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Extreme Weather Events in the United States: Trends and Projections

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National Symposium on Extreme Weather Event Impacts on Transportation infrastructure

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What is an Extreme Event??

"Researchers use different definitions depending on which characteristics of extremes they are choosing to explore at any one time, in the context of the particular issue they are studying."

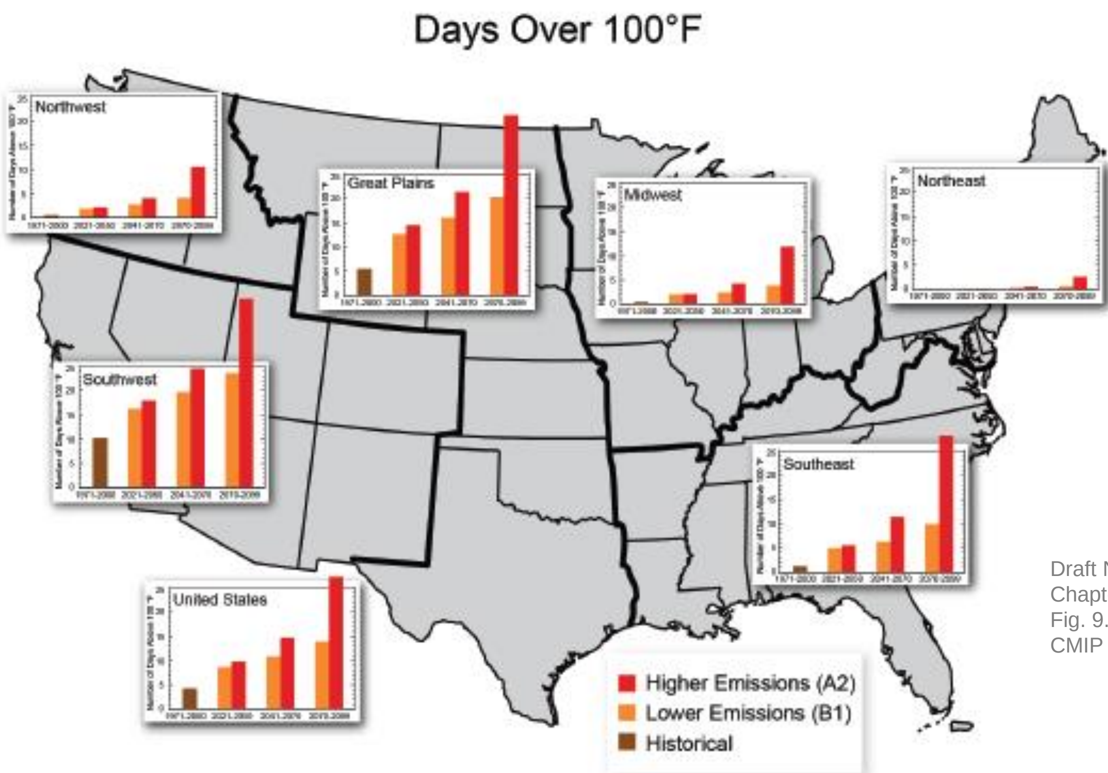
Draft of the National Climate Assessment (Jan. 2013)

"… To conclude, there is no precise definition of an extreme …"

IPCC, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX, 2012)

What is an Extreme Event??
Imprecise definitions

- **Extremes can be based on a threshold and/or a distribution**



Draft National Climate Assessment
Chapter 9 – Human Health
Fig. 9.7
CMIP 3 downscaled output

Extremes can be defined by a specific value (which is often a "round number").

Example terminology:

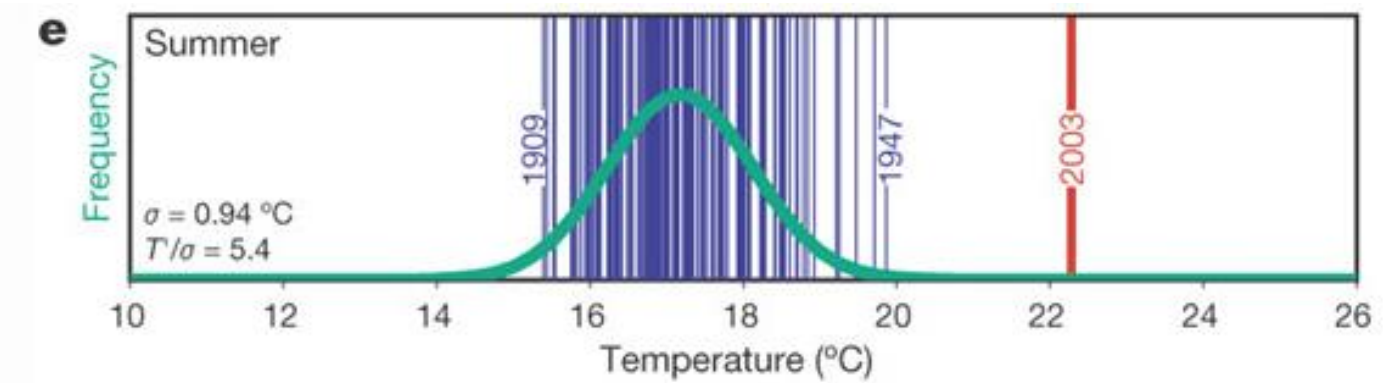
- *"Days exceeding of 100°F"*
- *"Hurricane" (sustained winds > 64mph)*
- *"EF5 Tornado" (wind speed >200mph)*

Thing to keep in mind:

- An "extreme" in one place may not be thought of as "extreme" in another

What is an Extreme Event??
Imprecise definitions

- **Extremes can be based on a threshold and/or a distribution**



Schär et al., *Nature* **427**, 332-336 (22 January 2004) ; Swiss temperature 1864-2003

Extremes can be defined based on the statistical distribution of observations that express some measure of probability.

Example terminology:

- *"5th percentile"*
- *"2 standard deviations"*
- *"1-in-100 event"*

Things to keep in mind:

- Can be tailored to a location
- Is dependent on a base period

For any definition of extremes…

- **Spatial scales are important**

  Looking at a small area (like a town or city) introduces “noise” into climate records…trends are less likely to be present/detectable

- **Timescales are important**

  Extremes can be identified at any timescale (e.g., hourly, daily, seasonal).

  Extremes on a short timescale may involve different processes than extremes on a longer timescale (ex: increases in heavy rainfall do not always correspond to wetter seasons)

- **Events may not be short or discrete in time**

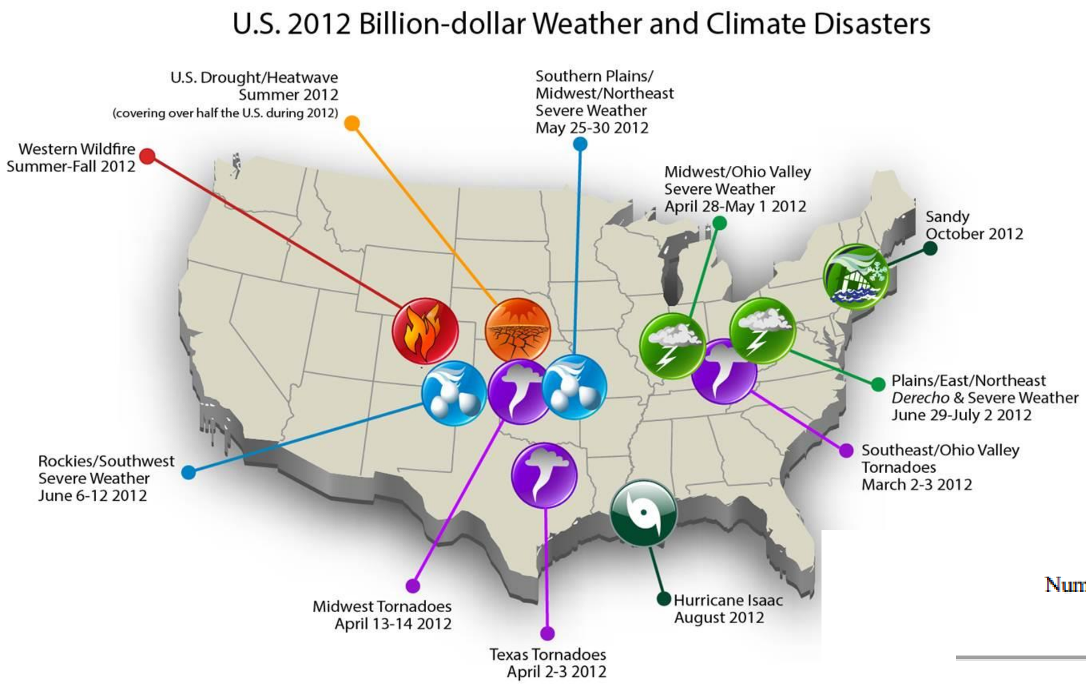
  Wildfires can last for days/weeks; snow or ice conditions can persist for days/weeks/months; droughts can last for month/years

- **Many indices and approaches exist**

  Indices are common. Methods can range in complexity (e.g., picking a threshold vs. applying Generalized Extreme Value theory)

- **Extremes may or may not relate to impacts (!)**

Extreme Events are costly



NOAA NCDC; http://www.ncdc.noaa.gov/billions/summary-stats

	Number of Disaster Events	Adjusted Damages ($ Billions)	Percent Damage	Percent Frequency
Tropical Cyclones	31	417.9	47.4%	23.3%
Droughts/Heatwaves	16	210.1	23.8%	12.0%
Severe Local Storms	43	94.6	10.7%	32.3%
Non-Tropical Floods	16	85.1	9.7%	12.0%
Winter Storms	10	29.3	3.3%	7.5%
Wildfires	11	22.2	2.5%	8.3%
Freezes	6	20.5	2.3%	4.5%
Total	133	881.2	100.0%	100.0%

Table 1 Damage, percent damage, frequency, and percent frequency by disaster type across the 1980-2011 period for all billion-dollar events (adjusted for inflation to 2011 dollars)

Smith and Katz, *Natural Hazards*, June 2013, Volume 67, Issue 2, pp 387-410

Extreme Events in the United States

Extreme Events in the U.S.

