Rising Heat, Ice, and Flooding in the ATL: Implications, Response, Challenges

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2013 President, American Meteorological Society

@DrShepherd2013 on Twitter

Author: The Urban Climate System (Wiley)

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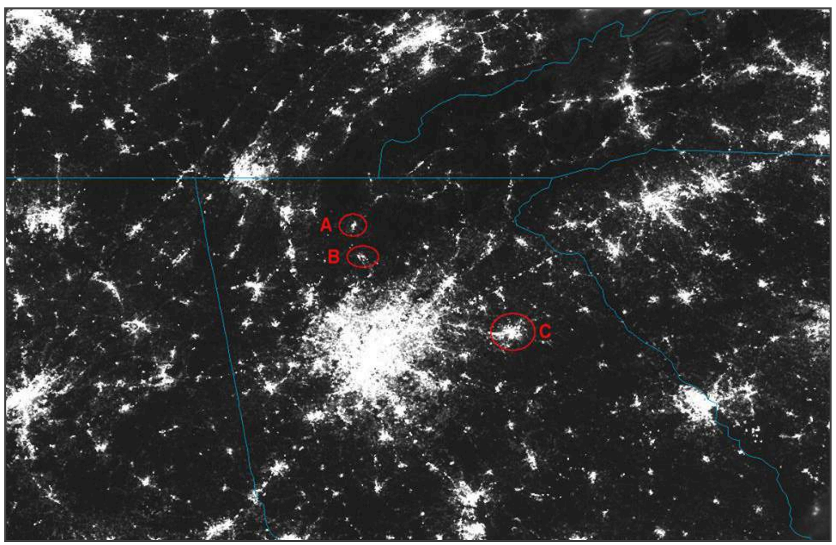
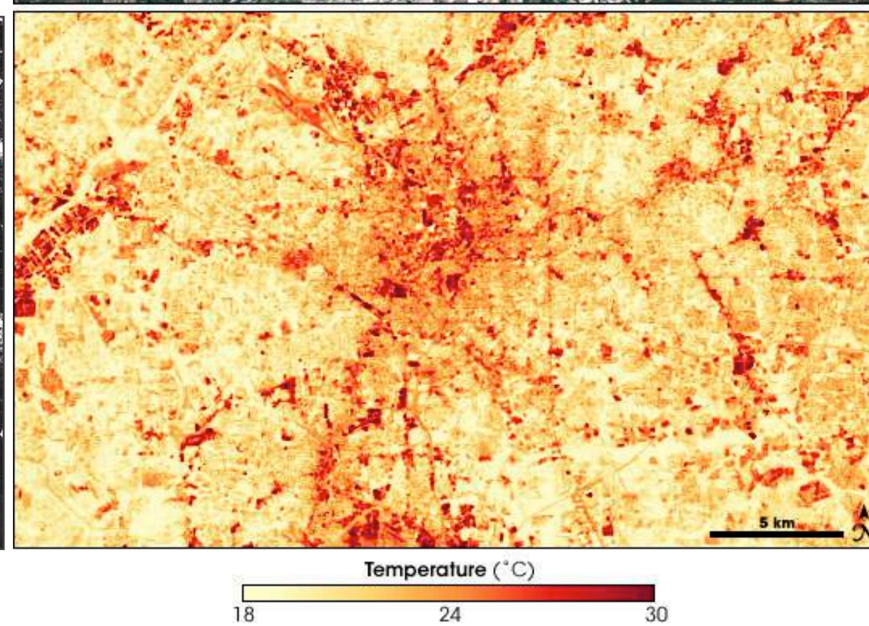
Heat isn't the only challenge….

- Flooding
- Ice Storms
- Severe Storms/Tornadoes
- Drought





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IPCC says more extremes

Phenomenon and direction of trend	Assessment that changes occurred (typically since 1950 unless otherwise indicated)	Assessment of a human contribution to observed changes	Likelihood of further changes	
			Early 21st century	Late 21st century
Warmer and/or fewer cold days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely*	*Likely* {11.3} – –	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warmer and/or more frequent hot days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely* (nights only)	*Likely* {11.3} – –	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warm spells/heat waves. Frequency and/or duration increases over most land areas	***Medium confidence*** on a global scale *Likely* in large parts of Europe, Asia and Australia {2.6} *Medium confidence* in many (but not all) regions *Likely*	***Likely*** (a) {10.6} Not formally assessed *More likely than not*	Not formally assessed (b) {11.3} – –	*Very likely* {12.4} *Very likely* *Very likely*
Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation.	*Likely* more land areas with increases than decreases (c) {2.6} *Likely* more land areas with increases than decreases *Likely* over most land areas	***Medium confidence*** {7.6, 10.6} *Medium confidence* *More likely than not*	*Likely* over many land areas {11.3} – –	***Very likely*** over most of the mid-latitude land masses and over wet tropical regions {12.4} *Likely* over many areas *Very likely* over most land areas
Increases in intensity and/or duration of drought	***Low confidence*** on a global scale *Likely* changes in some regions (d) {2.6} *Medium confidence* in some regions *Likely* in many regions, since 1970 (e)	***Low confidence*** {10.6} *Medium confidence* (f) *More likely than not*	*Low confidence* (g) {11.3} – –	***Likely*** *(medium confidence)* on a regional to global scale (h) {12.4} *Medium confidence* in some regions *Likely* (e)
Increases in intense tropical cyclone activity	***Low confidence*** in long term (centennial) changes *Virtually certain* in North Atlantic since 1970 {2.6} *Low confidence* *Likely* (in some regions, since 1970)	***Low confidence*** (i) {10.6} *Low confidence* *More likely than not*	*Low confidence* {11.3} – –	***More likely than not*** in the Western North Pacific and North Atlantic (j) {14.6} *More likely than not* in some basins *Likely*
Increased incidence and/or magnitude of extreme high sea level	*Likely* (since 1970) {3.7} *Likely* (late 20th century) *Likely*	***Likely*** (k) {3.7} *Likely* (k) *More likely than not* (k)	*Likely* (l) {13.7} – –	***Very likely*** (l) {13.7} *Very likely* (m) *Likely*

Source: IPCC AR5, Summary for Policymakers

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Averages or Extremes?

