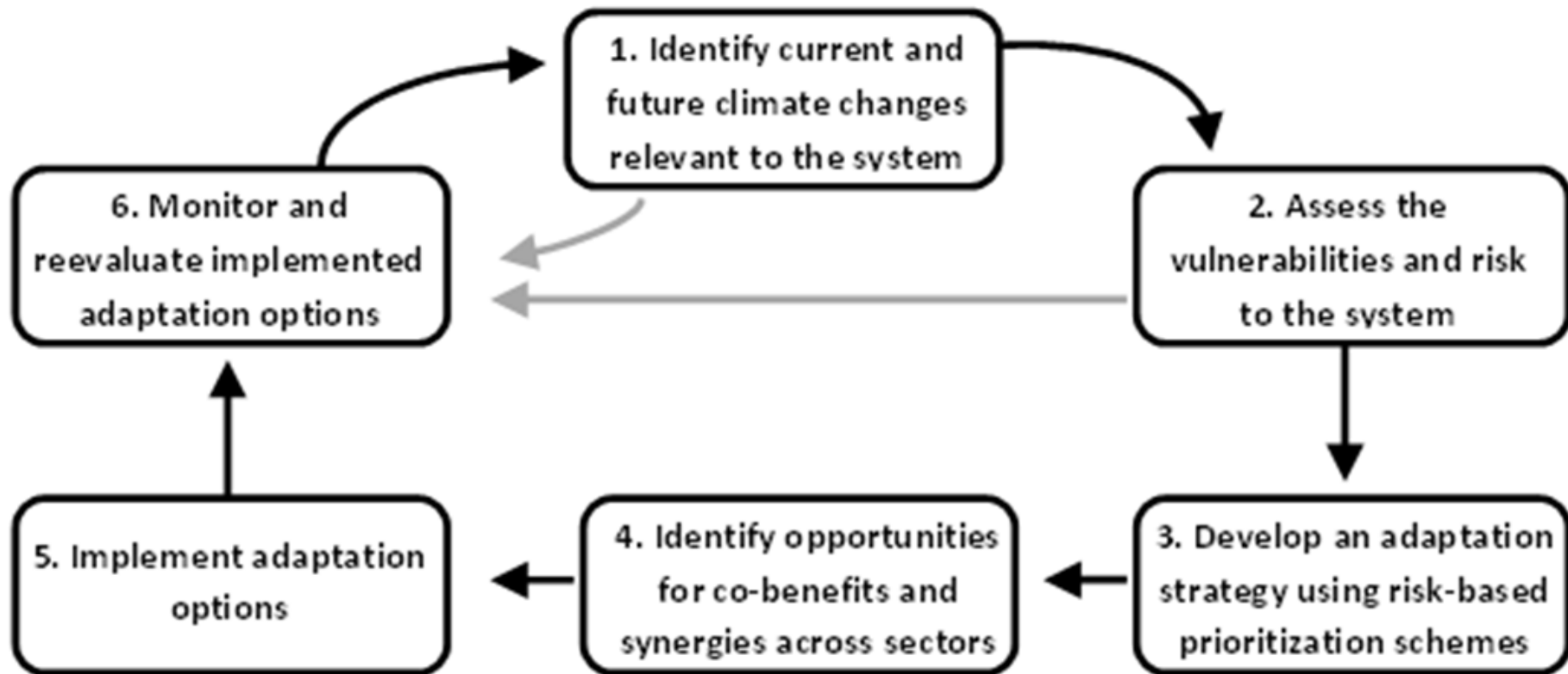
Mitigation of the Urban Heat Island over the Built Environment:

- Urban forestry and trees
- Cool roofs
- Green roofs
- Urban Heat Island mitigation
 - 1) modifying urban geometry
 - 2) altering surface thermal and energy balance properties, 3) increasing energy efficiency,
 - 4) reducing anthropogenic heat.



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Adaptation Strategies: Summary





There is a critical and timely need for the development of mitigation and adaptation strategies in response to climate change by the policy and decision making communities, to insure resiliency and sustainability of the built environment in the future.