A 30,000-foot view of:

- **Heat waves**
- **Heavy rainfall, flooding, and sea level rise**
- **Drought and wildfires**
- **Wind events: tropical storms, tornadoes, and strong storms**
- **Snow and ice?**

Heat Waves

National and Regional Trends Regional Trends	Implications	Projections
Nationally-averaged, more frequent high temperatures and heat waves Many recent record-breaking hot summers Strongest trends in West, less warming in SE	Limitations on construction hours Vehicle overheating Electrical system malfunctions and brownouts Loss of pavement integrity Rail buckling Air traffic slowdowns	Increases in severity and intensity in all regions

Warm extremes are outpacing cold extremes

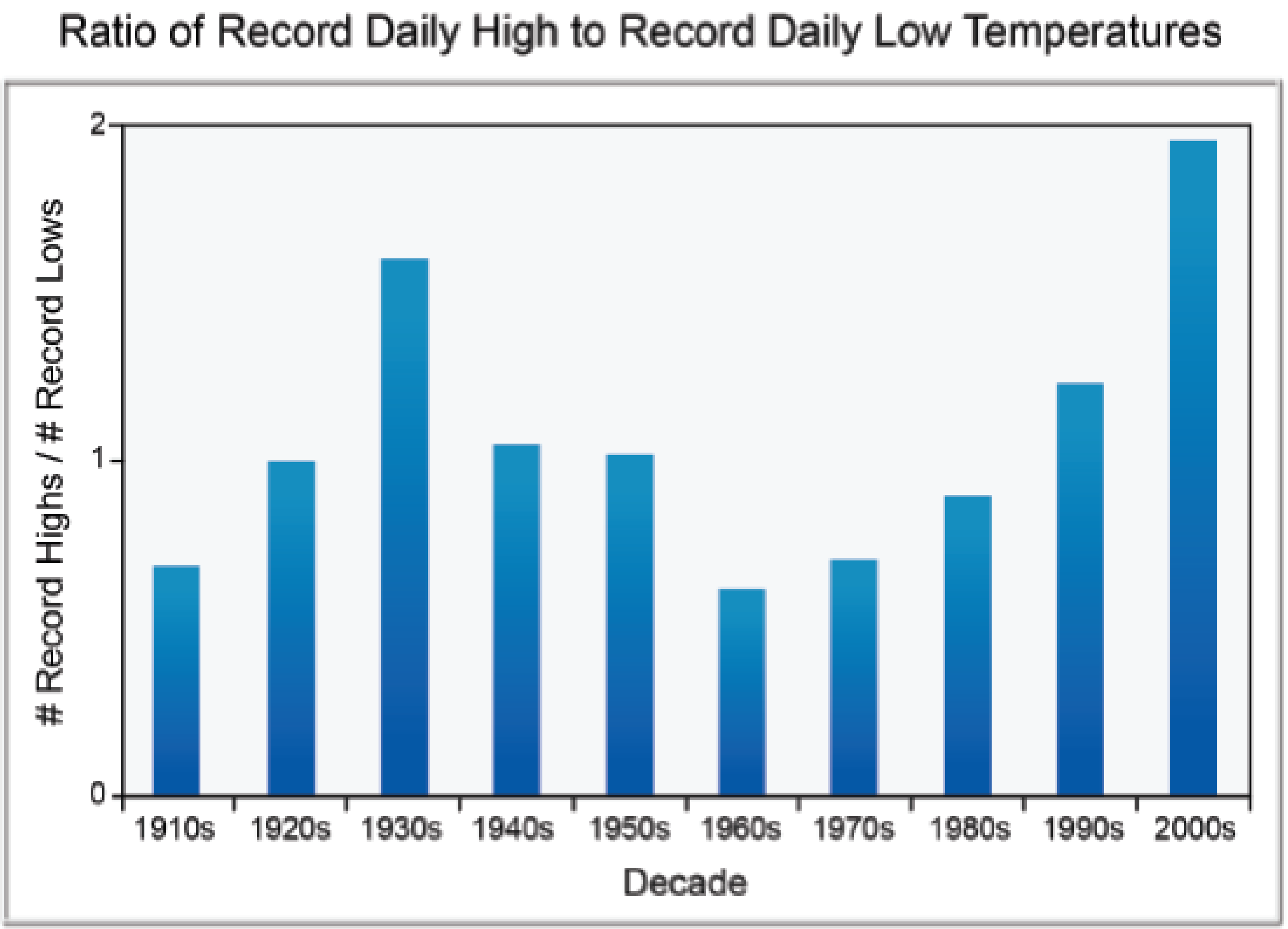


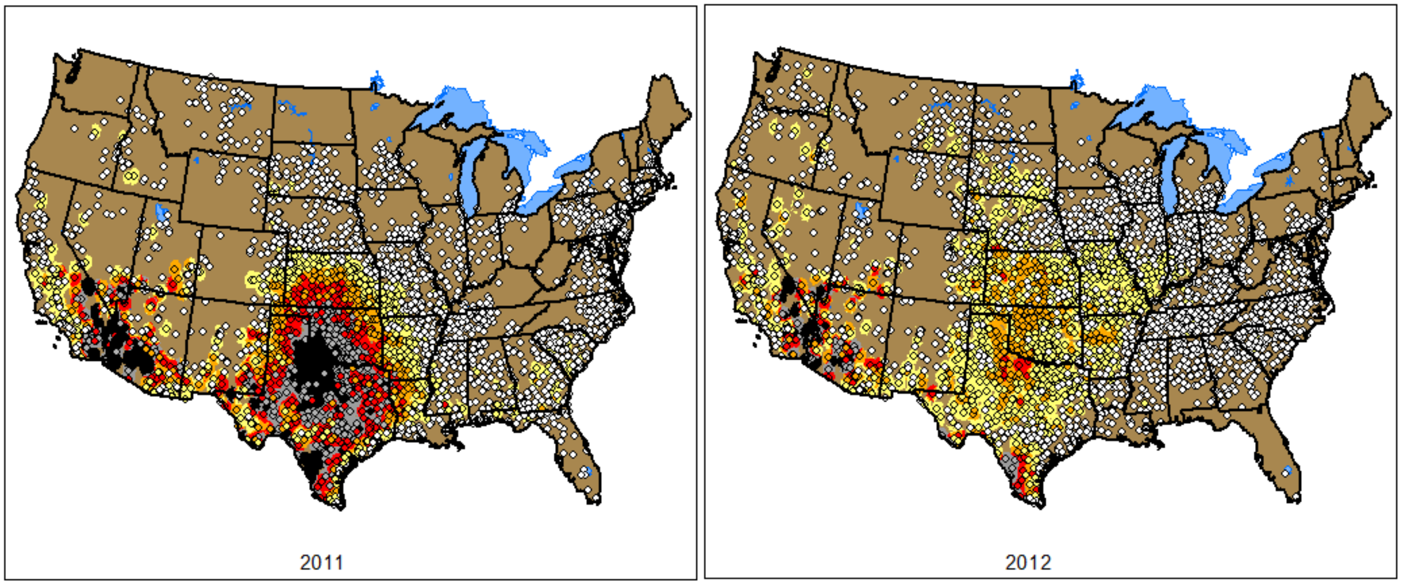
Figure 2.18: Ratio of Record Daily High to Record Daily Low Temperatures