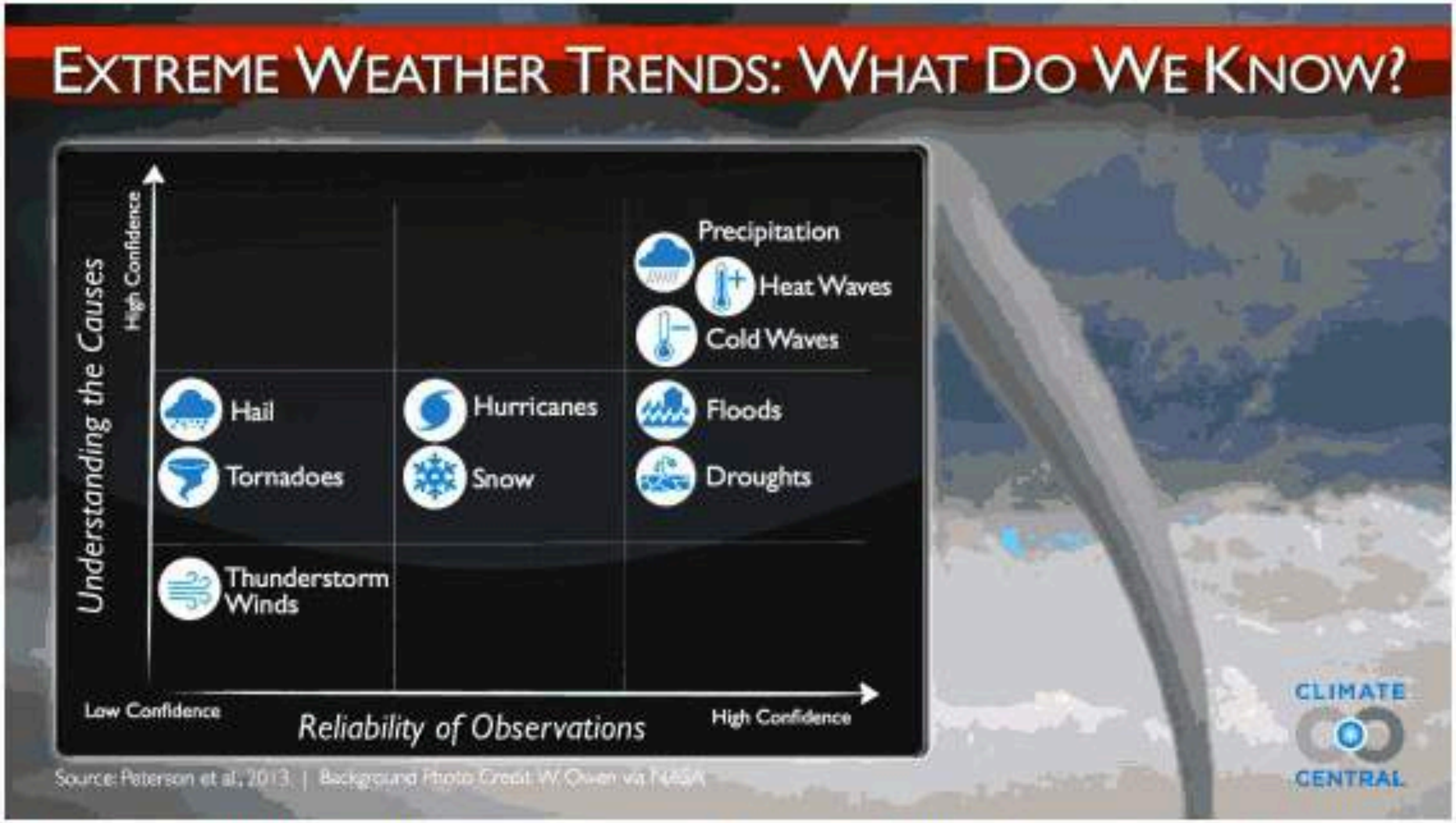
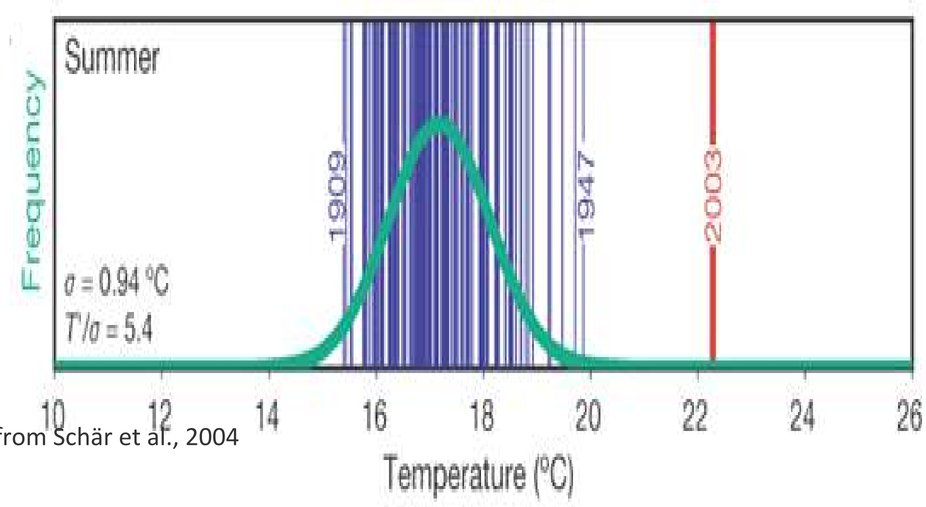


Figure 2: Our understanding of extreme weather trends within the context of climate change is a function of the reliability of our observations coupled with our understanding of the causes of the extreme weather phenomenon. Source: Peterson et al., 2013.

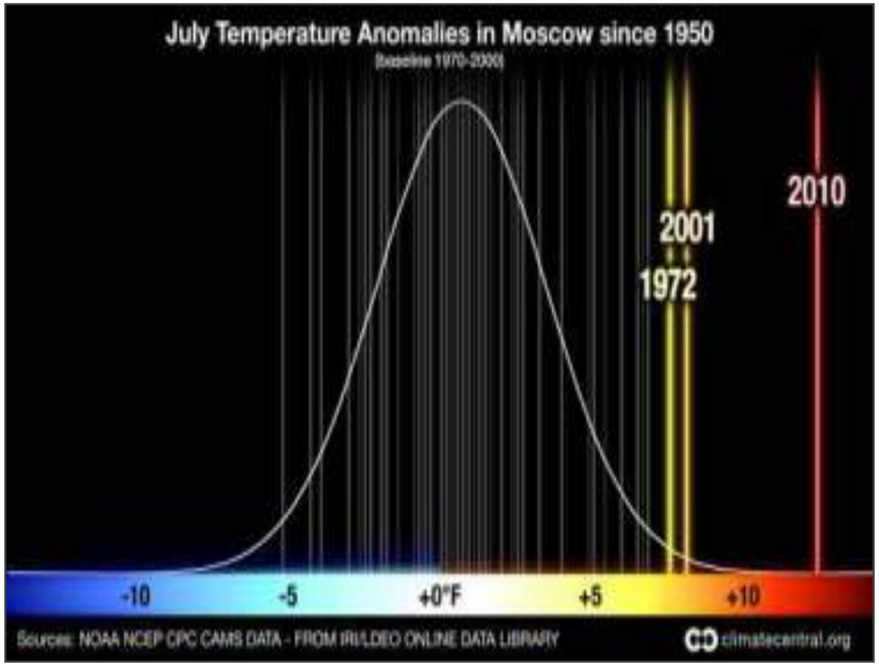
Some occurrences beyond historical experience

European heat wave of 2003



from Schär et al., 2004

Russian Heat wave of 2010



Source: Climate Central

Brian Stone/Ga Tech notes that not a single book written on European heat with > 30,000 deaths yet hundreds on SARS, Hurricane Katrina, 9/11 (less deaths)
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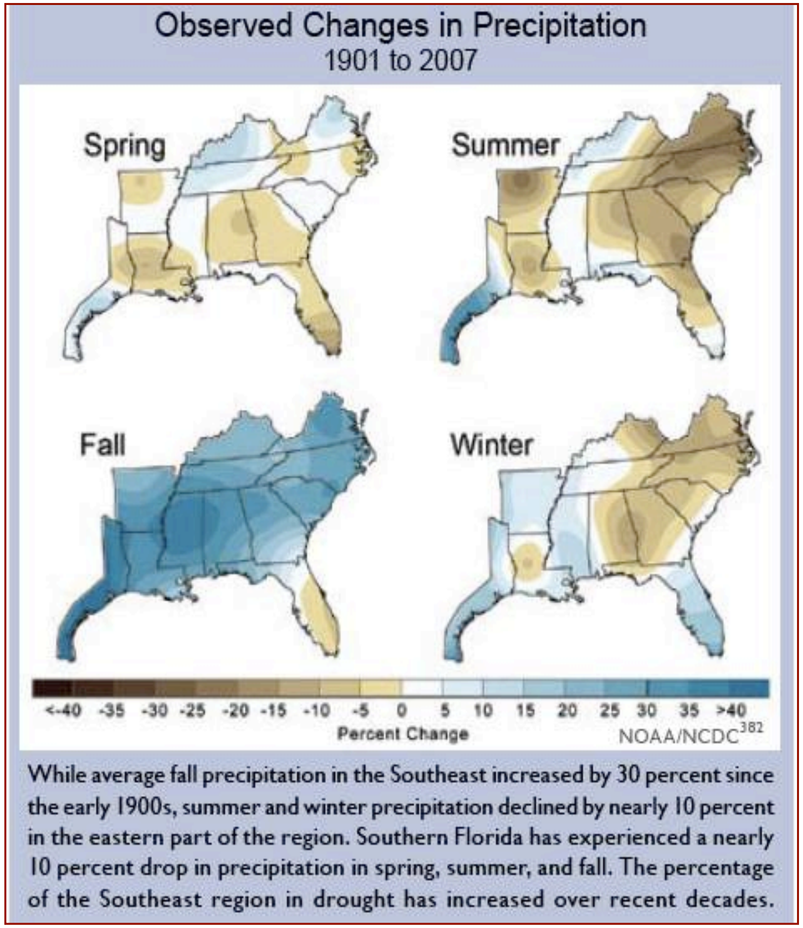
More and Stronger Floods and Droughts?



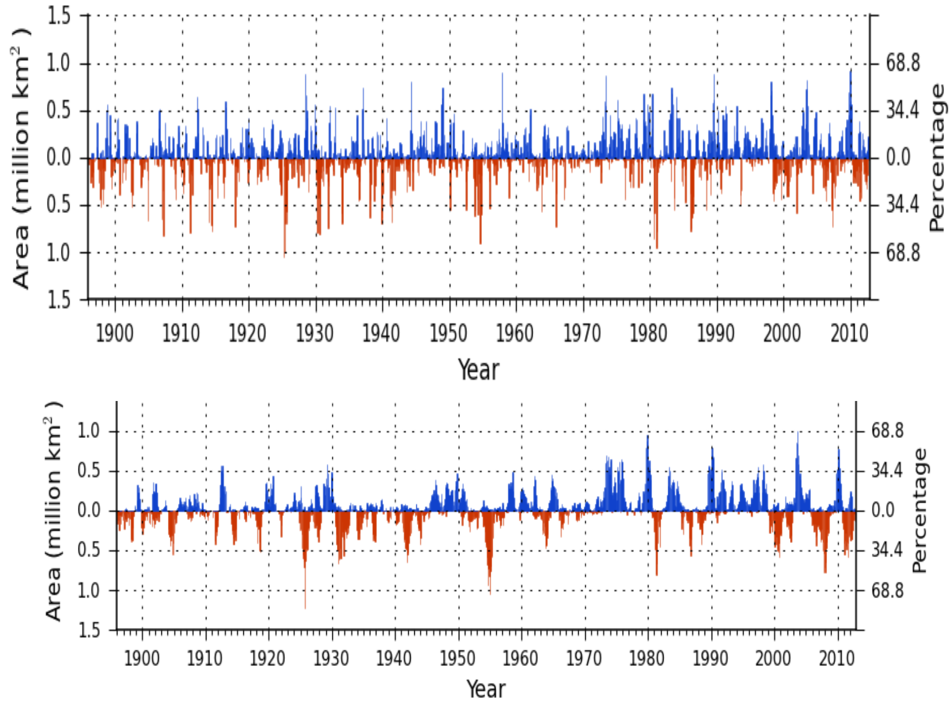


Figure 3.8: Area of the Southeast US under severe and extreme dry and wet events for 3-month and 12-month SPEI and for the period 1896-2012

S. Bernardes (2013), Bernardes, Shepherd, and Madden (2014), NSF Coweeta LTER

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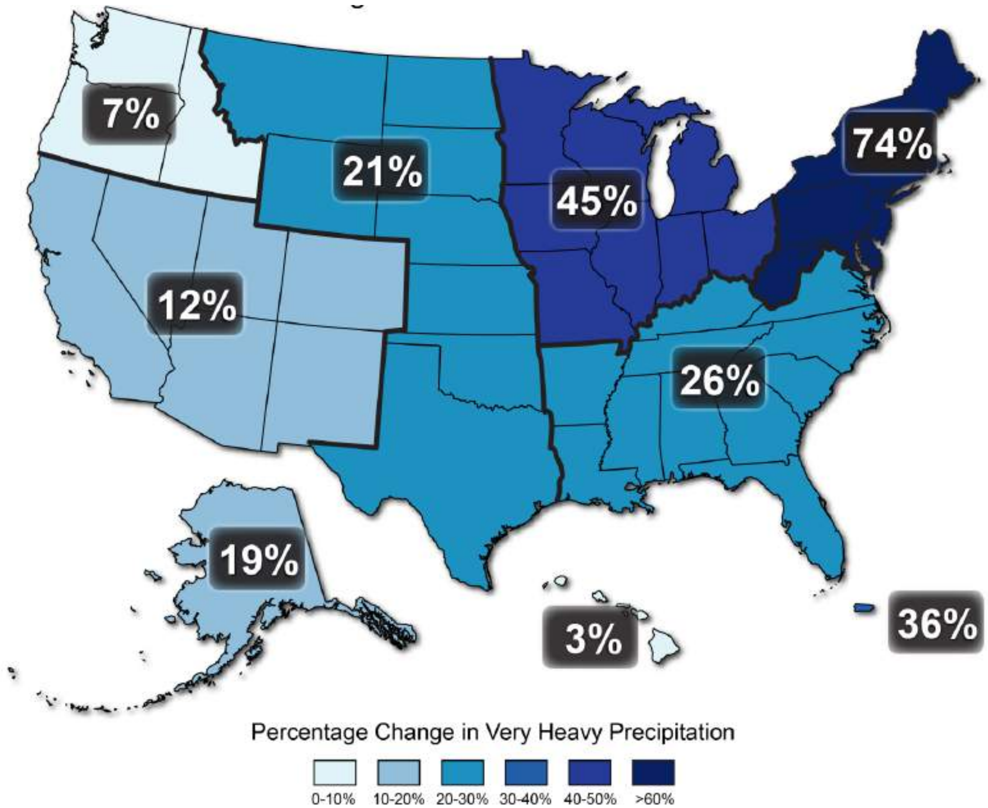
Increasing Flood Risks (Andersen and Shepherd 2013, Shepherd et al. 2011, NCA 2014)



% Change since 1950 in Top 1% Heaviest Rainfall Evets (NCA, 2013)

THE MAP ROOM

An Overview of Synoptic and Mesoscale Factors Contributing to the Disastrous Atlanta Flood of 2009

BY MARSHALL SHEPHERD, THOMAS MOTE, JOHN DOWD, MIKE RODEN, PAMELA KNOX, STEVEN C. MCCUTCHEON, AND STEVEN E. NELSON

Recent literature suggests that damage, loss of life, and costs from flooding have risen in recent decades (Ashley and Ashley 2008; Brissette et al. 2003). In a 2009 *Journal of Climate* article, Seager et al. noted that regions of the southeastern United States face increasing vulnerability to hydroclimatic extremes because of population growth and increasing population density. In 2008, a majority of the population lived in urban areas, and by 2030 this number is expected to reach 81%. The unsustainable, modified water cycle will affect the ecosystem, infrastructure, and societal activities, thereby requiring revolutionary designs, management, and policies. Burian and Shepherd (2005) and Reynolds et al. (2008) represent a sample of recent literature that has reconsidered implications of precipitation on urban drainage and hydrological processes.