Recent sweltering summers

Comparison of Summers

Number of Days Maximum Temperature ≥ 100°F

June 1 - August 31



Number of Days Max Temperature ≥ 100°F

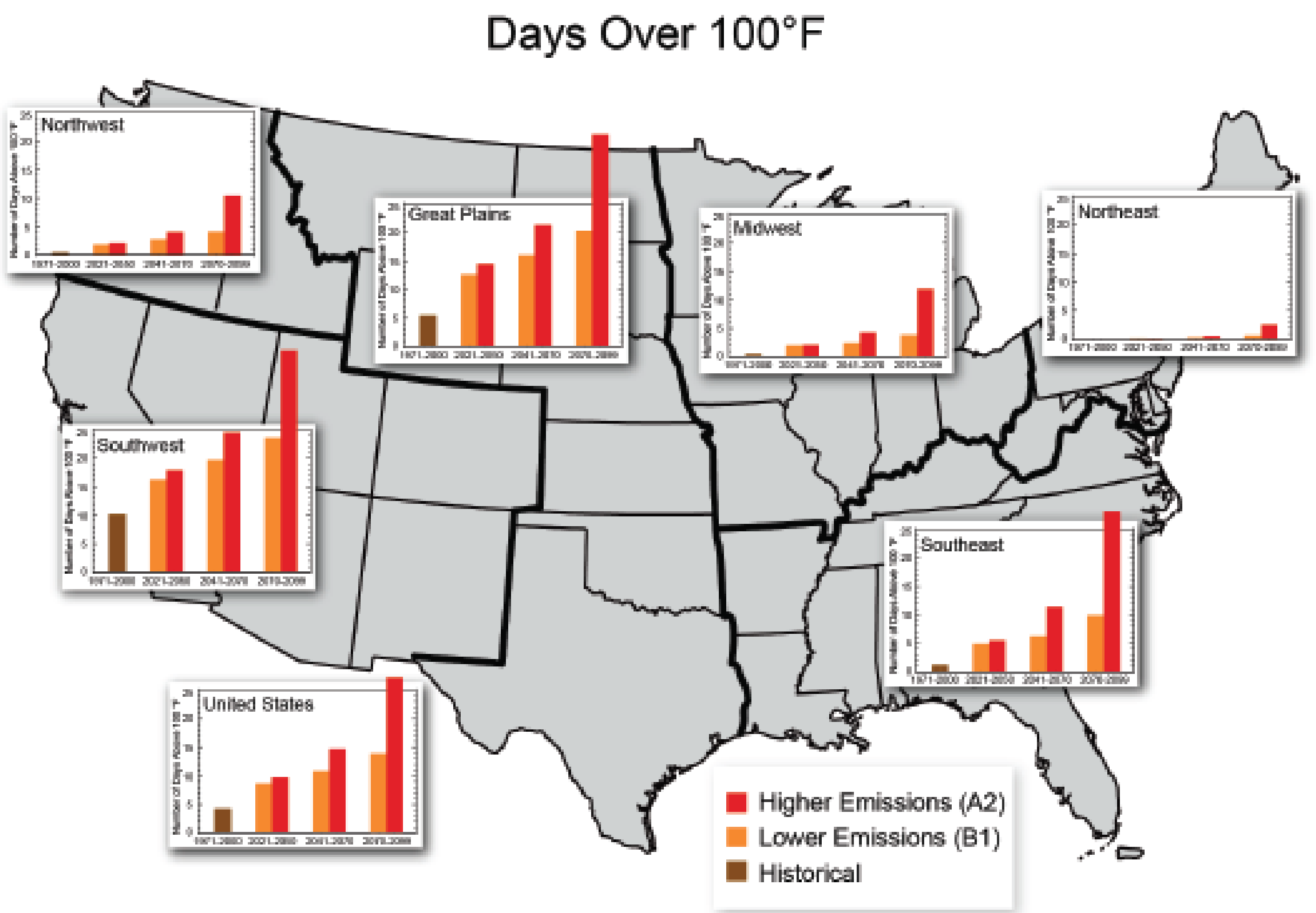
- 1 - 10
- 10 - 25 / 10 - 25
- 25 - 40 / 25 - 40
- 40 - 55 / 40 - 55
- 55 - 70 / 55 - 70
- > 70 / >70

	2011	2012
Total number of stations in analysis	2989	3518
Total number of stations with at least 10 days that met or exceeded 100°F	1283	1342
Station with the most number of 100°F days	Laredo AP, TX (90 of 92 days)	Maricopa, AZ (86 of 92 days)
Population affected by 10 or more 100°F days	>70 Million	>80 Million

Data only includes 60 or more non-missing days. 2012 data is preliminary.
A more complete analysis will follow once additional stations have been processed.
Population data (2010 census) is based on the number of people within 20 miles of a station.
Last updated: September 4, 2012

NOAA's National Climatic Data Center

Projections for Extremely Warm Days



Heavy Rainfall, Flooding, and Sea Level Rise

National and Regional Trends Regional Trends	Implications	Projections
Increases in heavy rainfall, esp. in East and Midwest	Increased erosion along rivers and coasts	Increase in heavy rainfall across all regions; but flooding responses are not always in lock-step
Riverine streamflow records show both increases and decreases in flooding	Loss of soil integrity and landslides	Sea level rise will exacerbate coastal storm surge and flooding
Many coastal areas are experiencing frequent/severe flooding	Roadway/railbed washouts	Changes in snow hydrology will continue to alter streamflow patterns
In many Western locations, changes in snow accumulation and snowmelt alters the timing of peak flows	Sewage overflows	

Trends in Heavy Rainfall

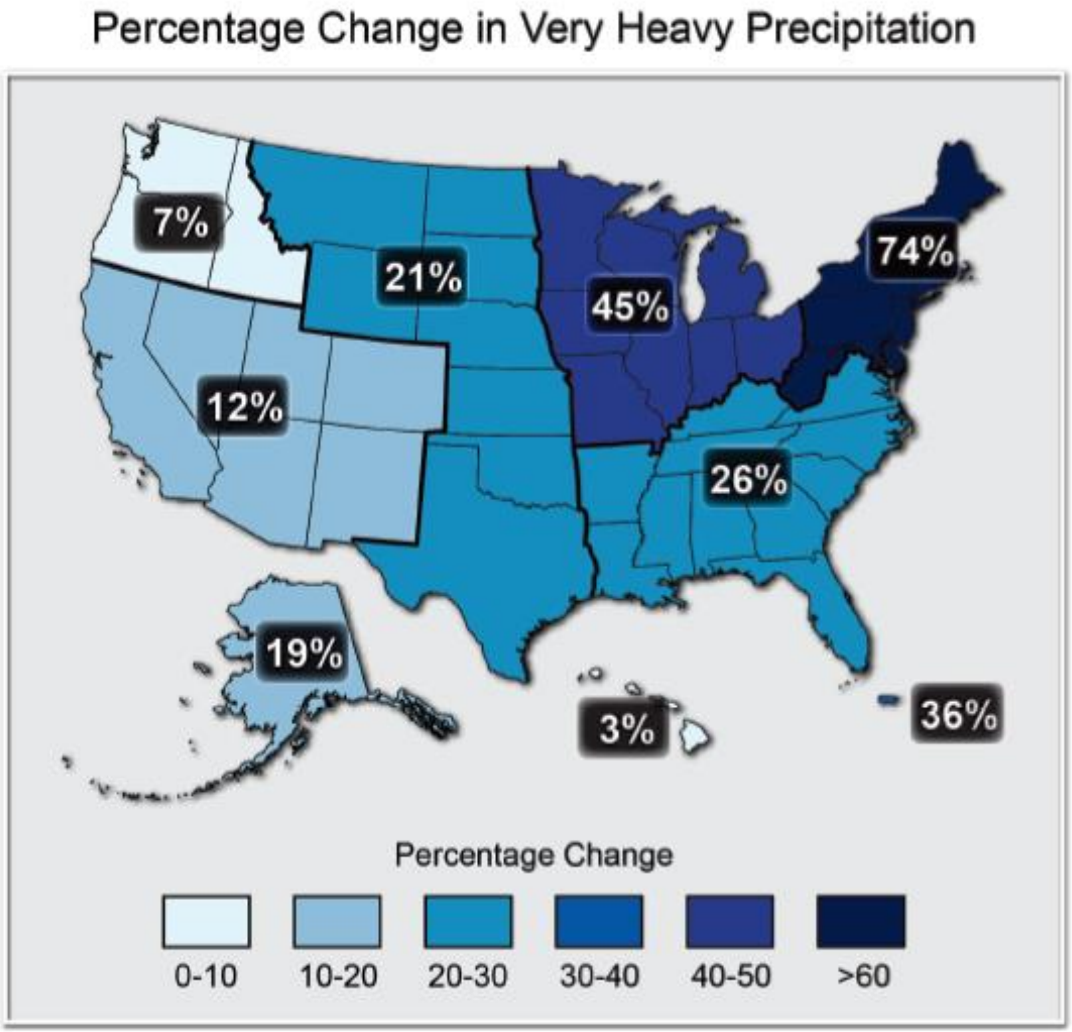


Figure 2.16: Percentage Change in Very Heavy Precipitation

Draft National Climate Assessment
Chapter 2– Figure 2.16

Trends in Flooding

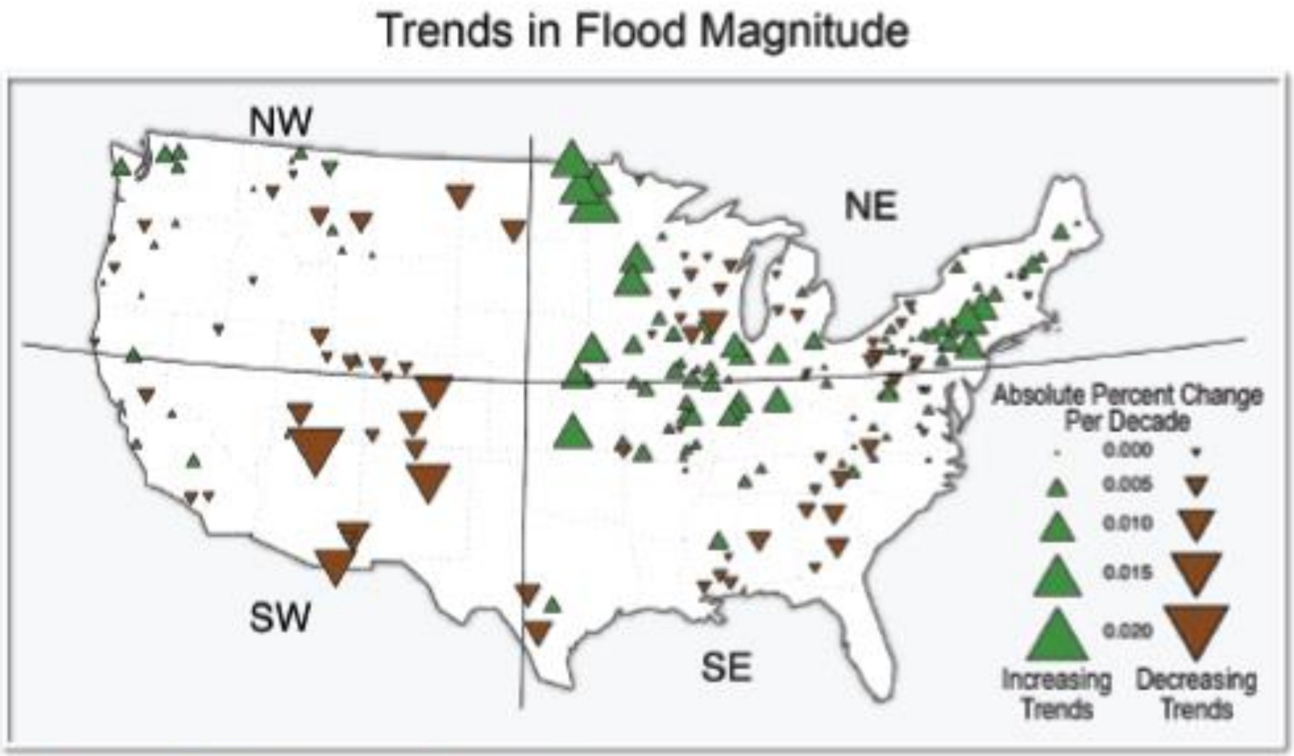


Figure 2.20: Trends in Flood Magnitude

Caption: Trend magnitude (triangle size) and direction (green = increasing trend, brown = decreasing trend) of annual flood magnitude from the 1920s through 2008. (Source: Hirsch and Ryberg 2012).

Projections for Heavier Big Downpours

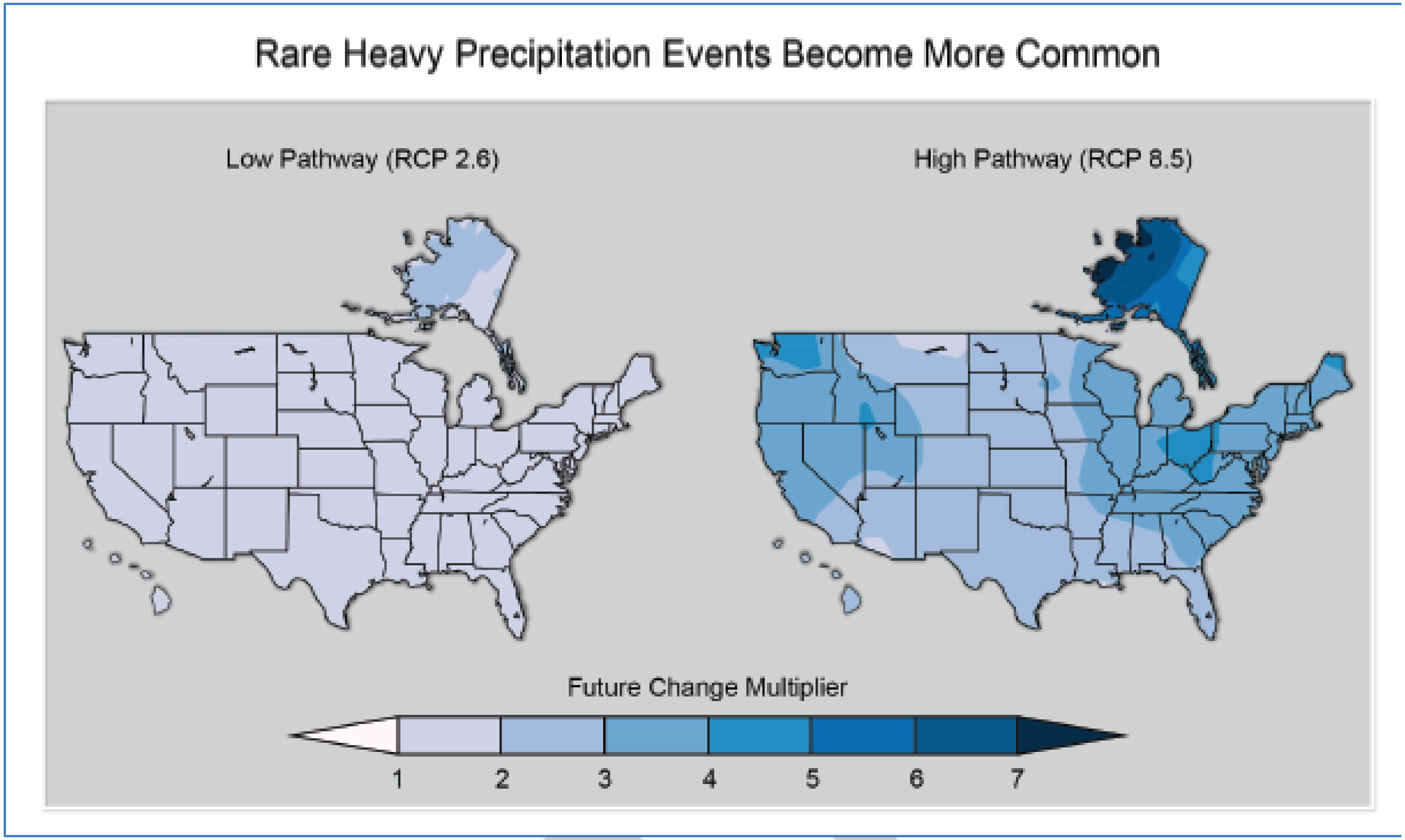


Figure 2.17: Rare Heavy Precipitation Events Become More Common

Draft National Climate Assessment
Chapter 2– Figure 2.17

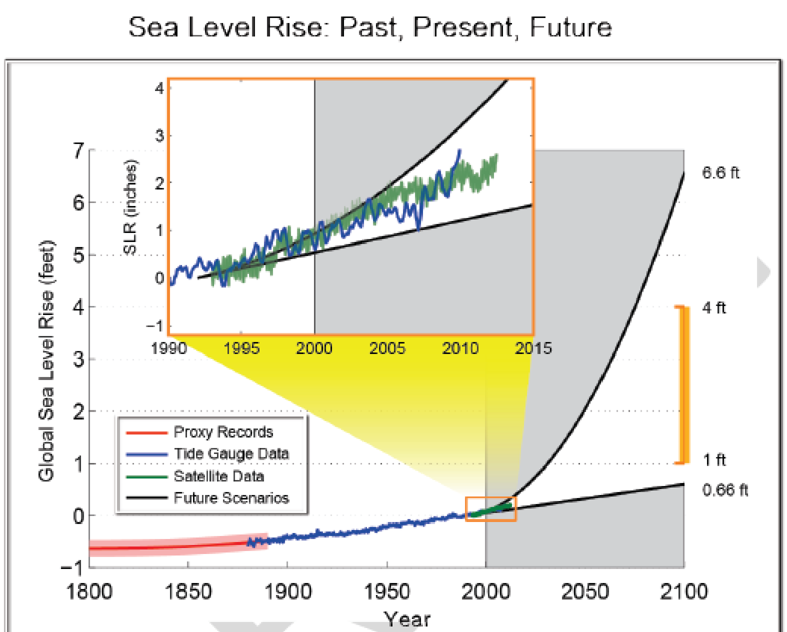
Sea level rise has allowed/will allow smaller coastal storms to cause greater flooding