In September 2009, the metropolitan area of Atlanta and surrounding areas in northern Georgia experienced disastrous urban flooding that inundated major transportation arteries, closed several major school systems, submerged the popular Six Flags theme park, and contributed to at least 10 deaths as of October 2009 (Fig. 1). The United States Geological Survey (USGS) measured the largest flow ever recorded on Sweetwater Creek near Austell, which has a streamflow record dating back to August 1904. Parts of Cobb and Douglas Counties were inundated to levels exceeding the estimated 500-yr flood. The Yellow River stream gauges in Gwinnett, DeKalb, and Rockdale Counties measured flows that submerged the 100-yr floodplains but failed to reach the 200-yr flood level, which has a 0.5% chance of occurring in any given year (www.usgs.gov/newsroom/article.asp?ID=2316). The 100-yr flood level with a 1% chance of occurrence in any given year is one of the standards that the Federal Emergency Management Agency (FEMA) uses to set flood insurance rates and prevent flood plain development. The USGS recorded 100-yr flood levels on the Chattahoochee River at Vinings in Atlanta (Fig. 2), where stage heights

FIG. 1. (top) Flooding on U.S. Interstate 285 loop around Atlanta and (bottom) Six Flags theme park.

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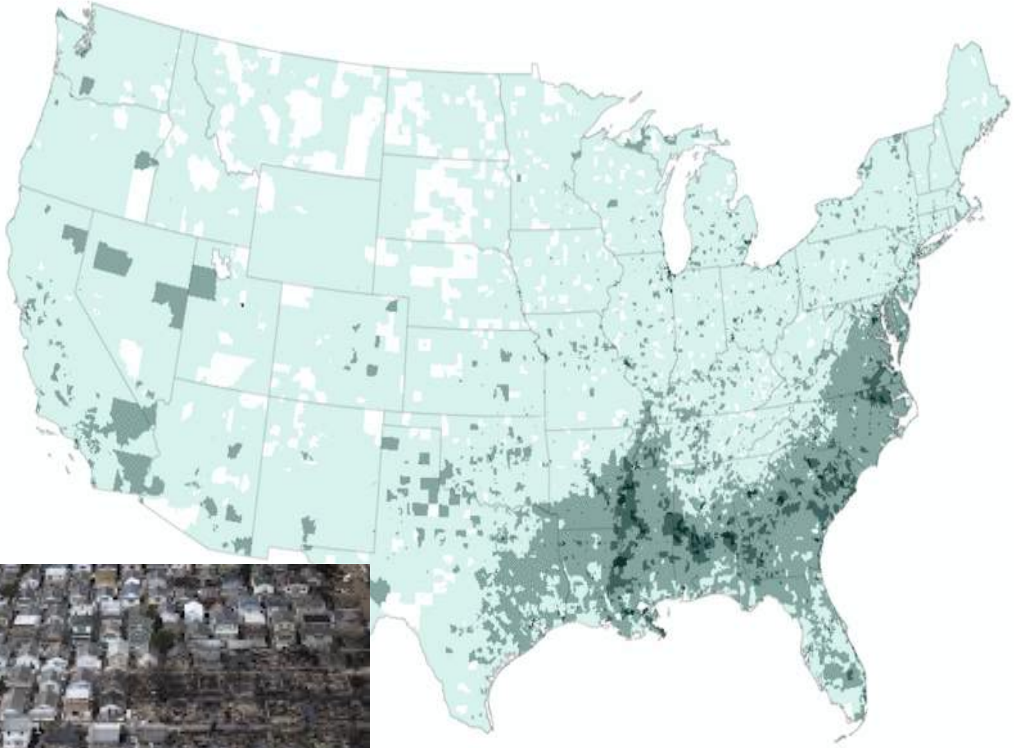
DOI:10.1175/2010BAMS3003.1

Southeast is Particularly Climate Vulnerable

- "*The South is prone to more climate-related disasters in both scale and magnitude by a ratio of almost 4:1.*" *(Emlich and Cutter 2011)*