Sea Level Trends

mm/yr (feet/century)

15 to 21 (5 to 7)	6 to 9 (2 to 3)	-3 to 0 (-1 to 0)	-12 to -9 (-4 to -3)
12 to 15 (4 to 5)	3 to 6 (1 to 2)	-6 to -3 (-2 to -1)	-15 to -12 (-5 to -4)
9 to 12 (3 to 4)	0 to 3 (0 to 1)	-9 to -6 (-3 to -2)	-18 to -15 (-6 to -5)

http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml



Draft National Climate Assessment
Chapter 1– Figure 1.2

Drought and Wildfire

National and Regional Trends Regional Trends	Implications	Projections
Country as a whole has gotten slightly wetter, led by Northern areas. Southwest has gotten slightly drier.	Low lake and river levels can slow/halt navigation	Droughts expected to be exacerbated by higher temperatures
No strong drought trends; periods of intense drought have periodically occurred in different regions	Wildfires can reduce visibility and air quality	Decreases in rainfall in the Southwest expected to increase frequency/severity of drought
More area burned in wildfires (management likely plays a role)	Wildfires can close roads and railways	Wildfires expected to be more extensive and severe

Droughts – no true national trend

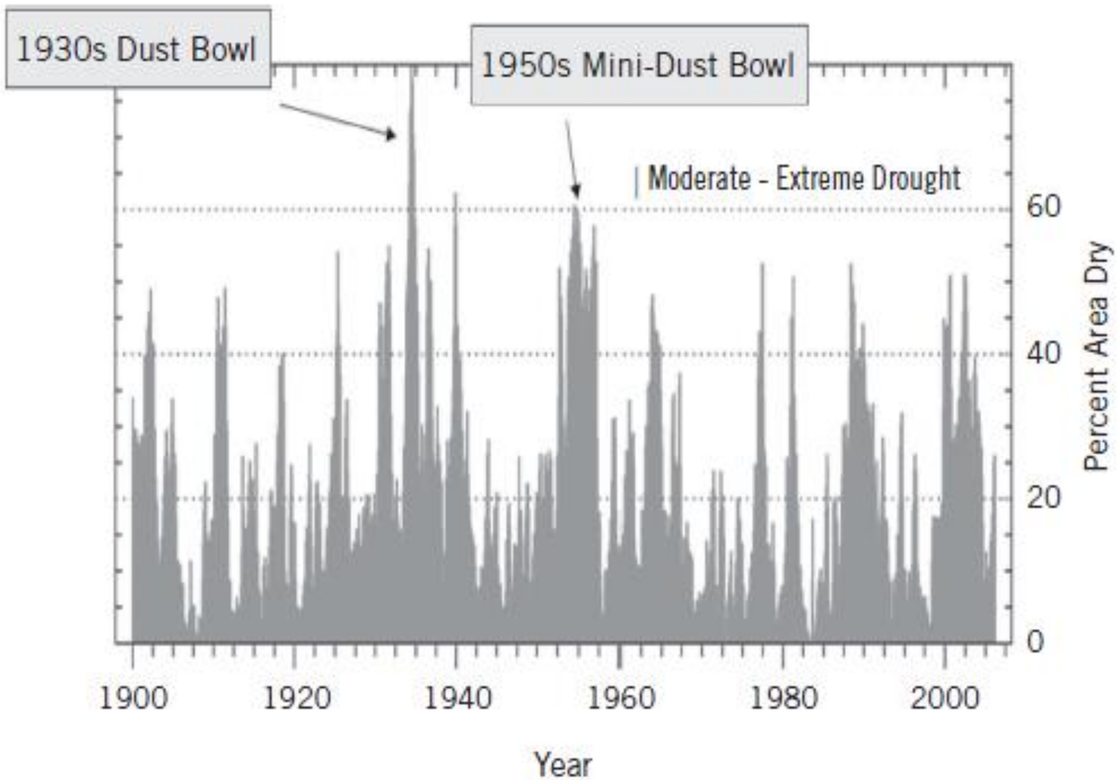
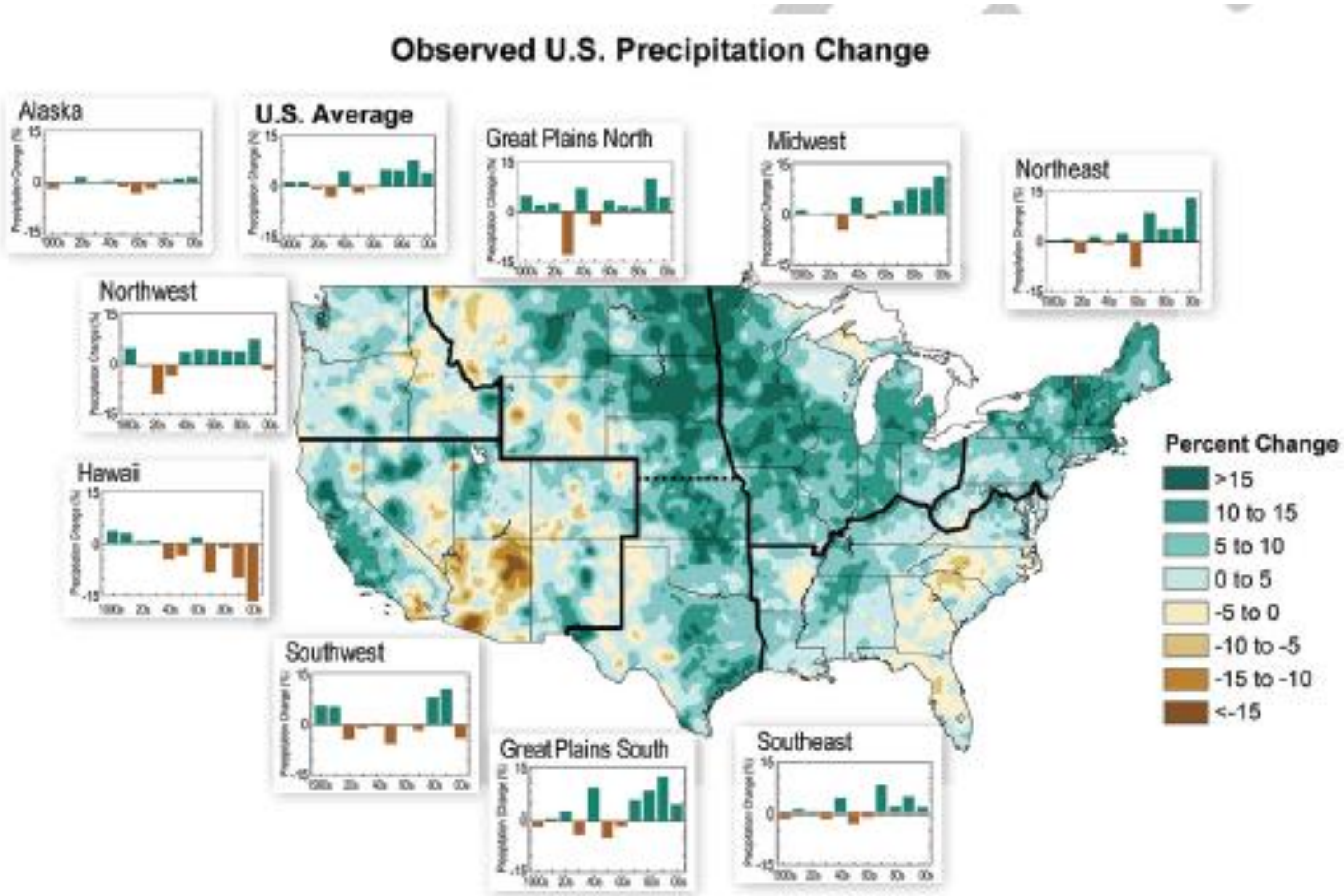


FIGURE 2-14 **Percentage of the contiguous U.S. land area in moderate to severe drought, January 1900–March 2006, based on the Palmer Drought Index.** (*Source:* NOAA, National Climatic Data Center.)

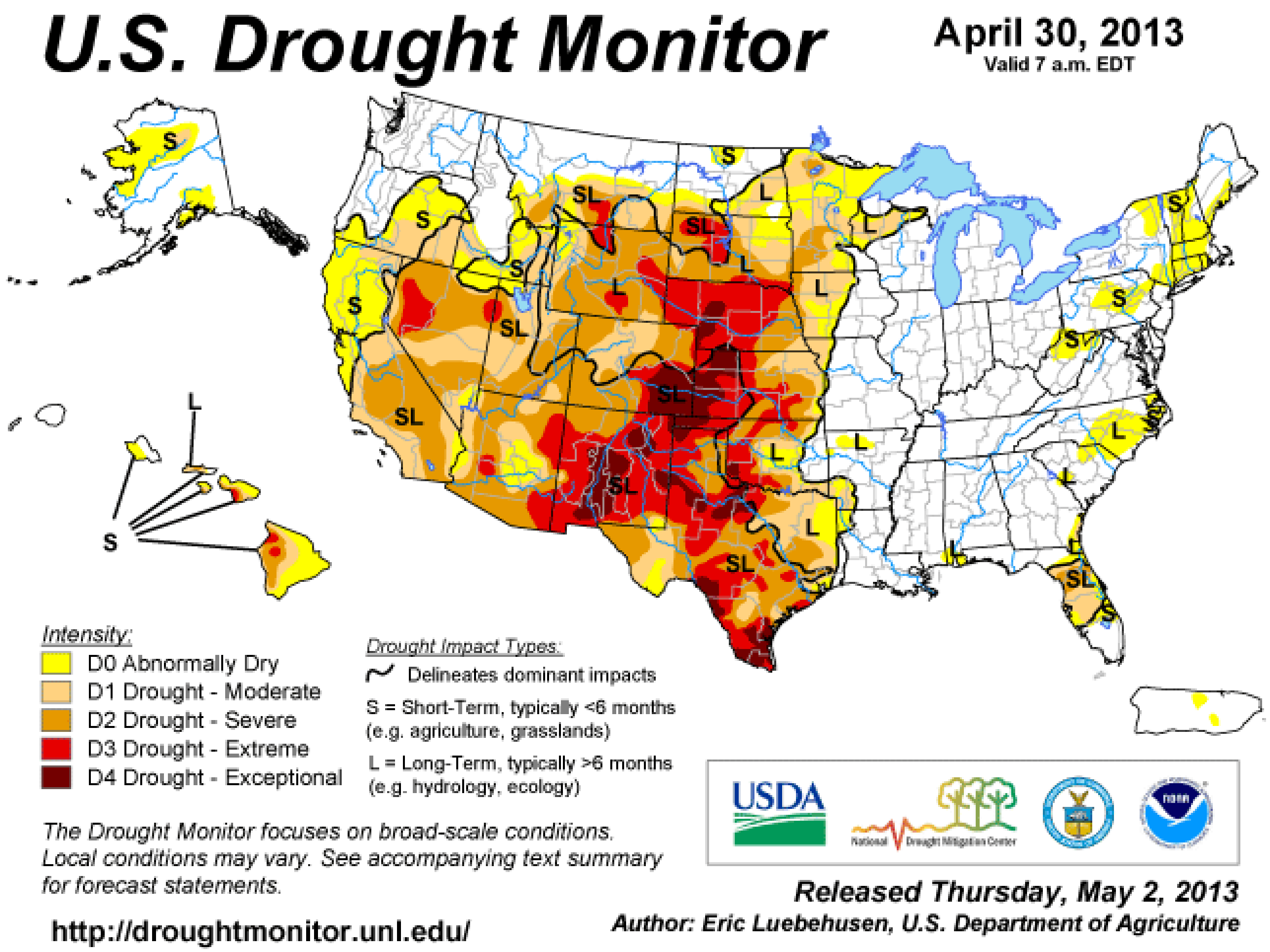
National Research Council
Potential Impacts of Climate Change on US Transportation: Special Report 290 (2008)

Observed changes in precipitation

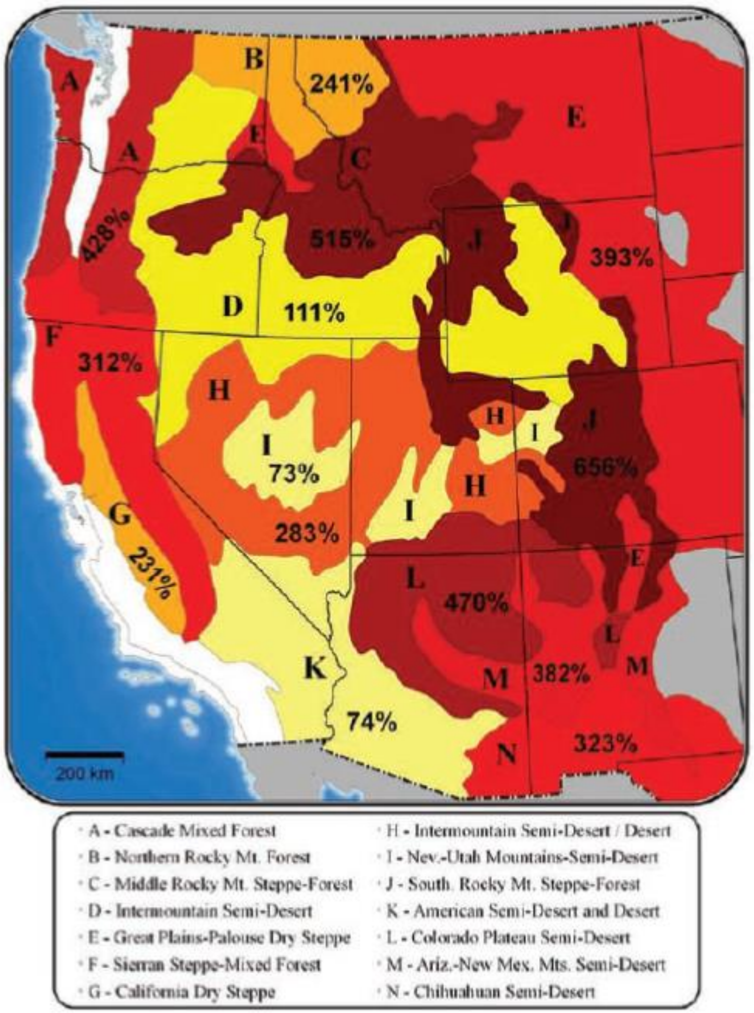


Draft National Climate Assessment
Chapter 2 – Figure 2.11

2011 and 2012 droughts have been/are significant



Wildfires



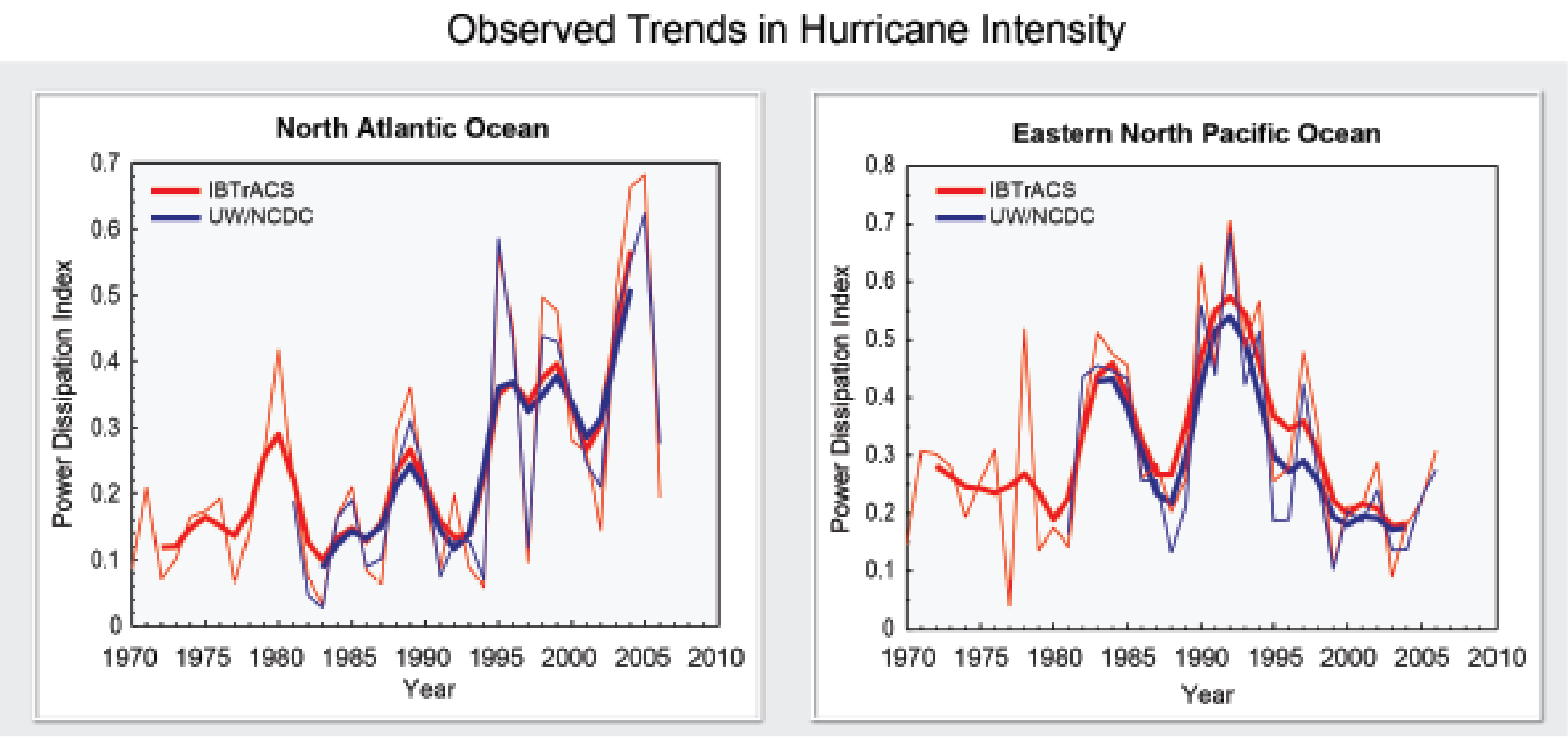
National Research Council
Climate Stabilization targets: Emissions, Concentrations, and Impacts over Decades to Millenia (2012)