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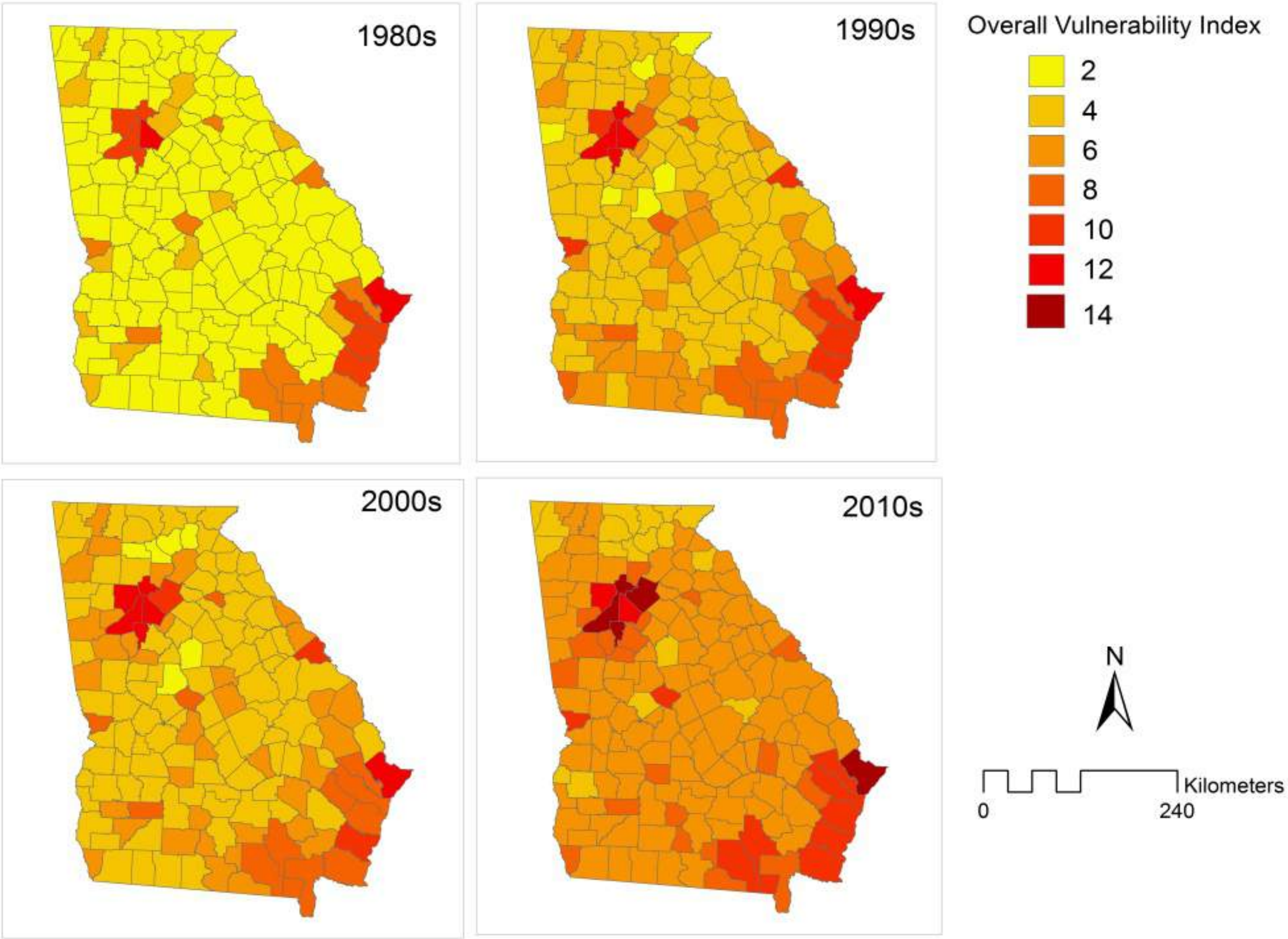
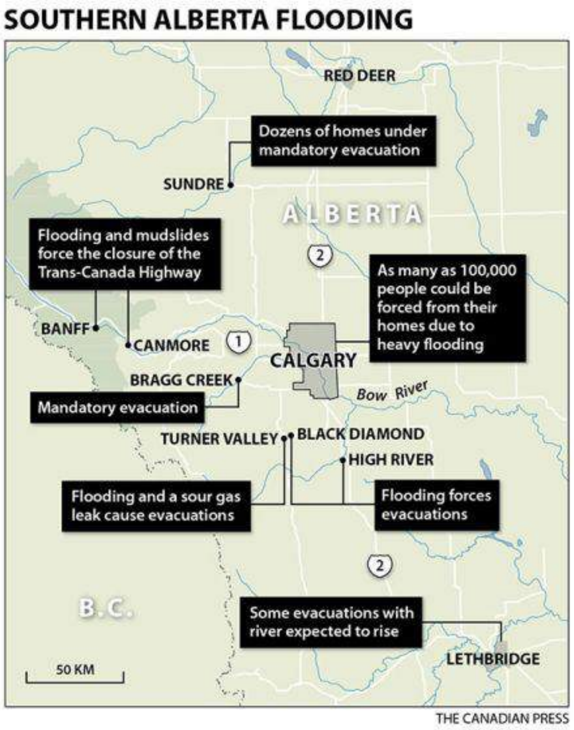
Georgia: Emergence of Hydroclimate Vulnerability (KC, Shepherd, and Johnson 2013)



Are urban floods increasing?

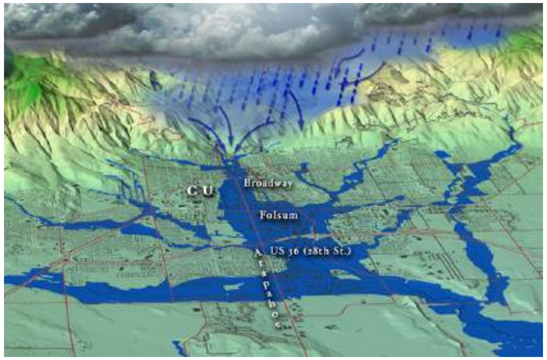
Calgary

2013



Mumbai 2005

Atlanta 2009



Boulder 2013

Nashville 2010

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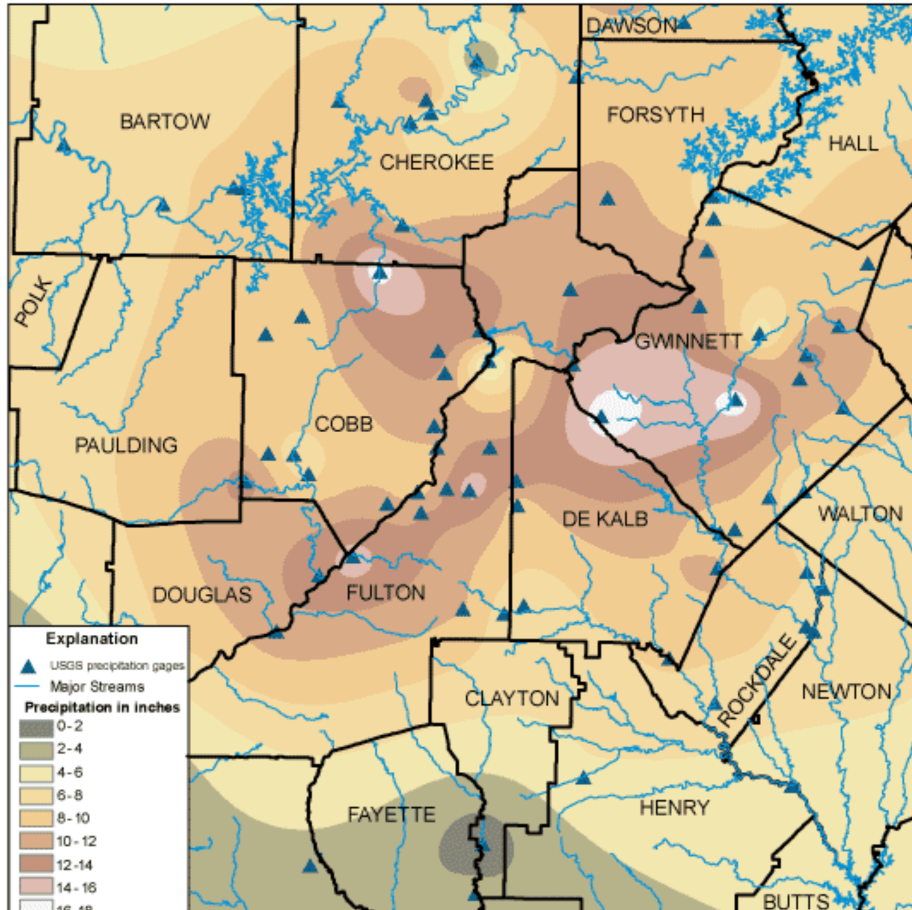
Atlanta Sept. 2009: Extreme Event Case Study

- September 2009 (227.0 mm) was *219% above normal and 5th wettest in Atlanta's history and the 4th wettest for Athens, Georgia.*
- Parts of Metro Atlanta were inundated to levels exceeding the estimated 500-year flood. 100 to 200-year flood levels common**. Belanger (AMS, 2011) suggests 10,000 yr event
- 10 fatalities, 16000 injured/federal aid requests, $500m +damages,~1500 evacuated, ~20,000 homes/businesses flooded , ~1500 schools closed, ~300 roads/ interstates closed/destroyed ,

Sources: NWS (Nelson, GEMA, AJC)