FIGURE O.6 Percent increase (relative to 1950-2003) in median annual area burned for ecoprovinces of the West with a 1°C increase in global average temperature. Changes

Wind Events: tropical storms, tornadoes, and strong storms

National and Regional Trends Regional Trends	Implications	Projections
Tropical storms have become more intense in the Atlantic basin No clear trend or clear mechanism for changes in thunderstorms and tornadoes No clear/strong trends in overall storminess; evidence that storm tracks are shifting northward through the Northern Hemisphere	Damage to infrastructure can affect transportation networks (and other supporting networks, like electricity) Near coasts, storm surge can lead to flooding	Atlantic tropical storms expected to become more intense, but potentially less frequent Considerable uncertainty regarding the magnitude and direction of changes (if any) in overall storminess or thunderstorms/tornadoes

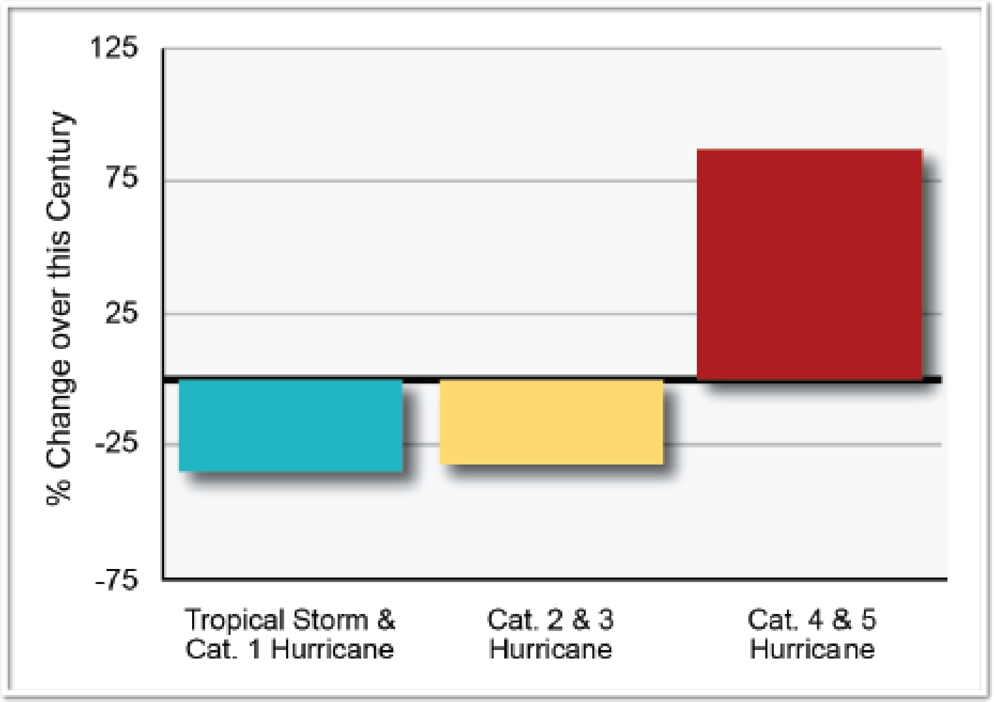
Recent uptick in Atlantic tropical storm activity



Draft National Climate Assessment
Chapter 2 – Figure 2.23

Tropical storms are expected to be more intense, but potentially less frequent

Projected Changes in Atlantic Hurricane Frequency by Category



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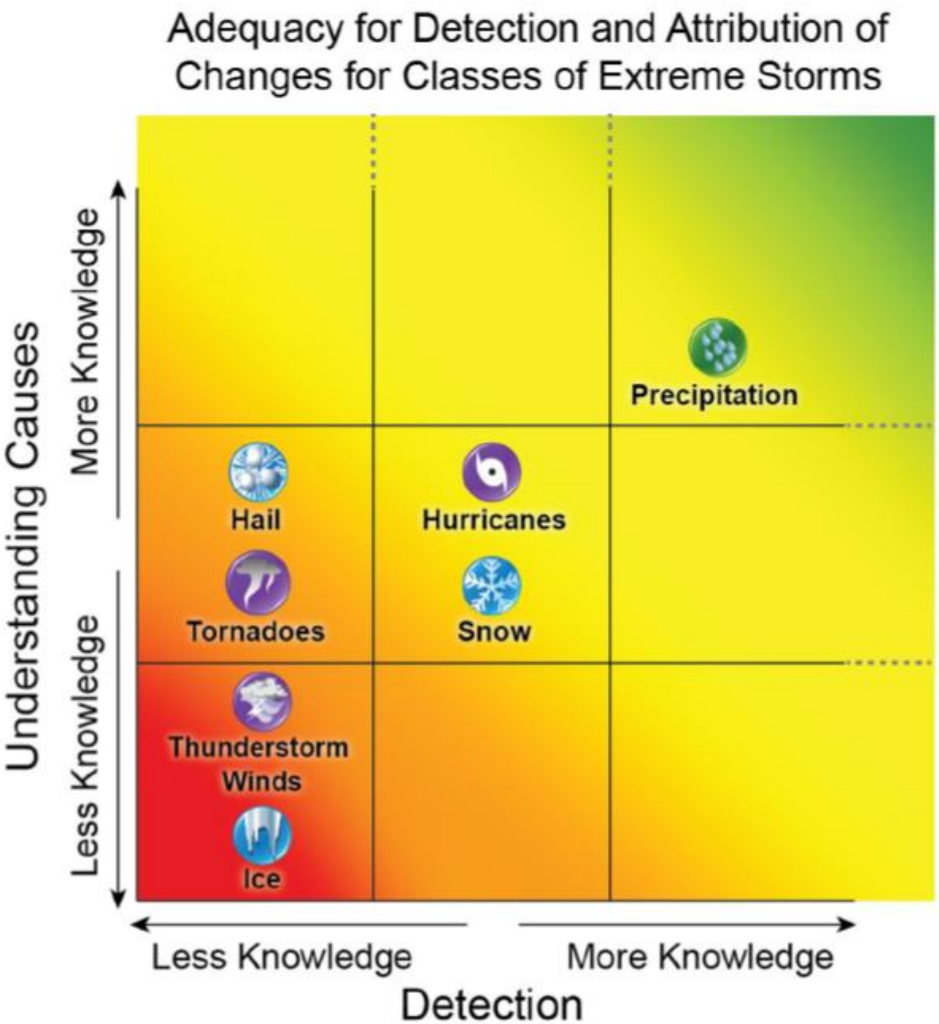
Draft National Climate Assessment
Chapter 2 – Figure 2.24

Snow/Ice?

- Trends in snowfall and icy precip are often weak/not statistically significant
- Areas often near freezing are likely to be warmer, and see less frozen precip.
- Regional circulation patterns determine winter weather; the impact of climate change on these patterns is uncertain



Kunkel et al., 2013, BAMS, **94** *(4)*, pp499-514

Putting knowledge into practice

- **How has your system been affected by extreme weather?**

  - Anecdotal evidence can be a critical first step to thinking about future issues

  - Quantitative evidence can be a useful tool for planning and prioritization

Informal
- Personal experience
- Discussions with key staff
- Workshops

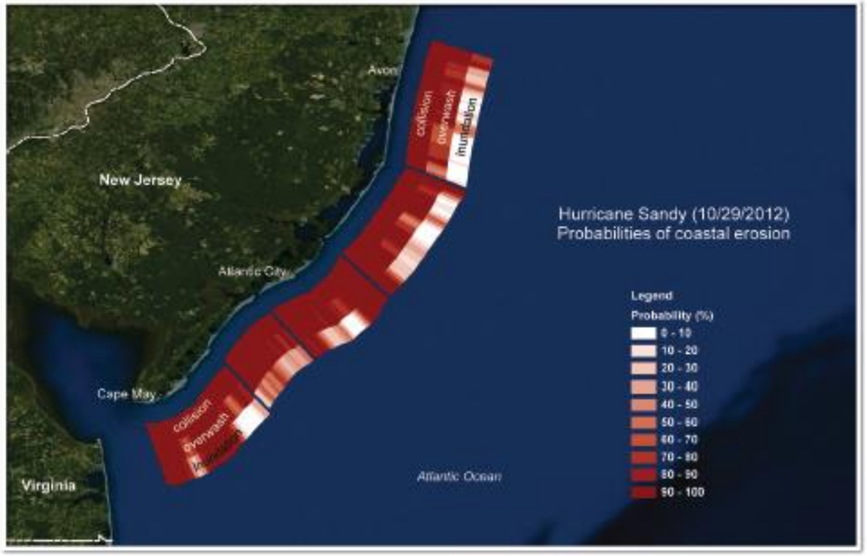
More formal
- Labor/repair tracking
- FEMA reimbursement accounting
- Asset management systems

- **It's difficult to use information about past or future climate if you can't answer this! Understanding your sensitivity can be more important than knowing the future climate**

Sensitivity will depend on MANY factors, and will change over time

- **Land use affects almost all impacts (ex: heat islands, impervious surfaces, presence of natural or built flood protection)**
- **Population growth and demographic shifts can affect how impacts play out, since they relate to service use and needs**

Coastal Flooding Along New Jersey's Shore



- **You may inherit other systems' sensitivities (ex: electricity, water)**
- **Disasters (and disaster response) can affect sensitivity**

Draft National Climate Assessment
Chapter 16 – Figure 16.5

Takeaways

- For heat, heavy rainfall, and coastal flooding, we have evidence that things have changed; strong evidence that they will grow in frequency and severity.
- We will continue to experience extreme events. Climate change may exacerbate some of their impacts.
- Details about future circulation patterns that affect local storminess remain uncertain.
- Sensitivity information about your assets/services is critical to using climate information effectively.

Takeaways

- At the local scale, climate is just one factor to consider…but ignoring the range of past climate variability, recent trends, and projected changes could put assets at risk.
- The status quo often provides an estimate for the costs of inaction.
- Uncertainty related to weather and climate can motivate building resilience to all sorts of shocks. Strategies include fortifying, monitoring, hedging, and establishing redundancy.

Resources

- **Draft National Climate Assessment: http://ncadac.globalchange.gov/**
- **IPCC Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: http://ipcc-wg2.gov/SREX/**
- **Potential Impacts of Climate Change on US Transportation: Special Report 290: http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf**
- **NRC Stabilization report: http://www.nap.edu/catalog.php?record_id=12877**
- **NOAA sea level trends: http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml**

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FOR MORE INFORMATION

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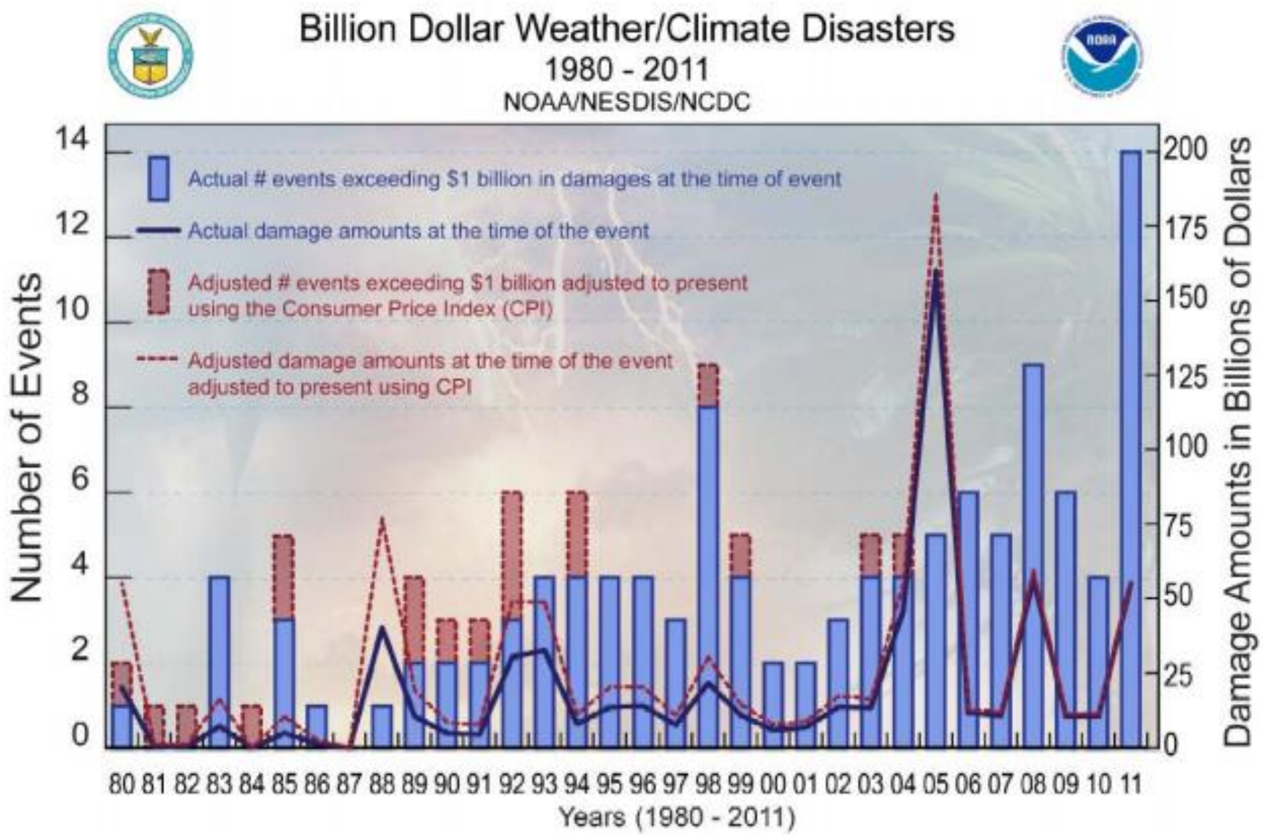

Fig. 1 US Billion-dollar Weather and Climate Disaster time series from 1980-2011 indicates the number of annual events exceeding $1 billion in direct damages, at the time of the event and also adjusted to 2011 dollars using the Consumer Price Index (CPI)

Smith and Katz, *Natural Hazards,* June 2013, Volume 67, Issue 2, pp 387-410

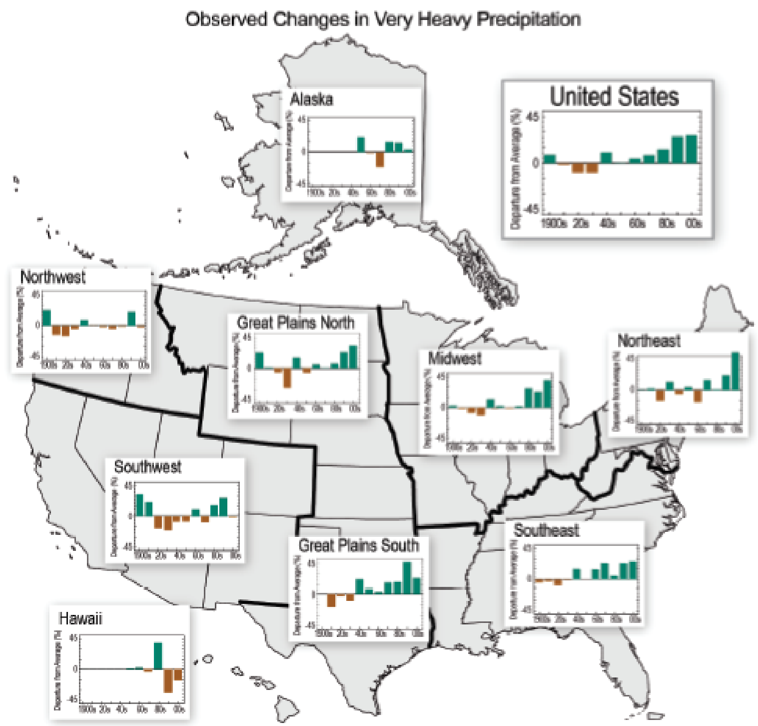

Figure 2.15: Observed Changes in Very Heavy Precipitation

Caption: Percent changes in the annual amount of precipitation falling in *very heavy* events, defined as the heaviest 1% of all daily events from 1901 to 2011 for each region. The far right bar is for 2001-2011. In recent decades there have been increases everywhere, except for the Southwest, Northwest, and Hawaii, with the largest increases in the Northeast, Great Plains, Midwest, and Southeast. Changes are compared to the 1901-1960 average for all regions except Alaska and Hawaii, which are relative to the 1951-1980 average. (Figure source: NOAA NCDC / CICS-NC)