**100-yr flood used by FEMA to set flood insurance rates



Rainfall in inches, measured at USGS gages, September 11 through 22, 2009 in the Atlanta, Georgia Area - Provisional data

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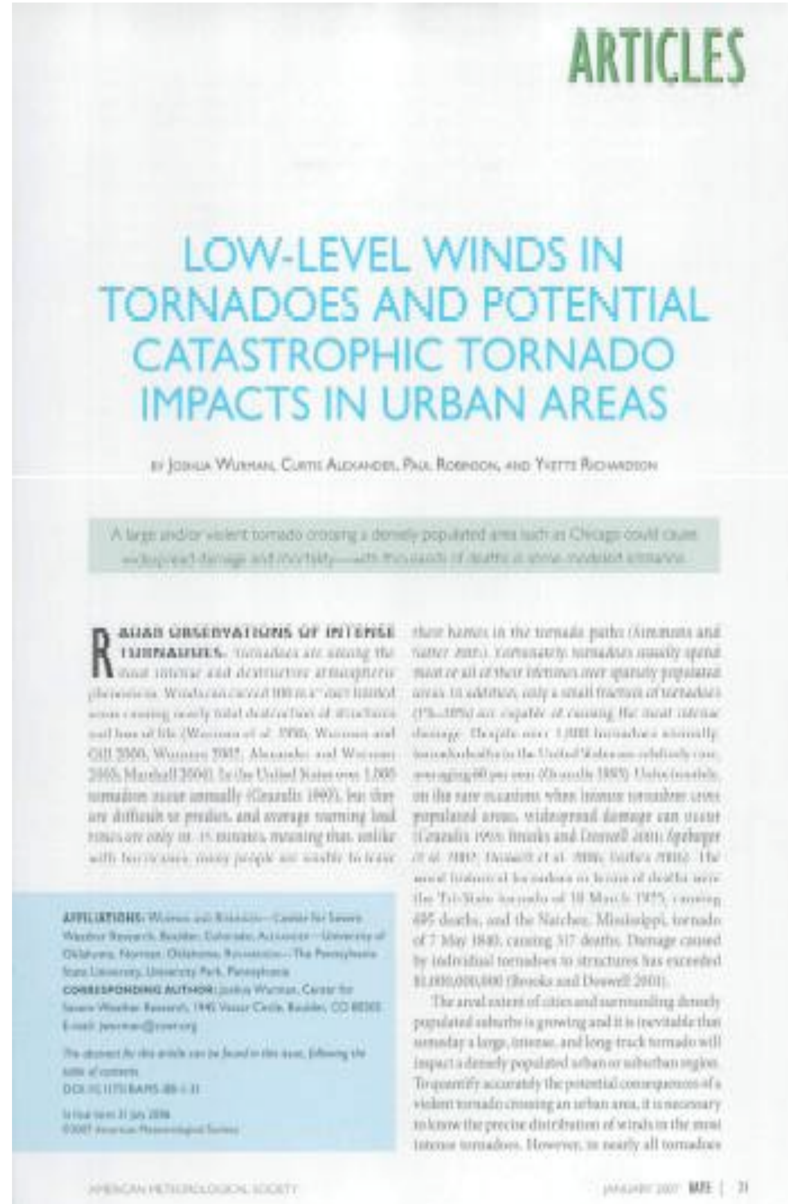
What about Urban Tornadoes?

- Wurman et al. 2007

“The areal extent of cities and surrounding densely populated suburbs is growing and it is inevitable that someday a large, intense, and long-track tornado will impact a densely populated urban or suburban region.”



ARTICLES

LOW-LEVEL WINDS IN TORNADOES AND POTENTIAL CATASTROPHIC TORNADO IMPACTS IN URBAN AREAS

BY JOSHUA WURMAN, CURTIS ALEXANDER, PAUL ROBINSON, AND YVETTE RICHARDSON

Atlanta's Growth: Increases Probability of Urban Tornado (Bigger Dart Board!!!)

1974

2005

Our initial research leads to the question of whether GEMA or the city of Atlanta should re-evaluate urban warnings (e.g. implementation sirens)

Landsat Images: UGA School of Ecology/NARSAL

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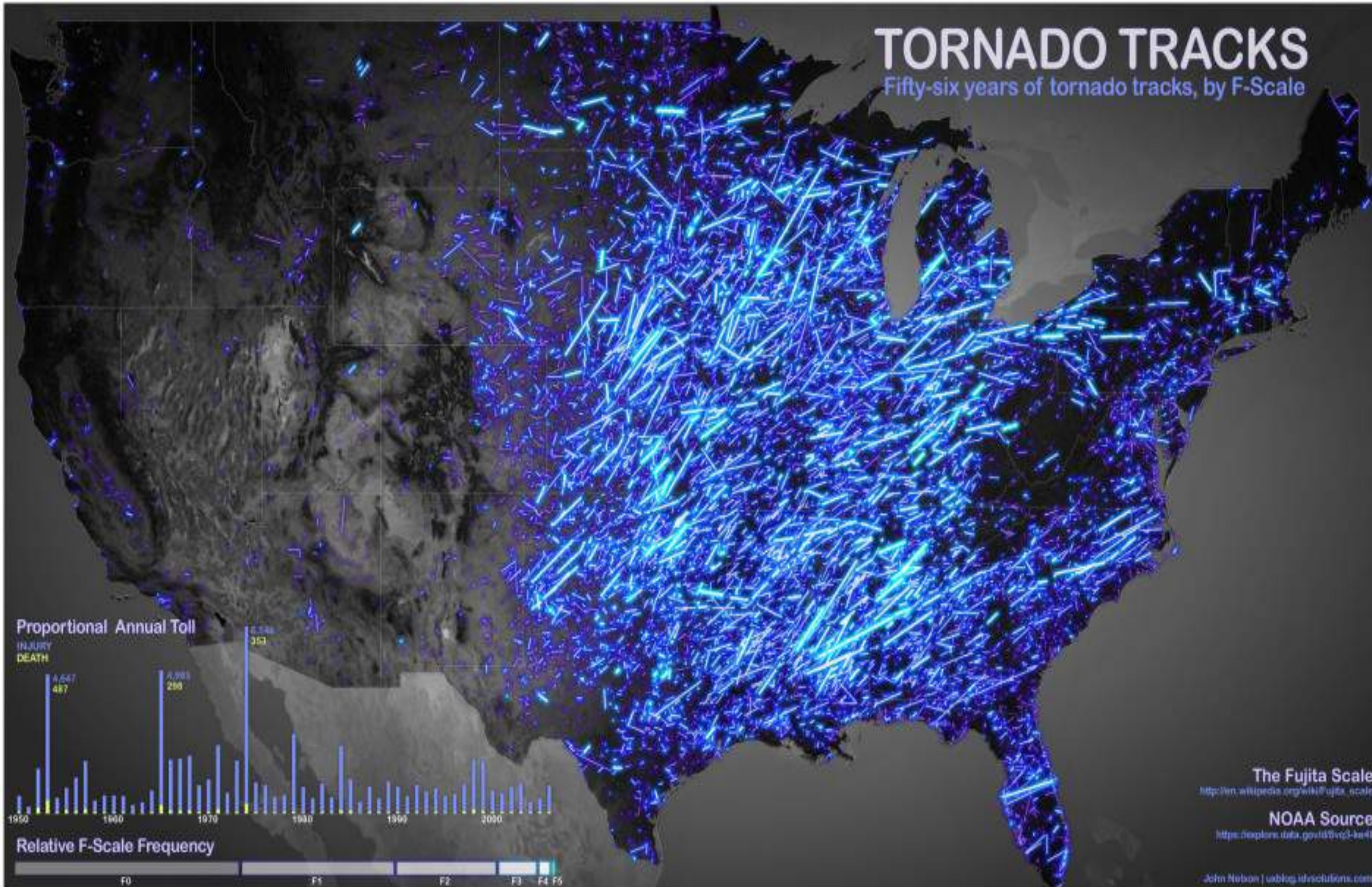
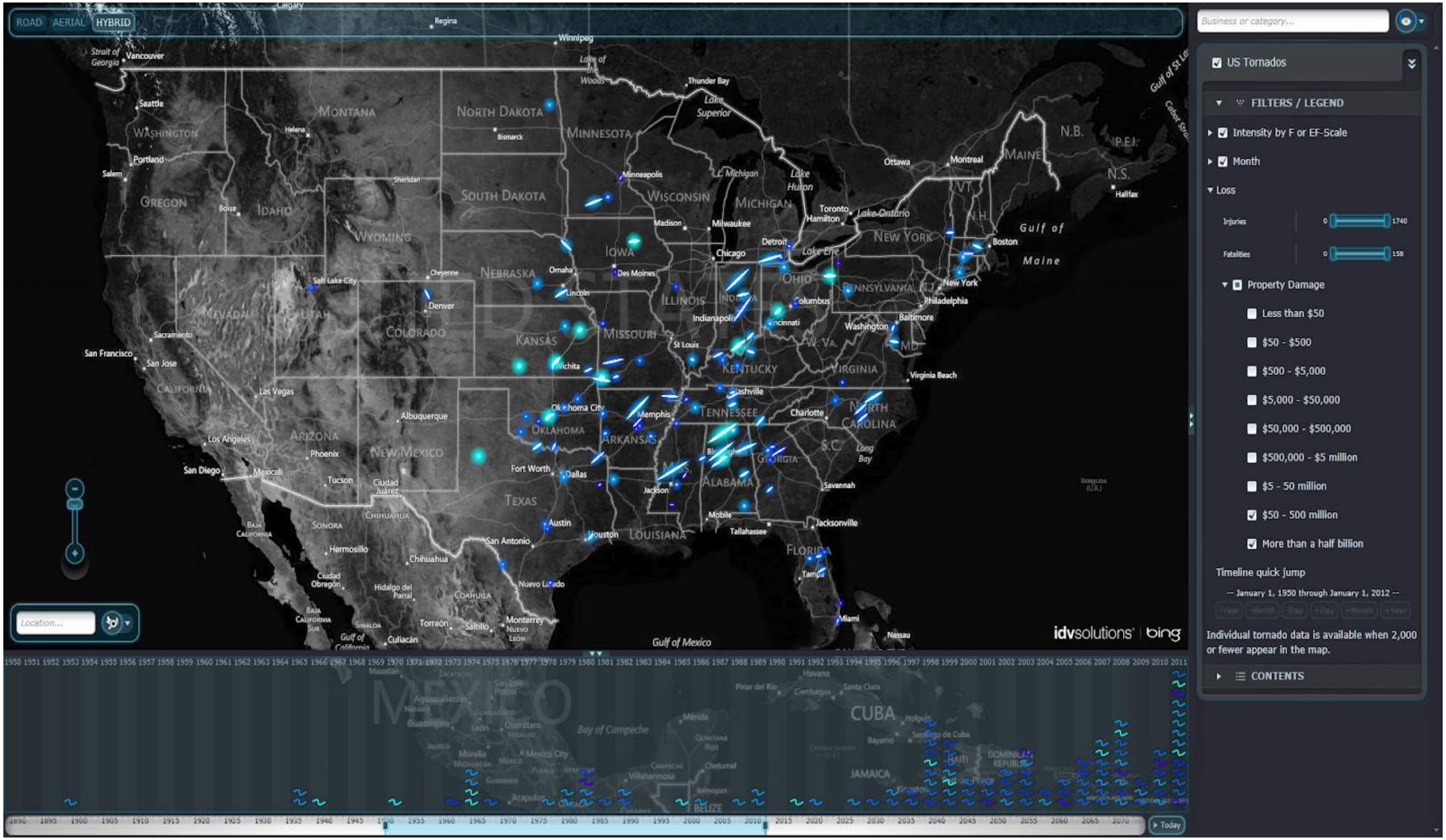
Tornado Tracks, Past 56 years



Here is every tornado that caused more than $50 million in property damage. Urban?



Urban Hospitals are at the Mercy of Extreme Weather and Climate Variability

http://www.earthzine.org/2011/06/28/code-grey-protecting-hospitals-from-severe-weather/

Oh….What About the Atlanta Ice Fiasco, What Can We Learn?

Some Key Recommendations from Gov. Deal Task Force (Full Report: http://gov.georgia.gov/press-releases/2014-04-03/deal-receives-final-winter-weather-task-force-report)

- As climate change/variability drives more extreme weather, better communication of threat is needed
  - Public doesn't understand nuances of watches/warnings/advisories
  - Weather Model forecasts evolve hourly
  - Who is the right source?
- Municipalities need more proactive, pre-emptive engagement for weather climate events in planning, emergency response, resiliency activities, etc.

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Making Urban Climate Science "Actionable"

- National Academy of Science/NRC Report offers insights on how to make applied climatology in the urban environment actionable

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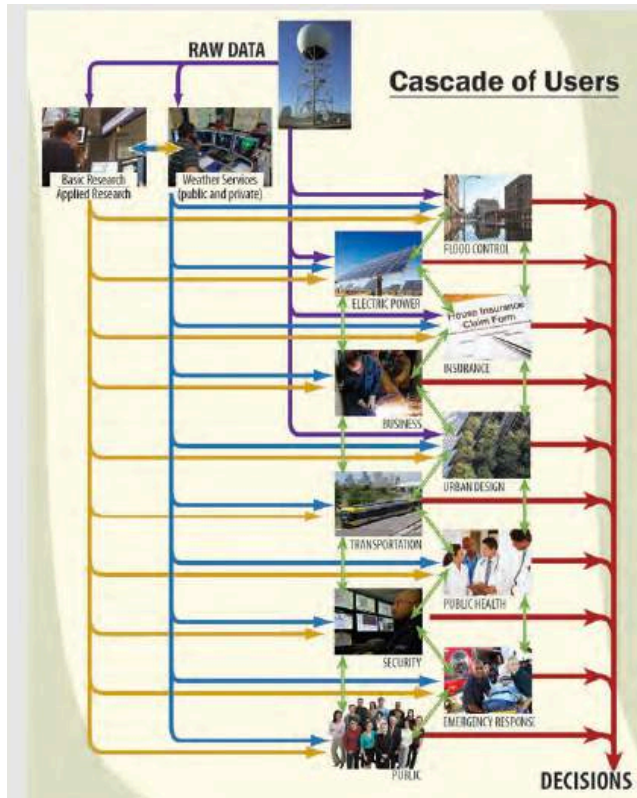

"Cascade of Users" diagram. End users may be viewed as a 'cascade' of inter-connected individuals and groups with varying information needs to make informed decisions.

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End User Unmet Needs

TABLE S.1 Sampling of Specific Unmet End User Data Needs.

Sector	Examples of Unmet Data Needs
Flood Control *(municipal and public safety officials)*	• Rainfall and snowmelt-runoff and storm water datasets • Urban flooding and/or overloading of combined storm water/ sewage systems due to localized precipitation and ability/ inability of urban pervious surfaces to store water • Atmospheric river (i.e., narrow corridors of concentrated moisture in the atmosphere that when striking land can produce hazardous storms) information
Electric Power *(power producers, grid operators, local utilities)*	• Air temperature for assessing energy demands and related loads on the grid • Wind and solar radiation data for renewable energy assessments
Insurance/Reinsurance *(company officials)*	• Accurate and timely forecasting of extreme events • Surface roughness, overland decay, and wind speed
Business *(company officials, public and private service providers)*	• Solar radiation, precipitation, and air quality data for agriculture (e.g. for agricultural regions near and/or impacted by cities) • Canyon-level wind flow (e.g. for construction sector)
Urban Design *(architects, urban planners, municipal officials)*	• Vegetations stress index for cities/optimization • Urban air quality • Assessment of urban heat island mitigation measures such as green roofs and tree planting campaigns • Development of climate change mitigation and adaptation strategies of cities and regions, • More dense array of first order meteorological stations in and around urban areas • Improved methods for assessing the extent to which rural meteorological stations are subject to the impacts of local land use change
Transportation Management *(officials in departments overseeing highways, railroads, airports, harbors, and rivers)*	• Canyon-level wind flow • Precipitation and its form (i.e., rain, freezing rain, sleet or snow) • Representativeness of surface observations • High spatial resolution forecasts (e.g. roadway scale) • Road surface temperatures
Public Health *(health department officials, environmental protection agency officials, air quality management districts, public safety officials, emergency managers)*	• Solar radiation, wind, humidity and air temperature at matching scales for health (e.g., heat indices) • Consistent urban heat island baseline datasets for vulnerability/risk assessments (standardized methods and data) • Spatially explicit datasets that characterize the urban heat island (i.e., further than just surface air temperature measurements; surface skin temperature, air temperature, humidity, wind and radiation data may provide a more comprehensive assessment of "heat") • Heat and cold wave and physical stress forecasts with temporal and spatial resolution at city scale • Street-level air quality • Extreme precipitation event forecasts • Extreme localized heat/cold advisories, disease vector, and air quality advisories

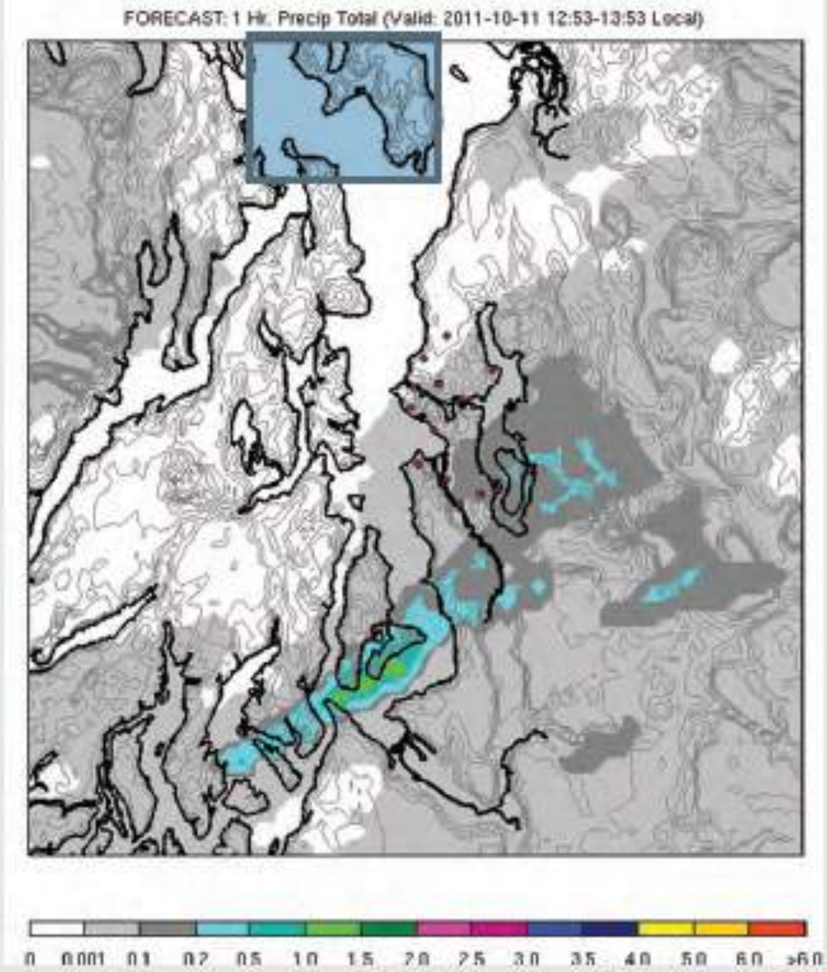
TABLE S.1 Continued

Sector	Examples of Unmet Data Needs
Security *(public safety and security officials)*	• Higher temporal, vertical, and horizontal spatial resolution data (e.g. urban boundary layer structure and mixing layer heights, vertical profiles of winds, turbulence, temperature of particular importance to dispersion applications) • Dual-use leveraging of data from other applications (e.g. radar-derived precipitation calibrated with rain-gauge data for flood predictions) • Regularly updated urban data (e.g. land-use characteristics building footprint data)
Emergency Response *(public and industrial safety officials)*	• Street-level detailed flood information • High spatial and temporal resolution wind, temperature, and moisture data in and above the urban canopy

Example: Tools Utilized by the Seattle Public Utilities

Seattle RainWatch

- a forecasting tool that predicts local rainfall patterns for the next hour and provides 1-to 48-hour rain accumulation totals
- gives SPU a one-hour window to identify which neighborhoods in the city will experience the highest rates of rainfall.
- Key operators, managers, and crews receive maps generated from Seattle RainWatch to help them quickly identify where resources should be deployed to ensure storm drains are clear and citizens are alerted (see figure below).



Example of a 1-hour RainWatch forecast (total precipitation expected in inches)
SOURCE: James Rufo Hill, Seattle Public Utilities, *http://www.atmos.washington.edu/SPU/*

Final Thoughts: Communicating Urban Weather/ Climate Hazards

- Cross-disciplinary teams that include natural scientists, decision scientists, social and communications specialists and other experts. (Fischhoff and Pidgeon)
  - People respond to warnings differently
  - Language and Intellect Barriers
  - Capacity to Respond
- Rather than avoiding communicating uncertainty altogether, science communicators should make an effort to understand beliefs held by the recipients of their messages. (Rabinovich 2012)
- Rather than simplifying and reframing scientific messages in an attempt to make them accept able for the general public, communicators might consider shaping their audience's under standing of what science actually is (Rabinovich 2012)
- People are able to make better decisions using probabilities. People make the best decisions when they are given more detailed information on forecast uncertainty (UK Met Office)
- Market Hype and Recent History (Recent DC Derecho, Tornadoes)
- Perception of One Threat vs Another (Tornado, Flood, etc.)